Proceedings of the

4th International Conference on Materials, Mechanics and Management

IMMM 2020

5th, 6th & 7th March 2020

Organized by

Department of Mechanical Engineering, Department of Civil Engineering & Department of Architecture

COLLEGE OF ENGINEERING TRIVANDRUM

THIRUVANANTHAPURAM, KERALA, INDIA - 695016

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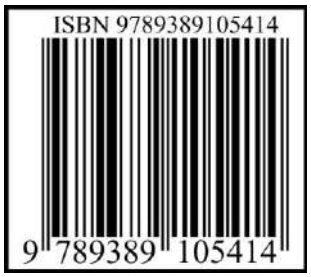

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About the College

College of Engineering Trivandrum is the first Engineering College in Kerala, founded in 1939, during the reign of King Sree Chithira Tirunal Balarama Varma of Travancore. The College is located on the Sreekaryam - Kulalhtur Road, 12 km from the Trivandrum Central railway station.

The institution offers 8 under graduate and 27 post graduate programmes, most of which are accredited with the National Board of Accreditation. The college also offers evening programmes at under graduate and post graduate levels for the benefit of working professionals. The college is a Quality Improvement Program centre of AICTE and offers research programmes leading lo PhD

About the Conference

Developments in materials, mechanics and management are directly influencing the progress in all walks of human life. The quest for meeting the necessities of the population has led to revolutions in construction and manufacturing with optimum management of resources.

IMMM 2020 is the fourth in the series organized by College of Engineering Trivandrum to discuss and debate the advancements made in these areas of engineering. The aim of the conference has been to provide a platform for the researchers, practising engineers, architects, academicians and the students to present their research findings and contributions. The conference is jointly organized by the Departments of Mechanical Engineering, Civil Engineering and Architecture.

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Prof. (Dr.) Nandakumar C G, Dept. of Ship Technology, CUSAT
Prof. (Dr.) K. P. Jaya, Anna University

SCHEDULE

DAY 1 (5th March 2020)

08.30AM to 10.00 AM: Registration

10.00 AM to 11.00 AM: Inauguration & Key Note Address

10.00 AM to 11.00 AM
Inauguration & Key Note Address
Venue: Grand Utsav, Hotel SP Grand Days

Welcome	Dr. Jiji C. V. IMMM2020 Conference Chair & Principal, CET
Inaugural address:	Dr. Rajasree M. S. Vice Chancellor, APJ Abdul Kalam Technological University
Presidential Address:	Dr. K. P. Indira Devi Director of Technical Education, Govt. of Kerala
Key Note Address:	Dr. R. Venu Gopal IPESS Deputy Chief Controller of Explosives Petroleum & Explosives Safety Organization (PESO) Government of India.
Vote of Thanks:	Dr. Asok Kumar N. IMMM2020 Organising Secretary

11.00 AM to 11.15 AM: Tea Break

DAY 1 (5th March 2020) : 11.15 AM to 12.45 Noon Key Note Lectures (Parallel Sessions # 1)		
Venue	**Topic**	**Speaker**
Spice Days	Recent advancements in high-strength materials	**Dr. Jayant Jain, IIT Delhi**
Aqua Grand B	Constitutive Modelling of Static and Cyclic Behaviour of Clays with Different Microfabric	**Dr. Rakesh J Pillai, IIT Palakkad**
Aqua Grand C	Mankind and the Need for Sustainability through Convergence of Resources	**Kedarnath Rao Ghorpade, Former Chief Planner of Mumbai MRDA**

1.00 PM to 2.00 PM: lunch Break

DAY 1 (5th March 2020): 2.00 PM to 3.30 PM Paper Presentation (Parallel Sessions # 1)			
Venue	**Paper Id**	**Topic**	**Speaker**
Chairs: Dr. Rohinikumar B(NITC) and Dr. Manoj T Nair(IIST) Session Manager: Dr. Anjan R Nair			
Spice Days	68	Performance Analysis of Serpentine Flat Plate Solar Collector	Lishad K P
	23	Fresnel Lens Concentrated Photo Voltaic/Thermal Hybrid Solar Collector	Askkar Ali P
	119	Numerical analysis of heat transfer and flow friction characteristics of perforated disc compact heat exchanger	Ghanashyam K C
	105	Experimental investigations on the effect of strut geometries in	V Sumesh

		supersonic mixing	
	158	Effect of Data Uncertainties in the Thermal Analysis of a Printed Circuit Board Using Monte Carlo Method	Midhun C
	115	Production, Engine performance and emission characteristics of blends of nano-fueled waste plastic oil obtained by pyrolysis method mixed with conventional diesel in a CI engine.	Alex Y
Chair: Dr. M. Satyakumar Co-Chair: Dr. Anu P Alex Session Manager: Prof. Preethi P			
Aqua Grand B	80	Stabilization of Pavement Subgrade Treated with Quarry Dust and Lime	Manjula Devi
	143	The 2019 Kerala floods: Impact of Natural Disasters on Traffic and Transportation	V S Sanjay Kumar
	169	Developing Cool Concrete Pavements using Phase Change Materials	Anupam B R
	83	Prediction of Unconfined compressive strength of stabilized soil using Regression analysis	Aditya Ahirwar
Chair: Prof. A Kasturi Rangan Co-Chair: T M Sudha Session Manager: Prof. Saritha G P			
Aqua Grand C	52	Disaster Risk Reduction Model: Case Panamaram, Wayanad	Pournami Narayanan
	60	Ecotourism Development Plan for Minicoy Island Lakshadweep	Prithvijith V. S. Nair
	74	Development of a settlement pattern for Kuttanad - A case of Kainakary	I S Durga
	110	An Assessment of Vulnerability of Fishermen Settlements to Coastal Hazards in Kerala- A Case of Kollam District	Smitha M V
	40	Community based disaster preparedness - A case of Western Ghats Kerala region	Jenny Maria Sony
	48	Planning Framework for the sustainable management of wetland - A case of Ashtamudi Lake in Kollam	Shahina Muthu S

3.30 PM to 3.45 PM: Tea Break

DAY 1 (5th March 2020): 3.45 PM to 5.30 PM Paper Presentation (Parallel Sessions # 2)			
Venue	**Paper Id**	**Topic**	**Speaker**
Chairs: Dr. Rohinikumar B(NITC) and Dr. Manoj T Nair(IIST) Session Manager: Dr. Sunil Kumar S			
Spice Days	5	Analysis of the Thermal Behaviour of Free stream Cooling of Microprocessor by Using Rectangular Type Heat Sinks	Dr. Arun Kumar Pandey
	13	Natural convection boundary layer flow over cylinders and cones.	Dinesh D
	157	Numerical study on heat transfer augmentation in a tube heat exchanger with symmetrical airfoil shaped insert	Anson John
	129	Numerical analysis of heat transfer and flow friction characteristics of curved longitudinally finned-tube heat exchanger	Sarath S
	30	Modelling and experimental investigation of the effect of particle size on biomass gasification	Vipindas M

	6	Effect of MWCNT Content of Heat Transfer Characteristics of Water Based Nano Coolant	Vijay Verma
Chair: Dr. Aadarsh S Co- chair : Dr. Shibu A Session Manager: Divya Chandran			
Aqua Grand B	10	Calibration of Water Distribution Network using Genetic Algorithm	Aryalakshmi M
	15	Analysis of Groyne Orientation in Meanders with Permeable Groynes – A Laboratory Study	Indulekha K P
	43	Gis Based Morphometric Ananlysis and Flood Hazard Vulnerability of Two River Basins Under Different Climatic Milieu	Arathy Nair G R
	139	Water Audit for Engineering College Campus	Shradha Phalle
	140	Assessment of Soil Surface Roughness Statistics Using a Simple Photogrammetric Acquisition System	V S Anagha
	167	Green Roofs for Urban Storm water Management: A Review	Ganga R S
Chair: Prof. A Kasturi Rangan Co-Chair: T M Sudha Session Manager: Prof. Saritha G P			
Aqua Grand C	58	A spatial framework for exploring the Sense of Community in planned residential areas – Sense of Community (SOC)	Feba K. Jones
	79	Study on the implications of Coastal Regulation Zone (CRZ) notification in the development of Islands - the case of backwater islands in Kochi, Kerala	Sharika Ravi
	90	Energy Efficient Planning for Cities – An Approach to Develop Parameters for Energy Efficient City Planning	Amala Sali Paul
	92	The Influence of Urban Planning in Road safety- Towards more Sustainable cities	Sharmin Shafeek
	133	Urban Resilience Index as an Instrument to Sustainable Development	Kiran Kumar S
	141	Post Disaster Planning Interventions in Nepal	Arun Shankar M

DAY 2 (6th March 2020)

DAY 2 (6th March 2020): 9.00 AM to 11.00 AM Paper Presentation (Parallel Sessions # 3)			
Venue	**Paper Id**	**Topic**	**Speaker**
Chairs: Dr. V. Madhusudanan Pillai (NITC)& Dr. V. Ravi (IIST)Session Manager: Dr. Binoosh S. A.			
Spice Days	27	Optimization of aviation turbine fuel transport in pipeline networks	Yeldho Peter
	62	Performance Improvement Verification Model in Educational Institutions	Althaf S M
	64	Exploration and Analysis of Advanced Green Tools Applicable for Process Industries	Leeja J
	136	Analysis of hand-arm vibration in hand-held power tool operators	Akhila S L
	151	Different Approaches in Playground Equipment Design To Bring Inclusiveness	Akshaya J
	96	E-Commerce Marketing Framework Using Consumer Online Presence	Vishnu A P

	152	Application of nature inspired algorithms for optimizing water distribution system post disaster; A review	Karthik D M
Chairs: Dr. Akshay Dilip Shende and Dr. Sheela A.M. Session Manager: Dr. Shibu K			
Aqua Grand B	67	Ozonation as a Technique for Domestic Wastewater Treatment	Preeti Shrivastava
	137	Study on Integrated Treatment system for Medium Strength Domestic Wastewater	Guru Munavalli
	146	Maintenance and Management of Parvathy Puthanar Canal in Thiruvananthapuram	Nidhi C Mohan
	147	Study on Depth and Characteristics of Sludge in Field-Scale Anaerobic Baffled Reactor	Satyam Shinde
	149	Estimation of Oxygen Transfer Parameter in Feeding System of Vertical Flow Constructed Wetland	Piyush Jadhav
	150	Package Treatment System for Domestic Wastewater: A Review	Vivek Patil
	155	Study on Alternate modes of plantation in Bio-rack Constructed Wetland	Tulsiram Jangid
	164	Urban Heat Island Effects: A Review	Najiya N
Chair: Prof. A Kasturi Rangan Co-Chair: T M Sudha Session Manager: Prof. Saritha G P			
Aqua Grand C	25	Readjusting Urban Land Through Town Planning Schemes in Kerala - A Critical Analysis	Anna John
	26	Framework for assessment of suitability of multi-storeyed residential buildings under Slum Upgradation Programmes: A case of Chennai Corporation	Agnes Rachel Simon
	31	Formulation of methodology to assess the effectiveness of Responsible tourism in Kerala	Rini Thomas Kutty
	33	Assessment of the Quality of Urban Parks in Kerala context- A case of Ernakulam city	Ann Joy
	156	Effective Land Management for conserving Paddy Farm Sector	Sandra Rose
	55	Framework for assessing Land Suitability for Robber Cultivation in Kerala	Reshma George
		Concluding by Chair & Co-Chair	

11.00 AM to 11.15 AM: Tea Break

DAY 2 (6 Feb 2020) : 11.15 AM to 12.45 Noon Key Note Lectures (Parallel Sessions – # 2)		
Venue	**Topic**	**Speaker**
Spice Days	Innovative Trends in Supply Chain Management	**Dr. Jayendran V, IIT Bombay**
Aqua Grand B	Sustainable Water Management: Concerns and Solutions in the Indian Context	**Prof. (Dr.) K.P. Sudheer, Ex Officio Principal Secretary S&T Department & Executive Vice President KSCSTE**
Aqua Grand C	Designing Future-Proof Cities	**Prof. Devi Prasad, Director, School of Architecture, VIT**

1.00 PM to 2.00 PM: lunch Break

DAY 2 (6th March 2020): 2.00 PM to 3.30 PM Paper Presentation (Parallel Sessions # 4)			
Venue	**Paper Id**	**Topic**	**Speaker**
Chairs: Dr. Praveen Krishna(IIST) and Er. Paul George(LPSC) Session Manager: Dr. Mini R S			
Spice Days	121	Feasibility study of epoxidised rice bran oil as cutting fluid	Jithin Prakash
	122	Fabrication and Performance Analysis of a Grease Formulation Setup	Gokul Biju
	138	Friction and wear characteristics of RCO derived biodiesel	Arvind P
	125	Performance Evaluation of Vegetable Oils as Metal Cutting Fluids	G V S Karthik
	77	Stearic Acid as a Green Anti-Wear Additive for Biolubricant	Abhijith K
	123	Feasibility study on the Formulation of rice bran oil based Bio-grease	Deepkant A
	17	Production of bio-ethanol from fruit peel	Arya S Nair
Chairs: Dr. Sheela S and Dr. Ruby Abraham Session Manager: Dr. Yashida Nadir			
Aqua Grand B	02	Finite Element Simulation of Roll Bending Process of Cylindrical Waffle Structure	Jeny J S
	09	Experimental Investigation on Mechanical Properties of Sustainable Concrete Incorporated with Fly ash, GGBS and Recycled Aggregate	Merin Mathew
	14	Pond Ash as Partial Replacement of Fine Aggregate in Concrete	Avadhuth K
	19	Buckling Analysis of Stiffened Functionally Graded Material Plates under Uniaxial Compression	Gayathri D S
	32	Addition of Glass Powder and Egg Shell Powder: A Green Solution for Improving the Mechanical Properties of Concrete	Dr.Mini Koshy
	37	Effect of Fly Ash Replacement on Strength and Durability Properties of Slag Based Geopolymer Concrete	Anusha Raj K

	108	Modelling of Post-Tensioned Beams with Parabolic Cable Profile	Surya Raghunath
Chair: Ar. Nirmal Chandy Co-Chair: Ar. Sachin Sathyan Session Manager: Prof. Saritha G P			
Aqua Grand C	21	Architecture and Interactions: The Role of Physical interface in facilitating user interactions at World Expos	Shagi S Nair
	12	Urban design strategies for retention of wetlands in urban areas	Benjoy C Joy
	34	Sensitive ecological issues leading to development induced landslides in urban highlands	Alli M Sudhan
	46	Need of Urban Consciousness in Designing Responsive Public Spaces	Jincy Varghese
	57	Commons to contested domain – Contemporary trends in transformation of urban riparian edge	Smitha C
	16	Reconsidering the concept of Residual spaces: "Flyovers" as a potential opportunity for the city fabric	Shagi S Nair

3.30 PM to 3.45 PM: Tea Break

DAY 2 (6th March 2020): 3.45 PM to 5.15 PM Paper Presentation (Parallel Sessions # 5)			
Venue	**Paper Id**	**Topic**	**Speaker**
Chairs: Dr. V. Madhusudanan Pillai (NITC) and Dr. V. Ravi (IIST) Session Manager: Dr. Sunil Kumar K			
Spice Days	162	Identification of risk due to RSI among auto rickshaw drivers	Jithu Gopinath
	163	Preparedness of E-pharmacy in Rural India: A Quantitative Analysis using DEA.	Betsy Mathai
	165	Effect of Variable Deterioration Rate on Perishable Food Supply Chains	Dileep M V
	71	Human skeleton tracking using Microsoft Kinect in pump manufacturing industries	Praveen S
	72	Performance improvement of a tertiary hospital using Kano model and quality function deployment	Amal Soni
Chair: Ar. Nirmal Chandy Co-Chair: Ar. Sachin Sathyan Session Manager: Prof Saritha G P			
Aqua Grand C	112	Waste management in Kerala urban neighbourhood by adapting 'zero waste city' concept – a case of Edappally	Swetha Santhosh
	114	Power, Politics and Identity of Capital Cities	Monisha V Kunjumon
	116	Form based code as a tool for creating sustainable mixed use neighbourhoods	Reshma P R
	54	Study of Kanadukathan- A Chettinad Village Development	Samyuktha Krishnan T M
	106	Maintenance Management Plan for Agraharams of Valiyashala	Miria Rose Jacob
		Conclusion by Chair & Co-Chair	

6.30 PM to 7.30 PM:
Traditional Dance Programme of Kerala & Music, Venue: Main Auditorium.

7.45 PM to 9.00 PM: Conference Dinner.

DAY 3 (7th March 2020)

DAY 3 (7th March 2020): 9.00 AM to 11.45 AM Paper Presentation (Parallel Sessions # 6)			
Chair: Dr. V. Ravi (IIST) and Er. Ganesh Pillai(LPSC) Session Manager: Dr. V. S. Unnikrishnan			
Venue	**Paper Id**	**Topic**	**Speaker**
Spice Days	51	Constructing a more efficient financial crisis warning model using various hybrid z-score models	Vishnupriya R. C
	44	Detection of defect in steel sheets using Convolutional Neural Networks	J Visweswara Iyer
	63	Diabetic retinopathy detection using machine learning	Kishore M V
	73	Machine Learning Based Methodology For Pneumonia Diagnosis	Arun Kumar S
	128	Futures Portfolio Optimization of Energy and Non-Energy Commodities	Sreelakshmi U
	132	Predicting exchange rates using commodity prices in the Indian market	Soumya Sankaran
	142	Comparative Study on Application of Hybrid Algorithms for Portfolio Optimization	Aswajith R S
	148	Price Prediction Using Machine Learning Algorithm on Daily Stock Prices	Anantha Narayan K R
	154	Advancements in Stock Price Prediction using Long Short Term Memory (LSTM) neural Network: A Review	Manisha.F
Chairs: Dr. Balan K and Dr. Sheela Evangeline Session Manager: Dr.Bindu J			
Aqua Grand B	38	Performance Study of Clay Mixture Amended with Activated Carbon as Clay Liner	S Anju
	39	Modelling and Analysis of Tapered Stone Columns using ABAQUS Software	Kiron Keerthi
	42	Behaviour of Circular Footing Subjected to Horizontal Loads	Amritha Varsha. T S
	45	Behaviour of Circular Footing Subjected to Moments	Sreedhu P S Potty
	113	Effect of Nickel on the Adsorption Characteristics of Landfill Liner using Marine Soil	Ajitha A R
	166	Influence of Flood on the Behaviour of Footing	Salini Valiyaparambil
Chairs:Dr. PraveenKrishna(IIST)&Er.PaulGeorge(LPSC)Session Manager:Dr.Gopalakrishnan KC			
Aqua	35	Numerical analysis on the Vibrational characteristics of Flexible tubes conveying fluids using Two way Fluid Structure Interaction.	Nizam Mon K S
	124	Vibration analysis of a rectangular plate immersed in a flowing fluid.	N Arun Kumar

Grand C	59	Modal analysis of horizontal axis jacket supported offshore wind turbine.	Jithin J
	24	Development of an experimentation setup for the analysis of flow induced vibrations in flexible tubes conveying fluid.	Amal G Nath
	135	Modal Analysis of a Launch Vehicle	Amal Surendran
	20	Design and Development of Performance Improved and Cost Effective 3d Printer	John George Simon
	120	Design of blast resistant hull for armoured vehicles	Sandeep K T
	168	Tool pin profiles and the quality of welds in friction stir welding of aluminium alloys	Abey Vishnu

12.00 Noon to 1.00PM: Valedictory Function

DAY 3 (7th March 2020): 12.00 Noon to 1.30PM
Valedictory Function
Venue: Spice Days

1.30 PM to 2.30 PM: lunch Break

3.00 PM to 4.00 PM: Certificate distribution to Participants.

SUMMARY OF THE WHOLE PROGRAMME

SCHEDULE

DAY 1 (5 Feb 2020)

08.30 AM to 10.00 AM: Registration

10.00 AM to 11.00 AM: Inauguration & Key Note Address

11.00 AM to 11.15 AM: Tea Break

11.15 AM to 12.30 Noon: Key Note Lectures (Parallel Sessions # 1}

1.00 PM to 2.00 PM: lunch Break

02.00 PM to 3.30 PM: Paper Presentation (Parallel Sessions # 1)

3.30 PM to 3.45 PM: Tea Break

3.45 PM to 5.15 PM: Paper Presentation (Parallel Sessions # 2)

DAY 2 (6 Feb 2020)

9.00 AM to 11.00 AM: Paper Presentation (Parallel Sessions # 3)

11.00 AM to 11.15 AM: Tea Break

11.15 AM to 12.30 Noon: Key Note Lectures (Parallel Sessions # 2)

1.00 PM to 2.00 PM: lunch Break

02.00 PM to 3.30 PM: Paper Presentation (Parallel Sessions # 4)

3.30 PM to 3.45 PM: Tea Break

3.45 PM to 5.15 PM: Paper Presentation (Parallel Sessions # 5)

6.30 PM to 7.30 PM : Traditional Dance Programme of Kerala & Music, Venue: Main Auditorium.

7.45 PM to 9.00 PM: Conference Dinner.

DAY 3 (7 Feb 2020)

9.00 AM to 11.30 AM: Paper Presentation (Parallel Sessions # 6)

12.00Noon to 1.00PM: Valedictory Function

1.30 PM to 2.30 PM: lunch Break

3.00 PM to 4.00 PM: Certificate distribution to Participants.

4TH INTERNATIONAL CONFERENCE
ON MATERIALS, MECHANICS AND MANAGEMENT

COLLEGE OF ENGINEERING TRIVANDRUM

0N 5, 6 AND 7 MARCH 2020

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19	72	Performance Improvement of a Tertiary Hospital Using Kano Model and Quality Function Deployment	Amal Soni and Regi Kumar V
20	73	Machine Learning Based Methodology for Pneumonia Diagnosis	Arun Kumar S and Regi Kumar V
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22	96	E-Commerce Marketing Framework Using Consumer Online Presence	Vishnu A P and Vinod M
23	105	Experimental Investigations On the Effect of Strut Geometries in Supersonic Mixing	V Sumesh And Balachandran P
24	115	Production, Engine Performance and Emission Characteristics of Blends of Nano-Fueled Waste Plastic Oil Obtained by Pyrolysis Method Mixed with Conventional Diesel in a CI Engine.	Alex Y and Chacko Preno Koshy
25	119	Numerical Analysis of Heat Transfer and Flow Friction Characteristics of Perforated Disc Compact Heat Exchanger	Ghanashyam K C and Dr S Sunil Kumar
26	120	Design of Blast Resistant Hull for Armoured Vehicles	Sandeep K T and C.P Sudheesh Kumar
27	121	Feasibility Study of Epoxidised Rice Bran Oil as Cutting Fluid	Jithin Prakash, Edla Sneha, Rani S, Muhammed Arif M and Ananthan D Thampi
28	122	Fabrication and Performance Analysis of a Grease Formulation Setup	Gokul Biju, Ananthan D Thampi, Rani S and Deepkant A
29	123	Feasibility Study On the Formulation of Rice Bran Oil Based Bio-Grease	Deepkant A, Baiju Sasidharan, Rani S, Ananthan D Thampi and Gokul Biju
30	124	Vibration Analysis of a Rectangular Plate Immersed in A Flowing Fluid	N Arun Kumar and C.P Sudheesh Kumar
31	125	Performance Evaluation of Vegetable Oils as Metal Cutting Fluids	G V S Karthik, E Sneha, S Rani, Abhijith Krishna and Jithin Prakash
32	128	Futures Portfolio Optimization of Energy and Non-Energy Commodities	Sreelakshmi U and Mahesh S

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IMMM2020_05

Analysis of the Thermal Behavior of Free stream Cooling of Microprocessor by Using Rectangular Type Heat Sinks

Ashutosh Kumar Saurabh
Department of Mechanical Engineering
Bundelkhand Institute of Engineering and Technology
Kanpur Road, Jhansi (UP) India

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Department of Mechanical Engineering
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Abstract— **The heat can be a major problem in any highly functioning system those consume more power to operate. Therefore, it is required remove the heat from these devices to improve the performance of these devices. For removing the heat from microprocessor, a heat sink may be used. Keeping these facts in mind, In this study, the modelling and simulation of rectangular heat sink has been carried out. For the simulation, six different geometrical sizes of heat sink have been used with twenty-four different cases. This study has facilitated comparison between different geometrical size heat sinks of rectangular fins type. The computational fluid dynamics (CFD) simulations have become more and more popular in electronic cooling research over the past decades. In this paper, ANSYS-FLUENT software has been used for computational fluid dynamics simulation, and thermal analysis is carried out to predict temperature distribution and flow field. The parameters considered in this study are fin material, fin thickness, base thickness and the number of fins. The simulation results show that the fin height, fin thickness and base height are found to be efficient at 32 mm, 1.5 mm and 5 mm, respectively for a heat sink design. The simulation approach has observed a satisfactory results and experimental validation of simulation results also have been performed.**

Keywords— Heat sink; Micro-Processor; Microelectronics; Simulation; Computational fluid dynamics; ANSYS

Nomenclatures:

Latin Letters

A	Surface area [m^2];
C_P	Specific heat capacity [J/kg-K]
D	Rectangular fin width [m];
h	convective heat transfer coefficient [W/m^2-K]
H	fin height [m];
m	mass flow rate [kg/s]
P	pressure [pa];
q	rate of heat transfer [W]
Re	Reynolds number;
T	Temperature [K]
T_H	heat source temperature [K];
u, v, w	velocity [m/s]
FT	Fin thickness;
BT	Base thickness
HF	Height of fins

Greek Letters

ΔP	pressure drop [pa];
ρ	density [kg/m^3]
K	thermal conductivity [W/m-K];
μ	dynamic viscosity [Pa-s]
ν	kinematics viscosity [m^2/s]

1. INTRODUCTION

How well we understand the hardware of your computer? It's a sure bet we have heard earlier about hard drives, processors, and RAM as they are the primary computer selling points. We will also learn about graphics cards and their role if we dig further into computer hardware. What's about heat sinks? do you understand what they are? We need to go back in time to remember a CPU that could fully function in the absence of a heat sink. The first Intel microprocessors have already produced a significant extent of heat, even then at a low condition processing work without any mechanism of heat eliminating device [1-2].

Advances over the past years, due to fast evolution of microelectronic technology, the electronic instruments and devices are always widespread use in everyday life. In the present day, the development to microelectronic products turn into thinner, lighter, shorter, & smaller [3]. The users prefer computers of higher performance that are used in gaming, video editing, 3D modeling, deep learning, rendering, scientific computing and desktop PC which are capable of processing additional information at remarkable speed. The microprocessors need one heat sink for effortless operation as the processing speed is improved [4].

However, over the past few years, the microprocessors become more effective. Currently, the major challenge restricting the use of multiple functionalities in electronic systems and devices due to their thermal management, it has become necessary that a CPU requires of a multi-fin heat sink

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in addition to a fan that makes sure sufficient airflow. The fins have shown smaller life span as overheated processors and often lead to issues such as system freezes or crash the system [5].

Several studies have shown that minimizing in the size of these microelectronic parts will result in a dramatic rise in the rate of heat generation. And because of the multifunction situation, improved clock cycle speed, reducing the size, and more energy removal, heat flux per unit region has also enhanced [6]. In addition, the electronic components operating temperature may exceed the required temperature amount. Thus, effective heat dissipation removal and safe operating temperature have therefore played a significant role in ensuring reliable and accurate functioning of micro-electronics components. The heat sink is widely used to provide a cooling feature for electronic parts in the cooling improvement of the present electronic sector [7]. The heat flux concentrations within the chips have risen because of electronic circuit components and energy transfer of electronics parts in-circuit chips. The concentration of huge amounts of heat can generate significant amounts of stress on chips, substrates and its neighbor components.

Some authors have conducted the research in the analysis of different types of heat sinks for the microprocessors at CPUs. Ledezma and Bejan have studied in natural convection, with tilted plate fins on the heat sink [8]. In air-cooled heat sinks, they explored the heat transfer increase merits of tilting the crest of plate fins. The results were achieved based on the heat flow areas and heat transfer three-dimensional numerical simulation. They also compared the results of the simulation with the experiments. The results indicate that the opposing force is buoyant due to downstream wall heating considerably impacts the distribution of velocity and temperature, the local Nusselt number, and the place and size of the downstream recirculation region [8].

Goshayeshi et al. have studied numerical research on fins connected to the base of sink. Natural heat transfer from heated fins, which are kept in a horizontal and vertical plane with air is discovered [9]. As the gap between the fins decreases the total heat transfer rate also decreases. They have also observed that the Reynold number is sufficiently an adequate amount for a convective heat transfer to occur, initially first it increases before crossing a maximum and then drops to an actual conductive value [9]. Mahmoud et al. have studied numerically and experimentally external steady natural convection heat transfer from vertically assembled interrupted rectangular fins, fin height varies between 0.25 and 1.0 mm and fin spacing between 0.5 and 1.0 mm. It was found to agree with published correlations between the experimental outcomes and those from the CFD modelling [10].

Lin et al. have studied with the use of inclined rectangular fins in the heat sink setup to enhance efficiency. A heat sink setup comprises of a heat sink with inclined rectangular fins, and a cooling duct with high-pressure longitudinal flow ($70x70x15mm^3$) has been designed, constructed and tested [11]. The constructed fan delivers an improved heat-dissipation capacity than the reference fan at low flow rates. Obviously, the cooling fan's static pressure is the overriding factor for a heat sink installation with high resistance [11]. R. Mohan and Dr. P. Govindarajan have studied CPU thermal assessment with heat sinks composite pin fin. They have used CFD simulation to describe a cooling solution for personnel pc using an 80 W CPU. This research investigates the performance of the heat sinks and compares them with distinct heat sinks [12].

Lee has studied the optimum heat sink design on different kinds of heat sinks [13]. He compared the results with simulation and discussed the effect on heat sinks efficiency and optimization of different design parameters. He also outlined the different kinds and categories of heat sinks, efficiency and price [13]. Patel and Belady have studied modeling and metrology of highly efficient heat sink modeling. They targeted on the pressure drop and thermal resistance of different air velocity. The present techniques of thermal sink measurement and modeling do not fulfil the accelerated cycles of product growth [14].

Ismail et al. have studied Pentium and AMD processors heat sinks those are commonly used to remove heat from microelectronic systems [15]. Four distinct kinds of heat sink were used in this research i.e heat sinks of the AMD Athlon and Duron, Pentiums III and IV. The paper introduces the Pentium, and AMD family heat sinks comparison. The simulation results in close sync with the experimental results [15]. Cheng-Hung et al. have studied a three-dimensional heat sink model in order to evaluate the optimum design factors. By using a thermal camera for ideal heat sink modules, temperature distributions are seen more clearly and outcomes are contrasted with numerical alternatives for validating the design [16]. C.J. Kobus et al. have researched the effect of thermal radiation on the thermal efficiency of heat sinks with a pin fin array through a theoretical and experimental method. A theoretical design, authenticated by experimental data, which involves the ability to predict the impact of thermal radiation on the thermal efficiency of a heat sink pin fin array was designed by introducing an efficient radiation heat transfer coefficient added to the heat transfer coefficient of convective heat transfer [17].

Sable et al. examined the natural convection of a heated vertical plate with various V-type fins surrounded by ambient air. V-type fin array was found to work better than rectangular vertical fin array and V-fin array with low spacing design among the three distinct fin array settings on vertical heated base [18]. The efficiency was noted to further enhance, with the height of the V-plates (fin height) being increased [18]. Li et al. have studied the efficiency with cross-flow of rectangular plate-fin heat sinks. The impact of various variables such as fin width, the height of fins, Reynold number of thermal resistance cooling air and heat sink pressure drop were researched [19]. Azar et al. has investigated a narrow channel heat sink used for cooling electronic high-power devices with

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air. Narrow channel heat sink's performance is not a strong function of flow direction. For high-power components, narrow channel heat sinks can be easily used [20]. Yu et al. have studied heat sinks efficiency with pin and plate fins. He discovered that plate-pin heat sink thermal resistance is better and about 30% less than plate-fin heat sinks thermal resistance [21].

After the critical study of different research papers, it has been found that many researchers have done researches on the various types of heat sinks (like rectangular fins, pin fin etc). However, there are some limitations that most of the research has been done only limited number of experiments on the heat sink of rectangular type fins for microprocessor chip on 8th generation processor. By keeping this fact in mind, in this study, we have done modeling and simulation by using CFD model of a heat sink for i7 8700 processor with boundary condition plays a crucial role to find out the thermal performance of microprocessor heat sink with all desirable quantities. The main objective of this work is to model the realistic situation of the rectangular type heat sink embedded on a microprocessor in the CPU cabin and to analyze the overall performance of the heat sink. In order to deal with this problem, the following parameters were considered to improve the performance of the heat sink to analyze the thermal behaviour of aluminum rectangular fin heat sink. Those parameters are fin thickness, base thickness, air velocity and the length and height of the fins. The effects of these parameters have been observed on the thermal behavior of aluminum alloy 1050 rectangular pin type heat sink.

2. MODELING

Three-dimensional CFD fluent software has been used to model and simulate the selected problem. The main steps during the simulation are;

1) Pre-Processing; 2) Solver Execution; 3) Post-Processing

Pre-Processing has been used where the modeling goals are determined and computational grid is created. In the second step that have been applied to numerical models and boundary conditions are set to start up the solver. Solver runs until the convergence is achieved. When solver is completed, the results have been examined which are the post processing part.

The most general form of fluid flow and heat transfer can be solved/Described by three basic physical law, or by using three equations such as continuity equation, momentum equation and energy equation. These equations may be written in partial derivatives forms as;

Continuity equation

$$\frac{\partial(\rho u)}{\partial x}+\frac{\partial(\rho v)}{\partial y}+\frac{\partial(\rho w)}{\partial z}=0 \quad (1)$$

Momentum equation

In x axis

$$\rho\left(\frac{u\partial u}{\partial x}+\frac{v\partial u}{\partial y}+\frac{w\partial u}{\partial z}\right)=-\frac{\partial P}{\partial x}+\mu_f\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}+\frac{\partial^2 u}{\partial z^2}\right) \quad (2)$$

In y axis

$$\rho\left(\frac{u\partial v}{\partial x}+\frac{v\partial v}{\partial y}+\frac{w\partial v}{\partial z}\right)=-\frac{\partial P}{\partial y}+\mu_f\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}+\frac{\partial^2 v}{\partial z^2}\right) \quad (3)$$

In z axis

$$\rho\left(\frac{u\partial w}{\partial x}+\frac{v\partial w}{\partial y}+\frac{w\partial w}{\partial z}\right)=-\frac{\partial P}{\partial z}+\mu_f\left(\frac{\partial^2 w}{\partial x^2}+\frac{\partial^2 w}{\partial y^2}+\frac{\partial^2 w}{\partial z^2}\right) \quad (4)$$

Energy equation

$$\rho c_p\left(u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}+w\frac{\partial T}{\partial z}\right)=k_f\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}+\frac{\partial^2 T}{\partial z^2}\right) \quad (5)$$

Table 1 Heat sinks with different geometrical size

Dimension of heat sink (in mm)	Total surface area (in cm^2)	Total volume (in cm^3)	Number of fins
FT = 0.5, BT= 2.5, HF= 32	1530.79	56.227	24
FT = 1, BT= 2.5, HF= 32	1366.55	82.570	21
FT = 2.5, BT= 2.5, HF= 32	1194.81	99.517	18
FT = 0.5, BT= 5, HF= 32	1538.77	71.865	24
FT = 1, BT=5, HF= 32	1374.60	98.550	21
FT = 1.5, BT= 5, HF= 32	1203.24	115.263	18

The simulation has been assumed to be incompressible and air velocity ranges from 2.5m/s to 7.5m/s for rectangular fin surface. In this study we have used hybrid meshing (i.e combination of tetrahedron and hexahedron mesh). The dimensions of rectangular type heat sink are shown in Fig.1. A rectangular heater of $42\times42mm^2$ with a temperature value of 71^oC supplied at the bottom surface heat sinks. The total surface area, volume and number of fins for all heat sinks in the present study are shown in Table 1.

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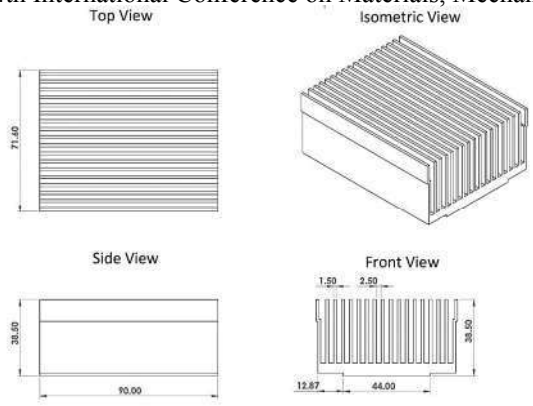

Figure 1 Heat sink with rectangular fins

3. NUMERICAL SIMULATION

In the solution process, numerical calculations were performed in steady-state conditions. A combination of the coupling algorithm for pressure-velocity based and a second-order upwind scheme for the determination of momentum and energy is included in the model. A model that is used in this study is k-epsilon model which is usually used for turbulence model as well as laminar model. The material used in this study is aluminium (Al) and aluminium 1050 (Al1050). The air has been selected for fluid domain each cell zone of fluid domain and for solid domain each cell zone of solid is selected as aluminium or aluminium 1050. After selecting zones; then the boundary conditions have been applied. These boundary conditions are velocity at the inlet face 2.5m/s or 5m/s or 7m/s air velocity, temperature of 344 ^{0}K which is maximum temperature of i7 8700 processor. And then solution initialize by some scalar values using hybrid initialization command and run solution upto 500 iterations. The thermal properties used for the Aluminium and Aluminium Alloy 1050 are given in Table 2 and 3, respectively.

Table 2 Aluminium properties

Density(ρ)	2719 kg/m^3
Specific heat(c_p)	871 J/kg-k
Thermal conductivity(k)	202.4 W/m-k

Table 3 Aluminium alloy 1050 properties

Density(ρ)	2710 kg/m^3
Specific heat(c_p)	900 J/kg-k
Thermal conductivity(k)	230 W/m-k

4. CONVERGENCE ISSUES

There exit only a few methods like convergence test that gives a satisfactory solution or well converged of the problems. The convergence is defined through the degree of the residual value drops. The close tolerance has been taken for flow and energy equation as 10^{-3} and 10^{-6} scalar value, respectively [22]. The quality of results increases by reducing the degree of magnitude of residuals value. It is observed that convergence conditions ensure that the iteration is repeated further or not; there is a common method to find out whether we go further or not. We have to observe that the change in temperature value in residual monitor. It was found that the scalar values remain same after further iteration, the solution can be said to converge. The convergence is attained at the continuity, and momentum residual value is drastically reduced over to 10^{-3} and energy residual value is set up below the 10^{-7}.

5. GRID INDEPENDENCE

Grid independence is another well-established method for analyzing the model with a coarse mesh, medium mesh and fine mesh. During the analysis, it is observed that the difference in the scalar values, flow vectors and the temperature distributions are quite similar. The model has sufficiently generated the fine mesh with 127823 number of nodes and 585778 number of elements for grid independent tests. The process is very time consuming and repetitive; 8 hours of time is needed for this single run analysis on a i7 4thgen, 3.6 GHz computer. The boundary condition that applied is velocity = 5m/s, Heat flux = 11400W/m^2 [15].

6. RESULTS AND DISCUSSION

With the aim to improve heat sink efficiency, the different computational setup comprising of 24 cases were designed to study the effect of parameters such as base thickness, thickness of fins, number of fins, material of heat sink. Three cases for heat sink made up of aluminum (Al) with 1.5mm fin thickness and 5mm base thickness at different velocity (2.5, 5, and 7.5m/s). Three cases for heat sink made up of aluminum alloy (Al1050) with 1.5mm fin thickness and 5mm base thickness at different velocity. Nine cases for heat sink made up of aluminum (Al) with 5mm base thickness with varying fin thickness (i.e 0.5mm, 1mm, 1.5mm) at different velocity. Nine cases were setup having heat sink made up of aluminum (Al) with base thickness of 2.5mm and varying fin thickness (i.e 0.5mm, 1mm, 1.5mm) at different velocity.

6.1 Effect of Fin thickness

To improve the performance of heat sinks, different heat sinks were investigated by using computational fluid dynamics (CFD). After doing appropriate modifications, velocity vectors of air from the fan and temperature distributions were analyzed and it was found that closely packed of fins were not able to allow the flow of sufficient air to the trailing end of heat sink for cooling.

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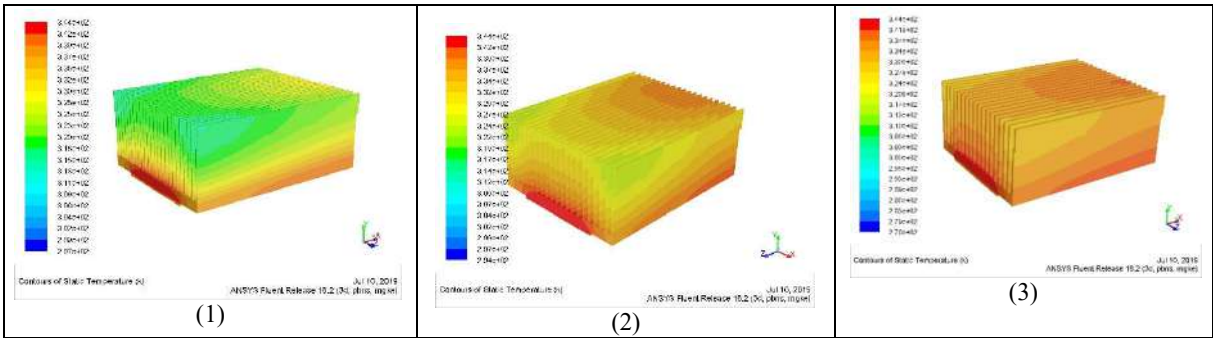
Table 4 Comparison According to number of Fins of heat sink

Fin thickness (in mm)	No. of fins	Air velocity (m/s)	Temperature along length of fins (in K)		Temperature along height of fins (in K)		Total heat transfer rate (W)
			Max.	Min.	Max.	Min.	
1.5	18	2.5	342.54	335.81	344	340.17	102.8239
		5	339.33	333.12	344	336.61	180.5450
		7.5	336.97	331.89	344	334.80	228.8324
1	21	2.5	342.24	332.62	344	339.04	115.3701
		5	337.70	328.73	344	333.95	203.24129
		7.5	334.33	326.97	344	331.25	250.95361
0.5	24	2.5	340.78	325.40	344	335.39	118.5356
		5	333.11	320.45	344	327.40	204
		7.5	327.96	318.54	344	323.5	254.2338



(1) (2) (3)

Figure 2 Temperature distribution of heat sink on different fin thickness (1) 0.5mm, (2) 1mm and (3) 1.5mm at 7.5m/s air velocity

From the Table 4, it is clear that by increasing of the number of fins in heat sink, the total heat transfer rate increases which results more uniform temperature distribution throughout. The numbers of fins are used for the analysis as 18, 21 and 24 successively as shown in Table 4. From the Table 4, it is evident that as the number of fins increases, the heat transfer rate also increases and 0.5 mm fin thickness at 7.5 m/s air velocity and 24 numbers of fins shows maximum heat transfer rate. It may be possible due to increase in the number of fins, the surface area responsible for the heat transfer increases. It is increased by 1.30% compared to 1 mm fin thickness and 7.5 m/s air velocity while it increases by 11.10% compared to 1.5 mm fin thickness and 7.5 m/s air velocity.

It has been seen from temperature distribution shown in Figure 2 that by increasing number of fins the efficiency of heat sink also increases. The surface of heat transfer region increases by adding fins, because total surface area increases during adding fins in sink without changing the fin spacing this will help better flow of air in heat sink as shown in Figure 2. Although there is huge change in total heat transfer rate, now it is possible to have use less material that is an enhancement for the producer. The proposed approach reduces the maximum temperature of heat sink and ultimately the efficiency of the CPU will increase.

6.2 Heat sink material

We have already seen that the increment in the number of fins improves the heat sink design. Now it's time to enhance the thermal conductivity of heat sink using aluminum alloy1050 (Al1050) instead of aluminum as Aluminium alloy 1050 has better thermal conductivity as compared to Aluminium as observed from the Table 2 & 3. The comparison results are shown in Table 5. From the Table 5, it is observed that the total heat transfer rate for the Aluminium alloy is more and better as compared to the Aluminium. The thermal performance of the heat sink was increased slightly in heat transfer rate. From Table 5, it is concluded that aluminum alloy 1050 heat sink with 7.5m/s air velocity gives the maximum heat transfer rate. It is increased by 2.19% compared to aluminum heat sink. This also indicates that small change in thermal conductivity of material does not cause a significant difference in the heat transfer.

Table 4 Comparison according to heat sink materials

Material	Air velocity (m/s)	Temperature along length of fins (in K)		Temperature along height of fins (in K)		Total heat transfer rate (W)
		Max.	Min.	Max.	Min.	
Aluminum (Al)	2.5	342.58	335.84	344	340.25	102.99231
	5	339.69	333.86	344	337.16	180.54
	7.5	336.95	331.90	344	334.68	227.0882

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Aluminum alloy 1050	2.5	342.75	336.70	344	340.67	104.20116
	5	339.87	334.23	344	337.44	183.95439
	7.5	337.69	333.09	344	335.63	232.07799

If all the heat sink is produced from aluminum alloy 1050, then the maximum heat sink temperature has risen. It is observed that the minimum temperature increased. Hence, the temperature difference on the heat sink is lower due to the high aluminum alloy 1050 thermal conductivity as shown in Figure 3 & 4. Despite the small changes in total heat transfer, relatively small differences were found that temperature of aluminum heat sink is higher than the aluminum alloy 1050 heat sink.

Figure 3 Temperature along length of fin at different velocity for Aluminium 1050 heat sink

Figure 4 Temperature along height of fin at different velocity for *Aluminium 1050 heat sink*

6.3 Base thickness

By fixing the parameters like fin length, fins thickness and aluminum heat sink while varying base thickness from 2.5mm to 5mm, the analysis shows that the higher temperatures were observed for thin base of heat sink.

Table 5 Comparison according to base thickness of heat sink

Base thickness (in mm)	**Air velocity (m/s)**	**Temperature along length of fins (in K)**		**Temperature along height of fins (in K)**		**Total heat transfer rate (W)**
		Max.	Min.	Max.	Min.	
2.5	2.5	340.78	326.40	344	335.38	118.5356
	5	332.5	322.1	344	327.8	201.0796
	7.5	328.05	320.39	344	324.5	245.60361
5	2.5	340.25	325.40	344	335.01	118.7425
	5	333.11	320.45	344	327.40	204
	7.5	327.96	318.54	344	323.5	254.2338

The temperatures of the heat sink tip are high because of the total length heat sink decreases, this means that total surface area decreases and which will decrease heat transfer rate resulting in the increase of the minimum and maximum temperatures. From the Table 6, it is observed that 5 mm base thickness, 0.5mm fin thickness and 7.5 m/s velocity show maximum heat transfer rate. It is increased by 3.51% compared to 2.5 mm base thickness, 0.5mm fin thickness and 7.5 m/s air velocity.

7. CONCLUSIONS

In this study, i7 8700 microprocessor cooling has been investigated with six different geometrical sizes of heat sinks at different velocities. And the performances of each heat sink are compared qualitatively and quantitatively. A blueprint for heat sink modeling has been established for simulation. In order to discover suitable method with the minimum computational expense, grid size, turbulence method selection and convergence technique are investigated. The methodology has been implemented in various geometrical size heat sink, and variation of temperature distribution in heat sink have been compared to the available experimental data. The comparisons results of predicted and experimental show a good agreement between computational simulation and experimental data. There is always some error found during simulation like convergence, temperature limit and poor quality mesh.

The main conclusions drawn from the study are as follows;

- Aluminum alloy 1050 has been used as heat sink material in place of aluminum, we have seen that aluminum alloy 1050 heat sink with 7.5m/s air velocity gives the maximum heat transfer rate as it is increased by 2.19% compared to aluminum heat sink.
- An improvement over performance of heat sink by changing the base thickness has been found significantly. It is observed that 5 mm base thickness, 0.5mm fin thickness and 7.5 m/s show maximum heat transfer rate as it increased by 3.51% compared to 2.5 mm base thickness. It is observed that the increase in the base thickness has been found performance steadily increases, but sometimes there are space restrictions in a computer for each heat sink.

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- In the current analysis, the stacks of fins 18, 21 and 24 fins are used successively and it is evident that 0.5 mm fin thickness and 7.5 m/s air velocity shows maximum heat transfer rate as it is increased by 1.30% compared to 1 mm fin thickness while it is increased by 11.10% compared to 1.5 mm fin thickness.
- The heat sink with 0.5mm fin thickness and 5mm base thickness with 7.5m/s air velocity shows maximum heat transfer rate as it is increased by 114.48% compared to 2.5m/s air velocity while increased by 24.62% compared to 5m/s air velocity.
- The number of fins, temperature distribution throughout the heat sink, base height and heat sink material greatly enhanced the abilities of the heat sink as well as save the materials requirement efficiently.

REFERENCES

[1] Subramanyam, Savithri, and Keith E. Crowe. "Rapid design of heat sinks for electronic cooling using computational and experimental tools." Sixteenth Annual IEEE Semiconductor Thermal Measurement and Management Symposium (Cat. No. 00CH37068). IEEE, 2000.

[2] Linton, Ronald L., and D. Agonafer. "Thermal Model of a PC." Transactions-American Society of Mechanical Engineers Journal of Electronic Packaging, 1994.

[3] Ravikumar, S., Chandra, P. S., Harish, R., & Sivaji. "Experimental and Transient Thermal Analysis of Heat Sink Fin for CPU processor for better performance." IOP Conference Series: Materials Science and Engineering. Vol. 197. No. 1. IOP Publishing, 2017.

[4] Aravindh, B., and T. R. Nair. "Heat Sink Performance Analysis through Numerical Technique." arXiv preprint arXiv, 2010.

[5] Marshall, Garrett J., Colin P. Mahony, Matthew J. Rhodes, Steve R. Daniewicz, Nicholas Tsolas, and Scott M. Thompson. "Thermal Management of Vehicle Cabins, External Surfaces, and Onboard Electronics." An Overview Engineering, 2019.

[6] Shabahangnia, E., S. Nasirivatan, M. Jafari, and A. Merdasi. "Experimental investigation of natural convection in inclined channel in presence of electrostatic field." International Journal of Heat and Mass Transfer, 2015.

[7] Yang, Yue-Tzu, and Huan-Sen Peng. "Numerical study of pin-fin heat sink with un-uniform fin height design." International Journal of Heat and Mass Transfer, 2008.

[8] G. Ledezma, A. Bejan, "Heat sinks with sloped fins in natural and forced convection." International Journal of Heat Mass Transfer, 1995.

[9] Goshayeshi, H. R., and F. Ampofo. "Heat transfer by natural convection from a vertical and horizontal surfaces using vertical fins." Energy and Power Engineering, 2009.

[10] Mahmoud, S., Al-Dadah, R., Aspinwall, D. K., Soo, S. L., & Hemida, H. "Effect of micro fin geometry on natural convection heat transfer of horizontal microstructures." Applied Thermal Engineering, 2011.

[11] S.C. Lin, F.S. Chuang, C.A. Chou. "Experimental study of the heat sink assembly with oblique straight fins." Experimental Thermal and Fluid Science, 2005.

[12] Mohan, R., and P. Govindarajan. "Thermal analysis of CPU with variable heat sink base plate thickness using CFD." International Journal of the Computer, the Internet and Management, 2010.

[13] Lee, Seri. "Optimum design and selection of heat sinks." IEEE Transactions on Components, Packaging, and Manufacturing Technology, 1995.

[14] C.D. Patel, C.L. Belady. "Modeling and metrology in high performance heat sink design." Proceedings of the 47th Electronic Components and Technology Conference, San Jose, California, IEEE, 1997.

[15] Ismail, M. A., M. Z. Abdullah, and M. Abdul Mujeebu. "A CFD-based experimental analysis on the effect of free stream cooling on the performance of microprocessor heat sinks." International Communications in Heat and Mass Transfer, 2008.

[16] Huang, Cheng-Hung, Jon-Jer Lu, and Herchang Ay. "A three-dimensional heat sink module design problem with experimental verification." International Journal of Heat and Mass Transfer, 2011.

[17] Kobus, C. J., and T. Oshio. "Predicting the thermal performance characteristics of staggered vertical pin fin array heat sinks under combined mode radiation and mixed convection with impinging flow." International Journal of Heat and Mass Transfer, 2005.

[18] Sable, M. J., S. J. Jagtap, P. S. Patil, P. R. Baviskar, and S. B. Barve. "Enhancement of natural convection heat transfer on vertical heated plate by multiple V-fin array." International Journal of Research & Reviews in Applied Sciences, 2010.

[19] Li, Hung-Yi, and Shung-Ming Chao. "Measurement of performance of plate-fin heat sinks with cross flow cooling." International Journal of Heat and Mass Transfer, 2009.

[20] K. Azar, R.S. McLeod, R.E. Caron. "Narrow channel heat sink for cooling of high powered electronic components." Proceedings of the 8th Annual IEEE Semi-therm Symposium, 1992.

[21] X. Yu, J. Feng, Q. Feng, Q.Weng. "Development of a plate-pin fin heat sink and its performance comparisons with a plate fin heat sink." Applied thermal engineering, 2005.

[22] D.W. Copeland, "Fundamental performance limits of heat sink." Transactions-American Society of Mechanical Engineers Journal of Electronic Packaging, 2003.

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Effect of MWCNT Content of Heat Transfer Characteristics of Water Based Nano Coolant

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Abstract— **In the present study, the heat transfer rate of Maruti Suzuki Alto vehicle radiator was experimentally evaluated by varying the concentration of (MWCNT) nano coolant in 50:50 ethylene glycol/water mixture. An experimental setup is fabricated similar to automobile cooling system and the results were compared with conventional coolant. During study the MWCNT nanoparticles volume fraction was varied as 0.01, 0.05 and 0.1 vol.% in 50:50 ethylene glycol water mixture (base fluid). Flow rate of the coolant in the study was also varied as 3, 5 and 7 LPM. The experimental analysis was carried out at inlet temperature of 65^{o}C and 70^{o}C. The results suggest that the heat transfer rate and average heat transfer coefficient increases with increase in volume fraction concentration of nano-fluids and flow rate. The heat transfer rate has a maximum enhancement of about 30% and average heat transfer coefficient has an improvement of about 22% at 0.1 vol.% MWCNT nanoparticle concentration in nano fluid as compared to that of base fluid.**

Keywords—Carbon nano tube, Heat transfer rate, Radiator, Nanofluid..

I. INTRODUCTION

Increasing cost of energy and fast depletion of fossil fuel i.e non-renewable energy resources is a big problem faced by the mankind. The increase requirement of fast and frequent transportation and travel become a common need today for all of us. The day by day increase in pollution, global warming and other environmental issues put a huge pressure on the automobile manufacturer and designers. The biggest challenge in this is to have low fuel consumption, high efficient, safe and low pollution causing automobiles. The alterations in internal combustion(IC) engines to increase efficiency of the engine and reduce the fuel consumption and pollution was the area of research for past few decade. Several alterations were suggested and implemented to increase the fuel efficiency, but still only 60% of the produced heat could be efficiently utilized and can be converted into useful power and remaining heat is dissipated in environment as waste without any utility [1]. The efficiency of the IC engine can be improved by maintained, monitoring and controlling the engine temperature. The heat exchanger i.e. the radiator was a very common device used for the purpose to cool down the recirculating coolant fluid temperature and thus regulate the temperature of the engine.

Conductive cooling is the main heat transfer mode used in case of automobile heat exchanger/ radiator. Larger the surface area of heat exchanger higher will be its efficiency. In case of automobile there is always be a space limitation coupled with low weight requirement criteria. The redesigning of radiator for increasing efficiency was started way back [2-8]. Redesigning the fins and using micro channels is one way to enhance the heat exchanger performance, is now reached to its limit [9-10]. The enhancement in heat transfer characteristics of the recirculating cooling fluid was the other way to enhance the efficiency and to further reduce the size of the heat exchanger/ radiator of automobile. Numerous attempts was made to improve the heat transfer characteristic of coolant either by blending them with low freezing point temperature solvents and other substances which enable low pressure operating of coolant. In this sequence one method is to have a solid metal and metal oxide ceramics nanoparticles suspension in coolant. The metal and metal oxide particles having at-least one dimension less than 100 nm was considered as nanoparticles. With the development in nanotechnology and methods to synthesis material in nano size make it feasible to use these nano particles to suspend/blend in coolant to enhance the heat transfer characteristics. The enhancement in heat transfer properties of nano coolant was due to exponential high surface area [9, 11-13].

Peyghambarzadeh et al. studied the effect of low Vol.% of nano Al_2O_3 (0.1 to 1.0 vol.%) in water based coolant recirculating through radiator heat exchanger at low (37^{o}C to

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49°C) inlet temperature. The author reported 45% increase in heat transfer efficiency of 1.0 vol.% Al_2O_3 water mixture coolant, relative to that of unblended water [9]. Vermahmoudi et al. [14] reported the enhancement of 13% in the overall heat transfer coefficient of automobile radiator with 0.65 vol.% Fe_2O_3 water coolant in comparison to that of unblended water.

In recent years nanoparticles of several metals and ceramics were used to have a nano coolant fluid for heat exchangers with special emphasis on automobile radiator. The other class of nano fillers gaining attention now a day was carbon based nano particles such as nano carbon powder, nano graphene sheet, single and multi-walled carbon nanotubes are common. These nano particles blends increase the heat transfer properties and thermal conductivity of the nano-fluid. [15].

Amiri et al. blended varying vol.% of nano graphene platelets to form graphene based nano coolant. The inlet temperature along with flow rate was also varied during the study. The author reported an increase of 130% for 0.2 wt.% of nano graphene platelets coolant when flow at 7 LPH. The author further reported that there is no significant effect of nano graphene platelets on pressure drop across the radiator16-17]. In a similar study Selvam et al [16] studied the effect of nano graphene platelets blended in water-ethyel glycol (70:30 by Vol.%) mixture. The author reported about 51% improvement in conductive heat transfer coefficient of 0.5 Vol.% nano graphene platelets water-ethyel glycol nano coolant relative to unblended water-ethyel glycol coolant, when air velocity was kets at 3 m/sec. more recently Selvam et al. reported that at constang 0.5 Vol.% of graphene nanoplatelets , 62.5 g/s flow rate and 5 m/s air velocity the maximum increase of about 100 % and 80% in overall heat transfer coefficient with 35°C and 45°C inlet temperature respectively [17]. Multi-walled carbon tube (MWCNT) is also a good material for making nano coolant fluid for moderate and high inlet temperature. The low volume fraction of MWCNT (0.5 Vol.%) will increase the heat transfer characteristic of nano-coolant by about 200% with 50:50 water: ethylene-glycol [1].

Thus it seems that majority of the work done was concentrated on utilization of metal and metal oxide nanoparticles for improving the heat transfer characteristics of conventional coolants. Few studies was also reported for carbon based nano materials including nano graphene platelets, carbon nanotubes and etc. from the literature it is also clear that out of very few studies the major emphasis of them was to experimentally evaluate the heat transfer characteristics of nano-coolant at low and high inlet temperatures. The ethylene glycol was also used to blend with water as anti-freezing agent in varying proportion from 30% to 50% by volume. Thus the present study has a great significance in advancing the carbon nano tubes based water-ethylene glycol nano-coolant fluid to be used as futuristic coolant for automobile and heavy machine heat exchanger application.

In the present work the low concentration (0.1 – 0.5 Vol.%) of MWCNT was blended in 50:50 ratio by volume in water : ethylene glycol mixture to prepare nano-coolant. The flow rate of the coolant was varied from 3.0 L/min - 7 L/min. The inlet coolant temperature was also varied in a range such that to study the effect of MWCNT concentration both in low and high inlet temperature of radiator.

II. Material and Method

The following section describe in details the material used in the study and the step by step process of conducting the experimental study

A. Material

In the present study the multi walled carbon nano tubes (MWCNT) was used as nano material to form the nano coolant fluid. The MWCNT was purchased from Platonic Nanotech Pvt. Ltd. India. The diameter of MWCNT was less than 30 nm and length less than 2 µm. The as received material without any treatment was used in the study. The properties of the MWCNT were listed in table 1. The SEM images of the MWCNT was shown in the figure 1. From the figure 1 it is clear that the MWCNT was with in the specified dimension and clear for defects. The ethylene glycol and the deionized water were purchased from the local vendor. The 50:50 by volume blend ratio of water and ethylene glycol was kept constant throughout the study and was treated as conventional coolant.

Table 1 Properties of the MWCNT used in the study. (Source: Provided by the supplier)

Form	Powder
Purity	>97%
Diameter	10-15(nm)
Length	2-10 micron
Specific surface area	250-270 m^2/g
Density	2.1 g/cm^3
Bulk density	0.06-0.9 g/cm^3
Specific heat	710 J/kg k

B. Nano coolant fluid preparation

In the present study 50:50 water and ethylene glycol mixture was blended with varying vol.% of MWCNT through high speed shear mixture. Initially the as received MWCNT was heated in air circulating oven. Then the pre-determined weight of MWCNT was blended in 1 liters of conventional coolant nano fluid and the mixture was processed through high speed shear mixture at 3000 rpm for 30 minutes in six steps. The small steps of shear mixing was taken so as to avoid the rupturing of MWCNT due to very high shear energy input in system by high speed shear mixture. The ready mixture was then mixed in the container having 4 liters of conventional coolant. Thus 5 liters of the coolant was used in each experimental step in the study.

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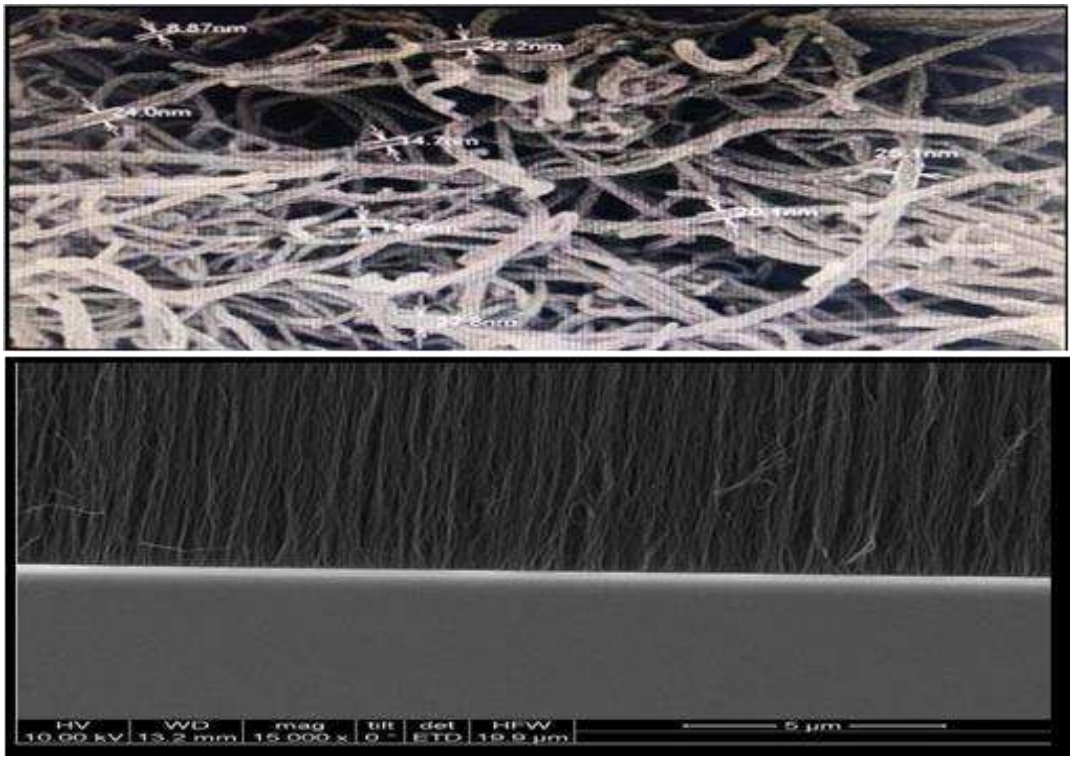

Fig.1. SEM image of MWCNT nano particles as provided by the supplier.

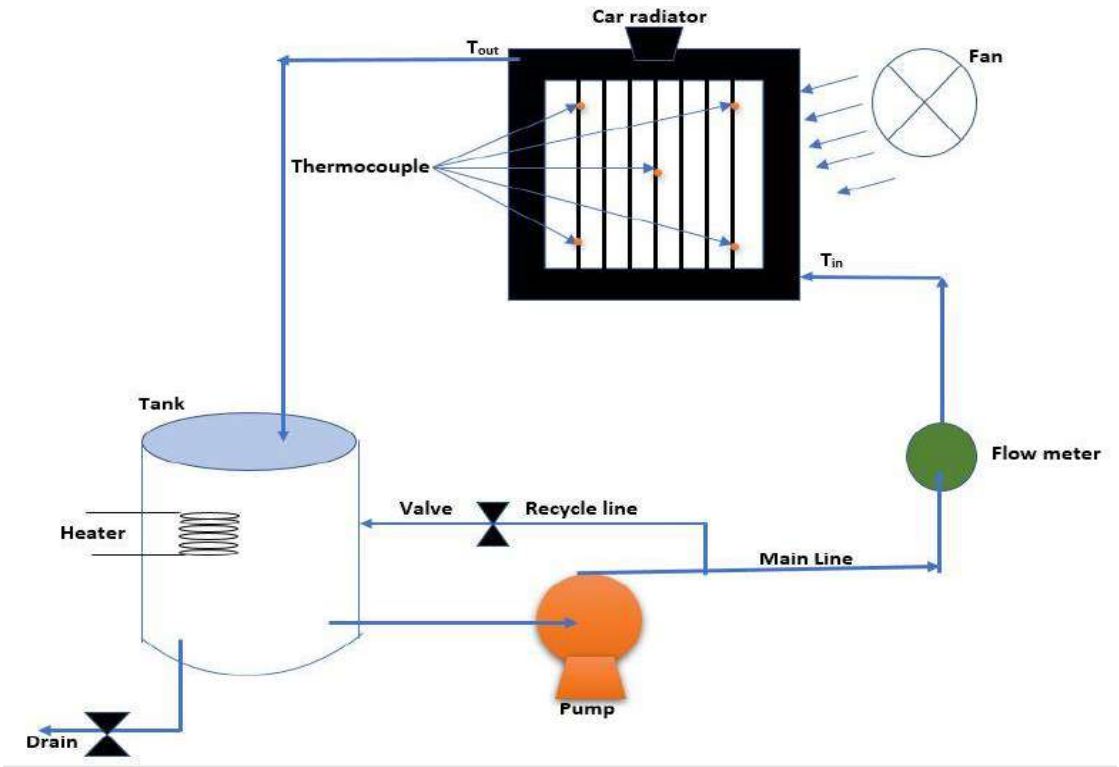

Fig. 2. Schematic diagram of experimental setup used in the study

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The concentration of MWCNT in conventional coolant was kept constant as 0.01, 0.05 and 0.1 Vol.% throughout the study. No visual sign of sedimentation of MWCNT in nano coolant fluid was observed in any sample during the complete study.

C. Fabrication of experimental setup

The schematic labeled sketch of Fig 2 shows the layout of experimental setup used for experimental investigation of the heat transfer rate and heat transfer coefficient of the car radiator. This experimental setup includes all the important component viz. car radiator, reservoir tank, electrical heater to generate heat, a centrifugal pump to pump the coolant through the radiator. A flow meter and flow control valve to measure the flow rate and to control the rate of flow of flowing coolant through the radiator. Tubes, fan, power supply were other items used in the setup. Data logger and 5 thermocouples was also used to record the temperature of the radiator wall and temperature of various other places in the setup. A radiator consists 49 vertical tubes with circular cross section with diameter of 5.1 mm. Two electrical heater of 2000 W are used to heat the nanofluid to obtain the required temperature of nanofluid for experiment. Digital temperature controller is used to control the coolant inlet temperature. A flow meter of capacity 0 - 1200 LPH and two valves used to measure and control the flow rate.

The fluid flows through plastic tubes (8 mm thick) by a centrifugal pump from the reservoir tank to the radiator at the flow rate range 3, 5 and 7 LPM. The capacity of centrifugal pump is 1 HP. The total volume of the nano-fluid used for experiment is five litres and is constant during the experiment. Two temperature sensors have been inserted in the inlet and outlet point to determine the inlet and outlet temperature of nano-fluid. Thermocouples at different five locations was fixed to the radiator outer wall surface to measure wall temperature during running the setup. The speed per minute (RPM) of a fan remains constant throughout the experiments. Table 2 chart the input variables parameters considered in the study. For each experimental trial the required parameter was adjusted and the setup was allowed to run for some time to attend the steady state. The inlet/outlet temperature and other reading and data logger was started after attending the steady state. The heat transfer characteristics and other output parameter of the nano coolant was than calculated from the measured temperature of the test conditions.

Table 2. Experimental test matrix.

Input control parameter	**Values of parameter**
Concentration (Vol.%)	0.01, 0.05, and 0.1%
Coolant flow rate (l/ min)	3, 5 and 7
Inlet temperature (^{o}C)	65 and 70 ^{o}C

D. Data reduction

III. The thermo-physical properties of MWCNT nano coolant fluid was calculated on the basis of solid – fluid mixture mathematical interaction as prescribed by Park and Cho [18]. **Density** of substance is defined as the mass per unit volume, density of nano fluid is calculated from the density model for nanofluid [18] given below

Fig. 3. Pictographic of the experimental setup (a) front view and (b) rear view.

$$\rho_{nf} = \varphi\rho_p + (1-\varphi)\rho_{bf} \quad (1)$$

Where ρ_{nf} is the density of nanofluid, ρ_{bf} represents the thermal conductivity of base fluid, ρ_p represents the thermal

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conductivity of MWCNT nano particles, and φ represents the Vol.% concentration of nanoparticles in nano-fluid.

Specific heat defines as the amount of heat required per unit mass of a material to raise the temperature by one degree centigrade. It is one of the fundamental properties influencing the rate of heat transfer in nano fluids. Specific heat of nano fluid is calculated from the specific heat model for nano fluid. [19]

$$C_{pnf} = (1-\varphi)\left(\frac{\rho_{bf}}{\rho_{nf}}\right)C_{pbf} + \varphi\left(\frac{\rho_p}{\rho_{nf}}\right)C_{pp} \quad (2)$$

Where C_{pnf} represents the specific heat of the nano fluid, C_{pbf} is the specific heat of base fluid and C_{pp} represents the specific heat of MWCNT nano particles.

Thermal conductivity of the nanofluid is calculated from the Hamilton crasser thermal conductivity model for nanofluid [19].

$$k_{nf} = \frac{k_p + (n-1)k_{bf} + (n-1)(k_p - k_{bf})\varphi}{k_p + (n-1)k_{bf} - (k_p - k_{bf})\varphi} k_{bf} \quad (3)$$

Where k_{nf} represents the thermal conductivity of nanofluid, k_{bf} represents the thermal conductivity of base fluid, k_p represents the thermal conductivity of MWCNT nano particles, n (n=3/ψ) represents the shape factor and ψ represents the sphericity of the particle.

Viscosity is a measure of a fluid's resistance to flow; viscosity of nano fluid depends on the volume fraction concentration of nano particle. Viscosity of nanofluid is calculated using viscosity model for nanofluid. [19]

$$\mu_{nf} = \mu_{bf}(1+2.5\varphi) \quad (4)$$

Where μ_{nf} represents the viscosity of nanofluid, μ_{bf} represents the viscosity of base fluid.

Heat transfer rate can be calculated by using equation as

$$Q = mCp(T_{in} - T_{out}) \quad (5)$$

where, m is mass flow rate and C_p specific heat capacity of the nano coolant.

From Newton cooling law

$$Q = hA(T_b - T_w) \quad (6)$$

$$T_b = (T_{in} + T_{out})/2 \quad (7)$$

$$T_w = (T_{w1} + T_{w2} + T_{w3} + T_{w4} + T_{w5})/5 \quad (8)$$

where, h is the heat transfer coefficient, A is surface area of tube. Here, T_b is bulk temperature and T_w is the wall temperature. T_b is assumed to be the average values of inlet and outlet temperature of the nano coolant through the radiator.

Then, the experimental heat transfer coefficient h_{exp} is obtained as follows

$$h_{exp} = \frac{mc_p(T_{in} - T_{out})}{A(T_b - T_w)} \quad (9)$$

IV. Results and Discussion

In the present work the specific heat, heat transfer rate and average heat transfer coefficient of mixture of MWCNT water ethylene glycol was experimentally evaluated using an used automobile radiator. The MWCNT concentration in nano coolant, nano coolant flow rate, and coolant inlet temperature was varied in the stud and the outlet coolant temperature and the radiator wall temperature was measured as output. Table 3 shows the variation of output parameter with the variation in the input parameter.

From the table it is clear that the outlet temperature decreases in both case low and high inlet temperature. The decrease in out let temperature is more with high inlet temperature. The decrease in outlet temperature is more with low flow rate (3 L/min) as compared to high flow rate (7 L/min). As the concentration of the nano particles (MWCNT particles) increase the outlet temperature also decrease both for low and high inlet temperature.

Thermal conductivity of nanofluid is a critical factor in heat transfer application. In the present study Hamilton and Crasser model have been used to calculate the thermal conductivity of nanofluid at different volumetric concentration of MWCNT nanoparticles. Thermal conductivity of (50:50) ethylene-glycol/ water (base fluid) is taken from M'hameds et al. research work, as they have also used the same base fluid [1]. Fig. 4(a) shows the variation of the thermal conductivity of the nanofluid with the concentration of MWCNT in the nano coolant fluid. From the fig 4 (a) it is clear that the thermal conductivity of base fluid is 0.3736 W/mK [1] and the thermal conductivity increases with increase in nanoparticle concentration, because MWCNT nano particles have high thermal conductivity as compared to base fluid. The nano fluid with concentration of 0.01 Vol.% have effective thermal conductivity of 0.4412 W/mK which increases with concentration up to k = 1.1166 W/mK at 0.1 Vol.% concentration. Thermal conductivity of nanofluid enhances by 199% at 0.1 Vol.% as compared to ethylene-glycol/water (base fluid).

Density of the MWCNT nano particles is more than the base fluid, increase in concentration of MWCNT nanoparticles enhanced the density of nanofluid. Variation of the density of the MWCNT nano coolant fluid was shown in the fig. 4. (b). The density of nanofluid is calculated from the density model for nano fluid [10]. Base fluid (water-ethylene glycol, 50:50) have density of 1050 kg/m^3[1] the density of nano fluid at 0.1 Vol.% is 1155 kg/m^3.

Specific heat capacity of a nanofluid is the amount of heat required to raise temperature of one gram of sample by one

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degree Celsius. The specific heat capacity of nanofluid depends on the volume fraction of the nanoparticles. Specific heat capacity of ethylene-glycol/water (50:50) is taken from M'hameds et al. research work, as they have also used the same base fluid and specific heat capacity of different nanofluid concentrations is estimated using theoretical model [1].

Table 3. Show the variation in the outlet temperature and wall temperature with the variation in concentration of MWCNT, flow rate and inlet temperature of nano coolant.

Concentration	**Flow Rate**	**Inlet Temp.**	**Outlet Temp.**	**Wall Temp. -1**	**Wall Temp.-2**	**Wall Temp.-3**	**Wall Temp.-4**	**Wall Temp.-5**
φ	**L/min**	**T_{in} °C**	**T_{out} °C**	**T_{w1} °C**	**T_{w2} °C**	**T_{w3} °C**	**T_{w4} °C**	**T_{w5} °C**
0	3	65	60.2	48	53	56	55	40
0	5	65	61.3	49	54	58	58	43
0	7	65	61.8	52	56	59	60	47
0	3	70	64.5	49	55	58	57	40
0	5	70	65.6	50	58	62	60	44
0	7	70	66.1	53	60	62	63	48
0.01	3	65	60.3	46	52	55	54	39
0.01	5	65	61.2	48	56	57	57	44
0.01	7	65	61.7	51	58	58	59	48
0.01	3	70	64.5	50	57	57	56	40
0.01	5	70	65.5	51	59	61	61	44
0.01	7	70	66.1	53	61	60	63	49
0.05	3	65	59.6	47	53	40	52	52
0.05	5	65	60.6	48	54	44	57	57
0.05	7	65	61.3	51	58	48	58	57
0.05	3	70	64.1	50	57	41	56	55
0.05	5	70	65	51	57	46	60	59
0.05	7	70	65.6	54	60	49	62	60
0.1	3	65	59.3	47	54	40	53	53
0.1	5	65	60.1	48	56	42	57	57
0.1	7	65	60.6	50	57	45	58	57
0.1	3	70	63.6	49	57	41	55	55
0.1	5	70	64.4	50	59	44	60	60
0.1	7	70	65	54	61	48	61	60

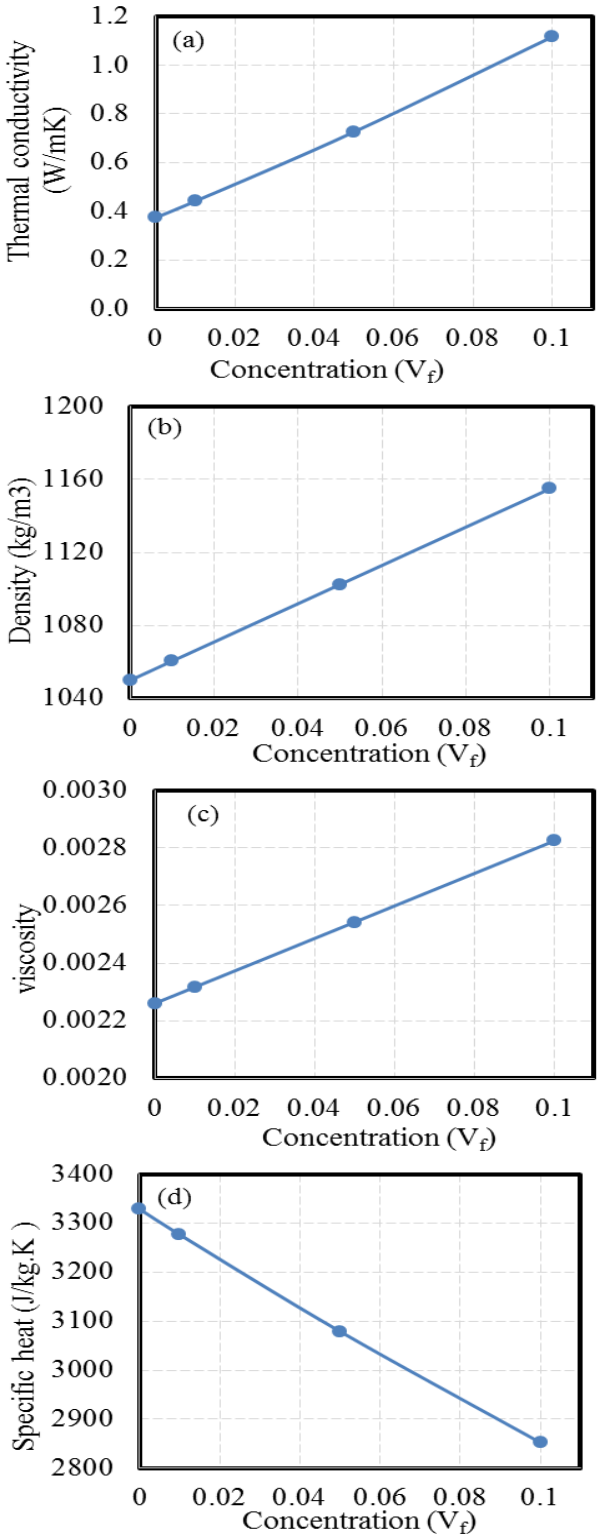

Fig. 4. Shows the variation of (a) Thermal Conductivity, (b) Density, (c) Viscosity, and (d) Specific heat; of nano coolant with the variation in concentration of MWNCT in nano coolant.

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The variation of specific heat capacity was shown in fir. 4 (c). From the figure 4(c) it is clear that the specific heat capacity of the nano fluid inreases with the increase in the concentration of the MWCNT. Specific heat capacity of base fluid is 3328.5 J/kg-K and specific heat capacity of nanofluid decreases with increased concentration, nanofluid at 0.1 Vol.% have specific heat capacity of 2852.41 J/kg-K which produces negative effect on heat transfer enhancement. The enhancement in the specific heat capacity was an effect of blending solid particles in the fluid.

Nanofluid's viscosity is the important parameter while designing nanofluid for flow and heat transfer applications because the viscosity affects the pumping power and convective heat transfer of the nanofluid. From the fig 4(d) it was seen that viscosity of nanofluid increases with increase in nano particle concentration. Increase in volume fraction concentration of MWCNT, the number of nanoparticles collisions with base fluid molecules also increases this leads to an increase in viscosity. For base fluid, ethylene glycol-water (50:50) viscosity is 0.00226 Pa-s and increased upto 0.002825 Pa-s at 0.1 Vol.% of MWCNT nanoparticle concentration.

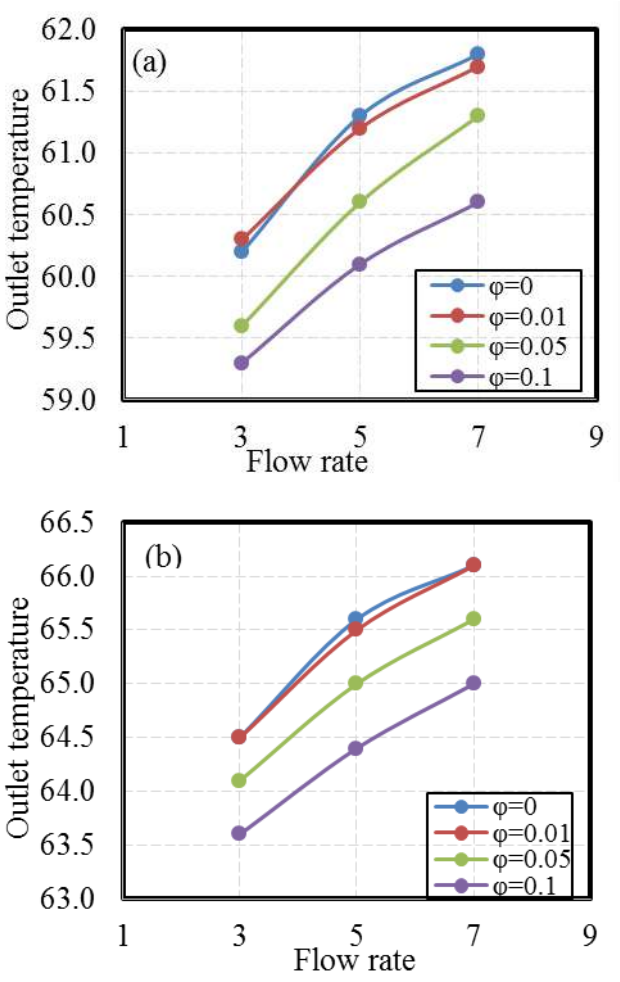

Fig. 5. Shows the variation in outlet temperature with the variation in the flow rate and concentration of MWCNT in nano coolant fluid with inlet temperature of (a) 65°C and (b) 70°C

The nano-fluid is blended with different volume fraction of MWCNT concentrations, (i.e. 0.01%, 0.05% and 0.1 Vol.%) and the coolant is forced flowed through the radiator. The flow rate of the coolant was varied as 3, 5, and 7 L/min to study the effect of concentration on thermal performance of the radiator different concentration of nanofluids. It is important to mention that for any cooling system, at equal mass flow rate larger the reduction in working fluid temperature at the exit indicates better thermal performance of cooling system. Variation in outlet temperature of the nano fluid at varying Vol.% of MWCNT concentration, at constant 65°C inlet temperature was shown in Fig. 5(a), from the Fig. we can observe that as the concentration of MWCNT increases the outlet temperature decreases. Maximum difference of about 5.7°C was observed at 0.1 Vol.%, when the flow rate was maintained at 3 L/min.

Radiator outlet temperature, with varying vol.% of MWCNT with flow rate of nano fluid coolant was shown in Fig.5(b). Four condition of data shown in this figure, one was of base fluid and other three are for three different concentrations of the MWCNT in nanofluids (0.01, 0.05 and 0.1 vol.%). The data shown in the figure was for inlet temperature of 70°C. It was observed that outlet temperature of the radiator decreases with increase in vlo.% of MWCNT nanoparticle. At 70°C maximum temperature difference of 6.4°C was observed at 0.1 Vol.% concentration and flow rate of 3 L/min.

Radiator outlet temperature increases with increase in flow rate of the nano fluid for all concentrations and for both 60°C and 70°C inlet control temperature. Increase in outlet temperature in more, with low inlet temperature (i.e. 65°C) as compared to that of high inlet temperature (70°C).

The concentration of nanoparticles plays an important role in the heat transfer rate of nano coolant fluid. Fig. 6(a and b) shows influence of vol.% concentration and flow rate of MWCNT nanofluid on heat transfer rate of MWCNT nano coolant fluid at low inlet temperature 65°C (Fig 6(a)) and at high inlet temperature 70°C (Fig. 6 (b)). It was observed from experimental data that heat transfer rate improves with increase in flow rate and volume fraction concentration of MWNCT nanoparticle. At 65°C maximum heat transfer rate of 1691.2W was observed at 0.1 vol.% concentration for flow rate of 7 L/min.

Fig. 6 (b) shows the effect of flow rate and MWCNT nanoparticle volume fraction concentration on the heat transfer rate of the radiator at 70°C. Heat transfer rate found to be increased with increase in particle volume concentration and flow rate of nanofluid. The maximum heat transfer rate by

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radiator at 70°C was 1921.8W at 0.1 Vol.% and flow rate of 7 L/min.

It was observed very less effect of particle concentration on heat transfer rate at flow rate of 3 L/min, but as the flow rate increases there is significant enhancement in heat transfer rate at constant particle volume fraction was observed. It was also observed that at very low concentration 0.01 vol.% of MWCNT nanoparticle there is no significant improvement in heat transfer rate of radiator.

Brownian motion of nanoparticles is responsible for enhancement of heat transfer in nanofluid. Random motion of nanoparticles in the base fluid causes the thinning of thermal boundary layer and it also improves heat transfer characteristics of nanofluid. The maximum enhancement in heat transfer rate of 29.6% was observed at 0.1 Vol.% concentration, constant flow rate of 7 L/min and 65°C fluid inlet temperature.

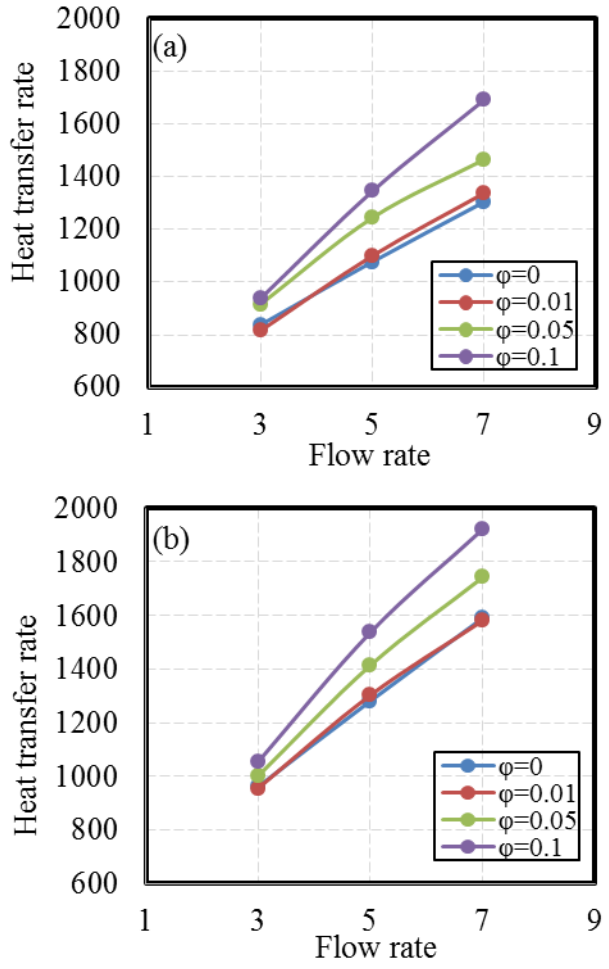

Fig. 6. Shows the variation in heat transfer rate with the varying in the flow rate and concentration of MWCNT in nano coolant fluid with inlet temperature of (a) 65°C and (b) 70°C

Fig 7 (a) show the effect of flow rate and MWCNT nano particle concentration on the average heat transfer coefficient of MWCNT nano fluid at constant 65°C inlet temperature. It was observed from experimental data that average heat transfer coefficient increased with increase in flow rate and nano particle volume concentration. The maximum average heat transfer coefficient at 65°C was 763.97 W/m^{2}K, observed at 0.1 Vol.% and flow rate of 7 L/min.

The obtained data of average heat transfer coefficient for 70°C fluid inlet temperature for different nanofluid volume concentration was shown in Fig. 7 (b). It is observed from the figure that average heat transfer coefficient enhances with increase in nanofluid volume concentration. In the present study 0.1% nanoparticle volume concentration was found to exhibit maximum heat transfer performance as compared to base fluid.

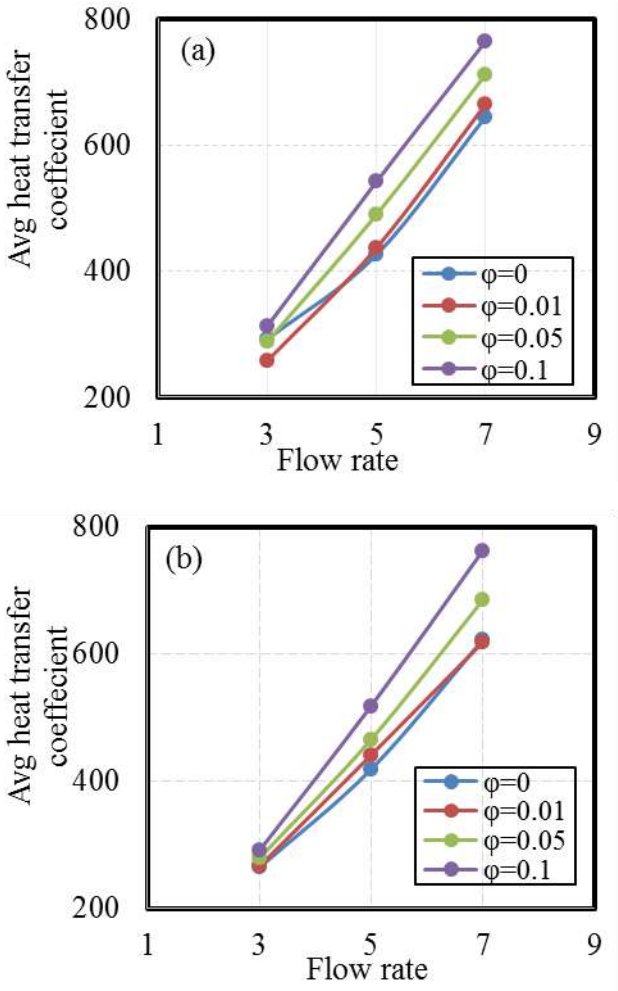

Fig. 7. Shows the variation in average heat transfer coefficient with the varying in the flow rate and concentration of MWCNT in nano coolant fluid with inlet temperature of (a) 65°C and (b) 70°C

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The obtained data of average heat transfer coefficient for 70^{o}C fluid inlet temperature for different nanofluid volume concentration was shown in Fig. 7 (b). It is observed from the figure that average heat transfer coefficient enhances with increase in nanofluid volume concentration. In the present study 0.1% nanoparticle volume concentration was found to exhibit maximum heat transfer performance as compared to base fluid.

It was also observed that the heat transfer coefficient of both nanofluid as well as base fluid enhanced with increase in coolant flow rate. Due to the collisions between nanoparticles and impacts of nanoparticles with the car radiator tube wall increases as the volume concentration increases, this results in a rise in the Brownian movement and energy exchange rate of nanoparticles. The effective thermal conductivity, Brownian movement of nanoparticles, and particle relocation increases as the nanoparticle concentration increases resulting in an increase in average heat transfer coefficient. The maximum average heat transfer coefficient at 70^{o}C was 762.67W/m^{2}K at 0.1 Vol.% MWCNT nanoparticle concentration and flow rate of 7 lit/min. From figure it can be concluded that presence of nanoparticles at high flow rate provides well mixing of nanoparticles and thus increases the average heat transfer coefficient.

V. CONCLUSIONS

In the present study the effect of volume fraction concentration of MWCNT nanoparticles was experimentally evaluated on the heat transfer characteristics of water/ ethylene glycol (50:50) nano coolant. Following were the major outcome of the study:

- The maximum heat transfer rate by radiator was 1921.8W at 70^{o}C at 0.1 vol.% content of MWCNT and flow rate of 7 L/min.
- Maximum enhancement in heat transfer rate of about 30% was observed at 0.1 Vol.% concentration when inlet fluid temperature was maintained at 65^{o}C. The higher increase was at 65^{o}C was due to lower heat transfer rate of unblended fluid as compared to 0.1 Vol.% MWCNT blended nano fluid.
- Maximum enhancement in heat transfer coefficient of 22% was observed at 0.1 Vol.% concentration and 65^{o}C fluid inlet temperature.
- Maximum average heat transfer coefficient at 65^{o}C was 763.97 W/m^{2}K, observed at 0.1 Vol.% and flow rate of 7 L/min.
- At 70^{o}C maximum inlet temperature difference of 6.4^{o}C was observed at 0.1 vol.% concentration on flow rate of 3 L/min.
- Heat transfer coefficient of both nanofluid as well as base fluid enhanced with increase in coolant flow rate.

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REFERENCES

[1] M'Hamed B., Sidik NAC., Akhbar MFA., Mamat R and Najafi G., Ëxperimental study on thermal performance of MWCNT nanocoolant in Perodua Kelisa 1000 cc radiator system, Int. Communication in heat and mass transfer" 76, 2016, pp 156-161.

[2] L.D. Tijing, B.C. Pak, B.J. Baek, D.H. Lee, "A study on heat transfer enhancement using straight and twisted internal fin inserts", International Communications in Heat and Mass Transfer, 33 (6), 2006, pp 719-726.

[3] P. Naphon, "Effect of coil-wire insert on heat transfer enhancement and pressure drop of the horizontal concentric tubes", International Communications in Heat and Mass Transfer, 33 (6), 2006, pp 753-763.

[4] B. Sahin, A. Demir, "Performance analysis of a heat exchanger having perforated square fins", Applied Thermal Engineering 28 (5-6), 2008, pp 621-632.

[5] Z. Zhnegguo, X. Tao, F. Xiaoming, "Experimental study on heat transfer enhancement of a helically baffled heat exchanger combined with three dimensional finned tubes", Applied Thermal Engineering 24 (14-15), 2004, pp 2293-2300.

[6] M.Y. Wen, C.Y. Ho, "Heat-transfer enhancement in fin-and-tube heat exchanger with improved fin design", Applied Thermal Engineering 29 (5-6), 2009, pp 1050-1057.

[7] S.H. Hashemabadi, S.Gh. Etemad, "Effect of rounded corners on the secondary flow of viscoelastic fluids through non-circular ducts", International Journal of Heat and Mass Transfer 49, 2006, pp 1986-1990.

[8] S.H. Hashemabadi, S.Gh. Etemad, M.R. Golkar Naranji, J. Thibault, "Laminar flow of non-Newtonian fluid in right triangular ducts", International Communications in Heat and Mass Transfer, 30 (1), 2003, pp 53-60.

[9] Peyghambarzadeh SM., Hashemabadi SH., Jamnani AS. and Hoseini SM., "Improving the cooling performance of automobile radiator with Al_2O_3/water nanofluid", Applied Thermal Engineering 31, 2011, pp 1833-1838.

[10] Subhedar DG., Ramani BM., and Gupta A., "Experimental Investigation of Heat Transfer Potential of Al2O3/Water-Mono Ethylene Glycol Nanofluids as a Car Radiator Coolant", Case Study in Thermal Engineering, doi.org/10.1016/j.csite.2017.11.009.

[11] S.U.S. Choi, W. Yu, J.R. Hull, Z.G. Zhang, F.E. Lockwood, "Nanofluids for vehicle thermal management", SAE Technical Papers, 2001 (art. No. 2001-01-1706).

[12] C.W. Maranville, H. Ohtani, D.D. Sawall, J.T. Remillard, J.M. Ginder, "Thermal conductivity measurements in nanofluids via the transient planar source method", SAE Technical Papers, 2006 (art. No. 2006-01-0291).

[13] S.M. Peyghambarzadeh, S.H. Hashemabadi, S.H. Hoseini, M.S. Jamnani, "Experimental study of heat transfer enhancement using water/ethylene glycol based nanofluids as a new coolant in the car radiator", Int. Commun. Heat Mass Transfer, 38 (9), 2011, pp 1283–1290.

[14] Y. Vermahmoudi, S.M. Peyghambarzadeh, S.H. Hashemabadi, M. Naraki, "Experimental investigation on heat transfer performance of Fe_2O_3/water nanofluid in an air-finned heat exchanger", Eur. J. Mech. B/Fluids, 44, 2014, pp 32–41.

[15] A.K. Rasheed, M. Khalid, W. Rashmi, T.C.S.M. Gupta, A. Chan, "Graphene based nanofluids and nanolubricants – review of recent developments, Renew", Sustain. Energy Rev., 63, 2016, pp 346–362.

[16] C. Selvam, D. Mohan Lal, S. Harish, "Enhanced heat transfer performance of an automobile radiator with graphene based suspensions", Appl. Therm. Eng., 123, 2017, pp 50–60.

[17] Selvam C., Raja R.S., Lal DM., Harish S., "Overall heat transfer coefficient improvement of an automobile radiator with grapheme based suspensions", International Journal of Heat and Mass Transfer, 115, 2017, pp 580-588.

[18] B.C. Pak, Y.I. Cho, "Hydrodynamic and heat transfer study of dispersed fluids with submicron metallic oxide particles", Exp. Heat Transf., 11, 1998, pp 151–170.

[19] Sandhya D., Reddy ACS., and Rao VV, "Improving the cooling performance of automobile radiator with ethylene glycol water based TiO_2 nanofluids", International Communication in Heat and Mass Transfer, 2016, doi.org/10.1016/j.icheatmasstransfer.2016.09.002.

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NATURAL CONVECTION BOUNDARY LAYER FLOW OVER CYLINDERS AND CONES

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ABSTRACT
Numerical and experimental studies are performed for natural convection flow and heat transfer around horizontal heated cylinder with uniform and converging circular cross sections. The experiment is conducted on a circular cylinder of varying cross section made on brass having diameter 60mm and 20mm with taper angle 20^o using schlieren technique. Numerical studies are done on horizontal heated cylinder with uniform and non-uniform cross section in an unconfined fluid for a wide range of Rayleigh number, different surface temperature and heat flux conditions. A two dimensional, steady, laminar numerical model based on finite volume formulation is solved using a commercial CFD software FLUENT (Release 14.5). Boussinesq approximation is used because the problem dealt with natural convection and body force term comes into picture. The model has been validated using available experimental data from the literature. Results show that, due to the increase in boundary layer thickness along the cylinder surface the Nusselt number decreases with increase in angular distance.When wall temperature increases, the air approaching the cylinder gets more heated up. The air velocity increases for larger temperature difference results in high heat transfer coefficient.

Keywords: CFD, Natural convection, boundary layer, heated cylinder.

I. INTRODUCTION

Natural convection heat transfer phenomenon has found technical application in the design of many engineering equipments like design of heat exchangers, design of boilers, electronic cooling, air cooling systems in air conditioning, under water pipe line. The most important geometric configuration which has application in wide range of engineering problem is that of horizontal cylinders. Because of the importance in industrial processes, overall natural convective heat transfer from horizontal cylinders has been the subject of many experimental and analytical studies. This will be useful in the design of electrical equipment like transformers, solar devices, food processing industry etc. Majority of the studies have concentrated on horizontal cylinders, while relatively less attention has been paid to natural convection around other surfaces such as conical sections. Therefore, the current study is focused on developing an experimental setup for studying natural convection flow around circular and conical sections followed by numerical investigations

II. LITERATURE REVIEW

Literature cites many works on natural convection flow around horizontal cylinders with uniform cross section comparatively few works have been carried on test section with non-uniform cross section. Morgan [1] studied natural convection flow around horizontal smooth cylinders and proposed correlation for average Nusselt number for Rayleigh number varying from 4.8×10^4 to 1.3×10^{15}. Churchill and Chu [2] proposed correlation for average Nusselt number based on experimental data for laminar and turbulent conditions. Two different correlations are proposed for uniform wall temperature condition and uniform heat flux condition. McAdams [3] proposed average Nusselt number correlation for a range of Rayleigh number from 10^4 to 10^9.One of the most important numericalstudy on natural convection around horizontal cylinder was conducted by Kuehn and Goldstein [4]. They solved the Navier Stokes equation using finite difference method and found that flow approaches natural convection flow from line heat source as Ra tends to zero and laminar boundary layer flow as Ra tends to infinity. Farouk and Guceri [5] conducted numerical study using finite difference method for laminar, steady state, two dimensional natural convection flow around cylinders submerged in a Boussinesq fluid. They found that at high Rayleigh number thinner fine mesh is required near the boundaries. Saitoh [6] studied natural convection flow around a horizontal circular cylinder with uniform surface temperature. They concluded that in order to get a good result the grid should be highly refined near the cylinder and the domain should be sufficiently large. Kitamura and Misumi [7] conducted natural convection experiments on large horizontal cylinders using water as the test fluid and find the critical Rayleigh number at which transition happens from laminar to turbulent condition.Herraez and Belda [8] conducted experiments to study natural convection flow around cylinders with different diameter but same length and different surface temperature using holographic interferometry technique. They determined the local and mean Nusselt number. Ozgur and Ismail [9] conducted experimental study on heated horizontal cylinders at different surface temperatures and different ambient temperature. Grafsronningen [10] conducted experiments to investigate the plume structure around uniform

horizontal cylinder using PIV technique. The experiment was conducted for a Rayleigh number ranging from 2.05 x 10^7 to 7.94 x 10^7 and found that local Nusselt number decreases with increase in circumferential angle. For horizontal heated cylinders there are various correlations available for average Nusselt number, but there is lack of correlations for local Nusselt number. Since all the numerical and experimental studies deals with horizontal heated cylinders with uniform cross sections, there is lack of literature for converging or diverging cross section. Thepresent study focuseson the variation of local Nusselt number around horizontal cylinders and to analyze the natural convection flow features around conical sections.

III. DETAILS OF EXPERIMENTAL SETUP

Schematic arrangement of the experimental setup is shown in figure 1. The test setup consists of test section, LED light source, DC power supply, mirrors, high speed camera, auto transformer and computer to store the camera recordings. Figure 2 represents the actual experimental setup.

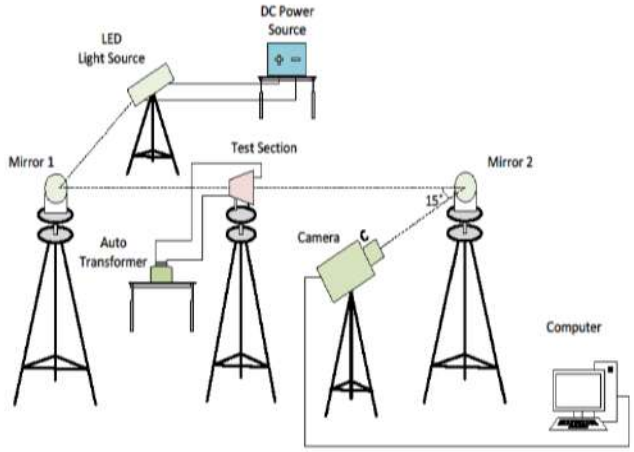

Figure1: Schematic arrangement of experimental Setup

The test section consists of a circular cylinder of varying cross section made of brass. The large end diameter is 60mm and the small end diameter is 20mm and the taper angle is 20º.The test section have a thickness of 0.5mm. The cylinder with varying cross section is made from brass cylindrical block by turning process using a mandrel specially made for the purpose. The cylinder is heated with a nichrome wire of 28 gauge which has a resistance of 9.93 Ω. The remaining space between the nichrome heater and inside portion of the cylinder was filled with magnesium dioxide which has good electrical resistance and thermal conductivity make it suitable for the application. The two sides of the cylinders are fixed with aluminium end caps which prevent the spilling of magnesium dioxide and also provide air tight packing. The test section is attached to two height adjustable post thereby ensuring stable support to the test section. The heat input to the test section heater is given by a single phase auto transformer. The temperature measurements are taken using non contactable infrared thermometer. Schlieren technique was used for the visualisation process. Schlieren visualisation is a process used to photograph the flow of fluids of varying density. The schlieren technique used in the experimental study uses two 8” mirrors which have a focal length of 80” and λ/8 surface finish. A high power LED which has a power of 100W is used as the light source. The light from the point source falls on the mirror1 produces a collimated light beam which passes across the test section and falls on mirror 2. A portion of light that reflects from mirror 2 is cut by a knife edge and the image thus produced is captured by a high speed camera, Phantom V1210. The images were captured at a resolution of 1280 x 800 and 12000 frames per second. The entire setup is arranged in an environment which ensures least ambient temperature variations and without any external flow disturbances during the experimental run.

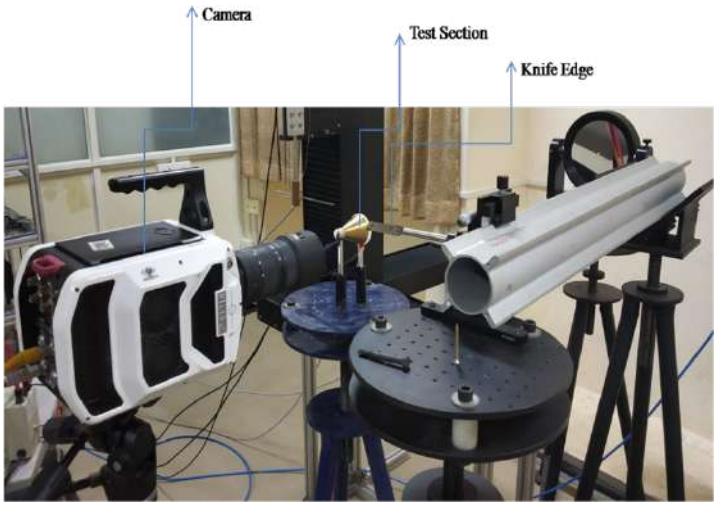

Figure 2: Photograph of Schlieren technique in actual experimental setup

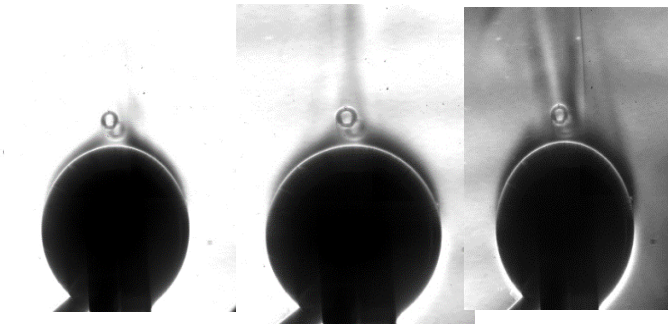

Figure 3:Images of boundary layer formation around horizontal converging cone at different knife edge positions

The major uncertainties involved in the measurements are uncertainty in temperature, voltage and current. The maximum uncertainty associated with non-contactable infrared thermometer was ±0.1^o C. The maximum deviation for voltage and current readings were ±0.1 V and ±0.01 A respectively. Considering the individual uncertainties, the estimated error in measurement of heat input is ±0.984%.Schlieren technique is a qualitative technique of visualisation, so no quantitative results can be generated using the technique and capturing the boundary layer near the bottom portion of the cylinder is difficult using schlieren method. The visualisation technique used in experimental study has to be changed to particle image velocimetry technique which will give velocity values. Figure 3 shows the qualitative images of boundary layer formation around horizontal cylinder at different knife edge positions.

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IV. DETAILS OF NUMERICAL STUDY

A two dimensional model is used to investigate the heat transfer and fluid flow characteristics for a range of Rayleigh numbers. The flow and heat transfer are considered as steady and laminar. The fluid is assumed as incompressible, with constant physical properties. Radiation heat transfer effects are neglected. The fluid properties were calculated at mean temperature, $Tm=(T_a + T_w)/2$. Boussinesq approximation and incompressible ideal gas equation is used for the numerical study. The problem was initialized using second order upwind scheme. The momentum and energy are initialized by second order upwind scheme. Body force weighted method is used for pressure interpolation. SIMPLE scheme is used for pressure velocity coupling and convergence criteria for the numerical study was 10^{-6} for continuity, momentum and energy.

Even though the test cylinder is kept in an infinite fluid medium, the computational domain should be finite. An imaginary boundary should be there which is far from the cylinder which defines the computational domain for the numerical study. Since the flow is symmetrical about the vertical axis only half portion of the cylinder is used to represent the cylinder in numerical study which reduces the computational time and cost. Numerical simulation was performed using FLUENT (Release 14.5). The geometry for the numerical study is developed in the Design Modeller in ANSYS work bench. Meshing of the computational domain is done using ANSYS software. The mesh consists of structured quadrilateral elements near to the cylinder and unstructured triangular elements in the outer portion. A fine mesh was provided near the cylinder to study heat transfer and flow characteristics near the cylinder.Meshing is done using a hybrid grid strategy with the structured and the unstructured-grid with a conservative coupling interface to associate patched structured and unstructured grids. The high quality meshes near the surface is generated with structured meshes and unstructured meshes are used near the domain boundaries as it is difficult to generate structured meshes even if multi-block typologies are applied. This combination are used to respectively discretize a portion of the flow domain where appropriate.

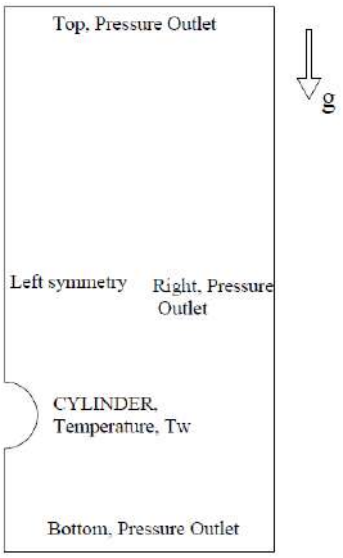

Figure 4. Computational Domain

The governing equations used for natural convection fluid flow and heat transfer are

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \quad (1)$$

$$\rho_a u \frac{\partial u}{\partial x} + \rho_a v \frac{\partial u}{\partial y} = -\frac{\partial (P - P_a)}{\partial x} + \mu \left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} \right) \quad (2)$$

$$\rho_a u \frac{\partial v}{\partial x} + \rho_a v \frac{\partial v}{\partial y} = -g\beta\rho_a (T - T_a) - \frac{\partial (P - P_a)}{\partial y} + \mu \left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} \right) \quad (3)$$

$$u \frac{\partial T}{\partial x} + v \frac{\partial T}{\partial y} = \alpha \left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} \right) \quad (4)$$

Isothermal wall temperature boundary condition is provided to the cylinder under study. Symmetrical condition is applied to the left boundary as the flow is symmetrical about the vertical axis, and pressure outlet condition is provided to other three boundaries. The fluid used for the numerical study is air and the surrounding fluid is assumed to be at ambient temperature. Cylinder with 20mm diameter was used for numerical studies for a range of surface temperatures, diameters and heat flux. A grid independency study was necessary for selecting optimum number of grid points to ensure that the flow is properly happening and for minimising the computational cost. Figure 5 shows the temperature along radial line in the vertical axis from the top of the cylinder up to the top boundary of the domain for different number of grid elements within the domain. As the number of grids increases the difference in temperature at any point from the cylinder top decreases. Based on the study, a grid with 1, 60,000 elements was chosen for the numerical study

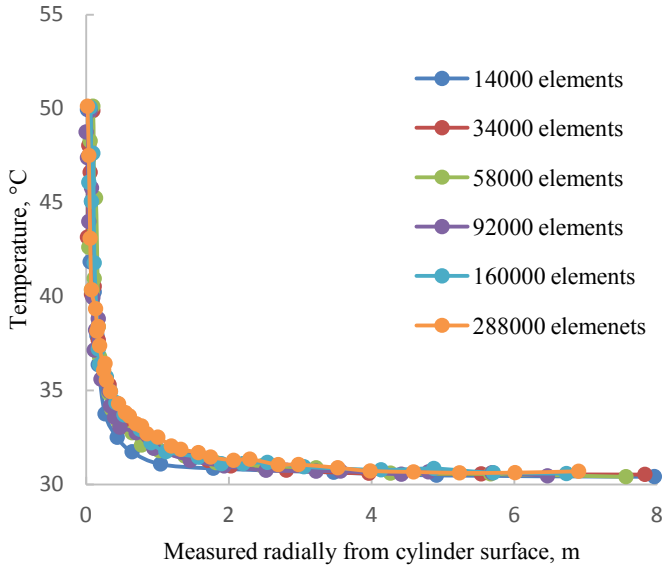

Figure 5. Grid independence study

The results obtained from the numerical solution needs to be compared with experimental results obtained under same conditions. The results obtained from the numerical study are compared with experimental results of Kitamura et al [7]. In the experimental study, the diameter of the test section is varied

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from 60mm to 800mm to conduct experiments for a wide range of modified Rayleigh number(Ra*) from 3 x 10^8 to 3.6 x 10^{13}.The flow over the surface of cylinders was visualized by dye crystal thermometry technique. Water at 20ºC was used as the test fluid and a uniform heat flux of 2000 W/m^2 was applied to the test cylinder. Figure 6 shows the variation of local Nusselt number for cylinder diameter 95mm with heat flux of 2000W/m^2. The results of the numerical study closely follow the trend of experimental results obtained by Kitamura et al [7]. The result of numerical study shows agreement with experimental data. The maximum variation in numerical and experimental data is around 7.6 %. This may be because of experimental errors or due to Boussinesq approximation.

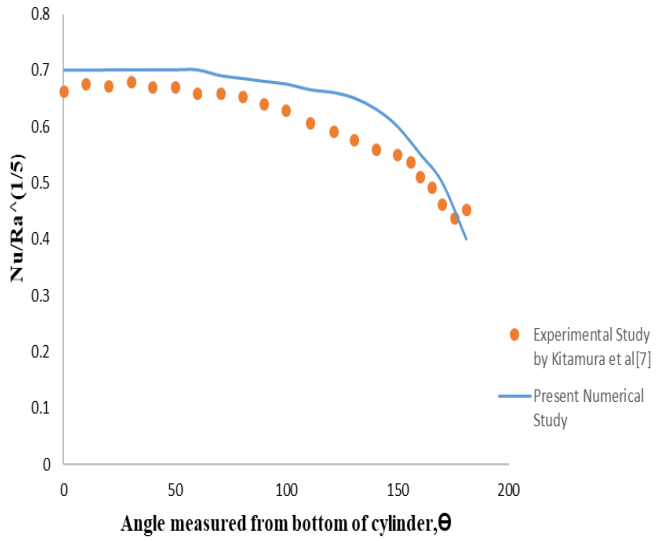

Figure 6. Validation of numerical study with Kitamura et al [7]

V. RESULTS AND DISCUSSION

Figure 7 shows the variation of Nusselt number with Θ for different Rayleigh numbers ranging from 10^1 to 10^6.The local Nusselt number increases with increase in Rayleigh Number at the surface of the cylinder. Nusselt number is maximum at the bottom of the cylinder for a particular Rayleigh Number. Nusselt number decreases as angle from bottom of cylinder increases due to formation of boundary layer which will decrease the thermal diffusivity. For small diameter cylinders, Rayleigh number will be small and the boundary layer formation will be large. As the diameter of the cylinder increases, the Rayleigh number increases and the boundary layer decreases which result in high Nusselt number.

Figure8 represents the velocity profile of heated horizontal cylinder at different Rayleigh numbers. Three forces are predominant in natural convectionflow namely: viscous force, inertia force and buoyancy force. Of the three buoyancy force is the driving force which causes natural convection resulting in heat transfer. Viscous or friction force and inertia force tend to oppose the flow. At the cylindersurface because of no slip condition velocity is zero. Velocity increases in magnitudeas distance from the cylinder surface increases. Thus in this region viscous –buoyancyforces are predominant. Due to low viscosity of air, viscous force is predominant onlyup to a small thickness adjacent to the cylinder wall. Beyond this thickness air buoyancy force is restrained by its own inertia. The air in contact with bottom most part of the cylinder gains the heat and rises up. As the air get heated up, the air density decreases, the air gains velocity and move sideways forming the boundary layer. When the air reaches half way of the cylinder the air gets high velocity and separates from the cylinder and rises above the cylinder as plume.

As wall temperature increases, the air near the cylinder gets more heated up. As a result, the air velocity and heat transfer coefficient increases for large temperature difference,ΔT.Figure 9 shows the variation of Nusselt number with angle measured from the bottom of cylinder for different wall temperature conditions. As the heat flux increases, the Nusselt number also increases. For 50% increase in heat flux, there is an increase of 50% in the Nusselt number. The percentage deviation in Nusselt number remains constant.

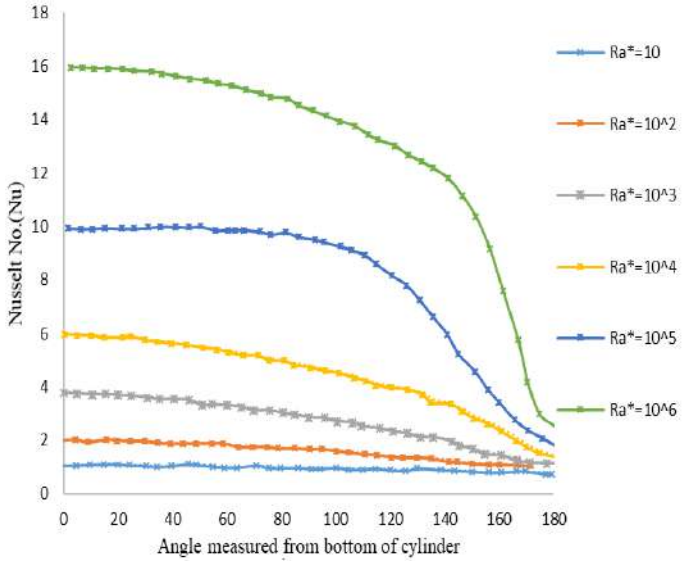

Figure 7. Nusselt Number variation with Θ for different Rayleigh numbers

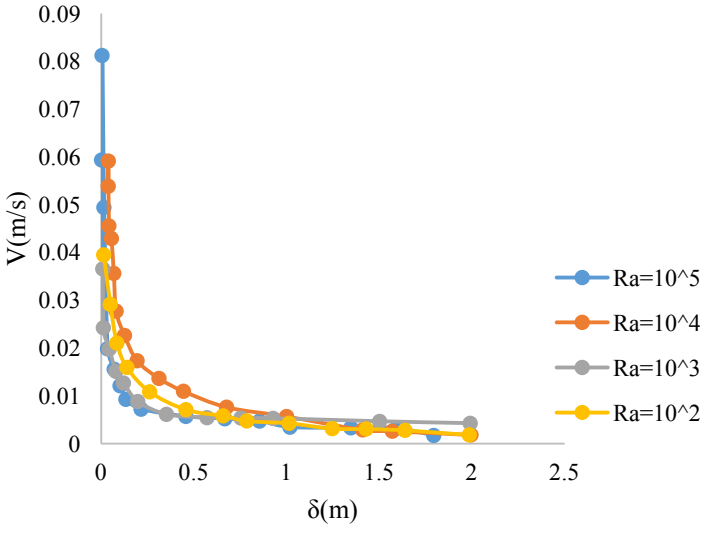

Figure 8. Velocity Profile for different Rayleigh number

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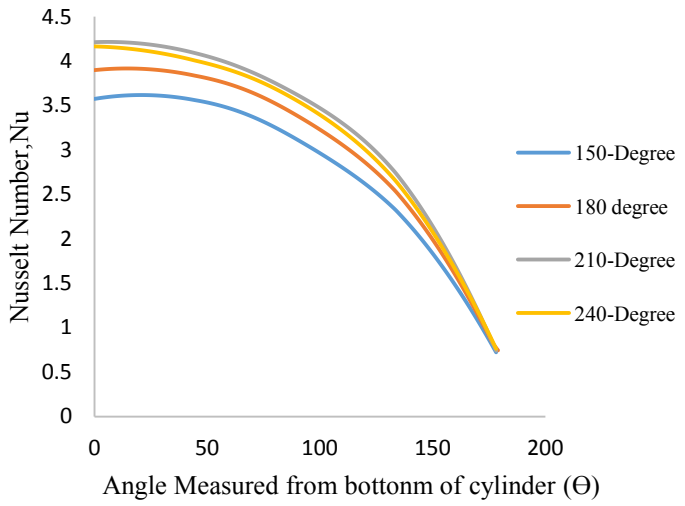

Figure 9. Nusselt number variation with angle measured from bottom of cylinder for different surface temperature condition.

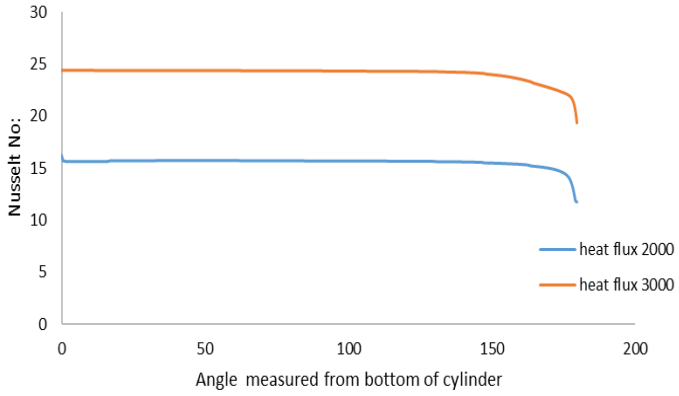

Figure 10. Nusselt number variation with angle measured from bottom of cylinder for different heat flux condition

At larger angles the turning of the flow to form the plume alters the temperature distribution. The boundary layer thickness is approximately infinite near the plume center creating a comparatively steeper drop in Nu and local heat transfer coefficient. It is also noted that as diameter increases, Rayleigh number increases and the boundary layer thickness decreases and alters the temperature distribution.

VI. CONCLUSION

The study presents the numerical and experimental work on natural convection boundary layer flow over horizontal heated cylinders kept in an unconfined fluid. An experimental setup was realized for studying the natural convection flow around horizontal cylinders with uniform and non-uniform cross sections. Experiments were conducted on horizontal heated cylinders at different heat flux and surface temperature condition. The plume structure around the cylinders at different heat flux conditions were captured using schlieren technique which can be used to validate the numerical model. A 2D steady laminar numerical model using Boussinesq approximation is solved using commercial CFD software FLUENT. The following observations are made for horizontal cylinder with uniform cross section. Nusselt number increases with increase in Rayleigh number. Nusselt number is maximum at the bottom of the cylinder. Nusselt number decreases from bottom to top of the cylinder due to the formation of boundary layer. The local Nusselt number is highest at the bottom and lowest at the top of the cylinder when the boundary layer flow remains laminar. For large Rayleigh numbers, the boundary layer thickness near the bottom portion of cylinder decreases. In the case of velocity, the air gets heated up near the cylinder and the density of air decreases which increases the air velocity. The increase in plume velocity is up to a certain height and then become almost constant. For the cases of various surface temperature, as the surface temperature increases, the air gets more heated up, the density of air decreases and correspondingly the velocity increases. This explains the reason for high heat transfer coefficient with increase in temperature. In the case of experimental studies, schlieren technique is a qualitative technique of visualisation, no quantitative results can be generated using the technique. Qualitative images representing the plume structure at different knife edge positions are generated from experimental studies

VII. REFERENCES

[1] V.T.Morgan (1975),''The Overall Convective Heat Transfer from Smooth Circular Cylinders", Adv. Heat Transfer, vol.11, p.199–264.

[2] S.W.Churchill, H.H.S.Chu (1975),"Correlating equations for laminar and turbulent free convection from a horizontal cylinder", International Journal of Heat and Mass Transfer, vol.18, p.1049–1053.

[3] W.H.McAdams (1954),"Heat Transmission.3rd edition", McGraw Hill New York.

[4] T.H.Kuehn, R.J.Goldstein (1980)," Numerical solution to Navier Stokes equations for laminar natural convection about horizontal isothermal circular cylinder". International Journal of Heat and Mass Transfer, vol.23, p.971–979.

[5] B.Farouk, S.I.Guceri (1981)," Natural convection from a horizontal cylinder laminar regime", Journal of Heat Transfer, vol.103, p.522–527.

[6] T.Saitoh, Tajiki, K.Maruhara (1993),"Benchmark solutions to natural convection heat transfer problem around a horizontal circular cylinder", International Journal of Heat and Mass Transfer, vol.36, p.1251–1259.

[7] K.Kitamura, F.Kamiiwa, T.Misumi (1999),"Heat transfer and fluid flow of natural convection around large horizontal cylinders", International Journal of Heat and Mass Transfer, vol.42, p.4093–4106.

[8] J.V.Herraez, R.Belda (2001)," A Study of free convection in air around horizontal cylinders of different diameters based on Holographic Interferometry-Temperature Field Equations and Heat transfer Coefficients", International Journal of Thermal Sciences, vol.41, and p.261–267

[9] S.O.Atayilmaz, Ismail (2009)," Experimental and Numerical Study of the Natural Convection from a Heated Horizontal Cylinder", International Communications in Heat and Mass Transfer, vol.36, p.731–738.

[10] S.Grafsronningen (2011)," PIV Investigation of buoyant plume from natural convection heat transfer above a

ISBN 978-93-89105-41-4

horizontal heated cylinder", International Journal of Heat and Mass Transfer, vol.54, p.4975–4987.
[11] Hermann (1954),"Heat transfer by free convection from horizontal cylinders in diatomic gases", NACA TM 1366.
[12] S.Nakai,T.Okazaki(1975)," Heat transfer from a horizontal circular wire at small Reynolds and Grashof numbers, Pts I and II",International Journal of Heat and Mass Transfer, vol.18, p.387–413.

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PRODUCTION OF BIO-ETHANOL FROM FRUIT PEEL

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Abstract— **Bioethanol is a form of renewable energy that can be produced from agricultural feedstocks. It can be made from some of the crops such as hemp, sugarcane, potato, cassava and corn. Due to rapid increase in population size and exponential growth in industrialization, load is increasing on the fossil fuel resources and thus these resources are being depleted very fast. Fruit wastes area are unit wealthy in sugars and carbohydrates which might be recovered and used for the assembly of bioethanol. Fruit wastes are rich in cellulose and hemicellulose and have low polymer contents, which are mostly loosely placed there between cellulose and hemicelluloses. This makes these wastes interesting for bioethanol production. Lignocellulosic raw materials are considered renewable source of energy and their use for bioethanol production may also help in CO_2 mitigation. To obtain high concentration of ethanol from cellulosic materials, fermentation process was conducted using Saccharomyces cerevisiae under anaerobic condition. All the pretreatment strategies are shown to effectively solubilize and hydrolyze cellulose and hemicellulose into monomeric sugars.**

Wastes from fruits like banana, plantain and pineapple peels which are in abundance and do not interfere with food security were subjected to simultaneous saccharification and fermentation for 7 days by co–culture of genus Aspergillus niger and Saccharomyces cerevisiae. Biomass yield, cell dry weight, reducing sugar concentration and also the ethanol yield were determined at 24 hours interval. The study applies an energy analysis to the production process of anhydrous ethanol obtained from the hydrolysis of starch and cellulosic and hemi cellulosic material present in the banana fruit and its residual biomass. Results confirmed that the ultimate production of ethanol was pretreatment dependent.

Keywords: bioethanol, banana peel, saccharification, fermentation, Saccharomyces cerevisiae.

I. Introduction

1.1 Ethanol

Ethanol, also called alcohol, ethyl alcohol and grain alcohol and is a clear, colourless liquid and the principle ingredient in alcoholic beverages. Ethanol is an ingredient in a wide range of products, personal care and beauty products to paint and varnishes to fuel is because it can readily dissolve in water and other organic compounds. Ethanol can be produced through the hydration of ethylene and also it is the natural byproduct of plant fermentation. Ethanol burns to produce carbon dioxide and water. Ethanol is the same type of alcohol found in alcoholic beverages and used as fuel. It is usually used as a motor fuel, mainly as a biofuel additive for gasoline.

1.2 Bio-Ethanol

Bio-Ethanol is manufactured by the chemical process of reacting ethylene with steam and is mainly produced by the sugar fermentation process. Bioethanol is the main fuel used for road transport vehicles as a petrol substitute. The main sources of sugar required to produce ethanol are fuel and energy crops. It has a many advantages over conventional fuels. Ethanol or ethyl alcohol is a clear colourless liquid, which is biodegradable, low in toxicity and causes little environmental pollution if spilt. Ethanol burns to produce carbon dioxide and water. Ethanol has replaced lead as an octane enhancer in petrol and is a high octane fuel. By blending ethanol with gasoline we will oxygenate the fuel mixture so it burns far more completely and reduces polluting emissions and ethanol fuel blends are widely sold in the United States. The main fuel used as a petrol substitute for road transport vehicles is bioethanol. Bioethanol fuel is manufactured by the chemical process of reacting ethylene with steam and is mainly produced by the sugar fermentation process. There are many ongoing research and development into the utilization of municipal solid wastes to supply ethanol fuel.

1.3 Preparation of Bio-Ethanol

Bio-Ethanol can be produced from biomass by the hydrolysis and sugar fermentation processes. Biomass wastes contain a complex mixture of carbohydrate polymers from plant cell wall known as cellulose, hemi cellulose and lignin. To produce sugar from biomass, it is pre-treated with acids or enzymes in order to reduce the size of the feedstock and to open up the plant structure. The cellulose and hemi cellulose portions are broken down (hydrolyzed) by enzymes or dilute

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acids into sucrose sugar that is then fermented into ethanol. There are three main principle methods of extracting sugars from biomass and are concentrated acid hydrolysis, dilute acid hydrolysis and enzymatic hydrolysis. In the plants it produce bioethanol from renewable raw materials and from raw alcohol of agricultural origin.

The bioethanol from wheat, maize, barley or triticale as well as from sugar syrups. At this plant the production of bioethanol from starch-containing cereals takes place in five steps:

1. Milling, i.e. it is the mechanical crushing of the cereal grains to release the starch components.
2. Heating and addition of water and enzymes for conversion into fermentable sugar.
3. Fermentation of the mash using yeast, whereby the sugar is converted into bioethanol and CO_2.
4. Distillation and rectification, i.e. concentration and cleaning the ethanol produced by distillation.
5. Drying (dehydration) of the bioethanol.

1.4 Saccharification

Saccharification is the process of breaking a complex carbohydrate (such as starch or cellulose) into its monosaccharide components. Saccharification of cereal starches into fermentable sugars and unfermentable dextrin's creates the basis of the wort a sugary solution that is later fermented into beer. Saccharification of starch, in the diastatic enzymes start acting on the starches, breaking them up into sugars (hence the term saccharification). The amylases are enzymes that work by hydrolyzing the straight chain bonds between the individual glucose molecules which make up the starch chain.

1.5 Fermentation

Fermentation is the process by which the chemical breakdown of a substance by bacteria, yeasts or other microorganisms, typically involving effervescence and the giving off of heat. It is the metabolic process in which an organism converts a carbohydrate, such as starch or a sugar, into an alcohol or an acid. Fermentation requires two things: yeast and sugars. A ripe organic grape is full of natural sugars and there are wild yeasts living on its skin and as soon as the skin of the grape is broken, fermentation can begin.

1.6 Simultaneous Saccharification and Fermentation

Simultaneous Saccharification and Fermentation, SSF is the process for bioconversion of lignocellulosic biomass. Fermentation and high glucan loading for hydrolysis and is an efficient approach to reduce the capital costs for bio-based products production. Simultaneous saccharification and fermentation (SSF) is that the process that mixes enzymatic hydrolysis with fermentation to get value-added products in a single step and is based on the use of an enzymatic complex to hydrolyze cellulose and obtain sugars. These sugars which are obtained by enzymatic hydrolysis are later used by the microorganisms and are converted into value-added products. SSF has several advantages compared to other fermentative processes. Some of the advantages compared to separate enzymatic hydrolysis and fermentation (SHF) are the use of a single vessel for the fermentation and saccharification process.

1.7 Ethanol from Banana Peels

Bioethanol is an alternative source of energy that has received special attention worldwide due to depletion of fossil fuels. In India, the sugar cane molasses is the main raw material for ethanol production. The cellulosic materials are of low cost and available in plenty but their conversion to ethanol involves many steps and is therefore expensive. Banana is one of major constitute of the food resources in the world and occupy the fourth world rank of the most significant foodstuffs after rice, corn and milk.

As per the FAO statistics, India is the largest producer of banana in the world and accounts for nearly 30% of the total world production of banana though banana peel is a fruit residue, it accounts for 30- 40% of the total fruit weight and contains carbohydrates, proteins, and fiber in significant amounts. The banana peels contain lignin in low quantities, it could serve as a good substrate for production of value-added products like ethanol.

An ideal microorganism used for ethanol production which must have the features such as rapid fermentative potential, improved flocculating ability, appropriate osmotolerant, enhanced ethanol tolerance and good thermo tolerance. Fruits are highly perishable products, currently most of the perishable fruits are lost during their journey through the agrifood chain, due to spillage, physiological decay, water loss, mechanical damage during harvesting, packaging and etc. So the effort have been directed towards the utilization of cheap and renewable agricultural sources such as banana peels waste as an alternative substrate for production of alternative biofuel like ethanol (Singh A K et al., 2014).

1.8 Ethanol from Matooke Peels

Matooke is a variety of banana which is from South West Uganda and it comes from the family of bananas known as the East African highland bananas. Due to high starch content Matooke cannot be peeled in the same way as ordinary (sweet) bananas. They appear to be green in color and thick at the midsection. Once the peel is removed, the fruit cannot be eaten raw but can be used only by cooked, and the peels are generally discarded or used as feedstock for cattle, goats, and pigs. Research has been conducted on the acid hydrolysis of starch to glucose, but little research has been done till now using banana peel as a substrate for fuel production. From the biofuels, bioethanol has been identified as the most used alternative fuel worldwide due to its significant contributions to a reduction in crude oil consumption, high oxygen content, high octane number, non-toxicity and reduced emission characteristics compared to gasoline, thus promoting a cleaner environment for the future.

1.9 Ethanol from Citrus Peels

CPW requires additional processing before bioethanol production. This is because the CPW is rich in various soluble and insoluble sugars, making it an ideal feedstock; it also contains a strong microbial inhibitor referred to as D-limonene. Citrus peel produce D-limonene from which

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is economically viable, as this byproduct has high added value as a flavoring agent and for various applications in the chemical industry. The removing and recovering D-limonene prior to the yeast fermentation process serves two purposes: high-value utilization and enhanced fermentation of CPW-derived sugars. Pretreatment step is the efficient removal of D-limonene from CPW. Most pretreatment methods are based on thermochemical or thermo physical processes such as milling or steam explosion. In the enzymatic hydrolysis phase, cellulolytic, xylanolytic, and pectinolytic enzymes are often used to degrade plant cell walls and catalyze the breakdown of complex carbohydrates into their monosaccharide components (i.e., saccharification). Both fungal species are considered extracellular producers of cell wall-degrading enzymes that have potential for important industrial applications.

II. Materials and Methods

2.1 Materials

Normal ripe yellow bananas (*Musa acuminata*), were procured from a local supermarket in bulk, juicing plant near the MIT campus, market in Jos Plateau State, Nigeria, Canarian Institute of Agricultural Research (Tenerife, Spain). Yeast (*Saccharomyces cerevisiae)* procured from Fleisch-mann's yeast (Fenton, MO, USA), chemicals from Fisher Scientific Inc., USA. *Aspergillus niger* inoculum is used, analytical grade chemicals such as, sulphuric acid (H2SO4), sodium hydroxide (NaOH), yeast extracts agar, urea, dextrose sugar (MgSO4.7H2O), baker's yeast (*Saccharomyces cerevisiae)*, distilled water, benzathine penicillin G (Oberoi H S et al.,2011, Gebregergs A et al., 2016, J Itelima et al., 2013, Velasquez-Arredondo H I et al., 2010, Guerreo A B et al., 2018). Citrus, apple, and pear waste was collected after juice extraction (Hurom, Seoul, Korea) (Choi I S et al., 2015). The raw material is two specific species of matooke, namely, sample A (Mbwazirume) and sample B (Nakyinyika) and are obtained from different locations in Uganda (Yusuf A A et al., 2019).

2.2 Methods

2.2.1 Feed Material

The collected peels were chopped into small pieces approximately 2-4 cm in length using a knife. The pieces were then sun dried for two days and then dried at 60°C for one day. Then the samples were taken out of the drier once they were dry enough to be crushed and the cut pieces were then crushed in the grinder. The ground sample was divided proportionally into two and one is seventeen separate samples of 10 g of ground banana peels and another two is two separate samples of 20 g of ground banana peels. The juice was prepared for each sample by adding 10:1 (v/w) ratio of distilled water to the sample in separate flasks. (Gebregergs A et al., 2016).

2.2.2 Preparation of Growth Medium and Inoculum

The growth medium used for preparing the *Aspergillus niger* inoculum (obtained from garden soil) consisted of 30g of the blended banana peels, peptone, 0.1%; malt extract, 0.1% (w/v), yeast extract, 0.2% (w/v), calcium carbonate 0.2% (w/v); ammonium phosphate, 0.2% (w/v), and ferrous sulphate.7H2O, 0.001% (w/v) and respectively. *Saccharomyces cerevisiae* (obtained from ripped banana peels) is the growth medium that was prepared using yeast-malt broth at pH 5.5. *Aspergillus niger* inoculum was prepared in 250cm³ cotton-plugged conical flask containing 100cm³ of the substrate growth media. The flasks were sterilized and inoculated with 0.11 (OD) *Aspergillus niger* spores.

Each of the flasks was incubated on a shaker with agitation rate of 300 rpm at 30°C for 5 days. *Saccharomyces cerevisiae* inoculum was prepared in the same way as the *Aspergillus niger* inoculum except that yeast malt broth was used. The growth medium was inoculated with 0.08 (OD) yeast cells and incubated for 24 hours. Ethanol fermentation was carried out in 1000cm³ conical flasks each containing 300cm³ of medium. The medium was sterilized and inoculated with 5% (v/v) growth media containing *Aspergillus niger* and *Saccharomyces cerevisiae* and is incubated on a shaker with an agitation rate of 300rpm at 30°C for 7 days (Itelima J et al., 2013).

2.2.3 Pretreatment

Dried and ground banana peel powder was suspended in distilled water at a solid-to-liquid loading of 10% (w/v) in baffled polycarbonate capped flasks (Fisher Scientific), along with (%; w/v) yeast extract 0.2, peptone 0.2 and MgSO4 0.1. We had observed that increasing the substrate concentration to 15% (w/v) resulted information of a solid mass, probably because of higher concentration of pectin and hemicellulose in BP. Therefore, the flasks containing 75ml fermentation medium composed of 10% (w/v) BP and nutrients were subjected to autoclave-sterilization process at 121°C, 15 psi for 15 min. The flasks were removed from the autoclave and cooled with cold water. The pH of the fermentation medium was adjusted to 5.5 with sterilized 5 N sodium hydroxide solution. The enzyme concentration used during SSF was obtained using Design Expert software (Oberoi H S et al., 2011).

2.2.4 Hydrolysis

2.2.4.1 Acid Hydrolysis

The first 25 ml of 0.5%-2.5% (v/v) diluted sulphuric acid was added to the insoluble component from the pretreatment steps. The fruit peels were hydrolysed in the reactor between 70 and 110°C for 10-30 min as the experiment design required. After hydrolysis, pH adjustment was carried out with 1 M NaOH until the pH reached a pH of 7 and filtration is used to separate the insoluble particles from the hydrolysate. The soluble component was then added with the previously filtered solution from the pretreatment step for the next procedure (Gebregergs A et al., 2016).

2.2.4.2 Enzymatic Hydrolysis

Enzymatic Hydrolysis (EH) analysis was performed with the unwashed and wet WIS of each biomass because water wash decreases the sugar content due to the removal of soluble sugars that may have remained after the separation of both fractions. An experimental design was developed following a 3^2 factorial design. The variables considered were enzyme dosage (7.5–22.5 FPU/g glucan) and solid loading (10–20% w/w). This infers low enzyme dosage (< 20 FPU/g

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glucan) and high solid loading (≥15%). Novozymes kindly provided the enzymes used in this work, which were Celluclast 1.5 L with an activity of 69 filter paper units (FPU.m/L) and Novozym 188 with an activity of 530 international units (IU.m/L).

Enzyme activities were measured following standard procedures according to the National Renewable Energy Laboratory analytical procedure NREL/TP-510-42628. The experiments were carried out in 250 mL glass bottles with a total reaction volume of 50 mL. In each of the bottle the desired amounts of WIS, enzymes, water and Na-citrate buffer (0.05 M pH = 4.8) were added. The bottles were placed in a STR4 rotator drive (Bibby Scientific Limited, Stone, UK) at 18 rpm, and incubated in stove at 50°C for the first hours of reaction. After the specified time, the flasks were transferred to an orbital shaker. The samples were taken at 0, 4, 8, 24, 48, 72 and 96 h and are centrifuged (13,000 rpm, 5 min) and the supernatant was used for sugar content analysis following the analytical method described. All experiments were carried out in triplicate (Guerreo A B et al., 2018).

2.2.5 Experimental Design

A four-factor and two-level CCD consisting of 27 experimental runs with three replications at central point was used for optimization of independent variables. The range for cellulase, pectinase, temperature and time was selected as 3–9 FPU/g-cellulose in the pretreated BP, 25–75 IU/g-pectin in the pretreated BP, 30–40°C and 8–20 h, respectively. In a SSF process the both enzymes and yeast cells are accommodated in the same vessel at the same time and therefore, a compromise was made in selecting the temperature range. The aim of this study was to improve process productivity, thus the maximum fermentation time was selected as 20 h. Ethanol production was fixed as a response for process optimization using RSM. In a SSF process, the residual sugar concentration was not considered as a response as sugars produced are simultaneously fermented. 5.5 is the initial pH of the fermentation medium was set, since formation of galacturonic acid (GA) by hydrolysis of pectin results in decline in pH during fermentation, thereby adversely affecting the fermentative ability of *Saccharomyces cerevisiae* cells. The experiment was performed in 27 capped baffled fermentation flasks, each flask containing 75 ml of the pretreated banana peel medium and inoculated with a freshly prepared inoculum of yeast cells at 10% (v/v) having cell concentration of 3×10^9cells/ml.

Experimental data from the CCD was analyzed using RSM algorithm Design Expert. The analysis of variance (ANOVA) and surface plots were generated using Design Expert, and the optimized value of four independent variables for best response was determined using a numerical optimization package of the same software. An experiment was also planned using enzyme concentration, hydrolysis temperature and time generated by the Design Expert software, but without addition of yeast inoculum to establish the role of enzymatic hydrolysis in production of sugars from the insoluble polysaccharide fractions (Oberoi H S et al., 2011).

2.2.6 Fermentation

Fermentation is the process of converting the pentose and hexose into ethanol using microorganisms, such as bacteria, yeast, or fungi. A microorganism such as yeast serves as a key factor in fermentation and has an important role in meeting those challenges (Yusuf A A et al., 2019). Fermentation with *Saccharomyces cerevisiae* only and fermentation with *Saccharomyces cerevisiae* and benzathine penicillin G. 100 ml from the in column was added to 0.5 g of yeast (5 g/L yeast), *Saccharomyces cerevisiae*, in 250-ml flask. To prevent air entrance (the growth was made anaerobically) the flask were covered with aluminum foil. The conical flask was then placed in a shaking incubator for 24 h at temperature of 30°C and 200 rpm, which was used for the fermentation process. In the fermentation step, the two samples were conditioned to a temperature of 30°C before the fermentation step started and is the working temperature throughout the entire fermentation process. At this step the pH was set to 5.0-5.5 (which is the optimum pH for the activity of *Saccharomyces cerevisiae*) by the addition of 1 M NaOH.

The flask's mouth was wrapped with aluminum foil and the 25 ml freshly prepared yeast culture was added into each of the flasks (1:4 (v/v) of samples). Then 0.05 g of benzathine penicillin G (0.5 g/L) was added into the second flask. Finally, both samples were placed in shaker incubator at 200 rpm at 30°C, for 3 days. The samples were checked every day by adjusting the pH to between 5.0 and 5.5. Finally, using a rotary evaporator the ethanol product from the banana peel juice was distillated (Gebregergs A et al., 2016).

2.2.7 GC analysis

In this method, the GC-MS was used to identify the molecular weights and structures that are within the two different samples of matooke peels. This analysis was conducted at Chemiphar Uganda limited and Makerere University Kampala, Uganda. The injector temperature was at 250 °C. The initial oven temperature was programmed for 80 °C (hold for 2 min) increased to 120 °C at a rate of 5 °C/min (and hold for 2 min) then increased to 240 °C at a rate of 10 °C/min (hold for a few moments), and finally increased to 420 °C at a rate of 15 °C/min (hold for a few minutes). The second analysis was conducted using GC-FID with automatic injection along with a blank consisting of demineralized water and standard solutions to measure the ethanol content within the samples and then compared with the initial analysis. According to presumed alcohol content the samples were injected, the samples containing least amount of alcohol injected first. This is to prevent carry-over from high concentrated alcohol samples to those with low alcohol content. The inlet was set at a temperature of 225 °C with splitless injection, and the injection volume was 1 µL. The column used was a Phenomenex ZB-FFAP GC-column, which is a high polarity column that is 30 m × 320 µm × 0.25 µm. The oven was set at a programme that had an initial temperature of 50 °C (held for 2 min) the increased to 245 °C at a rate of 45 °C per minute and held at 245 °C for 1 min. The flame ionization detector temperature was set at 285 °C with a flow of 30 ml/min H2, and the flow rate of O2 was set at 300

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ml/min. Finally, the total run was 24 min long, and the injection syringe was rinsed with demineralized water between every injection (Yusuf A A et al., 2019).

2.2.8 Batch Simultaneous Saccharification and Fermentation Process

The batch SSF experiment was carried out using the optimized parameters obtained through RSM in a 2-l batch reactor (Biostat B, BBI Sartorius, USA) containing 1.3 l of fermentation medium. The solid-to-liquid loading for the validation experiment was maintained at 10% (w/v) as was done for the optimization experiment. The medium was supplemented with (%, w/v) yeast extract 0.2, peptone 0.2 and MgSO4 0.1. The fermenter, along with calibrated pH probe, temperature probe, inlet air/gas provisions, baffles, condensate removal system, agitator, sample collection system, NaOH (5 N) solution, and exhaust system was sterilized in an autoclave at 121°C for 15 min. The fermenter was removed from the autoclave and cooled to 50°C and the pH was adjusted to 5.0 by addition of sterilized 5 N NaOH solutions.

From the RSM experiment, the medium was supplemented with the optimized concentrations of cellulase and pectinase obtained. The agitation was maintained at 200 rpm at 50°C for 3 h for solubilization of insoluble fractions of BP. The medium was subsequently inoculated with 130 ml yeast inoculum having a cell concentration of 3×10^9 cells/ml for SSF. The temperature during SSF was maintained at a level suggested by numerical optimization and model equations. During validation experiment the fermentation time was obtained from the optimization experiment, the samples were drawn at 3-h intervals to study the ethanol production pattern with time. The samples were drawn using nitrogen gas pressure and are analyzed for ethanol, residual sugar, and GA concentrations.

The validation experiment using the optimized parameters was conducted three times in a batch fermenter and the statistical analysis was done using SAS 9.0 software. Ethanol yield on sugar basis and sugar consumed basis (Yp/s) were calculated. Thus, the denominator represents the maximum ethanol possible theoretically from the substrate, which forms the basis for calculating ethanol production on available sugar basis as well as on the sugars consumed basis (Yp/s) (Oberoi H S et al., 2011).

III. Results and Discussion

The carbohydrate composition of the various fruit wastes is different. In the cell wall the total carbohydrate contents of the fruit wastes were separated into soluble sugars, which dissolve easily in water, and insoluble sugars (cellulose and hemicellulose). The arabinose and xylose were appeared in low concentrations in the fruit waste. So mainly focused on fermentable sugars (FS), namely, glucose, fructose, and sucrose and all the fruit wastes presented were high in FS content. FS contents in the various fruit wastes were ranged from 23.2% to 59.1%.

Thus, the use of hydrolytic enzymes in a SSF process enhanced ethanol production by about 50% during the validation experiment in a batch fermenter. Fermentation rate declined after 9h during SSF resulting in low ethanol concentration during subsequent fermentation periods. In addition to higher ethanol concentration, validation experiment using optimized parameters led to a substantial time savings. Highest ethanol concentration of 27g/l was obtained in 20h during the RSM trial, whereas the ethanol concentration of 28.2g/l was obtained in 12h during the validation run using optimized parameters. High ethanol concentration in less time results in improved productivity and which has a direct impact on process economics and commercial feasibility. The biomass left after 15h SSF was about 22% of the total BP biomass used initially for the batch SSF experiment.

The remaining constituents like fats, starch, polyphenols, and alkaloids were not analyzed in the residual biomass. Since the residual biomass is rich in protein and minerals and does not contain lignin in high concentrations, it could be ideally used for cattle feed. While comparing ethanol concentration, yield, and volumetric productivity with lignocellulosic biomass, such as, wheat straw, rice straw, and bagasse banana peel biomass offers a significant advantage as an ideal substrate for ethanol production for supplementing fuel ethanol requirement, especially in banana-producing countries. Since, banana peels are also rich in starch, we are now trying to exploit the use of an enzyme consortium comprising of amylase, cellulase, and pectinase for production of sugars and ethanol from BP. Lignocellulosic substrates also require energy intensive delignification treatments, because of presence of lignin in high concentrations (10–30%) and also high enzyme concentrations (15–30 FPU/g) for obtaining desired sugar yield which account for high production and energy cost. High ethanol volumetric productivity also means that a large number of batches could be successfully completed in short time, thus offsetting both the explicit and implicit costs involved in the production process.

The yeast and mould (biomass) yield was obtained by determining the absorbance of the samples at 690nm and which represented the cell density. The ability of the amylase and cellulase secreted by *Aspergillus niger* to breakdown the substrate into reducing sugar was determined in the study. The results are presented in terms of the amount of reducing sugars (mg/cm3) produced at 24 hours interval for seven days. The results show that the substrate the concentration of the reducing decreased gradually as the fermentation period increased. This was closely followed by banana. Agricultural wastes rich in fermentable sugars have been found to be good substrates for ethanol production, a promising alternative energy source for limited crude oil. The amount of biomass present in the substrate is directly proportional to quantity of ethanol production.

This suggests that the favorable region for bio-ethanol industrial production should have surplus biomass that would not affect food security. The susceptibility of sugars obtained after hydrolysis of the substrates by *Aspergillus niger* to the fermentation activity of *Saccharomyces cerevisae* is significantly depended on the composition of sugar. The fermentation process is significantly dependent on the

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effectiveness of sugar transporters of *Saccharomyces cerevisiae* cells on translocating different sugars across the cell membrane. Sugar transporters are membrane bound proteins that take up sugars from the environment and deliver them to the metabolic pathways insides cells. No other sustainable option for the production of liquid fuels can match ethanol from lignocellulosic biomass with respect to its dramatic environmental, economic, and infrastructure advantage (Itelima J et al., 2013).

Fruit waste and other solid residues, such as coffee waste and rice, from agricultural by-products which were considered bioethanol production materials. One main obstacle to achieving efficient bioethanol production is the cost of production. The commercial success of ethanol production depends on productivity, which in terms of volume and concentration. It is noted that the new process achieved high ethanol production without costly pretreatment, suggesting utility in industrial ethanol production applications. The high ethanol production during the validation experiment could be due to several factors, including suitable inhibitor removal conditions, enzyme production, loading volume, and continuous yeast fermentation (Choi I S et al., 2015).

In this study, the banana pseudostem and frond juices were extracted using a sugarcane pressing machine without pretreatments such as acid, alkali or enzyme. The total volume of juice extracted in banana pseudostem was 20% higher than banana frond. Two passes of sugarcane pressing did not completely remove all residues from banana frond and banana pseudostem, which remained 4% to 6% of residues in the biomass. The result shows the sugar composition (fructose, glucose and sucrose) of freshly pressed banana frond and pseudostem juice. The glucose contents of 16.56 g/L and 7.78 g/L were obtained in freshly pressed banana frond juice and banana pseudostem juice, respectively. The result of high fermentable sugar content in banana pseudostem and frond juices made it a potential fermentation feedstock for value-added product production. This study presented the potential of using freshly pressed banana banana frond and pseudostem juices which contained high sugar content as fermentation feedstock to overcome the challenges with respect to processing steps in converting lignocellulosic biomass to value-added product like harsh chemical and physical pretreatment due to the high level of lignin, enzymatic hydrolysis, inefficiency of microbial fermentation in solid-state, aseptic condition during sampling/harvesting and difficulty of inhibitory product separation (Chai S Y et al., 2018).

The fuel properties of the bioethanol from different matooke peels were found out and each indicates the quality of fuel used for the spark-ignition engine. By using the ultraviolet-visible spectrophotometer, the amounts of (0–100 g/L) reducing sugars were measured for each sample. However, various effects were considered such as pH at 5.0, temperature at 50, 70 and 90 °C, time of 20, 40 and 60 min, acid concentration of 0.5%, 1.5% and 2.5% (v/v). The physical and chemical properties of the matooke peel bioethanol are shown. By using the ASTM standard the density, heating values, ethanol content and viscosity of the fuels were measured. The study used an automatic bomb calorimeter (IKA C2000 basic) to measure the heating value of bioethanol using the ASTM D240 standard. The results show that the heating values of matooke bioethanol are slightly closer with the ethanol ASTM D4806. The measured fuels are within the acceptable range of standard ethanol and gasoline. However, these fuels can be used in the development of further experiments on performance and exhaust emissions test in an internal combustion engines (Yusuf A A et al., 2019).

IV. Summary and Conclusion

Banana peel is the most suitable input for the production of ethanol and the addition of benzathine penicillin G on ethanol production enhanced the fermentation process by 8.97%. The banana peels could serve as an ideal substrate for production of ethanol through SSF. Since, enzymes and *Saccharomyces cerevisiae* cells have different temperature optima, and enzyme cost and concentration are crucial in deciding the final product yield and commercial potential of the process, the Design Expert software helped in optimizing such parameters

The work conducted by Itelima J et al., shown that simultaneous saccharification and fermentation of waste materials from banana peel to ethanol by a mixture of starch digesting fungus *Aspergillus niger* and non-starch digesting sugar fermenter (*Saccharomyces cerevisiae*) is feasible. Simultaneous saccharification and fermentation has been found to effectively remove glucose and thereby increasing the yield and rate of cellulose hydrolysis. It is interesting to note that even though ethanol is produce from renewable resource, economic factors such as land availability, labour, taxation, utilities, crop processing costs and transportation are to be put into consideration otherwise there will be no profit for its production.

Future research must be conducted with the aim of optimizing the variables affecting the process performance, like temperature, reaction time, the water used in hydrolysis, glucose concentration and steam consumed in the distillation process, seeking to reduce the energy consumption and the inputs required. Saccharification and fermentation conditions of banana lignocellulosic residues for bioethanol production were optimized searching the adequate conditions which will be applied at an industrial level. The study also showed that use of a single vessel for pretreatment and SSF not only helped in increased ethanol production, but also help in economizing the entire process by reducing the number of unit operations leading to significant savings in energy and operating costs.

The matooke bioethanol can be used in the development of further experiments on performance and exhaust emissions test in an internal combustion engines. Utilizing this waste biomass for bioethanol production through a biotechnological process not only helps to reduce environmental pollution but also reduce the dependence on

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oil-producing countries and supports rural economies by creating jobs and also provides additional source of income.

Banana is a major crop of this country generating vast agricultural waste after harvest. Banana peel is a cheap source of alcohol because it is a fruit waste and it can be used as a base material for alcohol production. To make the large scale production more economic and more feasible, strain improvements can help in better yield of alcohol. Bioethanol provides great benefits for safeguarding the environment, boosting the rural economy and ensuring fuel security.

Fruit waste is one of the attractive biomass alternatives for bioethanol production because it has high levels of FS such as sucrose, glucose, and fructose. In this study, the sugars were hydrolyzed and fermented without an energy-intensive conventional pretreatment. After enzymatic hydrolysis with two in-house enzymes, D-limonene was removed using an adsorbent column containing raw cotton and activated carbon and directly conducted to an immobilized reactor (LRC–ICR) for fermentation. Ethanol production in this LRC–ICR system was 12-fold greater than that observed without prior use of the sorbent column (LRC) to remove the fermentation inhibiting D-limonene. The new approach for removing D-limonene and enhancing immobilized yeast fermentation could potentially be useful in more cost-effective bioethanol production.

Moreover, to reduce the enzyme cost research is needed in the direction to recover and reuse the enzymes. Another major concern is the generation of microbial inhibitors during the pretreatment process, which represent a significant carbon loss and consequently lignocellulosic ethanol economy is largely affected due to lower ethanol yield. The outcome of this research demonstrates that this process might represent a valid alternative to minimize the heavy waste burden of banana peels. The food waste from the food processing industry may bring serious environmental problems and can be minimized by the production of ethanol.

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REFERENCES

[1] Abbi, M, Kuhad, R. C, Singh, A (1996), Bioconversion of pentose sugars to ethanol by free and immobilized cells of Candida shehatae (NCL-3501): fermentation behaviour. *Process Biochemistry:* Vol. 31, 555–560.

[2] Abdulfatah, A. Y, Freddie, L, Inambao (2019), Bioethanol production from different Matooke peels species: A surprising source for alternative fuel, *Thermal Engineering*, (13), 100357.

[3] Abdul, M. K, Shaista, K, Rabia, S (2015), Investigation of waste banana peels and radish leaves for their biofuels potential. *Bull. Chem. Soc. Ethiop*. 2015, 29(2), 239-245.

[4] Alula, G, Mebrahtom, G. Omprakash, S (2016), Indutrial ethanol from banana peels for developing countries: Response surface methodology. *Natural science and engineering* (21), 101293.

[5] Ana, B. G, Ignacio, B, Mercedes, B (2018), The potential of agricultural banana waste for bioethanol production. *Fuel* (213), 176-185.

[6] A. Omemu, M. I, Akpan, M. O, Bankole and V. Teniola (2005), Hydrolysis of Raw Tuber Starches by Amylase of *Aspergillus niger* AMO7 Isolated from the Soil, *African Journal of Biotechnology*, Vol. 4, 19-25.

[7] Ballesteros, M, Oliva, J. M, Negro, M. J, Manzanares, P (2004), Ethanol from lignocellulosic materials by a simultaneous saccharification and fermentation process (SFS) with Kluyveromyces marxianus CECT 10875. *Process Biochem* : Vol. 39:1843–8.

[8] Choi, I. S, Yoon, G. L, Sarmir, K. K, Bok, J. P, Hyeun-Jong, B (2015), A low energy, cost effective approach to fruit and citrus peel waste processing for bioethanol production. *Applied Energy* (140), 65-74.

[9] Emaga, T. H, Robert, C, Ronkart, S. N, Wathelet, B, Paquot, M (2008), Dietary fibre component and pectin chemical features of peels during ripening in banana and plantain varieties. *Bioresource Technology:* Vol. 99, 4346–4354.

[10] Gebregergs, A, Mebrahtom, G, Omprakash, Sahu (2016), Industrial ethanol from banana peels for developing countries: Response surface methodology Pacific Science Review A: *Natural Science and Engineering*, Vol. 18, 22-29.

[11] Hammond, J. B, Egg, R, Diggins, D, Coble, C, G (1996), Alcohol from bananas. *Bioresource Technology:* Vol. 56, 125-130.

[12] H. I. Velásquez-Arredondo, A. A. Ruiz-Colorado, S. De, Oliveira, junior (2010), Ethanol production process from banana fruit and its lignocellulosic residues: *Energy analysis Energy*, Vol. 35, 3081-3087.

[13] Itelima, J, F, Onwuliri, E. Onwuliri, Isaac, Onyimba and S. Oforji (2013), Bio-Ethanol Production from Banana, Plantain and Pineapple Peels by Simultaneous Saccharification and Fermentation Process: *International Journal of Environmental Science and Development*, Vol. 4, No. 2.

[14] Joo, S. T, Pongsathon, P, Chee, K. L, Zee-W, L, Mohamad, H. A. B, Paramasivam. M (2019), Banana frond juice as novel fermentation substrate for bioethanol production by Saccharomyces cerevisiae, *Biocatalysis and Agricultural Biotechnology*, (21), 101293.

[15] Maria, P, Kristia, K. M, Eftychia, M, Marien, I. V, Chryssoula, D, Michalis, K (2017), Development of a citrus peel-based Biorefinery strategy for the production of succinic acid. *Journal of cleaner production (166)*, 706-716.

[16] Mudassir, H. T, Zilong, Z, Jianmin, R, T, R, Salman, R. N (2019), Thermo-kinetics and gaseous product analysis of banana peel pyrolysis for its bioenergy potential. *Biomass and bioenergy 122*, 193-201.

[17] Oberoi, H. S, Vadlani, P. V, Madl, R. L, Saida, L, Abeykoon, J. P (2010), Ethanol production from orange peels: two stage hydrolysis and fermentation studies using optimized parameters through experimental design. *Journal of Agricultural and Food Chemistry*: Vol. 58, 3422–3429.

[18] Oberoi, H. S, Praveen, V. Vadlani, Lavudi, Saida, Sunil, Bansal, Joshua, D. Hughes (2011), Ethanol production from banana peels using statistically optimized simultaneous saccharification and fermentation process: *Waste Management*, Vol. 31, 1576–1584.

[19] P. Susan (2010), Fermentation in the yeast *Saccharomyces cerevisiae*, *Science Journal:* Vol. 1, pp.8-12.

[20] P. Sharma, A. Mishra (2015), Biofuel production from banana peel by using micro wave: Int. J. *Sci. Eng. Technol*. 3 (4), 1015-1018.

[21] Saravana, K. T, Abu, S. A, Farid, N. A (2016), Review on bioethanol as alternative fuel for spark ignition engines, *Renewable and sustainable energy reviews*, (56), 820-835.

[22] Siu, Y. Chai, Sahar, Abbasiliasi, Chee, K. Lee, Tengku, Azmi, Tengku, Ibrahim, Saeid, Kadkhodaei, Mohd, S. Mohamed, Rokiah, Hashim, Joo, S. Tan (2018), Extraction of fresh banana waste juice as non-cellulosic and non-food renewable feedstock for direct lipase production. *Renewable energy* (18), 30361-6.

[23] Yang, B, Wyman, C.E (2008), Pretreatment: the key to unlocking low-cost cellulosic ethanol. Biofuels, *Bioprod Biorefining*: Vol. 2: 26–40.

[24] Y. Sun and J. Cheng (2002), Hydrolysis of Lignocellulosic Material from Ethanol Production: A review, *Bioresource Technology*, Vol. 83, 1-11.

DESIGN AND DEVELOPMENT OF PERFORMANCE IMPROVED AND COST EFFECTIVE 3D PRINTER

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***Abstract*— 3D printers are most commonly used for making 3D structure by using CAD files. These 3d printed designs are used making scaled down structures for prototyping. There are a number of materials that can be used for printing. The material used will determine the structural quality and aesthetics. The major drawback of 3D printer is the high cost of production. Those 3D printers with good quality is more costly and are only available abroad. We are developing a 3D printer which is cost effective and all metal design with a new approach using heat bed and hot end effectively for better print quality. The belt design used is the modified Corexy, which is used to attain high print speeds. The 32bit 3d printer board is used for the fast processing of data and gcodes. The hot end is air cooled which increases the print quality. The design mainly focuses on easy maintenance and nozzle change. Auto bed levelling is utilized by using aluminum as the print bed.**

Keywords*— *3D Printer, Economic Design, Better Print Quality, Better cooling, Auto bed leveling

I. INTRODUCTION (*HEADING 1*)

In the world of manufacturing technology, 3D printing is the main drivers of innovation. It uses FDM method to manufacture the 3d print from the cad design. FDM uses layer by layer adhesion to create the cad model and hence this is called additive manufacturing. Fusion Deposition Modeling (FDM) is most commonly is used in 3d printers.

One among the major advantage is Single Step manufacturing. Additive manufacturing machine completes a build in one step, without any intervention from the operator doing build phase . The ability to make the product in single step reduces the dependence of different manufacturing processes. More design freedom is offered in 3D printing such that the restrictions imposed by traditional manufacturing is not relevant here. The concept of design freedom and customization has been used by medical and dental industry for manufacturing of custom prosthetics, implants and dental aids.

II. LITERATURE REVIEW

R. Jerez-Mesa[4] *concludes that cooling should be provided in a liquefier to get maximum performance.* A.Guerrero-de-Mier[5] *has built a 32-bit 3d printer controller with increased performance.* Dipak Shelar[7] *addresses that reduction in operational time and increased accuracy is obtained by the installation of fan on extruder for the fast cooling of polymer filament on heat bed.*

Antonio Lanzotti[11] *analyzed the effect of various process parameter.*

III. METHODOLOGY

A. Improved Design

A new design is provided which uses the V-Slot aluminum Extrusions for the frame and the combination of a 3D printed 625zz wheels and 625zz bearing for the movements of the X axis, Y axis and Z axis. Our 3d printer frame is made using V-slot aluminum extrusion which removes the traditional linear bearing and linear rods and helps in reducing the cost considerably. This design is based on the CoreXY kinematics so as to attain high speed. This design is a modified version the traditional Corexy design. In the traditional design the print head movement is kept at the top of the 3d printer and the bed moves up and down. In this design the bed is fixed and

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the corexy print head moves up and down. In a corexy print head the X and Y motor is combined to produce and integrated movement as shown in Fig.1.

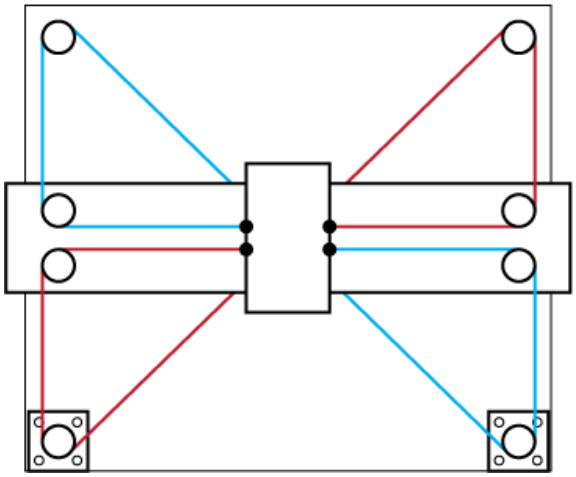

Fig.1: CoreXY print head

The frame is made using 2020 extrusion. The frame design is shown in Fig.2. The frame is in the form of a cuboid. The frame consists of a rectangular base which is made using the four 2020 aluminum extrusions 360mm long. The vertical column consists of four 2020 columns 420mm long and is connected by four 360mm 2020 extrusion at the top. The bed is fixed at the base of the frame and the corexy print head moves up and down. The corexy print head moves up and down with the help of four Z sliders and two Z motor in coupled with a Tr8x2 lead screw.

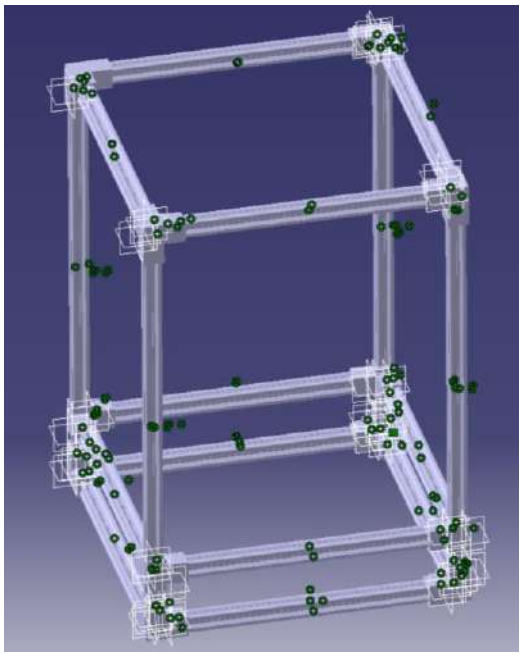

Fig.2: 3D Printer Structure

The linear movement is done by moving V-Slot wheels on the V-Slot extrusion. In this design the all the sides of the V-Slots are constrained using the V-Slots wheels in such a way that the only movement is linear along the V-Slots of the extrusion. This reduces the vibration and the increases the print quality.

The print head is equipped with a direct drive Extruder setup and liquefier or the hot end used is the E3D v6 hotend. The hotend is a new design improved one which provides easy maintenance and easy filament loading and unloading. The new hotend comes with a air cooled fan and has provision for water cooling. The heated block in the filament is provided with slots for easy changing of nozzle.

The print bed consists of 3 layers. The bottom layer consists of a PCB heated bed followed by an aluminum plate and a glass plate at the top. The PCB heat bed has a resistance of 2ohm. The PCB has a dimension of 235x235mm and has five holes. Four M3 holes on the corner and 1mm diameter hole on the center for inserting the thermocouple. The aluminum plate is used as it spreads heat evenly and it's also used for bed level sensing feature. An inductive sensor is used for bed leveling. The dimension of the bed is 235x235x3mm and has four M3 holes at the corner. The topmost layer has a removal spring sheet of dimensions of 235x235x0.5mm. The plate is also used for print adhesion. The plate is made of borosilicate which can resists high temperature about 500 degree Celsius without failure. The PCB layer and aluminum layer are kept together using thermal paste. The thermal paste has good adhesion and it is a good conductor of heat and transmit heat evenly to the aluminum plate. Then the glass plate is aligned with the M3 holes and with the help of spring and M3 nuts and bolts the three-layer bed is mounted on the y carriage.

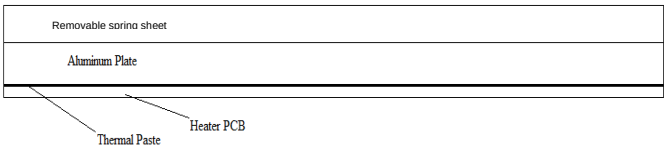

Fig.3: Printer Bed

All the electronics and power supply are mounted on the bottom side of the rectangular frame. The power supply used is rated at 24V 20A. The motherboard has a 32bit microcontroller which about the same price as an Arduino but it has faster processing speed and more space in which more features can be added.

B. Improved Slider Design

There are mainly three sliders in this 3D printer which are the X slider, Y slider and Z slider.

The Z axis is the most important axis of a 3D Printer and the movement of Z axis determines the print quality. By providing a perfect linear motion the quality of the print can be increased. The proposed V slot X slider restricts all the degrees of freedom except the motion along the axis of the slider. The traditional V-slot X slider consists of 3 bearing wheels which slides along the V slot of the 20mm side of the

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2020 aluminum (one bearing wheel on the outer end and two bearing on the inner end). In the new design the slider has six bearing wheels. Four bearings wheels placed vertically on both sides of the top 20mm side and the last two bearing wheels on the placed alternatively on both sides of the V slots of the front of 20mm side.

The Y slider should have low vibration while moving. The X axis is mounted on the Y axis with the help of Y slider. This slider consists of 8 bearings and they are placed in such a way that there are two bearing on both the top and bottom and two on bottom the left and right also. The X and Y axis are controlled by stepper motors. The stepper motors control the print head by using gt2 belts and pulley. The gt2 pulley used has 20 teeth. This reduces the vibrations and provides the most of the load to the top bearings and less load on to the side bearings and thereby reducing the vibration.

The X slider carries the print head which consists of the hot end or the liquefier and the extruder also. As the extruder setup is direct drive the extruder is mounted with the printer. Due to this one side of the extruder projects outside and acts as a cantilever beam and the chances of vibration increases. In order to overcome the vibration, the slider is placed on a 2020 aluminum extrusion with eight bearings. Two bearings are placed on each side of the aluminum extrusion. This restricts the vibration to a small value.

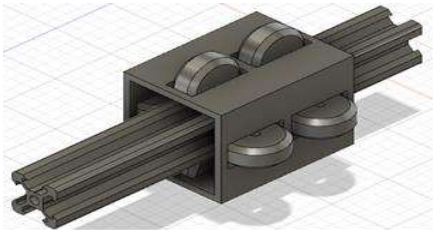

Fig. 4: X Slider

C. Hot end or Liquefier Cooling

Cooling is one of important factors that affect the print quality. The liquefier has an important part which is the heat break and this consists of three zones the hot zone, the intermediate zone and the cold zone. The hot zone is the region where heating of the filaments take place. The lowest part of the heat break is mounted on a heating block which is an aluminum block with a heater attached and this provides the heating. The filament is heated to about 200 to 250 degree in order to melt materials like PLA, ABS, etc. In this zone the materials are in liquid state so as to push the material through the nozzle. The intermediate zone is 3mm in height i.e. the middle portion the heat break and it is the transition between the cold zone and hot zone. The filament is a semisolid condition in this state. The topmost part of the heat break is the cold zone where the filament should be in completely solid and this zone should be maintained below 60 degree Celsius for the free movement of the filament.

In order to maintain the cold zone at that temperature cooling should be provided. The is provided either by air cooling or water cooling.

The air cooling is provided by using a simple fan rated at 12v DC. The cold zone initially has a heat sink fitted to the heat break and the fan is mounted on to the heat sink. This zone is insulated by with a short fin with tip insulated. This arrangement helps in reducing the heat generated by the hot end to transfer into the cold zone.

In water cooling the heat break is fitted with a cold block with consists of a spiral tubing arrangement which allows the for the circulation of water. The circulation of water is provided with the help of a pump. The pump is 12V DC pump which is controlled by an external microcontroller and a temperature sensor. The heat is radiated from the water with the help of a radiator and a fan. This helps in regulating the temperature in the cold zone to about 40 degree Celsius. More the heat removed more will be the quality of the print.

D. Print Cooling

The print should be cooled by using a radial fan of rating 12V. The fan is controlled by the microcontroller.

By providing cooling the print quality can be increased considerably. In 3D printing, printing is done by layer by layer adhesion. The liquid filament is forced through the nozzle and the molten filament forms each layers of the 3D print. The layer formed is at a temperature of 170 degree Celsius and it is in liquid state. The molten material in the print should solidify and provide a good foundation for the next layer. If the layer is not solidified properly before the next layer, the previous layer may get compressed under the new layer. This decreases the details of the print and thereby decreases print quality.

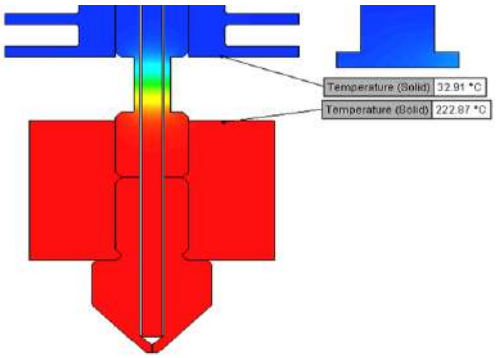

Fig.5: The thermal diagram of hotend

E. Hotend or Liquefier Print Cooling design

The hotend consist of a heat break which transmits heat and provides a path for the flow of filament. The heat break is concentric rod made of stainless steel and the inner diameter is maintained at 2mm diameter. But the outer diameter varies for different zones. The hot zone has 6mm thread for mounting the heat block, then the intermediate zone of smaller diameter and height of 3mm and the cold zone is smooth rod with a diameter of 6mm. There is two cylindrical projection of dimension of 7mm diameter and 3mm thickness at the ends of the cold zone.

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These projections are provided for fitting the heat break and the heat sink. A thermal image of a hotend with different zones is shown in Fig.5.

The heat sink is made in a modular design for easy maintenance. The heat sink has two cylindrical halves. The heat sink consists two cylindrical depression for placing the heat break. The heat break is installed in between the two cylindrical halves and they fixed together with help of screws.

F. Auto Bed Leveling

In order to ensure accurate prints, the 3D printer should have a level build platform or bed. Usually it is done manually by adjusting the screws to level the bed and this can be a tedious and time consuming. After several hours of repeated prints, there is a possibility for bed to go out of the alignment and leveling process has to be carried out again. A poor adhesion of printed part is obtained for an unlevel bed due to unexpected first layer issues. This can lead to extruder clogging or scratch mark on build surface if the nozzle is too close to the surface. It is mounted as shown in Fig.6.

In this 3d printer an inductive sensor is used for sensing the bed irregularities and provides prints according to the distance measured by the sensor. The inductive sensor is placed near to the tip of the extruder. This sensor is used to probe various locations over the build platform to calculate the distance between the bed at each point and the nozzle. Then the nozzle's movement in XY axes is compared with the data obtained to compute actual orientation of the print bed. This information is actively used by the printer's firmware to adjust the nozzle position as it moves across the bed while printing. The firmware will make adjustments to the Z-axis there by ensures that a perfect distance is kept between nozzle and print bed.

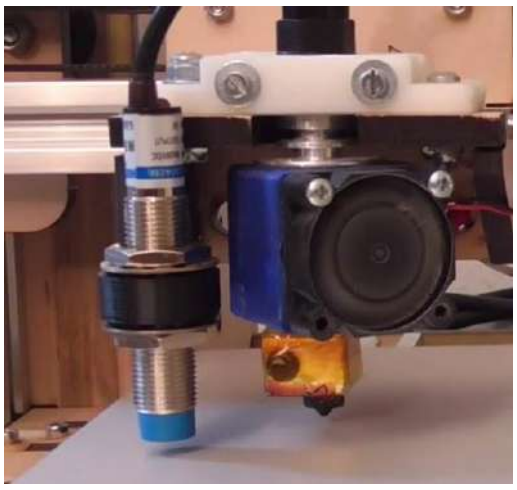

Fig.6: Inductive sensor installed in the print head

G. 32-bit Controller Board

3D printer controllers have to do a lot of stuff very fast. Performing kinematics and dynamics calculations while sending many thousands of precisely-synchronized step pulses per second is really a hard process. The 32-bit board used is the SKR v1.3

The 8bit AVR line of microcontrollers used in older 3D printer controllers is basically a late-1990s era. They are overloaded fast processing cannot be on microprocessors executing basic printing functions in simple (eg Cartesian) printers, and adding additional calculation load will bog them down and cause slowdowns, stuttering, pausing, and so on.

The advantages of a 32-bit controller can be summed up as follows:

- Speed – 32-bit controllers speed up the hotend drastically when calculating curves and arcs.
- Acceleration – Appropriate centripetal/radial acceleration can be calculated appropriately, providing better speed and good resolution can be obtained.
- Print Quality – Better motion planning on a higher-speed processor can improve the print.
- Reduced noise – The stepper interrupt on 8-bit processors can bottleneck the processor, so firmware will often compensate with step doubling, which causes louder and rougher motor motion.

Avoiding firmware problems – Many software-based hacks have been created to compensate for the lack of hardware floating point in 8-bit processors. Firmware updates can completely bog down an 8-bit processor if they have not been tested under a variety of conditions.

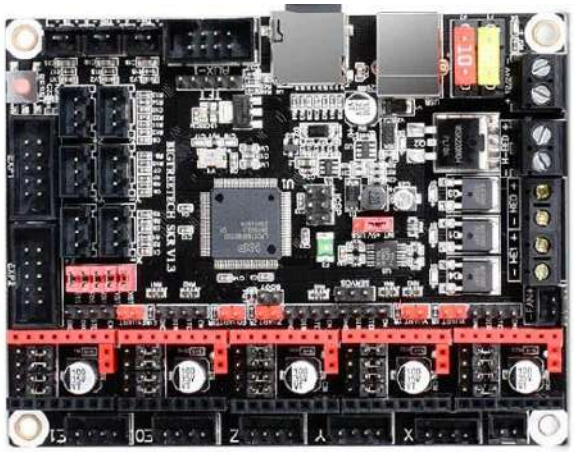

Fig.7: SKR v1.3

H. Stepper motor and Lead Screw

The axis of the 3d printer is controlled by the movement stepper motor. This motion is controlled by the controller using stepper motor drivers. There are three types of stepper motors used in this 3D printer.

(i) X,Y Stepper motor
(ii) Z Stepper motor
(iii) Extruder stepper motor

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The X and Y motors are belts driven and they control the kinematics of the Corexy print head. The belt used is a GT-2 timing belt which is about 6mm in thickness. The GT-2 pulley are employed to provide motion between the motor an the print head. The X and Y stepper motors are made to work at the same time to get linear motion on the X and Y axis.

The Z motor is used to move the print head up and down. The motion is achieved with the help of Tr8x2 lead screw with drives the Z axis. The extruder motor is used to drives the filament into the hotend with the help of a gear and idler gear mechanism.

Fig.8: Tr8x2

I. TMC2130 Stepper Motor Driver

The TMC2130 is a stepper driver that provides high performance when compared to the generic Drv8825 and A4988. This stepper motor driver has 1/16 microstepping and this can be interpolated to 1/256 microsteps. The stepper driver reduces the vibrations, noise during movement, and provides sensorless homing. These stepper driver gives good torque and maximum efficiency.

The sensor less homing eliminates the use of the sensors.

The TMC2130 are used in a wide range of application. This varies from a simple battery powered system to an embedded system. The stepper driver can detect the loss of microsteps and can send a feedback to the microprocessor. By this way the endstops of the axis can be determined i.e. the home position of the nozzle.

The TMC2130 stepper driver supports both UART and SPI mode which are the different ways to interface the TMC2130 stepper driver.

The main features of the TMC2130 Stepper motor driver are StealthChop, SpreadCycle, DcStep, CoolStep and MicroPlyer. These features enables the stepper motor driver to increase the efficiency

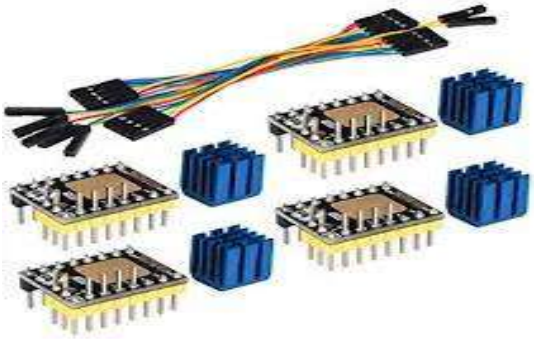

Fig.9: TMC2130

IV. CONCLUSION

The 3D printer can have good efficiency and provide better print quality. The use of V-slots slider will provide better linear movement along the X, Y and Z axis. The hot end used will provide easy assembly and maintenance. The SKR v1.3 will increase the print speed and quality. The usage of TMC2130 will reduce the vibration and the unwanted noise.

In the new design the linear rod is not used instead a V slot and wheel arrangement is used. When the cost of whole 3d printer frame and the linear rod of traditional are considered the new design is cost effective.

ACKNOWLEDGMENT

We thank the Management for their support and express our sincere gratitude to Dr Rajesh T N, HOD, Department of Mechanical Engineering, MBCET for his boundless technical guidance to us.

REFERENCES

[1] CoreXY 3D printer the baic structure and the details of the mechanisms is obtained from https://reprap.org/wiki/CoreXY

[2] The basic idea of a 3d printer is obtained from https://reprap.org/wiki/RepRap

[3] The mechanism and the working of the CoreXY kinematics was obtained from https://corexy.com/theory.html

[4] Jerez-Mesa , J.A. Travieso-Rodriguez, X. Corbella, R. Busqué, G. Gomez-Gras, *Finite element analysis of the thermal behavior of a RepRap 3D printer liquefier*, Volume 36, Pages 119-126, June 2016.

[5] A. Guerrero-de-Miera, M.M. Espinosaa , M. Domíngueza, *Azara:* A new 32 bit RepRap with improved performance, *The Manufacturing Engineering Society International Conference*, ELSEVIER Publishers, Spain

[6] B. P. Huynh, CONVECTIVE COOLING OF AN EXTRUDATE, *5th Joint ASME/JSME Fluids Engineering Conference*, ASME

[7] Kalpesh Dapurkar, Rahul Singh, Sitaram Gawas, Rahul Ugale, Dipak Shelar, Design and Fabrication of 3D Printer to Enhance Productivity, *International Research Journal of Engineering and Technology*, Volume: 06 Issue: 05 | May 2019

[8] Sukhvinder Kang, David Miller, John Cennamo, *CLOSED LOOP LIQUID COOLING FOR HIGH PERFORMANCE COMPUTER SYSTEMS*, ASME Publications

[9] D. Pollarda, C. Warda , G. Herrmanna , J. Etchesa, Filament Temperature Dynamics in Fused Deposition Modelling and Outlook for Control, *27th International Conference on Flexible Automation and Intelligent Manufacturing*, ELSEVIER Publications

[10] Chun-Ying Lee, Chung-Yin Liu, The Influence of Forced-Air Cooling on a 3D Printed Part Manufactured

by Fused Filament Fabrication, *Additive Manufacturing (2018),* September 2018

[11] Antonio Lanzotti, Massimo Martorelli, Gabriele Staiano, *Understanding Process Parameter Effects of RepRap Open-Source Three-Dimensional Printers Through a Design of Experiments Approach, ASME Publication*, February 1, 2015

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Fresnel Lens Concentrated Photo Voltaic/Thermal Hybrid Solar Collector

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***Abstract*— Solar concentrators are ubiquitous for thermal engineering applications. Even though, they are not common for photo voltaic (PV) applications. In this paper, use of solar concentrator for photo voltaic solar panel along with thermal energy is dealt with. Fresnel lens is being used for concentrating solar radiation into a 3W solar panel. Immersed cooling technique is used to harness thermal energy. The water flowing above the solar panel cools it by absorbing heat as well. The Fresnel lens made up of Poly Methyl Meth Acrylate is being used for experimentation. This study evaluates the performance of pure photovoltaic panel and integrated PV/Thermal system under concentrated Fresnel lens. Electrical efficiency of ordinary solar panel was observed as 13%. By introducing solar concentrator, electrical efficiency is reduced to 7% but the overall efficiency of PV/T system was observed as 56%. The total electrical energy output is also improved for PV/T system. Moreover, Fresnel lens concentrated system can harness solar thermal energy too unlike conventional solar panel.**

Keywords—Concentrated PV; Fresnel lens; hybrid solar collector; PMMA.

I. INTRODUCTION

Importance of renewable energy is increasing day by day due to growing environmental concerns. Solar energy is the most promising renewable energy. Use of solar photo voltaic panels has also increased recently as the cost of manufacturing is decreased considerably. Application of solar panels has no limit nowadays. CIAL (Cochin International Airport Limited), Kerala launched 40 MWp solar panel system and the International airport is now running completely on solar photo voltaic. A lot of solar power plants based on solar PV are being installed in various parts of world. However the low efficiency and high land area required are the main drawbacks of the solar panel.

Solar Concentrators can be classified depending upon the number of suns, the unit for solar magnification. Low concentration PV is system with a solar concentration of 2-100 suns. Conventional or modified silicon solar cells are typically used in low concentration PV. The heat flux is low enough at these concentrations and the cells do not need to be actively cooled. Medium concentration PV is solar system with concentrations of 100 to 300 suns. This type of concentrated PV systems need two axes solar tracking and cooling of panel. High concentration photovoltaic (HCPV) systems use concentrating optics consisting of dish reflectors or Fresnel lenses that concentrate sunlight to intensities of 1000 suns or more. The solar cells need effective cooling system to prevent thermal destruction. Multi junction solar cells are now favored over single junction cells, as they are more efficient and have a lower temperature coefficient [1]. Subash Y Nagwase discussed various types of solar concentrators used and the advantages of using Fresnel lens as solar concentrator compared with other solar concentrators [2].

Kribus, Kaftori, Mittelman, Hirshfeld, Flitsanov and Dayan [3] invented a novel miniature concentrating PV (MCPV) system. The system is producing both electrical and thermal energies, which is supplied to a nearby consumer. The heat energy from MCPV collector is not limited to low-temperature applications as like in ordinary PV/thermal (PV/T) flat collectors. The miniature concentrating PV system can be installed on any rooftop, near to the energy consumer. The design is based on a small parabolic dish, similar to a satellite dish. It is very easy to handle, transport and install without specialized equipment. A heat transferred fluid is pumped into the PV array to remove the heat of the PV cells.

Fresnel lens can be used as a cost-effective, lightweight alternative to conventional continuous surface optics. A grooves-out design directs the facets towards the opposite side of focal point. But the grooves-in design orients the facets towards the focal point. A Fresnel lens can be used for various applications like as a magnifier to magnify an object, as a collimator for a confined beam of light and also as a concentrator [4].

Yupeng Wu, Eames, Mallick and Sabry [5] investigated various heat losses from a point focus Fresnel lens concentrator using indoor experimentation. The experimentation was conducted with a simulated solar radiation varying from 200 to 1000W/m^2. Electrical resistance heaters were used to simulate the amount of heat generated at the solar cells. Temperature of cell increased linearly as the simulated solar radiation increased during all experiments. Main modes of heat transfer of the Fresnel lens concentrator system were conduction and convection.

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Operating temperature of the solar panel has an important role in the photovoltaic conversion process. The electrical efficiency and hence the power output of a PV module decrease with increase in operating temperature. Various correlations proposed in the literature can be applied to PV modules or PV arrays and PV/Thermal collectors. They involve basic environmental variables. The numerical parameters were material dependent as well as system dependent. [6]

J.K. Tonui and Y. Tripanagnostopoulos [7] analysed the module temperature measured with no air circulation for all the PVT/AIR configurations. Air circulation by forced or natural flow in the air channel reduces the PV module temperature by at least 5º C. Reduction in module temperature improves electrical output power. The proposed modifications yield higher thermal efficiency than the normal system, with better electrical performance because of achieved PV cooling.

Mehrotra, Rawat, Debbarma & K. Sudhakar [8] studied the feasibility of immersing solar panel in a heat absorbing liquid to reduce panel temperature. PV cell was submerged in water to maintain low surface temperature and to provide better efficiency. The panel was placed at different depths of liquid to control the surface temperature from 31°C to 39 °C and the cell was monitored to calculate various electrical parameters of the cell. Conductivity was the main problem faced with water as coolant but its effect on electrical parameters was considerably less.

Pradish Rawat and Pradeep examined the performance of a conventional flat plate PV/T system. A conventional solar panel without using a solar concentrator is used for experimentation. Copper sheets and copper tubes are attached to the bottom of 37W polycrystalline solar panel through which water is flowing. They found an increase of 6% in exergy efficiency for a mass flow rate of 0.002 kg/s [9].

Nia , Nejad, A M Goudarzi, M Valizadeh and P Samadian [10] utilized Fresnel lens to concentrate solar beam on thermoelectric module (TE module) to generate electrical power. Karimi, Hongtao Xu, Zhiyun Wang, Jian Chen and Mo Yang [11] conducted an experimental study of PV/T system using Fresnel lens. The study evaluated performance of both Fresnel lens concentrated pure thermal collector and PV/T system. Experimentation was conducted for 4-5 hours. Solar panel was fixed on the top of a thermal collector which was composed of copper plate and water flow channel. Cooling water was flowing through the channel to absorb thermal energy.

In this article, the performance of a Fresnel lens concentrated solar PV/T system with immersed cooling technique is studied. Experimentation was conducted from morning to evening with solar tracking. Experimentation on an ordinary flat plate solar panel was also conducted simultaneously on same days to compare the performance.

A. Fresnel lens as concentrator

Fresnel, a French physicist, worked out his thought that since refraction occurs at the curved surface of a glass, the rest of the glass is unneeded. If the non-essential glass is removed and the remaining glass segments are flattened, a Fresnel lens can be obtained [4]. The profiles of the refracting surface of a lens defines its focusing properties. The bulk of material between the refracting surfaces has no effect on the optical properties of the lens other than increasing absorption losses. Steps in derivation of Fresnel lens from glass surface are shown in fig. 1.

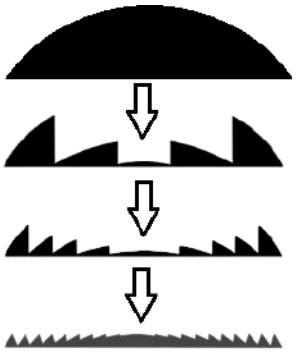

Fig. 1. Derivation of Fresnel lens from glass surface

II. EXPERIMENTATION AND METHODOLOGY

A. Fresnel lens

The Fresnel lens used in this research work is made from poly-methyl-meth-acrylate (PMMA) material which is economically feasible and has a high transmittance. Specifications of the Fresnel lens are given in Table 1. The focal length of the Fresnel lens is 60 cm.

B. PV panel with immersed cooling System

A 3W PV panel was used for the experimentation. The panel was placed inside a small container immersed in water. The container has provision for the cooling water to flow through it. Cooling water enters the container, absorbs heat from the panel and the hot water flows to collecting tank. Flow of cooling water was controlled by monitoring the panel temperature. The panel container was also placed on the adjustable supporting stand. Another 3W panel identical with this panel was used to study the performance without concentration and immersed cooling. Specification of the panel is given in table 2.

Table 1. Fresnel lens specifications.

Parameter	**Value**
Length	61.20 cm
Width	46.60 cm
Width of Outer Frame	1.00cm
Focal Length	60 cm
Material	Acrylic

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Table 2: PV panel specifications

Parameter	Value
Rated Power	3 W
Open circuit Voltage	11.00V
Short Circuit Current	0.40 A
Voltage at Maximum Power	8.70 V
Current at Maximum Power	0.35 A

For proper tracking of the system, direct solar radiation should be perpendicular to the plane of Fresnel lens and the rectangular image of the lens should fall on PV panel. Manual tracking was done in each interval of time from morning to evening. Arrangement of Fresnel lens and solar panel is shown in fig. 2.

C. Experimental Setup

Schematic diagram of the experimental setup is shown in fig.3. The experimental setup contains the following

- Fresnel lens with adjustable stand
- PV panel immersed in water
- Water tank and collecting tank
- Measuring instruments
- Ordinary flat plate solar panel

Solar radiation falling on the Fresnel lens is concentrated to the panel and a rectangular image is formed on solar panel. Solar panel generates electricity and the water flowing above the panel absorbs thermal energy. Photograph of the experimental setup is shown in fig. 4. Detailed experimentations were done simultaneously on two identical 3W panels, one was the Fresnel lens concentrated (FLC) solar panel with immersed cooling technique and the other was an ordinary flat plate (OFP) solar panel.

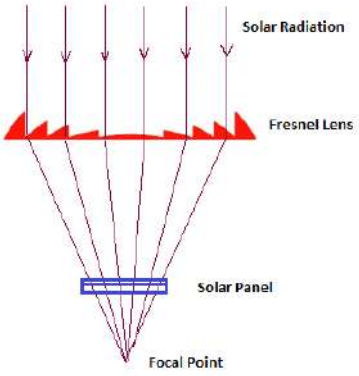

Fig. 2. Arrangement of Fresnel lens and PV module

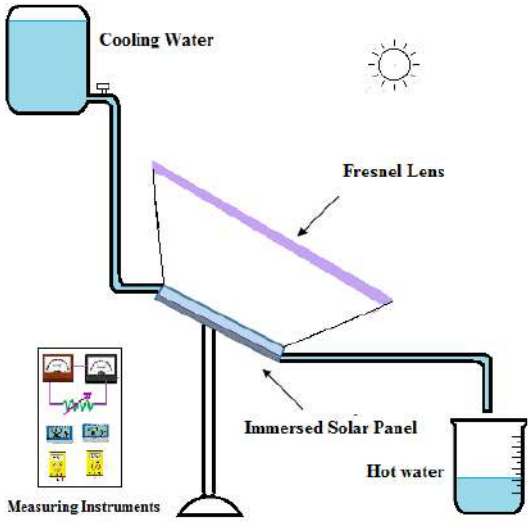

Fig.3. Schematic diagram of Experimental Setup.

Distance between lens and panel was fixed as 48cm corresponding to 0.8f (focal length) for the experimentation so that concentrated rectangular image falls exactly on the panel. The panel is always kept parallel to the Fresnel lens. A potentiometer was connected with solar panel as electrical load. Voltage and current define the electrical performance of any solar panel. Thermal energy output can be measured by noting the rate of quantity of cooling water over the panel and its temperature difference.

Resistance load of potentiometer was varied from minimum to maximum for noting current and voltage in different load conditions. A set of current (I) and Voltage (V) from minimum to maximum value, rate of flow of cooling water (m_w), temperature of inlet cooling water to panel container (T_{in}), temperature of outlet hot water (T_{out}) and intensity of solar radiation (G) were noted each hour from morning to evening in each day of experimentation. Flow of water was adjusted by noting the panel surface temperature with the help of a flow control valve. Current and voltage readings of ordinary flat plate panel were also noted each time.

Fig. 4. Photograph of Experimental Setup

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The electrical power output, Q_{el} and the thermal power output, Q_{th} of the PV panel at any instant of time can be calculated from the measured data using following equations

$$Q_{el} = I_{\max} V_{\max} \tag{1}$$

$$Q_{th} = m_w c_p (T_{out} - T_{in}) \tag{2}$$

Where Q_{el} and Q_{th} are in Watts. c_p is the specific heat of the average fluid temperature in kJ/kg K, m_w is the mass flow rate in kg/s and T_{out} and T_{in} are the outlet and inlet temperatures of water respectively in ^{0}C. Thermocouples are used for measuring temperatures. I_{max} and V_{max} are the current and voltage of the panel at the maximum power point.

Total electrical energy output and total thermal energy output of the PV panel in each day of experimentation can be calculated from the instantaneous power using (3) and (4)

$$Q_{el,total} = \sum_{i}^{n} (I_{\max} V_{\max})_i \Delta t_i \tag{3}$$

$$Q_{th,total} = \sum_{i}^{n} [m_w C_p (T_{out} - T_{in})]_i \Delta t_i \tag{4}$$

Where i is the number of measurement, n is the final measurement and Δt is the time between two measurements. $Q_{el,total}$ and $Q_{th,total}$ are in Jouls. Readings were taken from morning 8AM to evening 6PM in an interval of 1 hour.

Total solar radiation energy (G_{total}) is calculated by integrating solar radiation intensity over the entire experimental period

$$G_{total} = \sum_{i}^{n} (G)_i \Delta t_i \tag{5}$$

Electrical efficiency of OFP solar panel can be calculated using (6)

$$\eta_{el} = \frac{Q_{el,total}}{A_P G_{total}} \tag{6}$$

A_p is the collector area. For an ordinary flat plate solar panel, collector area is the area of the panel.

In the case of FLC solar panel there must be some normalization factors for the intensity of solar radiation G, as the total solar radiation falling on lens will not reach the solar panel. These normalization factors include reflection losses of Fresnel lens and subtraction of diffused solar radiation from global radiation. So the normalized value of solar radiation G^* is given by (7)

$$G^* = I_d \tau G \tag{7}$$

I_d is the share of direct radiation from global radiation and τ is the transmission factor of Fresnel lens. PMMA Fresnel lens was used in this experimentation. Value of τ is taken as 0.7 and I_d as 0.5 [11]. Total solar radiation energy (G^*_{total}) is calculated from (5) using this normalized value of G^*.

Now the electrical efficiency of FLC solar panel is calculated using (8)

$$\eta_{el} = \frac{Q_{el,total}}{A_c G^*_{total}} \tag{8}$$

Where A_c is the collector area. In the case of FLC solar panel, area of Fresnel lens is the collector area.

Thermal efficiency and overall efficiency of the FLC panel can be calculated using (9) and (10)

$$\eta_{th} = \frac{Q_{th,total}}{A_c G^*_{total}} \tag{9}$$

$$\eta_o = \eta_{el} + \eta_{th} \tag{10}$$

III. Results and Discussions

A. I-V characteristics

I-V curve is graphical representation of feasible combination of current and voltage generated in the solar panel. If the output terminals of the panel are open, the voltage produced will be maximum. Voltage of the panel at this point is known as open circuit voltage V_{oc} and corresponding current is zero. If there is no resistance in the circuit of the panel, current flowing through it will be maximum. This maximum current is known as short circuit current I_{sc} and the output voltage will be zero. In both cases, no power is delivered by the solar panel

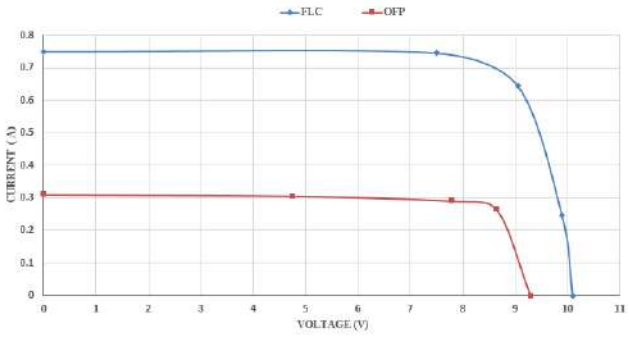

Fig. 5. I-V characteristics of FLC and FPC panels (at 1:00PM on the day of experimentation).

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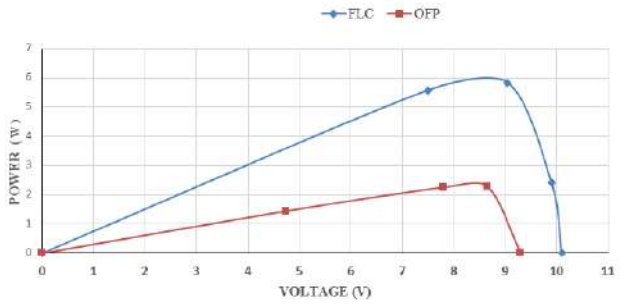

Fig. 6. P -V characteristics of FLC and FPC panels (at 1PM on the day of experimentation).

I-V characteristics of the Fresnel lens concentrated solar panel are shown in fig.5. Highest value of maximum power (P_{max}) is obtained at 1 PM and the values obtained at 1 PM is used to plot the I-V and P-V characteristics of the panel. I-V curve of an ordinary flat plate panel was also plotted on the same graph.

B. P-V characteristics

P-V curve is another important graphical representation to define the performance of a solar panel. Power, P is calculated for each combination of voltage and current. P – V graph is then plotted taking voltage as abscissa and power as ordinate. Fig.6 represents P -V characteristics of FLC solar panel and that of OFP solar panel. Performance of FLC solar panel is far better than that of OFP solar panel.

C. Maximum power

Maximum power point (MPP) is the top most point of the P-V curve and it is very important to work the panel always at MPP. Maximum power obtained from the panel in each hour is used to plot the graph between P_{max} and time. Fig. 7 represents maximum power obtained from the FLC solar panel in each time in an interval of one hour. Maximum power obtained from OFP is also plotted for comparison.

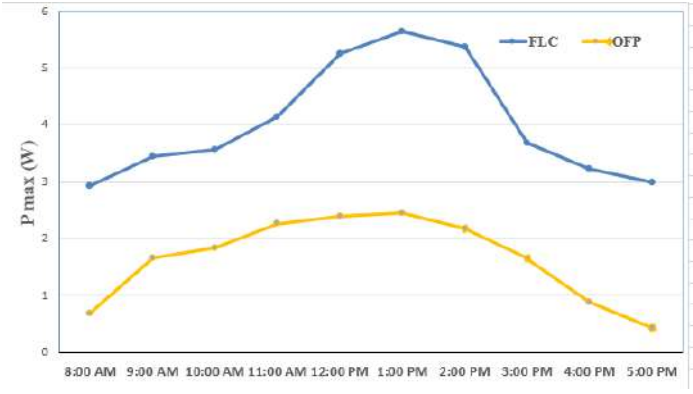

Fig. 7.Hourly variation of maximum power (P_{max}) delivered by FLC and OFP solar panels.

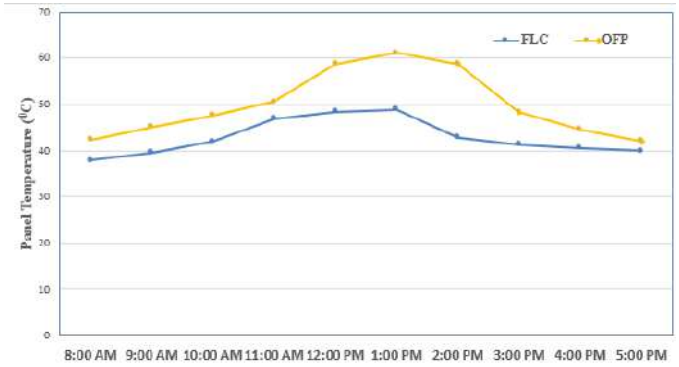

Fig. 8. Hourly variation of panel temperature of FLC and OFP panels.

One of the main drawbacks of solar panel is non-uniformity in the power developed. The bell curve of the OFP panel in fig.7 explains the non-uniformity in P_{max}. Peak generation of electricity is in between 11AM and 3PM for any ordinary panel. However, FLC panel is producing rated power between 9AM to 5PM consistently. This graph clearly exemplifies the importance of concentration on solar panel.

D. Temperature of solar panel

Temperature of solar panel has a crucial role in electrical performance. The electrical efficiency and the power output of panel decrease with increase in operating temperature [6]. As the module is immersed in cooling water, there was considerable dip in the panel temperature in FLC unit. Fig.8 represents variation of panel temperature of FLC and OFP panels. An average of 7^0C decrease in FLC panel temperature was noted compared with that of OFP panel. This improves the efficiency of the panel. Also, the hot water obtained can be used for heating purpose.

E. Electrical Efficiency and Thermal efficiency

Maximum electrical efficiency obtained for OFP panel was 13%. But the electrical efficiency of FLC panel was only 7%. The result was similar to the values obtained by Fariborz Karimi [11]. Even though, electrical efficiency is reduced, the maximum power produced for FLC was much higher than that of OFP panel. Moreover, the overall efficiency of the FLC system was 56%.

F. Total electrical energy output

Total electrical energy output per a day is another important parameter of a solar panel which says the real capacity of the panel. This is the total electrical energy of the solar panel that can be delivered to an external load in a day. Table 3 shows the electrical energy output obtained from FLC in Watt-hour (Wh). The output obtained from the OFP on that days are also given. Even though electrical efficiency of FLC system decreased, FLC panel can deliver total electrical energy of 2 to 2.5 times that of OFP panel. Thermal energy output is not compared here as OFP panel cannot harness any thermal energy.

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Table 3. Daily electrical energy output of FLC and OFP

Day of experimentation	**FLC** (Wh)	**OFP** (Wh)
Day 1	41.3	16.6
Day 2	40.2	15.8
Day 3	41.6	17.1

IV. CONCLUSIONS

In this study, performance of Fresnel lens concentrated solar PV system with immersed cooling technique was investigated experimentally. Fresnel lens with focal length 60cm made up of PMMA was used in experimentation. Two identical 3W panels were used, one in FLC and the other as OFP. Experiments showed that performance of FLC was much better than that of OFP because of the following reasons

1. High maximum power: FLC solar panel produced more electric power as it was exposed to higher solar insolation.

2. Consistency: OFP solar panel can produce electricity consistently only between 11AM to 3PM. But the FLC panel produced rated power between 9AM to 4PM consistently.

3. Low panel temperature: As FLC panel was cooled by water, panel temperature could be maintained within the optimum temperature level. So the overall efficiency was higher than OFP panel.

4. Harnessed thermal energy: Heat energy absorbed by the cooling water can be used for low temperature applications.

NOMENCLATURE

A_c	Fresnel lens area (m^2)
A_p	Solar panel area (m^2)
c_p	Water specific heat capacity (J/kg K)
G	Solar radiation Intensity (W/ m^2)
G^*	Modified solar radiation Intensity (W/ m^2)
G_{total}	Total solar radiation energy (J/ m^2)
G^*_{total}	Total modified solar radiation energy(J/ m^2)
I	Current (A)
I_d	Direct radiation factor
m_w	Mass flow rate of cooling water (kg/s)
Q_{el}	Electrical power output (W)
Q_{th}	Thermal power output (W)
T_{in}	Inlet temperature of cooling water (^{0}C)
T_{out}	Inlet temperature of cooling water (^{0}C)
T_{out}	Outlet temperature of cooling water (^{0}C)
V	Voltage (V)
τ	Transmission factor of Fresnel lens
η_{el}	Electrical efficiency
η_{th}	Thermal efficiency
η_o	Overall efficiency

REFERENCES

[1] D. Pacho n, G. Sala, "Characterization of Optical Collectors for Concentration Photovoltaic Applications", progress in photovoltaic Research and applications, vol. 11,pp 387–405, 2003.

[2] Subash Y Nagwase, Snehal N More, Hemraj H. Patil, Amol V. Tadkar, "Solar Concentration Technology for Increasing Solar Energy: Review", Journal of Applied Science and Computations, vol 6, pp 1273-1279, 2019.

[3] Abraham Kribus, Daniel Kaftori, Gur Mittelman, Amir Hirshfeld, Yuri Flitsanov, Abraham Dayan, "A miniature concentrating photovoltaic and thermal system", Energy Conversion and Management, vol 47, pp 3582–3590, 2006

[4] Arthur Davis , Frank Kuhnlenz, "Optical Design Using Fresnel Lenses" , Wiley-VCH Verlag Weinheim, optik & Photonik, vol 4, pp 52-55, 2007.

[5] Yupeng Wu, Philip Eames, Tapas Mallick, Mohamed Sabry, "Experimental characterisation of a Fresnel lens photovoltaic concentrating system", Solar Energy, vol 86, pp 430–440, 2012.

[6] E. Skoplaki, J.A. Palyvos, On the temperature dependence of photovoltaic module electrical performance: A review of efficiency/power correlations, Solar Energy, vol 83, pp 614–624, 2009.

[7] J.K. Tonui, Y. Tripanagnostopoulos, "Improved PV/T solar collectors with heat extraction by forced or natural air circulation", Renewable Energy, vol 32, pp 623–637, 2007.

[8] Saurabh Mehrotra, Pratish Rawat ,Mary Debbarma & K. Sudhakar, "Performance Of A Solar Panel With Water Immersion Cooling Technique", Environment and Technology, vol 3, pp1161 – 1172, 2014.

[9] Pratish Rawat and Pardeep Kumar, "Performance Evaluation of Solar Photovoltaic / Thermal (PV/T) System", International Journal of Science and Research, vol 4, 1466-1471, August 2015.

[10] M. Hasan Nia, A. Abbas Nejad, A.M. Goudarzi, M. Valizadeh, P. Samadian, "Cogeneration solar system using thermoelectric module and fresnel lens", Energy Conversion and Management, vol 84 pp 305-310, 2014.

[11] Fariborz Karimi, Hongtao Xu, Zhiyun Wang, Jian Chen, Mo Yang, "Experimental study of a concentrated PV/T system using linear Fresnel lens", Energy, vol. 123, 402-412, 2017.

[12] D.yogi Goswami., Frank Kreith, Jan F Krider, Principles of solar engineering; Taylor & Francis, Philadelphia, 2000.

[13] Dr. Ralf Leutz, Dr. Akio Suzuki, "Nonimaging Fresnel Lenses Design and Performance of Solar Concentrators", Springer-Verlag Berlin Heidelberg, New York, 2001.

[14] Xinyue Han,Yiping Wang and Li zhu, "Electrical and Thermal Performance of silicon concentrated solar cells immersed in dielectric liquids", Applied Energy, vol 88, pp 4229-5230, 2011.

[15] David C.Miller, SarahR.Kurtz, "Durability of Fresnel lenses: A review specific to the concentrating photovoltaic application", Solar Energy Materials & Solar Cells, vol 95, pp 2037–2068, 2011.

[16] H.G. Teo , P.S. Lee , M.N.A. Hawlader, "An active cooling system for photovoltaic modules", Applied Energy, 90, 309–315, 2012

[17] J.S. Coventry, "Performance of a concentrating photovoltaic/thermal solar collector", Solar Energy, vol 78, pp 211-222, 2005

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Development of an Experimentation Setup for the Analysis of Flow Induced Vibrations in Flexible Tubes Conveying Fluid

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Abstract

Flexible tubes are used to transfer a wide range of fluids including gaseous fluids and liquids and hence find numerous applications in the industrial field, medical field, etc. Polyurethane (PU) tubes are one among the most widely used flexible tubes owing to their superior qualities and long life. Fluids conveyed through these tubes may not be always in steady condition, rather there are conditions of velocity or pressure varying flow. They can induce severe disturbances to the flexible tube than that induced during the steady condition. These can be extremely hazardous depending on the field of application. So it is needed to investigate the dynamic behavior of flexible tubes in velocity varying flow. Even though vast studies have been conducted in the steady flow through flexible tubes, more experimental studies are needed to be done concentrating velocity.

This paper attempts to introduce an advanced experimental setup for the study of flow-induced vibrations in flexible tubes. Flow is made velocity varying using a linear actuator coupled plunger rod mechanism which varies the flow from zero to maximum value through the plunger movement and this variation in flow velocity results in pressure pulsations in the fluid. The pressure variation is monitored by a pressure transducer and the dynamic responses of the fluid conveying tubes are acquired by means of a Laser Doppler Vibrometer. The experiments are found to be highly useful in the investigation of the dynamic behavior of the flexible tube under pulsatile flow and flow-induced vibration.

Keywords— Flexible tube, Polyurethane, Flow-induced vibration, Velocity, Pressure

Notations

Length of tube, m	= L
Interior Perimeter of tube, m	= S
Inside area of tube, m^2	= A
Linear density of pipe, kg/m	= m
Flexural Rigidity, $Mpa.m^4$	= EI
Coefficient of viscoelastic damping in the pipe, MPa	= E^*
Coefficient of viscous damping, Ns/m	= c
Pressure, Pa	= P
Poison ratio,	= υ
Linear density of fluid, kg/m	= M
Axial fluid flow rate, m/s	= U
Longitudinal tension in tube, N	= T
Transverse shear force, N	= q
Bending Moment, kg.m	= M_b

I. INTRODUCTION

The dynamics of pipe conveying fluid has always been one of the concentrated areas of attention as it shows interesting as well as occasionally nonlinear behavior. Fluid-structure interaction resulting from the transfer of energy from and to the fluid can cause vibrations which can be severe in nature. These vibrations are sometimes hazardous and risky. So it is necessary to study the fluid-structure interaction and flow-induced vibration for practical engineering problems. Internal fluid flow is an important aspect to study the flow-induced instabilities and the dynamic characteristics of fluid conveying pipes. The analysis of natural frequencies of pipe conveying fluid helps to identify the safe operating frequencies of pipes and to design its supports. If the natural frequency of pipe matches with the frequency of structure or other attachment, resonance may occur and it can affect the pipe stability. They can result in leakage and failures.

Many devices which incorporate flexible fluid conveying tubes are now designed for engineering applications, hydraulic machinery application, utilization in hospital, etc. Polyurethane combines the best properties of both plastic and rubber. It offers tear resistance, high tensile and low compression set. It offers high elongation values like rubber and abrasion resistance superior to PVC. Polyurethane is naturally flexible and exhibits superior flexural abilities. As it possesses good chemical resistance with excellent weathering characteristics, polyurethane is superior to most other thermoplastics.

As Paidoussis and Li [1] found, experimental studies on the dynamics of fluid conveying flexible tubes are not numerous even though the theoretical, as well as numerical studies, are many. Naguleswaran and Williams [2] investigated the effect of pressurized flow on natural frequency in a clamped-clamped neoprene tube. Jendrzejczyk and Chen [3] conducted similar experiments on polyethylene and acrylic tubes under various support conditions. All these studies were limited to steady flow conditions and the effects of various parameters like pressure, flow velocity, initial stretch, etc on the critical flow velocity and natural frequency.

Unnikrishnan et. al.[4] discussed an experimental method for calculating dynamic characteristics of horizontal pre-stretched PU tube. Factors affecting modal parameter estimation are found out and optimum parameters are suggested. Zhang et al. [5] conducted an experimental study on pulsating and steady

fluid flow in an initially stretched rubber tube subjected to external vibration and found out the effect of flow velocity and stretch rate on the damping ratio.

Velocity varying flow through flexible pipes should be investigated in a detailed way as it can cause more flow-induced vibrations compared to steady flow and also the behavior of the tube can't be predicted. Velocity variation can induce pressure changes to the flow and hence it is a potential area to be studied. The present work is dedicated to the development of a new experimental setup for investigating the flow-induced vibrations in flexible tubes conveying fluid.

II. THEORY

A. Dynamics of Pipes conveying steady fluid

The governing equation for fluid conveying vertically placed slender pipe is presented in Paidoussis [7] as follows. The fluid element is shown in Fig. 1 is subjected to:

- Pressure forces acting on fluid element due to the frictional losses.
- Reaction forces of the pipe, pipe shear force q.
- Gravity forces.

The general equation of motion based on beam theory if the effect of gravity is not negligible, plug flow model for fluid and assuming small perturbations in the velocity of flow along the radial direction is given by,

$$(E^{*}\frac{\partial}{\partial t}+E)I\frac{\partial^4 w}{dx^4}+\left\{MU^2-T+PA(1-2v\delta)-\left[(M+m)g-M\frac{\partial U}{\partial t}\right](L-x)\right\}\frac{\partial^2 w}{\partial x^2}$$
$$+2MU\frac{\partial^2 w}{\partial x\partial t}+(M+m)g\frac{\partial w}{\partial x}+c\frac{\partial w}{\partial t}+(M+m)\frac{\partial^2 w}{\partial t^2}=0 \quad (1)$$

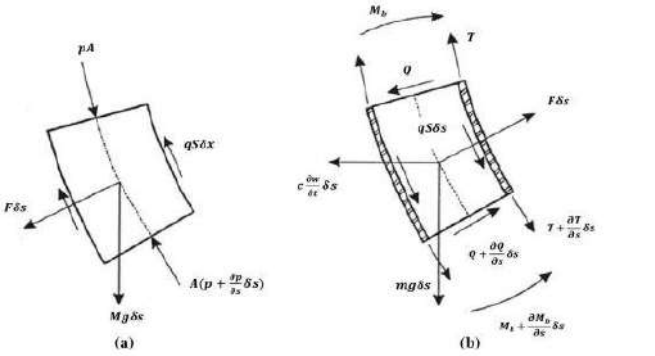

Fig.1 (a) Force balance of a fluid element δs. (b)Force and moment balance of the corresponding element of pipe. [7]

If the effect of sagging (gravity), damping (energy dissipation), pre-tensioning and internal fluid pressurization are absent or neglected the equation (1) simplifies to

$$EI\frac{\partial^4 w}{\partial x^4}+MU^2\frac{\partial^2 w}{\partial x^2}+2MU\frac{\partial^2 w}{\partial x\partial t}+(M+m)\frac{\partial^2 w}{\partial t^2}=0 \quad (2)$$

The four terms in equation (2) are the flexural restoring force, the centrifugal force, the Coriolis force, and the inertial force, respectively.

But for velocity varying flow through flexible tubes, internal fluid pressurization is not absent rather it is dominant as the velocity variation causes pressure variation. It is evident from equation (1) that pressurization will cause imbalance to the whole system. Also, the assumption that velocity remains constant is not applicable. So there is a need for experimental study concentrating on the velocity varying flow through flexible tubes.

III. EXPERIMENT ON FLEXIBLE PU TUBE CONVEYING VELOCITY VARYING FLUID

A. Design of Component

A linear actuator – plunger mechanism was devised for the purpose of imparting velocity variation in the fluid flow. In the mechanism, the main components are – A linear solenoid actuator (REMORE 12V solenoid actuator- 25mm displacement), plunger rod and casing. The linear actuator has a stroke length of 20-610mm which can be chosen and a rated maximum load of 7000N. Linear actuator and the plunger rod are mechanically coupled. The plunger rod is placed inside the casing as shown in Fig. 2. In order to prevent fluid leakage, a couple of oil rings are provided at the end of the plunger rod which is coupled with actuator and the plunger is tight fit inside the casing. A spring of low stiffness is placed between other end of plunger rod and casing in order to ensure smooth motion and to prevent metal to metal contact. Spring stiffness is 300N/m and the number of coils is 14.

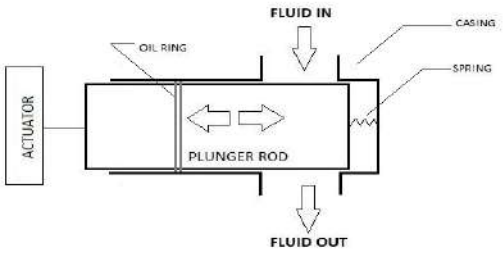

Fig. 2 Schematic diagram of the linear actuator-plunger arrangement

Fig. 3 Fabricated plunger arrangement

The casing has an inlet and outlet opening so that it can be connected to a pipeline. The linear actuator is allowed to move to and fro at high speed and as the plunger rod is mechanically coupled with it, it will also move to and fro. As the movement occurs, it is evident from Fig. 2 that this movement will

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change the flow rate from maximum to zero condition. When the displacement of the actuator is nil, the flow will be maximum and when the actuator displacement is maximum, flow is restricted to a zero condition as the plunger closes the path. This flow rate variation induces a velocity variation and which induces a pressure variation in the fluid flow when continuously operated and thereby desirable flow can be generated. The spring will be compressed at a full displacement of the plunger and it regains the structure as the plunger moves back with actuator. The actuator system can be electronically controlled and so the displacement and speed can be controlled. Velocity can be controlled by controlling the flow rate.

B. Test Facility

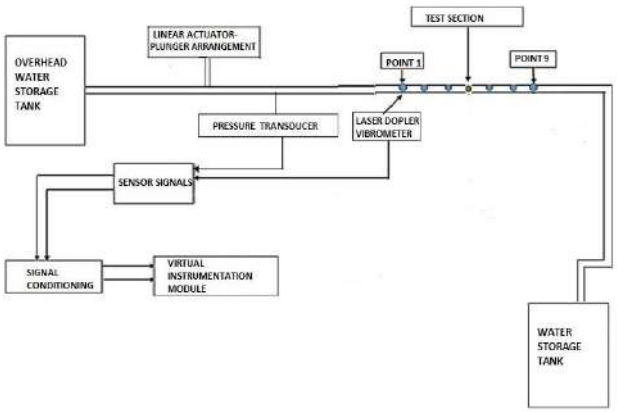

Fig. 4 Layout of the experimental test setup

The test setup consists of a test field, fluid storage tanks, pulsation device, and measurement devices and control devices. A clamped-clamped PU tube placed horizontally is used as a test section. The length of the test section is taken as 36cm and inner and outer diameters are 6mm and 8.5mm respectively. Water is used as test fluid and is filled in the tank and a head of 2m is maintained using a float valve mechanism. A pump is employed to refill the reservoir tank from the collecting tank. Flow is made unsteady using the linear actuator-plunger rod mechanism. It is introduced before the test section. A Pressure transducer [Make: Baumer, Model: ctx 333b220] is introduced in between the pulsation device and the test section to monitor the pressure change which is induced. The dynamic response of the tube can be measured using a Laser Doppler Vibrometer (Model: IVS400, Make: Polytec). Dynamic Signal Analyzers (NI-USB 4431, NI CDAQ 9278 and 9205) are used for the measurement and analysis of acquired signals.

C. Experimental Method

The flexible PU tube was kept horizontal by applying a pre-stretch of 5% of its initial length. Initial pre-stretch was given so as to reduce the sagging of the flexible pipe when fluid is transferred through it. Boundary conditions are made sure by clamping both ends of the test section. The test section consists of 8 equal divisions with fixed points numbered as 1, and 9 as endpoints. For the reflection of the laser beam, reflective tapes are cut accordingly and pasted to the 7 intermediate points of the test section. Laser Doppler Vibrometer is used to analyze the dynamic response from these 7 points.

Fig. 5 Test section

The constant head is maintained by means of 2 interconnected above head water tanks and the float valves maintain constant water level inside the storage tank. Fluid coming from the tank is made unsteady by the actuator-plunger rod arrangement and then fed to the test section. The Dynamic Signal Analyzers processes the signals received from the pressure transducer and the Laser Doppler Vibrometer. The post-processing of signals received is done using ME'scope VES analysis software and LABVIEW Signal Express2011 software.

Table 1: Optimum Parameters for data acquisition

Time	
Number of samples	8192
Time resolution (sec)	0.0008
Frequency	
Number of samples	4096
Frequency resolution (Hz)	0.153
No of averages	5
Window type	Hanning

The optimum parameters for data acquisition were adopted from Unnikrishnan et.al. [4]

IV. RESULTS AND DISCUSSION

A PU tube of 36cm length is used to investigate the dynamic characteristics when the tube is subjected to velocity varying flow. The velocity varies from zero to maximum similar to the flow condition resembling a rectified AC signal as shown in Fig.6. When the flow is restricted to no flow condition, the inertia of liquid in the test section will create a negative pressure region and hence the pressure variation will be from a negative pressure region to the maximum pressure region. This forms a pressure pulse and flow tends to pulsatile flow.

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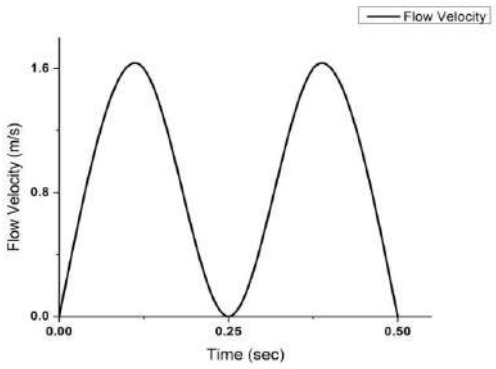

Fig. 6 Flow velocity vs time graph

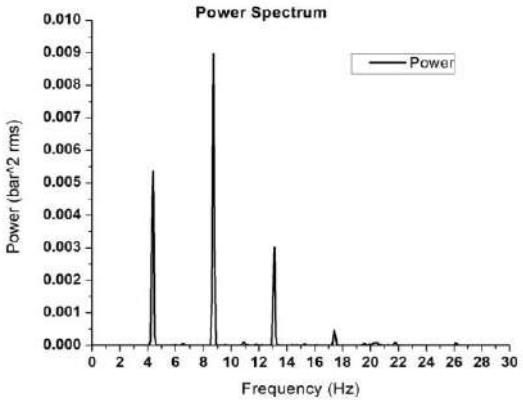

Fig. 7 Power Spectrum obtained from the pressure transducer

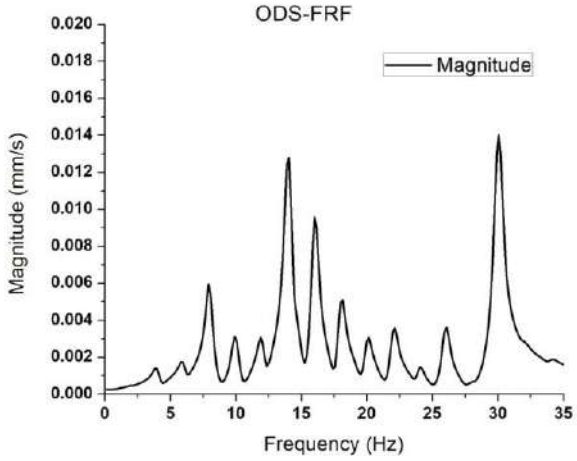

Fig. 8 ODS-FRF obtained from Laser Doppler Vibrometer

Fig. 7 and Fig. 8 represent the power spectrum of pressure pulse obtained from the pressure transducer and Operating Deflection Shape - Frequency Response Function (ODS-FRF) which shows the dynamic characteristics of the flexible tube respectively. The power spectrum represents the frequency of pressure pulse induced in the system. The dynamic response shows the combined effects of pulsation, fluid-structure interaction and flow-induced vibration

As Svete et al [6] explained the interaction of pulsating fluid and tube will result in additional vibrations. The frequencies of these vibrations will be f_1, nf_p, $nf_p + f_1$ and $nf_p - f_1$ where f_1 is the first fundamental frequency, f_p is the pulse frequency and n=1,2,3…

Pulse frequency is obtained from the power spectrum as 4.2Hz. It is evident that there will be vibrations in frequencies ranging from 4.2Hz onwards as shown and these vibrations are the combined effect of pulsation and tube properties. So this setup can be employed to study the dynamic characteristics of flow through the flexible tube with flow-induced vibration.

V. CONCLUSION

This paper brings forward an advanced experimental setup for the study of flow-induced vibrations in flexible tubes conveying fluids. Flow-induced vibration comes in to picture when the steady flow condition is not applicable. Velocity varied flow and pulsed flows are similar conditions where the steady nature of the fluid is not applicable. Hereby means of an indigenously developed plunger-actuator mechanism, the flow velocity could be varied by regulating the fluid flow, thereby resulting in pulsatile flow. The pulse generated can be monitored through pressure transducers and digital signal analyzers. This pressure pulse gives rise to flow-induced vibrations which can be analyzed by means of laser scanning technology and digital signal analyzers. Tests were conducted using the experimental setup and results are obtained. The result reveals the solemnity of the need for further studies related to this area. The setup can be used for the analysis of flow-induced vibrations in flexible tubes conveying fluid.

REFERENCES

[1]Paidoussis, M.P., Li, G.X. Pipes conveying fluid: a model dynamical problem, Journal of Fluids and Structures,**7**, 1993, pp 137-204.

[2]S. Naguleswaran, C.J.H. Williams, Lateral vibration of a pipe conveying fluid, Journal of Mechanical Engineering Science 10, 1968, pp 228–238.

[3]Jendrzejczyk, J.A., Chen, S.S., Experiments on tubes conveying fluid, Thin-Walled Structures, 3, 1985, pp 109-134.

[4] Madhusudanan Unnikrishnan, Akash Rajan, Binulal Basanthvihar Raghunathan, Jayaraj Kochupillai, Dynamic Testing of a Pre-stretched Flexible Tube for Identifying the Factors Affecting Modal Parameter Estimation, Journal of Institution of Engineers (India) 98,2016, pp 421-430

[5] Zhang, Y.L., Reese J.M., Gorman D.G, An experimental study of the effects of pulsating and steady internal fluid flow on an elastic tube subjected to external vibration. Journal of Sound and Vibration, 266, 2003, pp 355-367.

[6] A. Svete, J. Kutina, G. Bobovnika, I. Bajsića, Theoretical and experimental investigations of flow pulsation effects in Coriolis mass flowmeters, Journal of Sound and Vibration,352, 2015, pp 30-45

[7] Michael P. Paidoussis, Fluid-Structure Interactions. Volume 1: Slender Structures and Axial Flow-Academic Press, 2014, pp 66.

OPTIMIZATION OF AVIATION TURBINE FUEL TRANSPORT IN PIPELINE NETWORKS

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***Abstract*—Pipelines are the most secure and least expensive method for conveying huge volumes of products from processing plants to distant depots. Aviation turbine fuel (ATF) is a particular kind of oil based fuel, which is utilized as a source of energy and powers in most of the aircrafts. Aero engine has to function within pre determined parameters such as specified altitude and flight speed range. Hence fuel has to be of consistent quality and the properties such as fuel density, stability, fluidity, volatility and non-corrosively should be maintained.**

The project is meant to optimize the mass flow rate in pipeline network transport of ATF from refinery storage to different airport depots. The main objectives of the optimization problem is to maximize the mass flow rate of ATF from sales tank. The constraints are the quality that should be maintained based on electrical conductivity, quantity of product available in the sales tank ,demand of truck and wagon and government norms in airport storage. The scope of this work is to develop an optimization model for of ATF dispatch which further reduces extensive manual operations in order to achieve maximum demand condition

Keywords— ATF, Volatility, Aero engine

I. INTRODUCTION

Jet fuel, aviation turbine fuel (ATF) is a type of aviation fuel designed for use in aircraft powered by gas-turbine engines. It is colorless to straw-colored in appearance. JETA- 1-Jet A-1 is a kerosene grade of fuel suitable for most turbine engine aircraft. This work is done to optimize the mass flow rate of ATF in pipeline network subjected to uncertain demand at depots. It helps to maintain better flow rate of ATF and provide maximum evacuation from the sales tank and to develop a real time interface for supply demand calculation of ATF transport from refinery storage. The real time interface helps to reduce the human manual calculations in the transport of ATF to different airport depots and maintain proper mass flow rate. The interface can be applied in the visualization of day to day transport of ATF . It can be apply in future scope in diesel and petrol pipeline transport from refinery depots to achieve better mass flow rate from sales tank.

II. LITERATURE REVIEW

[1] Heuristic methods are used for solving most of the pipeline transportation problem. Mainly problems are solved as assignment problem which was converted from scheduling problem and various objective functions are solved using Pareto-optimization method. It's discovered the cost of oil transportation through pipeline are affected by the flow rate from the storage tanks. Capacity constraint of storage tanks is the principle limitation in the optimization problem [2] The network model was developed to study the demand in a base time. Continuous distribution of packets through an pipeline network was analyzed based on minimum time and required demand condition The primary target of the system model was to fulfill the quantity condition of unit packets at the sink point in time. The quantity to be delivered to the source and the receiving quantity at the sink points, capacity range of the storage tank , pumpable quantity range in each storage tank.[3] The decision variables mentioned in the work mainly deals with storage tank volume to deliver required quantity of fuel and supply to the sink points based on the accessible space in the sink point. The quantity limit of each tank varies based on storage capacity. In the natural gas transportation systems model, the system was defined based on two type of factors such as capacity limits of storage tanks and satisfaction of gad quality norms. The gas transport activities are characterized as transient procedures based on time limits and steady state condition. They assume it as an irreversible flow in steady-state as the gas can flow through a pipeline in one direction only.

The gas pipeline problem deals with limiting the fuel utilization in compressors in order to provide maximum delivery[4].Ant colony optimization technique was used in the gas pipeline transportation problem. The objectives were solved using MOACO Algorithm. The result obtained help

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to study methods in improving the operating conditions and performance of a gas pipeline network. Dynamics computer simulation model was developed to find the effects of alternate water source development based on the causal feedback relationships in water supply management system [7]. The historical data was collected and used to analysis and verify the constructed computer model and develop the required model. Comparison between the simulated result and historical data of the variables in the model helps to identify historical trends of the case study system. Stock and flow diagram of the computer model constructed using STELLA.

III. MODEL OF THE OIL PIPELINE NETWORK

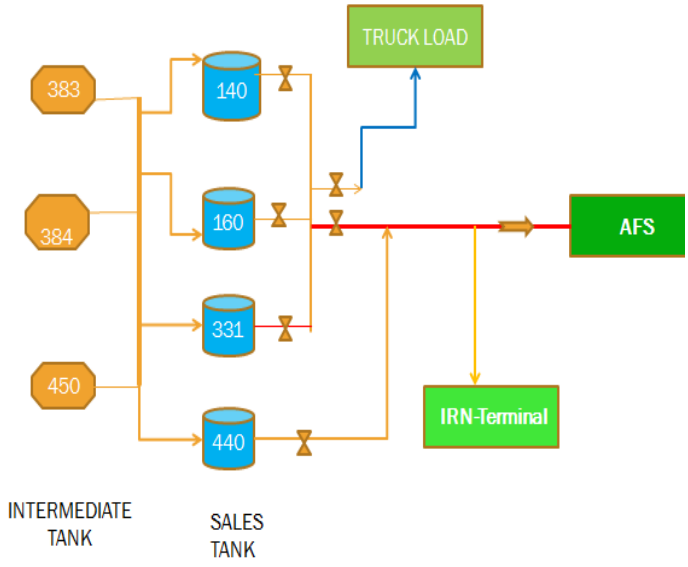
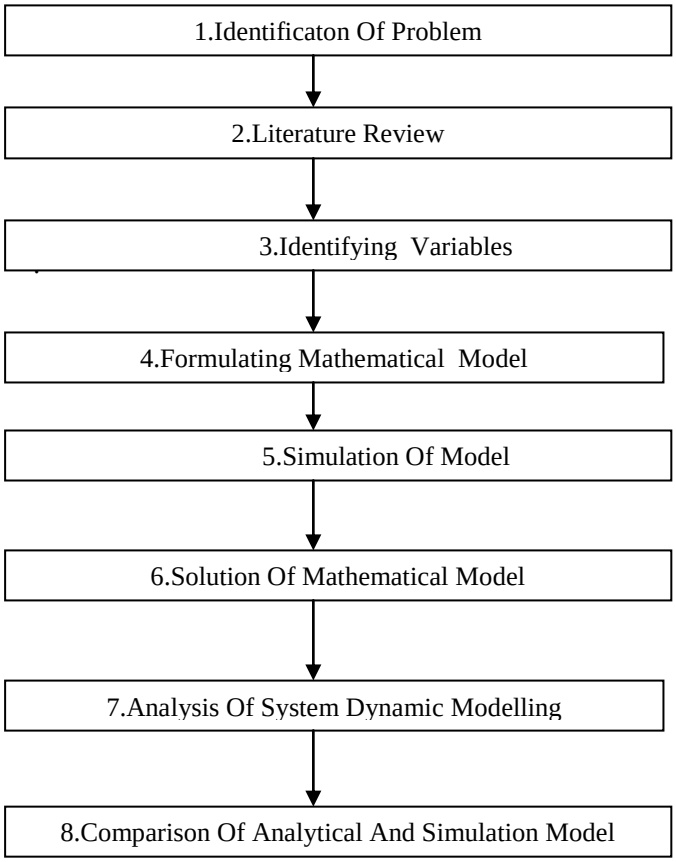


Figure 1.Flow Diagram

From a public sector refinery storage, ATF was transported to airport depots through a single pipeline carrying two different quality fuels. Tanker loading of ATF is also fed from the same four sales tanks at same time. The quality check delay at the sales and intermediate tank make it difficult to maintain required mass flow rate on demand condition. Extensive manual calculation is required to supply fuel to various depots based on quality requirements, demand quantity and government norms. Hence it is very difficult to maintain the mass flow rate of ATF from different sales tank.

IV. METHODOLOGY:



The plant layout for the ATF dispatch section consists of three intermediate tanks and four tanks. The fuel is transported from the tank farm to the intermediate tank based on regular supply basis. The fuel is stored in the three intermediate tank for 1-1.5 Hr quality check and can be fed to the sales tank on demand. In the sales tank, 24 Hr quality check schedule is done in order to maintain better quality product output from the tank. The requirement of fuel at each depot varies based on conductivity of the fuel. The main mode of sales of ATF is through tanker's which is working on 12Hr basis. The main sales outlet is through a single pipeline to two different depots. One of the depot point is the airport fuel station of CIAL another is the BPCL Irumpanam station (BPCL IPM). The BPCL IPM mainly deals with transport of ATF using rail wagon and ship. So high grade quality of fuel should be maintained at this station.

V. BASIC MATHEMATICAL MODEL

OBJECTIVE FUNCTION:

1. To obtain maximum mass flow rate from the sales tank.

CONSTRAINTS:

1. To reduce mixing of different quality of fuels in the

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sales tank.

2. To maintain quality conditions based on electrical conductivity at the sales tank ,demand of truck and wagon and government norms in airport storage.

3. The quality check delay time at both the intermediate and sales tank.1-15 Hr quality check delay at the intermediate tank and 24Hr quality and certification delay in the sales tank before sales.
4. The main two government norms include 3-4 days stock maintain at the AFS and 350 grade of ATF fuel should only be transported to IPN only.
5. Each sales tank has different levels of refilling. The fuel refill should be done at minimum level attainment.
6. Measurement losses occur due to thermal expansion of the fuel.

N_{ij}=Number of source node=3
N_{sj}=Number of sales node=4
N_{dj}=Number of sink node=3
Q=Upper limit capacity of the tank
q=lower limit capacity of the tank
K=Quantity of fuel in the tank
E=Quantity send/hr.
R=Quantity received/hr.
M_{d3}=Maintained quantity in AFS.

PRIMARY OBJECTIVE FUNCTION:

$$\text{MAX}(\sum_{S=1}^{4}\sum_{j=1}^{4}(E_{sj})$$

PRIMARY OBSERVED CONSTRAINTS:

C1:Quantity should be maintained in each tank should be between minimum and maximum level.

$$\mathrm{Q_{ij}} - \mathrm{q_{ij}} \le \mathrm{K_{ij}}$$
$$\mathrm{Q_{sj}} - \mathrm{q_{sj}} \le \mathrm{K_{sj}}$$
$$\mathrm{Q_{dj}} - \mathrm{q_{dj}} \le \mathrm{K_{dj}}$$

C2:Quantity at AFS should be maintained at a given level (government norms).

$$\mathrm{A_{d3}} \ge \mathrm{M_{d3}}$$

C3:Quantity of fuel send to AFS must be equal to quantity received

$$\mathrm{E_{s4}} + \mathrm{E_{s1A}} + \mathrm{E_{s2A}} + \mathrm{E_{s3A}} = \mathrm{R_{d3}}$$

C4:Quantity of fuel send to IPN must be equal to quantity received

$$\mathrm{E_{s1B}} + \mathrm{E_{s2B}} + \mathrm{E_{s3B}} = \mathrm{R_{d2}}$$

C5:Quantity of fuel send to Tankers must be equal to quantity received

$$\mathrm{E_{s1A}} + \mathrm{E_{s2A}} + \mathrm{E_{s3A}} = \mathrm{R_{d1}}$$

C6 :Total quantity of fuel send to sink tanks must be equal to their capacity

$$\sum_{\mathrm{j=1}}^{\mathrm{n}}\left(\mathrm{E_{dAj}} + \mathrm{E_{dBj}}\right) = \sum_{\mathrm{j=1}}^{\mathrm{n}}(\mathrm{Q_{dj}} - \mathrm{q_{dj}})$$

C7: Total quantity of fuel send to sales must be equal to the quantity send from intermediate tanks

$$\sum_{\mathrm{i=1}}^{\mathrm{n}}(\mathrm{E_{i1}} + \mathrm{E_{i2}} + \mathrm{E_{i3}}) = \sum_{\mathrm{s=1}}^{\mathrm{n}}(\mathrm{R_{s1}} + \mathrm{R_{s2}} + \mathrm{R_{s3}} + \mathrm{R_{s4}})$$

C8:Total quantity of fuel send to sales tanks must be equal to their capacity

$$\sum_{\mathrm{j=1}}^{\mathrm{n}}\left(\mathrm{E_{sAj}} + \mathrm{E_{sBj}}\right) = \sum_{\mathrm{j=1}}^{\mathrm{n}}(\mathrm{Q_{sj}} - \mathrm{q_{sj}})$$

VI. BASIC SYSTEM DYNAMIC MODEL :

System dynamics is way to understand the functioning of complex systems in a time frame. It deals with internal feedback loops and time delays that affect the behavior of the entire system. The time delay help to model the pipeline optimization problem based on human error. The system dynamic models are created dependent on a framework elements that are made out of four fundamental segments: stocks, streams, converters, and interrelations between them. The estimation of every segment is determined at every delta time (DT) for an estimated time frame characterized in the developed model, starting at the model estimations of the stocks variables, and dependent on the useful relations among each variable parts.

IF-Inflow rate to source (intermediate) tank
IMF-Outflow rate to sales tank
OF-Outflow rate to sink tanks

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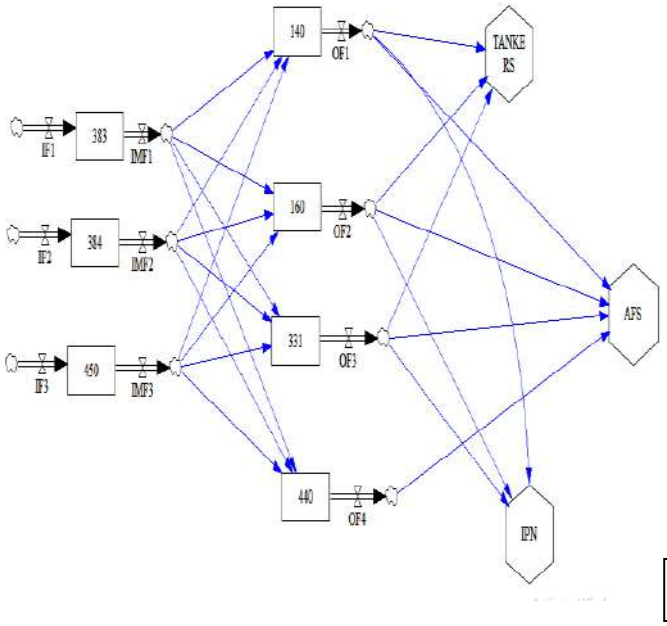
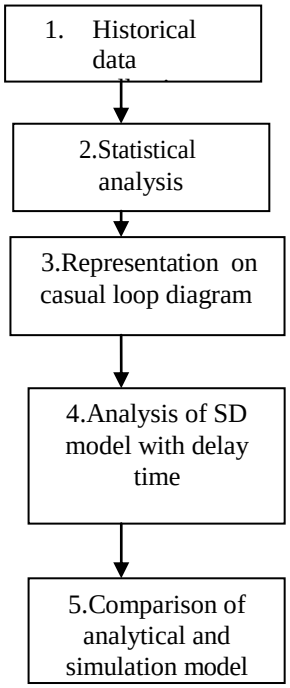


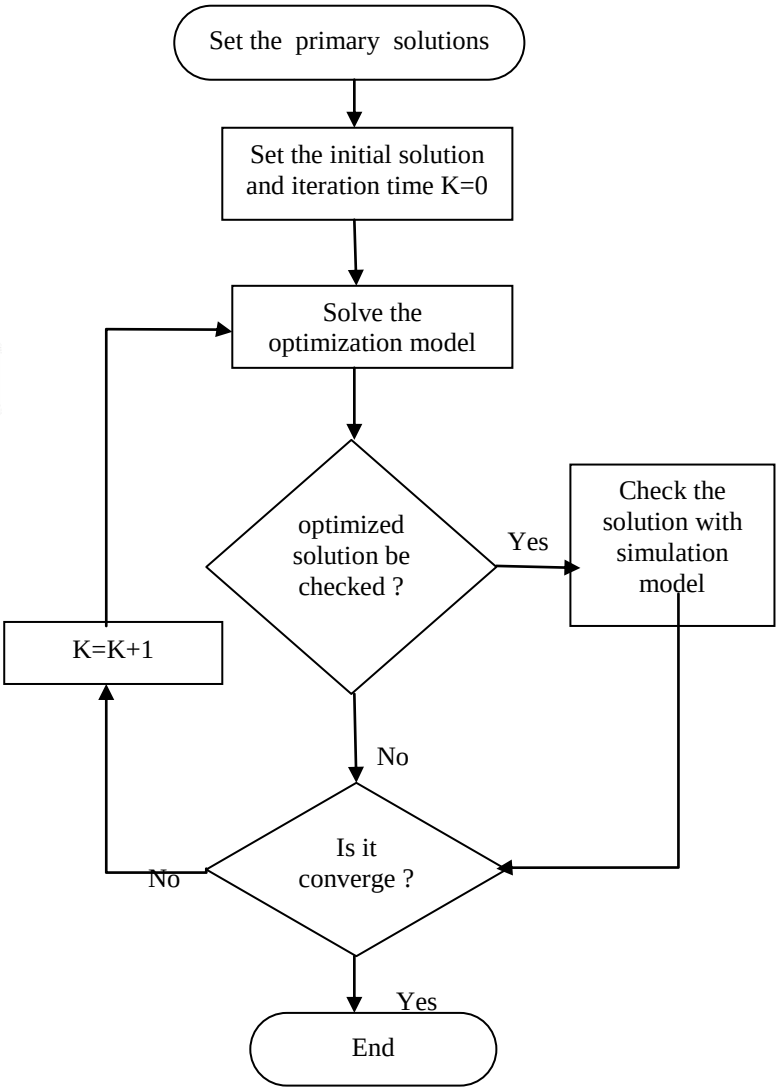
Figure 1:Casual loop diagram of ATF pipeline network

METHODOLOGY :

The methodology adopted for system dynamic modelling analysis :



PROCESS REPRESENTATION OF COMBINING SIMULATION AND ANALYTICAL MODELS :



DATA COLLECTED:

Sl. No	Tank No.	Tank Dia.	Level Min	Level Max	Max. Capacity	Pumpable Quantity
		cm	cm	cm	KL	KL
1	140	2130	200	1140	4069.8	3355.8
2	160	2134	200	1160	4141.2	3427.2
3	331	3230	230	1105	9049.95	7166.25
4	383	2600	260	1030	10475.1	7830.9
5	384	3600	260	1030	10475.1	7830.9
6	440	1101	260	1175	4453.25	3467.85
7	450	1101	260	1175	4453.25	3467.85

Table 1.Tank Details

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VARIABLE TYPE	VARIABLE NAME
STOCK	Supply Rate
	Expansion
	Capital
	Average unit price of fuel
CONVERTER	Daily consumed fuel /section
	Delay time
	Pump Failure
	Human Error

Table 2. Stock and exogenous variables of the ATF supply system

VII. CONCLUSION

The first phase of the work had been completed. Identification of problem and selection of parameters had been done based on the problem faced by despatching section of the refinery. The objective function and constraints are analyzed based on the current defined problem and is mathematically formulated based on the observation.

Formulating mathematical model for better analysis of mass flow rate in the pipeline system, identify suitable algorithms to optimize the mass flow rate of the pipeline storage system and to develop an user friendly interface to reduce human manual calculation is to be done. The system dynamic basic model is developed for the analysis of simulation model. The expected result of the study is to find the optimum mass flow rate of ATF from the sales tank, maximizing revenue and minimizing mixing of different grades of fuel developing a user friendly interface for optimum transportation of ATF to each airport depots and improved quality supply of fuels.

REFERENCE

[1] Pareto-Optimization for Scheduling of Crude Oil Operations in Refinery via Genetic Algorithm (2015). 2168-2216 IEEE transactions on systems, man, and cybernetics: systems

[2] Amdea cruz, Multi-objective optimization of the transport in oil pipeline network.(2013)0-7803-7937+3/03-IEEE

[3] Roger Z Optimization problems in natural gas transportation system :A state of the art review. Applied Energy (2015) 147,536-555..

[4] Adarsh Kumar ,Multi-objective optimization of a gas pipeline network: an ant colony approach. Journal of petroleum exploration and production technology. (2018),8:1389-1400.

[5] Luiz Aizemberg, Formulation for a problem of petroleum transportation. Formulation for a problem of petroleum transportation(2014)-10:3-12.

[6] A Cheboubaa, Optimization of natural gas pipeline transportation using ant colony optimization .Computer and operational research (2019) 36-1916-1923

[7] Suwan Park, A system dynamic computer model to assess the effect of developing an alternate water source on the water supply system management. Procedia Engineering (2015) 119:753-760.

[8] A.Herra'n-Gonza'lez, Modeling and simulation of a gas distribution pipeline network. Applied Mathematical Modelling (2009) 33: 1584-1600.

[9] Maskims (2018) System dynamics model for natural gas infrastructure with storage facility. Energy procedia,549-557.

[10] Palm W J ,System Dynamics ,McGraw-Hill, New York,2005

[11] Xia Wu,(2018)Operation optimization of natural gas transmission pipelines based on stochastic optimization algoritham:A review mathematical problem in engineering volume 18.

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Modeling and experimental investigation of the effect of particle size on biomass gasification

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***Abstract*— Gasification is a process that converts solid or liquid hydrocarbons in to syngas. It proved to be one of the effective alternatives for the management of waste, chemical production and energy production from non-conventional feeds like forest waste, agricultural waste, municipal solid waste(MSW). This conversion process is more complicated than combustion and is influenced by a number of factors including amount of oxygen, feedstock, gasifier temperature, etc. the gasifier reactor need to be designed either based on experimental data or by using a mathematical model of the gasification process in a reactor. In this work we are using ASPEN plus software for modeling a downdraft gasifier. It uses operation blocks, such as reactors, heaters, pumps, etc. These blocks are joined using material and energy streams to create a flow sheet for the process. In this work a downdraft gasifier is modeled using Aspen plus software. Effect of particle size on syngas composition is analysed using the developed model. The result obtained were experimentally validated by a downdraft gasifier test setup. It is found that a decrease in particle size yields more hydrogen production in syngas.**

Keywords—Gasification, Downdraft gasifier, Syngas

I. INTRODUCTION

Every day increase of demand of energy put burden on the government of that country to search for other energy resources. Continuous exploitation of conventional energy resources depleted the reserves of such sources. People are in search of an alternate for their energy sources. One form of such energy source is biomass fuel. The conversion of biomass to syngas through the gasification process could be used as an alternative energy source to fulfill the future energy requirement. In addition, it would help to minimize biomass waste efficiently. It can be seen that in the future, agricultural waste and forestry waste will be the significant contributor to the replacement of fossil fuel. Gasification performance is influenced by many factors including the chemical and physical properties of biomass, gasifier design and operational conditions, such as temperature, equivalence ratio, and gasifying agent, etc. Nowadays, various types of gasifier designs such as updraft, downdraft and fluidized-bed gasifier are used. Among this the downdraft gasifier is the most sustainable for both heat and power generation because of low tar and particulate composition in the produced syngas. Various Studies are conducted on the performance of the gasifier in different operating conditions like temperature, equivalence ratio, air flow, etc to understand the conditions at which the gasifier gives its optimum output. In the present work, air gasification of Coconut shell having different particle size (1-10mm, 20-30mm) is experimentally investigated in a fixed-bed downdraft gasifier. The purpose of this study is to model the gasification process using ASPEN plus software and evaluate the effect of particle size, temperature and airflow on gasification output with reference to syngas composition (CO, CO_2, CH_4, and H_2). The model is validated using a downdraft gasifier test setup.

Juan Manuel de Andres[1] , presented a non-stoichiometric model based on Gibbs free energy minimization. Sensitivity analysis of the model is done by varying the temperature, equivalence ratio(ER) and steam to biomass ratio (SBR). Air as gasification agent increases the temperature, and increases H_2 and CO content of syngas. At 800^0C equivalence ratio is varied between 0.2 and 0.4, as ER increase both gas production and carbon conversion also increases. In paper [2] contains micro algal gasification model based on Gibbs free energy minimization. Temperature and Equivalence ratio are varied between 600^0C -1000^0C and 0.1 - 0.4. Increase in temperature favors the H_2 and CO yields CH_4 produced at maximum rate at low temperature. The highest H_2 was obtained at 660^0C, CH_4 obtained at 600^0C. The CO_2 yield increases with increase in ER. Rajul Nayak [3] modeled a fluidized bed gasifier in ASPEN plus. The effect of various parameters like steam to coal ratio and oxygen flow rate on product gas composition were studied. The compositions of H_2 decreases with very small deviation in oxygen flow rate. As Steam to coal ratio

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increases, a decreasing trend in all components of the producer gas is observed. Wenjun Duan[4] studied two parameters, temperature and steam to coal ratio (S/C) and their impacts on the coal integrated gasification combined blast furnace slag waste heat recovery system . As temperature increases the syngas product efficiency also increases but after some temperature (900^0C) it will be constant. When S/C ratio increase, syngas product efficiency and carbon gasification efficiency also increases. Ingrid Lopes Motta[5] compared Circulating Fluidized Bed(CFB) and Bubbling Fluidized Bed(BFB) gasifiers with different operating parameters, sugar cane bagasse as feed stock. Only steam as oxidizer gives high H_2 yield in CFB gasifier Pressure and H_2 concentration has an inverse relationship. As moisture content (MC) and steam to biomass ratio (SBR) increases, H_2 content of syngas also increase. Temperature, SBR, Moisture content are the parameters that lead to higher H_2 generation. Mehrdokht.B Nikoo[6] Narendra Sadhwani[7] A comprehensive process model is developed for biomass gasification in an atmospheric fluidized bed gasifier using the ASPEN plus simulator. When temperature increase H_2 concentration and enhances carbon conversion efficiency. ER is directly proportional to CO_2 production carbon conversion efficiency. S. Rupesh[8] studied the effect of temperature on product gas composition with and without CaO sorbent. In both cases H_2 concentration is found to increase to a maximum and then decreases with increase in temperature. Up to a sorbent/ biomass ratio of unity CO_2 is found to decrease due to enhanced carbonation reaction. Fenxia Huang [9] presented a pine wood down draft gasifier (DDG) in aspen plus and analysed the effect of particle size on syngas composition. Highest concentration is for CO_2 (52.83%) and which is given by 80 mesh size. As temperature increase, H_2/CO Ratio increases. [10] developed a model of DDG and gasification process was considered to consist of three stages; drying, pyrolysis gasification. Increase in temperature promotes the formation of a produced gas with high H_2 and CO concentration, higher Lower Heating Value (LHV). When SBR increase, Lower Heating Value decreases. Gasification efficiency increases with increase in temperature. SBR to a maximum value and then decreases due to energy addition in the form of steam. Sharmina Rasul [11] developed an integrated fixed bed gasifier model for four different biomass feedstocks, namely MSW, green wastes, wood wastes and coffee bean husks. The effects of air-fuel ratio and gasifier temperature on gasification performance is studied, and compared to identify the most suitable operating conditions with MSWs, green wastes, coffee bean husks and wood wastes. The following results were identified: gasifier temperature of 650^0C and air-fuel ratio of 0.3 is a good combination of operating conditions for all four feedstocks.

II. MODELING OF DOWNDRAFT GASIFIER

The modeling of downdraft fixed bed gasifier is done in ASPEN plus software. ASPEN plus is a chemical process optimization software, which was developed by Massachusetts Institute of Technology (MIT). It uses unit operation blocks, such as reactors, heaters, pumps, filters, scrubbers, etc. These blocks are joined using either material or energy streams to create a flow sheet for the process. The simulation calculations are performed using the built in physical properties database. The program uses a sequential modular (SM) approach, i.e. solves the process scheme module by module, calculating the outlet stream properties using the inlet stream properties for each block. This simulation package has been used for modeling a coal biomass power generation systems in many research projects[8]. Nonconventional fuels, e.g. biomass, municipal solid waste (MSW) and specific coals can be used by ASPEN plus by incorporating a user defined Fortran code. The following assumptions were considered in modeling the gasification process:

- Process is steady state and isothermal
- Biomass devolatilization takes place instantaneously and volatile products mainly consist of H_2, CO, CO_2, CH_4
- Particles are spherical and of uniform size
- Char only contains carbon and ash
- Process is taking place at atmospheric pressure
- Pressure drop in the gasifier is neglected
- 20% carbon is considered as unconverted

The proposed model of biomass downdraft gasifier developed in ASPEN plus software is shown Fig. 1 The developed model consist of various components/ blocks which represents the gasification operation in ASPEN plus. The current model consist of various reactors like RYIELD, GIBBS, separator, mixer, cyclones, scrubber, chiller, etc. the types of blocks used depends on the types of gasifier arrangements. The biomass resting in the respective zone and partially meets the energy requirement of pyrolysis and drying. The heat Generated in the combustion zone is utilized by reduction, pyrolysis and drying zones. The producer gas leaving from top of the gasifier is accompanied by a high amount of tar and moisture. The TABLE I given below describes the function of each components in the model.

III. EXPERIMENTAL ARRANGEMENT

The experiment is done in fixed bed downdraft gasifier. Fixed-bed gasifiers are the oldest and most common reactors employed to synthesize syngas. Large-scale (higher than 10 MW) fixed-bed gasifiers are losing the interests of industrial units due to scale-up issues[10]. However, small-scale (lower than 10 MW) fixed-bed gasifiers with high thermal efficiency are in use for decentralized power generation and for thermal applications in many industries. Depending upon the direction and entry of airflow, the gasifiers are classified as updraft and downdraft. In an updraft gasifier, the biomass is fed from top of the gasifier, while air is supplied at the bottom of the gasifier. At the top of the gasifier, the fed biomass gets dried and it passes through the pyrolysis zone, where the feed is decomposed to volatiles, tar and char. Volatile-free biomass moves downward towards the combustion zone and released volatile combine with the gas stream leaving the reduction zone located above the combustion zone. In the combustion zone, the biomass gets oxidized and flue gases are produced.

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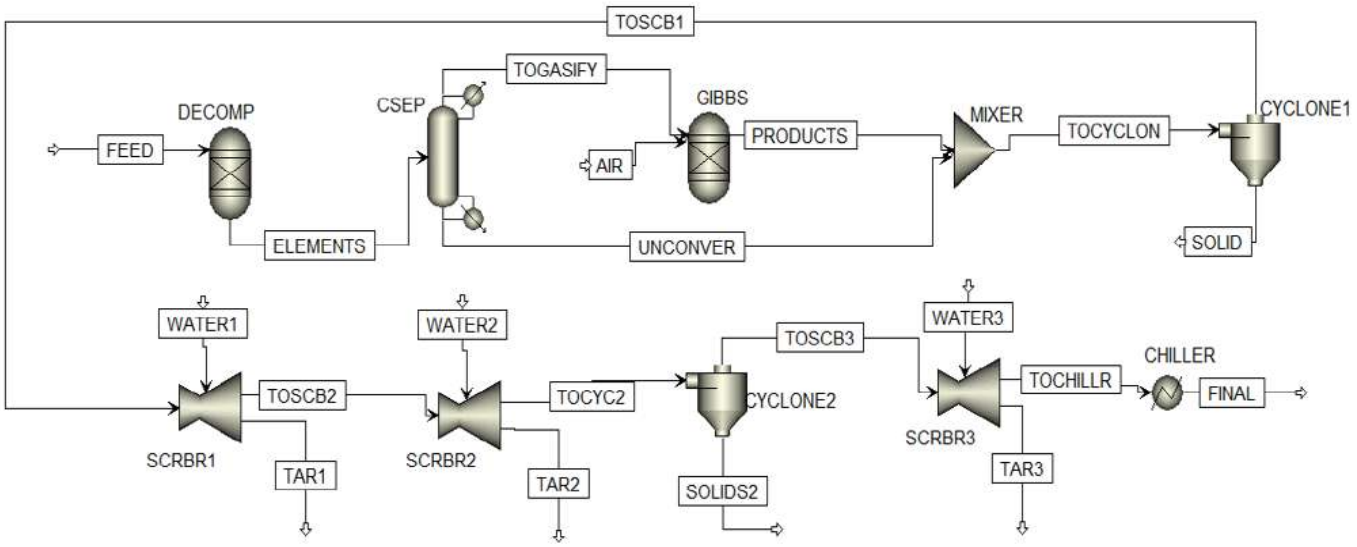

Fig. 1 ASPEN Plus Model of Downdraft gasifier

TABLE I MODEL COMPONENTS

SI NO.	ASPEN plus NAME	BLOCK ID	DESCRIPTION
1	RYIELD	DECOMP	Yield reactor converts the non-conventional stream 'FEED' into conventional components
2	CSEP	CSEP	Separator-extracts a portion of the carbon contained in the feed so that it remains unreacted
3	RGIBBS	RGIBBS	Gibbs free energy reactor simulates gasification
4	MIXER	MIXER	Mixer-mixes the unreacted carbon with syngas
5	CYCLONE	CYCLONE	Separator separates the ungasified solids from gases
6	SCRUBBER	SCBR	Sprinkling the water over syngas to remove solid particles
7	COOLER	COOLER	Cooler simulates gas cooling to normal temperature

It passes through the reduction zone containing charcoal, produced by pyrolysis of the biomass, and gets converted into producer gas. The producer gas leaving the reduction zone passes through the pyrolysis and subsequently the drying zone. It provides its sensible heat to the biomass resting in the respective zone and partially meets the energy requirement of pyrolysis and drying. The heat generated in the combustion zone is utilized by reduction, pyrolysis and drying zones. The producer gas leaving from top of the gasifier is accompanied by a high amount of tar and moisture.

A. BIOMASS PREPARATION

Coconut shell used as biomass feedstock because of its availability and good heating characteristics. 50kg of coconut shell was brought from a local coconut oil mill near puthiyatheru, Kannur, kerala. Coconut shell are dried in sunlight for one week and in shades for one week then it is crushed. Manually crushed the coconut shell with hammer in to different particle sizes. Particle sizes are grouped in to 2 categories 0-10 mm, 11-20mm, 21-30mm as shown in Fig. 2. Sieved the particle to group them in the above category. For sieving crushed coconut shell, SI standard sieve from civil Engineering Material Testing lab is used.

Fig.2 Sieved CS with different sizes

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Fig. 3 Experimental setup

B. EXPERIMENTAL SETUP

Fig. 3 shows the experimental setup consisting of a Betel Biomass downdraft gasifier manufactured by Bioresidue Energy Technology Private Limited with technology back up with portable infrared syngas analyzer made by Hubei Cubic-Ruiyi Ltd. The procedure of the experiment is as follows, first of all switch on the main switch of the gasifier, chiller and water circulation tap. Then feed the biomass in to the gasifier. Fire the gasifier when the chiller temperature reaches at 8 – 9^0C. Switch on the blower and after 20 minutes fire the gas at the exhaust pipe. The output of downdraft gasifier which is syngas is given as input to the portable infrared syngas analyzer. The portable infrared syngas analyzer is connected to a computer system which continuously monitor and record the syngas composition in given interval of time. The syngas Analyzer shows the volume percentage of each components, such as H_2, CO, CO_2, CH_4, N_2, O_2 and lower heating value. The results can be exported in to excel sheet for further purposes.

IV. RESULTS & VALIDATION

A. SENSITIVITY ANALYSE

The sensitivity analysis was performed to the all investigated parameters include temperature and Equivalence ratio(ER) in terms of air flow value. In this analysis, gasification temperature and ER value were studied. For gasification temperature study, the values were varied from 400°C to 1200°C in the GIBBS BLOCK (Fig. 1) while the other parameters remained unchanged at 0.25 ER value and 4 kg/hr biomass loading. The gases formed from the process were Hydrogen (H_2), Carbon monoxide (CO), Carbon dioxide (CO_2), Methane (CH_4), Ammonia (NH_3), Water (H_2O), and Sulphur dioxide (SO_2). However, only four gases (H_2, CO, CO_2, and CH_4) were considered during the simulation process.

VARIATION OF OUTPUT GASES WITH VARYING AIR FLOW RATE

From the Fig. 4 it can be seen that, the yields of H_2, CO, CO_2, and CH_4 were quantified to decrease with increase in air flow values. This phenomenon occurred due to the increase in oxygen supply that favored the CO_2 production, thus affecting the efficiency of the gasification. An efficient gasification produce more CO than CO_2 (Nikoo and Mahinpey 2008). The ER value must be kept as low as possible but must be high enough to ensure complete combustion of char. Another graph air flow Vs calorific value is plotted. It can be seen that, the calorific value decreases with increase in air flow (Fig. 5)

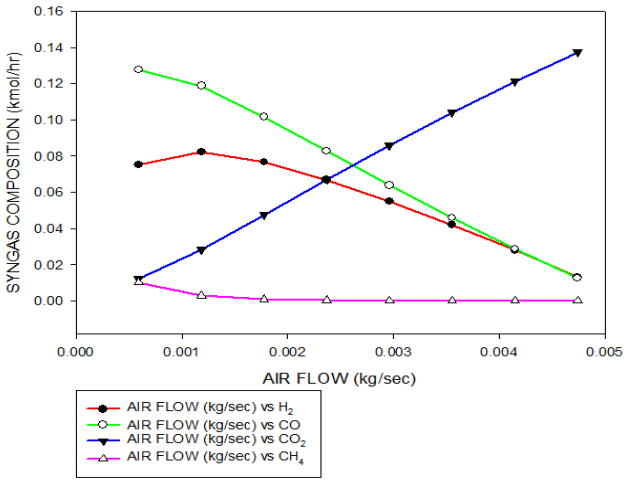

Fig. 4 Air flow Vs Syngas composition

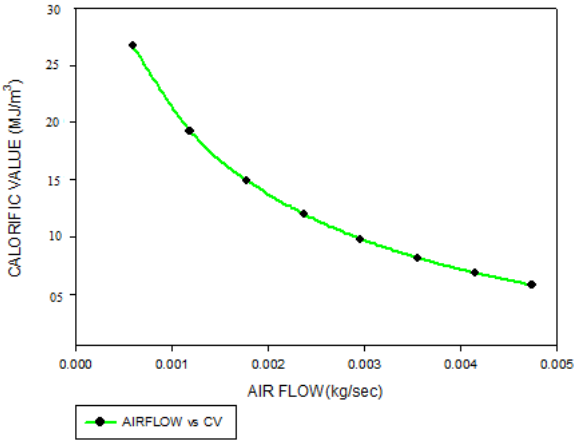

Fig. 5 Air flow Vs Calorific value

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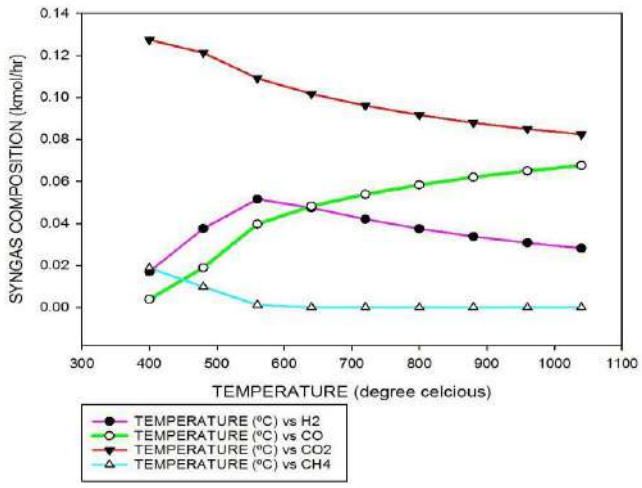

Fig. 6 Temperature Vs Syngas composition

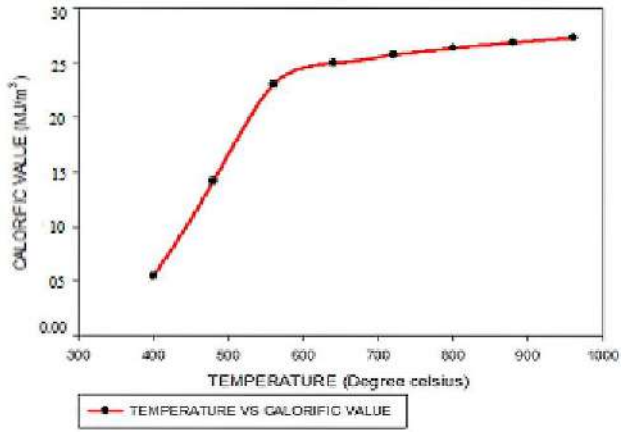

Fig. 7 Temperature Vs Calorific value

TABLE II PERCENTAGE ERROR (1-10mm particle)

SI NO.	COMPONENTS	EXPERIMENTAL VALUES Vol%	MODEL VALUES Vol%	% ERROR
1	H_2	11.23	9.98	12.52
2	CO	25.7	28.96	-11.25
3	CO_2	9.14	8.89	14.06
4	CH_4	2.46	1.97	24.24
5	N_2	50.18	49.12	-2.79
6	O_2	1.29	1.08	-16.27

TABLE III PERCENTAGE ERROR (11-20mm particle)

SI NO.	COMPONENTS	EXPERIMENTAL VALUES Vol%	MODEL VALUES Vol%	% ERROR
1	H_2	10.19	9.21	-9.61
2	CO	22.32	24.36	9.13
3	CO_2	9.21	10.45	11.29
4	CH_4	2.29	2.62	14.41
5	N_2	54.82	52.07	-5.01
6	O_2	1.17	1.29	10.25

VARIATION OF OUTPUT GASES WITH VARYING TEMPERATURE

Temperature is one of the significant parameters that affect the syngas compositions. The H_2 production was low at lower temperature due to the tar formation and unburned carbon (Nikoo and Mahinpey 2008). Low yield of gases was also attributed to the water-gas shift reaction. This lower yield achieved at higher temperature can be explained by the Bouduard reaction where the process converts the carbon into CO at high temperature. Consequently, the CO_2 yield was decreased at higher temperature due to the water-gas shift reaction, favoring the H_2 and CO production. The reduction of CH_4 yield was also observed as the temperature increased. The reverse methanation reaction occurs at higher temperature which converts CH_4 into H_2. It can be seen from the Fig. 7 as the temperature increases the Calorific value also increase.

B. MODEL RESULT

Modeling of a downdraft gasifier is done in ASPEN plus software. Modeling result shows that H_2 and CO content of the

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TABLE IV PERCENTAGE ERROR (21-30mm particle)

SI NO.	COMPONENTS	EXPERIMENTAL VALUES Vol%	MODEL VALUES Vol%	% ERROR
1	H_2	7.68	8.97	-14.38
2	CO	18.56	15.23	21.86
3	CO_2	9.32	12.65	-18.41
4	CH_4	2.18	2.72	24.77
5	N_2	61.18	59.13	-3.18
6	O_2	1.08	1.3	20.37

syngas is higher in small particle size (1-10mm) than that of other two particle sizes.

C. EXPERIMENTAL RESULT

Experiment is carried out in a downdraft gasifier with different particle sizes (1-10mm, 11-20mm, 21-30mm) From the experimental results it can be seen that, the trend of composition of syngas like, H2 and CO is same as in case of model result. The ASPEN plus model result is validated with the experimental result of the downdraft gasifier. By comparing the model and the experimental results it can be seen that there is a slight difference between the model and the experimental results. This may be due to the various assumption given during modeling the gasifier in ASPEN plus software.

V. CONCLUSION

Model of downdraft gasifier were developed in Aspen Plus software. The simulation data were in good agreement with the experimental data but there is some error between model and experimental result. . Increase in temperature of gasification favors CO and H_2 production as due to water gas shift and reverse methanation reaction. CH_4 was produced at maximum rate at low temperature due to unburned carbon and formation of tar. As the temperature increases, these carbon and tar were burned to form syngas. From experiments it is clear that particle size and syngas composition are related as presented in some other papers. Minimum particle size gives higher H_2 content in syngas, so in order to produce syngas with high H_2 content we need to crush the feedstock in to small pieces. From the experiment it can be seen that air flow promotes CO_2 formation rather than H_2 and CO. However, there are some deviations in the predicted data from the simulation. This deviation might be resulted from different experimental and model parameters, where the experimental parameter temperature and pressure are was kept constant in the simulation.

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REFERENCES

[1] J. M. De Andres, M. Vedrenne, and M. Brambilla, “Modeling and model ´ performance evaluation of sewage sludge gasification in fluidized-bed gasifiers using Aspen Plus,” vol. 2247, 2018.

[2] M. S. N. Atikah and R. Harun, “Simulation and Optimization of Chlorella vulgaris Gasification Using Aspen Plus,” 2019.

[3] R. Nayak and R. K. Mewada, “Simulation of Coal Gasification Process using ASPEN PLUS,” pp. 8–10, 2011.

[4] W. Duan et al., “ASPEN Plus simulation of coal integrated gasification combined blast furnace slag waste heat recovery system,” ENERGY Convers. Manag, vol. 100, pp. 30–36, 2015.

[5] L. Motta, N. T. Miranda, R. M. Filho, M. Regina, and W. Maciel, “Biomass and Bioenergy Sugarcane bagasse gasification: Simulation and analysis of different operating parameters, fluidizing media, and gasifier types,” vol. 122, no. January, pp. 433–445, 2019.

[6] M. B. Nikoo and N. Mahinpey, “Simulation of biomass gasification in fluidized bed reactor using ASPEN PLUS,” vol. 32, pp. 1245–1254, 2008.

[7] N. Sadhwani, P. Li, M. R. Eden, and S. Adhikari, Process Modeling of Fluidized Bed Biomass-CO_2 Gasification using ASPEN Plus, vol. 40. Elsevier Masson SAS, 2017.

[8] S. Rupesh, C. Muraleedharan, and P. Arun, “ASPEN plus modelling of air – steam gasification of biomass with sorbent enabled CO_2 capture,” Resour. Technol., vol. 2, no. 2, pp. 94–103, 2016.

[9] “Investigation of biomass (pine wood) gasification: Experiments and Aspen Plus simulation,” no. October 2018, pp. 1178–1187, 2019.

[10] R. Tavares, E. Monteiro, F. Tabet, and A. Rouboa, “Numerical investigation of optimum operating conditions for syngas and hydrogen production from biomass gasi fi cation using Aspen Plus,” Renew. Energy, vol. 146, pp. 1309–1314, 2020.

[11] S. Begum, M. G. Rasul, D. Akbar, and N. Ramzan, “Performance analysis of an integrated fixed bed gasifier model for different biomass feedstocks,” Energies, vol. 6, no. 12, pp. 6508–6524, 2013.

Numerical analysis on the vibrational characteristics of flexible tubes conveying fluids using two way fluid structure interaction.

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Abstract

Many complex mechanical engineering problems depend on numerical methods to get accurate results for analysis. Fluid-structure interaction is one such problem which results in the vibration of the structure due to the momentum transfer between the fluid and structure. Fluid-structure interaction problem can be solved using both coupled as well as uncoupled numerical techniques. The coupled technique is considered as a better option over uncoupled technique as it enables the simultaneous data transfer between the structure and fluid that result in a precise solution. The present study focuses on the fluid structure interaction due to the fluid flow inside a pre-stretched silicone tube, using coupled technique. ANSYS 18 software is used for investigating the problem by solving equations from different modules simultaneously. Two-way fluid-structure interaction coupling technique enables the parametric design of the ANSYS transient structural and ANSYS fluent separately and then combines the setup information using system coupling feature. The geometric features of the ANSYS static and ANSYS transient structural module are coupled together to obtain the pre-stretch conditions of silicone rubber tube. The energy transfer is visible in the form of local deformation of the silicone rubber tube or flow-induced vibration of the entire tube system. The numerical analysis is used to simulate the pressure variation along the silicone tube by coupling the solution file of transient structural with the results of the fluent part. The total deformation of the tube along the fluid flow is also presented. The natural frequency found out by coupling the data with ANSYS modal gives the values corresponding to 10% and 15 % pre-stretched conditions respectively of the tube and are compared with the experimental values for the above mentioned pre-stretched conditions.

Introduction

Fluid structure interaction is the term used to define the interaction between a solid structure and fluid flow. Fluid structure interaction has applications in many fields like marine engineering, underground water, oil or fluid conveying piping systems, internal fluid carrying applications in medical field such as blood transfusion device, tubes used to convey hot fluids in steam generator and the pipelines used to distribute fuel in rocket propelling engine. Depending on the complexity of the fluid structure interaction, different techniques can be employed. Simple fluid structure interaction problems involving rigid body motion such as an impeller rotating in a mixing tank can be solved completely using ANSYS CFD module. As the complexity increases one way fluid structure interaction technique can be used to solve the simulation involving the transfer of data from CFD module to structural and simulates the structural deformation. One way FSI technique solves the fluid and solid part one by one and the solution is obtained by using traditional solvers. The main drawback is the difficulty in the implementation of the bidirectional interaction between fluid part and solid structure. Two way fluid structure interaction technique is used to overcome this difficulty through a unified approach by formulating both fluid and solid equations together and solved synchronously with effective transfer of information from one module to another and vice versa.

The study on the flexible tube can be dated back to 1808 in which Young [2] conducted experiments using rubber hoses, flexible tubes and conducted experimental tests on flexible tube conveying incompressible fluid and obtained a relation to find propagation velocity of the pressure wave. Findings from this paper were mismatching with that of the experimental data because of the inability to formulate the coupling equation explicitly. But later in 1878 the work was rediscovered and analyzed properly by Korteweg et al. [3]. Reuderink et al. [4] formulated a method to identify the effect of pressure variation along the flow through the tube. The energy interaction between the tube surface and fluid is considered and accommodated the nonlinearity emerged in the flexible tube and compared with the experimental data. The linearity of mass and momentum conservation formula is found to be varying and nonlinearity is showing significant influence. Womersley et al. [5] did experiments using flexible tube conveying fluid and found out that viscous stress is directly proportional to the local strain rate. Experiments were conducted using tubes individually and tubes which were bundled together with axial binding force. Atabek et al. [6] did investigations analytically to analyze the fluid flow through a flexible tube and found that the fluid-structure interaction leads to the dilation of the tube at starting end and it leads to elastic deformation of the tube in repeated cycles. The obtained result was incorporated in the study of blood flow

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through arteries and was found out that the pulsatile flow-induced due to the pumping of blood from heart affect the flow through those arteries whose length is not long enough to damp out the pressure pulsation. This study inferred that the pressure wave propagation pattern can be analyzed at the inlet of the tube. Atabek et al. [7] worked on the theory proposed by Womersley [5] and considered flexible tubes of thin thickness in which the effect of flow is analyzed in both axial and radial direction. The existence of waves in two different planes was independently interpreted from Womersley [5] theory even though he did not highlight the inference himself. Governing equation for frequency was formulated by using momentum and continuity equation. The solution of these equations will give the value for velocity along two directions. The experimental setup was designed in such a way that a flexible pre-stretched tube conveying fluid with high viscosity to understand the flow characteristics of blood in blood vessels. The flexible tubes used for the experiment is having a very low thickness and is homogenous and isotropic. The wave propagation pattern is analyzed to reach at an inference that the propagating pressure waves are having wavelengths larger than the tube diameter. .

Though the development of preliminary governing equations and basic theories related to fluid-structure interaction were started from the early 1970's, the advanced analysis of fluid-structure interactions were possible only after the involvement of computer systems which could solve the governing equations within a short span of time. The development of simulation software which involves development and usage of user-defined functions paved the way to a new dimension in the analysis of fluid-structure interaction. For the analysis and modelling of pulsatile flow in stenotic arteries Bathe and Kamm [8] used the technique of coupling iteration using the prescribed value of time step and the obtained data were compared and validated with an existing analytical model and experimentally obtained data. The numerical analysis using two way fluid structure interaction has a major role in validating the experimental data because of its effectiveness in solving different set of equations together precisely and consuming lesser time than analytical method. Bak et al. [9] conducted investigations for the non-linear analysis of thin fabric made simple-shaped sail. Bak et al.[10] have conducted the fluid-structure interaction analysis by employing a partial two-way FSI method to calculate the 3-dimensional deformation of the main sail shape without the mast. The obtained results were comprising changes in the effective angle of attack, 3-dimensional flow separation, and stall. The study releved that it has the ability to change the thrust performance of a yacht according to changes in the lift and drag forces. Bak and Yoo [11] investigated the changes in lift and drag forces before and after deformation of the sail and rig for a sloop yacht with a masthead type rig. The shrouds and stays were not modeled with the fixed boundary conditions on each connecting points, so that the deformation of the rig simulated was not precise. Similar to these studies, Trimarchi et al. [12] used the Boundary Element Method to calculate the surrounding flow and the Finite Element Method (FEM) to calculate deformation of the sail without considering the mast and rig. The above literature review revealed that the numerical analysis of flexible tubes conveying fluid under pre-stretched condition has not yet been done. So this study employs the two way FSI technique using ANSYS 18 for the numerical analysis of the vibrational characteristics of pre-stretched silicone rubber tube conveying fluids.

Theory

Two way fluid structure interaction is a Multiphysics technique available in ANSYS 18 to simulate the interaction between the structure and fluid and vice versa. The stability of the structure can be get compromised because of the vibrations induced due to fluid structure interaction. ANSYS 18 is used to simulate the phenomenon of fluid structure interaction in order to ensure the safety and reliability of the system. Two way fluid structure interaction technique can be used for the analysis of complex problems. System coupling technique in ANSYS is used to solve both fluid and structural part simultaneously and the exchange of information happens in each step in to and fro direction. This method is used for the vibrational analysis of pre-stretched silicone rubber tube conveying fluid. The fully coupled fluid-structure interface to obtain the pressure variation along the tube surface, total deformation and the natural frequencies of the tube is shown in figure 1. The different ANSYS module involved in the two way FSI here are the static structural, transient structural, fluent and modal which are coupled using system coupling. The modal module is used to obtain the natural frequencies.

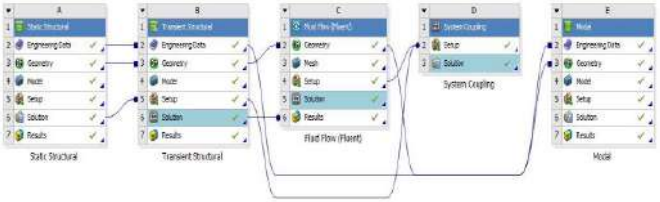

Figure 1- Two-way FSI coupled interface

Results and discussions

Two-way fluid-structure interaction technique is used in order to accommodate the effect of fluid pressure on the internal surface of the tube and the dilation effect of the tube on the fluid by coupling both ANSYS transient structural module and ANSYS fluent module by using system coupling.

The first step is the development of the pre-stretched condition using ANSYS static structure module by applying a force of 10 N and 14.5 N on one end of the tube while the other end held fixed and the data is coupled with transient structural module as shown in figure 1. The above mentioned values for force is selected by analyzing force-displacement curve corresponding to 10% and 15% pre-stretch. A pre-stretch of 2.5 cm and 3.75 cm is accommodated corresponding to 10% and 15% conditions respectively. The pre-stretch values 10% and 15% is selected in order to compare and validate the results obtained with experimental values[1]. In the next step selection of required modules in ANSYS

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workbench is done and then coupling is done between geometries in both transient structural and ANSYS fluent. The setup files from both transient and fluent is coupled using system coupling module. The further work in numerical analysis involves the selection of appropriate values for engineering data such as density of the flexible tube, young's modulus and poisons ratio. The material and geometric properties for static, transient and fluent part is assigned using the modelling and setup cells of the respective modules. Engineering data used for the design of silicone rubber tube is given in table 1. The experimental results for the silicone tube conveying fluid is obtained from [1].

Table 1- Engineering data for silicone rubber tube

PROPERTY	VALUE
Length	250 mm
Diameter	9 mm
Thickness	1.5 mm
Density	1150 kg/m^3
Young's modulus	30 MPa
Poison's ratio	0.47

The geometry of the silicone rubber tube is designed in such a way that the interaction between the fluid pressure and tube deformation at the fluid-tube interface and vice versa can be simulated precisely. The tube structure is designed as three separate elements such as line element, external tube surface and internal fluid element.

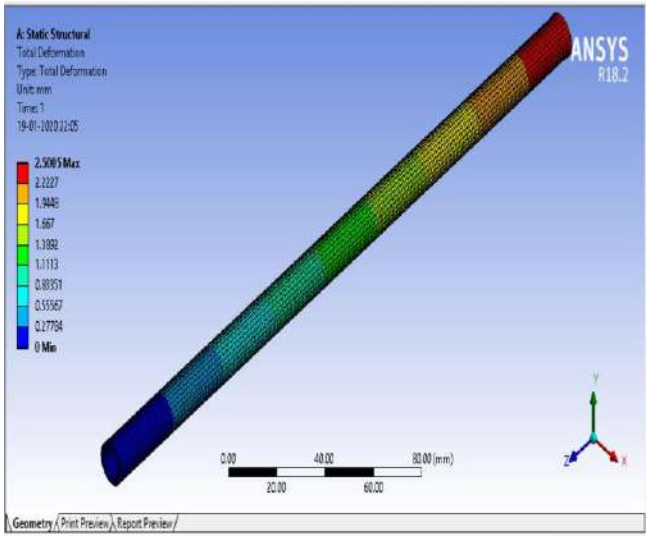

Figure 2- 10% pre-stretched silicone rubber tube

In the transient structural interface, the model cell is updated by keeping the line element and interior water element suppressed. The tube surface element is updated with a wall thickness of 1.5 mm. Both ends of the tube are fixed and the tube surface is made fluid interaction solid. Then the entire body has meshed finely with an element size of 1 mm.

In the next stage, we are dealing with the ANSYS fluent module. The line and the surface elements are being suppressed and the interior liquid element is made active and the liquid element is incorporated with a fine meshing of 1 mm. The element is incorporated with the inflation feature in which the scoping method is geometry selection and the side face selected with the corresponding circumferential edge as the limiting zone. In the inflation feature, the total thickness is specified with a number of layers 9, growth rate 1.2 and a maximum thickness of 2.5 mm. The algorithm used to incorporate inflation feature is pre-programmed in ANSYS. One of the two end faces is selected as velocity inlet profile and the other as pressure outlet face. The curved surface area is selected as the deforming wall and the entire body is made as a water element. The fluent body quality is checked and made sure the mesh quality is good enough to proceed with the analysis. The solver type is based on absolute velocity and transient time condition.

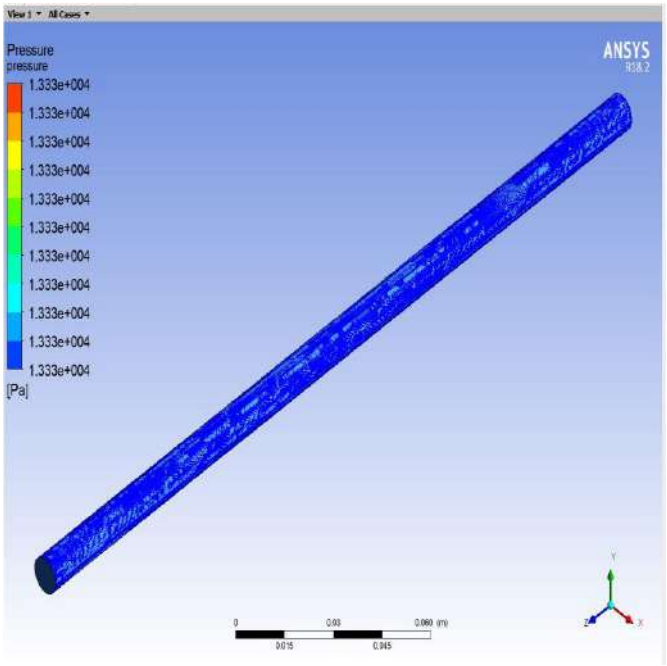

Figure 3 - Pressure variation along the tube surface

The minimum and maximum value of pressure is 12999.2 Pa and 13330 Pa. Therefore there is no significant variation observed in Figure 3.The material section under the solution setup tree is made active and fluent database is used to create the interior water element along with that material properties of water element such as density, shear viscosity etc. are selected. The cell zone condition for the interior fluid flow is updated as water-liquid from fluent database. The interior fluid flow element is loaded with user-defined function to control the flow velocity. The user-defined function written in C-language is used to give velocity boundary condition to the interior fluid flow. The system coupling module is now been updated with the data blocks in ANSYS transient and ANSYS fluent. The analysis settings in setup cell is updated with pre-programmed coupling initialization. The details of parameters assigned during the calculation and initialization step is shown in table 2.

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Table 2- Parameters used in calculation and initialization procedure

Number of time steps	100
Time step size	0.01 sec
Maximum number of iteration	5
Reporting time interval	1 sec
End time	1 sec

Then the data transfer components for both the fluid-solid interface and deforming wall is created. The fluid-solid interface data transfer is done by selecting transient structural as source with incremental displacement and the target component is fluid flow (fluent) with displacement selected as variable for the deforming wall. The second data transfer is formulated by providing source as fluid flow and target as transient structural in order to obtain the fluid-structure interaction coupling correctly. After setting all the data required to couple both transient structural and fluent component, the convergence is tested with the system coupling solution cell. Once the convergence is attained, the solution cell of the transient structural component is coupled with the result of the fluent module. The results of the fluent element are again analyzed using CFD-post tool to obtain the pressure variation across the tube surface by inter linking wall deformation and the family component consisted of velocity inlet, pressure outlet and deforming wall. Further, the total deformation of the tube is obtained using transient structural and is shown in figure 4.

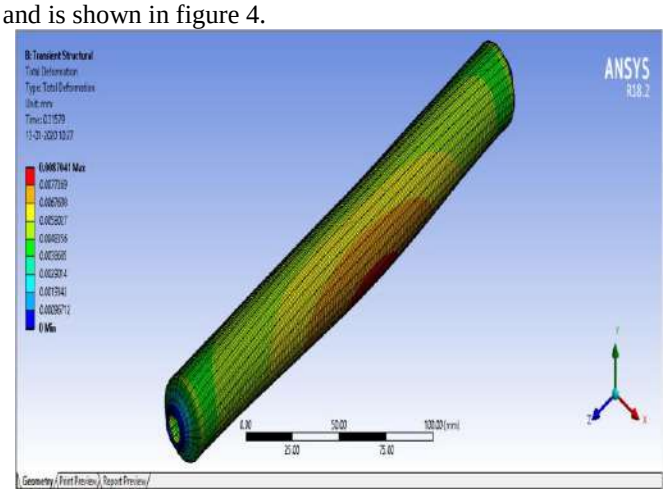

Figure 4- Total deformation of the silicone rubber tube

The obtained details are being coupled with the modal analysis module to obtain the natural frequencies of the tube conveying fluid. The result shows a first mode frequency of 24.342 Hz and 26.161 Hz for 10% and 15% pre-stretched conditions respectively. The first six frequencies are free-free condition frequencies and are neglected. The results obtained by using two-way fluid-structure interaction is validated by comparing with the experimental results [1]. The natural frequencies obtained experimentally for 10% and 15% pre-stretch are 24 Hz and 25.7 Hz for the first mode. The comparison of results obtained using two-way fluid-structure interaction coupling technique and experimental setup is given in table 3.

Table 3 - Numerical and experimental natural frequency of silicone tube.

SI No	Natural frequency (Hz)			Percentage variation in frequency (%)
	Pre-stretch	Two way FSI	Experimental	
1	10%	24.342	24	1.42
2	15%	26.161	25.7	1.76

The variation in natural frequencies may be due to the variation in boundary conditions of the tube in the experimental setup. The percentage variation of results obtained using numerical simulation and experimental setup is shown in table 3. The pre-stretching of the tube involves a major role in deciding the natural frequency of the tube as it reduces the sagging effect and natural frequency is being increased. The mode shape for the first fundamental frequency that is simple bending is shown in figure 5.

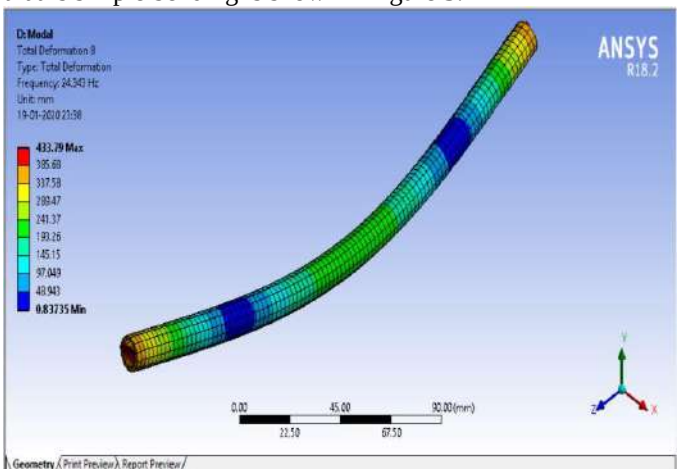

Figure 5- First mode shape of the silicone tube

Conclusions

The two-way fluid-structure interaction coupling technique simulates the interaction between the fluid flow and the tube surface and vice versa by means of momentum transfer. The pressure variation along the tube surface shows the change in energy interaction throughout the length of the tube. The deformation diagram indicates the correctness of the coupling technique as it shows the expansion and contraction of the silicone tube due to the fluid flow. The natural frequencies corresponding to 10% and 15% pre-stretched condition obtained using numerical technique is validated with the experimental results [1]. The variation of the experimental values of natural frequency with numerical values may be due to the variations in the boundary conditions of the

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experimental setup. The effect of pre-stretch will reduce the effect of sagging in the tube, which results in the increase of natural frequency. The further numerical analysis will be done in future with the pre-stretched condition for different lengths and thickness in order to find the optimum tube dimension for different applications.

Acknowledgement

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References

[1].R.Kamal Krishna, M.R. Mahesh, Madhusudanan Unnikrishnan, Jayaraj Kochupillai, Effect of sagging on dynamic characteristics of silicone tube conveying fluid, Journal of the institution of engineers(India) Series C, Online first, 2020.

[2].Young .T (1808). “Hydraulic investigations, subservient to an intended Croonian lecture on the motion of the blood.” Philosophical transactions of the royal society of London 98, 164-186. Also in (1809) Nicholson's journal 22, 104-124.

[3].A. Isebree Moens and D.J. Korteweg: on the speed of propagation of waves in elastic tubes A S Tijsseling department of mathematics and computer science, Eindhoven university of technology, the Netherlands, andanderson school of mechanical and systems engineering the university of Newcastle, United Kingdom.

[4].P. J. Reuderink, H. W. Hoodstraten, P. Sepkema, B. Hillen, N. Westerhof, Linear and non-linear one-dimensional models pf pulse wave transmission at high Wormersly numbers,journals of biomechanics,1989.

[5].J. R. Womersley oscillatory flow in arteries: the constrained elastic tube as a model of arterial flow and pulse transmission aeronautical research laboratory, wright air development centre, dayton, oluo, u.s.a,1957.

[6].R. Chieh, C. Chang and H. B Clent, Atabek, The inlet length or oscillatory flow and its effects on the determination of the rate of flow in arteries, Department of aeronautical engineering, University of Minnesota.

[7].H. B. Atabek and H. S. Lew, Wave propagation through a viscous incompressible fluid contained in an initially stressed elastic, department of space science and applied physics, the catholic university of America, Washington, D. C, Biophysical journal,volume 6,481-503

[8].Bathe. M. and Kamm R.D, A fluid-structure interaction finite element analysis of pulsatile blood flow through a compliant stenotic artery, Journal of biomechanical engineering-transactions of the ASME,1999, 121, 361-369.

[9].Bak, S., Yoo, J., Song, C,. Fluid-structure interaction analysis on the deformation of simplified yacht sails. J. Soc. Naval Architect. Korea 50 (1),2013, 33-40.

[10]Bak, S., Yoo, J., Song, C, Fluid-structure interaction analysis of deformation of sail of 30-foot yacht. Int. J. Naval Archit. Ocean Eng. 5 (2),2013, 263-276.

[11]Bak, S., Yoo, J., FSI simulation of the sail performance considering standing rig deformation. J. Soc. Naval Architect. Korea 55 (5),2018, 421-430.

[12]Trimarchi, D., Turnock, S., Chapelle, D., Taunton, D., Fluid-structure interaction of an isotropic thin composite materials for application to sail aerodynamics of a yacht in waves. In: 12th Numerical Towing Tank Symposium. Cortona, Italy 04-06 October 2009.

Detection of defect in steel sheets using Convolutional Neural Networks

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***Abstract*— The paper presents an application of machine vision algorithm based on Convolutional Neural Networks (CNN), which helps in identifying manufacturing defects on a steel sheet while locating them with high accuracy. The use of machine learning tries to improve the accuracy and speed of quality testing with regards to traditional methods. This paper demonstrates the use of machine learning in detection of 4 different kinds of defects than occur on the surface of hot rolled steel sheets. The algorithm uses a CNN based classifier and training model to identify, locate and classify the different defects based on their geometrical, shape and depth features from a set of grayscale images. This work tries to help engineers improve the algorithm by locating and classifying surface defects on a steel sheet. It will help keep the manufacturing standards for steel high and enable industries to continue their innovation, leading to a stronger, more efficient world all around us.**

Keywords*— Steel production, Algorithms, Machine Learning, Convolutional Neural Network (CNN)

I. INTRODUCTION

Steel is one of the majorly used materials in construction as well as production. The quality of steel affects the overall quality of the product. Steel, while manufactured, can be subjected to defects like oil spills, scratches, roller mark, inclusion, spots, cavities, grinning etc. Machine learning based inspection of quality has the following advantages over the traditional inspection methods:

a. Providing 100% inspection of the production with the full speed of the production line.

b. Immediate detection and classification of defects saves valuable time and production.

c. Improving real-time process control, high productivity and reliability.

From heating and rolling, to drying and cutting, several machines touch flat steel by the time it's ready to ship and may be subject to defects like pinch mark, roll mark, scratch, hole, rust etc. The production process of flat steel sheet is prone to various metallurgical as well as manufacturing defects, causing scrap or rework of the product, incurring huge costs and thereby worsening the financial position of the company and may affect the economy of the country as a whole.

This paper presents an algorithm which is efficient for locating a surface defect on a steel sheet, based on Machine Learning, using images from high frequency cameras.

II. RELATED WORK

A. Machine Learning

The first advent of machine learning came with Samuel, A. L. [1] describing a new signature table technique together with an improved book learning procedure which is thought to be much superior to the linear polynomial method. This was developed to play checker games by learning from opponents' moves. The machine was unable to outplay checker masters but the program's playing ability improved notably.

Noordam, J. C *et. al.* [2] developed a high-speed machine vision system for the quality inspection and grading of potatoes. The vision system grades potatoes on size, shape and external defects such as greening, mechanical damages, silver scab, common scab, cracks and growth cracks. The color segmentation procedure uses Linear Discriminant Analysis (LDA) in combination with a Mahalanobis distance classifier to classify the pixels. The procedure for the detection of misshapen potatoes uses a Fourier based shape classification technique.

Dietterich, T. G. [3] summarized four directions of Machine Learning (1) the improvement of classification accuracy by learning ensembles of classifiers, (2) methods for scaling up supervised learning algorithms, (3) reinforcement learning, and (4) the learning of complex stochastic models.

B. Neural Networks

Zeng, X. M *et. al.* [4] discusses the use of neural networks for parameter prediction for improving quality inspection of TIG welded joints. A neural network was trained to predict the welding conditions (procedure) necessary to produce a good quality weld. The types of defects arising by the use of other welding conditions were also predicted by their work.

D. Soukup and R. Huber-Mork [5] trained Convolutional Neural Networks (CNNs) on a database of photometric stereo images of metal surface defects. Unsupervised, layer-wise pre-training and data augmentation were used to prevent over-fitting and improve the performance of recognition by overcoming the drawbacks of small training datasets.

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C. Steel defect detection

Kang, G. W., & Liu, H. B. [6] used an approach of Machine Learning to detect surface defects in steel strips based on feed-forward neural network (FFN). Their experimental results show that the method of machine learning is effective in identifying the defects in steel sheets. This work opened a new approach in quality testing by using machine learning algorithms.

Kang, G. W., & Liu, H. B. [7] an approach to detect surface defects of steel strips based on feed-forward neural network (FFN) is discussed. The experiments show that the method is effective.

Tang, B. *et. al.* [8] describes the structure of the surface automated inspection system. The software and image processing of steel strip surface inspection is presented and the algorithms of detect surface defects of steel strip is discussed. The system is capable of both detecting and classifying surface defects in cold rolling steel strip.

Sun, X. *et. al.* [9] proposes an automatic steel surface defects detection method based on deep learning. Two deep learning models for defect detection are evaluated. The experimental results show that the evaluated methods can detect steel surface defects more effectively and accurately than the traditional methods.

B Samanta et. al. [10] presents a study to compare the performance of bearing fault detection using two different classifiers: Artificial Neural Networks (ANNs) and Support Vector Machines (SVMs). The vibration signals of a rotating machine with normal and defective bearings are processed for feature extraction and training. The results show the effectiveness of the features and the classifiers in detection of machine condition.

III. Data Analysis

High frequency camera images of size 1600 pixels x 256 pixels were collected from Kaggle datsets as shown in figure 1. Images were named with a unique Image_Id. A training dataset of 12,568 images and a test set of 1,801 images were obtained.

The training dataset contains encoded space delimited list of pairs representing the start position and run length; i.e., '1 3 10 5' implies pixels 1,2,3,10,11,12,13,14 are the pixels of defect location. The pixels are numbered from top to bottom, then left to right: 1 is pixel (1,1), 2 is pixel (1,2) etc.

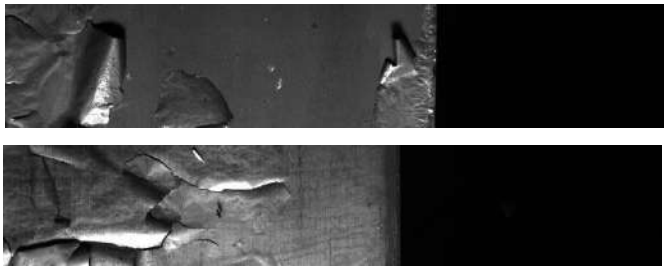
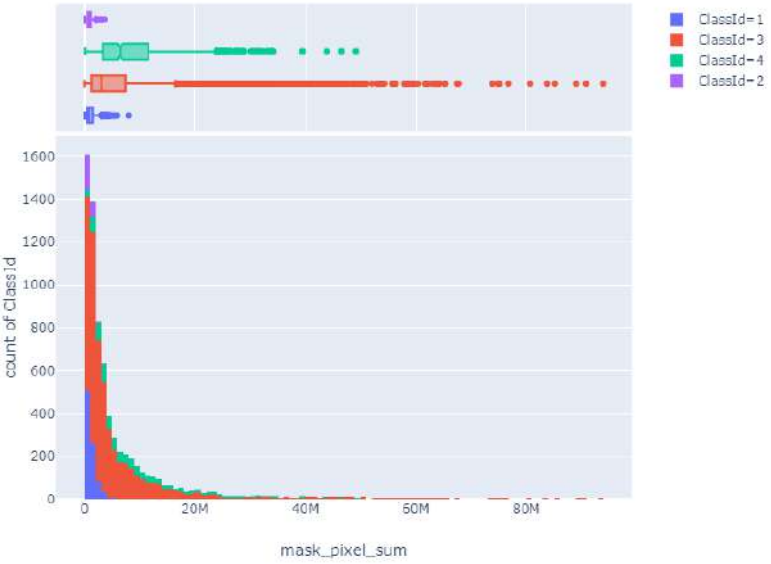


Fig. 1 Training Images of surface defects [12]

A. Data visualization

A total number of 12568 unique images were taken, out of which 5902 images had no defect. Total instances of 7905



defects were identified among 6666 images with at least one defect. Data was found to be right skewed from box plot, shown in figure 2.

Fig.2 Box-plot and histogram of the defect pixels data

Image sizes were examined and found to be of equal size of 256x1600px.

B. Data cleaning

Comma separated value file containing the data regarding the defect pixels location was processed using pandas library. The location was processed using pandas library. The column1 of the CSV file was split using lambda function into defect class and image id. Then the rows with no defect location were deleted.

IV. Methodology

A. Mask visualization

Utility functions were used to create mask from the run length encoded (RLE) data and the results are shown in figure 3.

Fig. 3 Original image and image with mask

The areas under the masks were calculated, but large masks contained empty spaces without any defect in some cases.

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B. Segmentation

Segmentation requires information from the entire image, so that surface defects can be identified locally. Therefore, splitting of images into crops and training only on images with nonzero masks was used as an effective strategy. In particular, it was useful in training the model using large enough batches and keeping only parts of images containing useful information.

256x256 fast.ai cropping was used to avoid masks with non-zero masks. A kernel using a UNet model with pre-trained resnet18 encoder was utilized for the segmentation of RLE.

C. Training

A combined classification and segmentation pipeline was used for training the model. ResNet34 classifier was paired along with a ResNet18 segmentation for training of RLE data.

V. Result and Discussion

A machine learning model based on Mask R-CNN was developed and trained using 6666 images to learn about 4 classes of defects from 7905 occurrences. The model uses 256x256 fast.ai cropping and 5 epochs are run. Pre-trained ResNet classifiers were used for classification of defects.

The model dice coefficient is calculated, which is the intersection over union ratio of the ground truth and the predicted mask. The Dice coefficient is ratio of intersection over union; i.e., a little mistake prediction of no-defect material (false positive) makes Dice coefficient reduce largely.

Training minimum defect pixels for defects e1, e2, e3 and e4 are 163, 316, 115 and 491 respectively; therefore, it is better to make prediction of no defects under these minimum number of pixels in the predicted masks.

Hence, at the first step is to classify no-defects and defects and at the second step to do segmentation.

Further, the model can be trained to detect more number of defects. As future work, better model can be developed to detect defects from a machined part rather than flat sheets as is done in this paper.

Acknowledgment

The model in this paper has been trained and tested using the data provided by Kaggle datasets. Severstal, a leading Russian steel manufacturer, has created one of the industry's largest data lakes, with large amount of useful data. Kaggle kernels were used for model building.

References

[1] Samuel, A. L. (1967). Some studies in machine learning using the game of checkers. II—Recent progress. *IBM Journal of research and development*, *11*(6), 601-617.

[2] Noordam, J. C., Otten, G. W., Timmermans, T. J., & van Zwol, B. H. (2000, March). High-speed potato grading and quality inspection based on a color vision system. In *Machine Vision Applications in Industrial Inspection VIII* (Vol. 3966, pp. 206-217). International Society for Optics and Photonics.

[3] Dietterich, T. G. (1997). Machine-learning research. *AI magazine*, *18*(4), 97-97.

[4] Zeng, X. M., Lucas, J., & Fang, M. T. C. (1993). Use of neural networks for parameter prediction and quality inspection in TIG welding. *Transactions of the Institute of Measurement and Control*, *15*(2), 87-95.

[5] D. Soukup and R. Huber-Mork, (2014). Convolutional Neural Networks for Steel Surface Defect Detection from Photometric Stereo Images. Springer International Publishing Switzerland.

[6] Kang, G. W., & Liu, H. B. (2005, August). Surface defects inspection of cold rolled strips based on neural network. In *2005 International Conference on Machine Learning and Cybernetics* (Vol. 8, pp. 5034-5037). IEEE.G. Eason, B. Noble, and I.N. Sneddon, "On certain integrals of Lipschitz-Hankel type involving products of Bessel functions," Phil. Trans. Roy. Soc. London, vol. A247, pp. 529-551, April 1955.

[7] Kang, G. W., & Liu, H. B. (2005, August). Surface defects inspection of cold rolled strips based on neural network. In *2005 International Conference on Machine Learning and Cybernetics* (Vol. 8, pp. 5034-5037). IEEE.

[8] Tang, B., Kong, J. Y., Wang, X. D., & Chen, L. (2009, April). Surface inspection system of steel strip based on machine vision. In *2009 First International Workshop on Database Technology and Applications* (pp. 359-362). IEEE.

[9] B. Samanta, K.R. Al-Balushi, S.A. Al-Araimi, 2003. Artificial neural networks and support vector machines with genetic algorithm for bearing fault detection. Engineering Applications of Artificial Intelligence 16 657–665.

[10] Sun, X., Gu, J., Huang, R., Zou, R., & Giron Palomares, B. (2019). Surface Defects Recognition of Wheel Hub Based on Improved Faster R-CNN. *Electronics*, *8*(5), 481.

[11] Tang, B., Kong, J. Y., Wang, X. D., & Chen, L. (2009, April). Surface inspection system of steel strip based on machine vision. In *2009 First International Workshop on Database Technology and Applications* (pp. 359-362). IEEE.

[12] www.kaggle.com

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Constructing a more efficient financial crisis warning model using various hybrid z-score models

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***Abstract*— Bankruptcy is a state of insolvency in which the company is not able to repay the debt amount to creditors. It is necessary to develop methods to identify firms that might run a risk of going bankrupt and more in an environment such as the current one which is of recession. The work focusses mainly on the suitability of major bankruptcy prediction models by applying them to the companies in the Indian manufacturing sector, which have been declared sick. First, the fruit fly optimization algorithm (FOA) is used to adjust the coefficients of the parameters in the ZSCORE model (FOA_ZSCORE). Afterward, the generalized regressive neural network (GRNN model), with optimized spread by FOA (FOA_GRNN model) is used to forecast the difference to promote the forecasting accuracy. Various models, including ZSCORE, FOA_ZSCORE, FOA_ZSCORE+ GRNN, AND FOA_ZSCORE +FOA_GRNN need to be trained and tested. The main aim of this work is to check the performance of new hybrid models, FOA_ZSCORE+FOA_GRNN which offers better performance than the original ZSCORE model.**

Keywords—Fruit fly optimization algorithm (FOA); generalized regressive neural network (GRNN); multivariate adaptive regressive splines (ROA); financial crisis forecast model.

I. INTRODUCTION

Financial crisis is a situation where a firm is in capable of meeting its financial obligations. When a firm failed to fulfil those obligations, creditors may take over through a legal mechanism referred to as bankruptcy. Bankruptcy become a vital subject in corporate finance because of the global financial crisis which occurred in 2008. So the bankruptcy of a certain company can lead to enterprise crisis and further increase to this will cause domino effect, and that will influence the investment return of investors, and cause financial crisis. A feasible financial crisis warning model can help to prevent the occurrence of the enterprise crisis in advance and thus by reducing the influence on society and economy.

There have been many methods developed and used across the firms. Some of the more common method is the Altman zscore. Each model has its own limitations and financial institutions are finding for the best method to evaluate credit worthiness.

The purpose of this work is to examine the suitability of major bankruptcy prediction models in the Indian manufacturing sector companies that are declared sick and by doing so find out which model is more suitable for firms. The work is done to improve the prediction and accuracy of the ZSCORE model. The fruit fly optimization is employed in order to adjust the coefficients of the parameters of ZSCORE model. In order to promote the prediction accuracy of ZSCORE MODEL the difference between the forecast value of the FOA_ZSCORE model and the actual value of the target variable were find out using GRNN model. The generalized neural network uses the optimal spread value, for that we use the fruit fly optimization algorithm (FOA). Hence the parameters we used here for ZSCORE may vary for different stock markets and for different prediction time, so for getting appropriate parameters for bankruptcy prediction we use multivariate adaptive regressive splines (MARS).

II. LITERATURE REVIEW

This review focuses on summarizing previous reports published, that are related relevant in enhancing the knowledge about ZSCORE and qualitative bankruptcy prediction.

A. Literature review on bankruptcy

Beaver. W (1966) he conducted this study when ratio analysis was in the embryonic stage, current ratio was used for a single purpose- the evaluation of credit worthiness. Nowadays the ratio analysis have variety of users including credit lenders, credit rating agencies investors and management. The current purpose of the ratio is for the prediction of failures. Here for the study the first step is the selection of failed firms. The samples are taken from moody s industrial manual. It consists of financial statement data for industrial publicly owned corporations. Then classified on the basics of industry and asset

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size. Then the list of nonfailed firms need to be selected. The data that is taken can be analyzed into three steps.

(1) comparison of mean values

(2) dichotomous classification test

(3) and analysis of likelihood rules.

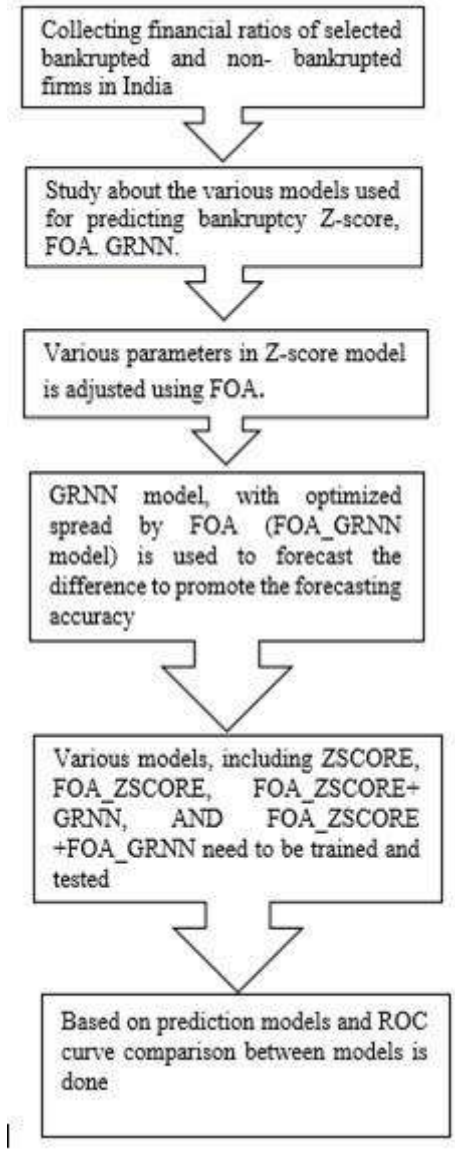
The mean ratios can be computed for failed and nonfailed firms in each year before failure. The comparison of mean value is called profile analysis. The term is adopted here because it provides the accurate analysis that is provided by comparison of means. This test is not a predictive test it is only helpful in understanding general relationship between failed and nonfailed firms. The dichotomous classification test provides only the failure status of a firm based on financial rules. It is a predictive test as likelihood ratios. The likelihood of ratios can be accessed by financial ratios. By different analysis he could able to conclude that the ratios are used to detect financial failures in a firm there are several firms whose illness were detected before failure occurred, and the firm did not fail. The sample of failed firms include whose illness is not detected using these ratios. And on other side the ratios are used by financial institutions to determine the credit of its borrowers. The ratio distribution of nonfailed firms are stable throughout five year before failure. The cash flow to total debt has the ability to correctly classify both failed and nonfailed firms to s greater extent than through random prediction and this could exist for last five years before prediction. And he founded not all ratios have a good predictive power but cash flow to total debt ratio have an excellent discriminatory power. Non failed firms can be classified to a greater extent than failed firms through ratio analysis. The findings implies that it is more risky to have a very high ratio than to have a lower one in a range where most of non-failed firms appear.

Altman. E. I (1968) used discriminant analysis to rank firms on the basis of a weighted combination of five ratios. His results were 95% effective in selecting future bankrupts in the year prior to bankruptcy. He created a financial early warning model, and proposed the ZSCORE model.

Narender. V Rao (2013) studied the suitability of major bankruptcy prediction models by applying then to companies in the Indian manufacturing sector, which have been declared sick. He uses Altman's z-score and KMV Merton distance to default are the two bankruptcy prediction methods which were used to check the health of companies. He concluded that Altmans z-score model is able to predict bankruptcy filing efficiently as compared to the KMV Merton distance to default model. The study shows Altman model is able to predict that a firm might get in to the state of distress at least two years prior to the situation. While KMV Merton does not have a fixed period where in it can with certainly state that a firm will get into financial distress. The study then concluded that a logit model such as z-score is more appropriate than the KMV Merton model. The primary reason that is related to KMV model is its dependency on the equity volatility. The logit models are more effective in terms of their simplicity and extensibility. A model could be able to build based on the historic financial data which is easier to interpret and use.

Pan W. T (2009) used GA to adjust the ANFIS parameter in order to forecast the difference from the real value, which had good performance. Two years later, he proposed to use FOA to optimize the spread of GRNN and resulted in a new model termed FOA_GRNN. In order to improve the accuracy of the bankruptcy prediction, this study uses the FOA to adjust the values of the coefficients of the ZSCORE model and uses the FOA_GRNN to forecast the difference between the forecast value of the FOA_ZSCORE model and the real value of the target variable. Ciampi and Gordini (2013) treated small enterprises as the sample to conduct credit-risk evaluation and found that the artificial neural network had the better performance as compared with traditional performance. Cornelius Casey and Norman Bartczak (2015) founded that operating cash flow data can increase the accuracy of accrual based multiple discriminant and logit models to distinguish between bankrupt and non-bankrupt firms.

III. FLOW CHART



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VI. OBJECTIVES

The major objective of this study are:

•To avoid enterprise crisis, which influences the national economy, investment return of investors, and financial crisis.

•To prevent the possibility of enterprise crisis in advance.

•The main purpose of this project is to develop an efficient financial crisis warning model.

V.METHODOLOGY

Step 1: Study about the various manufacturing firms in India

Step 2: A detailed study about the various bankrupted and good preforming companies under the manufacturing sector.

Step 3: Study about the various models used for predicting bankruptcy Z-score, FOA, GRNN.

Step 4: Various parameters in Z-score model is adjusted using FOA.

Step 5: Create hybrid models which could able to give more accuracy in prediction.

Step 6: Various hybrid models are trained and tested.

Step 7: Based on prediction models and ROC curve comparison between models is done.

VI. BASIC MODEL

Z-SCORE

The ZSCORE model was proposed by Altman. Here 20 companies are taken among which 10 companies experienced bankruptcy and 10 companies were performing well. In total 22 financial ratios including liquidity, solvency, profitability, leverage, activity are included. After applying the multivariate discriminate analysis on the data set, five financial ratios are selected to build the ZSCORE model.

$Z\text{-SCORE}= 1.2X_1 +1.4X_2+3.3X_3+0.6X_4+1.0X_5$

Where Z is a Z-SCORE of five predictors defined in the following:

X_1= working capital/total assets

X_2=retained earnings/total assets

X_3=earnings before interest and taxes/ total assets

X_4=market value equity/book value of total liabilities

X_5=sales/ total assets.

VII. DATA REQUIRED PROPOSE

The data is collected for a period of 5 years that is from 2016 to 2020. About 10 bankrupted and 10 good working manufacturing firms had been selected from BSE.

LIST OF BANKRUPTED COMPANIES

- Lanco infratech
- Hindustan dorr oliver
- Moser bear
- Supreme tax mart
- LML and HANUNG toys and textiles
- Samtel color
- Amar remedies
- Servalakshmi paper

LIST OF NON BANKRUPTED FIRMS

- Ashok Leyland
- Larsen and Toubro
- Apollo tyres
- Cipla
- Hindustan Unilever Limited
- Videocon group
- TVS motors
- Asian paints
- BPL group
- Jindal steels

VIII. CONCLUSION

The first phase work has been completed. Various bankrupted and non bankrupted manufacturing firms are collected and financial ratios are also collected. These ratios are then equated to the basic equation of Z-SCORE and calculated the value for different companies. In the next phase various hybrid models are evaluated and ROC curve is generated by using MATHLAB and check the efficiency of other hybrid models compared with Z-SCORE.

REFERENCES

[1] Altman, E.I. (1968), “Financial ratios, discriminant analysis and the prediction of corporate bankruptcy”, The Journal of Finance.

[2] Beaver, W. (1966), “Financial ratios as predictors of failure”, Journal of Accounting Research.

[3] Casey, C. and Baetczak, N. (1985), “Using operating cash flow data to predict financial distress: some extensions”, Journal Accounting Research.

[4] Edmister, R.O. (1972), “An empirical test of financial ratio analysis for small business failure prediction”, Journal of Financial and Quantitative Analysis.

[5] Ohlson, J.A. (1980), “Financial ratios and the probabilistic prediction of bankruptcy”, Journal of Accounting Research. [6] Martin.D(1977),“Earlywarningofbankfailure:alogitregressionapproach”,JournalofBanking and Finance.

[7] Ohlson, J.A. (1980), “Financial ratios and the probabilistic prediction of bankruptcy”, Journal of Accounting Research.

[8] Zmijewski, M. (1984), “Methodological issues related to the estimation of financial distress prediction models”, Journal of Accounting Research.

ISBN 978-93-89105-41-4

[9] .Specht, D.F. (1991), "A general regression neural network", IEEE Transactions on Neural Network.

[10] .Tam, K.Y. and Kiang, M. (1992), "Managerial applications of neural networks: the case of bank failure predictions", Management Science.

[11] Zhang, Y., Wang, S. and Ji, G. (2013), "A rule-based model for bankruptcy prediction based on an improved genetic ant colony algorithm", Mathematical Problems in Engineering.

[12] Zhou, L., Lai, K.K. and Yen, J. (2014), "Bankruptcy prediction using SVM models with a new approach to combine features selection and parameter optimisation", International Journal of Systems Science.

[13] Zmijewski, M. (1984), "Methodological issues related to the estimation of financial distress prediction models", Journal of Accounting Research.

[14] Hand, D.J. and Till, R.J. (2001), "A simple generalisation of the area under the ROC curve for multiple class classification problems", Machine Learning.

[15] Hopfield, J.J. (1982), "Neural networks and physical systems with emergent collective computational abilities", Proceedings of the National Academy of Science.

[16] Hsieh, T.J., Hsiao, H.F. and Yeh, W.C. (2012), "Mining financial distress trend data using penalty guided support vector machines based on hybrid of particle swarm optimization and artificial bee colony algorithm", Neurocomputing.

[17] Khashei, M., Rezvan, M.T., Hamadani, A.Z. and Bijari, M. (2013), "A bi-level neural-based fuzzy classification approach for credit scoring problems", Complexity.

[18] Koh, H. and Tan, S. (1999), "A neural network approach to the prediction of going concern status", Accounting and Business

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MODAL ANALYSIS OF HORIZONTAL AXIS JACKET SUPPORTED OFFSHORE WIND TURBINE

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***Abstract*—The mankind has been using wind energy from the medieval times. It is one of the major renewable energy resources. There is no environmental hazards by using renewable energy resources and thus the study in this area is very much important for the stable and environmental friendly development of the society. The off shore wind turbine is being used more widely because of its less noise pollution and visual impact compared to the on shore wind turbines. Since it is on the ocean it is vulnerable to various loads such as wind, hydrodynamic waves and earthquake. It should have sufficient structural integrity and stability to withstand all these loads. In this context the dynamic analysis of such structures is very significant. In this work, the mode shapes of the off shore wind turbine structure are studied by discretizing the tower as well as the jacket. The results are compared with those reported in literature with no discretization of the tower. This paper emphasizes the need to do discretization of the whole system rather than treating a part of it for determining the natural frequencies and mode shapes.**

***Index Terms*—mode shapes, tower , visual impact**

I. INTRODUCTION

The wind energy is one of the most widely used and promising renewable energy resources. The major challenge of this wind turbine is that it is having high capital and maintenance cost, the foundation of the structure contributes more to the capital cost of the system by an amount of 15-25 percentage[2]. The wind turbine can be classified into four different types based on their foundations such as jacket supported, mono- pile, crown pile and floating wind turbine. For performing modal analysis the structure (i.e., the geometry and the dimensions) should be well defined. There are many papers that determine the mode shapes of the structure. Some of them uses only jacket discretization [4]. Some authors have only determined the natural frequencies but not plotted any mode shapes. [1]. The mitigation of vibration generated using different loads is usually done with dampers, especially with Tuned Mass Dampers (TMD) and Tuned Liquid Column Dampers (TLCD). Reduction in the amplitudes using magnetorheological damper have also been reported in some papers [2]. The authors studied the in-plane vibration of the wind turbine blades with active tuned mass damper and good results have been obtained even for high turbulent loading. The effect of active tuned mass damper on the tower vibration has been studied by some authors [22]. The absolute displacement of the tower and the relative velocity of the damper mass control the actuator force used in this study. Furthermore, some researchers [REF] placed an ATMD into the tower of an onshore wind turbine and estimated the improved reliability of the system under stochastically generated wind loads. Onshore wind turbine and estimated the improved reliability of the system under stochastically generated wind loads.

In previous study the tower of the turbine is only discretized into one element and the jacket into more number of elements [4]. Their main objective was to plot the modal vibration characteristics of the jacket and to determine them the tower is considered to be highly stiffened, whereas in actual case it is not so. As the structure is discretized into more number of elements the modal shapes of the structure will become closed to the actual mode shapes. The paper is divided into four sections: (I) the description of the basic model of the structure (II) modal analysis of the structure (III) results and discussion and finally (IV) the conclusion

II. DESCRIPTION OF BASIC MODAL OF THE STRUCTURE

This section gives the description of the 5 MW Horizontal axis jacket supported offshore reference turbine [4]. The structure of the turbine is divided into three main components such as tower, jacket and the transition piece. The transition piece is built in between the tower and the jacket and it is made up of concrete block having dimensions of $9.6m \times 9.6m \times 4m$, and its Young's modulus is $17GPa$. The dimensions of the jacket and tower are described in the following subsections and the schematic representation of the jacket supported off shore wind turbine is shown in Fig.1

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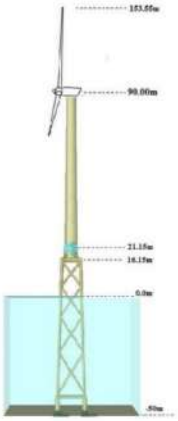

Fig. 1. Schematic representation of jacket supported off shore wind turbine[3]

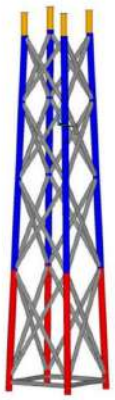

Fig. 2. Dimensional representation of the jacket of the reference turbine[3]

A. Tower

The tower is designed in a truncated cone shape. Inside portion of the tower is hollow. Like jacket, the diameters and thickness of the tower are linearly varying [3]. The wind tower is made of steel with a length of 80 m. The nacelle mass is 240 tons. The rotor mass is 110 tons. The turbine diameter is 126 m (Figure 3). The wind tower has a truncated cone shape; at the bottom, the diameter is 4 m and the thickness is 0.18 m; at the top, the diameter is 3.5 m and the thickness is 0.10 m. At half tower height, the diameter is 3.75 m and the thickness is 0.14 m. The hub is at z = +90 m. The wind tower produces a rated power of 5 MW.

B. Jacket

The diameters The diameters and thickness of each section of the jacket, including the X braced are taken as follows. For the red part, That is the lower leg the diameter is 1.2 m, and thickness is 50 mm. Similarly for the blue part of the jacket that indicates the middle portion of the jacket has a diameter of 1.2 meter and a thickness of 35 mm. For the jacket crossing tip the diameter is 1.2 m and thickness is 40 mm. These dimensional reorientation of the structure is shown in Fig.2

III. MODAL ANALYSIS

The modal analysis of the structure is very much important to identify the vibration characteristics of the structure. Modular examination encourages one to decide the characteristic frequencies and Mode shapes (the states of twisting of the structure). This is helpful mainly in protecting a structure from fatigue failure due to the excitation frequencies

A. Estimation of modal frequencies [4]

In the previous work of Alessi et al (2019) [4], they have discretized the structure into six nodes. The tower and the transition piece were considered to be one element, while the jacket was discretized into 5 elements to obtain the corresponding modal frequencies and mode shapes. For validation of the formulation presented in this paper, the modal frequencies and mode shapes are reproduced as follows. First of all, the stiffness and mass matrix of the structure are calculated. Mass matrix is calculated by multiplying the density of the material with its volume for each node. The density of the steel is considered to be 7850 kg/m^3

$$M = \begin{bmatrix} 937,000 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1,587,300 & 0 & 0 & 0 & 0 \\ 0 & 0 & 122,400 & 0 & 0 & 0 \\ 0 & 0 & 0 & 147,100 & 0 & 0 \\ 0 & 0 & 0 & 0 & 242,300 & 0 \\ 0 & 0 & 0 & 0 & 0 & 206,700 \end{bmatrix} \quad (1)$$

The stiffness matrix (N/m) is formulated by using the stiffness equa- tion of the beam and is given by

$$K = \begin{bmatrix} 0.0121 & 0.0121 & 0 & 0 & 0 & 0 \\ 0.0121 & 0.6689 & 0.6568 & 0 & 0 & 0 \\ 0 & 0.6568 & 1.1290 & 0.4722 & 0 & 0 \\ 0 & 0 & 0.4722 & 1.0345 & 0.5622 & 0 \\ 0 & 0 & 0 & 0.5622 & 1.1307 & 0.5685 \\ 0 & 0 & 0 & 0 & 0.5685 & 1.2073 \end{bmatrix} .10^9 \quad (2)$$

The modal frequencies obtained using Matlab are $\omega_1 = 3.13 rad/s$, $\omega_2 = 8.45 rad/s, \omega_3 = 36.02 rad/s, \omega_4 = 71.90 rad/s, \omega_5 = 90.62 rad/s, \omega_6 = 111.50 rad/s$

B. Modal frequencies after tower discretization [Present work]

In the previous work [4] the tower is considered as one element and hence it will significantly affect the modal frequencies of the entire system. In that case the tower is considered to be more stiffened but in actual case it's not. In this work, the tower is discretized into four elements. So nine natural frequencies and nine modal shapes will be obtained. The mass and stiffness matrices after tower discretization is

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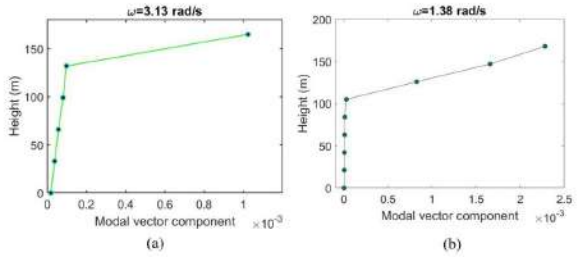

Fig. 3. Modal shape for the first modal frequency (a) without and (b) with discretization

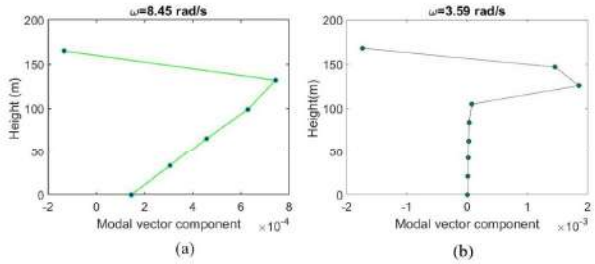

Fig. 4. Modal shape for the second modal frequency (a) without and (b) with discretization

given below

$$M = \begin{bmatrix} 115725.33 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 115725.33 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 115725.33 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 589824 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1587300 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 122400 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 147100 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 242300 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 206700 \end{bmatrix}. \quad (3)$$

$$K = \begin{bmatrix} 0.000814814 & -0.000814814 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ -0.000814814 & 0.001868614 & -0.0010538 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & -0.0010538 & 0.0023811 & -0.0013273 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & -0.0013273 & 0.065927 & -0.0643 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & -0.0643 & 0.7211 & -0.6568 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -0.6568 & 1.1290 & -0.4722 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & -0.4722 & 1.0345 & -0.5622 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & -0.5622 & 1.1307 & -0.5685 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & -0.5685 & 1.2073 \end{bmatrix}. \quad (4)$$

The modal frequencies obtained after discretizing the tower into four components are $\omega_1 = 1.3870 rad/s$, $\omega_2 = 3.5980 rad/s, \omega_3 = 5.3118 rad/s, \omega_4 = 6.6200 rad/s, \omega_5 = 13.0013 rad/s, \omega_6 = 36.0607 rad/s, \omega_7 = 71.9067 rad/s$, $\omega_8 = 90.6265 rad/s, \omega_9 = 111.5062 rad/s$. The modal frequencies are close to the actual modal frequency of the structure because here the tower is not considered to be stiffened and it is discretized

IV. RESULTS AND DISCUSSION

Fig 3 to 10 show the modal shapes of the structure with and without discretization of the tower. Fig 9 and 10 shows the mode shapes of frequency corresponding to higher modes after the tower discretization. From fig it is clear that because of the discretization, the tower of the structure appears to be more flexible compared to the result obtained in REF[]. For the first

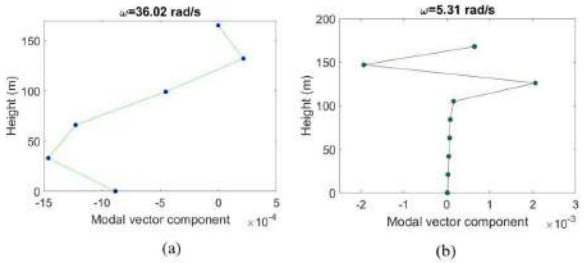

Fig. 5. Modal shape for the third modal frequency (a) without and (b) with discretization

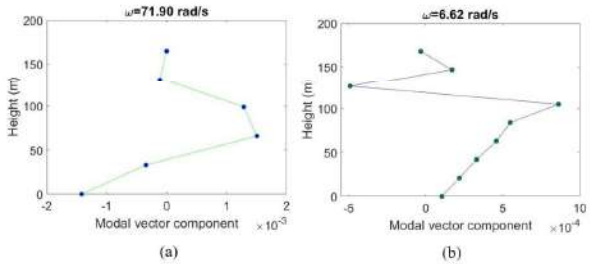

Fig. 6. Modal shape for the fourth modal frequency (a) without and (b) with discretization

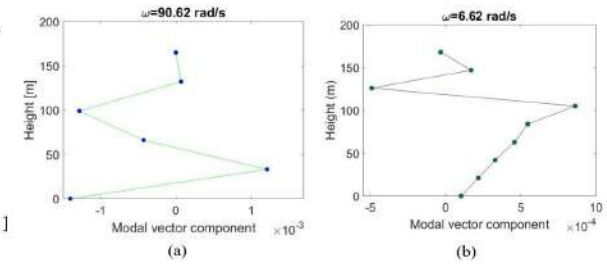

Fig. 7. Modal shape for the fifth modal frequency (a) without and (b) with discretization

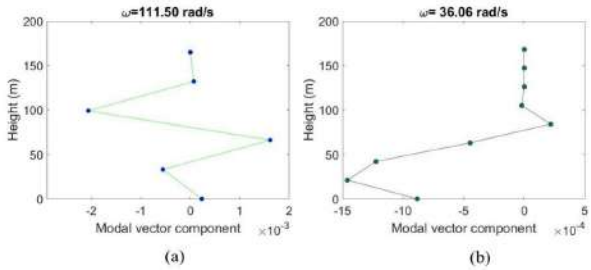

Fig. 8. Modal shape for the sixth modal frequency (a) without and (b) with discretization

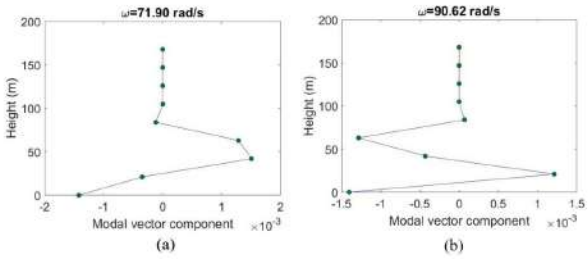

Fig. 9. Modal shapes of the structure with discretization

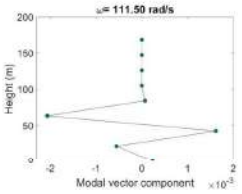

Fig. 10. Modal shapes of the structure with discretization

mode the difference in the two results is not seen appreciably, while for the second mode it is not much different. The mode shapes obtained in each case are shown in figures [3-10]

V. CONCLUSION

The modal frequencies of the structure are found out in this work after calculating the mass and stiffness. The mode shapes given in ref[] are plotted and validated. The tower is discretized into more elements and the mass and stiffness matrices are calculated for plotting the new mode shapes of the structure. From the results obtained, it is clear that the tower is more flexible after discretization and thus, to do a vibration analysis it is important that the whole structure needs to be discretized. From the mass and stiffness matrices the undamped free vibration responses of the structure can be studied. Also, the vibration response study of the structure with and without different types of, dampers, especially Tuned mass damper and Tuned liquid column dampers, can be studied. A parametric study can be carried out by varying the liquid inside the Tuned liquid column damper and also by varying the mass ratios with different types of dampers.

REFERENCES

[1] Hemmati, Arash, Erkan Oterkus, and Mahdi Khorasanchi. "Vibration suppression of offshore wind turbine foundations using tuned liquid column dampers and tuned mass dampers." Ocean Engineering 172 (2019): 286-295

[2] Seidel, M. "Substructures for offshore wind turbines Current trends and developments." Festschrift Peter Schaumann (2014): 363-368

[3] Vorpahl, Fabian, Wojciech Popko, and Daniel Kaufer. "Description of a basic model of the" UpWind reference jacket" for code comparison in the OC4 project under IEA Wind Annex XXX." Fraunhofer Institute for Wind Energy and Energy System Technology (IWES), Germany (2011

[4] Alessi, Lorenzo, José AFO Correia, and Nicholas Fantuzzi. "Initial Design Phase and Tender Designs of a Jacket Structure Converted into a Retrofitted Offshore Wind Turbine." Energies 12.4 (2019): 659

[5] Lee, H. H., S-H. Wong, and R-S. Lee. "Response mitigation on the offshore floating platform system with tuned liquid column damper." Ocean engineering 33.8-9 (2006): 1118-1142

[6] Colwell, Shane, and Biswajit Basu. "Tuned liquid column dampers in offshore wind turbines for structural control." Engineering Structures 31.2 (2009): 358-368

[7] Brodersen, Mark L., Ann-Sofie Bjørke, and Jan Høgsberg. "Active tuned mass damper for damping of offshore wind turbine vibrations." Wind Energy 20.5 (2017): 783-796

[8] Li, Jie, Zili Zhang, and Jianbing Chen. "Experimental study on vibration control of offshore wind turbines using a ball vibration absorber." Energy and Power Engineering 4.03 (2012):

[9] Dinh, Van-Nguyen, and Biswajit Basu. "Passive control of floating offshore wind turbine nacelle and spar vibrations by multiple tuned mass dampers." Structural Control and Health Monitoring 22.1 (2015): 152-176.

[10] Zuo, Haoran, Kaiming Bi, and Hong Hao. "Using multiple tuned mass dampers to control offshore wind turbine vibrations under multiple hazards." Engineering Structures 141 (2017): 303-315

[11] Bi, Kaiming, and Hong Hao. "Using pipe-in-pipe systems for subsea pipeline vibration control." Engineering Structures 109 (2016): 75-84

[12] Colwell, Shane, and Biswajit Basu. "Tuned liquid column dampers in offshore wind turbines for structural control." Engineering Structures 31.2 (2009): 358-368

[13] Damgaard, Mads, and Jacob KF Andersen. "Natural frequency and damping estimation of an offshore wind turbine structure." The Twenty-second International Offshore and Polar Engineering Conference. International Society of Offshore and Polar Engineers, 2012.

[14] Tena-Colunga, Arturo. "Stiffness formulation for nonprismatic beam elements." Journal of Structural Engineering 122.12 (1996): 1484-1489

[15] Philippe, Maxime, Aurélien Babarit, and Pierre Ferrant. "Modes of response of an offshore wind turbine with directional wind and waves." Renewable energy 49 (2013): 151-155

[16] Moll, H., Fabian Vorpahl, and Hans-Gerd Busmann. "Dynamics of support structures for offshore wind turbines in fully-coupled simulations-influence of water added mass on jacket mode shapes, natural frequencies and loads." European Wind Energy Conference (EWEC). Fraunhofer Institute for Wind Energy and Energy Systems Technology IWES. 2010.

[17] Jalbi, Saleh, and Subhamoy Bhattacharya. "Closed form solution for the first natural frequency of offshore wind turbine jackets supported on multiple foundations incorporating soil-structure interaction." Soil Dynamics and Earthquake Engineering 113 (2018): 593-613.

[18] Hung, Y-C., Y-Y. Chang, and S-Y. Chen. "Natural frequency and vibration analysis of jacket type foundation for offshore wind power." Materials Science and Engineering Conference Series. Vol. 276. No. 1. 2017

[19] Jalbi, Saleh, and Subhamoy Bhattacharya. "Minimum foundation size and spacing for jacket supported offshore wind turbines considering dynamic design criteria." Soil Dynamics and Earthquake Engineering 123 (2019): 193-204

[20] Eisenberger, M. "Stiffness matrices for non-prismatic members including transverse shear." Computers Structures 40.4 (1991): 831-835

[21] Caterino, Nicola. "Semi-active control of a wind turbine via magnetorheological dampers." Journal of Sound and Vibration 345 (2015): 1-17

[22] Fitzgerald, Breiffni, Biswajit Basu, and Søren RK Nielsen. "Active tuned mass dampers for control of in-plane vibrations of wind turbine blades." Structural Control and Health Monitoring 20.12 (2013): 1377-1396

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Performance Improvement Verification Model in Educational Institutions

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***Abstract*— This paper presents a study which focuses on a Performance Evaluation Matrix (PEM) model to understand the effectiveness of performance improvement in case of an educational institute. The detailed steps include observing different Critical To Quality (CTQ) parameters and evaluating its relative importance, suggesting improvement strategies to improve the performance of CTQ parameters, analyzing pre-improvement and post improvement variations (if any) and to quantitatively evaluate whether effectiveness in CTQ parameters has improved or not. It is expected to evaluate the performance improvement application on the selected case and to understand the short comings that should be eliminated in future studies.**

Keywords—Voice of the customer (VOC), Critical to Quality (CTQ), Performance Evaluation Matrix (PEM), Total quality management (TQM).

I. INTRODUCTION

Every institution works for improved customer satisfaction thereby improving its quality parameters. This can be understood by achieving a common knowledge pool on how the customer perspectives could be met by institutions. Much has been written about this process, and there are many possible ways to gather the information – focus groups, individual interviews, contextual inquiry, ethnographic techniques, etc. But all involve a series of structured in-depth interviews, which focus on the customers' experiences with current products or alternatives within the category under consideration. Needs statements are then extracted, organized into a more usable hierarchy, and then prioritized by the customers .It is critical that the product development core team are involved in this process. They must be the ones who take the lead in defining the topic, designing the sample (i.e. the types of customers to include), generating the questions for the discussion guide, either conducting or observing and analyzing the interviews, and extracting and processing the needs statements.

Decision matrix (e.g. Performance Evaluation Matrix) is used to describe a multi-criteria decision analysis (MCDA) problem. An MCDA problem, where there are M alternative options and each needs to be assessed on N criteria, can be described by the decision matrix which has N rows and M columns, or M × N elements. A decision matrix is a list of values in rows and columns that allow an analyst to systematically identify, analyze, and rate the performance of relationships between sets of values and information. Elements of a decision matrix show decisions based on certain decision criteria. The matrix is useful for looking at large masses of decision factors and assessing each factor's relative significance.

The focus point of the study was to make use of a performance improvement verification model and understand its effectiveness by an application to a case study of an education system. The first performance evaluation matrix (PEM) was made by understanding the voice of customers (VOC) through their perceived level of satisfaction and importance. This method has been widely applied to understand and improve performance scorings in various industries. For example, the beta distribution can be used to describe the satisfaction of customers and the factors to which they attribute importance.

A. Quality Function Deployment (QFD)

QFD is a tool under the umbrella of Total Quality Management (TQM), used for assessing the customer demands and needs and to prioritize those using qualitative factors of satisfaction. A house of quality matrix is used to convert the qualitative aspects into numerical value and to evaluate them under various customer satisfaction levels. The customer requirements forms the base of the house of quality matrix, along with a technical requirements, which are then correlated with the customer demands and further interrelated with themselves using a relationship chart. The results from the QFD helps in creating an action plan which is optimal in increasing the customer satisfaction with minimum technical requirements.

II. PROBLEM DEFINITION

- Education institutions in Kerala, (preferably schools) maintain high quality standards.
- But the quality studies are normally done on macro level approach and may not certainly evaluate improvements which are suggested during the due course of quality evaluation.
- Individual institutions may not be able to attain a pre set level of quality because of the negligence of micro level quality improvement implementation and evaluation.

Thus there is a need for micro level study of quality improvement parameters and its evaluation will suggest the effectiveness of improvements.

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III. RELATED WORK

A. *Literature Review*

Since no model of quality dimensions specific to education was found, the models proposed for non-educational environments (e.g. products, software and general services) were used as a guideline for studying the framework in which the quality dimensions and their corresponding characteristics were identified. Common elements in the different models were examined and each individual dimension was investigated for possible interpretation/generalization in an educational context.

1. QFD features in higher education showed that the type of activities carried out is so different from those experienced in other sectors.[1]
2. It is specified that depend on its applications and due to its systematically process, QFD must be considered both as a tool and as a system. [2]
3. PEM based approach enabled performance before and after the improvement measures to be measured and compared.[3]
4. CTQ Selection is the most important step, since the limits of robustness and performance will be determined by the potential of CTQ's. [4]
5. The mean of customer satisfaction can be utilized as a measurement benchmark and can be widely used to perform analyses in researched. [5]
6. Based on the concept of continuous quality improvement in TQM, the means of the two indices served as a dynamic evaluation criteria.[6]
7. On the basis of calculated customer importance ratings and target values for the design parameter of education it is concluded that quality of both processes could be improved.[7]
8. QFD may be used as a tool for improvement of teaching quality and also for the Benchmarking to improve their overall quality.[8]

IV. METHODOLOGY

A. *Comparison study of existing methodologies*

From the literature review it is observed that different methods are utilized to performance evaluation. So a comparative study is to be made.

KANO-SERVQUAL INTEGRATED MODEL [9,11]	ANALYTIC HIERARCHY PROCESS (AHP) MODEL[10,12]	PERFORMANCE EVALUATION MATRIX MODEL [3,7,5]
1. Both customer and management aspects are evaluated over time	1. It represents the most accurate approach for quantifying the weights of criteria.	1. Used for performance evaluation management and monitoring.
2. It is best suited for long term goals as it proposes product feature.	2. It does not require unique information sets.	2. It is one of the most precise measures of voice of customer as it utilizes continuous improvement.
3. The analysis is difficult and tedious survey process is to be completed.	3. If there is any expansion or erasure of an option, then the request of the rank may differ	3. Accuracy of matrix is directly proportional to the accuracy of fuzzy linguistic scale.

Table 1: Comparison of methodologies

Thus the PEM model is utilized for the study and the major concepts can be detailed as follows:

B. *Proposed methodology*

A. Important parameter identification (CTQ factors):

Features that influence customer satisfaction level are identified and listed in accordance to their criticality. These CTQs forms the basis for QFD preparation.

B. Questionnaire & Data collection:

1. CTQ factor based Questionnaire preparation:

The identified CTQs are transformed into a questionnaire using linguistic scale.

2. Sample Survey and reliability check:

A sample consisting of 10% of the target population is selected which represents the population in demographics and distribution. A sample survey is run using the prepared questionnaire and reliability check is done based on Cronbach's Alpha value in SPSS. The final draft of questionnaire is prepared using the results of the reliability check.

3. Objective based survey:

The final survey is conducted on the target population using the objective based questionnaire.

C. Index calculation:

Means can be utilized as index for the conditions of full data set. Here two indexes such as satisfaction index as well as influence index are calculated.

D. Mathematical evaluation:

The evaluation has to be set in accordance with PEM. The four quadrants represent the relation between the two indexes. The improvement possibility can be seen directly from the matrix

E. Secondary data collection and identification of improvements:

When the item to be improved is targeted, the next step is to create a questionnaire to troubleshoot the shortcomings. Promotion of new and valuable methods may in turn help in achieving the specified performance level.

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F. Evaluating whether there is effective improvement or not:

This may be mathematically be seen either as a gradual upcoming of improvement or not. This will help in concluding the improvement possibility and level.

C. *Model questionnaire framework*

The questionnaire is set as per the requirement of available dataset. It is often seen as the initial phase of gathering much valuable data through multiple scale question set seen as collective gathering of information.

Dimensions and Sub dimensions

[A]. Personal aspects

1. Ease of understanding
2. Ease of access
3. Attitude towards learning
4. Attitude from instructor
5. Content consistency

[B]. Community aspects

6. Ease of discussion in the group.
7. Ease of discussion with instructors.
8. Provision of study materials among the group.
9. Group tasks.

[C]. Content of study

10. Adequacy in content.
11. Relevance in content.
12. Regular evaluations

[D]. Control aspects.

13. Chances in generating personalized projects.
14. New and varied idea generation and its promotion

[E]. Overall satisfaction. (15)

The evaluation is based on a performance evaluation matrix (PEM) having an influence index as the vertical axis and a satisfaction index as the horizontal axis. Based on the concept of continuous quality improvement in total quality management, the means of the two indices served as the dynamic evaluation criteria. Items providing satisfaction below the mean are placed on a list for improvement, and those providing low satisfaction but having high influence are prioritized.

The satisfaction index and influence index may be obtained as follows,

$$Q_h = \frac{\bar{X}_h - 1}{k - 1}, \tag{1}$$

$$B_h = \frac{\sum_{i=1}^{n} (X_{h,i} - \bar{X}_h)(X_{(q+1),i} - \bar{X}_{(q+1)})}{\sqrt{\sum_{i=1}^{n} (X_{h,i} - \bar{X}_h)^2} \sqrt{\sum_{i=1}^{n} (X_{(q+1),i} - \bar{X}_{(q+1)})^2}}, \quad h = 1, 2, \ldots, q+1, \tag{2}$$

Where,

Q_h = Customer satisfaction index
B_h = Influence index
$\overline{X}_h$ = Mean level of satisfaction
q = Questionnaire terms
h = Satisfaction level on a particular item
j = Proportional level of choosing a particular item.
k = Number of measure scales

When resources are limited, the evaluation criteria established in this study will enable managers to quickly and conveniently identify items considered critical to quality (CTQ) and effectively enhance the learner satisfaction of learning systems.

V. APPLICATION

A practical case study can be seen as follows from an e-learning platform [5]. To plainly exhibit the proposed technique and efficiency improvement confirmation model, computerized English-language-learning is chosen as the sector for study. Following information identified with student fulfillment, the proposed model requires that to choose the contributing assets and to make the suggested upgrades. Practically speaking, the institutions have restricted assets and can just consider improving their own CTQs; cross-hierarchical coordinated effort is often troublesome. In this manner, an international science and education university is chosen for the study. It is confirmed that the chances of improvement of things with fulfillment lower than a specific value and impact more prominent than threshold can satisfy the need of proceeding improvement in all out quality administration.

The members of this examination included 197 understudies in 6 classes at a science and innovation college in Taiwan. The pre-improvement fulfillment poll review was controlled during the fourth week after the understudies started utilizing the e-learning framework. Next, the PEM of the e- learning framework is categorized to distinguish the things requiring improvement. Three months were apportioned to the usage of the improvement techniques. Fulfillment reactions with respect to the things requiring improvement were expected to confirm the improvement chances, reconsidered the fuzzy semantic scale reaction technique and furthermore to keep respondents from speculating the appropriate responses and causing variations.

In the pre-improvement system framework fulfillment poll study, 197 polls were circulated and 177 surveys were recollected. After the three-month improvement period, the post-improvement fulfillment review was conducted. A set of 197 surveys were dispersed and recollected 168 polls. After the adequacy confirmation it is seen that the parameters which were showing negative growth and indicated by second quadrant in the PEM had improved adequately.

A similar study is to be proposed in the school education, preferably in high school section. The proposal is to find the CTQ factors in relevant model and to segregate them into PEM model. Thus the factors which have to be improved can be sort out and worked upon. The post improvement dataset can be utilized to evaluate the improvement efficiency by quantifying the same.

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VI. Result and Discussion

A performance evaluation verification model can be utilized in determining the improvement, not only in service sector but may even be used to focus upon individual quality up-gradation studies.

The Improvement effectiveness verification model may be obtained by assuming the null hypothesis (H_0) and alternative hypothesis (H_1) are expressed as:

H_0: p=0.5(no significant changes in effectiveness after improvement)

H_1: p =0.5 (changes in effectiveness after improvement)

$$p\text{-value} = \begin{cases} p^{-}\text{-value} = 2\Phi\left(\dfrac{I_{h0} - (np + 0.5)}{\sqrt{np(1-p)}}\right), & \text{if } I_{h0} \le n/2 \\ p^{+}\text{-value} = 2 - 2\Phi\left(\dfrac{I_{h0} - (np - 0.5)}{\sqrt{np(1-p)}}\right), & \text{if } I_{h0} > n/2 \end{cases}$$

Where,

I_{h0} = Incident number

n = Total number of events

Suppose the significance level is 'a':

(1) If p-value > a, then do not reject H_0. No significant differences in effectiveness before and after improvement are indicated.

(2) If p-value = p+-value ≤ a, then reject H_0. This indicates that effectiveness has improved significantly.

(3) If p-value = p--value ≤ a, then reject H_0. This indicates that effectiveness has in fact declined.

The target population of this study is school children. They are to be randomly selected from a particular class. The survey is to be completed through personal distribution of the questionnaire. After careful examination, valid responses are to be selected and studied. Based on study the data sets are to be calculated and performance evaluation matrix is to be constructed.

The outcomes will include:

- Understanding the relative importance of each CTQ parameter incorporated in the study.
- Understanding the shortcomings in the suggestion improvement strategies.
- Quantifying the performance strategy.
- Understanding the effectiveness in the focused improvement strategies.

Since VOC collected using a fuzzy linguistics scale with k measures does not follow a normal distribution, we used order statistics and nonparametric statistics to develop a statistical testing method to verify effectiveness. Therefore, novel advantages of this model are that it overcomes the issue of pre-improvement and post-improvement differences in sample size and that it is also applicable when the population does not follow a normal distribution.

Conclusion

The model can be used as an effectiveness improvement identification tool [5]. The improvement strategies can be reconsidered to adequate number of times so as to obtain a significant output. This method enhances the chances of fine understanding of user needs and hence seen as a user oriented tool. The model often gives chances to prevent unnecessary usage of resources in the later stages of improvement [6].

Acknowledgement

The model discussed has been trained and tested for some QFD related work, even in service sector. A leading educational institution had offered cooperative study in the similar topic in order to quantify the model building.

References

[1]Mohammad S. Owlia, (2010).Application of Quality Function Deployment for the Improvement of Quality in an Engineering Department, *European Journal of Engineering Education, 23:1, 105-115.*

[2]Dr.Arash Shahin,(2012).Quality Function Deployment: A Comprehensive Review, *Department of Management, University of Isfahan, Isfahan, Iran Review vol 1, 67-87.*

[3]Hsi-Tien Chen & Kuen-Suan Chen, (2015).Applying a revised SQPM in the define step of six sigma and a case study. *Total Quality Management & Business Excellence.*

[4]Tetsuo Hosokawa,(2019).Quality engineering-based management: a proposal for achieving total optimization of large systems *Total Quality Management & Business Excellence*

[5] Kuen-Suan Chen.(2018).Service Quality Evaluation Model of Automated Teller Machines Using Statistical Inference and Performance Evaluation Matrix, *Journal of Economics and Management, Vol. 14, No. 2, 173-190.*

[6]Chun-Min Yu, (2016). Developing a performance evaluation matrix to enhance the satisfaction of an e-learning system, *Total Quality Management & Business Excellence.*

[7]Ajit Kumar Singh, (2018).Application of QFD in education sector: A Review, *International Journal of Mechanical Engineering and Technology (IJMET)Volume 9, Issue 3, March 2018, pp. 592–599.*

[8]*Muhammad Imran Qureshi*, (2012) Quality Function Deployment in Higher Education Institutes, *Middle-East Journal of Scientific Research 12 (8): 1111-1118.*

[9]Vivianne Bouchereau (2008). Methods and techniques to help quality function deployment (QFD), *Benchmarking An International Journal, Research gate.*

[10]Rahul K. Singh.(2012).Comparative Analysis of Quality Function Deployment Methodologies: A Case Study Analysis, *Quality Management Journal, 19:1, 7-23.*

[11]Dr. Dwi Sulisworo.(2012).Integrating Kano's Model and SERVQUAL to Improve Healthcare Service Quality *Global Public Health Journal.*

[12]André Andrade Longaray (2015). Proposal for using AHP method to evaluate the quality of services provided by outsourced companies, *Procedia Computer Science 55 (2015) 715 – 724*

[13]Sisay Filketu (2016) Decision-making on job satisfaction improvement programmes using fuzzy QFD model: a case study in Ethiopia. *Total Quality Management & Business Excellence.*

[14]Ching-Wen Chen (2017). Implementing KM programmes using fuzzy QFD *Total Quality Management & Business Excellence, 22:4, 387-406.*

[15]Ali Reza Shahraki (2011) Ranking the voice of customer with fuzzy DEMATEL and fuzzy AHP *Indian Journal of Science and Technology Vol. 4 No. 12.*

Diabetic Retinopathy Detection Using Machine Learning

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***Abstract*—Diabetic Retinopathy is the main cause of blindness in many people around the world. It is the leading cause of blindness among work aged population. It is becoming a public health problem due to increase in the number of diabetic patients.Early detection and treatment of Diabetic Retinopathy in patients can significantly reduce the risk of vision loss.A Machine learning model using Convolutional Neural Network is formulated to extract important features by data pre-processing and to speed up the process of detection of disease.**

Keywords—Machine Learning, Convolutional Neural Network, Diabetic Retinopathy, ResNet

I INTRODUCTION

Diabetic retinopathy (DR) is the leading cause of blindness in the working-age population. About 96 million people around the world are being affected. Diabetic Retinopathy is one of the most frequent causes of visual impairment in developed countries[10]. It is estimated that about 75 people go blind every day due to DR. India will become one of the major hubs of diabetic population during the next 20 years [17].Effective treatment for DR require early diagnosis and continuous monitoring of diabetic patients, but the disease shows few symptoms which makes it difficult to detect until it is too late to provide treatment.

Diabetic retinopathy occurs when diabetes damages the tiny blood vessels inside the retina[8], the light sensitive tissue at the back of the eye. It commonly affects both eyes and can lead to vision loss if not properly treated.

Poorly controlled blood sugars, high blood pressure and high cholesterol increase the risk of developing DR.This tiny blood vessel will leak blood and fluid on the retina leading to the formation of features such as micro-aneurysms, hemorrhages, hard exudates, cotton wool spots or venous loops[11].Diabetic retinopathy can be classified as non-proliferative diabetic retinopathy (NPDR) and proliferative diabetic retinopathy (PDR). Depending on the presence of features on the retina, the stages of DR can be identified.

The various features of Diabetic Retinopathy include micro aneurysms and neovascularization, intra-retinal hemorrhages, exudates, red lesion, area, perimeter, width and branching angles[12]. The micro aneurysms are deformations in walls of blood vessels. The hemorrhages are formed due to leakage of blood from the damaged capillaries. The hemorrhages are divided into three categories: dot, flame and blot. Hard exudates are bright yellow or white colored objects on the retina.

The types of DR are based on damage of blood vessels, number of micro aneurysms and haemorrhages[13]. The type of DR is divided into following levels of DR.

1. Normal: If no DR sign is observed.
2. Mild: Only microaneurysms are present.
3. Moderate DR: If the number of microaneurysms and haemorrhages are less.
4. Severe DR: If the number of micro aneurysms and haemorrhages are more.
5. Proliferate diabetic retinopathy (PDR): It results due to the formation of abnormal new blood vessels. It is the sever stage of retinopathy and new blood vessels start growing anywhere in eye[14].

Currently, diagnosis of DR is performed by manual evaluation of retinal images by experts who identify presence of lesions in the eye such as micro-aneurysms (red lesions), hemorrhages and exudates (bright lesions).This process is slow and requires time. Further, the expertise and equipment required for such evaluation may be lacking in many areas with a large DR affected population.

As the number of individuals with diabetes continues to grow, the infrastructure needed to prevent blindness due to DR will become even more insufficient.The need for a comprehensive and automated method of DR screening has long been recognized, and previous efforts have made good progress using image classification, pattern recognition, and machine learning. In this paper a machine learning algorithm is developed using CNN (Convolutional Neural Network)[2] for detecting the severity of the disease.

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II RELATED WORK

Various research have been carried out on methods for classifying images of retina for detecting Diabetic Retinopathy. Artificial Neural Networks have already been applied widely in medical imaging, but special kind of neural networks known as Deep Networks especially CNN[1](Convolution Neural Networks) are producing outstanding results in automatic features extraction and classification.

CNN is one of the most popular neural network model used for image classification. CNN uses few parameters which helps in the reduction of time and data required to train. Automated detection of DR images helps in early treatment of DR efficiently. Early detection and treatment are important for delaying or preventing visual impairment.Deep CNNs structures were originally used for solution of natural image classification, and recent research has made rapid progress in working on DR images classification.

M .Partha Sarathietal [2] proposed a machine learning model for detecting DR. This framework utilizes Contrast Limited Adaptive Histogram Equalization (CLAHE) for eliminating the background from the source image and enhances the foreground blood vessel pixels, Tandem Pulse Coupled Neural Network (TPCNN) model is endorsed for automatic feature vectors generation, and Deep Learning Based Support Vector Machine (DLBSVM) is proposed for classification and extraction of blood vessels.

Nazir Aun Irtaza[4] proposed a technique to precisely detect the various stages of DR. The concept of tetragonal local octal patterns (T-LOP) is introduced for feature extraction. T-LOP is a novel image representation scheme that particularly is designed for analyzing the fundus images that is a composition of blood vessels and textured lesion and are classified through machine learning model.

In 2012, Krizhevsky et al[18] developed an architecture for the Deep Convolutional Neural Network. This laid the foundation for the traditional CNN, a convolutional layer followed by an activation function followed by a max pooling operation.

Zilly et al[15] introduced a segmentation method based on a multi-scale two-layer CNN model that is trained with boosting. First, the region around the retina is cropped, down-sampled by a factor of 4, converted to L*a*b color space and normalized. Then, the region is processed by entropy filtering to identify the most discriminative points and is passed to the CNN model, which is trained using the gentle AdaBoost method. The logistic regression classifier produces a probability map from the output of the CNN model. This method was evaluated with DRISHTI-GS dataset using performance metrics: F-score, overlap measure and boundary error.

Nadeem Salamat [5] analyzed the algorithms for automated detection and grading of DR algorithms. The various features and types of DR and the essential image pre processing terms used in these algorithms were described. various algorithms were discussed in this paper and their performance measures were compared and tabulated.

Shaohua Wan[3] proposed an algorithm for automatic diagnosis of DR using fundus images classification. The latest CNNs model such as AlexNet,VggNet,GoogleNet and ResNet were used for DR Detection. Deep CNNs structures were originally presented for the solution of natural image classification, and recent research has made rapid progress in working on DR fundus images classification.

Wang et al[7] adopt a CNN (LeNet-5) model to extract image features for addressing blood vessel segmentation. These methods has some limitations. Firstly, because of the features of dataset are extracted manually and empirically, their accuracy can't be guaranteed. Secondly, the data sets are small in size and low in quality, usually only a few hundred or even dozens of fundus images with relatively single collection environment, bringing difficulties to compare the performance of algorithms in the experiment.

One of the most important network models, ResNet [6] was proposed in 2015, which further enhances the performance of CNNs in image classification. The performance measures such as sensitivity, specificity and accuracy were measured and compared with each other.Transfer learning and hyper-parameter tuning are adopted and the experimental results have demonstrated the better accuracy than non-transferring learning methodology on DR image classification.

Residual Neural Network (ResNet) is put forward by Kaiming [6].By means of using the Residual Unit, it successfully trains 152 deep neural network and get a 3.57% error rate classification for top 5 classes, which is quite prominent though the number of parameters is less than VGGNet[16]. The core of ResNet, uses the skip connection to let some input into the layer indiscriminately in order to integrate the information flow which can avoid the loss of information transferring in the layer and gradient vanishing problem. The most effective way is still to increase more label data, to achieve a higher training accuracy and the approximate level of traversal. The ResNet structure can greatly accelerate the training of ultra-deep neural networks and improve the accuracy of the model.

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III.PROPOSED METHOD

A.MODEL

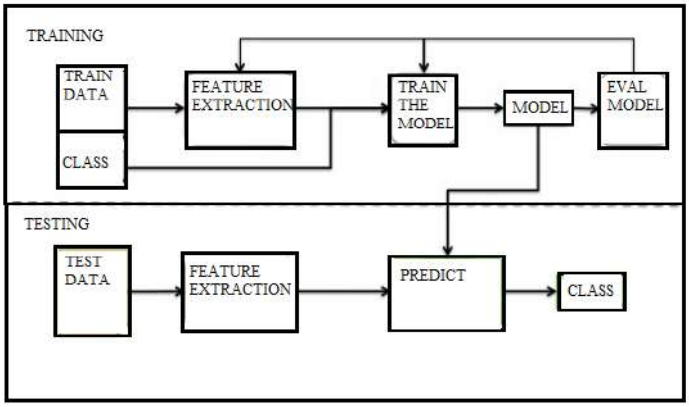


Fig.1 Overall Model

The machine learning model extracts important features from the training data and builds the model using Convolutional Neural Network. The model then classifies the test data into various classes of severity.

B.NETWORK ARCHITECTURE

ResNet follows VGG's full 3×3 convolutional layer design. The residual block has two 3×3 convolutional layers with the same number of output channels. Each convolutional layer is followed by a batch normalization layer and a ReLU(Rectified Linear Unit) activation function. Then, these two convolution operations are skipped and added to the input directly before the final ReLU activation function. This kind of design requires that the output of the two convolutional layers be of the same shape as the input, so that they can be added together. An additional 1×1 convolutional layer is introduced to transform the input into the desired shape for the addition operation.

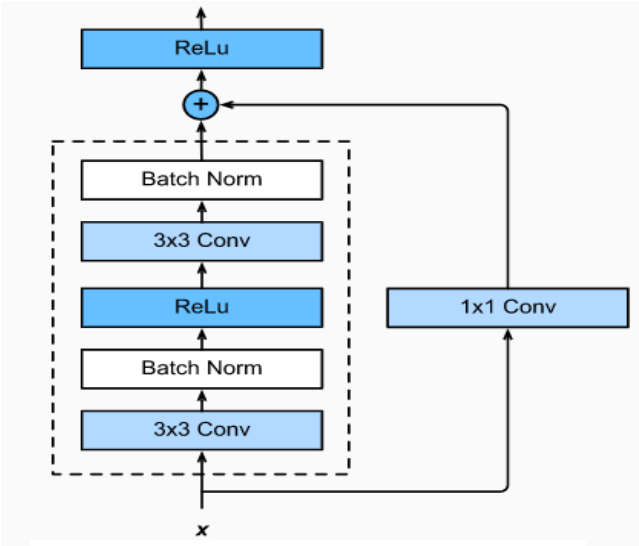


Fig.2 ResNet block with 1*1 convolution

IV.EXPERIMENTS

A.DATA SET AND TOOL

The Data for the machine learning model is obtained from Kaggle[6]coding website.The images were provided by Aravind Eye Hospital in India. It consists of retina images of patients of various classes of severity of Diabetic retinopathy. The training set consists of 3662 images and testing set consists of 1992 images. Both the training set and the testing set image contains a unique id code and a corresponding class number. The images were trained in python using ANACONDA interface.

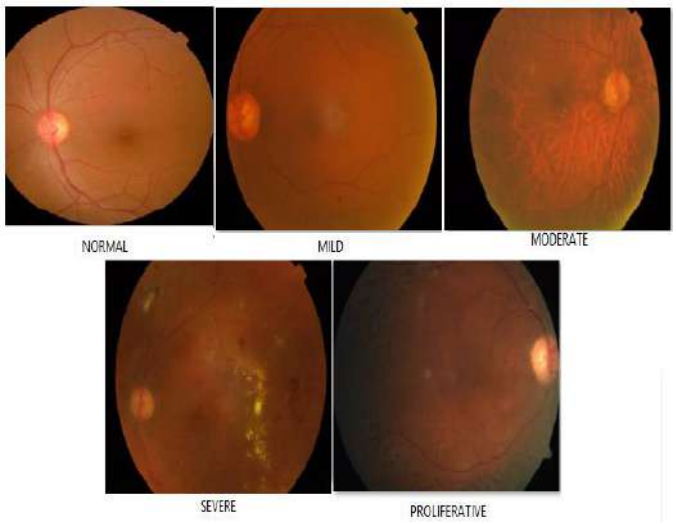
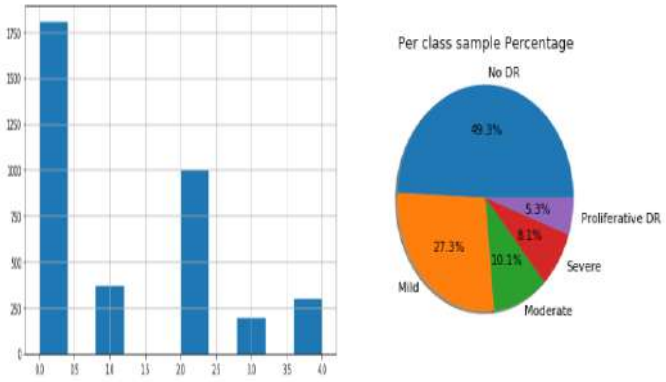


Fig.3 Stages of Diabetic Retinopathy

B.DATA DESCRIPTION

From Training Data the number of images corresponding to each severity level was plotted. The data from the training set is used to train the model. The maximum number of images were of the severity level 0. The minimum number of images were of severity level 4. The mean and standard deviation of the data was found to be 1.26980 and 1.29840.



class

Fig.4 Data Visualization

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C.DATA PREPROCESSING

The data set consists of images of various sizes and varied levels of lighting conditions. This affects the pixel intensity values and makes it difficult for classification. The pixel intensity of images was normalized using OPEN CV package.

a) Cropping:The black border around the images were cropped as they are unnecessary for classification purpose.

b)Resizing:The images in the dataset were of different resolution, so the images were resized to a common resolution of 512*512 so that the model could easily classify the images.

c)RGB to Grey scale: The RGB image is converted to Grey scale image so that the features are more visible. RGB image contains lots of data which may not be required for processing. By converting RGB image into Gray scale lot of information which are not required for processing are discarded thereby improving the computational power.

d)Data Augmentation: Data augmentation is done to expand the size of the training data set by flipping and rescaling the data.

D.NETWORK PARAMETERS

The various parameters for the model were fixed similar to Res Net architecture[6] and are as follows: batch size(8),epochs (20),learning rate(0.0001),height(512),width(512),canal(3), warm up learning rate(0.001) and warm up epochs(2).

E.TRAINING AND TESTING

The machine learning model was trained using ResNet. A low learning rate of 0.0001 was used for 20 epochs to stabilise the weights. The network was trained on training set of images through stochastic gradient descent and the performance of the network is monitored on the valdation data set.The whole training takes about 9 hours to complete.After training the model the testing data which consists of about 1929 images is provided.the machine learning model is required to classify the images according to their severity level.

V RESULT AND ANALYSIS

A confusion matrix is developed which provides data regarding the performance measures of the model. Confusion matrix is a simple way to show the results of the prediction model.The main elements of the confusion matrix are True Positive(TP),True Negative(TN),False Positive(FP) and False Negative(FN).The diagonal elements of the confusion matrix represents the True positive values of the respective classes.The various performance measures include sensitivity,specificity and accuracy can be calculated from the confusion matrix. sensitivity is defined as the number of images correctly identified as having DR out of the true amount with DR, and specificity as the number of images correctly identified as not having DR out of the true amount without DR.Hence the performance measures can be calculated from the confusion matrix.The model has a accuracy of 93%. The sensitivity and specificity of the model was found to be 52% and 96%.

0.98	0.01	0.00	0.00	0.00
0.01	0.54	0.42	0.00	0.02
0.00	0.03	0.94	0.01	0.03
0.00	0.00	0.63	0.18	0.20
0.00	0.01	0.39	0.04	0.56

0-No DR 1-Mild 2-Moderate 3-Severe 4-Proliferative DR

Fig.5 Confusion Matrix

A curve was plotted between Training and validation accuracy. The curve shows the intersection of validation accuracy and accuracy. The training set is used to train the model, while the validation set is only used to evaluate the model's performance. After every epoch, the model is tested against a validation set and validation accuracy is calculated. The validation accuracy provides an estimate on how the model is at predicting output for the given input. The training and validation accuracy of the machine learning model was found to be 97% and 93%.

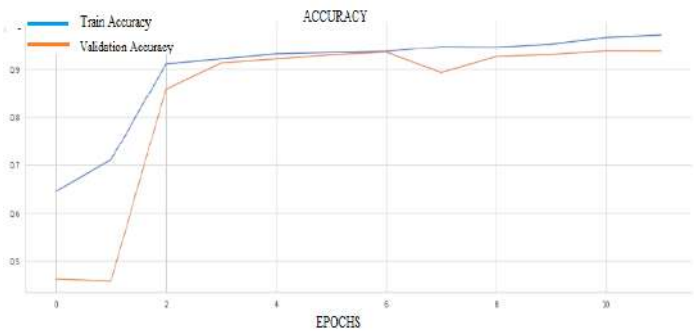

Fig.6 Training versus Validation accuracy

The test images were classified into various classes according to the severity ranging from 0 to 5 and are plotted. The maximum number of images belongs to class2(moderate level) which consists of about 1200.The minimum number of images belong to class 4 (proliferative) which is about 400.The number of images in class 0,1 and 3 are 250,100 and 210.

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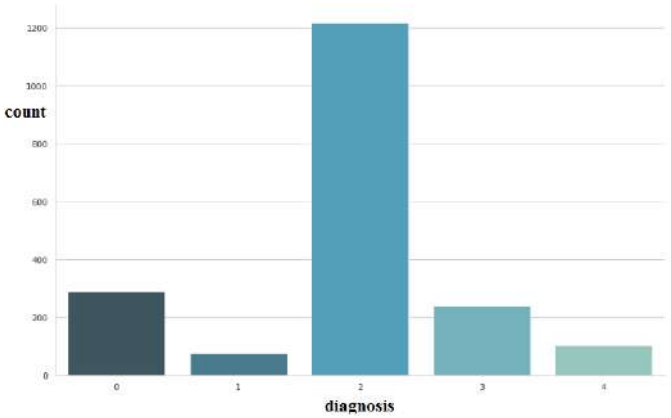

Fig.7 Classification of DR

VI.CONCLUSION AND FUTURE WORK

The machine learning model network proposed in this paper was able to learn the features required to classify the fundus images, accurately classifying the majority of proliferative cases and cases with no DR. In this paper, a network architecture based on ResNet was used to classify DR into five classes. The model classifies the images into required severity level. The various performance measures such as accuracy, sensitivity and specificity were calculated using confusion matrix and the training and validation accuracy were plotted. The training and validation accuracy was found to be 97%and 93%.The machine learning model makes it possible to classify thousands of images in a short period of time thereby improving the diagnostic efficiency of the process. Classification technique used in the study helps in building the prediction model.

To improve the accuracy of the model there needs to be more individual data collected and a more deeper network should be developed. Continued research in this area by collecting more data can refine the model. The machine learning model can also be extended to other diseases affecting eye such as glaucoma.

VII.AUTHOR CONTRIBUTIONS

Kishore.M.V: Implementation, Data Analysis and interpretation, Selection of algorithm, writing paper, Submission of paper

Mahesh S: Interpretation, Implementation, selection of algorithm, critical review of the paper

VIII.REFERENCES

[1] Varun G. and Lily P. A Deep Learning based Computer-Aided Diagnosis Systems for Diabetic Retinopathy: A Survey. arXiv preprint arXiv:1811.01238.

[2] M .Partha Sarathietal Retinal blood vessel segmentation from diabetic retinopathy images using tandem PCNN model and deep learning based SVM. Optik, 199, 163328.

[3] Wan, S., Liang, Y., & Zhang, Y. (2018). Deep convolutional neural networks for diabetic retinopathy detection by image classification. Computers & Electrical Engineering, 72, 274-282.

[4] Nazir, T., Irtaza, A., Shabbir, Z., Javed, A., Akram, U., & Mahmood, M. T. (2019). Diabetic retinopathy detection through novel tetragonal local octa patterns and extreme learning machines. Artificial intelligence in medicine, 99, 101695.M

[5] Salamat, N., Missen, M. M. S., & Rashid, A. (2019). Diabetic retinopathy techniques in retinal images: a review. Artificial intelligence in medicine, 97, 168-188.

[6] He, K., Zhang, X., Ren, S., & Sun, J. (2016). Deep residual learning for image recognition. In Proceedings of the IEEE conference on computer vision and pattern recognition (pp. 770-778).

[7] Wang S , Yin Y , Cao G , Wei B , Zheng Y , Yang G . Hierarchical retinal blood vessel segmentation based on feature and ensemble learning. Neurocomputing 2015;149:708–17

[8] Klein, R., Klein, B. E., & Moss, S. E. (1984). Visual impairment in diabetes. Ophthalmology, 91(1), 1-9.

[9] http://kaggle.com

[10] Ong, G. L., Ripley, L. G., Newsom, R. S., Cooper, M., & Casswell, A. G. (2004). Screening for sight-threatening diabetic retinopathy: comparison of fundus photography with automated color contra. American journal of ophthalmology, 137(3), 445-452.

[11] Faliagka, E., Syrimpeis, V. N., Tsakalidis, A., Matsopoulos, G. K., Tsaknakis, J (2010, January). DIAGNOSIS-A Global Alignment and Fusion Medical System. In International Conference on Health Informatics (Vol. 2, pp. 21-28). SCITEPRESS.

[12] Zhang, M. (2008). Blood vessel detection in retinal images and its application in diabetic retinopathy screening. Texas A&M University.

[13] Wilkinson, C. P., Ferris III, F. L., Klein, R. E., Lee, P. P., Agardh, C. D., Davis, M., ... & Group, G. D. R. P. (2003). Proposed international clinical diabetic retinopathy and diabetic macular edema disease severity scales. Ophthalmology, 110(9), 1677-1682.

[14] Venkatesan, R., Chandakkar, P., Li, B., & Li, H. K. (2012, August). Classification of diabetic retinopathy images using multi-class multiple-instance learning based on color features. In 2012 Annual International Conference of the IEEE Engineering in Medicine and Biology Society (pp. 1462-1465). IEEE.

[15] Zilly, J. G., Buhmann, J. M., & Mahapatra, D. (2015, October). Boosting convolutional filters with entropy sampling for optic cup and disc image segmentation from fundus images. In International workshop on machine learning in medical imaging (pp. 136-143). Springer, Cham.

[16] Shin, H. C., Roth, H. R., Gao, M., Lu, L., Xu, Z., Nogues, I., ... & Summers, R. M. (2016). Deep convolutional neural networks for computer-aided detection: CNN architectures, dataset characteristics and transfer learning. IEEE transactions on medical imaging, 35(5), 1285-1298.

[17] Raman, R., Rani, P. K., Rachepalle, S. R., Gnanamoorthy, P., Uthra, S., Kumaramanickavel, G., & Sharma, T. (2009). Prevalence of diabetic retinopathy in India: Sankara Nethralaya diabetic retinopathy epidemiology and molecular genetics study. Ophthalmology, 116(2), 311-318.

[18] Krizhevsky, A., Sutskever, I., & Hinton, G. E. (2012). Imagenet classification with deep convolutional neural networks. In Advances in neural information processing systems (pp. 1097-1105)

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Exploration and Analysis of Advanced Green Tools Applicable for Process Industries

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***Abstract*— Supply chain involves activities ranging from suppliers to manufacturers and finally delivering to the consumers. Supply chain management carries out the management of various supply chain processes effectively and efficiently. Collaboration of green component to the supply chain practices of lean manufacturing, material sourcing, design, transportation and marketing activities, broadens the scope of achieving sustainability. The article aims at studying how the" Greening" of the supply chain could be achieved by successful application of green tools in process industry.**

Keywords—Supply Chain Management, GSCM, SDGs, Green tools

I. INTRODUCTION

With the increasing depletion of natural resources, pollution and environmental issues, there is a growing concern among the industrialists for manufacturing green products and applying green practices to the industry. With the introduction of sustainable development goals (SDGs) in "Technology, innovation and infrastructure", companies are becoming responsible for steering the industries to the adoption of sustainable practices. Industry 4.0 necessitates the integration of technological tools with supply chain practices, in gearing towards sustainability. This could be better applied in process industries in achieving better operational efficiency and effectiveness in the supply chain. This literature discusses the application of green tools in all dimensions of the process industries, their green specialties, along with their pros and cons.

II. LITERATURE REVIEW

The researcher Hervani et al favored the addition of green component to supply chain management by influencing and instituting it to the natural environment. According to them, it can be defined as: Green Supply Chain Management (GSCM) = Green Purchasing + Green Manufacturing/ Materials Management + Green Distribution/ Marketing + Reverse Logistics. Green purchasing refers to use of products/raw materials that can be procured with minimal environmental impact(2015).The various sustainable manufacturing approaches that can be considered in the implementation of green practices include reduction in use of energy, water and emissions. To improve supply chain efficiency, reverse logistics means like recycling or reusing the products plays a crucial role. Raghuram et al (2017) focused on the emerging trends in the supply chain management with the emerging I.T. services. He stressed on the fact that the development in the supply chain management sector has created a competitive environment between the industries. So in order to compete in this environment, industry need to have complete knowledge in the emerging technologies in the supply chain management. Masoumik et al (2015) discussed the factors that should be considered to make the GSCM initiatives strategically beneficial.

III.PROCESS INDUSTRIES AND THEIR GREEN SPECIALITIES

The industries in which the primary production processes are continuous is called as a process industry. The production can also occur on a batch of materials that are indistinguishable. All process industries does not follow an ideal process layout. Depending on the manufacturing processes and conditions (like the job to be moved around frequently) the layout may be a product layout in a process industry.

A. Process Industry with Product Layout

In a process layout similar tools and supplies are kept together at one place. But to reduce frequent movements of the job, this process layout is replaced by a product layout. A product layout is one in which rather than having a specific section for each group of similar tools and supplies forming assembly line in which the required tools and supplies are located at each section of the assembly line, based on where product is in production. So an industry does not get its name from the layout but from the nature of operations done in the industry.

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Such an industry should make use of green practices to reduce environment pollution.

B. Green Practices of Process Industry

Green practices of a process industry involves practices done to reduce impact of production on environment. These practices includes reducing use of natural resources, reducing production of waste and e-waste, recycling and reusing waste, reducing use of harmful chemicals, reducing emissions and pollution etc. In a process industry with a product layout, the following of such green practices is of at most importance for the company to balance its emissions and pollution so as to improve impact of their production process on the surrounding environment.

IV. GREEN TOOLS FOR PROCESS INDUSTRIES

A. Radio Frequency Identification

The implementation of various technologies in the supply chain has worldwide acceptance. It helps in improving the efficiency of supply chain as well as the reduction of costs. One of the most widely used technologies is the RFID technique or the radio frequency identification technique.

RFID is actually a form of data communication between RFID scanner and RFID tag. The tags are placed on any number of items and stores information regarding the order ID number, order status, location etc. When the RFID scanners scans an item, it reads the information from the tag, thus helps in forecasting and planning. RFID helps in tracking the location of the products as well as the quantity of the products, thereby reducing the excess-stock in the system.

The supply chain in an industry faces major problems related to delay in production, excess stocks, delivery delay, out-of-stock etc. These problems can be easily rectified through the use of RFID.

It tracks the inventories so that excess stock could be reduced by removing the inventory or out-of-stock problem could be rectified by increasing the production. The RFID tag also provides information regarding the specifications of the products like color, price, date of purchase etc. It is actually a paper-less approach, thus focusing on a greener supply chain. Another problem that a supply chain face is the human errors. RFID stores the information in tags without relying on manually written tables, thus advancing into an analog supply chain. The retailers could easily locate the product thus providing product visibility and transparency. Also, the involvement of humans in the supply chain could be easily reduced with the advancement of RFID technology. The information in the RFID tags could be used to identify items that are out of season or items that have a prolonged expiration date.

Another technology similar to RFID is the RFDC or Radio frequency Data Capture. This technology also helps in knowing the status of items by the process of data collection.

Another major advantage of this technology is that it focuses on the implementation of sustainable practices in the supply chain. RFID technology counts the right amount of products at the right time in the right place, thus reducing the waste of natural resources. By properly managing the inventory, the waste, emissions as well as energy use could be reduced. It also makes the information flow faster without the use of paper thus reducing the destruction of trees. Since the exact location and quantity of the products are known, the transportation costs is decreased, thereby reducing carbon dioxide emissions. It identifies the opportunities for reuse, recycle and reduce.

Since, RFID tags are not sustainable, it paved the way for the development of ECO RFID tags. The ECO RFID tags are produced on renewable paper label, without the usage of plastic or any other harmful chemicals. Thus, the tags are recyclable and renewable. It reduces the carbon footprint. Thus, 'Green Tags' utilizes paper and aluminium for its development by increasing the environmental performance.

B. Service - Oriented Architecture

Service - Oriented Architecture is an architecture in which the business functions are made available to the users or consumers on an IT platform. It could be used to share information between the systems or departments which is entirely different from the silo system.

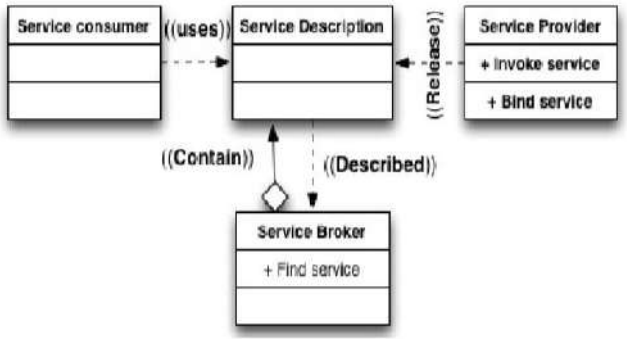

Fig 1 Conceptual model of SOA architecture

Source:- [8]

In SOA, there are three primary elements which include service provider, service consumer and service broker. The service provider prepares a service description in the service registry. The service consumer picks up and uses the required service from the service register by invoking it. The service broker is not necessarily essential as the consumer could get the service directly from the service provider.

The organizations which run based on the silo system face problems in efficiency and integration. This could be easily resolved by disintegrating the silo system into shared system.

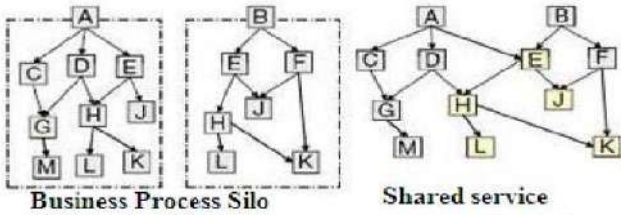

Fig 2 the shared capability by shared services
Source: - [8]

In the supply chain context, the integration of various processes is difficult to operate i.e. the order entry, billing, shipping etc. require right amount of shared information, which is impossible in silo system. SOA adoption could easily cooperate almost all elements in the supply chain, thereby reducing the cost and improving the efficiency. The faster transfer of information helps in the early delivery of the product, as well as in inventory control. The paper-less flow of information makes it more ecologically sustainable without causing destruction to the trees.

In an SOA adopted system, the dependency between business functions and applications could be decreased by the usage of shared services.

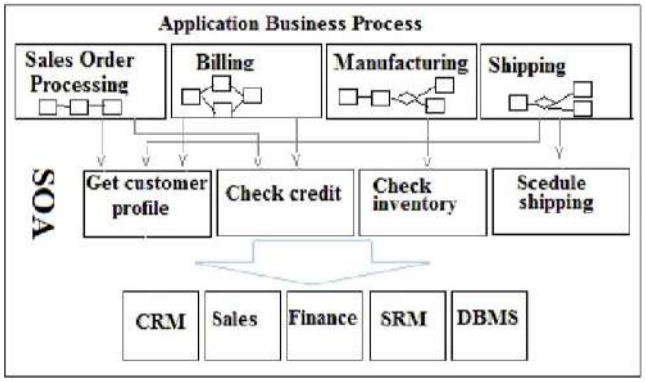

Fig 3 the reusable and shared services in SOA approach

Source: - [8]

Therefore, the integration of various supply chain processes is perfectly possible by using SOA along with IT service.

C. *Artificial Intelligence*

Artificial Intelligence, referred as AI is a technology that works similar to the functionalities in the human brain. It utilizes a set of learning algorithms and mimics the human actions. AI contains related methodologies which include machine learning, neural network, genetic algorithms etc.

AI's can be easily implemented in a supply chain for prediction, optimization, simulation etc. With the help of AI, an expert system could be designed in order to select the appropriate suppliers. Also, various expert tools could be developed for improving the supplier performance as well as reducing risk. This can be done for the supplier entity for improved efficiency.

In the case of distributors or distribution in the supply chain, various genetic algorithms have been used successfully. Distribution could be made more cost effective by finding optimum routes using vehicle routing methods. The VRP method finds routes with minimum costs, which starts with a central depot, distributes the items to the customers and finally returns back to the depot. Another advancement is the application of robotics in supply chain where self-driving vehicles could be promoted. These applications actually help the logistics function more efficient and cost effective.

AI along with natural language processing (NLP) could be used to extract data from the customers regarding the type of product, tastes and preferences etc. Machine learning or ML algorithms could be utilized to analyze the future trends and finally make decisions. Also, it could be used along with AI to forecast the demand. It ensures the production of right amount of goods at the right time in the right place. In the warehouses, various robotic vehicles could be used to store and pick up the goods.

AI helps in responding to the customers quickly, thereby reducing the costs and inventory. AI actually helps in transforming the distribution completely automated, by utilizing drones as well as robotic vehicles. Amazon has effectively utilized this facility in their warehouses.

Another major specialty is the improved customer experience. An example is Amazon's voice-based service used to track orders using Alexa. The customers could easily communicate with Alexa in order to track the parcels.

In the context of green supply chain, AI models could be used to identify the required raw materials. It also provides the optimum operating parameters in order to reduce energy usage. It also detects the product defects earlier thus reducing the wastes dumped into the soil. The usage of drones or robotic vehicles could reduce the carbon dioxide emissions thereby making the process more sustainable.

D. *Internet of Things*

It is a collection of interrelated physical devices for data transfer, tracking and monitoring. They measure various environmental factors like light, temperature, humidity etc. IoT devices include wireless sensors, software, actuators, and computer devices. IOT drives sustainability in supply chain with efficient management of resources like fossil fuels, water, and space. It can be used to track products, maintain inventory, keep a record of buyers and suppliers, and reduce theft and mishandling, in addition to many other benefits

IoT tech helps finding better driving routes and directing merchandise according to demand, which significantly reduces fuel consumption and controls greenhouse gas emissions. The automatic driverless vehicles can be introduced to move goods around 24/7, increasing operational efficiency and avoiding traffic jams. The use of remote-piloted drones eliminates the need of shuffling the products multiple times to various warehouses and distribution centers.

Individual monitoring of the different layers in supply chain avoids delays and setbacks. Reduction at any point in the section can be compensated by other sections pick up the deficit. This avoid delays and built up of inventory or excess materials at different sections in the supply chain reducing energy wastage and increasing efficiency.

By utilizing IoT over satellite, will have a competitive advantage in achieving sustainability by strategic collaboration and management decisions.

For perishable and environmentally sensitive products, monitoring the factors like temperatures, humidity and other conditions can be helpful for maintaining risk control." Despite, IoT can also measure vibration and shocks during

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shipment. This lets the transporter and goods receivers know about the delivery, shipment and replacement of products in advance and better planning and control. When block chain collaborated to this increases the transparency and security. This could reduce the generation of waste in the supply chain loop.

E. Software as a Service

SaaS is a software application delivery model where the web-based application developed by the vendor used by customers through the internet. Customers pay for using it rather than owning it. It is a cloud computing technique that could improve the collection, sharing and exchange of information more efficient within the chain. SaaS improves transportation management applications like load planning, shipment scheduling, and container tracking. Checking into each carrier websites is time consuming and tedious. The centralized portal improves energy management, shipment locations and increases operational efficiency. Integration to large carriers eliminates multiple logging into websites but creates the problem of B2B integration. A mapping of data between the customers and the transportation vendors is a must. In this case SaaS provides a "network effect" to all participants in the chain. SaaS models can also be implemented in fields of CRM, ERP and SFA.

F. Big Data

With development of Industry 4.0, massive chunks of data generated has become the resource for wealth for future development in industries. Big data analytics (BDA) is a kind of advanced analytics, involving applications like predictive models, statistical algorithms, what-if analysis etc., that helps organizations analyze and draw conclusions from the data to make informed decisions in the future. With structured and unstructured data making it difficult for analysis, supply chain helps it manipulate and integrate the data adaptable to the requirements of end users.BD concept involves collection, analyzing, sharing, processing and exchange of large data sets in the organization. BDA helps in decision making, by drawing critical information from large sets of structured, unstructured and historical data, to predict and forecast future likelihood events in real time.BD impacts on sustainable investment in supply chain by shortening the SC layers by integration of economic marginalization and planning smart sustainable investments.

G. Electronic data Interchange

EDI or Electronic data interchange is simply transfer of data or information that are important in the business processes of the two companies with the use of any format. It helps in reducing use of resources that cannot be maintained for a long time e.g. use of information sent in electronic format using computers than those sent in physical form (through paper). Companies using EDI for information transfer are called trading partners. Two examples for EDI transfers are bill of materials and production order (PO). EDI helps in transfer of data through a full "paperless" interchange while also making the information standard. In the traditional data transfer, EDI replace the construction and management of documents associated with it.

EDI has been widely used by companies in supply chain management (SCM) like for purchase orders and invoices for inter-changing information and transaction processes. The companies inter-change valuable data that makes the business processes to work smooth and effectively with minimum wastage of time and resources. EDI will provide productive and correct information about company's sales of product. This makes the supply chains much simple and faster. The areas where EDI acts are payments done online, tracking of shipments (from both the buyer and seller), EPOS. It is also used in getting data related to accounts, payment balances, trading etc. There are many advantages in using EDI for transfer of information, major ones being productivity increase, minimized work on paper and its usage, correct tracking of resources, good tracking of customers, cost effectiveness etc. It also helps in minimizing wrong calls in the S & D (supply and demand) data which leads to improvement of supply chain information.

H. Barcode Scanner

Nowadays technologies are improving at a faster pace. The bar codes are thus evolving in the process. The companies are struggling to get SCM to pick up speed because customers are expecting instant gratification at every turn of customer-manufacturer returns. Any new innovation in bar code scanning will make the efficiency of supply chain to increase. New technologies in bar code scans are changing how distribution centers works, thereby making sure that the correct products will reach the correct customers in much faster taking less time than before. These are the ways barcodes help in improving supply chain management:

1. better management of data of tracking products and inventory
2. Even with damaged barcodes, we get better accuracy
3. At every stage, better transparency (more detail on products)

The bar code scanner are machines that helps to easily read the number series or lines of codes that will provide us with the details regarding a product. These lines of codes can be horizontally (ladder arrangement) or vertically (fence arrangement) arranged with different widths. This codes will make the operations to get faster for e.g. a product with these lines of code can be easily tracked back to its stock code in distribution centers and hence its stock can be grouped and identified with much ease thereby updating the stock record upon further receiving or dispatching of products.

Nowadays bar codes are commonly used in big retail shops (e.g. super markets) and malls. During the billing process, the lines of code (or bar code) of the product is scanned. This minimizes the complex process of billing and time taken for it, thereby increasing ease in SCM operations.

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I. Cloud Computing And 3D Printing

Cloud Computing is the use of software and hardware to deliver a service via a network mostly the internet. With cloud computing, users can have access to files and use applications from any device using the Internet. An example of a cloud computing provider is G-mail from Google.

The cloud model based on service is classified as: 1.IaaS (infrastructure-as-a-service) 2.PaaS (platform-as-a-service) 3.SaaS (software-as-a-service) or, storage, database, information, process, application, integration, security, management, testing-as-a-service. Cloud model can be classified based on deployment model as: 1.public, 2.private cloud provides the same benefits of Public Cloud, but uses dedicated, private hardware. 3. Hybrid cloud of course, means, using both private and public clouds, depending on their purpose. 4. Community cloud implies an infrastructure that is shared between organizations, usually with the shared data and data management concerns.

The most common cloud service is that one offering data storage disks and virtual servers, i.e. infrastructure. Examples of Infrastructure-as-a-Service (IaaS) companies are flexi scale, Rackspace, amazon.

Additive Manufacturing is a process by which digital 3D design data is used to build up a component in layers by depositing material. The advantages of Additive Manufacturing lie in those areas where conventional manufacturing reaches its limits. The technology is of interest where a new perspective to design and manufacturing is required so as to come up with feasible solutions. The technology is of viable interest where a new method to design and manufacturing is required so as to come up with solutions.

V. PROS AND CONS OF GREEN TOOLS IN PROCESS INDUSTRIES

A. Radio Frequency Identification Technique

Table I (RFID)

PROS	CONS
• Helps in inventory control which in turn offers greater visibility, thereby giving better customer satisfaction. • Helps in identification and tracking of items. • Performs real-time data collection. • RFID tags are more durable than barcodes.	• Doesn't provide security measures, making the technology prone to viruses. • Initial investments as well as developmental costs are high. • New technology may cause RFID to become outdated.

B. Service Oriented Architecture

Table II (SOA)

PROS	CONS
• Promotes easy integration of services. • Better sharing of information. • Doesn't depend upon the location of services.	• The interaction between services becomes heavy and lead to increased time. • Greater implementation costs. • Highly complex architecture.

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C. Artificial Intelligence

Table III (AI)

PROS	CONS
• Can easily extract data from the customers. • Transforms every traditional process to an automated one. • Easily detects the defects of various products. • Improves the efficiency of supply chain. • Timely delivery of items to the customers.	• Initial investments and maintenance costs are huge. • Loss of information due to machine damage. • AI implemented machines are even misused. • Requires the assistance of experts. • Difficult to control.

D. Internet of Things

Table IV (IoT)

PROS	CONS
• Offers better communication between the departments. • Provides end-to-end visibility of the products. • Helps in better stock management. • Less human intervention leading to increased automation.	• Doesn't provide much security. • Managing and analyzing the data is difficult. • Arises compatibility issues. • Information collected is not as safe as they are prone to unauthorized intruders.

E. Software as a Service

Table V (SaaS)

PROS	CONS
• Provides greater level of accessibility as every operation is done online. • Dedicated team to ensure security. • Better continuity as the cloud technology is enhanced.	• Downtime occurs as many clients are serviced at the same time. • Has only minimal control over the servers. • Data localization is possible and thus much complicated.

F. Big Data

Table VI (BD)

PROS	CONS
• Analyzes the trends and patterns and helps in demand forecasting. • Uses past performance of the products, thereby increasing effectiveness in sourcing of products. • Warehouse management is appreciable. • Real-time sharing of the data resulting in better distribution and logistics.	• Future predictions of human behavior are difficult. • Results in data bias since different departments concentrate on particular metrics. • Increased cost. • Real-time big data requires major changes. • Data-storing warehouses are costly to both purchase and maintain.

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G. Electronic Data Interchange

Table VII (EDI)

PROS	CONS
• Resource and administration costs are lower. • Various business operations are performed at a much faster rate. • As paperwork is not done, human errors are least. • Automatic entry of data.	• Setup costs are huge. • The network to transmit and receive information is highly complex. • Initial setup requires increased amount of time. • Huge investment in security measures and computer networks.

H. Barcode Scanner

Table VIII (BS)

PROS	CONS
• Can easily scan and track bulky items. • Better to scan inventory in a warehouse as it's handheld. • Inexpensive multi-use flexible scanners.	• Hard to scan items that are far away (20 feet). • Not a hands-free scanner, thus reducing productivity. • Not much secure. • Prone to damage easily.

I. Cloud Computing

Table IX (CC)

PROS	CONS
• Core focus is not on managing data centers, but on business. • New applications could be easily developed. • The expenses never go unutilized. • Greater flexibility and efficiency.	• Cloud infrastructure is not much secure. • Not suitable for all the workloads. • Server downtimes are quite often, since the system depends on reliable internet connection. • System is prone to attacks as the data can be accessed from anywhere.

J. 3D Printing

Table X (3D P)

PROS	CONS
• Saves transportation costs and total logistics expenses. • 3D components used in vehicles saves fuel and reduces CO_2 emissions. • Better for limited mass production. • Implementation of just-in-time system manages inventory.	• Raw materials are costly and hard to obtain. • Speed of the production is less. • Equipment also requires greater initial investment. • Required 3D softwares are not easily available.

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VI. CASE STUDY

A. Purpose of the study

The health sector is one of the main sectors that consists of businesses that provide medical equipments, medical services, drugs and other facilities related to healthcare. It is the largest and most complex sector that promotes the well-being of the citizens. One of the problems that emerges out from the modern healthcare facilities is the production of large amounts of solid wastes including drugs, electronic devices, bandages, plastic etc. The disposal of these scrap materials have become a major issue of concern. The accumulation of these wastes have caused very many health issues in the society.

Many industries in the medical field have utilized various advanced green technologies in order to cope up with the sustainability issue.

B. Research Methodology

Let's consider a framework to identify the various green practices recommended in an industry in order to deal with the above mentioned issue.

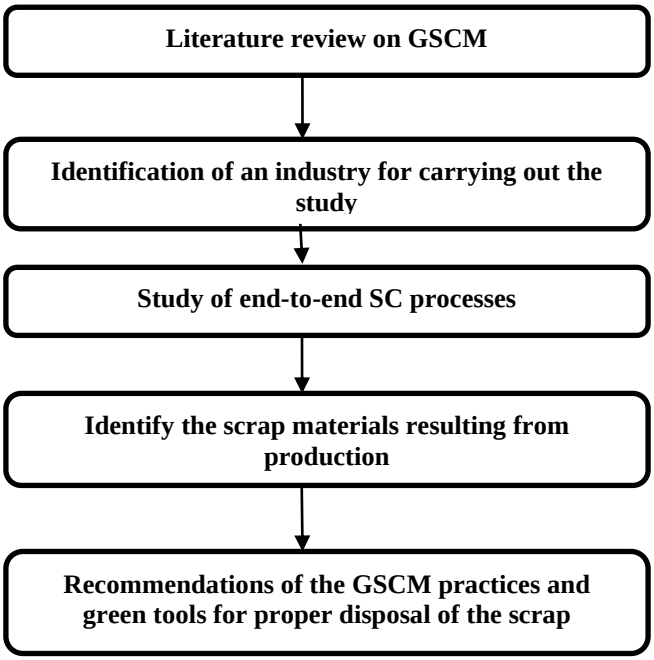

Fig 4 Framework for identifying green practices in the supply chain

C. About Case Organization

The industry we have identified is the HLL Life care Limited located at Akkulam, popularly known as AFT (Akkulam Factory, Thiruvananthapuram). It involves in the manufacture of Blood Bags and other medical devices. The products are manufactured in class 10000 and class 100 clean room facilities maintained in a centrally air conditioned atmosphere. The annual production capacity of blood bags at the factory stood at 12.5 million pieces and surgical sutures at 1, 25,000 dozens.

The various products developed in the industry is as follows:-

Blood Bags
Intra-Uterine Devices (IUDs)
Surgical sutures (Absorbable and Non-absorbable)
Tissue expanders
Tubal rings

Table XI

Source:- www.lifecarehll.com

D. Production of blood bags

Let's consider an example of the production of blood bags and its supply chain.

Blood bag system is a disposable bio-medical device used for collecting, storing, transporting and transfusing human blood and blood components. The system consists of a single or multiple bag connected with tubes, needle, needle cover, clamp etc. The different types of blood bags produced include single, double, triple, pediatric and transfer bags. The raw materials for the production of blood bags are latex or bio-compatible PVC pellets.

The following are the major steps required for the manufacture of blood bags:-

- **Compounding: -** The PVC material is compounded with additives like stabilizers, lubricants etc.
- **Extrusion: -** Extrusion of the compounded PVC is done through a die so that the conversion of plasticized material into sheet form is completed. The extruded part is cut into the required size and sent to the welding section.
- **Molding: -** Injection molding is performed in order to produce the components like transfusion ports, needle cover etc.
- **Welding: -** High frequency welding technique is used to fabricate the blood bags. PVC sheets are placed between the electrodes and high frequency is applied. PVC gets heated quickly and sealing takes place between the electrodes. Transfusion ports, donor and transfer tubing's are kept in a particular position with the bag and welded to form an integral part of the blood bag system.
- **Solution: -** The blood bag is filled with anticoagulant agent.

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- **Sterilization:** - Blood bags are sterilized using steam autoclave.

E. Blood Bag Supply Chain

The following figure shows the flow diagram of a blood bag supply chain:-

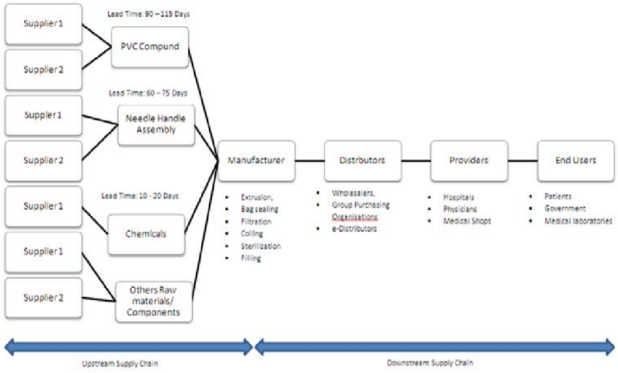

Fig 6 Blood Bag Supply Chain
Source: - www.researchgate.net

Blood bag production supply chain is basically divided into two processes: - (1) Upstream supply chain (2) Downstream supply chain.

In the case of upstream supply chain, it consists of the basic material for production from different suppliers namely supplier 1, supplier 2, supplier 3 etc. Examples include PVC compound, needle handle assembly, chemicals and so on. The raw materials are then transferred to the manufacturer thus moving onto the downstream supply chain. The manufacturing includes processes such as extrusion, filtration, sterilization, filling etc. Then, the manufactured product is onto the distributors including wholesalers as well as e-distributors. The distribution echelon acts as a middleman between the manufacturers and consumers. Then, the distributors distribute the product to the providers which include hospitals, physicians, and medical shops and so on. The final step includes the product reaching the customers who are the users including patients, government and medical laboratories.
But the production of blood bags results in a huge amount of scrap and other hazardous wastes.

F. Biomedical wastes

The scrap materials and their quantity generated are tabulated as follows:-

Table XII

Sl. No.	Item	Quantity (in kg)
1	Plastic (PVC, bucket, can, bottle)	500
2	Paper waste	12000
3	Corrugated carton scrap	15000
4	Plastic cover scrap (pp cover and tubings)	2500
5	Cut bag scrap (wet)	30000
6	SS Needle scrap of blood bag (Needle with poly carbonate holder or without holder)	5000
7	Rubber scrap	300

Source: - www.lifecarehll.com

G. Recommendations

Burial of the wastes in an inappropriate manner might cause leaching of toxins and microorganisms into waterways, incineration causes an increase in the emission of greenhouse gases. Plastics, commonly used as a packaging material break down into microscopic constituents known as micro plastics, which causes serious health issues while being ingested by the people. It is recommended that appropriate green practices and green technologies must be utilized in order to dispose the biomedical wastes in a most effective and efficient manner.

The various green practices and green tools recommended in the industry for proper disposal of blood bags include:-

- Plastic specimen bags should never be discarded after single use. It could be recycled and reused.
- The packaging materials such as Styrofoam and other cartons & cardboard products could be taken back by the suppliers and reused.
- The PVC pellets and tubings must also be recycled and reused.
- Autoclaving of the blood bags under a pressure of 2 bar at a temperature of 121^0C could be done.
- Blood bank irradiators could be used for the irradiation of cellular blood components. Blood products that are irradiated do not impose problems related to radioactivity.
- The materials used for producing blood bags could be made sustainable by replacing plastic with wood pulp.
- Different technologies like RFID, IoT, and EDI and so on could also be implemented.

These simple green practices would make the production of blood bags more ecofriendly and environmentally sustainable.

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CONCLUSION

In this study the green principles is integrated with the supply chain management for reducing waste emissions, reduction of fuel consumptions, better material procurement. It suggests on various emerging technologies for application in Green supply chain Management and how these green tools can be efficiently used in varied layers of operations in supply chain to achieve green goals. An analysis on the service framework along with limitations in implementations have been thoroughly analyzed. The benefits as well as barriers related to the implementation of the various green technologies have been discussed. It has been found that green practices and related green technologies make the supply chain much more environmentally sustainable.

REFERENCES

[1] Abhijna Neramballi, Movin Sequeira, Martin Rydell, Alexander Vestin, and Maria Ibarra ,A Comprehensive Literature Review of Green Supply Chain Management ,School of Engineering, Jönköping University ,April 2017.

[2] Thoo Ai China, Huam Hon Tatb, Zuraidah Sulaimana, Green Supply Chain Management, Environmental Collaboration and Sustainability Performance, 2015.

[3] Manavalan E, Jayakrishna A, an Analysis on Sustainable Supply Chain for Circular Economy, 2019.

[4] Govindan K, Hasanagic M. A systematic review on drivers, barriers, and practices towards circular economy: a supply chain perspective. International Journal of Production Research. 2018; p. 1-34.

[5] Warley Henrique Silva, Patricia Guarnieri 2, José Márcio Carvalho, Josivania Silva Farias and Silvia Araújo dos Reis, Sustainable Supply Chain Management: Analyzing the Past to Determine a Research Agenda, 16 April 2019.

[6] Hsu, C.C.; Choon Tan, K.; Hanim Mohamad Zailani, S.; Jayaraman, V. Supply chain drivers that foster the development of green initiatives in an emerging economy. Int. J. Oper. Prod. Manag. 2013, 33, 656–688.

[7] Naga Vamsi Krishna Jasti, Aditya Sharma and Rambabu Kodali, Lean to green supply chain management: A Case study, March 20, 2012.

[8] Mohsen Mohammadi, Muriati Bt. Mukhtar, Applying Service-Oriented Architecture to Supply Chain Process, September 2013`

[9] M. Mohammadi, M. Mukhtar, "A Review of Object-oriented Approach in Supply Chain Processes", AISS, Vol. 5, No. 8, pp. 9 ~ 17, 2013.

[10] F.A Cummins,. "Building the agile enterprise with SOA, BPM and MBM. Elsevier/Morgan Kaufman Publications, Amsterdam, Boston, 2009.

[11] Maguire, S., Koh, S. and Magrys, A. (2007). "The adoption of e-business and knowledge management in SMEs", Benchmarking: An International Journal, Vol. 14 No. 1, pp. 37-58.

[12] Shiels, H., McIvor, R. and O'Reilly, D. (2003). "Understanding the implications of ICT adoption: insights from SMEs". Logistics Information Management, Vol. 16 No. 5, pp. 312-26.

[13] Venkatraman, N. (1991) IT-induced business reconfiguration. In M.S. Scott-Morton (ed.), The Corporation of the 1990s: Information Technology and Organizational Transformation. New York: Oxford University Press, 1991, pp. 122-158.

[14] B.S.Sahay, J.N.D Gupta, R.Mohan," Managing Supply Chain for Competitiveness: The Indian Scenario", Supply Chain Management: An International Journal Volume 11, (2006), pp-15- 24, India`.

[15] M. Martin (2010) Logistics/Supply Chain website[online].

[16] B.S.Sahay, J.N.D Gupta, R.Mohan," Managing Supply Chain for Competitiveness: The Indian Scenario", Supply Chain Management: An International Journal Volume 11, (2006), pp-15- 24, India`

[17] Yu, J., N. Subramanian, K. Ning, and D. Edwards. 2015. "Product Delivery Service Provider Selection and Customer Satisfaction in the Era of Internet of Things: A Chinese E-Retailers' Perspective." International Journal of Production Economics 159: 104– 116.

[18] Zawadzki, P., and K. Żywicki. 2016. "Smart Product Design and Production Control for Effective Mass Customization in the Industry 4.0 Concept." Management and Production Engineering Review 7 (3): 105– 112.

[19] Agrawal, S., and M. Lal Das. 2011. "Internet of Things – A Paradigm Shift of Future Internet Applications." In 2011 Nirma University International Conference on Engineering. Ahmedabad, India

[20] Alexandru, A. M., A. De Mauro, M. Fiasche, F. G. Sisca, M. Taisch, L. Fasanotti, and P. Grasseni. 2015. "A Smart Web-Based Maintenance System for a Smart Manufacturing Environment." In 2015 IEEE 1st International Forum on Research and Technologies for Society and Industry Leveraging a Better Tomorrow (RTSI). Torino, Italy.

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Performance Analysis of Serpentine Flat Plate Solar Collector

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***Abstract*—In recent years solar energy is promoted as viable energy source, because of it is abundance in nature and environmental friendly characteristics. So in order to convert this solar energy into useful thermal energy, it is necessary to use solar collectors. Present study aims to analyse performance of serpentine type solar collector by varying mass flow rates of absorbing fluids (water), using Al_2O_3/water nanofluid with volume fraction of 0.05%, 0.1%. The results shows that there is 9.5% increase in thermal efficiency when the mass flow rate increases from 0.063 kg/s (Re=901) to 0.013 kg/s (Re=1904). Results also shows that thermal efficiency increased upto 13.5% and 6% for nanofluid with volume fraction of 0.1% and 0.05% respectively compared to distilled water. Numerical simulation was also carried out using three dimensional computational fluid dynamics (CFD) to predict outlet water temperature and efficiency of solar collector. It was found that the numerical model predicts the outlet temperature of the solar collector with reasonable accuracy.**

Keywords : Serpentine, Flat plate solar collector, Nanofluid, Computational fluid dynamics (CFD), Thermal efficiency.

NOMENCLATURE

$\dot{m}$	mass flow rate (Kg/s)
C_p	Specific heat capacity of fluid at constant pressure(J/Kgk)
ΔP	Pressure drop (Pa)
η_i	Instantaneous collector efficiency (%)
μ	Dynamic viscosity (Pa.s)
ϕ	Volume concentration of nanofluid
ρ	Density of fluid (Kg/m^3)
$\tau\alpha$	Absorptance-transmittance product
A_c	Area of the absorber plate
F_R	Heat removal factor
H/D	Twist ratio
Q_{in}	Available energy at collector
Q_{use}	Rate of useful energy gained (W)
R^2	Correlation coefficient
U_L	Overall loss coefficient of solar collector (W/m^2K)
G	Solar radiation flux (W/m^2)
Re	Reynolds Number

I. INTRODUCTION

Energy demand, which is one of the most important inputs of everyday life, is constantly increasing, and energy resources are rapidly being consumed. Keeping this important aspect in mind, it is important to develop new methods to take increasing advantage of limited energy resources by reconsidering current energy conversion systems. We know that sun is one of the renewable energy source which is abundance in nature, also environmental friendly. Unfortunately about 90% solar energy is wasted without utilising it [1]. But interesting fact is that this solar energy can be converted into useful thermal energy by using solar collector, and there by this thermal energy can be used as in domestic purpose, space heating and other industrial application. Solar collectors are device which collects solar energy and converted into useful thermal energy in the absorbing fluids. Solar collectors have wide application such as in domestic purpose, space heating, industrial heating purpose etc. There are different types of solar collectors which is classified on construction features and structures. Main types are evacuated tube solar thermal systems, flat plate solar thermal systems, thermodynamic panels, solar thermal air collectors, solar thermal bowl collectors, domestic solar hot water systems etc. However in general flat plate solar collectors are widely preferred in domestic purpose, due to less manufacturing cost compared with other types of collectors.

Critical problem for flat plate solar collector is low value efficiency (30% to 40%), so it is necesary to improve the efficiency. This can be achieved by either by optimizing the structure of collector or developing new type of working medium [2]. There have been lot of research done on performance analaysis of solar collector by using different working fluid, changing geometrical parametrs etc. But majority of the studies focuses on parallel plate solar collectors. Serpentine flat plate collector is another type of collector with interesting prospects [3]. However, very few studies have been done on serepentine flat plate collector.

Serpentine type solar collectors are types of flat plate collector in which working fluid passes single tube (usually

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zig zag form) from inlet to outlet. But in the case parallel flat plate collector there is parallel riser tubes which are connected to two header tubes at inlet and outlet respectively. Main advantage of serpentine collectors are leakage chance is less as there is no welding between pipes as here only use single long tube and flow throw the single tube is uniform in nature compared with parallel flat plate collectors. Also cost is less compared to parallel flat plate collectors, because here single long tube is used and no welding is used to connects the pipes.

II. RELATED WORK

There has been increased amounts of researches on solar collectors, especially on parallel plate solar collectors for improving the efficiency of solar collector. Oliy et.al [4] investigated the serpentine flat plate solar collector with using working fluids as distilled water. Results shows for low flow rates serpentine type collectors are more efficient compared with parallel flat plate collector, experimental study gives maximum efficiency of 70% at 0.0028 kg/s flow rate and solar radiation flux of 650 W/m^2. Gupta et.al [5] investigated the effect of Al_2O_3/H_2O nanofluid on the direct absorption solar collector. Major aim of the study was how the nanofluids enhance the performance of direct absorption solar collector. It is found that use of nanofluid improves the optical and thermophysical properties that results in increasing efficiency of the collector. There is increase 8.1% in efficiency at 1.5 lpm flow rate for the 0.1 wt% of nanofluids compared with water.

Gunjo et.al [6] investigate the parallel flat plate collector experimentally and numerically. The effects of different operating parameters, mainly the inlet water temperature, solar insolation, ambient temperature and mass flow rate of water on the outlet temperature of water and thermal efficiency were studied. It was observed that thermal efficiency of the solar collector increases with ambient temperature, solar insolation, mass flow rate of the water. Also CFD results validated the experimental results. The authors have devoleped a model to predict outlet water and absorber plate temperature with reasonable accuracy. Babu et.al [7] investigated the performance of parallel flat solar collector with and without internal fins. Due to the internal fins there was a enhancement in heat transfer which leads to increase the efficiency of 4.5% as compared to conventional flat plate collector without fins. Waghole et.al [8] did experimental investigations on heat transfer, friction factor of silver nanofluids in parabolic trough collector with twisted tapes inserts. They made experiment with Reynolds number range 500 to 6000 with twisted tape inserts of different twist ratio in the range $0.577 \leq H/D \leq 1.732$, concluded that when twisted tape inserts are used results shows the great enhancement of heat transfer rate in working fluids, heat transfer coefficient and friction of $0 \leq \phi \leq 0.1\%$ volume concentration of silver nanofluid are higher as compared to flow of water collector. Study also shows that Nusselts number, friction factor and enhancement efficiency was found to be 1.25 to 2.10 times, 1.0 to 1.75 times and 135%.

Sunder et.al [9] investigated of Al_2O_3/water nanofluids on the effectiveness of solar flat plate collectors with and without twisted tape inserts. Study shows there is favourable enhancement of effectiveness due to the effect of nanofluid and turbulence effect twisted tape. Results shows that for a Reynolds number 13000 the heat transfer enhancement for 0.3% volume concentration of nanofluid is 21% for the plain tube and it is further enhanced to 49.75% when a twisted tape of H/D = 5 is inserted in the tube. Also The thermal effectiveness of the plain collector is enhanced to 58%, when the 0.3% nanofluid is used and it is further enhanced to 76% with a twisted tape of H/D = 5 at a mass flow rate of 0.083 kg/s. Results also shows the maximum friction penalty only of 1.25 times was observed for 0.3% nanofluid with H/D = 5 when compared to water in a plain collector. Alim et.al [10] investigated Flat plate solar collector with working fluid as SiO_2/ethylene glycol with volume fraction varied from 0 to 1%, results shows that with increase in nanofluid concentration from 0 to 1%, the thermal efficiency increases approximately between 4 and 8% where heat loss parameter limits to zero. Tyagi et.al [11] investigated direct absorption solar collector with carbon nanotubes (CNT) water nanofluid at 150 ppm of CNT, study shows that thermal conductivity increases with increasing in temperature and CNT volume fraction. But dependence of the thermal conductivity on temperature is much more significant. With these promising properties there is increase in overall efficiency of 32.2% with respect to base fluid.

Shareef et.al [12] studied the parabolic solar collector with Al_2O_3/water nanofluid as working fluid. Studies shows that there is improvement in thermal and optical properties, thermal conductivity enhancement is depentent on the amount of nanoparticles. The efficiency of the collector improved by upto 10%. The chief difficulty faced was agglomeration of nanoparticles. Li et.al [13] performed various experiments in tubular solar energy systems using ZnO/water, MgO/water with nanoparticle diameters $<$20 nm and achieved the best results for the 0.2% ZnO/water nanofluid. Ziyadanogullari et.al [14] studied performance enhancement of flat plate collectors by means of three different nanoparticles of Al_2O_3, CuO, TiC with water as base fluids at volume fraction of 0.2, 0.4, 0.8 vol% with flow rate of 250 l/h. Results shows that maximum efficiency achieved for CuO/water nanofluids and there is increase in efficiencies of 87.8%, 84.6%, and 73.1% than water for volume fraction of 0.2, 0.4, 0.8 vol% respectively.

It has been well documented in the literature that there is only few studies have been done on the serpentine flat plate solar collector, there is no attention given on effect of nanofluid as working fluids in the serpentine solar collector. The present study is to analyse the performance of the serpentine flat plate solar collector with use of the Al_2O_3/H_2O nanofluid and varying different flow rates.

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III. EXPERIMENTAL SETUP

A. Preperation of nanofluids

Nanoparticles were purchased from Sigma Aldrich Bangalore. Nanofluids of 0.05% and 0.1% volume concentrations were prepared by dispersing Al_2O_3 nanoparticles in deionized water by using probe type sonicator and water bath type sonicator. Surfactants were added to avoid sedimentation of Al_2O_3 nanoparticles in the base fluid. Sodium dodecyl benzene sulphate (SDBS) surfactant with 25% weight of nanoparticles were added. Volume concentration of nanofluid is calculated by using the following equation.

$$\phi = \left[\frac{(w_{np}/\rho_{np})}{(w_{np}/\rho_{np}) + (w_{bf}/\rho_{bf})}\right] \times 100 \quad (1)$$

The amount of nanoparticles required to get the desired volume concentrations were calculated using the above equation. Thermophysical properties of nanofluid with volume fraction of 0.1% is shown in Table 1.

TABLE I
THERMOPHYSICAL PROPERTIES OF Al_2O_3/WATER NANOFLUID FOR ϕ=0.1%

Density	1010 kg/m^3
Specfic heat capacity	4151 J/kg-K
Thermal conductivity	0.9 W/m-K
Viscosity	0.001253 kg/m-s

B. Serpentine solar collector experimental apparatus

Schematic of experimental setup of the closed loop serpentine solar collector systems used for the present study is shown in Fig 1. Water storage tank was connected to the inlet of the flat plate collector by means of of hose pipe of diameter 2.5 inch. Water from the inlet of the storage tank circulated by centrifugal pump, two valves are used to adjust the flow rate of working fluid. It is gets heated up in the collector and it is recirculate to storage tank through the outlet of the collector. Inlet and outlet thermocouples are used to measure the temperature gain of the working fluid in the collector.

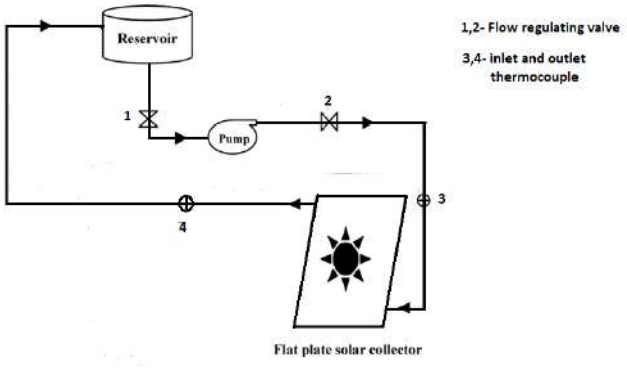

Fig. 1. Schematic of experimental setup

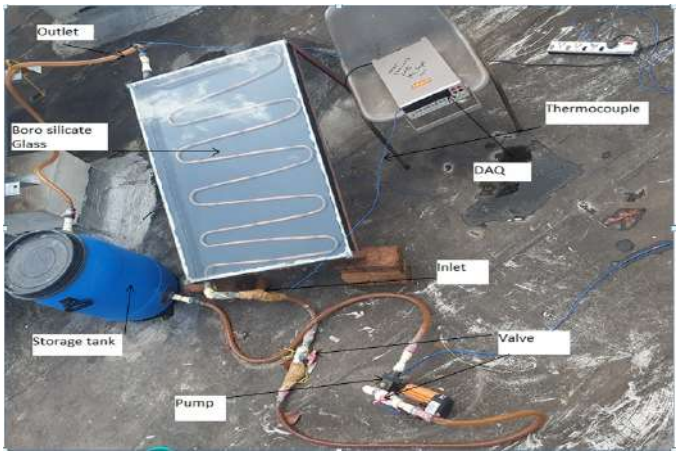

Fig. 2. Experimental setup

Experimental set up is shown in Fig 2. Experiments are carried out at College of Engineering Trivandrum (8.5241^o N, 76.9366^o E) in the month may and june. Solar collector is placed facing towards south direction and experiment is starts from 9.30 AM to 4 PM. Thermal response are noted in the intervel of 30 minutes and solar radiation data's are collected. T type thermocouples are used to measure the temperatures. Specification of components used in the experimental setup is shown in Table 2.

TABLE II
SPECIFICATION OF THE COMPONENTS OF EXPERIMENTAL SET-UP

Component name	**Specification**
Serpentine solar collector	1m x 0.65m x 0.07m
Thermocouple	T type (0^o C to 200^o C)
DAQ	Agilent 34970A
Storage tank	60 L capacity
Flow adjusting valve	2 no's
Pump	Centrifugal pump(0.125 HP)

C. Equations Used

Useful energy gain of working fluid is energy abosrbed by the working fluid when solar radiation falls on them, which is given by:

$$Q_{useful} = \dot{m}C_p(T_o - T_i) \quad (2)$$

where $\dot{m}$ is mass flow rate in kg/s, C_p is heat capacity of working fluid in J/kgK, T_o and T_i are the outlet and inlet temperature of working fluid in ^{o}C respectivly.

The heat gain of fluids also expressed in terms of energy absorbed by the absorber and energy lost from the absorber as given by Eq. 3

$$Q_{useful} = A_cF_R[G(\tau\alpha) - U_L(T_i - T_{amb})] \quad (3)$$

Where A_c is area of collector in m^2, F_R is heat removal factor, U_L is the overall heat transfer coefficient in W/m^2K,

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T_{amb} is ambient temperature in ^{o}C and $(\tau\alpha)$ is absorptance-transmittance product.

Available solar energy at collector plate is given by Eq. 4 where G is solar radiation flux in W/m^2K.

$$Q_{in} = A_c G \tag{4}$$

Thermal efficiency of collector, η_i given by Eq. 5 and Eq. 6

$$\eta_i = \frac{Q_{useful}}{A_c G} \tag{5}$$

$$\eta_i = F_R(\tau\alpha) - F_R U_L(\frac{T_i - T_{amb}}{G}) \tag{6}$$

IV. NUMERICAL MODELLING

Numerical modelling was done using the commercial CFD package ANSYS FLUENT. 3 D model of the serpentine flat plate collector is generated in FLUENT design modeller. The geometry of computational domain is shown in Fig 3. Cartisian coordinate system is used for computational analysis. Four regions in computational domain is given below:
1) Inlet
2) Outlet
3) Top surface
4) Bottom surface

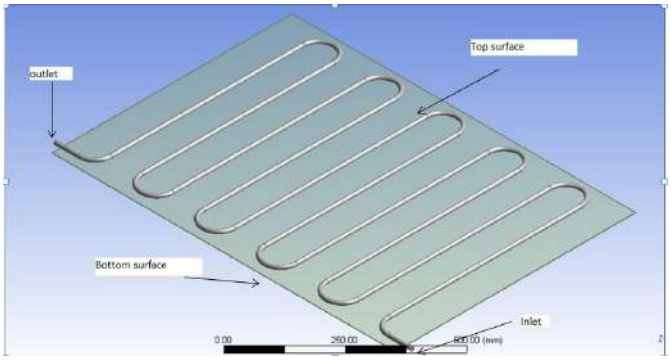

Fig. 3. Geometry of the computational domain

Hexahedral mesh are used with 2.1 million computational elements and 2.4 million nodes. Mesh of computational domain is shown in Fig 4.

Analysis was carried out based on the following assumptions:
a) The thermal and physical properties of the absorber plate, riser tube and water are constant during the flow.
b) Flow is incompressible
c) Heat loss from the bottom side of the absorber plate and tube is by convection which depends upon the wind speed.
d) Radiation flux is assumed to be constant over the top surface and can be applied as contstant heat flux.

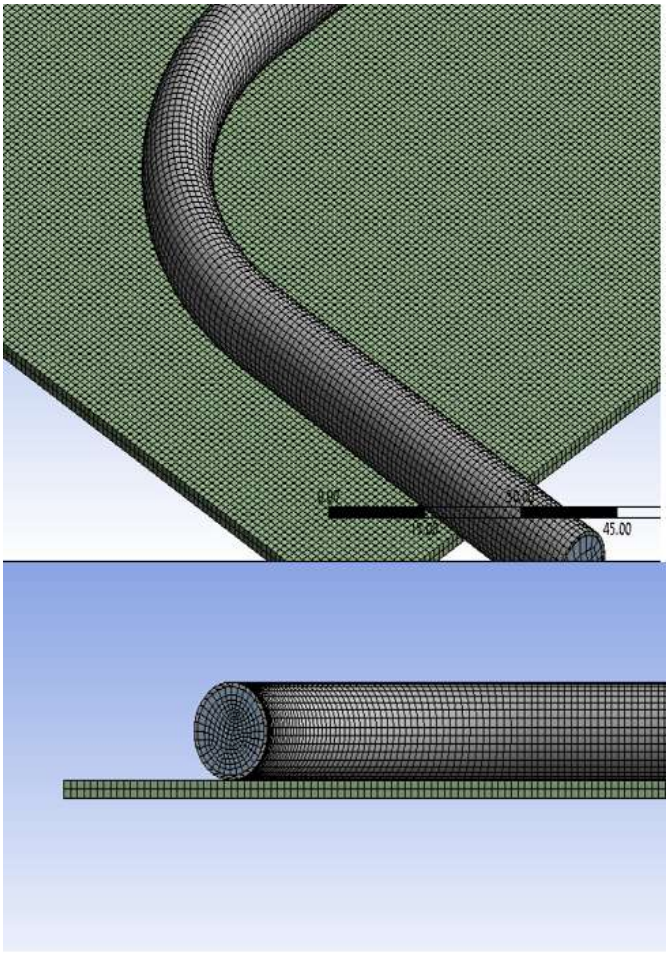

Fig. 4. Computational mesh domain

A. Methodology

The outlet water and absorber plate temperature of the solar collector depends on the flow distribution in the riser tubes. Flow at low Reynolds number (<0.016 kg/s) would give uniform flow with homogenous temperature distribution in each riser tubes. The CFD model was developed to predict the outlet and efficiency of the collector. For modeling, the absorber plate length, width, tube diameter and tube thickness are 1.0 m, 0.6 m, 0.010 m and 0.001 m respectively, which is the same dimension of the experimental setup. The data used for the modeling, viz., inlet water temperature, ambient temperature, solar insolation and wind speed is based on the data obtained from few initial experiments. The velocity and temperature field for the water flow in the riser tube is determined by solving the equations of continuity, momentum and energy. CFD modeling is done for two flow rates of 0.0063 kg/sec (Re = 901) and 0.013 kg/sec (Re = 1904) and $Al_2O_3 - H_2O$ nanofluids volume fraction of Φ =0.1%. The grid independency test was done to check the quality of mesh on the solution. Fig 5 shows the variations of outlet temperature of the absorbing fluid with respect to number of mesh elements. The solutions converged when the values of

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residuals in the computational domain fell below 10-6. Further grid refining resulted in an error less than 0.05%. The number of elements for the computational domain consisting of water, water tube and absorber plate is 2184900.

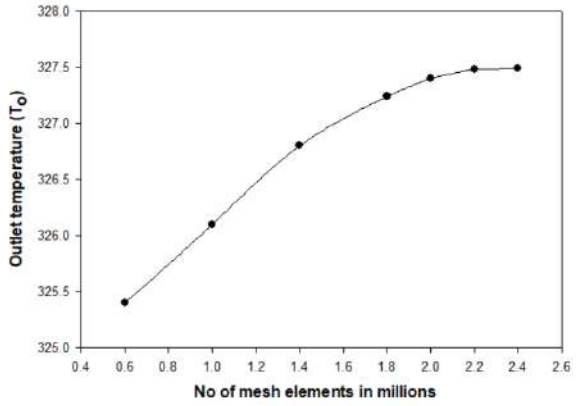

Fig. 5. Outlet temperature(T_o) vs number of mesh elements graph

B. Boundary Conditions

At inlet section mass flow rate and inlet temperature as given, which are taken from initial experiment. At outlet section presure outlet condition is applied with gauge pressure is equal to zero. A constant heat flux (solar irradiance) is applied on the top surface of the absorber plate and riser tube. The bottom surface is set as convective wall boundary. The convective heat transfer coefficient of the bottom surface is obtained by the expression [14]:
h_b = 2.8 + 3V_w where V_w is wind velocity in m/s.
At top surface:
$-k\frac{\partial T}{\partial y}|_{y=0} = \dot{q}$
At inlet :
u = u_i, v=0, w=0
T = T_i
No-slip boundary condition is used close to the wall of the fluid :
u = w = z = 0
Pressure outlet boundary condition is adopted at the outlet of the riser tube :
P_o = P_a = 0.1013 MPa
The coupling wall boundary at the solid-fluid interface is applied :
T_s=T_f

V. RESULTS AND DISCUSSIONS

Studies were conducted for mass flow rates of 0.0063kg/s (Re=901) and 0.013 kg/s (Re=1904), nanofluid with volume fraction of 0.05% and 0.1% and compare experimental results with CFD, based on simulation parametric studies on performance of solar collector for various input conditions were carried out.

A. Variation of thermal efficiency under different inclinations

Variation of efficiency with respect to time under the different inclination is shown in Fig 6. It is shows that there is increment in efficiency for inclination 24^o compared with other inclinations, mainly due to more interception of solar radiation (entrapment) compared with other inclinations. There is approximately 10% increase in efficiency for inclination 24^o. For the inclination 16^o, 34^o efficiencies are almost same, and the efficiencies is lowest for inclination 44^o. From this Fig 6, it is clear that optimum inclination of solar collector out of the four inclination is 24^o

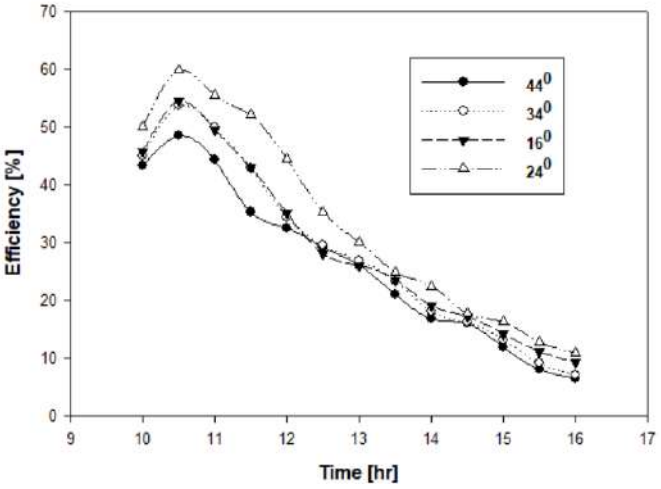

Fig. 6. Variations of efficiency of collector with respect to time for four different inclination

B. Variation Temperatures and Efficiency with respect to Time with Collector Inclination of 24^o

Average solar radiation flux variation of during experimental days is shown in Fig 7. Maximum radiation available in between 12.30 h to 13 h with maximum solar radiation flux of 845 W/m^2.

Variation of inlet temperature, outlet temperature, ambient temperature and thermal efficiency at 24^o inclination with respect to time is shown in Fig 8. From the figure it is clear that ambient temperature increases as time increases and reaches maximum value of 38.5 ^{o}C at 14 h then decreases gradually to 32 ^{o}C at 16 h. Due to closed loop arrangement inlet temperature increases gradually upto 60 ^{o}C at 14 h, then decreases slowly is due to decreasing solar radiation and ambient temperature. Similarly outlet temperature increases gradually upto 64 ^{o}C at 14 h, then decreases with minimum value of 60.1 ^{o}C at 16 h. Difference in inlet and outlet temperature is maximum at 10.30 h, then decreases gradually to 0.9 ^{o}C at 16 h. This due to that heat loss from the collector dominates over input solar radiation. Similarly the thermal efficiency increases first from 50% to 59.2% for 10 h to 10.30 h, then decreases gradually. Even though radiation flux increasing, efficiency reduces due to increases of heat loss over

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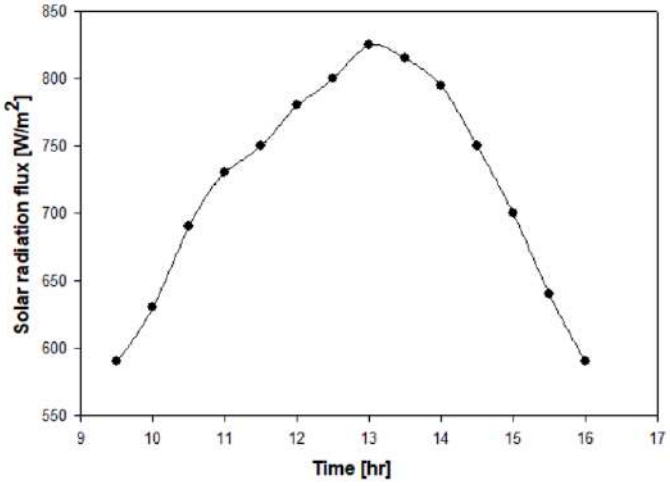

Fig. 7. Average variation of solar radiation flux

the solar radiation flux as time increases. Minimum value of efficiency is 10.1% at 16 h.

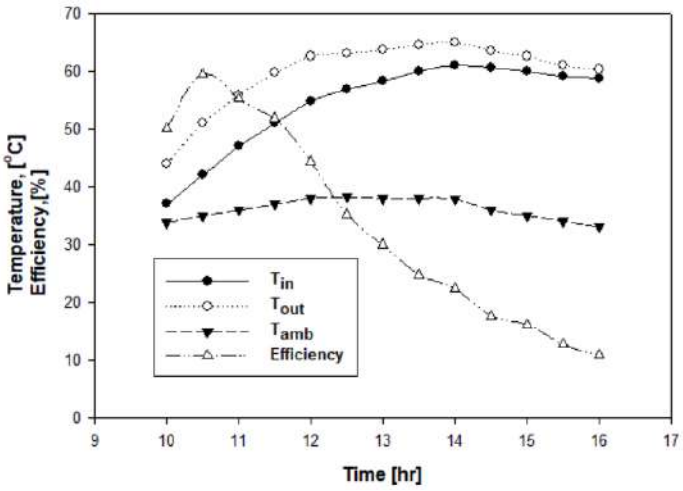

Fig. 8. Experimental results versus time curve for inclination of 24^o and mass flow rate of 0.0063kg/s

C. Efficiency Variation for Two Different Mass Flow Rates

Figure 9 shows the variation of thermal efficiency under the two mass flow rates. From the figure it is clear that thermal efficiency inreases as mass flow rates increases from 0.0069 kg/s (Re=901) to 0.013 kg/s (Re=1902). Maximum efficiency (T_i=T_{amb}) for mass flow rate of 0.013 kg/s increased upto 8% compared with flow rate of 0.0063 kg/s. This is due to that as flow rate increases heat transfer rates between abosorbing fluid and wall of the pipe increases there by net useful gain increases. Fitting parameter for the efficiency curve is shown in Table 3.

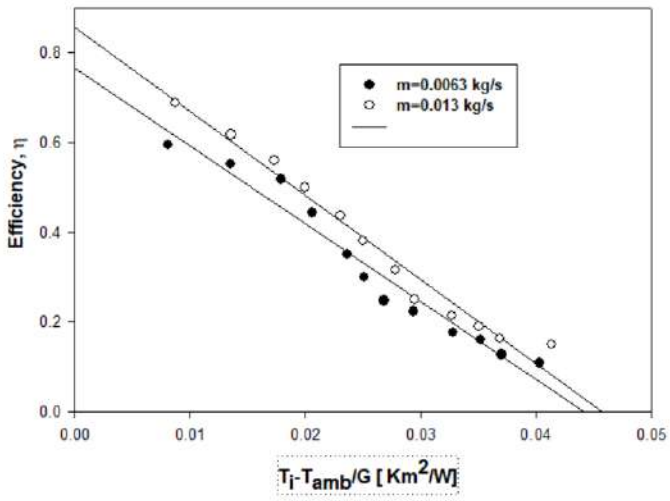

Fig. 9. Efficiency versus reduced temperature curve for $\dot{m}$ =0.0063 kg/s and $\dot{m}$=0.013 kg/s

TABLE III
FITTING PARAMETERS OF COLLECTOR EFFICIENCY CURVES AT TWO DIFFERENT FLOW RATES

Flow rate in Kg/s	$F_R(\tau\alpha)$	F_RU_L	R^2
0.0063	0.77	17.343	0.9584
0.013	0.82	18.131	0.9726

D. Efficiency variation for nanofluid and water

Efficiencies versus reduced temperature curve is shown in Fig 10 and corresponding fitting parameter is shown in Table 4. From figure it is clear that thermal efficiency is

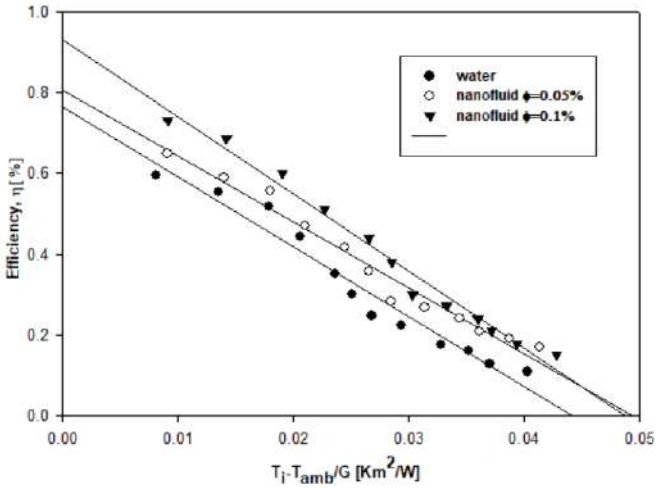

Fig. 10. Efficiency versus reduced temperature curve for water and nanofluids

more for nanofluids compared with distilled water (base-fluid). Maximum efficiency (T_i=T_o) with 0.1% vol.fraction of Al_2O_3/H_2O nanofluids increased upto 16% compared to distilled water. But for the Al_2O_3/H_2O nanofluid with

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0.05 volume fraction, maximum efficiency increased upto 7% compared with distilled water. This is due to that nanofluids possess the good thermal properties compared to basefluid. As the nanofluids concentration increases, thermal conductivity of working fluids increases, which enhances the heat transfer rates. Fitting parameter for efficiency curve is shown Table 4.

TABLE IV
FITTING PARAMETERS OF COLLECTOR EFFICIENCIES FOR NANOFLUID AND WATER

Working fluid	$F_R(\tau\alpha)$	F_RU_L	R^2
water	0.77	17.343	0.9584
Al_2O_3/water ϕ=0.05%	0.8	16.89	0.973
Al_2O_3/water, ϕ=0.1%	0.91	19.8	0.987

E. Model validation

For the solar radiation flux of 670 W/m^2 , inlet temperature of 42^{o}C , convective heat transfer coefficient of 7 W/m^2K and mass flow rate of 0.0063 kg/s (input parameter corresponds to experiment values at 10.30 AM) simulated results are shown below.

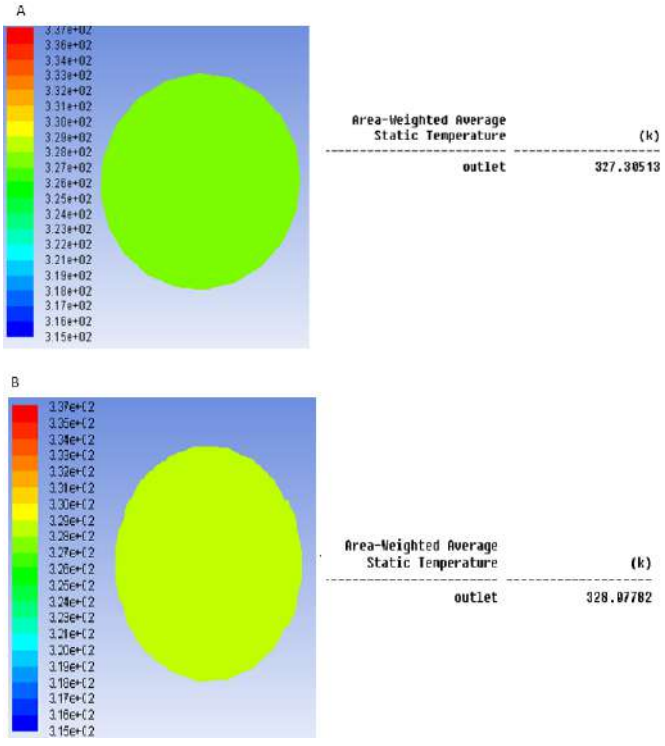

Fig. 11. Outlet section temperature for A) water B) Al_2O_3/water (ϕ=0.1%) at mass flow rate of 0.0063 kg/s

Figure 11 shows that outlet sectional temperature distribution for water and nanofluid. It is found that Average sectional temperatures for water as absorbing fluid is 327.3 K at outlet. But for the nanofluids average temperature at outlet is increased to 328.077 K, which is 0.8 K more than that of water. This is due to that thermal conductivity of nanofluid is very high and specific heat is low compared to water, which causes better heat transfer and higher temperature outlet for nanofluid.

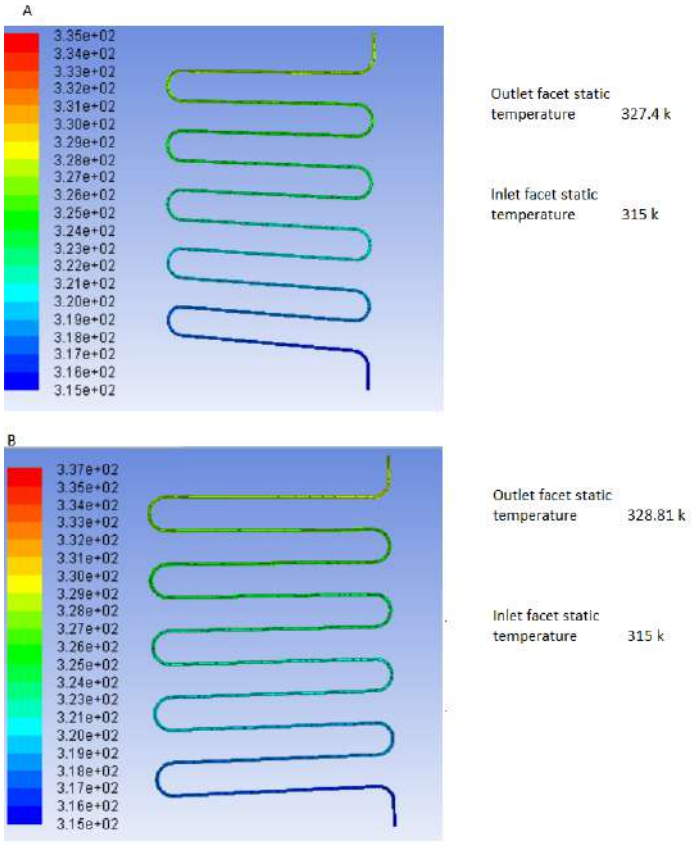

Fig. 12. Temperature variation along A) water B) Al_2O_3/water (ϕ=0.1%) in the tube at the mass flow rate of 0.0063 kg/s

Figure 12 shows variation of temperature along the water and nanofluid (ϕ=0.1%) in the tubes from inlet to outlet. From the figure it is clear that net temperature gain between inlet and outlet is 12^{o}C, which is 2.9^{o}C more than that of experimental value. This is due to perfect contact between absorber plate and pipe. For the Al_2O_3/H_2O nanofluid net temperature gain between inlet and outlet is 13.8^{o}C which is around 1.8^{o}C more than that of water.

F. Comparison of CFD predicted outlet temperature with Experimental data

Plots of experimental and simulation results of outlet water temperatures for mass flow rates of 0.0069 kg.s^{-1} is shown in Fig 13. The relative error between experimental results (X_{exp}) and simulation values (X_{sim}) is expressed by:

$$Error\% = \frac{\mid X_{sim} - X_{exp} \mid}{X_{sim}} \quad (7)$$

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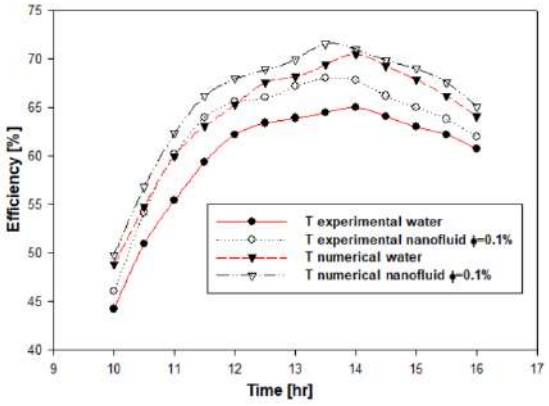

Fig. 13. Variation of predicted and experimental outlet water temperature vs time for water and nanofluids with ϕ=0.1%

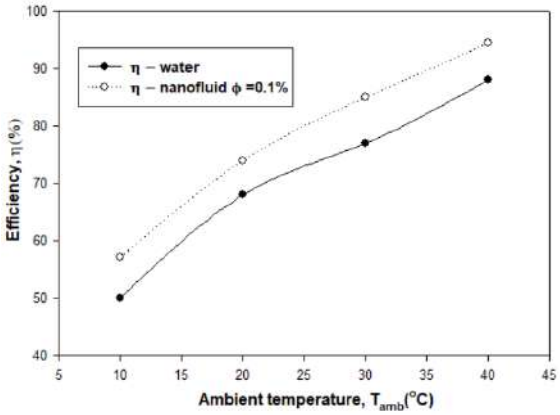

Fig. 14. Curve of thermal efficiency (η) vs Ambient temperature (T_{amb}) for water and nanofluid

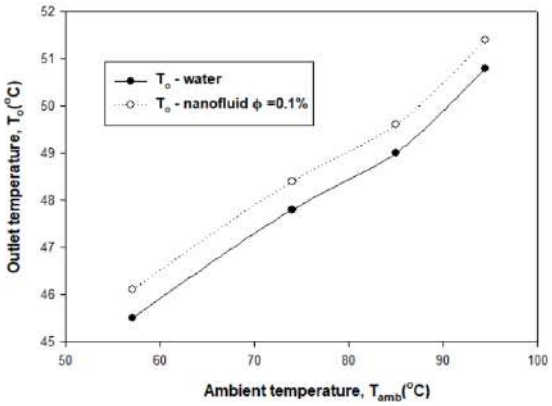

Fig. 15. Curve of outlet temperature (T_o) vs Ambient temperature (T_{amb}) for water and nanofluid

Maximum relative error for prediction of outlet temperature are 9.6%, 8.4% for the water and nanofluid (ϕ=0.1%) respectievely which is indicating good agreement experimental values. Relative error obtained in the present study nearly same as that of study by Gunjo et.al [6]. In the present study higher predicted outlet temperature compared to experimental values is due to simulation was based on assumption of a perfect contact between absorber plate and tube, better heat transfer occures between plate and tube compared to actual case. Also radiation and convection losses from glass cover are not included in this study.

G. Parametric Study

Based on the simulation, parametric studies on performance of the solar collector for various inputs, viz, inlet water temperature, ambient temperature, water flow rate were carried out.

Figure 14 shows variation of collector efficiency vs Ambient temperature for solar radiation flux of 650 W/m^2, flow rate of 0.01 kg/s and inlet temperature of 42^{o}C. As ambient temperature increases from 10^{o}C to 40^{o}C the thermal efficiency and increases from 50% to 88% for water and from 57.1% to 94.5% for nanofluid ϕ=0.1%. It is evident that as the ambient temperature increases the collector heat loss decreases thereby increases the thermal efficiency of the collector. Fig 15 shows variation of outlet temperature (T_o) with respect to ambient temperature (T_{amb}). It is found that as ambient temperature increases outlet temperature also increases. In addition, with higher ambient temperature, the collector receives more heat from the solar radiation as well as from the surrounding atmosphere thus increases the outlet water temperature.

Variation of of collector efficiency versus inlet water velocity and outlet temperature versus inlet velocity for 42^{o}C inlet temperature and 650 W/m^2 radiation flux is shown in Figs 16 and 17. Efficiency increases from 70% to 88%, while outlet water temperature decreases from 48.4^{o}C to 44.2^{o}C for water. With increase in water flow rate the heat transfer rate increases leading to decrease in the absorber plate temperature. This results in decrease in heat losses from the system with gradual increase in thermal efficiency.

Figure 18 shows variation of thermal efficiency with respect to inlet temperature at 650 W/m^2 and Fig 19 shows variation of outlet temperature with respect to inlet temperature at 650 W/m^2 solar radiation flux and ambient temperature of 25^{o}C and flow rate of 0.01 kg/s. As the inlet water temperature increases from 20^o C to 50^{o}C, the thermal efficiency of the collector decreases from 86% to 56% for water and 93% to 63% for nanofluid ϕ=0.1%. whereas the outlet water temperature increases from 31^{o}C to 56^{o}C for water and 31.75^{o}C to 56.7^{o}C for nanofluid ϕ=0.1%. At higher inlet water temperature, the temperature difference between inlet and outlet decreases, thereby thermal efficiency decreases.

VI. CONCLUSIONS

In this study the performance analysis of serpentine flat plate solar collector is done with experimentally and the results are compared numerically with ANSYS FLUENT. Parametric study also carried out for different input parameter and its effect on thermal efficiency of solar collector and outlet temperature of the working fluid were analysed.

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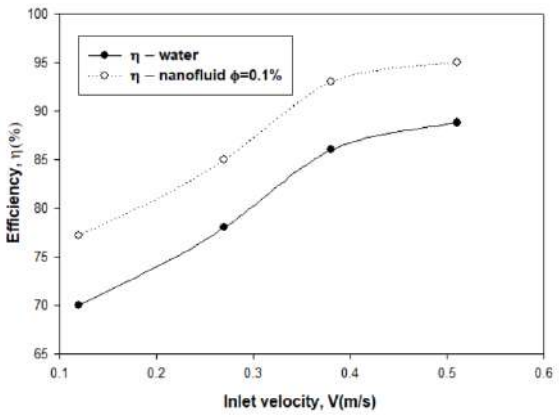

Fig. 16. Curve of thermal efficiency (η) vs inlet water velocity(v)

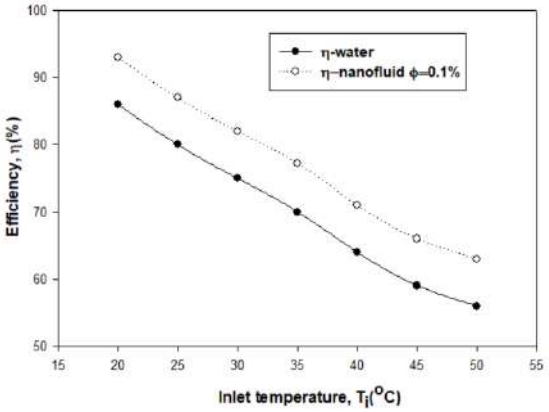

Fig. 18. Thermal efficiency (η) versus inlet water temperature curve (T_i)

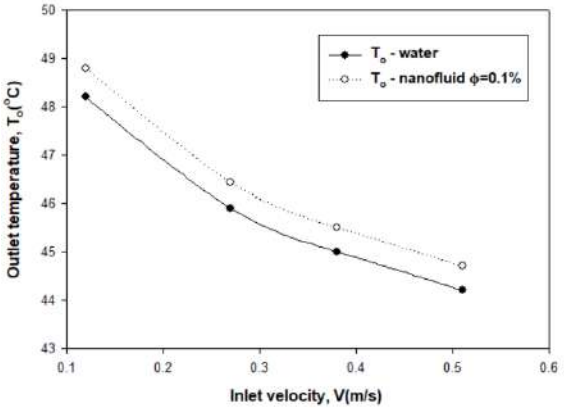

Fig. 17. Curve of outlet water temperature (T_o) vs inlet water velocity(v)

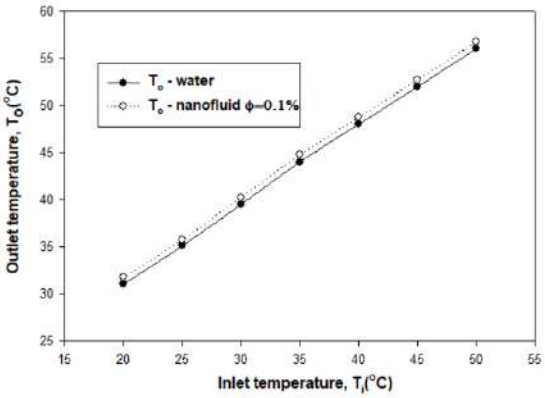

Fig. 19. Outlet temperature (T_o) versus inlet water temperature curve (T_i)

1) Performance of solar collector studied with different inclinations (16^o,24^o,34^o,44^o) of solar collector and found that optimum inclination of solar collector is 24^o.
2) At the inclination of 24^o maximum efficiency of 59% achieved at 10.30 am, and efficiency gradually decrease as time increses and reaches minimum value of 10.4% at 4 PM.
3) Performance of collector is analysed at mass flow rate of 0.0069 kg/s and 0.013 kg/s and it is found that maximum efficiency (when $T_i = T_{amb}$) for mass flow rate of 0.013 kg/s is 8% more than that of the 0.0069 kg/s flow rate.
4) Performance of collector is analysed with using different absorbing fluid mainly water and $Al_2O_3/water$ nanofluid with volume fraction of 0.05% and 0.1%, results shows that maximum efficiency (when $T_i = T_{amb}$) of nanofluids with volume fraction of 0.1% is 16% more than that of water and for nanofluids with volume fraction of 0.05%, it is 7% more than water. Also it is found that heat loss parameter $F_R U_L$ is minimum for the nanofluid with volume fraction of 0.05%.
5) CFD modelling of serpentine flat plate collector was done using ANSYS FLUENT and model predict the outlet temperature with reasonable accuracy, with maximum reletive error between experimental results and numerical results of 9.6% and and 8.4% for water and nanofluid respectively for the volume fraction of 0.1%.
6) Parametric study using the CFD model was carried out and reveals that the thermal efficiency of the collector increases with increase in water flow rate, ambient temperature and decrease with inlet water temperature.

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VII. Reference

[1] Youwei Tian, Chong Zhao, A review of solar collectors and thermal energy storage in solar thermal, Applied Energy, 104(2013), 538-553.

[2] H. P. Garg, Absorber Plate Configuration and Optimization, Journal of Ambient Energy, 1995, 93-11.

[3] Hottel HC, Woertz BB, Performance of flat plate solar heat collectors, Transactions of the ASME, 64(2005), 91–104.

[4] Gutu Birhanu Oliy, Auch Venkata Ramayya, Experimental testing of a serpentine flat plate solar water heater, International Journal of Energy and Power engineering, 6(2016), 61-67.

[5] Hemanth Kumar Gupta, Ghanashyam Das Agrawal, Invstigation for effect of Al_2O_3/H_2O nanofluid flow rate on the efficiency of direct absorption solar collector, Case Studies in Thermal Engineering, 15(2015), 3-12.

[6] Dawit Gudeta Gunjo, Pinakeswar Mahanta, P.S. Robi, CFD and experimental investigation of flat plate solar water heating system under steady state condition, International Journal of Renewable Energy, 20(2016), 265-280.

[7] M.Dinesh Babu, M.Venkata Ramanan, Experimental analysis on the performance of a solar flat plate water heater with and without internal fins, International Journal of Ambient Energy, 80(2016), 26-38.

[8] Dnyaneshwar R.Waghole, R.M.Warkhedkar, V.S.kulkarni, Shrivastva, Experimental investigations on heat transfer and friction factor of silver nanofliud in absorber-receiver of parabolic trough collector with twisted tape inserts, Energy Procedia, 45(2014), 558 – 567.

[9] L. Syam Sundar, A. Kirubeil, V. Punnaiah, Manoj K. Singh, Effectiveness analysis of solar flat plate collector with Al_2O_3/water nanofluids and with longitudinal strip inserts, International Journal of Heat and Mass Transfer, 127(2018), 422–435.

[10] T. Yousefi, F. Veysi, E. Shojaeizadeh, S. Zinadini, An experimental investigation on the effect of Al_2O_3/H_2O nanofluid on the efficiency of flat-plate solar collectors, Journal of Renewable Energy, 39(2012), 293–298.

[11] H. Chaji, Y. Ajabshirchi, E. Esmaeilzadeh, S.Z. Heris, M. Hedayatizadeh, M. Kahani, Experimental study on thermal efficiency of flat plate solar collector using TiO_2/H_2O nanofluid, Journal of Modern Applied Science, 7(2013), 60–69.

[12] F.S. Javadi, R. Saidur, M. Kamalisarvestani, Investigating performance improvement of solar collectors by using nanofluids, International Journal of Renewable Sustainable Energy, Rev. 28(2013), 232–245.

[13] L.S. Sundar, K.V. Sharma, Turbulent heat transfer and friction factor of Al_2O_3 nanofluid in circular tube with twisted tape inserts, International Journal of Heat Mass Transfer, 53(2010), 1409–1416.

[14] O. Mahian, A. Kianifar, S.A. Kalogirou, I. Pop, S. Wongwises, A review of the applications of nanofluids in solar energy, International Journal of Heat and Mass Transfer, 57 (2013), 582–594.

[15] Selmi Mohamed, Al-Khawaja Mohammed J, Marafia Abdulhamid, Validation of CFD simulation for flat plate solar energy collector, Journal of Renewable Energy, 33(2008), 383–7.

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Human skeleton tracking using Microsoft Kinect in Pump manufacturing industries

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Abstract— **Ergonomics deals with the interaction between man and work environment to make sure that tasks, equipment, information, and environment suit each worker. It is used to minimize the risk of injury, accidents, and errors without compromising productivity and human comfort. According to International Labors Organization, every year 2.3 million women and men die due to occupational injury or diseases. In India, 4,80,000 people die in an average per annum due to work-related hazards. Manufacturing industries adhere to operate tasks manually due to the high capital expenditure required to invest in automated systems, high level of maintenance and low degree of flexibility. This increase work-related musculoskeletal disorders. Previously available prediction techniques (e.g., ergonomic rules and checklist based on a survey) for work-related musculoskeletal disorders are not suitable for measuring the physical demands required for real-time manual working conditions. So, the human skeleton tracking (motion capture) approach is used to obtain a worker's posture information for measuring physical load in body parts (e.g., shoulder, neck, back) during pump assembly. The objective of this study is to generate motion data (3D coordinates values) for a manual task in the pump assembly section using wireless motion capturing technology. These motion data are used to evaluate work-related musculoskeletal problems and contribute to modern workplace design by using the biomechanical approach. The resulting information from biomechanical analysis contains forces of body parts and it is capable of identifying the allowable strength and thereby helping to determine awkward posture during tasks. The human skeleton model is tracked by using Microsoft Kinect V1 sensor with the help of MATLAB coding environment. Microsoft Kinect sensor and MATLAB are interfaced with the help of Image acquisition toolbox. Image acquisition toolbox is a module that is used to connecting a Kinect sensor with MATLAB. In experimentation, the non-return valve body of a radial flow type submersible pump is lifted from one place to another place for the assembly operation. For this operation, human skeleton model is tracked from real-time 3D world and coordinate points are collected in '.xlsx' format for 100 frames and fixed 30 fps configuration. Data collected from skeleton tracking is more precise in the range between 1.75 to 3.60 m. This study result helps to do biomechanical analysis for various manual processes in all manufacturing sectors to enhancing human comfort and productivity without changing the basic operation.**

.

Keywords—musculoskeletal disorder; motion data; lifting; biomechanical; skeleton; Matlab; image acquisition toolbox

I. INTRODUCTION

Despite growing advancement in automation manual material handling activities are still play a major role in many small-scale industries [1]. A significant problem associated with such activities is the fact that the primary cause of work-related injuries [2]. The moral and economic consequences that result from pain and injury made it necessary to study and attempt to solve such problems.

In a small scale, manufacturing industries automation techniques have been employed widely and many tasks are still accomplished manually especially in the assembly process. Assembly section is the most relevant area of human involvement for major reasons. According to the US Occupational Safety and Health Administration (OSHA), work-related musculoskeletal disorders account for more than 15 to 20 billion dollars each year. Moreover, several studies are identified as a relationship between ergonomically problematic tasks and quality deficiencies to the extent that among 30 to 50% of all quality flaws are related to ergonomic problems. The investigation from various manufacturing industries further reveals a correlation that 60 to 70% of work-related musculoskeletal disorders are caused by the product design and 30 to 40% by the manual assembly process like lifting, pushing, pulling, carrying and bending [2].

In the manual assembly, process biomechanics play a major role. Biomechanics is a study of the structure, function, and motion of the mechanical aspects of the biological systems. In biomechanics is a field that combines the engineering mechanical fields with biology and physiology. It applies a mechanical principle to the human body in order to understand the mechanical influence on bone and joint health. Biomechanics can be applied to individuals, analyzing their movements during manual tasks and assist them for more effective movements to reduce work-related injuries. These movements are captured by using a motion capturing system. Motion analysis can be defined as a technique used by a clinician to quantify the human movement pattern. The processing of three-dimensional data majorly contributes to the research area for modern applications in the field of engineering with the help of Microsoft Kinect camera [3]. The Kinect camera is an inexpensive and easy way for user interaction [4]. Microsoft Kinect camera is an alternative tool

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of motion capturing system and gaming purpose due to low cost when compared to conventional motion capture systems like Vicon3D. Kinect sensor produces accurate and reliable data and the measuring system demonstrates an error of 5% variance [5]. Kinect sensor gives accurate data for postural data collection when comparing to video capturing [6]. Data acquisition of Kinect sensor using the image and depth sensor with the precision of 4 to 40 mm from the sensor and 640 x 480 pixels used for spatial modeling of the moving body [7]. Kinect SDK is used to achieve the 3D point clouds from the depth image for 3D visualization. During motion tracking, Kinect sensors are placed pairwise in a row along walking direction to achieve more accurate tracking [8]. In motion capturing Kinect camera is placed about 3 meters from the subject to capture the whole body standing upright [9]. Fusion kit is used to synchronization of multiple Kinect and Kinect camera were fixed on the circumference of 9 ft from the subject center location and 4 ft 6-inch height from the floor [10].

In earlier studies of biomechanics, manual lifting task have mainly considered situations where the lifting task was performed in an unrestricted workspace. Among the different work postures, restricted postures were found to be associated with an increased risk for work-related injury like low back pain [11]. In restricted postures occurs when there is a mismatch between a worker's body size and the job requirements. Low back injury is the most common cause of pain and disability in many workplaces and it leads to high costs associated with clinical diagnosis, treatments and lost workdays [12].

In overall cost of the product or process is increased due to worker health effects, productivity losses, and quality losses. By using biomechanics analysis workplace design is improved to increase productivity and quality. This biomechanical analysis is done with the help of Open simulator software. Opensim software is an emerging open-source modeling and simulation platform with growing musculoskeletal model libraries [13]. Opensim includes a wide range of studies, including analysis of walking dynamics, studies of sports performance, surgical procedure simulation, Analysis of joint loads, design of the medical device, and animation of animal and human movement [14]. This biomechanical analysis needs a motion input to analyze the workloads during the various manual task.

II. Problem Definition and Objectives

In manufacturing industries are prone to some hazardous manual task that includes repetitive actions and sustained postures during assembly and processing tasks. Due to this manual task some musculoskeletal disorders like lower back pain, degenerative disc diseases, and thoracic outlet compression, etc., are produced for workers. Low back pain is developed due to large disc compression and it is viewed as a risk factor and a good predictor of a lower back injury. In occupational lower back injury is caused by static compression alone, especially during manual lifting tasks with twisting movements. Due to this lifting task muscle force is increased and it may also contribute to increasing the lumbar spinal loading. Sometimes hard and stressful physical work in the manufacturing and assembly section must be accomplished by a decreasing number of skilled workers. Industrial engineering and particularly workplace design contribute significantly to improving the situation. To fulfill these responsibilities and requirements the existing method of workplace design is critically reviewed and potential for improvement must be identified.

New methods and approaches to evaluate and assessment of occupational problems must be developed and assessed as regards their contribution to modern workplace design. A detailed biomechanical analysis of the workplace regarding physiological workload and linked effects of the workforce has been performed by simulation of the whole-body musculoskeletal model in the OpenSim platform. So, this work is focused to generate the motion data for biomechanical analysis for manual working conditions by using marker less motion capturing systems.

III. Methodology

Motion tracking means tracking the human skeleton model to generate the motion file for biomechanical analysis purposes. By this motion tracking, three-dimensional data of human joints are generated with the help of the Microsoft Kinect sensor along with anyone coding platforms like visual studio and Matlab.

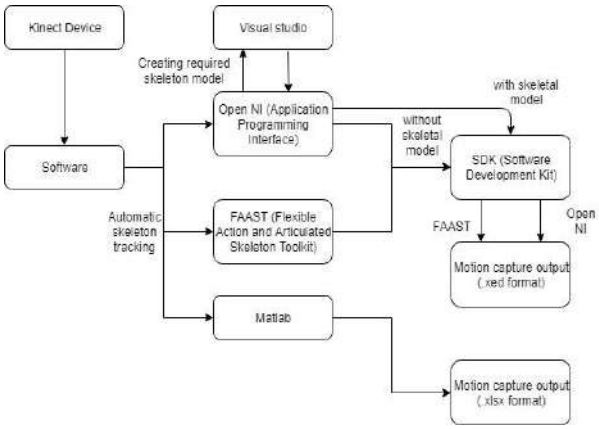

Fig. 1. Motion tracking methods

Figure 1 represents the various flow of motion tracking by using a Kinect sensor. In this motion tracking system Kinect sensor is used as an input device. Inputs are in the form of a video basis.

Kinect sensor is only used for detecting the object but the coordinate points are generated with the help of some other applications. There are many applications are available to get the coordinate data of the human skeleton model like visual studio, OpenNI, FAAST (Flexible Action and articulated skeleton toolkit) and Matlab. By using this flow motion file is generated for biomechanical analysis. The Kinect sensor has a 320 x 240-pixel resolution in depth sensor with 30 frames per second. Here Matlab 2013 is used for programming and visualization purposes.

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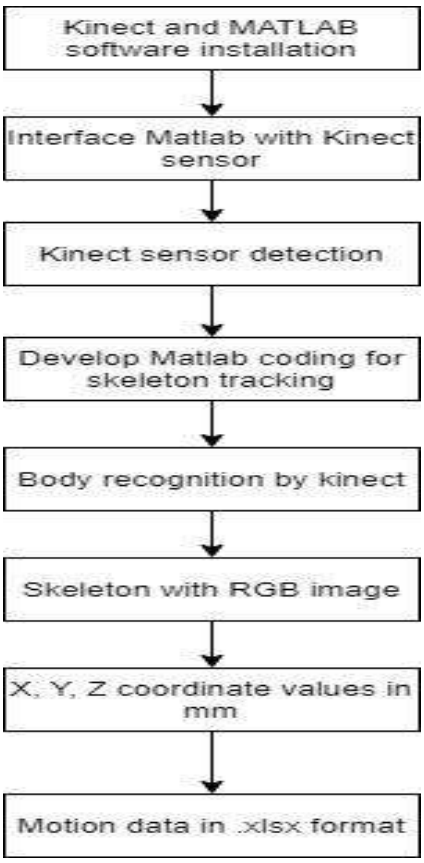

Fig. 2. Steps to generate motion data

A. Interface Kinect with Matlab

The interface between Kinect V1 and Matlab is achieved by the Image acquisition toolbox. This toolbox is commonly used for developing image processing applications. It is an application which enables the user to integrate the software and hardware properties of the device for various image acquisition toolbox.

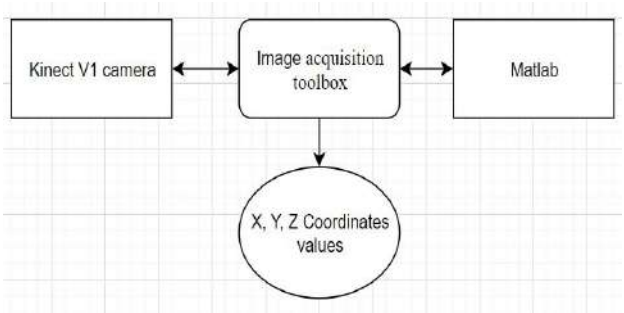

Fig. 3. Interface Kinect with Matlab

In the image acquisition toolbox is used to manage memory buffers by control hardware triggering of an input device. The below-mentioned code is used to detect the Kinect sensor,

```
hwInfo = imaqhwinfo('kinect');
```

B. Kinect sensor detection

Microsoft Kinect V1 has two sensors. One is a depth sensor and another one is a color sensor. During video capture, separate video input is given to achieve independent acquisition by using an image acquisition toolbox.

```
hwInfo.DeviceInfo(1)

hwInfo.DeviceInfo(2)

colorVid = videoinput('kinect',1);

depthVid = videoinput('kinect',2);
```

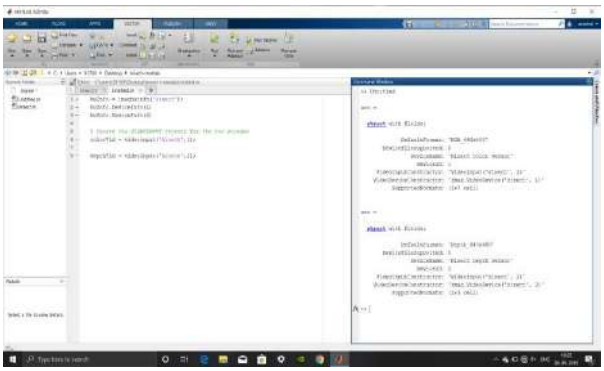

Fig. 4. Kinect Initialization

C. Matlab programming for skeleton tracking

Human skeleton tracking is achieved with the help of Matlab programming. Matlab coding is developed for initiating the system and generating the motion data.

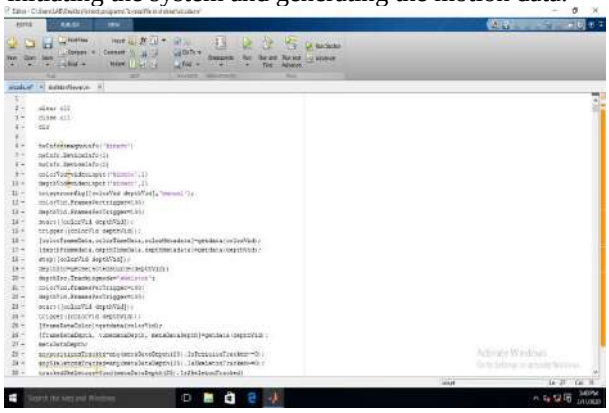

Fig. 5. Matlab programming

IV. Result and Discussion

The Kinect sensor can detect one or two users at the same time with a high amount of accuracy and detecting the 20 joints in the human skeleton model. Figure 7 represents the skeleton joints of humans [15]. By linking these joints, we can get the bone links. In Kinect V1 sensor provides various modes for skeleton tracking. These modes are configured from a video source object in-depth device.

```
depthSrc = getselectedsource(depthVid)
```

In tracking mode control, the skeleton is tracked whether all the joints are tracked during capturing time. Joints

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tracked during skeleton tracking is achieved by body posture property. In skeleton tracking selectively track one or more skeletons with the help of skeleton tracking ID.

depthSrc.TrackingMode = 'Skeleton';

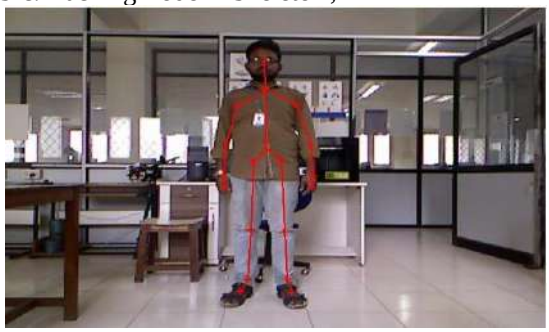

Fig. 6. Kinect skeleton tracking with RGB image

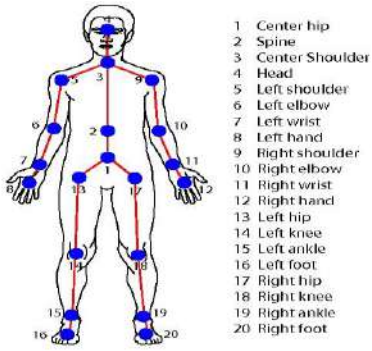

Fig. 7. Skeleton tracking joints

Acquired skeleton image mapping over the RGB image can be observed with the help of image preview windows in Matlab. The distance of a user from the Kinect sensor in three-dimensional space is captured. During motion capturing, measurements along the Z-axis as depth distance and (X, Y) as the 2-dimensional position of a joint in a definite frame. For experimentation different length from the Kinect sensor to the human model is taken into consideration. From that 1.75 m to 3.6 m is a precise length for motion tracking.

Fig. 8. Skeleton tracking during manual task

Figure 8 represents the skeleton model is superimposed into human RGB image with the help of Matlab coding. In this model non-return valve body of the submersible pump is transferred to one table to another table. The length of large and small table height is 480mm and 600mm from the ground respectively. During this manual lifting task, the human skeleton model is tracked by using a Kinect sensor and Matlab coding.

The coordinate values for 20 joints are represented in figure 9 from the Matlab command window. These coordinates values are 95th frame values. For this motion capturing, the Microsoft Kinect sensor takes 100 frames during the motion capturing time. With the help of this coordinate values motion file is generated for biomechanical analysis.

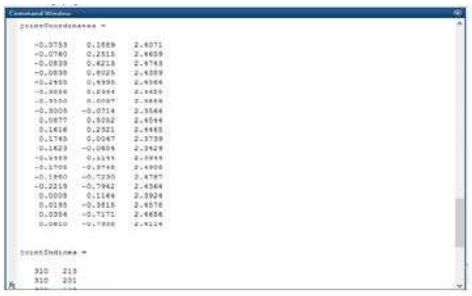

Fig. 9. 3D coordinate values in command window

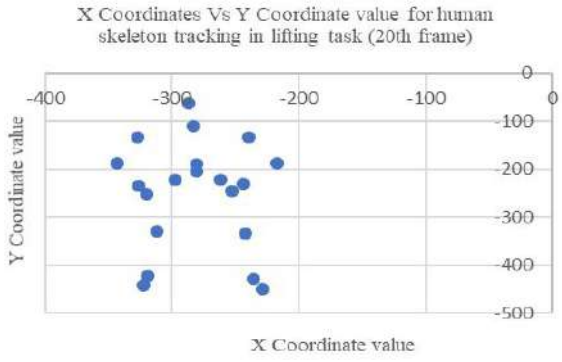

Fig. 10. Skeleton tracking in 20th frame

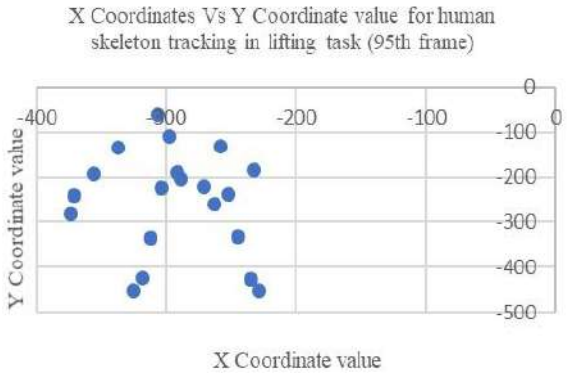

Fig. 11. Skeleton tracking in 95th frame

Figures 10 and 11 represent the 20th and 95th frame joint coordinates values for lifting tasks. In this task maximum movement is observed in the left hand and right-hand side because this manual task is mainly focused on hands. There is

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no maximum deviation in other joints in the human body. Based on these human skeleton tracking motion files will create. Initially, in motion capture system 3D coordinate values are displayed in the Matlab command window for 20 frames only. The remaining frame values are not visible in the command window. After that piece of Matlab code is developed to write these coordinate values in .xlsx format for 100 frames.

```
R1=jointIndices1
R2= jointCoordinates2
xlswrite('Results.xlsx',R1,'sheet1','(A1:A20) : (B1:B20)')
xlswrite('Results.xlsx',R2,'sheet2','(A1:A20) : (C1:C20)')
```

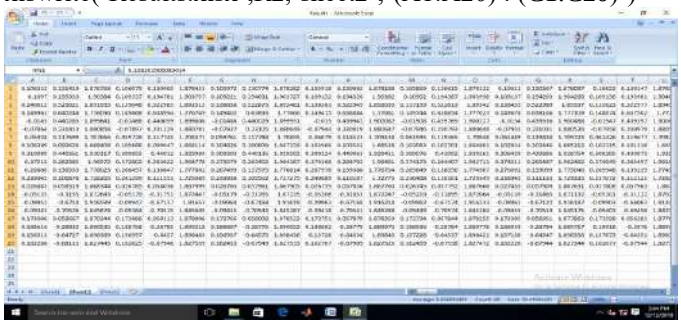

Fig. 12. Output motion data in .xlsx format

IV. CONCLUSION

Human Skeleton is tracked by using Microsoft Kinect with the help of Matlab programming. Based on this tracking, coordinate data for the skeleton model is observed with 100 frames per second. During the execution of the Matlab coding coordinate, values are displayed in command windows. In a single execution, only 10 frames data are visible in the command window but remaining frame data are not displayed. So, some piece of code is developed to write these 3D data values in the spreadsheet. After that motion data is generated in .xlsx format.

Based on this output coordinate values, the motion file will create with the help of .XML language. The future scope of this work is to generate a motion file for the various manual task in the manufacturing industry. The whole-body musculoskeletal model is undergone biomechanical analysis in the Opensim platform with the help of a motion file. Based on the output of biomechanical analysis predict the best posture and redesign the existing workstation in various manual handling sections in manufacturing industries.

REFERENCES

[1] Farag E. Elfeituri, "A Biomechanical Analysis of Manual Lifting Tasks Performed in Restricted Workspaces," International journal of occupational safety and ergonomics, 333–346, 2001.

[2] Diliang Chen, Yi Caia, Jiawei Cui, Jia Chen, Haotian Jiang, Ming-Chun Huang, "Risk Factors Identification and visualization for Work-related Musculoskeletal Disorders with Wearable and Connected Gait Analytics System and Kinect Skeleton Models," Journal of Smart Health, S2352-6483(17)30113-7, 2018.

[3] Ayushi Prajapati, Meet Bhatt, Yash Joshi, Rohit Negi, "Skeleton Tracking Using Microsoft Kinect for Windows on Matlab," International Journal of Recent Research Aspects, pp-377-380, 2018.

[4] Yi Li, "Multi-scenario Gesture Recognition Using Kinect," International Conference on Computer Games, 978-1-4673-1121-2, 2012.

[5] Katherina Bujang, Ahmad Faiz, Ahmad Nazri, Ahmad Fidaudin, Ahmad Azam, Jamaluddin Mahmud, "Development of a motion capture system using kinect. Journal of Technologies," 76:11 (2015) 75–86, 2015.

[6] Vishnu Sasikumar, second champakkadayil Abdul basheer Binoosh, "A model for predicting the risk of musculoskeletal disorders among computer professionals," International Journal of Occupational Safety and Ergonomics, ISSN: 1080-3548, 2018.

[7] A. Proch azka, o. Vy sata, m. Vali, m. Yadollahi, "The MS kinect use for 3d modelling and gait analysis in the matlab environment," 76:11 (2015) 75–86, 2015.

[8] Bjoern Mueller, Winfried Ilg, Martin A. Giese, Nicolas Ludolph, "Validation of enhanced kinect sensor-based motion capturing for gait assessment," 12(4): e-0175813, 2017.

[9] Jose Rosado, Filipe Silva, Vítor Santos, Zhenli Lu, "Reproduction of Human Arm Movements Using Kinect-Based Motion Capture Data," International Conference on Robotics and Biomimetics, 978-1-4799-2744-9, 2013.

[10] Saikat Chakraborty, Dibyayan Mondal, Anup Nandy, "A Study on Human Gait Kinematic Validation in Multi-Kinect v2 Environment," Institute of Electrical and Electronics Engineers, 978-1-5386-8235-7, 2018.

[11] M. P. De looze, k. Van greuningen, j. Rebel, kingma, P. F. M. Kuijer, "Force direction and physical load in dynamic pushing and pulling," Ergonomics, 377-390, 2000.

[12] Laura Punnett, David H. Wegman, "Work-related musculoskeletal disorders: the epidemiologic evidence and the debate," Journal of Electromyography and Kinesiology, 14 (2004) 13–23, 2004.

[13] Erica Beaucage-Gauvreau, William S. P. Robertson, Scott C. E. Brandon, Robert Fraser, Brian J. C. Freeman, Ryan B. Grahamj, Dominic Thewlis, Claire F. Jones, "Validation of an OpenSim full-body model with detailed lumbar spine for estimating lower lumbar spine loads during symmetric and asymmetric lifting tasks," Computer methods in biomechanics and biomedical engineering, 1025-5842, 2019.

[14] Zedong Hu, Chenguang Yang, Wei He, Zhijun Li, Shunzhan He, "Modeling and Simulation of Hand based on OpenSim and Leap Motion," Institute of Electrical and Electronics Engineers, 978-1-5386-3524-9, 2017.

[15] Saeid Motiian, Paola Pergami, Keegan Guffey, Corrie A Mancinelli, Gianfranco Doretto, "Automated extraction and validation of children's gait parameters with the Kinect," Biomedical Engineering Online, 2938-015-0102-9, 2015.

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Performance Improvement of a Tertiary Hospital Using Kano Model and Quality Function Deployment

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***Abstract*— In the dynamic and growing world quality is given prime importance by people. There is no compromise given to quality by the customers. Improving the quality of services provided in the hospitals has the potential to improve the performance of hospitals. Improved quality performance increases the demand of services by the users as well as improve the overall trust that patients have in the health institutions. Low quality social insurance around the world makes continuous harm human wellbeing in low and centre pay countries. Patient fulfilment with medicinal services administrations is a significant presentation measure for human services suppliers. Actually, it is one of the all inclusive objectives of social insurance suppliers as patient fulfilment legitimately mirrors the status of any human services office. Meeting tolerant fulfilment is confounded because of the consistently changing requests and human services needs of patients however it stays for the most part acknowledged measuring stick that compares palatable patient criticism to medical clinic achievement. Furthermore, quiet fulfilment is one of the most significant pointers in deciding patient wellbeing results.**

In this paper a Fuzzy Quality Function Deployment (QFD) model is planned to develop with other techniques such as Kano model and SERVQUAL is to analyse performance improvement of a tertiary hospital in Kerala. This paper aims to identify the customer's requirement in the tertiary health care sector through a primary data collection. A Fuzzy set theory is planned in order to priorities the requirements according to the weights associated with each factors. After the customer requirements and the technical requirements are found out the House of Quality matrix (HOQ) is plotted to find the correlation between the customer requirements and the technical requirements. The House of Quality matrix provides details of factors which are to be given more importance in the tertiary hospital.

Keywords*— *QFD; Fuzzy Set Theory; House of Quality; Tertiary Hospital

I. INTRODUCTION

In the dynamic and competing environment need for quality improvement is given prime importance. Quality upgrade in the neighborliness business can prompt fulfilled clients, Increment the quantity of guests and decidedly influence the GDP of nations. This venture proposes a crossover model utilizing the House of Quality (HOQ), SERVQUAL and Kano models for the clinic part. Clinics are places where elevated level executions in various quality criteria are required. Quality Function Deployment is a significant technique utilized for improving quality. The dynamic and serious condition of the present economy has constrained organizations and companies to make the client the focal point of consideration so the way toward giving a help or an item starts and finishes with the client. Just companies with fulfilled clients can remain in business and, to fulfill clients, it is basic to perceive client needs and satisfy them with the most elevated conceivable quality. The impalpability of the administration division expands its intricacy and makes it generally hard to evaluate and oversee quality.

One of the major factors of appraisal in the Kano model is the edge characteristics. These are fundamentally the highlights that the item should have so as to satisfy client needs. In the event that this trait is neglected, the item is basically deficient.

SERVQUAL, invented by Leonard berry, is a multi-dimensional research instrument, designed to capture consumer expectations and perceptions of a service along the five dimensions that are believed to represent service quality.

QFD has different quantification mechanism to make the procedure easy. Fuzzy set theory is a quantitative measure to find the weight of each requirement. QFD's purpose is to assure that customer needs are properly deployed throughout the design and to improve the product development process itself. This examination means to investigate and comprehend the client prerequisites of the present social insurance administrations and afterward to choose the ideal arrangement of the human services administrations. By embracing Quality Function Deployment (QFD) and fluffy rationale, this examination proposes another way to deal with help the basic leadership process in medicinal services industry. It gives a structure to breaking down the specialized necessities that can prompt the union of a client situated framework. It additionally changes the inborn ambiguity of the human discernments to be as exact as could be allowed so they become important data for the investigation of the framework.

II. LITERATURE REVIEW

In Lee, C. K. M.'s [1], paper Fuzzy QFD is applied to a health sector and priorities the customer needs. Research on the selection of fluffy rationale in medicinal services analytic framework to regulate the procedure execution and perceive

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certain predefined design has been directed for partner the notable issues utilizing the standard based methodology strategy.

Beheshtinia, M. A. [2] proposed a half and half model utilizing the House of Quality (HOQ), SERVQUAL and Kano models for the lodging business under spending imperative. The model was then executed at a lodging in the city of Rasht in Iran. Subsequent to recognizing 31 client needs, they were organized utilizing a blend of the SERVQUAL and Kano approaches.

Lee, H. [3] provides details about the psychometric properties of different healthcare service quality assessed by the physicians. The multi-trait method revealed that convergent validity was established for measured items based on multi rating item method.

Al-Neyadi, H. S. [4] assesses the nature of human services segment by researching factors influencing patient's fulfilment out in the open and private area dependent on SERVQUAL. The reason for this paper is to assess the nature of medicinal services benefits by researching the variables influencing quiet fulfilment in private and open emergency clinics in the UAE dependent on five help quality components of the SERVQUAL to be specific; physical assets, unwavering quality, responsiveness, affirmation, and compassion. An altered SERVQUAL survey was utilized to assemble the exploration information.

Ajwinder, S. [5] evaluates the nature of social insurance benefits by exploring the components influencing quiet fulfillment in private and open medical clinics in the UAE dependent on five assistance quality elements of the SERVQUAL in particular; effects, dependability, responsiveness, affirmation, and compassion. An adjusted SERVQUAL poll was utilized together the exploration data. The measurement of affirmation was appraised the most elevated while responsiveness was seen as the least significant of the five SERVQUAL measurements. The five components of the SERVQUAL seemed, by all accounts, to be a steady and dependable scale for estimating human services administration quality in the United Arab Emirates setting. The adjusted SERVQUAL might be utilized to contribute in improving the nature of medicinal services benefits in UAE and in other comparative conditions.

Gupta, P. [6] applied an integrated model of kano model and QFD. Kano model is applied to identify the customer needs and to calculate customer satisfaction coefficient that helps to prioritize importance of service quality that increases the customer satisfaction.

III. Performance Factors Related to Tertiary Hospitals

In the rapidly growing world performance factors analysis is very much important for quality improvement ina tertiary hospital. The various performance factors related to tertiary hospitals are managerial factors, Hospital characteristics, Top managers' characteristics, staff management and quality management system. Each factors play a crucial role in calculating the performance factors related to a tertiary hospital. Each of the characteristics are explained below.

1	***Managerial factors***
a	Management steadiness
b	Fulltime senior and center directors Systematic methodology
c	Delegation of power Managers' dedication and duty
d	Internal consistency Managers
e	Motivation Process approach
f	Parity of Authority and responsibility
g	Process Approach
2	***Hospital characteristics***
a	Interaction with protection associations
b	Bed inhabitance rate
c	Hospital size
d	Hospital claim to fame Organizational structure
e	Unique instructive condition
f	Full time specialists
3	***Top manager's characteristics***
a	Commitment and duty
b	Managerial encounters
c	Acceptance Moral qualities
d	Communication aptitudes
e	Flexibility
f	Honesty
4	***Staff management***
a	Organizational autonomy
b	Recruitment strategy
c	Salary Staff
d	Training
e	Motivation
f	Method of recruitment
g	Communication network
5	***Quality management system***
a	Management commitment
b	Staff participation in the improvement process
c	Analyze and solving problems Self assessment
d	Clinical guidelines
e	Complaint management

IV. General Performance Factors Related to Service Sectors [7]

The difficulties and development possibilities for the administrations part accordingly contrast across exercises. They rely upon the auxiliary attributes of various administrations markets, including their potential for innovative change and profitability development, their present level of guideline and innate extension for residential and universal challenge, just as the general jobs of people in

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general and private areas in every action. In spite of this decent variety, two expansive strategy difficulties can be distinguished that are the way to cultivating development in administrations:

1. Instructions to cultivate a progressively powerful and serious business condition that urges administrations firms to upgrade profitability, offer new administrations and make new work.
2. Step by step instructions to supplement such basic changes with powerful advancement and innovation dissemination strategies that can defeat obstructions to development and mechanical change in the administrations segment.

The development of rivalry in administrations segments is significant for another explanation; it encourages the development and new passage of firms that are especially imaginative and effective in fulfilling buyer need. The exhibition factors identified with administration segments are physical elements, work execution factors, co-ordinations the executives. The point by point factors are recorded underneath.

A. Physical factors

a) Quality of raw materials
b) Modern technology in equipment and machinery
c) Balance in production line

B. Job performance factors

a) Appropriate practical skill
b) Appropriate of shifts and rest periods
c) Affective decision-making process related to the production.
d) Appropriate Informal organization
e) Addressing of deviations rapidly
f) Accurate timetables of the production process
g) Effective organizational competencies
h) Incentives for workers linked to Productivity

C. Logistics management

a) On time delivery Cost
b) Overrun caused by logistic
c) Unpleasant weather
d) Accidents during delivery

V. Quality Improvement Techniques for Hospital Sectors

There are various quality improvement techniques used for hospital services. Quality improvement is very much important in the growing world. There are various quality improvement factors used for hospital sectors. This includes Kano models, Six sigma methodology, QFD. The various quality improvement techniques are listed below.

A. Six sigma

Six Sigma, initially structured as a business methodology, includes improving, planning, and observing procedure to limit or wipe out waste while streamlining fulfillment and expanding budgetary strength. The exhibition of a procedure—or the procedure capacity—is utilized to quantify improvement by looking at the pattern procedure ability (before progress) with the procedure capacity in the wake of guiding potential answers for quality improvement. One part of Six Sigma utilizes a five-staged procedure that is organized, trained, and thorough, known as the characterize, measure, dissect, improve, and control (DMAIC) approach.

B. Kano model

One of the major factors of appraisal in the Kano model is the edge characteristics. These are fundamentally the highlights that the item should have so as to satisfy client needs. In the event that this trait is neglected, the item is basically deficient. In the event that another item isn't analyzed utilizing the edge angles, it may not be conceivable to enter the market. This is the first and most significant quality of the Kano model. The item is being fabricated for some sort of buyer base, and along these lines this must be a pivotal piece of item development. Edge features are basic segments to an item.

C. Quality Function Deployment

Quality Function Deployment (QFD) is a strategy created in Japan starting in 1966 to help change the voice of clients into designing attributes for an item. The place of value, a piece of QFD is the fundamental plan instrument of value work deployment. It recognizes and arranges client wants (What's), distinguishes the significance of those wants, recognizes building attributes which might be important to those wants (How's), corresponds the two, takes into consideration confirmation of those connections, and afterward relegates targets and needs for the framework prerequisites. This procedure can be applied at any framework synthesis level (for example framework, subsystem, or segment) in the structure of an item, and can take into consideration appraisal of various reflections of a framework. It is seriously advanced through various progressive degrees of what's and How's and investigations each phase of item development (administration upgrade), and creation (administration conveyance).

VI. Advanced Methodology Proposed

The proposed approach receives one of the QFD instruments, House of Quality (HOQ), to move client prerequisites to specialized necessities. client necessities of the chose human services administration are distinguished. At that point, comparing specialized prerequisites which are the approaches to fulfill client needs are recorded. A study is intended to gather client discernments with respect to current fulfillment levels and significance of the client prerequisites. Fluffy etymological factors are received to dole out the significance of client prerequisites and specialized necessities. The measurable populace was chosen arbitrarily from the

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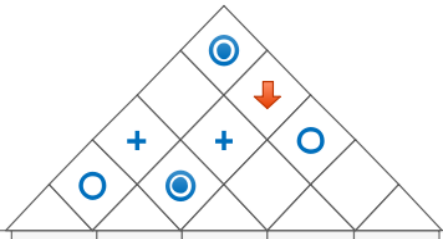
clients of the inn. The Cochran recipe to be utilized with 5% mistake to decide the example size for the SERVQUAL and Kano polls. The SERVQUAL and Kano polls are standard surveys with a high level of unwavering quality and legitimacy.

Some of the customer requirements obtained by visiting the tertiary hospital are listed below.

a) Ease of navigation around the hospital
b) Pleasing attitude of staffs
c) Healthcare provider's professionalism;
d) Doctor's professionalism Pharmacist's professionalism Nurse's professionalism
e) Speediness of healthcare services
f) Quality of healthcare services
g) Emergency equipment's availability
h) Quality of ICUs in hospital
i) Help desk availability

Some of the technical requirements found out are

a) Hospitals interior and exterior settings
b) Registration features
c) Standardized procedures inside the hospital
d) Follow up procedures after discharge
e) Consultation procedures



	Hospitals interior and exterior settings	Registration features	Standardized procedures inside the hospital	Follow up procedures after discharge	Consultation procedures
Ease of navigation around the hospital	9			1	1
Pleasing attitude of staffs		9			3
Healthcare provider's professionalism	1		9	3	3
Doctor's professionalism				3	9
Speediness of healthcare services		3	3		9
Quality of healthcare services	3		9		9
Emergency equipment's availability	9				1
Quality of ICUs in hospital	1		3		9
Help desk availability	3	3			

Fig. 1 House of Quality

House of Quality matrix is plotted using the technical requirements and customer requirements as shown in figure 1.

VII. Result

The proposed model identifies the crucial factors in level of quality based on customer needs and the available technical requirements in hospital management studies. The top three factors are:

a) Ease of navigation
b) Quality of healthcare service
c) Healthcare provider's professionalism.

The results show that, by improving the infrastructure of the Hospital and by maintaining high professionalism in standard procedures, the customer service level can be elevated supremely. An effective action plan is to be developed for implementing the identified technical characteristics.

References

[1] Lee, C. K. M., Ru, C. T. Y., Yeung, C. L., Choy, K. L., &Ip, W. H. (2015). Analyze the healthcare service requirement using fuzzy QFD. *Computers in Industry*, *74*, 1-15.

[2] Beheshtinia, M. A., &Farzaneh Azad, M. (2019). A fuzzy QFD approach using SERVQUAL and Kano models under budget constraint for hotel services. *Total Quality Management & Business Excellence*, *30*(7-8), 808-830.

[3] Lee, H., Delene, L. M., Bunda, M. A., & Kim, C. (2000). Methods of measuring health-care service quality. *Journal of Business Research*, *48*(3), 233-246.

[4] Al-Neyadi, H. S., Abdallah, S., & Malik, M. (2018). Measuring patient's satisfaction of healthcare services in the UAE hospitals: Using SERVQUAL. *International Journal of Healthcare Management*, *11*(2), 96-105.

[5] Ajwinder, S., & Ajay, P. (2017). Measuring healthcare service quality from patients' perspective: using Fuzzy AHP application. *Total Quality Management & Business Excellence*, *30*(3-4), 284-300.

[6] Gupta, P., & Srivastava, R. K. (2011). Customer satisfaction for designing attractive qualities of healthcare service in India using Kano model and quality function deployment. *MIT Int J MechEng*, *1*(2), 101-107.

[7] Afsharkazemi, M. A., Manouchehri, J., Salarifar, M., &Nasiripour, A. A. (2013). Key factors affecting the hospital performance: a qualitative study using fuzzy logic. *Quality & Quantity*, *47*(6), 3559-3573.

[8] M. Mccellan, S.J. Beales, S.I. Cohen, M. Macdonnell, A. Thoumi, M. Abdulmalik, et al., Accountable care around the world: a framework to guide reform strategies, Health Affair 33 (9) (2014) 1507–1515.

[9] P.Y. Leung, N. Tse, D. Yeung, Sustaining quality, performance and costeffectiveness in a public hospital system, in: Proceedings of the 37th World Hospital Congress IHF Conference, Dubai, United Arab Emirates, 2011.

[10] O.P. Keown, G. Parston, H. Patel, F. Rennie, F. Saoud, H. Ai Kuwari, et al., Lessons from eight countries on diffusing innovation in health care, Health Affair 33 (9) (2014) 1516–1522.

[11] J. Lim, V. Joshi, Public perceptions of healthcare in Singapore, Ann. Acad. Med. Singap. 37 (2) (2008) 91.

[12] D.R. Graber, Organizational and individual perspectives on caring in hospitals, J. Health Hum. Serv. Adm. 31 (4) (2009) 517–537.

[13] C.L. Yeung, S.K. Kwok, H.C. Mui, An investigation of an RFID-based patient-tracking and mobile alert system, Int. J. Eng. Bus. Manag. 3 (1) (2011) 50–56

[14] H. Lee, L.M. Delene, M.A. Bunda, C. Kim, Methods of measuring health-care service quality, J. Bus. Res. 48 (3) (2000) 233–246.

[15] L.K. Chan, M.L. Wu, Quality function deployment: a literature review, Eur. J. Oper. Res. 143 (3) (2002) 463–497.

[16] L.Y. Zheng, K.S. Chin, QFD based optimal process quality planning, Int. J. Adv. Manuf. Technol. 26 (7–8) (2005) 831–841.

ISBN 978-93-89105-41-4

[17] J.R. Hauser, D. Clausing, The house of quality, Harv. Bus. Rev. 1 (1988) 3–13.

[18] M. Cermani, M. Mengoni, M. Peruzzinin, A QED-based method to support SMEs in benchmarking co-design tools, Comput. Ind. 63 (2012) 12–29.

[19] Y.Q. Yang, S.Q. Wang, D. Mohammad, S.P. Low, A fuzzy quality function deployment system for buildable design decision-makings, Autom. Constr. 12 (4) (2003) 381–393.

[20] R. Radharamanan, P.G. Leoni, Quality function deployment as applied to a health care system, Comput. Ind. Eng. 31 (1996) 443–446.

[20] C.C. Chiou, Y.C. Cheng, An integrated method of Kano model and QFD for designing impressive qualities of healthcare service, Ind. Eng. Eng. Manag. (2008) 971–978.

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Machine Learning Based Methodology Proposal For Pneumonia Diagnosis

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***Abstract*— The application of Machine learning (ML) in the medical imaging field is increasing rapidly where it helps from the detection to the diagnosis of the diseases including pneumonia. ML is a major technically advancing field of Artificial Intelligence (AI) which gives computer programs the capability to learn automatically and improve from past experiences without the need to be programmed manually. This paper aims to suggest a methodology using machine learning to detect a visual signal for pneumonia in medical images and to specifically locate lung opacities. The data was provided by Kaggle in DICOM format which include 30227 images out of which 28989 images were selected for the final study. The main training dataset include the patient ID, the bounding box coordinates, and the target label [0,1]. The proposed ML methodology uses Convolutional Neural Network (CNN). This method of disease diagnosis will help the doctors to identify the disease in less time and more accurately. As the available data set is not pertaining to India, performance of the model in the Indian context is limited.**

Keywords— ***pneumonia, machine learning, artificial intelligence, convolutional neural network.***

I. INTRODUCTION

Pneumonia can be considered as a critical form of acute lower respiratory infection which primarily affects the lungs. The infection results in the inflammation of air sacs. The air sacs will fill with purulent material(fluid/puss) causing cough with phlegm(puss), difficulty breathing, chills, fever. There are 120 million episodes of pneumonia per year in children under 5, over 10% of which(14million) progresses to severe episodes.[5] Internationally, about 15% of children below the age of 5 dies because of pneumonia. About $109 million/year is spend for treatment and diagnosis of pneumonia.[3] According to WHO, one in three deaths caused by pneumonia is in India. The best test for pneumonia diagnosis is through an X-ray. Pneumonia can be accurately diagnosed through the review of a chest radiograph (CXR) by highly trained specialists followed by validation through clinical history, vital signs and laboratory exams. Clinicians are faced with reading high volumes of images every shift. It would be difficult for the radiologists and the physicians to find out what is clinically relevant from such a huge data,[6] which leads to backlog of unreported studies.[7] With pneumonia, the alveoli of the lungs gets filled with pus and fluid in one or both lungs resulting in the hinderance to breathing and reduced oxygen absorption. Improper and untimely image (X-ray and CT) diagnosis is a factor contributing to the pneumonia deaths.

The process of Medical imaging is a method of making visual representations of the interior of a body for clinical analysis and medical intercession. The visual representation of the function of some organs or tissues (physiology) are also made for diagnosis. Medical imaging lets out the internal structures that are hidden by the bones and skin of the body, which helps in identifying and treating disease. It also provides a means to set up a database of normal anatomy and physiology which can help to detect abnormalities. The imaging of the removed body parts and tissues are considered to be part of procedures of pathology as an alternative to medical imaging. As per the worldwide data available till 2010, 5 billion medical imaging studies were done. Medical imaging is considered to be a part of biological imaging which includes radiology, magnetic resonance imaging (MRI), medical ultrasonography or ultrasound, endoscopy, elastography, tactile imaging, thermography, medical photography, and positron emission tomography (PET) and single-photon emission computed tomography (SPECT). Electroencephalography (EEG), magnetoencephalography (MEG), electrocardiography (ECG) are measurement and recording techniques which are not predominantly constructed to produce images. Other technologies produce data that can be represented as a parameter vs. time graph or maps that contain data about the measurement locations. In this paper our prime focus will be on chest X-rays.

Machine learning (ML) can be considered as the field of exploring computational algorithms and statistical models which is used to execute a particular task automatically without human intervention for explicit programming, depending on patterns and inference based on memory. ML is a part of a major technology known as artificial intelligence (AI). ML algorithms try to create a mathematical model based on the sample data called as "training data", which is then used to create predictions or decisions based on which a task is to be executed. ML algorithms are mostly used for a variety of

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applications spanning from suggesting a video to identifying cancer.

II. LITERATURE REVIEW

Machine learning techniques are now becoming more popular and successful in image-based detection, disease prognosis, and risk evaluation. Before 1980, classical classifiers such as Linear Discriminant Analysis (LDA), Quadratic Discriminant Analysis (QDA), and a k-nearest neighbor classifier (k-NN) were used for classification. LDA and QDA are used to separate measurements of two or more classes of objects or events. In 1986, MLP was put forward by Rumelhart and Hinton, which generated the 2nd extensive neural network (NN) research after the first in 1960s. In 1995, Vapnik proposed Support Vector Machine (SVM) for classification and regression analysis. Random forests were proposed by Ho in 1995, and dictionary learning by Mairal. In 1980, Fukushima proposed Neocognitron, which was the first among ML with image input (image-based ML) technique. In 1989, LeCun proposed Convolutional Neural Network (CNN) based on Neocognitron. In 1994, Suzuki tried applying a multilayer perceptron (MLP) to cardiac images and in 1996, for reducing noise in the images, he developed neural filters using a modified MLP. In 2000, he suggested of neural edge enhancers and in 2003, he came up with the idea of Massive Training Artificial Neural Network (MTANN) for classification of patterns, detecting objects in 2009, separating different patterns from various training patterns that occur in X-ray images, in 2006, and reducing the noise and artifacts that tend to occur on CT images, in 2013. Hinton developed a different deep brief network (DBN) in 2006 which was a generative graphic model. Deep learning had gained popularity only after late 2012.[14]

Suzuki, K. (2009).[15] used MTANN to developed a supervised filter for the magnification of actual models in a CAD scheme for sensing of lungs nodules in CT. It helped in improving the sensitivity and specificity of the model. Sivaramakrishnan, R., et al. (2017).[10] proposed a unique model of Convolutional Neural Network based Deep Learning (DL) model for precisely localize the abnormalities when used in X-ray screening. A series of layers of non-linear processing units of CNN based DL model is used for the end-to-end feature extraction and classification. Islam, M. T., et al. (2017).[11] explored the application of Deep Convolutional Network architectures on various kinds of chest and lung anomaly. It was found that Deep Convolutional Neural Network does not perform well across all abnormalities. Lopes, U. K., et al. (2017).[12] showed the application and potential of pretrained CNN as feature extractors in medical images. They suggested that using other clustering algorithms like Expectation Maximization (EM) algorithm may yield a superior result when compare to K-mean algorithm. Yates, E. J., et al. (2018). [7] demonstrated binary image classification using Convolutional Neural Network (CNN) and the use of an ML-based approach to categorize the given chest radiographs as normal or abnormal. They studied about the 14 categories of thoracic pathologies using the machine learning algorithm developed.

III. DATA COLLECTION AND ANALYSIS

The training data set consists of 30227 images and test data set of 3000 image with a pixel size 1024*1024 in DICOM format taken from Kaggle. Digital Imaging and Communications in Medicine (DICOM) format is used to save medical images. The DICOM file contains an image from a medical scan and an including identification data of the patient indicating that the image is linked to a specific individual.

The main training dataset include the patient ID, the bounding box coordinates, and the target label [0,1] as in table 1.

- ‘patientId _’ - Each patient ID corresponds to a unique image.
- Bounding boxes are defined as follows: (x-min y-min width height).
- x_ - the upper-left x coordinate of the bounding box.
- y_ - the upper-left y coordinate of the bounding box.
- width_ - the breadth of the bounding box.
- height_ - the height of the bounding box.
- Target_ - the binary Target, indicating whether the sample has evidence of pneumonia.

Table 1: Training dataset

Patient ID	x	y	Width	Height	Target
006cec2e-6ce2-4549-bffa-eadfcd1e9970					0
00704310-78a8-4b38-8475-49f4573b2dbb	323	577	160	104	1
00704310-78a8-4b38-8475-49f4573b2dbb	695	575	162	137	1
008c19e8-a820-403a-930a-bc74a4053664					0
009482dc-3db5-48d4-8580-5c89c4f01334					0
00c0b293-48e7-4e16-ac76-9269ba535a62	306	544	168	244	1
00c0b293-48e7-4e16-ac76-9269ba535a62	650	511	206	284	1
00d7c36e-3cdf-4df6-ac03-6c30cdc8e85b					0

- Multiple images with same patient Ids are screened out and 28989 images are selected for final analysis.
- The patient with pneumonia (label 1) and without pneumonia (label 0) is shown in figure 1. The three class labels are shown in figure 2.

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Figure 1: the number of patients with pneumonia and without pneumonia.

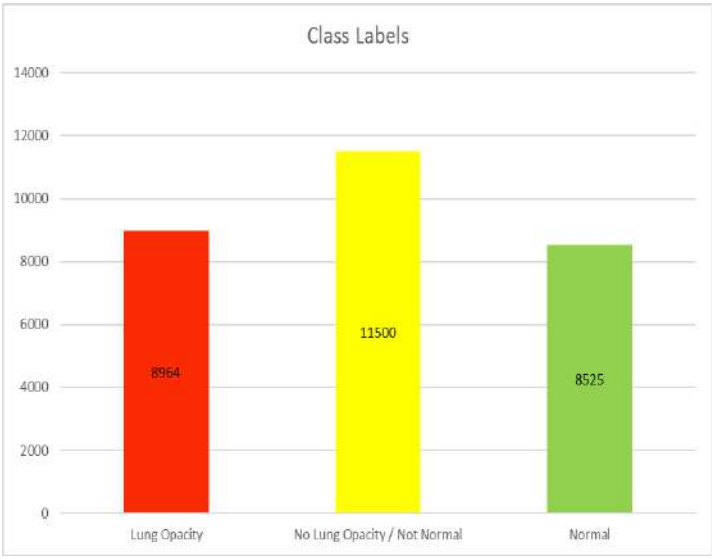

Figure 2: Plot of 3 class labels

In the X-ray images, we are looking for white opacities. Lung opacities are vague, fuzzy clouds of white in the darkness of the lungs, which makes detecting them a real challenge. Usually the lungs are full of air. When someone has pneumonia, the air in the lungs is replaced by other material - fluids, bacteria, immune system cells, etc. That's why areas of opacities are areas that are grey but should be more black. This area indicates that the lung tissue in that area is probably not healthy. The sample images with label 0 and 1 I shown in figure 3.

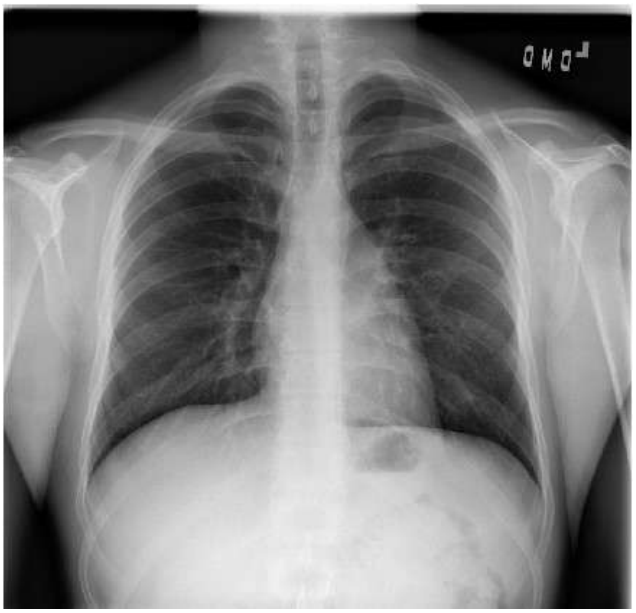

Figure 3(a): X-ray image with label 0(normal image)

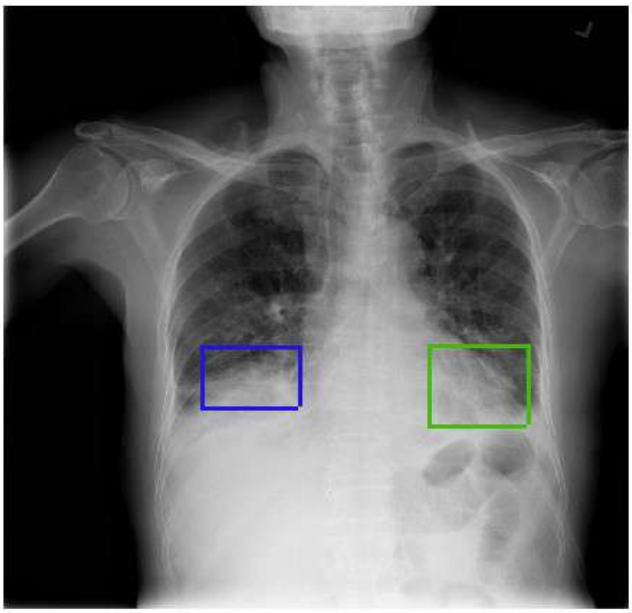

Figure 3(b): X-ray image with label 1(lung opacity)

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Figure 3(c): X-ray image with label 1(lung nodules and masses)

IV. PROPOSED METHODOLOGY

Firstly, a convolutional neural network (CNN) is used to segment the image, using the bounding boxes directly as a mask. Then, connected components are used to separate different areas of predicted pneumonia followed by drawing a bounding box around the connected components.

A. Convolution Neural Network

The network consisting of a number of residual blocks with convolutions and down-sampling blocks with max pooling is used. A single up-sampling layer is used to convert the output to the same shape as the input at the ending of the network.

As the input to the network is 256 by 256 (instead of the original 1024 by 1024) and the network uses down-sampling a number of times without subsequent up-sampling, the final prediction is found to be very crude. When the network down samples 4 times the final bounding boxes changes with at least 16 pixels.

B. Segmentation

ResNet18 encoder is used for segmentation and classification task. A pre-trained model from the Unet kernel is utilized for this purpose. Various utility functions are called upon to classify the images based on non-zero mask regions through down-sampling operations combined with R-CNN masking.

C. Training

Mask R-CNN is used for training the classification model. Firstly, an RPN (Region Proposal Network) is used to point out the Regions of interest (RoI) and the region is bounded by boxes and cropped for model building.

The segmentation model is trained on Resnet18.

D. Testing

The model is verified on the test data and the results corresponding to the data is obtained. The ratio of intersection over union (IoU) of areas of ground truth and predicted mask is calculated.

V. RESULT AND DISCUSSION

A methodology for pneumonia detection has been proposed to enhance the efficiency and the outreach of diagnostic services. The performance of the generated model can be calculated using the parameters like F1 score, accuracy, sensitivity, specificity, area under receiver operating characteristics (ROC) curve (AUC), True positive rate (TPR) and False positive rate (FPR).

ACKNOWLEDGMENT

I express my gratitude towards the Radiological Society of North America (RSNA), the US National Institutes of Health, The Society of Thoracic Radiology, and MD.ai for providing the data set through Kaggle.

REFERENCE

[1] https://data.unicef.org/topic/child-health/pneumonia/

[2] https://www.nhp.gov.in/world-pneumonia-day-2017_pg

[3] https://www.who.int/en/news-room/fact-sheets/detail/pneumonia

[4] https://www.nhlbi.nih.gov/health-topics/pneumonia

[5] https://www.thoracic.org/patients/patient-resources/resources/top-pneumonia-facts.pdf

[6] Eid, M., Spearman, J. V., van Assen, M., De Santis, D., Sahbaee, P., Landreth, S. P., & De Cecco, C. N. "Machine Learning and Artificial Intelligence in Cardiovascular Imaging". CT of the Heart (2019)., pp: 893-907.

[7] Yates, E. J., Yates, L. C., & Harvey, H. (2018). "Machine learning "red dot": open-source, cloud, deep convolutional neural networks in chest radiograph binary normality classification". Clinical radiology (2018)., Vol. 73(9), pp: 827-831.

[8] Marleen, de, Bruijne., "Machine learning approaches in medical image analysis: From detection to diagnosis". *Medical Image Analysis* (2016).

[9] Kim, G. B., Jung, K. H., Lee, Y., Kim, H. J., Kim, N., Jun, S., & Lynch, D. A. "Comparison of shallow and deep learning methods on classifying the regional pattern of diffuse lung disease". *Journal of digital imaging* (2018)., Vol. 31(4), pp: 415-424.

[10] Sivaramakrishnan, R., Antani, S., Xue, Z., Candemir, S., Jaeger, S., & Thoma, G. R. "Visualizing abnormalities in chest radiographs through salient network activations in Deep Learning". *IEEE life sciences conference (LSC)* (2017), pp: 71-74.

[11] Islam, M. T., Aowal, M. A., Minhaz, A. T., & Ashraf, K. "Abnormality detection and localization in chest x-rays using deep convolutional neural networks". *arXiv preprint arXiv:1705.09850* (2017).

[12] Lopes, U. K., & Valiati, J. F. "Pre-trained convolutional neural networks as feature extractors for tuberculosis detection". *Computers in biology and medicine* (2017), Vol. 89, pp: 135-143.

[13] Rajpurkar, P., Irvin, J., Zhu, K., Yang, B., Mehta, H., Duan, T., & Lungren, M. P. "Chexnet: Radiologist-level pneumonia detection on chest x-rays with deep learning". *arXiv preprint arXiv:1711.05225* (2017).

[14] Suzuki, K. "Overview of deep learning in medical imaging". *Radiological physics and technology* (2017), Vol. 10(3), pp: 257-273.

[15] Suzuki, K. "A supervised 'lesion-enhancement'filter by use of a massive-training artificial neural network (MTANN) in computer-aided diagnosis (CAD)". *Physics in Medicine & Biology* (2009), Vol. 54(18), S31.

Stearic Acid as a Green Anti-Wear Additive for Biolubricant

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Abstract— **Majority of the lubricants, around 85% used now are mineral oil based. Mineral oils, which are mainly used as base oils for lubricants are non-bio degradable, toxic and can cause harm to our environment. Huge amount of lubricants, approximately 150 million barrels are used every year globally. In order to tackle and overcome the bad effects of mineral oils on environment, environmental friendly bio-lubricants have to be developed. Vegetable oils exhibiting good lubricating properties, biodegradability and non-toxicity became the flag bearers in this new bio lubricant formulation methods. A significant amount of research is being carried out in the field of vegetable oils as lubricant base oils. In this paper, the chemical, rheological and tribological properties of two base oils, rice bran oil and jatropha oil are found out. Also a green anti-wear additive, stearic acid is used in different percentages and its properties are also evaluated. Stearic acid added bio-lubricants is found to reduce the wear scar as compared to the pure vegetable oils used.**

Keywords- biolubricant, vegetable oil, rice bran oil, jatropha oil, stearic acid, tribological properties.

I. INTRODUCTION

Escalating environmental concerns and increasing regulations over the contamination and pollution caused by using fossil fuel based lubricants have increased the necessity for renewable and biodegradable lubricants. Majority or almost all of the lubricants available in the market are mineral oil based, they attained prominence because of their superior properties and availability at low cost [1]. But they are non-renewable and causes irreparable damage to the environment. Studies have showed that the mineral oil lubricants, expelled out into the atmosphere harmed our environment in various ways due to its toxic and non-biodegradable nature [2, 3]. Since biodegradability and non-toxicity became the most important concerns, an alternate to the traditional lubricants, known as, environmentally friendly lubricants gained more popularity. Several advantages and properties shown by vegetable oils such as biodegradability, good lubricity, better thermal stability, low toxicity, higher viscosity and flash point are enabling it to be a good potential alternate source of lubricant base oil [4, 5]. The downside of using vegetable oils are that its poor oxidation stability and also poor low temperature characteristics [6]. It can be overcome by using chemical modifications such as transesterification, epoxidation or hydrogenation [7]. Enhancement of properties by using different additives can also be done. A number of works has been reported on Rice bran oil (RBO) [8] and jatropha oil (JO) [9] which are chosen here as the base oils.

Vegetable oil molecules consists of two parts, a glycerol part and a fatty acid part, three fatty acids are attached to the glycerol, because of which it is called triglycerides. Rice bran oil was found to have good lubricant properties comparable to the commercially available mineral oil based lubricant SAE20W40 [8]. RBO is a vegetable oil, which is extracted from the outer husk of rice grains. It has 38.4% oleic acid and 2.2 % stearic acid content respectively [10, 11]. It is observed that higher oleic acid content improves oxidation stability. Jatropha oil is obtained from the seeds of jatropha plant, which is a drought resistant shrub or tree. The oil extracted from Jatropha contains saturated and unsaturated fatty acids, of which palmitic acid with 14.1% and stearic acid with 6.7% are saturated [12].

Stearic acid (SA) is a type of saturated fatty acid having 18 carbon chain in the hydrophobic (moisture repelling) end and

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a carboxyl group on the hydrophilic (moisture attracting) end [13]. It has been widely used by many research teams to hinder the susceptibility of hydrophilic materials to moisture [14]. It was found that stearic acid was the most influential boundary lubrication additive in sunflower oil, which decreased wear and provided a uniform reduction of the coefficient of friction [15]. It shows good lubricity but is not soluble in synthetic oils. Saturated hydrocarbons show good tribological properties but reduce the pour point of the oil so a trade off can be made between lubricity and pour point or it is considerably better to use pour point depressants and improve the overall usability of the oil. Stearic acid forms a hydrophobic layer on the metal surface, which acts as lubricant film with anti-corrosion properties [14].

In this study the chemical, rheological and tribological properties of pure RBO and pure JO are found out. Stearic acid is added to both the oils in different percentages and the above properties are again evaluated and the change in the properties are analysed.

II. MATERIALS AND METHODS

A. Materials

The oils were obtained from commercial suppliers. Chemicals used for the study, such as stearic acid, methanol, acetic acid, chloroform, etc were purchased from Sarabhai Chemicals, Trivandrum. Pure RBO and JO with different percentages, i.e, 1%, 2%, 3%, 4%, 5% of stearic acid were tested. The required samples were mixed using a magnetic stirrer as in figure 1.

Figure 1 : Mixing of oil sample in magnetic stirrer

B. Chemical Properties

The chemical properties, which indirectly hints at the ability of an oil to provide good lubrication, like acid number and peroxide number were evaluated based on IS: 548 (Part 1) – 1964. Acid number can be defined as a measure of amount of free fatty acids present in the oil. The acid value is found out by using chemical tests. First of all, weigh 5 ± 0.1 grams of oil sample in a conical flask. Then, 30 ml of methanol and 3-4 drops of the phenolphthalein indicator are added to the sample inside the conical flask. Then titrate the mixture against the potassium hydroxide (KOH) solution, in the burette. The break point can be seen as the point at which the mixture colour turns pink or reddish pink colour in the conical flask. The acid value is calculated using (1).

$$A = ((56.1 \times V \times N)/W) \quad (1)$$

Where A= Acid Value, V= Volume of KOH solution used in burette, N= Normality of alkali solution (KOH), W=Weight of the oil sample.

The peroxide value is defined as the amount of peroxide oxygen present per 1 kilogram of oil. It shows the start of rancidity in unsaturated oils. It gives an understanding to the extend to which an oil sample has underwent autoxidation, which is the primary mode of oxidation in oils. Peroxides are formed as intermediates in the autoxidation reaction. The procedure for finding the peroxide value is as follows. Take 5 grams of required oil in a conical flask. Add 50ml of 3:2 solution of acetic acid and chloroform to the oil. Add 0.5ml of potassium iodide (KI) solution to the mixture and stir it intermittently for 1 minute. Add 30ml of water and 0.5ml of starch solution, the mixture turns deep blue/black. Titrate against 0.01N sodium thiosulfate solution till the blue colour disappears. The titration volume was noted and the peroxide value was determined by using (2).

$$P = [(s - b) \times N \times 1000)/W] \quad (2)$$

Where P = Peroxide value, s = Burette reading, b = Blank reading (value obtained by doing the whole experiment without oil), N = Normality of sodium thiosulfate solution, W = Weight of oil sample in g.

The test setup for both acid and peroxide are similar with only the titration mixture in the burette different. The test setup is as shown in figure 2.

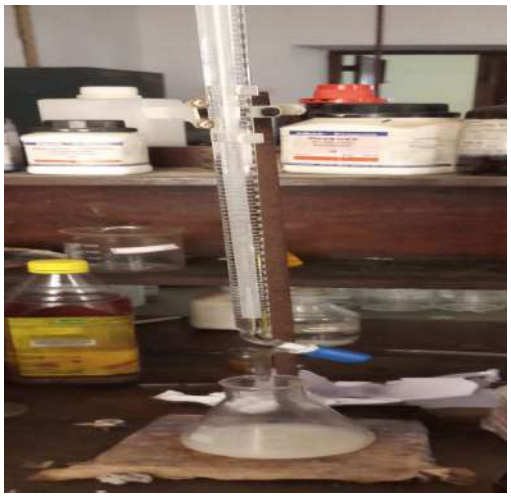

Figure 2: Test setup for acid and peroxide value

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C. Rheological Properties

The viscosity of the oils were evaluated using Cannon-Fenske Opaque Viscometer according to ASTM D446 standards. The oil samples are taken in a Cannon-Fenske tube and kept in the viscometer bath as shown in figure 3. The time taken for the oil to fill the bulbs are noted and the viscosity is calculated. The kinematic viscosity in centiStokes (cSt) is obtained at temperatures 40,50,60,70 and 80 degree celsius. The practical application of finding the viscosity at these temperature is that the temperature dependence of viscosity can be found out.

Figure 3: Cannon-Fenske Viscometer with oil sample

D. Tribological Properties

As per ASTM D 4172 standard, the coefficient of friction (COF) and wear scar diameters (WSD) were evaluated by using the Four Ball Tester tribometer. The tests were carried out for 60 minutes at 1200rpm. The test temperature is 75°C, which is nearly the average temperature of a lubricant in an engine. The balls used for the test are Chrome alloy steel balls, with 12.7mm diameter. A rotating steel ball, held using a collet, is pressed against the three steel balls, kept in the ball pot, which are firmly held together and immersed in the lubricant which is being tested. The ball pot with the balls fixed and the chamber in which the test is done, which houses the spindle running unit on which the collet can be attached, are shown in figure 4.

Ball pot Spindle running unit

Figure 4: Four ball tribometer parts

All the test parameters such as load applied, test time, temperature and rotational speed are computer controlled and are set before the test is started. The wear scar diameter on the bottom three balls are measured by using optical microscope.

III. RESULTS AND DISCUSSIONS

A. Chemical, Rheological and Tribological Properties of Pure Oils

The acid and peroxide values of the pure oil samples, RBO and JO were evaluated as explained earlier and are tabulated in table 1, along with tribological properties. The change in colour observed during acid test is shown in figure 5. When the acid value of the oil is high, it may corrode the parts which it comes in contact with. So industrial lubricants such as engine oils, cutting fluids, etc should have minimum acid number. The acid value of RBO is very less as compared to JO because of the presence of more free fatty acids in JO. The peroxide value of RBO is higher than JO. It shows the primary oxidation of the oil. The change in colour before and after titration is shown in figure 6.

Figure 5: Oil sample before (left) and after (right) acid test.

The tribological properties such as COF and WSD of RBO and JO are evaluated by a four-ball tester as per ASTM D 4172 standards. The experiment was repeated for 3 times for each sample and the average value is taken. The wear scar was measured using an optical microscope. The wear scar diameter for RBO is slightly lesser than JO whereas the COF is slightly higher because of the presence of more saturated fatty acid content.

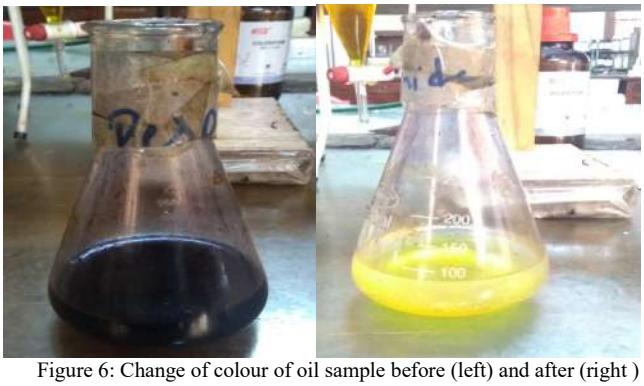

Figure 6: Change of colour of oil sample before (left) and after (right) titration for peroxide test.

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The viscosity of the samples are found using Cannon-Fenske Viscometer. The viscosity at a temperature range of 40℃ to 80℃ is evaluated for the pure oil samples. The viscosity is expressed in cSt ie, it is the kinematic viscosity being evaluated. The results are tabulated in table 2. The viscosity of RBO is higher than JO.

Table 1: Chemical and Tribological Properties of pure oils

Name of the Oil	Acid Value (mg KOH/g)	Peroxide Value (meq/Kg)	WSD (μm)	COF
RBO	1	9.5	547	0.0898
JO	19.5	2.5	571	0.0673

B. Chemical, Rheological and Tribological Properties of RBO with different percentages of SA

Stearic acid was mixed in RBO in increasing weight percentages. The mixture with 5% stearic acid(w/w) showed agglomeration after some time. It can be observed visually the separation of the additive. The saturation point for the oils is therefore 5% by weight, hence that sample was not used further. All the other samples ie, 1%, 2%, 3%, 4% showed good stability and its properties were evaluated. The acid and peroxide values of each sample was found out and is tabulated in table 3, along with the tribological properties, COF and WSD.

Table 2: Kinematic viscosity of pure oils

Temperature (℃)	Kinematic Viscosity (cSt)	
	RBO	JO
40	48.3	34.18
50	42.27	24.66
60	25.17	18.62
70	19.44	14.33
80	15.55	11.36

Stearic acid being acidic in nature, due to saturated fatty acids increases the acid number of the oil. As the stearic acid percentage is increased the acid number is also increasing.The peroxide values reduces with increase in stearic acid percentage in RBO, it shows that autoxidation is reduced in RBO with increased percentage of stearic acid. The tribological properties showed a significant reduction as SA is added.

Table 3: Chemical and Tribological Properties of RBO with SA

Wt % of SA	Acid Value (mg KOH/g)	Peroxide Value (meq/Kg)	WSD (μm)	COF
1	5.4	25.8	514.67	0.0597
2	5.9	20.9	491.34	0.0591
3	8.62	14.88	490.67	0.0585
4	9.4	12.65	472.34	0.0582

The optimum value obtained was 4% of SA by weight. The stearic acid increases the saturated fatty acid content in the oil which increases the lubricity of the oil. The viscosity of the different oil samples were found out as explained before and the results are shown in table 4. There is a slight reduction in viscosity of RBO with addition of SA. As the SA percentage is increased the viscosity also increases by a relatively small amount. The percentage change in viscosity with respect to the pure oil is shown in table 5 The change in viscosity due to the addition of SA is also represented graphically in figure 7.

For all the different percentages of SA in RBO, the percentage change (reduction) is almost constant for each temperature. At higher temperatures (70℃, 80℃), the percentage change in viscosity is less as compared to that at lower temperatures (40℃,50℃).

Table 4: Kinematic viscosity of RBO with SA

Temperature (℃)	Kinematic Viscosity (cSt)			
	RBO+1% SA	RBO+2% SA	RBO+3% SA	RBO+4% SA
40	43.70	43.70	44.82	46.57
50	31.52	30.70	31.13	31.52
60	23.23	23.02	22.98	22.93
70	17.70	17.19	17.56	17.91
80	13.92	13.61	13.84	13.92

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C. *Chemical, Rheological and Tribological Properties of JO with different percentages of SA*

Stearic acid was mixed in JO in increasing weight percentages. The mixture with 5% stearic acid(w/w) showed agglomeration when kept for some time. The saturation point for JO is therefore 5% by weight (identified by visual inspection), hence that sample was not used further. All the other samples ie, 1%, 2%, 3%, 4% showed good stability and its properties were evaluated. The acid and peroxide values of each sample was found out and is tabulated in table 6, along with the tribological properties, COF and WSD.

Table 5: Percentage Reduction in Kinematic Viscosity of RBO with SA

Temperature (°C)	Percentage Reduction in Kinematic Viscosity			
	RBO+1% SA	RBO+2% SA	RBO+3 %SA	RBO+4% SA
40	9.52	9.52	7.2	3.58
50	25.43	27.37	26.35	25.43
60	7.71	8.54	8.7	8.9
70	8.95	11.57	9.67	7.87
80	10.48	12.48	11	10.48

In this case also the acid value of JO is increased by the addition of SA. The acid value of 4% SA is very high, which can cause significant corrosion if used in practical application. The peroxide value of JO is not affected significantly by the addition of SA, which is a positive result. It shows that the increased saturated fatty acids increase the primary oxidation stability. The tribological properties show that the addition of SA significantly improves the WSD. The optimum percentage is found as 4%. The SA forms a film on the material due to chemisorption and it reduces the wear.

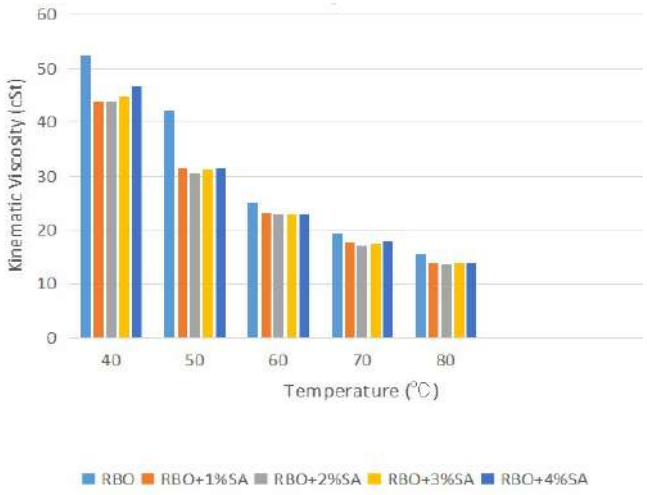

Figure 7: Change in Kinematic viscosity of RBO with SA

Table 6: Chemical and Tribological Properties of JO with SA

Wt % of SA	Acid Value (mg KOH/g)	Peroxide Value (meq/Kg)	WSD (μm)	COF
1	22.42	2.84	398.34	0.0627
2	26.8	3.98	384.34	0.0619
3	32.54	4.35	384.67	0.0611
4	45.2	4.73	383.67	0.0597

The kinematic viscosity of the oil samples were evaluated and is shown in table 7. There is no appreciable change in viscosity of JO with the addition of SA. Thee is a very slight reduction in the viscosity as the percentage of SA is increased. The change in viscosity is also represented graphically in figure 8. The percentage change of viscosity of JO with SA at different temperature is shown in table 8.

Table 7: Kinematic viscosity of JO with SA

Temperature (°C)	Kinematic Viscosity (cSt)			
	JO+1% SA	JO+2% SA	JO+3% SA	JO+4% SA
40	34.79	34.69	34.59	34.59
50	25.08	24.97	24.97	24.85
60	18.83	18.73	18.62	18.53
70	14.73	14.63	14.43	14.51
80	10.74	10.54	10.54	10.53

Unlike RBO, the kinematic viscosity is showing a slight increase, for all composition of SA in JO except at 80°C. At that temperature there is a reduction in kinematic viscosity for all composition of SA in JO.

IV. CONCLUSIONS

The increasing environmental issues arising due to the use of fossil fuels, deforestation, use of non-biodegradable materials etc are pushing the manufacturing industry to develop and adopt green manufacturing techniques. Lubricant industry is a

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multi-million dollar industry which is investing more resources into bio-lubricants.

Table 8: Percentage Change in Kinematic Viscosity of JO with SA

Temperature (°C)	Percentage Change in Kinematic Viscosity			
	JO+1% SA	JO+2% SA	JO+3% SA	JO+4% SA
40	1.78	1.49	1.2	1.2
50	1.7	1.26	1.26	0.77
60	1.13	0.59	0	-0.48
70	2.79	2.09	0.7	1.26
80	-5.46	-7.22	-7.22	-7.31

Vegetable oils are excellent contenders for the replacing existing mineral oils. The purpose of this study was to evaluate certain lubricating properties such as acid value, peroxide value, kinematic viscosity, COF and WSD of vegetable oils, Rice Bran Oil and Jatropha Oil, with a non toxic biodegradable additive, stearic acid. The chemical, rheological and tribological properties of the pure vegetable oils as well as with increasing percentages of stearic acid were found out. From the results, it can be concluded that:

- Acid value of RBO is very less as compared to JO. The addition of SA increases the acid value for both oils, but the increase in JO is very significant.

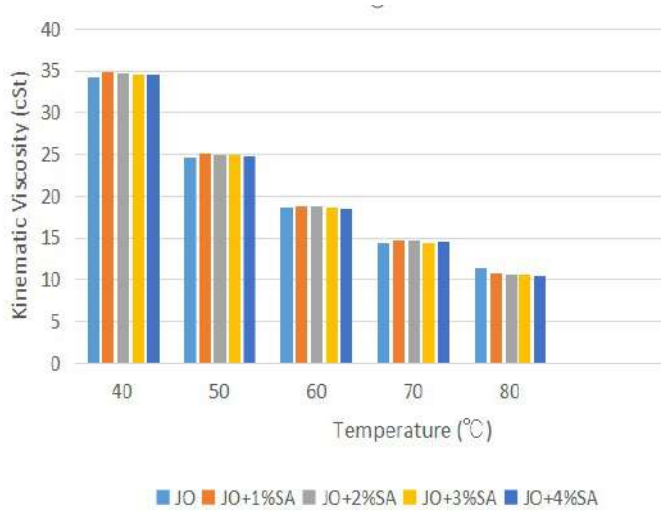

Figure 8: Change in Kinematic Viscosity of JO with SA

- Peroxide value of JO is lower as compared to RBO. The addition of SA into JO very slightly increases peroxide value while it is reduced in RBO.
- RBO has better viscosity than JO. There is no appreciable change in viscosity with increasing percentages of SA for both oils.
- Wear scar diameter of both RBO and JO is significantly reduced by adding SA. As the stearic acid percentage is increased, the wear scar is reduced for both the oils, which is due to the chemisorption of stearic acid to the metal surface, which forms a film that reduces the wear thereby increasing the lubricity of the oil.
- The optimum percentage of SA was found to be 4% for both oils, in terms of tribological properties. But the acid values are higher at this percentage composition.
- The percentage change in kinematic viscosity is higher for RBO as compared to JO with the addition of SA. In the case of RBO, for all percentage compositions the kinematic viscosity is lower as compared to pure RBO, while in the case of JO, the values show less deviation from the pure oil.

To use either of these oils as base oil for an industrial application, the oxidative stability have to be improved. The oxidative stability can be checked using Hot Oil Oxidation Test. It can be enhanced by chemical modification of the oil. The tribological results prove that these vegetable oils can be used instead of mineral oils in industrial applications with necessary modifications. Future works can be done concentrating on the chemical modification of vegetable oils so that it can replace mineral oils completely.

REFERENCES

1. D, D., "*History of Tribology*". New York: Longmans Green., 1971: p. 125-254.
2. Aluyor, E.O., K.O. Obahiagbon, and M. Ori-jesu, "*Biodegradation of vegetable oils-A Review*". Scientific Reasearch and Essay 2009. **4**: p. 543-548.
3. Kayode, J., "*Evaluation of the Effects of Pollution with Spent lubricating oil on the physical and chemical characteristics of soil*". The pacific Journal of Science and Technology, 2009. **10**: p. 387-394.
4. Asadauskas and S. Erhan, "*Lubricant base stocks from vegetable oils*". Industrial Crops and Products. **11**: p. 277-282.
5. Boyde, S., "*Green lubricants. Environmental benefits and impacts of lubrication*". Green Chemistry, 2002. **4**(4): p. 293-307.
6. Adhvaryu, A., S.Z. Erhan, and J.M. Perez, "*Tribological studies of thermally and chemically modified vegetable oils for use as environmentally friendly lubricants*". Wear, 2004. **257**(3-4): p. 359-367.
7. Zainal, N.A., et al., "*A review on the chemistry, production, and technological potential of bio-based lubricants*". Renewable and Sustainable Energy Reviews, 2018. **82**: p. 80-102.
8. Rani, S., M.L. Joy, and K.P. Nair, "*Evaluation of physiochemical and tribological properties of rice bran oil – biodegradable and potential base stoke for industrial lubricants*". Industrial Crops and Products, 2015. **65**: p. 328-333.

ISBN 978-93-89105-41-4

9. Rahim, E.A., A.S.A. Sani, and N. Talib, "*Tribological Interaction of Bio-Based Metalworking Fluids in Machining Process"*, in *Lubrication - Tribology, Lubricants and Additives*. 2018.
10. Shashidhara, Y.M. and S.R. Jayaram, "*Vegetable oils as a potential cutting fluid —An evolution".* Tribology International, 2010. **43**(5-6): p. 1073-1081.
11. Sneha, E., S. Rani, and M. Arif, "*Evaluation of lubricant properties of vegetable oils as base oil for industrial lubricant".* IOP Conference Series: Materials Science and Engineering, 2019. **624**: p. 1-6.
12. Kumar, A. and S. Sharma," *An evaluation of multipurpose oil seed crop for industrial uses (Jatropha curcas L.): A review".* Industrial Crops and Products, 2008. **28**(1): p. 1-10.
13. Mirzadeh, M., et al., "*Effect of stearic acid as a low cost and green material on the self-cleaning and anti-corrosion behavior of anodized titanium".* Colloids and Surfaces A: Physicochemical and Engineering Aspects, 2019. **583**.
14. Ye, X., J. Wang, and M. Fan, "*Evaluating tribological properties of the stearic acid-based organic nanomaterials as additives for aqueous lubricants".* Tribology International, 2019. **140**.
15. Fox, N.J. and G.W. Stachowiak, "*Vegetable oil-based lubricants—A review of oxidation".* Tribology International, 2007. **40**(7): p. 1035-1046.

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E-Commerce Marketing Framework Using Consumer Online Presence

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***Abstract*— E-Commerce is now seen as a reality part of a business plan. This paper highlights some guidelines for companies to create an E-commerce strategy or to revise their existing strategy. This plan emphasizes on age based targeted marketing in such e-commerce platform which will tap the full potential of marketing and a predictable business dynamics. Adopting such a strategy gives a competitive edge allowing all the products to be marketed to each and every group. In this project a prototype will be created to exercise individual targeting using their online presence in the e-commerce platform.**

Keywords*— Targeted marketing, e-commerce, individual targeting, e-business

I INTRODUCTION

E-commerce has helped businesses establish a wider market presence by providing cheaper and more efficient distribution channels for their products or services. For example, the mass retailer Target has supplemented its brick-and-mortar presence with an online store that lets customers purchase everything from clothes to coffee-makers to toothpaste to action figures.

By contrast, Amazon launched its business with an e-commerce-based model of online sales and product delivery. Not to be outdone, individual sellers have increasingly engaged in e-commerce transactions via their own personal websites. Finally, digital marketplaces such as eBay serve as exchanges where multitudes of buyers and sellers come together to transact.

II LITERATURE REVIEW

In order to explore issue of user interface, [1] identifies and analyzes features of user interfaces and common location of e-commerce function on e-commerce web sites. Design elements that are being researched are site navigation, home link, search, view cart, get help, manages account, catalogue, and personalization functions. The content analysis was performed toward 120 companies' furniture web sites in U.S, China, German, and Indonesia, aiming to identify the most common features used on e-commerce websites. The results show that none of design practices among those examined in this study met Nielsen's criteria for de-facto standard. This study also aims to explore web design practices across-national border. With the huge amount of information available online [2], the World Wide Web is a fertile area for data mining research. The Web mining research is at the cross road of research from several research communities, such as database, information retrieval, and within AI, especially the sub-areas of machine learning and natural language processing.

The main purpose of [4] is to study the process of Web mining techniques and its application in e-commerce applications. This paper using the methods that introducing the concept of Web mining, and describing the process of Web data mining in detail: source data collection, data pre-processing, pattern discovery and pattern analysis, using a detailed case of Web mining application in e-commerce

III PROCESS OF E-BUSINESS

The term e-BUSINESS framework is related to software frameworks for e-business applications. They offer an environment for building e-commerce applications quickly.

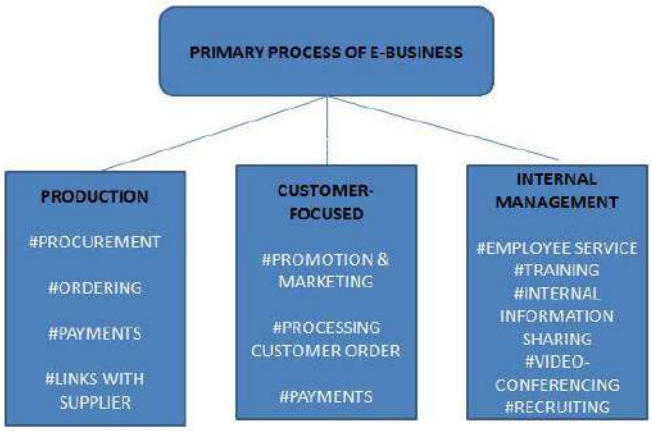

Fig 1 primary process of e-business

IV TRENDS IN E-COMMERCE ENVIRONMENT

A. Current Trends

Ecommerce is changing. Mobile conversions continue to be on the rise. The mobile industry saw sales increase by 55 percent in 2018, and by 2022, smartphone will account major sales. Customer expectations are growing at the same time: 38 percent of shoppers now expect high street businesses to offer same-day delivery. Other ecommerce trends are very much in

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line with the web design trends that are pushing the industry forward this year. Progressive web apps, for example, use advanced technologies to bring the speed and features of a mobile app to a mobile website, even allowing for shopping platforms to be accessible offline, "The key benefit to retailers is that they no longer have to choose between investing in their mobile sites or their apps." The e commerce market is using more customer interactive approach which help to approach the customer interaction for more inclusive business. They use AI chat bots to interact with the customer those who are visiting the online e-commerce platform. From certain instance these platform has boosted the sales and business in both organized and the unorganized sector of the economy. This proactive step will take the business dynamics to a whole new level.

B. Present marketing strategy

A strategy is a summary of how an e-store is planning to achieve its goals and improve its position in the market. There are different types of strategies depending on the goals. In this case, we will focus on how to reach more customers for our e-commerce business. Make sure your online store is:

a) Accessible from every device (PC, laptop, phone etc.).
b) Readable with clear design and information on it.

For this purpose, our ecommerce store needs to have a responsive web design and a mobile-friendly theme. Customers expect mobile-friendly sites. Businesses with a mobile-friendly website will make more sales over those which do not have one. Latest statistics show increasing mobile device usage._Web store home page, product pages, and product categories are the most visited places in an online store are they designed in a way to be understood as well to make it user friendly.

V TARGETED MARKETING

Target Marketing involves breaking a market into segments and then concentrating your marketing efforts on one or a few key segments consisting of the customers whose needs and desires most closely match your product or service offerings. It can be the key to attracting new business, increasing your sales, and making your business a success.

A. Demographic Segmentation

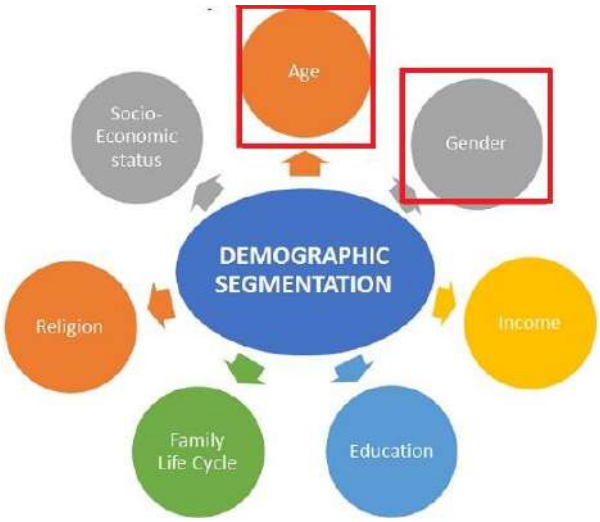

Fig 2: Demographic segmentation

B. Geographic Segmentation

Geographic segmentation involves segmenting the market based on location. Home addresses are one example.

Fig 3 Geographic segmentation

C. Psychographic Segmentation

Psychographic segmentation divides the target market based on socio-economic class, personality, or lifestyle preferences. The socio-economic scale ranges from the affluent and highly educated at the top to the uneducated and unskilled at the bottom. The UK-based National Readership

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Survey defines social class according to the following categories:

Social Grade	Social Status	Occupation
A	upper middle class	higher managerial, administrative or professional
B	middle class	intermediate managerial, administrative or professional
C1	lower middle class	supervisory or clerical, junior managerial, administrative or professional
C2	skilled working class	skilled manual workers
D	working class	semi and unskilled manual workers
E	those at lowest level of subsistence	state pensioners or widows (no other earner), casual or lowest grade workers

D. Modules in e-commerce

This fully-featured e-Commerce system allows you to promote and sell your products online. With our browser-based catalog and order management tools, you can quickly and easily manage a vast array of products and product variants.

VI DESIGN AND FRAMEWORK

This design proposes an approach to retrieve information from a given e-commerce website, collecting data from the site's structure, retrieving semantic information in predefined locations and analysing user's access logs, thus enabling the development of accurate models for predicting users' future behaviour.

When the customer has made the purchase the information and the process flows through the these 3 modules : customer account, payment gateway, check out and shipping. These function modules are the same for any typical e-commerce industry. But when they have login id for buy in their information makes our model more robust and can be targeted more accurately that our demographic metrics makes sense .The design change where the online presence is accounted and age and gender is categorized and then put the next module which does the targeted marketing. Identifying the target market for their services, the company could target the desired market with a direct mail campaign, or a Facebook ad aimed at customers within a specific geographic area, increasing the return on investment on their marketing - and bringing in more customers.

VII METHODOLOGY

C#, pronounced as "C-Sharp", is an object-oriented programming language provided by Microsoft that runs on .Net Framework. A schematic version of the proposed target marketing strategy is given below. Here we demonstrate 2 cases.

Searching for a class 10 physics book and a lipstick, so the module identifies the visitors age is 10 and a female, so the then products will be marketed in a way that products for a female of age 15 will be targeted.

VIII RESULT AND CONCLUSION

This paper proposes a design that conceptualized some of the guidelines for companies to create an E-commerce strategy or to revise their existing strategy. E-Commerce is now seen as a reality part of a business plan. This plan emphasizes on age based targeted marketing in such e-commerce platform which will tap the full potential of marketing and a predictable business dynamics.

Adopting such a strategy gives a competitive edge allowing all the products to be marketed to each and every group. In this project a framework for such a prototype will be formulated to exercise individual targeting using their online presence in the e-commerce platform. Such demographic segmentation based marketing and geographic segmentation based marketing allows us to tap the full potential of it.

REFERENCES

[1] Purwati, Y.. Standard features of e-commerce user interface for the web. Researchers World 2011;2(3):77.

[2] Kosala, R., Blockeel, H.. Web mining research: A survey. ACM Sigkdd Explorations Newsletter 2000;2(1):1–15.

[3] Mei, L., Cheng, F.. Overview of Web mining technology and its application in e-commerce. 2010 2nd International Conference on Computer

[4] Engineering and Technology 2010;7:V7–277–V7–280. URL http://ieeexplore.ieee.org/lpdocs/epic03/wrapper.html

[5] Peska, L., Vojtas, P.. Evaluating various implicit factors in e-commerce. CEUR Workshop Proceedings 2012;910(Rue):51–55. URLhttp://www.scopus.com/inward/record.url?eid=2-s2.0-84891904908{\&}partnerID=tZOtx3y1.

[6] Gefen, D.. Customer loyalty in e-commerce. Journal of the association for information systems 2002;3(1):2.

[7] Wei, K., Huang, J., Fu, S.. A survey of e-commerce recommender systems. In: Service Systems and Service Management, 2007 International Conference on. IEEE; 2007, p. 1–5.

[8] Yiing Jia Loke, Wei Yoong Chan. 2007. Seasoned and potential internet shoppers: a multinomial logit analysis. Applied Economics Letters 14, 43-47.

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Experimental investigations on the effect of strut geometries in supersonic mixing

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***Abstract*— Effective mixing in a short mixing chamber is a major challenge in supersonic air breathing engines, especially the mixing between two high speeds co-axial streams. The residence time is a major factor to get the two streams properly mixed. The selection of mixing method is crucial in the supersonic conditions. An experimental study has been performed on the supersonic mixing of air from strut injections of various combinations in their trailing ramp angles with a free stream air of Mach number 2. Two different configurations of geometries, a plain geometry and a lobed geometry, considered and further two different combinations, slot and hole injections, are taken for the study in each geometry. Among different combinations, it is found that a better mixing enhancement is achieved for the 9^o lobbed geometry struts.**

Keywords—supersonic mixing, strut injection, momentum flux

I. INTRODUCTION

The fuel injection, mixing, ignition, combustion and residence time are important activities in the scram jet engines since all these activities should be performed in the order of milliseconds. The combustion is mainly depending upon the effective mixing of two streams of high velocities in the case of such engines and hence the mode of mixing is of great importance. Active and passive methods are broadly used as mixing enhancements. In active methods, induction of turbulence, shock interactions, swirls etc. are generated by the active components like cavities or struts. In passive methods, the initial condition of the jet is changed by changing the nozzle geometry. A strut is a geometrical structure spans the entire width inside the nozzle along the primary stream. This will help the secondary stream, the fuel, directly injects into the core of the primary stream to enhance the uniform spreading of fuel in the lateral direction. More enhancements in mixing may be achieved if one can make necessary changes in the trailing ramp angles. Further advantages in the strut based injections are the formation of a recirculation zone, can be used, for flame holding combustion and the generation of vortices by ramps of the struts to accelerate the mixing.

Majority of the secondary injections are performed by the wall injection, wall injection with cavity, and strut injection with ramps or wedges. Flow field structure and the mixing characteristics of the injectors by Schlieren technique is studied by Desikan and Job Kurian [1] using three different strut designs with straight and tapered ramps. The effect of strut geometry influences the generation of various sizes of vortices and changes in the shock system and the ignition conditions due to the presence of boundary layer along the wall in the combustion chamber is observed by Gerlinger, Stoll, Kindler, Shneider and Aigner [2]. The computational investigations by Naveen, Sumesh, Balachandran and Samitha [3] and Manu, Sumesh, Balachandran and Samitha [4] showed very good mixing improvements with lobed struts. The capability to enhance the mixing in supersonic flows from struts with various trailing ramps were achieved by Sujith, Muruganadam and Job Kurian [5] with a free stream air at Mach number 1.63 and a secondary air injection. Linguin, Bernhard and Marius [6] in their numerical analysis of multi staged injection found that the two stage injection makes full use of the residual oxygen near the wall and the second stage injection avoids the strong shock waves in the far downstream locations results a rising wall pressure and hence to achieve a good burning effects after the wall injection. This allows more fuel to be injected into the combustor without causing thermal choking.

In this work a simulation of the non-reacting supersonic flow is generated to study the effect of wedge angle for the mixing effectiveness and total pressure loss of an intrusive secondary injection technique using wedge strut. Two streams of atmospheric air, one at a supersonic speed of 2 Mach supplied axially through a convergent divergent nozzle as a primary flow and the other one through a strut, which is fixed inside middle of the nozzle, supplied tangentially from both sides of the strut as a secondary flow allowed passing parallel to the main stream flow

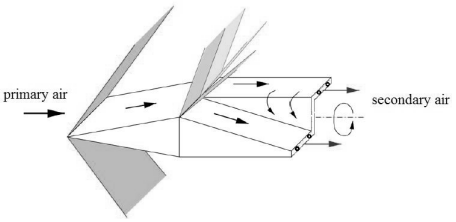

Fig.1. Stream wise vortices created by the lobed strut

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The flow from the strut exit into the core of the main stream flow facilitates mixing of secondary and the primary streams in a mixing chamber as in Fig. 1. This intrusive method of the secondary stream allows proper mixing between two streams.

II. MIXING PARAMETERS

TABLE I. NOMENCLATURE

D	Degree
DoM	Degree of Mixing
L/W	Length to Width ratio
x/h	Position of the stagnation pressure probe at the ratio of horizontal to vertical
um	Unmixed
Φ	Uniformity factor
μ	Momentum flux

A. Momentum Flux

The supersonic jet from the nozzle enters into the mixer with different momentum and stagnation pressures. The momentum flux distribution at the exit of the mixing chamber in the lateral direction is the measure of the bulk mixing. Momentum flux is calculated [7] as

$$\mu = p\,(1+\gamma M^2)$$

where p is the static pressure and M is the Mach number calculated from the measured values of stagnation pressure. The momentum flux at which uniformity attained indicates the axial distance where mixing is complete.

B. Degree of Mixing

In order to compare the performance of mixing for different strut configurations based on a quantitative assessment of level of mixing achieved, a dimensionless parameter called uniformity factor Φ is defined as:

$$\Phi = 1-[\sigma_\mu(x)/\mu_{av}(x)]$$

where $\sigma_\mu(x)$ is the standard deviation of radial distribution of momentum flux at a given axial location along the mixing chamber and $\mu_{av}(x)$ is the average momentum flux along a lateral line at the location considered. Uniformity factor Φ is a measure of the uniformity of the momentum flux distribution in the lateral direction at a given location. For a properly mixed flow, the distribution has to be uniform across the section. A mixing parameter called degree of mixing (DoM) is defined, using the uniformity factor, as:

$$DoM = (\Phi - \Phi_{um})/(1- \Phi_{um})$$

where Φ_{um} is the values of Φ when the two streams are totally unmixed and DoM will be zero.

III. EXPERIMENTAL SET-UP

A schematic of the experimental setup is shown in Fig. 2. The setup consists of a high pressure compressor and the storage vessels of 3000 litres of total capacity. The exit air from the storage is maintained for 8 bar, which is supplied as the main stream air to the nozzle. A secondary supply line is made for the air supply through the strut, which is placed inside the nozzle.

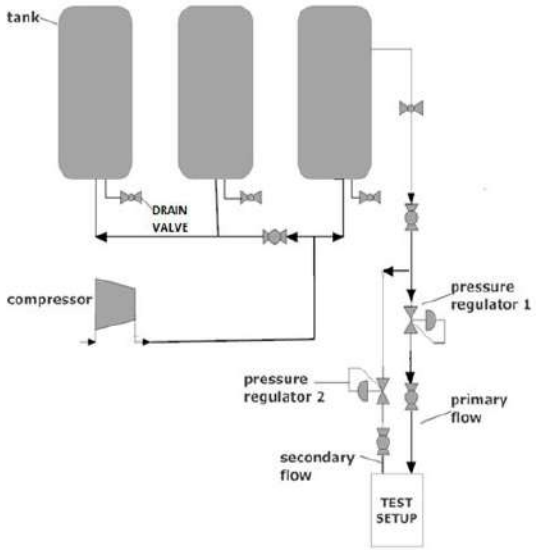

Fig.2. Schematic of the experimental setup

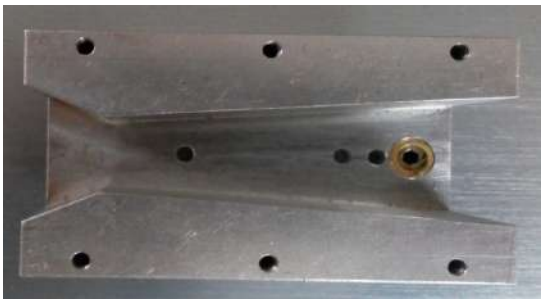

Fig. 3 Rectangular convergent divergent nozzle

A. Rectangular Nozzle

A rectangular convergent divergent nozzle is made with the help of gas dynamic relations by considering the main stream pressure and the static pressure corresponding to the atmospheric conditions. The throat and the exit area of the nozzle is calculated and the convergent angle is considered here as 13^o, following the conventional practice. Fig. 3 shows the rectangular convergent divergent nozzle.

B. Strut Geometry

Based on the available duct area to maintain the supersonic flow, the strut dimensions are decided. Out of two different secondary passages, one is through holes and the other is slots. In each secondary passage configurations, two different strut geometries being considered. A planar geometry and a lobed geometry. The struts were made from Aluminium blocks. In the lobed struts an alternate wedge unswept strut is chosen. There are two upward wedges and one downward wedge at the middle in the lobed struts as in

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Fig. 4.(a) and (b). and in Fig. 5 (a) and (b) as per the details in Table. II.

The strut occupies the full width of flow channel, as shown in Fig. 6, thereby dividing the flow equally in the subsonic region itself. The flow in the upper and lower portion of the strut flows without any deflection up to the starting of the wedges.

TABLE II. STRUT CONFIGURATIONS

Strut geometry	Strut exit configuration	Number of Exits
Planar Strut	Slot	Single
Lobed Strut	Slot	Single slot in each three lobes
Planar Strut	Hole	7 holes
Lobed Strut	Hole	3 holes in the middle lobe and 2 each holes in the other two lobes

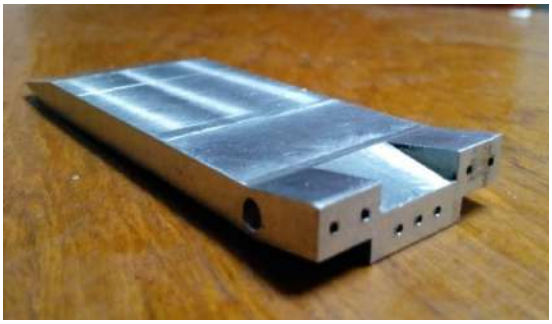

Fig. 4 a. Lobed strut with holes

Fig. 4 b. Lobed strut with slots

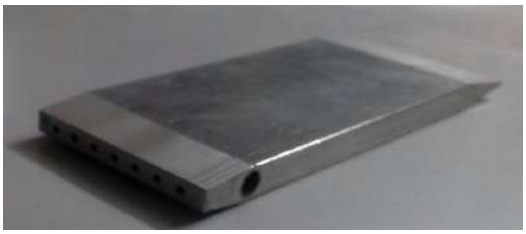

Fig. 5 a. Planar strut with holes

Fig. 5 b. Planar strut with slots

Fig. 6. Nozzle and strut assembly

In the upper compartment, the cross sectional area just above the upward bend portion reduces and pushes the air to the middle section. Likewise for the lower compartment

C. Test set-up

The primary and secondary air supplies were equipped as shown in Fig. 7 with pressure regulators to control the pressure from the stored vessels to the required pressure for performing the experiment. A pressure probe is fitted with a three way traversing mechanism was used for measuring stagnation pressure at various points at the exit of the mixing chamber.

D. Mixing Chamber

Mixing chambers of aspect ratio L/W = 5 was fabricated with necessary provisions to measure the static and stagnation pressure. The length of the mixing chamber was 154 mm.

Fig. 7. Test set-up

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E. Experimental Procedure

The experiments were conducted by applying same boundary conditions and procedure for all strut configurations. The air was compressed and stored at 20 bar. The stored air was allowed to flow through the main stream line with a pressure of 8 bar and the secondary line with a pressure of 2 bar respectively by controlling the pressure regulating valves. The digital manometers were used to record the static and stagnation pressure. More stagnation pressure readings are taken with the help of a three way traversing mechanism.

IV.RESULTS AND DISUSSIONS

A. Momentum Flux

The momentum flux distribution of various strut configurations are shown in Fig.8, 9, 10, 11, and 12. The flatness characteristics of the momentum flux show the mixing uniformity along transverse direction. The momentum flux distributions were more flat in lobed struts than that of the planar struts. This indicates the lobed strut is better in mixing performance. Fig. 8 shows the momentum flux distributions of planar and 9 degree lobed struts with slots whereas Fig. 10 shows that of struts with holes. A flat characteristic in the curves of both the lobed strut geometry shows its improvement in mixing. Moreover, the hole geometry exhibit a very good mixing efficiency. In Fig. 9, a comparison of numerical [4] and experimental results presented for the slot configuration. Both planar and lobed struts very closely match their results in numerical as well as in the experimental approaches. Therefore the numerical approach can be considered valid with the experimental outcomes and the 9 degree lobed strut with slot shows more efficient in mixing in the experimental result of slot combination.

Similarly a comparison of numerical [3] and experimental results presented in Fig. 11 for the struts with hole configuration. Here the numerical and experimental results of 9 degree lobed struts exactly match with each other.

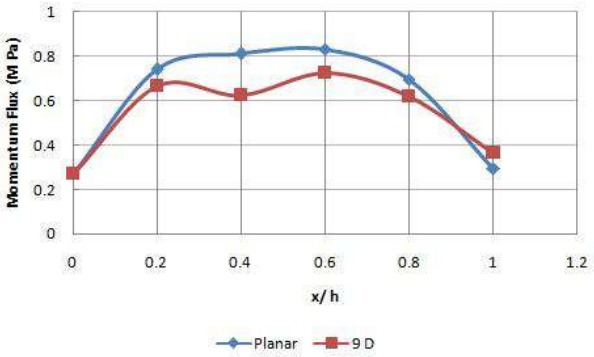

Fig.8. Momentum flux distribution of struts with slots

Another variation is presented for the geometries of both planar and lobed struts with slot and hole configurations in Fig. 12. The hole configuration geometries are better than that of slot configurations. The lobed geometry with hole predominate the others in mixing efficiency.

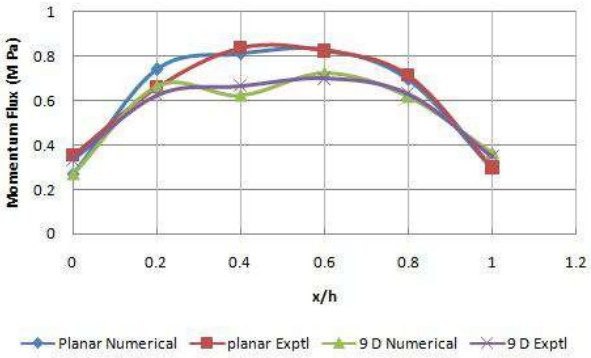

Fig.9. Numerical and experimental comparison for struts with slots

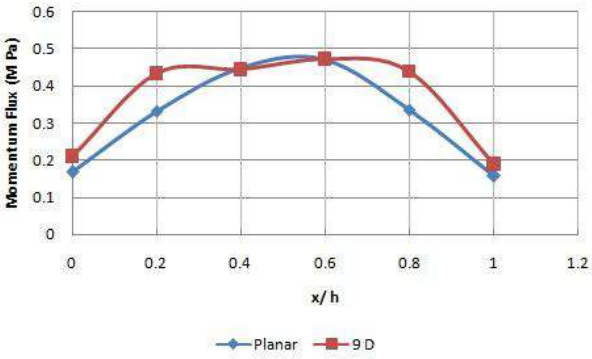

Fig. 10. Momentum flux distribution of struts with holes

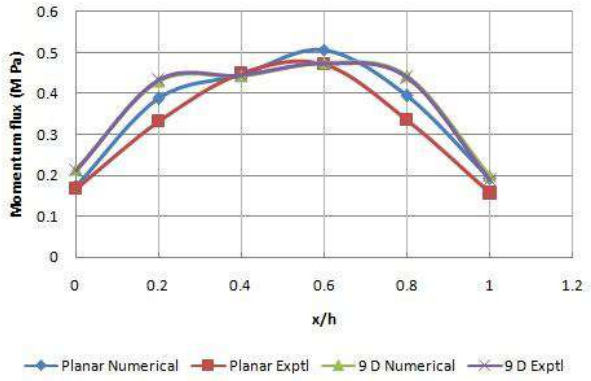

Fig. 11. Numerical and experimental comparison of struts with holes

B. Degree of Mixing

From the analysis of results the degree of mixing for different strut configurations are given in Table III below. Among these four configurations, 9 degree lobed strut geometries showed better DoM, which contributes that the mixing enhancement by the lobed geometry.

V.CONCLUSIONS

Experimental investigations to study the mixing characteristics of different strut geometries were carried out.

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Strut with slot and hole configurations inserted in to the nozzle of the same throat area and the same mixing chamber used. The conclusions drawn from the study and analysis are as follows

- The momentum flux distribution in lateral direction at an axial location of L/W = 5 for different strut geometries analyzed and the results indicated the 9 degree lobed struts had better mixing than the other configurations.
- DOM with higher value obtained in lobed struts indicates that they are efficient in mixing.
- The comparison of numerical results published for these configurations with experimental results indicates better match with each other, which shows the numerical method taken for the present evaluation, was appropriate.

TABLE III. Degree of Mixing

Strut geometry	Exit configuration	DoM %
Planar	Slot	58.7
9° Lobed	Slot	66.5
Planar	Hole	61
9° Lobed	Hole	65

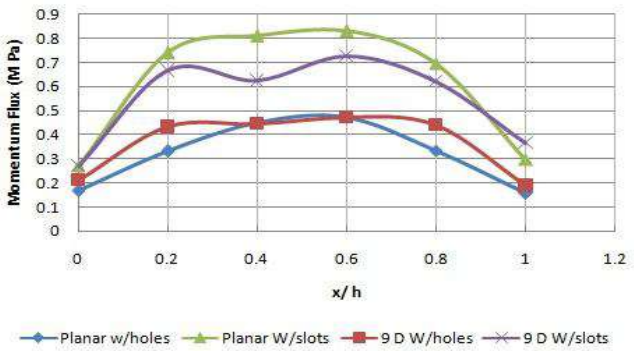

Fig. 12. Comparison of geometries of struts

REFERENCES

[1] Desikan S. L. N and Job Kurian, 2005 Mixing studies in Supersonic Flow Employing Strut Based Hypermixers, 41st AIAA/ASME/SAE/ASEE Joint propulsion Conference and Exhibit, 3643

[2] Peter Gerlinger, Peter Stoll, Markus Kindler, Fernando Schneider and Manfred Aigner., 2008, Numerical Investigation of Mixing and Combustion Enhancement in supersonic Combustors by Strut induced Streamwise Vorticity, Aerospace Science and Technology, 12, 159-168

[3] Naveen P. R., Sumeh V., Zamitha Z. A., P. Balachandran, 2014, CFD Analysis of Supersonic mixing using strut with holes, National Conference on Technological Trends (NCTT) August 2014, Paper ID 22390

[4] Manu Ratnan, Sumesh V.,Dr. P. Balachandran, Dr. Samitha Z. A.,2014, Numerical Investigation of Supersonic Mixing Using Planar and Lobbed Struts with slit, National Conference on Technological Trends (NCTT) August 2014, Paper ID 22391

[5] Sujith S., Muruganandanam, T. M., and Job Kurian, 2013, Effect of Trailing Ramp Angles in Strut Based Injection in Supersonic Flow, Journal of Propulsion and Power, vol. 29, No. 1, January-February.

[6] Lingyun HOU, Bernhard WEIGAND, Marius BANICA, 2011, Effects of Staged Injection on Supersonic mixing and Combustion, Chinese Journal of Aeronautics, 24, 584 – 589

[7] Z. A. Samitha, B. Swaraj Kumar, P. Balachandran, 2007, Experimental Study on Supersonic Mixing Using Clover Nozzle, 45th AIAA Aerospace Sciences Meeting and Exhibit 8-11 January, AIAA 2007-839.

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PRODUCTION, ENGINE PERFORMANCE AND EMISSION CHARACTERISTICS OF BLENDS OF NANO-FUELED WASTE PLASTIC OIL OBTAINED BY PYROLYSIS METHOD MIXED WITH CONVENTIONAL DIESEL IN A CI ENGINE.

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Abstract

The depletion of conventional fossil fuels due to their increased consumption and the stringent emission norms, urge us to search alternative fuels for automotive engines. Alongside, the intense challenges posed to the environment by the waste plastic in terms of its nondegradability leads to pollution can afflict land, waterways and oceans is threatening human sustainability. Both these issues can be addressed by converting waste plastic into useful energy. In this paper, blends of diesel and oils derived from waste plastic were used in a diesel engine, without any engine modifications to study the effect of blending waste plastic oil to neat diesel on the performance and combustion characteristics of the engine by adding nanoparticle. Blending the pyrolysis oils with neat diesel could not improve the thermal efficiency but there is a significant change in the brake specific fuel consumption. At the same time the addition of nanoparticles into blends reduces the emissions to a great extent. However, Nanoparticle added plastic pyrolysis oil bended diesel oil improves the engine performance when compared to the blended diesel oils, the yielded oils have almost same brake specific fuel consumption, which conveys that it is better to blend diesel with plastic oil in addition to nanoparticles at higher rates gives better output.

Keywords – Plastics; pyrolysis; oil; nanofuel; diesel; emission

I. INTRODUCTION

The broad applications of plastics in every aspect of human life from house-hold applications, automobile parts and so on, has paved the way for enormous growth in their production. Plastics are typically organic polymers of high molecular mass and sometimes contain other substances. They are usually synthetic, most ordinarily derived from petrochemicals. Irrespective of their excellent features, the nondegradability of waste plastics has become a serious concern in now a days. This characteristic of plastics, nondegradability, complicates the waste management dangerously. Apparently, only 60% of the plastic waste disposed in India is actually recycled [1]. After the detailed study on the production of plastics shows that recycling is not at all profitable, while comparing with production process. The fact that the solid waste plastic management could not cope up with the demand for plastic production, which urges us to search for different alternative effective methods to recycle the waste plastics.

One of the important sectors like automobile, commercial, and generally production industrials have been depending on conventional petrofuels like Petrol, Diesel and Liquid. Petroleum gases (LPG) in meeting their economic needs for the past few decades. These consuming sources, despite of their applications, contribute to atmospheric emissions [2]. The depleting sources and the severe emission norms have urged the technology to search for alternate fuels.

Inappropriate waste plastic management, depleting petroleum sources, and severe emission norms can be addressed by converting the waste plastic into fuel energy by new technology [3]. Many of the researchers experimentally proves the blending of pyrolysis oils improves the efficiency of Engine by performance. One of the researcher named Kiran Raj et al. reviewed the utilization of waste plastic oil as a sources of sustainable energy for automotive engines and mentioned the experiment results carried out by different authors on high speed diesel engines using neat waste plastic oil as a fuel from pyrolysis process [4]. These were mentioning the blending of diesel may improves the efficiency in performance of engine but no such changes in the emission.

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The emission or pollutants leads to acid rain and contamination emissions can neglect by increasing the efficiency of the engine and reducing the specific fuel consumption. One the best way to reformulate the diesel by using nanoparticles to reduce emissions [5]. From the available metal oxides, cerium has many interesting properties like hardness, high stability, high insulation and transparency. Instead of that the nanoparticle has major applications such as catalyst insulator, surface protective coating and composite material.

Adding cerium oxide nanoparticles to diesel can help the decomposition of HC and CO [6]. Thus, it reduces the amount of pollution and also reduces the amount of fuel consumption. Here In this paper, the investigation on the performance and emission characteristics of diesel engine using neat diesel fuel, diesel fuel using cerium oxide nano particles and diesel fuel using cerium oxide nano particles blended with plastic pyrolysis oil is investigated in different existence.

II. MATERIALS AND METHODOLOGY

A. Sample preparation of Plastic Pyrolysis Oil (PPO)

Pyrolysis is the process of treatment of organic materials which undergoes thermal decomposition at uplift temperatures in the absence of Oxygen. During pyrolysis, polymers get converted to monomers. In this process the organic substances produces volatile products and leaves a solid residue enriched in carbon, char. Here the feedstock (solid waste plastics) is fed to the sizing machinery like cutters and crushers. Then the obtained crushed materials is graded into consistent size for easy handling. It is then fed to a hot reactor and heated in the absence of Oxygen to a temperature of 400°C – 500°C, for nearly 4 -5 hours, at atmospheric pressure. Thus resulting products of pyrolysis are condensed to hydrocarbons which can be separated through fractional distillation. The obtained waste plastic pyrolysis oil are then mixed with chemicals and heated at particular temperature and then allowed for double filtration process. Thus leads purified plastic Pyrolsysis oil.

B. Sample Preparation of Cerium oxide nanoparticles

Cerium oxide nanoparticles were prepared chemically by adopting the precipitation method. This method is considered as the economical and convenient way to prepare the nanoparticles. Initially the chemicals such as cerium (III) nitrate, analytical iso propanol and aqueous ammonia were placed for the preparation process. The reaction process is carried out within the room temperature, 1M of cerium (III) nitrate solution in water-iso propanol mixture is mixed thoroughly, and then the prepared solution was stirred for 60 minutes at 300C - 600C with magnetic stirrer attached with heating mantle.

The temperature is maintained at the desired level at the same time the pH value of the solution should be adjusted to 10 by adding ammonium hydroxide, as alkaline medium gives smaller particles than acidic medium. After one hour the pale red color of reactants turns to yellow, indicating the formation of cerium oxide nanoparticles.

The synthesized nanoparticles were transferred to a crucible china dish and are calcinated in a muffle furnace at 5000C for 3-4 hours for obtaining crystalline nanosized particles. The final product obtained is a yellow finely powdered material which is the cerium oxide nanoparticles.

Fig. a

Fig. b

Fig. c

Fig. d

Fig. 1. Stages of CeO_2 nanoparticle synthesis

a. Cerium (III) nitrate solution in water-iso propanol mixture at 600C and the solution turned pale red after addition of NH_4OH and heated
b. Calcination at 300^0C in muffle furnace and
c. Prepared CeO_2 nanoparticles
d. CeO_2 nanoparticles made into powdered form for testing and blending.

In this synthesis process a surfactant has been used for obtaining better dispersion of cerium nanoparticles in neat diesel and plastic pyrolysis oil blended diesel. The selection of surfactant depends on the hydrophilic lipophilic balance (HLB) value of the surfactant, which is the relative degree to which the surfactant is water soluble or oil soluble. Here Tween – 20 surfactant is added as surfactant for the procedures. Addition of Tween - 20 in diesel will also improve the detergent properties.

The samples of ceriumoxide nanoparticles, one with surfactant coating and the other without coating were synthesized. The characterization of nanoparticles by means of TEM (*Transmission electron microscope)* and EDS (Energy Dispersive X-Ray Spectroscopy).

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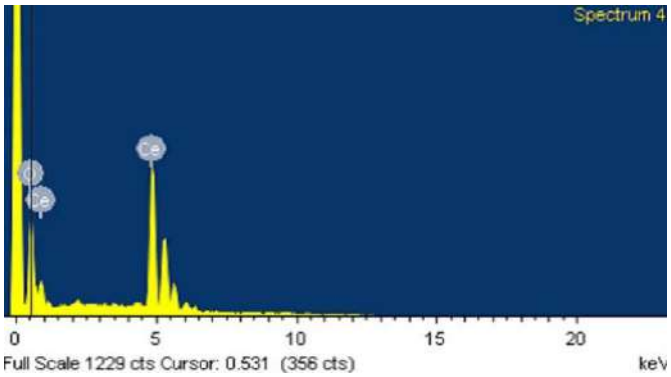

Figure 2. EDS spectrum obtained from primary nanocrystalline CeO_2

Table 1. Weight and atomic percentage of elements present in synthesized cerium oxide nanoparticles from EDS data

Element	Weight %	Atomic %
O (K)	16.01	62.55
Ce (L)	83.99	37.45
Total	100	100

The elemental composition of the synthesized ceria particles was obtained by means of energy dispersive spectroscopy as shown in Figure. The weight percentage and atomic percentage of cerium present in the synthesized sample are quantitatively represented in Table 1.

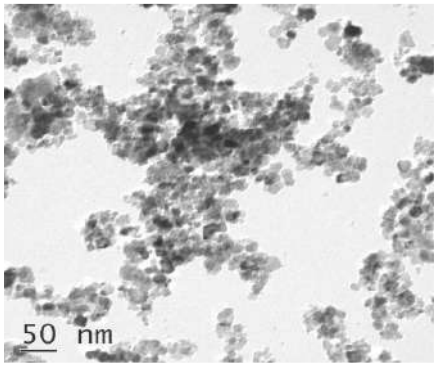

Fig. 3 HR-TEM image of synthesized CeO_2 nanoparticles

Fig. 3, represent the HR-TEM image of nano-sized CeO_2 nanoparticles. The results proved that the size of both categories of nanoparticles was much less than 50 nm (approxm.). These characteristics are found to be critical in their inclusion as lubricant additives.

C. Preparation of Nanoparticle (Cerium Oxide) Added Fuel (Plastic Pyrolysis Oil blended with diesel)

The dosing level of cerium oxide nanoparticles samples (by weight) in diesel was varied from 5 to 40 ppm [7]. In order to obtain a uniform suspension of nanoparticles in neat diesel and blended diesel, a standard ultrasonic shaker has been used for the mixing of nanoparticles corresponding to the required dosing level. The catalytic nanoparticles added to the diesel was agitated for about 30-40 minutes in an ultra-sonicator to obtain a stable nanofluid. The modified fuel was used in the experiments immediately after preparation, then only the considerable time is not allowed for sedimentation to set in.

D. Determination of properties of fuel.

American standard test methods (ASTM) have been employed for the determination of various properties of fuel such as viscosity, flash, and fire points. The viscosity was measured using the redwood viscometer and open cup flash and fire point apparatus were used for measuring the flash and fire point and noted below.

E. Engine Performance and Emission Testing of fuels using CI Engines.

Performance and emission of diesel and blended diesel fuels studies have been conducted in a four-stroke, single cylinder, water-cooled compression ignition engine (CI Engine). Standard constant speed load tests were conducted on the engine.

III. RESULTS AND DISCUSSION

Nanoparticles (Cerium oxide) is synthesized in controlled laboratory conditions, by means of precipitation method (PM), were used for the preparation of diesel blended nanofluids. Tween - 20, a surfactant, was added for improving the stability of nanofluids. Various physicochemical properties of fuels were determined by comparing it with standard ASTM test methods. The tests were conducted with diesel and nanoparticle blended diesel and the results obtained were compared. Diesel engine performance and exhaust emissions tests were conducted with diesel and nanoparticle added diesel fuel and results were also compared.

A. Combustion characteristics

Combustion characteristics include flash point, fire point kinematic viscosity and density at desired temperature are mentioned based on the experimental values of neat diesel, blended neat diesel with plastic Pyrolsysis oil and Neat diesel blended with Cerium oxide nanoparticle mixed Plastic pyrolysis oil.

Property	Diesel	Diesel with PPO	Diesel with CEON PPO
Density at 30°C (g/cc)	0.84	0.8388	0.8495
Kinematic viscosity at 40°C (cst)	2.01	2.12	2.24
Heating value (MJ/kg)	46.5	46.284	46.133
Flash point (°C)	50	49.2	49.3
Fire point (°C)	56	54.9	55.4

Table 2. Physiochemical properties of samples

From the above physiochemical properties (Table.2) of three samples shows similar properties with the neat diesel, also it reported that Cerium oxide blended plastic Pyrolsysis oil with neat diesel shows much higher properties than neat diesel. From the initial studies shows the efficiency of prepared sample output is better than conventional diesel oils.

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B. Engine Performance

The performance tests of diesel variants were conducted on a diesel engine. Figures shows the variation of brake thermal efficiency with increasing load for different concentrations of cerium oxide nanoparticles. The brake thermal efficiency was increased by about some amount of increase on the addition of cerium oxide nanoparticle in diesel with plastic pyrolysis oil.

1) Brake thermal efficiency (BTE)

The below figure represents the variation of brake thermal efficiency (BTE) with the varying load. As shown in the figure, BTE in case of Diesel with Plastic pyrolysis oil and Diesel blended with Cerium oxide nanoparticles with Plastic Pyrolsysis oil is higher than that in case of diesel, at almost all the load conditions. The variation of exhaust gas temperature with the load for different fuels, which clearly indicates slightly lower exhaust gas temperature in case of diesel when compared to both levels. Alongside, above 40% load, both blends of diesel have a positive effect of slightly reduced BTE than that of neat diesel.

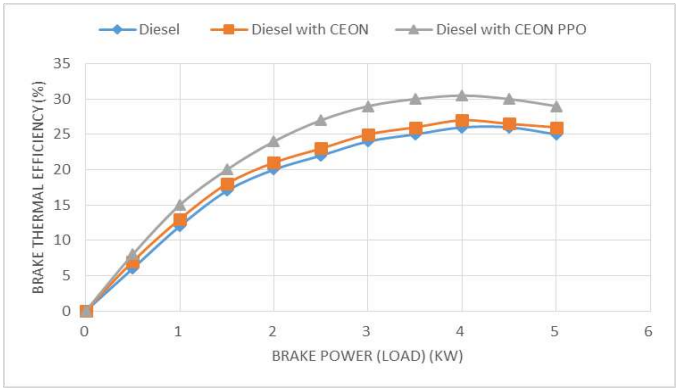

Fig.4 Variation of brake thermal efficiency of three samples with respect to the varying load

2) Specific Fuel Consumption

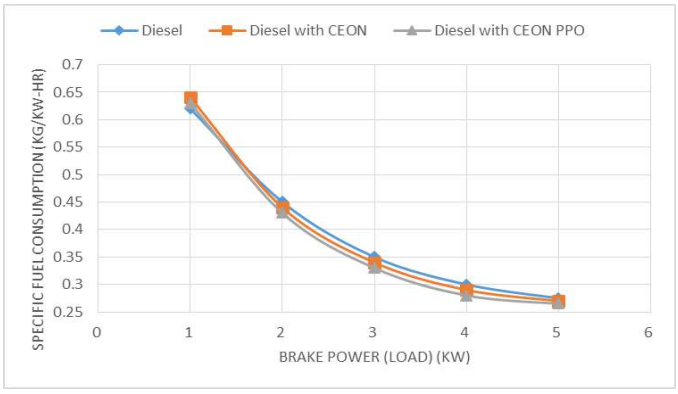

Fig.5 Variation of Specific fuel consumption of three samples with respect to the varying load

The performance tests were conducted on a diesel engine with diesel and modified diesel fuels. The variations of specific fuel consumption for the neat diesel and the cerium oxide nanoparticles mixed diesel fuels and the cerium oxide nanoparticles mixed diesel blended with plastic pyrolysis oil at various loads have been depicted in Fig. 5

C. Exhaust Emission

1) Oxides of Nitrogen (NOx)

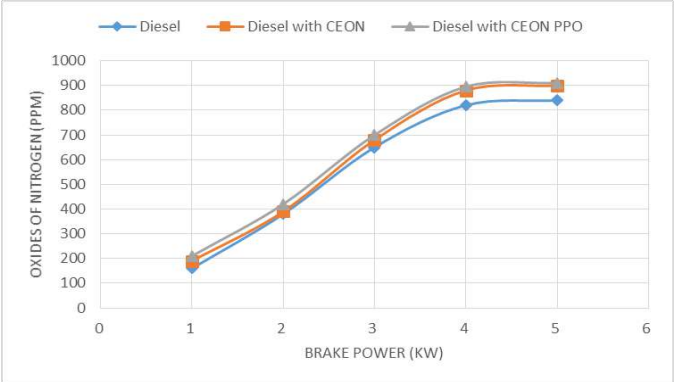

Fig.6 Variation of NOx of three samples with respect to the varying load

The NOx emissions of the engine at different variants of diesel with the different engine loads have been shown in Fig. 6. It is clear that, the NOx emission radically increases, by means of cerium oxide nanoparticles additive and blends with plastic pyrolysis oil. NOx emission is directly proportional to efficiency of the engine because NOx increases with combustion pressure and exhaust temperature of the engine. The additional oxygen content in the modified fuel blends with plastic pyrolysis oil and neat diesel increases the in cylinder combustion temperature which in turn increases the NOx emission.

2) Carbon monoxide (CO)

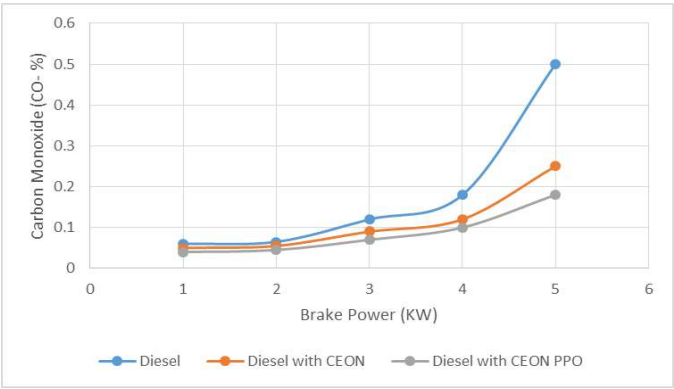

Fig.7 Variation of CO of three samples with respect to the varying load

The variation of carbon monoxide (CO) with brake power is shown in Fig. The carbon monoxide emission changes by

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decreases with the addition of cerium oxide nanoparticles with the diesel fuel and blended with plastic pyrolysis oil. Generally, the CO emission is caused due to the poor mixing of air and fuel, and incomplete combustion of fuel, these problems are overcome by adding cerium oxide, because cerium oxide consist of oxygen molecules which reduces the content of carbon monoxide. The CEON present in the fuel acts as an oxygen buffer, releasing oxygen depends upon the partial pressure of oxygen for fuel combustion.

IV. EXPERIMENTAL AND TEST PROCEDURE.

Experiments were conducted on four stroke, single cylinder, and air cooled diesel engine. The rated power of the engine was 5.2 kW at 1500 rpm. The engine was operated at a standard injection pressure of 300 bar at a constant speed of 1500 rpm.

The AVL smoke meter is used to measure the smoke density and the rest of the pollutants. A burette is used to measure the fuel consumption for a particular time interval. During this particular time interval, how much of the fuel in the engine consumes is measured, with the help of a stopwatch.

V. CONCLUSION

The current experimental work aims the synthesis of plastic pyrolysis oil and Cerium oxide nanoparticle. Thus the investigation on the effect of nanoparticles with plastic pyrolysis oil blended with neat diesel results on various physicochemical properties of diesel and engine performance and emissions tested on diesel engine. Characterization techniques includes TEM and EDS have been used for studying the properties of the cerium oxide nanoparticle prepared by the precipitation method shows similarity to the conventional nanoparticle [9]. Surfactant has been added to the diesel for improving the stability and dispersion of the nanofluid, used for the experimentation purpose. Though load test and emission tests has been done in the diesel engine with three samples to investigate the effect of catalytic nanoparticles on the efficiency and the emissions from the engine. Based on the experiments the following conclusions were drawn.

They are:

- The synthesis of cerium oxide nanoparticles by precipitation method was confirmed by tested the samples with several tests. Thus it proves that the samples are economical and efficient.
- Synthesis of Plastic pyrolysis oil by pyrolysis process gives raw PPO, after purification using chemicals gives purified plastic pyrolysis oil.
- Mixing of cerium oxide nanoparticle with neat diesel gives significant output, while compare with neat diesel.
- Blending of plastic pyrolysis oil with Cerium oxide nanoparticle and neat diesel gives better output in engine performance tests and emission tests.
- By comparing the three samples from neat diesel, neat diesel mixed with cerium oxide shows remarkable output when compared it with neat blended with plastic pyrolysis oil mixed with cerium oxide nanoparticles.
- Notable changes occurred in emission testing while adding cerium oxide nanoparticles with samples.
- Hence, it is clear that cerium oxide nanoparticles are efficient in improving performance and reducing the exhaust harmful emissions from the diesel engine.

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REFERENCES

[1] Janyalertadun, A., Santaweesuk, C., & Sanongraj, S. (2017). Fuel production, performance, and emission of a CI engine using waste plastics oil. World journal of engineering, 14(2), 114-120.

[2] Baskaran, R., & Kumar, P. S. (2015). Evaluation on performance of CI engine with waste plastic oil-diesel blends as alternative fuel. International Journal for Research in Applied Science & Engineering Technology, 3(4), 642-46.

[3] Raj Bukkarapu, K. (2017). Comparative Study of Different Biodiesel–Diesel Blends. International Journal of Ambient Energy, 28, 1-9.

[4] Bukkarapu, K. R., Gangadhar, D. S., Jyothi, Y., & Kanasani, P. (2018). Management, conversion, and utilization of waste plastic as a source of sustainable energy to run automotive: a review. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 40(14), 1681-1692.

[5] Lenin, M. A., Swaminathan, M. R., & Kumaresan, G. (2013). Performance and emission characteristics of a DI diesel engine with a nanofuel additive. Fuel, 109, 362-365.

[6] Ganesh, D., & Gowrishankar, G. (2011, September). Effect of nano-fuel additive on emission reduction in a biodiesel fuelled CI engine. In 2011 International conference on electrical and control engineering (pp. 3453-3459). IEEE.

[7] Sajeevan, A. C., & Sajith, V. (2013). Diesel engine emission reduction using catalytic nanoparticles: an experimental investigation. Journal of Engineering, 2013.

[8] Aalam, C. S., & Alagappan, N. (2015). Cerium oxide nano particles as addiditve with diesel fuel on DI diesel engine. International Journal of Innovative Research and Creative Technology, 1(2), 215-219.

[9] Philip, J. T., Koshy, C. P., Mathew, M. D., & Kuriachen, B. (2019). Tribological characteristic evaluation of coconut oil dispersed with surfactant modified ceria-zirconia hybrid nanoparticles. Tribology-Materials, Surfaces & Interfaces, 13(4), 197-214.

Numerical analysis of heat transfer and flow friction characteristics of perforated disc heat exchanger

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***Abstract*—Compact heat exchangers are considered the most critical components of any cryogenic refrigeration and liquefaction system. The performance associated with these heat exchangers mainly depends on the overall effectiveness, colburn factor, and friction factor. Along with good effectiveness, it has sufficient compactness, which is the ability to accommodate large surface area in small volume. Perforated disc heat exchangers satisfy such requirements. In the present work, a heat exchanger consisting of perforated discs, in which discs are used instead of commonly seen fins on the annular side of a tube in tube heat exchanger, is analyzed numerically. The study involves the development of a three dimensional, steady flow, laminar numerical model using ANSYS FLUENT 16.0 for predicting the j factor, f factor, and effectiveness of perforated disc surfaces. Numerical study was compared with the experimental results reported in the literature at the same operating and geometrical parameters with the aid of Colburn j factor and effectiveness. The deviations of numerical results of j factor and effectiveness from the experimental results were found to be in the affordable range. Now the variation of colburn factor, friction factor, and effectiveness are plotted for different geometrical and operating parameters.**

Keywords— colburn j factor, f factor, compact heat exchanger, surface area density

I. INTRODUCTION

In the field of cryogenic refrigeration or liquefaction system, compact heat exchangers are considered the most vital components. The performance of which is mainly rated by the parameter effectiveness itself. The fact is that if the effectiveness of the heat exchanger goes below a certain value, the entire operation of the system associated will cease to function. Along with that, the low level of coefficient of performance of the overall system may result in an increase in the cost of the operating system. Thus, it justifies introducing a compact heat exchanger with high effectiveness and less occupied space. When the performance level is low the effectiveness mainly depends on the heat transfer coefficient [1]. But if the effectiveness exceeds certain value of 90 percentage, it results in some irreversibilities, which act as controlling factors on such occasion. These irreversibilities are 1) Axial conduction 2) Flow misdistribution 3) Wall thermal resistance 4) Heat transfer to surrounding. Along with good effectiveness, it is required to have attractive compactness, which is the ability to accommodate larger surface area in smaller volume. Thus McMahon et al. [2] introduced a new type of heat exchanger termed to be matrix heat exchanger, which consist of several discs stacked together with perforations.

A matrix heat exchanger actually consists of several plates (usually copper) and spacers that are placed alternatively, in which spacers (usually stainless steel) with lower conductivity are used to prevent axial conduction. The lateral heat transfer mainly take place across the perforations, while the conductive resistance offered by the spacer placed in between plates mainly controls the longitudinal heat conduction through the wall. The lateral heat transfer is due to the convective resistance in the channel as well as the conduction resistance in the plate.

Venkatarathnam et al. [1] made a detailed review on the chronological developments in the field of matrix heat exchangers. He had discussed the development of different bonding techniques and various numerical models used in the literature to arrive at Colburn j factor and Friction f factor. Several correlations in the literature were reported by him for colburn factor, friction factor and nusselt number. He said the variations in correlations are due to the various geometrical and operating conditions used by several authors during their experiments.

Sunil Kumar et al. [3, 4] made a detailed numerical analysis of different geometries of perforated plates and found out that the effectiveness of high NTU heat exchanger depends on the geometry of the flow channels as well as the longitudinal heat conduction through the outer walls. Longitudinal heat conduction through the outer wall reduces the effective NTU of a PPHE significantly. Performance deterioration is more severe at low mass flow rates or at high NTU operations. They compared their numerical results with the results reported in the literature. They also fabricated and

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tested many heat exchangers. The numerical results were also compared with their experimental results.

made a detailed correlation for the colburn factor and the friction factor, which covers wide range of porosity beginning from 0.2 to 0.36. Nilles et al. [8] also made numerical and

Table 1

Nomenclature

d_i = Inner ring inner diameter (m)
D_o = Outer ring outer diameter (m)
d_o = Inner ring outer diameter (m)
D_i = Outer ring inner diameter (m)
t_p = plate thickness(m)
n = Number of holes
N = No of discs
d_p = diameter of holes(m)
A_s = Total heat transfer area(m^2)
V = Volume occupied by air flow side(m^3)
Re = Reynolds number
Nu = Nuss0elt number
D_h = Hydraulic diameter(m)
k = Thermal conductivity(W/mk)
V = Velocity of air flow(m/s^2)
h = heat transfer coefficient(W/km^2)
j = Colburn factor
f = friction factor
T_{ci} = cold fluid inlet temperature(K)
T_{co} = cold fluid outlet temperature(K)
Tw = Average water temperature
Ta = Average air temperature
A_f = Fluid flow area(m2)
C_p = Specific heat(J/kgK)
L = Length of heat exchanger(m)
G = Mass velocity(Kg/m^2 s)
Pr = Prandtle number
t_s = spacer thickness(m)

Greek symbols

2θ = Semi-angle subtended by sector
μ = Coefficient of viscosity(Ns/m^2)
ρ = Density of air(Kg/m^3)

Abbreviation

SAD = Surface area density (m^2/m^3)

Another important conclusion they made is for a given channel geometry and operating condition, there exist an optimum channel height at which effectiveness of the heat exchanger is the maximum. They conducted the numerical analysis by modelling seven spacer plate pairs and made correlations for colburn j factor and friction factor.

Orlov and shevyakova [5] constructed a perforated plate heat exchanger and made detailed analysis on hydraulic resistance with respect to distance change and noticed that change in the distance between the perforated plates has a significant effect on the coefficient of hydraulic resistance (per unit pack height) and almost no influence on the rate of heat transfer.

Mikulin et al. [6] constructed a matrix heat exchanger and a parametric study was conducted on the hydraulic and thermal characteristics. Comparison between aligned hole type and shifted hole type was made and found out that the geometry with aligned holes provide more efficiency compared to the shifted one. Raju et al. [7] made numerical analysis on matrix heat exchangers with rectangular shape and circular holes and experimental studies on perforated discs. Unlike others, he mainly focused his studies on finding the numerical solutions of various heat exchanger equations and also procedures were given for defining the characteristics of the perforated plates; like the properties of the plate matrix and spacer materials (e.g. copper, stainless steel), and the properties of the working fluid.

When it comes to high temperature applications, the double pipe heat exchangers are widely used with air acting as the working fluid. To provide better heat transfer rate, the best method is to increase the heat transfer area across the flow and improvement in effectiveness can be justified using Newton's law of cooling. Nagarani et al. [9] used circular and elliptical fins to justify this and found out the heat transfer rate was higher in elliptical fins. Heat transfer coefficient depends on the fin spacing, flow conditions, and fluid properties.

The present work is aimed at the development of a three dimensional, steady flow, laminar numerical model using ANSYS FLUENT 16.0 for predicting the j factor, f factor, and effectiveness of perforated plate surfaces. For this purpose, a numerical model is constructed on a stack of centrally hollow

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perforated circular discs (as in matrix heat exchanger) followed alternately by spacers; so that plate and spacer pair forms passages for fluid flow and heat transfer. Parametric studies are conducted for j factor, f factor, and effectiveness for various porosities and flow Reynolds numbers.

II. METHODOLOGY

A. *Selecting surface area density*

Surface area density is one of the important parameter which determines the compactness of a heat exchanger. If surface area density goes beyond 700 m^2/m^3 the heat exchanger is considered to be compact heat exchanger.

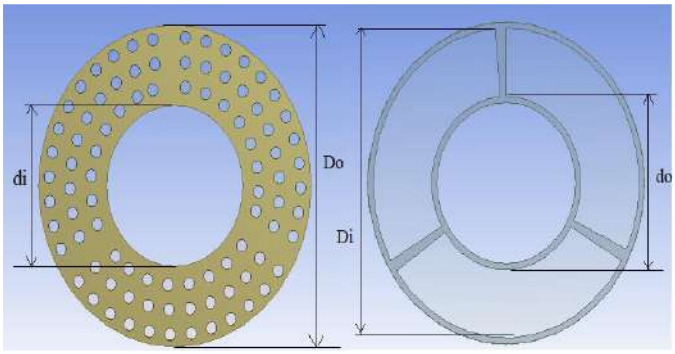

Figure1. Spacer and disc cross sectional view

The equations regarding to surface area density of entire heat exchanger is suitably given below:

Total heat transfer area

$$A_S = 6N(\frac{\pi}{4}D_i^2\frac{2\theta}{360} - \frac{\pi}{4}d_o^2\frac{2\theta}{360} - n\frac{\pi}{4}d_p^2) + 3nN\pi d_p t \quad (1)$$

Total volume

$$V_S = N((\frac{\pi}{4}D_O^2 - \frac{\pi}{4}d_i^2)t - 3n\frac{\pi}{4}d_p^2 t) \quad (2)$$

Surface area density be

$$SAD = \frac{A_S}{V_S} \quad (3)$$

Surface area density (SAD) was obtained for (the perforated plate matrix heat exchanger surfaces) the numerical heat exchanger model as 1920 m^2/m^3.

B. *Numerical modelling*

Numerical model is built on a stack of circular perforated plates which are placed with a gap or spacers. There are total seven plates in the stack of which only third and fourth plates are test plates. First, second, fifth, sixth and seventh plates are used for flow stabilisation. Variation in number of plates has only very small influence on SAD. In order to have low thermal conductivity and to prevent axial thermal conduction, stainless steel is preferred for spacer, while plates are selected to be copper to ensure good conduction.

Inner wall of the geometry is considered isothermal, because the wall material is copper which is of high thermal conductivity and we use here 15 mm length only; over which the temperature change is very negligible.

Since three separate channels with the same inlet conditions are occurring, a single channel is only required to be modelled. Symmetry boundary condition was applied on the two faces of the model to reduce the domain size. The meshing was done using ANSYS ICEM CFD which is inbuilt in FLUENT 16.0. For the fluid, tetrahedral mesh is preferred, but while meshing solid component hex mesh is preferred with an overall skewness of 0.22381

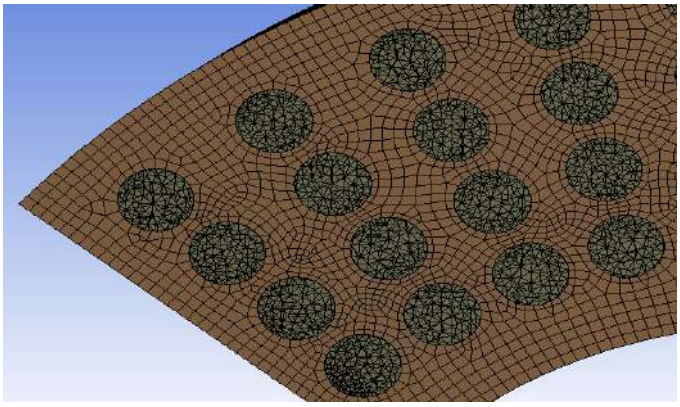

Figure2. Meshed model of plates and fluid

The walls of the test plates and their holes, which are in contact with the fluid, are defined with a constant wall temperature. The wall surfaces of the other plates and the spacers are assumed as adiabatic. This ensures that the heat transfer to take place only through the test plates.

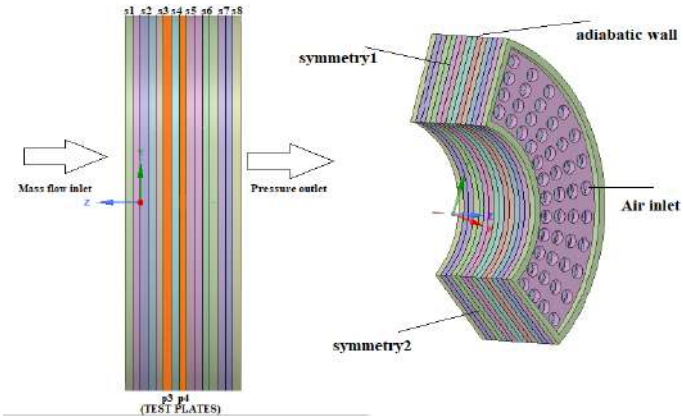

Figure3. Computational domain with boundary conditions

Following boundary conditions are given for the perforated heat exchanger numerical model:

1. At the inner wall, isothermal boundary condition is given.
   $T = T_w = 343K$

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2. At the inlet of the first spacer, mass flow inlet boundary condition is given, T = T_{ci} = 300 K ($\dot{m}$ is obtained from the corresponding Reynolds number of Eq. (4).)
3. At the outlet of the eighth spacer, Pressure outlet boundary condition is given, P = P_{atm} (gauge pressure zero)
4. At inner wall, no slip boundary condition is given,

   $V_z = 0$
5. At adiabatic faces,
   $q. = 0$ W/m^2

Three-dimensional pressure based solver with Semi Implicit Method for Pressure Linked Equations (SIMPLE) pressure-velocity coupling scheme was used in all computations. Second order upwind discretization method was used in both energy and momentum equations. The temperature is constant throughout the wall surface. The temperature of air is increasing while flowing from inlet to outlet side. The mean outlet temperature of air is calculated by using area weighted average method and average pressure is found using volume average of fluid.

For computation and analysis purpose, several authors have considered laminar flow only [11, 12] in their models. Hence in the proposed model laminar flow has been used.

The grid independence study is done as shown in Figure 4 to find out the most accurate result and the corresponding mesh size, so that the computation time, hardware requirement and the storage space requirement can be reduced. The mesh size is varied from higher grid size to the smaller grid size and stopped where the corresponding results converge. Grid independence study is carried out for Re=500, porosity ratio of 0.34 and for a length of 0.36mm. Wall temperature on water side is 343K while air inlet temperature is 300 K. From the Figure 4, it can be seen that for the 5th and 6th observations the results are close. So the result corresponding to the 0.15 mm grid size was taken as the most accurate result and the same grid was used for further numerical computations. Simulation is carried out for the selected grid size with 3135254 elements.

Equations used:

Mass flow rate is given by

$$m_a = \frac{\mathrm{Re}\, A_f \mu}{D_h} \qquad (4)$$

The air properties were taken from fluid property tables. Corresponding to area average temperature of air, T_{co}. The heat transfer coefficient h was calculated from the heat balance equation given by

$$h = \frac{m_a c_p (T_{co} - T_{ci)}}{A_f (T_w - T_f)} \qquad (5)$$

The Nusselt no which is a non dimensionalised form of heat transfer coefficient is given by

$$Nu = \frac{hD_h}{k} \qquad (6)$$

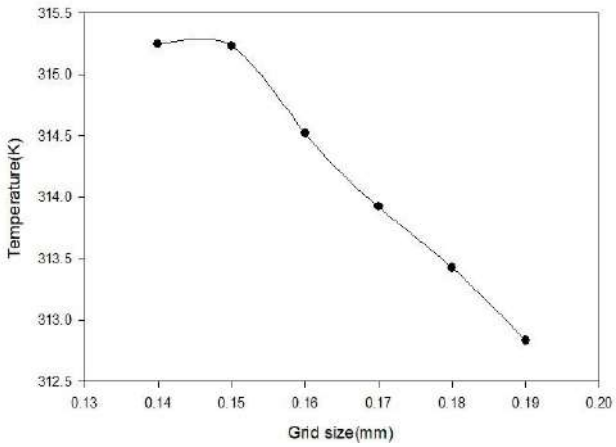

Figure4. Grid independence study

The Colburn j factor is given by

$$j = \frac{Nu}{\mathrm{Re}\,\mathrm{Pr}^{.33}} \qquad (7)$$

The friction factor f is given by

$$f = \frac{2\Delta p\, \rho D_h}{4LG^2} \qquad (8)$$

C. Governing equations

Continuity equation

$$\nabla.\vec{v} = 0 \qquad (10)$$

Momentum equation in all direction

$$\rho(\vec{v}.\nabla)\vec{v} = -\nabla P + \mu\nabla^2\vec{v} \qquad (11)$$

Energy equation be

$$\rho C_p(\vec{V}.\nabla)T = k\nabla^2 T \qquad (12)$$

Operators are

$$\nabla = \frac{\partial\vec{i}}{\partial x} + \frac{\partial\vec{j}}{\partial y} + \frac{\partial\vec{k}}{\partial z}, \nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2} \text{ and}$$

$$\vec{v} = u\vec{i} + v\vec{j} + w\vec{k}$$

III. RESULTS AND DISCUSSION

Colburn factors are now compared with the works of Orlov and shevyakov [5] as shown in Figure 5, and found that the maximum deviation is within 8.2% and 8.8% respectively. The numerical results are validated with the work of Farhani et al. [10] as shown in Figure 6. The effectiveness is compared using four different mass flow rates and found out that maximum percentage of deviation is 8.319 %.

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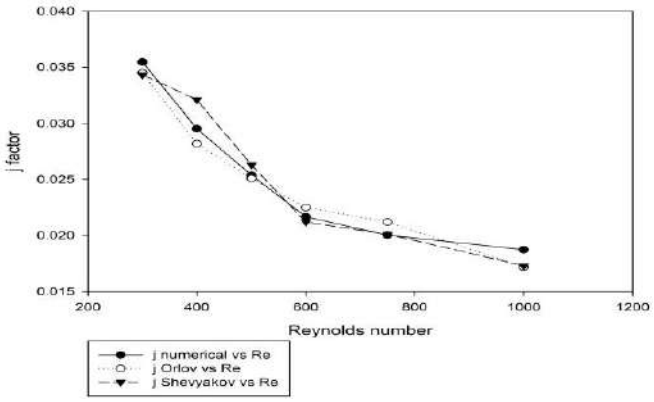

Figure5 Validations with Orlov and Shevyakova [5]

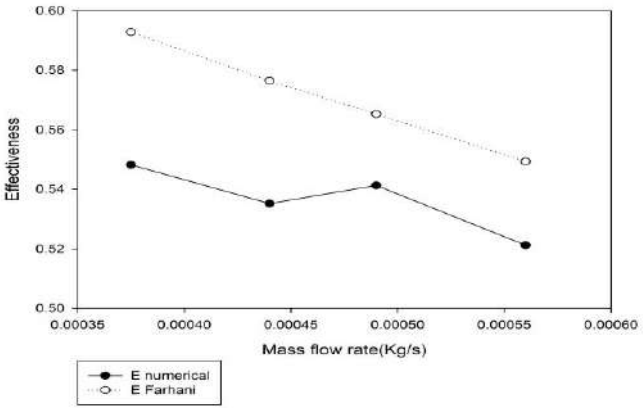

Figure6. Validations with Farhani et al. [10]

Variation of j and f factors with porosity

Now conducted a numerical study on a geometry with dimensions t_s =1mm t_p =1mm, D_o =52mm d_i =26 mm and two different porosities of 0.20 and 0.28 up to Reynolds number 800, starting from 100. The j factor decreases with the increase in Reynolds number, which is a common behaviour because j factor is inversely proportional to Reynolds number. Friction factor reduces with increase in Reynolds number because friction factor is inversely proportional to square of air velocity. Friction factor also increases with pressure drop, which is higher at higher Reynolds number and length of heat exchanger. But the effect of air velocity variation is more influencing than increased pressure drop. So the net effect is to decrease the friction factor with increase in Reynolds number.
When compared the j factor at different porosities, it is found that as the porosity increases, j factor is found to be increasing. For porosity 0.20, j factor varies from 0.022131 to 0.007699 with increasing Reynolds number. While porosity is 0.28, the variation is from 0.029886 to 0.09864. So that there found a maximum increase of 37% and minimum increase of 28%. When porosity increases, heat transfer area decreases so temperature output is high for lower porosity heat exchanger. But the effect of mass flow rate on heat transfer rate make higher heat transfer rate in higher porosity heat exchanger. Result is that j factor is high for higher porosity heat exchanger.Since diameter of holes increases, flow area of jet is also getting improved, so that frequent impact of higher amount of air actually helps for more efficient mixing at spacer gap. It is shown in figure 7.

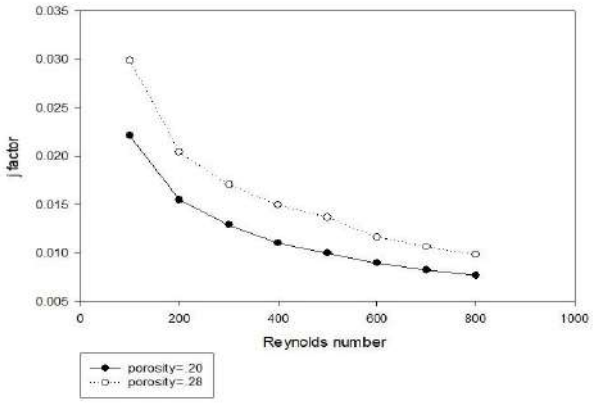

Figure7. j factor for different porosities

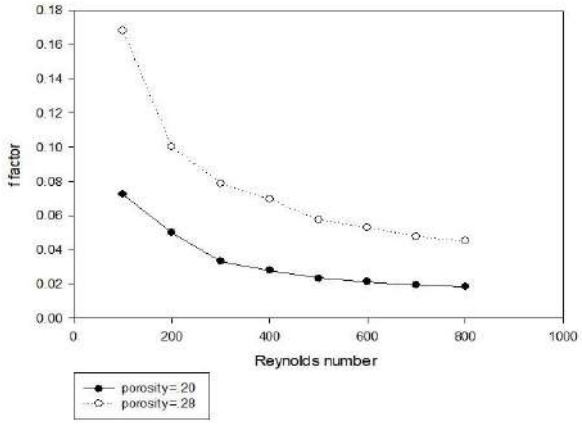

Figure8. f factor for different porosities

With increase in porosity, f factor is found to be increasing. There will be an increase of pressure drop as we increase porosity. It is mainly attributed to the fact that under laminar flow conditions pressure drop is proportional to volumetric flow rate, which results in increased pressure drop. During higher porosity condition, free flow area is high, results volume flow rate to increase. Friction factor is proportional to pressure drop and inversely proportional to square of velocity and this results increase of friction factor. For porosity 0.20, f factor varies from 0 0.072498 to 0.018315 with increasing Reynolds number. While porosity is 0.28, variation is from

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0.168466to 0.045227. So that there found a maximum decrease of 59.5% and minimum decrease of 50% as shown in figure 8.

Now effectiveness is also plotted for different porosities as shown in figure 9 and found out that heat exchanger with porosity 0.20 has advantage over the other one with porosity 0.28.The least improvement is found, when Reynolds number is lower to 100, which is of 4.7% and a maximum improvement of 11.2 % is found, when Reynolds number is 800. It is evident that as we increase porosity, the outlet temperature of air is being reduced due to low heat transfer area. It is assumed that the water flow is isothermal and logarithmic mean temperature difference (LMTD) is being improved. This results in decrement of number of heat transfer units, so that its effect on effectiveness can be observed.

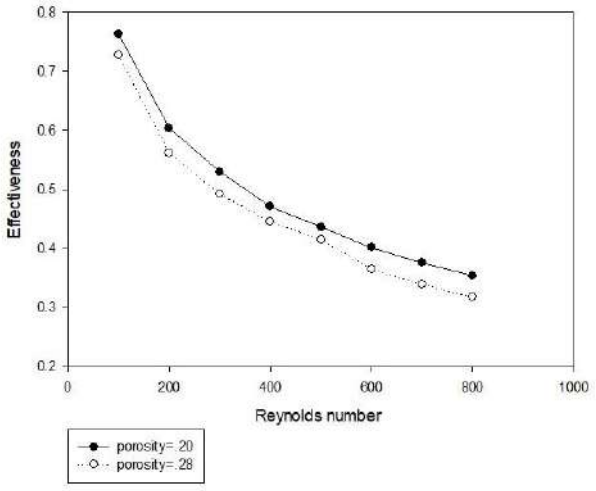

Figure9. Effectiveness for different porosities

IV. CONCLUSION

A heat exchanger is designed for the high temperature applications. For that the matrix heat exchanger, which is widely used in the field of cryogenics is modified and introduced for high temperature applications. The porous portion of matrix heat exchanger here actually act as the extended surface for the newly developed compact heat exchanger. Now numerically, problem is designed with the help of ANSYS 16.0 and simulated the results for a range of Reynolds number varying from 100 to 800 and for different porosities. Using this variation of effectiveness, colburn factor and friction factor are noticed and found out that

1) The j factor decreases with the increase in Reynolds number, which is a common behaviour because j factor is inversely proportional to Reynolds number. As the porosity increases j factor increases due to improved heat transfer and heat transfer coefficient. There found a maximum increase of 37% and minimum increase of 28%.

2) Friction factor reduces with increase in Reynolds number because friction factor is inversely proportional to square of air velocity. Friction factor also increases with pressure drop, which is higher at higher Reynolds number. But the effect of air velocity variation is more influencing than increased pressure drop. So the net effect is decrease in friction factor with increase in Reynolds number. With decrease in porosity, f factor found to be decreasing. So that there found a maximum decrease of 59.5% and minimum decrease of 50%.

3) The improvement in porosity results in increment of j factor, f factor and decrement of effectiveness. Since colburn factor is the indicator of thermal performance of a heat exchanger it would be recommended to have increased porosity while slight reduction in effectiveness can be neglected without accounting. But increased pressure drop results in increased pumping power. So it would be recommended to take suitable measures to reduce this friction factor in future works, oriented to matrix heat exchangers.

REFERENCES

[1] G. Venkatarathnam and Sunil Sarangi “Matrix heat exchangers and their application in cryogenic systems” Cryogenics 36 (1996) 235-24

[2] McMahon, H.O., Bowen, R.J. and Beyle Jr. A perforated matrix heat exchanger Trans ASME (1950) 72 623-632

[3] S. Sunil Kumar, L. Ratna Raju, T.K. Nandi “Thermal performance of perforated plate matrix heat exchangers with effects from outer wall and flow channel geometry” Cryogenics 72 (2015) 153_160

[4] S. Sunil Kumar “Thermal performance of perforated plate matrix heat exchangers with effects from outer wall and flow channel geometry” PhD thesis cryogenic center IIT Kharagpur 2015

[5] Orlov VK, Shevyakova SA and Valeev GW 1978 “Heat exchange and hydraulic resistance in perforated-plate heat exchangers” *Khim. Neft Mashin.* 10-11; Transl: 1978 *Chem. Pet.r Engg.* 701-4

[6] E.I.Mikulin, Yu.A.Shevich, V.N.Potapov, and M.Ya. Solntsev, and G. M. Yusova “Study of matrix type heat exchangers made up of perforated plates” 1980

[7] Ratna Raju, S Sunil Kumar, K Chowdhury and T K Nandi “Heat transfer and flow friction correlations for perforated plate matrix heat exchangers”2017 IOP Conference

[8] Nilles MJ, Calkins ME, Dingus ML and Hendricks JB 1995 “Heat transfer and flow friction in perforated plate heat exchangers” Exp. Thermal and fluid science 10 238–47.

[9] N. Nagarani, K. Mayilsamy “Experimental heat transfer analysis on the annular circular and elliptical” fins 2010, 2(7): 2839-2845.

[10] Farhani F Matrix heat exchangers for cryogenic applications PhD thesis cryogenic center IIT Kharagpur 1996

[11] Krishnakumar K and Venkatarathnam G 2007 “Heat transfer and flow friction characteristics of perforated plate matrix heat exchanger’s” International journal of heat Exchangers. 7 1-16.

ISBN 978-93-89105-41-4

[12] Hayes A M, Khan JA, Shaaban A H and Spearing IG 2008 “The thermal modeling of a matrix heat exchanger using a porous medium and the thermal non-equilibrium model” Int. J. of Thermal Science. 47-1306-15.

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DESIGN OF BLAST RESISTANT HULL FOR ARMOURED VEHICLES

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***Abstract*—Armoured vehicles are integral parts of the defense forces of any country. These vehicles protect the soldiers from severe injuries caused due to the external hazards in the war field. These hazards include bullets fired from guns, blasting of grenades, or even the detonation of land mines. The armoured vehicles are designed to give protection to its occupants from such hazards. The hull geometry significantly influences damages caused due to mine blast. Analyses with flat and V-shaped hull (with 90^0 included angle) have been done and reported in the past. It has been illustrated that, with the use of proper hull design (90^0 V-hull) and by using the best material, the damages caused to the vehicle and the injuries to the occupants can be well controlled. Studies showing the influence of hull angle (in the range from 0 to 90^0) on the damage caused to the structure has also been carried out. In this paper, structural analysis of the hull with a different profile with 90^0 included angle is performed. This is done to obtain an optimal hull design with minimum induced stress.**

***Index Terms*—Armoured vehicle, Mine blast, Hull, Styling, ANSYS**

I. INTRODUCTION

Safety of the passengers in an armoured vehicle is of primary concern in a war affected zone. The main vehicles used for transport and extraction of soldiers are the Light Armoured Vehicles (LAVs). These vehicles must be designed in such a way that they take are exposed to least damage in a battle field, causing less injuries to the passengers [1]. The main hazard to be considered in a war affected zone is land mine. These highly potential explosive causes severe damages to the Light Armoured Vehicles. It can even lead to loss of lives of the vehicle occupants [2].Therefore, it is necessary to examine and improve the response of LAVs to these high intensity short term loads, especially in the early design stages of prototype development.

Fig. 1.1.VALUK 6X6 LAV.

Different hull shapes were invented in the past. But the most commonly used armoured vehicle hull in today's world is the common flat hull [3]. The flat hull of the armoured vehicle takes the most damage [4]. Therefore modifications in hull designs have to be made so that the hulls are subjected to the least damage and thus protecting its occupants. Many hull designs with different geometries have been tried till date. The U hull, V hull [5-7] etc. were the proposed designs for the new and modified hulls. The effects on these hulls were analyzed and were compared with each other and also with the flat hull. Before coming up with a new and modified design, the blast wave propagation and intensities have to be studied. For this analysis, the particles of the blast wave were considered. The behavior and nature of the wave particles were analyzed and recorded. The study of the blast particles during a blast gave rise to the term called Smoothed Particle Hydrodynamics (SPH) [8, 9]. This concept represents the waves as particles scattering during a blast. The blast response of the occupants in an armored vehicle are studied either by simulation or by actual experiments using a dummy with human like characteristics [10]. The seating position of the occupants and the weight of the occupants are the parameters

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To be considered while studying the human effect due to the blast loading. The main damage taken by human occupants in an armored vehicle is the under belly blast loading. The main injury takes place below the waist area. Also, the damage due to the extreme load to the skull and brain should also be considered. The data from previous blast experiments and computations of the blast loading should be considered while designing a new hull. Earlier experiments were conducted by actually blasting using a land mine. A data collection setup was also made to record the previous experiment data [11-16]. Different methods like drop tower test were also conducted. Since it is not practically and economically feasible to increase the thickness of the hull for effective blast resistance, the research should be focused on introducing new materials that can withstand the blast more when compared to armoured grade steel. Simulations and experiments on the effect of the blast on the hull due to variation in shapes of the plate were also done. In this work, the main focus is on studying the effect of the mine blast on the hull plates by varying the shape of the hull. Simulations using ANSYS software and the maximum stress developed on the hulls are recorded and compared. The hull that is considered in the present paper is that of VALUK6X6 which a Light Armoured Vehicle (LAV).

Kunc et al. [17] conducted the blast response of Light Armored Vehicle hull for both flat and V hull with 90^0 angle. Both these hulls were simulated to obtain the stress developed during the blast and to study the particle dispersion due to the blast. The simulation was done using LS-DYNA software. It was observed that the particle dispersions after the blast were different in both the hulls. The V hull with 90^0 angle had smooth particle dispersion when compared to the flat hull. Maximum stress developed in the flat hull was observed to be more than that of the maximum stress developed in the V hull. V hull with 90^0 was found to be the better design.

Markose et al. [18]studied the response of V shaped hulls subjected to blast loading. From the blast particle dispersion study, it was found that the dispersion of particles in a flat hull was rough. This lead to think about the introduction of a new and better design for the armoured vehicle hull. Simulation was done by varying the included angle of the V hull.

Jovan et al. [19] used ABAQUS software to simulate U hull, V hull and flat hulls for comparison on the basis of maximum stress development on the hulls. Before the introduction of the V hull concept, U hulls were introduced. The study through Smoothed Particle Hydrodynamics (SPH) lead to the discovery of U hulls also. The obtained maximum stresses were noted. Then, the V hull was taken for simulation. The included angle of the V hull was varied to study the effect of included angle variation on the maximum stress development due to the blast. The data were recorded and all the maximum stress values were compared to obtain the least stress developed. The V hull with 90^0 included angle had the least maximum stress developed compared to all the other hull.

Anderson et al.[20]conducted the actual mine blast loading experiments. This was done to obtain data for mine blast from under the armored vehicle. They took circular, rolled, V, U and flat hulls for the blast experimentation. The stand-off distances of the plates subjected to the blast were also varied to study the effect of blast. This information was recorded for references for future experiments and simulations. It was found that V plate with the maximum stand-off distance showed the least effect due to the blast.

Galvez et al. [21] worked on the concept of add-on armour plates. Ceramics were the main material used for the add-on armor for armored vehicles. Ceramics have high blast protection potential and high thermal resistance. The introduction of ceramics in the armed forces began in 1960s. It was first used by the US Army when there was a requirement for light weight armor in the helicopters. Since ceramics are extremely brittle materials, they are backed with a ductile material before the add-on armor application. These add-on armors are of the same thickness as that of the main armor. The add-on armor are either glued or screwed on to the main armor hull. This way, even if the add-on armor is damaged, it can be easily replaced by another ceramic armour backed by

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the ductile material. Today, there is a new method to produce ductile ceramics by the process called flash sintering. It is simply adding electric field to the normal sintering process. The shapes of the add-on armor can be varied so that better protection can be achieved.

Soleiman et al. [22] introduced a new and better replacement for the common armor steel used for the hull. The new material is known as Dyneema HB26 fibre. Dyneema is an ultra-light weight polyethylene fibre composite that has excellent blast protection and high thermal resistance. The actual experimentation was done on both the steel armor plate and Dyneema fibre plate. This was done to compare the effect of the blast on both the plates. It was found from the obtained data that the effect of the blast on the Dyneema fibre was less than that of the steel armor. The effect of blast on the Dyneema fibre plate was found to be 30 percent less. Thus, this fibre can be considered as an appropriate replacement for the armor steel plate.

II. METHODOLOGY

In this work ANSYS software is used to simulate the blast on the flat and the V hulls. In ANSYS Workbench, the Explicit Dynamics module is used for performing the simulation. The materials selected for the hulls are S-7 STEEL, which is a military grade steel used for ballistic and armor applications. This steel follows the Johnson-Cook model as per the blast conditions. The explosive material used for executing the blast is HMX-TNT. This is a commonly used explosive in land mine blasts. Modeling of the geometry is done as shown in Fig.2.1. Both the hulls are modeled at a fixed stand-off distance of 410 mm from the ground.

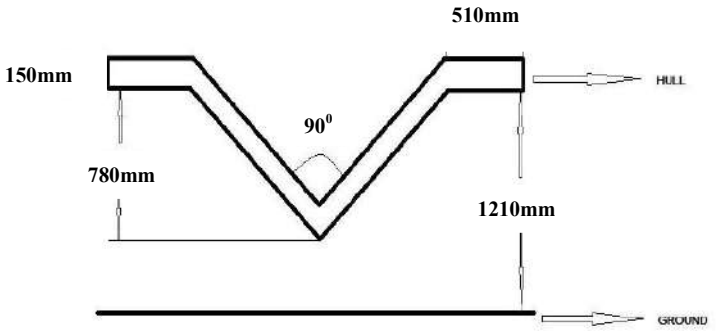

Fig. 2.1 Geometry of a V-hull.

In the Model option in the Explicit Dynamics, materials are assigned to both the hull and the explosive. S-7 STEEL is assigned for the armor hull, whereas HMX-TNT is given for the explosive. Meshing is done for the hull and the ground by using the mesh option. After meshing, detonation point is selected using the Explicit Dynamics option. The point for detonation is assigned on the ground at a distance of 410 mm from the hull at the exact center of the hull for both the flat and the V hulls. Then, in the Analysis settings, the time for the blast and the safety factor are given according to the standard parameters for a TNT blast. The model is initially solved. In the solution option, equivalent Von-Mises stress option is selected for obtaining the maximum stress developed on each of the hull during the land mine simulation blast. The maximum stress developed on the hulls are obtained and recorded for comparison based on the maximum stress development. Both the Flat hull and V hull with 60^0, $90^0$and 120^0 angles are simulated in this manner. This is done in order to replicate the work in the base paper for initial validation of the maximum stress development values. From this validation, better models can be simulated by studying the Smoothed Particle Hydrodynamics (SPH) concept. Initially V hull with 90^0 angle is found to develop the least maximum stress during the land mine blast simulation. The work in the actual base paper was done using the LS-DYNA software. The same work is replicated in this paper using the ANSYS Workbench software. Similar results are obtained in both the base paper and this work. Since the V hull with 90^0 angle is better for effective blast protection, a better design can be obtained from the V hull by thoroughly studying the nature of dispersion of particles after the mine blast has taken place. Then, a better hull is designed in the ANSYS software by assigning the hull to the S-7 STEEL material and the blast material as HMX-TNT. Then, this design is simulated for the land mine blast and the value of maximum stress developed can be found out and the value is recorded. This data for the maximum stress developed is then compared with the existing V hull with 90^0 included angle to see if the newly developed design is better than the existing V hull.

III. GOVERNING EQUATIONS FOR BLAST LOADING

All the materials subjected to blast must follow the Johnson- Cook model for the scale of dispersion of the blast wave. This J-C equation gives the relationship between the stand-off distance of the armor vehicle hull from the ground and the equivalent mass of the explosive used for the land mine blast. The J-C model for blast states that the scaled distance of the blast wave is the ratio of stand-off distance of the of the hull of the armored vehicle from the ground and the cube root of the mass of the explosive used for the land mine blast. It is a proven theory that all the materials subjected to the land mine blast should follow this J-C model. The materials for which blasting is done should be selected based on the following equation [23] where Z is the scaled distance of the blast, R is the

$$Z = \frac{R}{\sqrt[3]{W}} \qquad (1)$$

Stand-off distance of the armored vehicle hull from the ground (in mm) and W is the mass of the explosive (in kg). With the increase in stand-off distance of the hull from the ground, the scaled distance of the blast also increases. Equation (2) gives the pressure developed during the mine blast

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represented as a function of time [23].

$$P(t) = P_0\left[1 - \frac{t}{t^*}\right] \times e^{\frac{-t}{t^*}} \qquad (2)$$

where P_0 is the atmospheric pressure (in Pa), t is the total time for the blast (in μs), and t* is the time duration at which the pressure variation of the blast is positive (in μs). Figure 4.1 illustrates the pressure variation as a function of time.

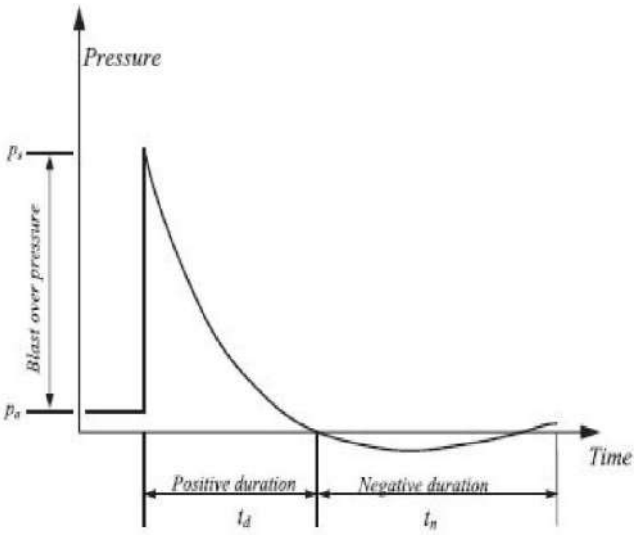

Fig. 3.1 Blast pressure as a function of time.

IV. RESULTS AND DISCUSSION

A. SIMULATION RESULT

The following hulls are designed in ANSYS Workbench and these hulls are subjected to blast loading.

1. Flat hull
2. V hull with 60^0 included angle.
3. V hull with 120^0 included angle.
4. V hull with 90^0 included angle.

These hulls are modeled in the ANSYS software and the results are obtained for the maximum stress in the hull.

1. Flat hull

The flat hull is developed in ANSYS software according to the standard dimensions as in [17]. The standoff distance given for the hull is fixed at 410 mm from the ground. The detonation point is given at the exact center of the Flat hull both length wise and breadth wise. The blast is simulated and the maximum stress developed is as follows: $\sigma = 3.2396 \times 10^9$ Pa

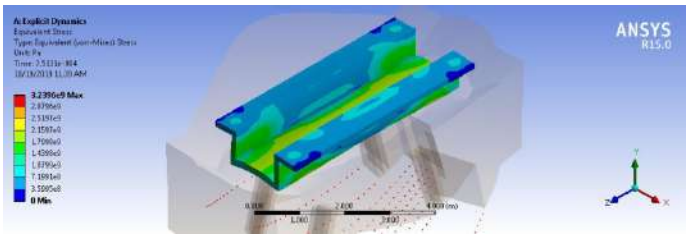

Fig. 4.1. Stress developed on flat hull due to the blast.

2. V hull with 60^0 included angle

The V hull with 60^0 included angle is developed in ANSYS

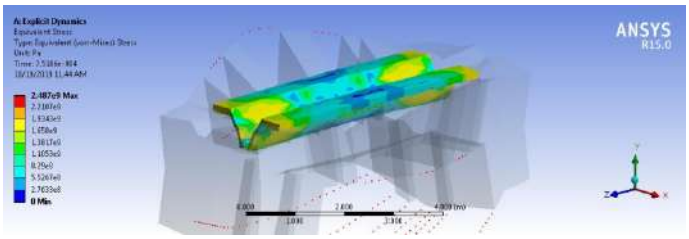

Fig. 4.2. Stress developed on V hull due to blast.

software according to the standard dimensions as mentioned in [17]. The stand-off distance given for the hull is fixed at 410 mm from the ground. The detonation point is given at the exact center of the V hull both length wise and breadth wise. The blast is simulated and the maximum stress developed is noted as follows: $\sigma = 2.487 \times 10^9$Pa

3. V hull 120^0 included angle

The V hull with 120^0 included angle is developed in

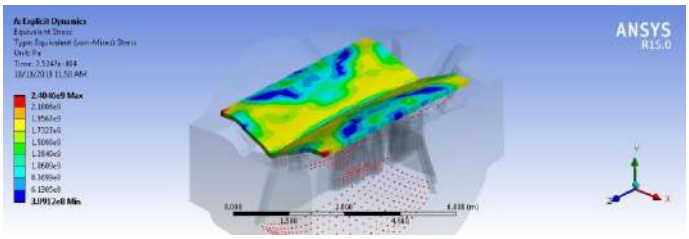

Fig. 4.3. Stress developed on V hull due to blast.

ANSYS software according to the standard dimensions as given in [17]. The stand-off distance given for the hull is fixed at 410mm from the ground. The detonation point is given at the exact center of the V hull both length wise and breadth wise. The blast is simulated and the maximum stress developed is noted: $\sigma = 2.404 \times 10^9$ Pa

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4. V hull with 90^0 included angle

The V hull with 90^0 included angle is developed in ANSYS

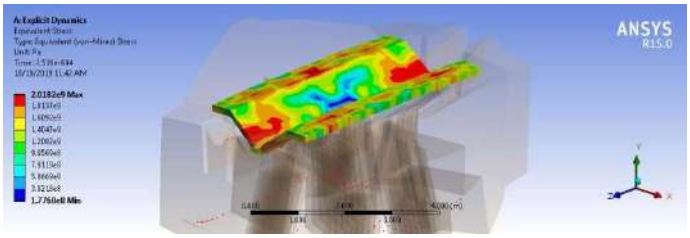

Fig. 4.4. Stress developed on V hull due to blast.

software according to the standard dimensions. The stand-off distance given for the hull is fixed at 410 mm from the ground. The detonation point is given at the exact center of the V hull both length wise and breadth wise. The blast is simulated and the maximum stress developed is noted:$\sigma = 2.0182 \times 10^9$ Pa

The above obtained results are compared based on the value of maximum stress development due to the blast. This work is validated by comparing the values the maximum stress developed on the V hull with 90^0 included angle in the base paper to the maximum stress developed on the V hull with the same angle as obtained in this work. The compared values of the maximum stress developed are given in the table below. After the validation, a graph is plotted between the

Table 1. Validation of numerical results

STRESS [17] ($\times 10^9$ Pa)	STRESS [Present] ($\times 10^9$ Pa)	PERCENTAGE ERROR
2.052	2.0182	3.3%

maximum stress developed and the included angle of the V hull. This is done to understand the variation of maximum stress development on the hulls due to varying included angles. From the graph, it is seen that minimum stress is developed

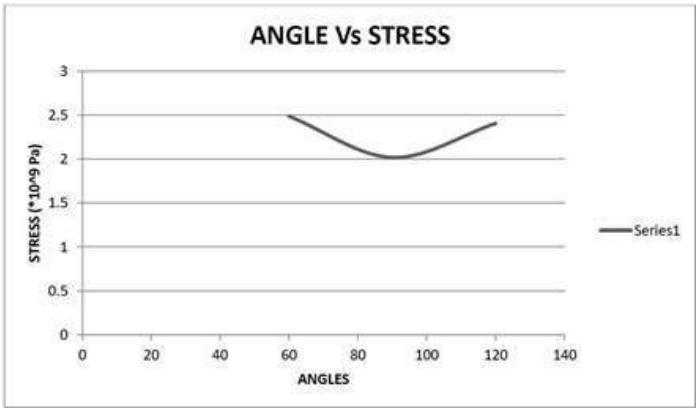

Fig. 4.5 Stress as a function of included angle.

when the included angle is 90^0. When the angle decreases, stress development is more because the blast dispersion is not smooth. Angles greater than 90^0 develop less stress than angles less than 90^0 as the blast dispersion will be much smoother.

B. ANALYTICAL RESULTS

$$\frac{P_{max}}{P_a} = \frac{808\left[1+\left(\frac{z}{4.5}\right)^2\right]}{\sqrt{1+\left(\frac{z}{0.048}\right)^2}\times\sqrt{1+\left(\frac{z}{0.32}\right)^2}\times\sqrt{1+\left(\frac{z}{1.35}\right)^2}} \quad (4)$$

where the Z is obtained using Eq. (1).

P_{max}- maximum pressure developed during the blast(Pa)
P_a- atmospheric pressure (Pa)
By taking the weight of the explosive as 16 kg and stand-off distance of 410 mm as specified in [ ], the maximum pressure is found to be P_{max}=1.989×10^9Pa. T

It is shown in Fig.4.6 that when the weight of the explosive

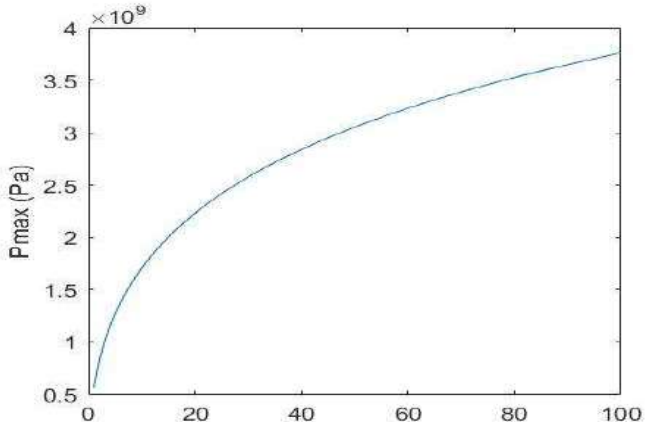

Fig. 4.6 Maximum pressure as a function of explosive mass

is increased, the maximum pressure developed due to the blast also gets increased. So, increasing the weight of the explosive can cause more damage.

V. DEVELOPMENTOF A NEW DESIGN

After studying the particle dispersion of the blast [5, 17], the existing V hull is subjected to modifications to obtain better designs. The blast simulation of the new hull is done in ANSYS software. S-7 STEEL (the conventionally used material) is assigned for the hull and the explosive used is (HMX-TNT).The standoff distance of the hull from the ground is kept constant at 410 mm.

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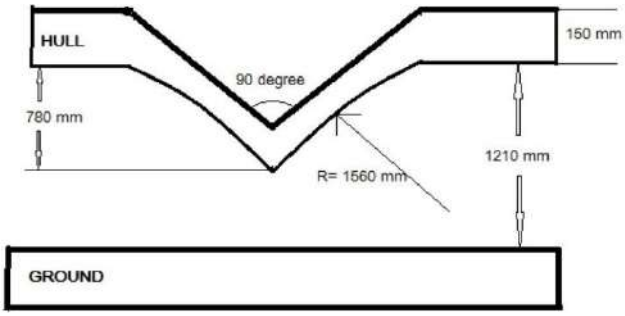

Fig. 5.1 Geometry of the modified hull.

This model is simulated and the maximum stress developed on the hull is obtained as $\sigma = 1.882 \times 10^{9}$ Pa.

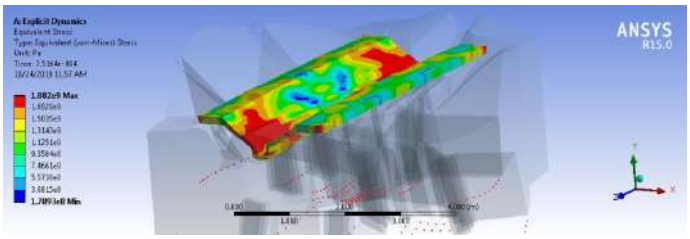

Fig. 5.2 Stress developed on the modified hull.

The stress developed on the modified hull due to the blast is found to be even less than that in the V hull with an included angle of 90^0 Further investigations, both numerical and experimental, need to be carried out to obtain an optimal geometry which gives least damage to the hull and the occupants in the vehicle when subjected to mine blast.

VII. CONCLUSION

The simulation of all different hulls is carried out using ANSYS software. The hulls used for the basic evaluations are: Flat hull, V hull with 60^0 included angle, V hull with 90^0 included angle and V hull with 120^0 included angle. It is found that V hull with an included angle of 90^0 shows the least stress developed due to the land mine blast. From the existing 90^0 design, a modified design is created and it is simulated for stress development. The stress developed is found to be less than the existing V hull design with 90^0 included angle. An important factor considered while designing a hull is the passenger safety in a Light Armored Vehicle. Even better designs can be developed to reduce the stress development on the hull due to the blast so that the effect of the mine blast on the passengers can be further reduced.

REFERENCES

[1] F. Tchantchou et al., "Neuropathology and neurobehavioral alterations in a rat model of traumatic brain injury to occupants of vehicles targeted by underbody blasts,"Exp.Neurol., vol.289,pp.9–20,2017.

[2] Ganpule, Shailesh, et al. "Mechanics of blast loading on the head models in the study of traumatic brain injury using experimental and computational approaches." *Biomechanics and modeling in mechanobiology* 12.3 (2013): 511-531.

[3] F. J. Mostert, "Challenges in blast protection research," Def. Technol., vol.14,no.5,pp.426–432,2018.

[4] N. Newell, W. Neal, T. Pandelani, D. Reinecke, W. G. Proud, and S. D. Masouros, "The Dynamic Behaviour of the Floor of a Surrogate Vehicle Under Explosive Blast Loading," J. Mater. Sci. Res., vol. 5, no. 2, p. 65,2016.

[5] A. Markose and C. L. Rao, "Mechanical response of V shaped plates under blast loading," Thin-Walled Struct., vol. 115, no. February, pp. 12–20,2017.

[6] B. Hazrati and M. A. SaeimiSadigh, "Failure Simulation in the Reinforced V-Shape Plates Subjected to Localized Blast Loading," J. Fail.Anal.Prev.,vol.16,no.4,pp.683–693,2016.

[7] L. S. B. Veeredhi, N. V. RamanaRao, and V. R. Veeredhi, "Effect of Plate Curvature on Blast Response of Structural Steel Plates," J. Inst. Eng.Ser.A,vol.99,no.3,pp.463–471,2018.

[8] J. L. Lacome, "Smooth Particle Hydrodynamics (SPH): A new feature in LS-DYNA," pp. 29–34,2000.

[9] Koneshwaran, Sivalingam, David P. Thambiratnam, and ChamindaGallage. "Blast response of segmented bored tunnel using coupled SPH–FE method." *Structures*. Vol. 2. Elsevier, 2015.

[10] K. Suhaimi, M. S. Risby, K. S. Tan, and V. F. Knight, "Simulation on the shock response of vehicle occupant subjected to underbelly blast loading,"ProcediaComput.Sci.,vol.80,pp.1223–1231,2016.

[11] H. R. TavakoliandF. Kiakojouri, "Numerical dynamic analysis of stiffened plates under blast loading," Lat. Am. J. Solids Struct., vol. 11,no.2,pp.185–199,2014.

[12] M. Grujicic, G. Arakere, W. C. Bell, and I. Haque, "Computational investigation of the effect of up-armouring on the reduction in occupant injury or fatality in a prototypical high-mobility multi-purpose wheeled vehicle subjected to mine blast," Proc. Inst. Mech. Eng. Part D J. Automob.Eng.,vol.223,no.7,pp.903–920,2009.

[13] A. T. 1 and G. N. 2, "Experimental study on the impact resistance of 2Dplain-wovenC/SiCcomposite,"pp.1–28.

[14] M. Grujicic and W. C. Bell, A computational analysis of survivability of apick-uptrucksubjectedtominedetonationloads,vol.7,no.4.2011.

[15] M. Cheng, J. P. Dionne, and A. Makris, "A computational analysis of survivability of a pick-up truck subjected to mine detonation loads," Int. J.ImpactEng.,vol.37,no.12,pp.1180–1187,2010.

[16] P. Baranowski and J. Malachowski, "Numerical study of selected military vehicle chassis subjected to blast loading in terms of tire strength improving," Bull. Polish Acad. Sci. Tech. Sci., vol. 63, no. 4, pp. 867–878,2015.

[17] J. Trajkovski, J. Perenda, and R. Kunc, "Blast response of Light ArmouredVehicles(LAVs) with flat and V-hull floor," Thin-Walled Struct.,vol.131,no.December2017,pp.238–244,2018.

[18] P. K. Choudha, A. Kumaraswamy, G. G. Dutta, and K. D. Dhote,"Effect of shape of explosive charge in failure of rolled homogenous armour plate,"ProcediaStruct.Integr.,vol.14,no.2018,pp.191–198,2019.

[19] Trajkovski, Jovan, Robert Kunc, and Ivan Prebil. "Blast response of centrally and eccentrically loaded flat, U."

[20] Anderson Jr, Charles E., et al. *Mine blast loading: experiments and simulations*. No. SWRI-18.12544/011. SOUTHWEST RESEARCH INST SAN ANTONIO TX, 2010.

[21] Gálvez, Vicente Sánchez, and Laura Sánchez Paradela. "Analysis of failure of add-on armour for vehicle protection against ballistic impact." *Engineering Failure Analysis* 16.6 (2009): 1837-1845.

[22] Fallah, A. Soleiman, et al. "Dynamic response of Dyneema® HB26 plates to localised blast loading." *International Journal of Impact Engineering* 73 (2014): 91-100.

[23] Tavakoli, H. R., and F. O. A. D. Kiakojouri. "Numerical dynamic analysis of stiffened plates under blast loading." *Latin American Journal of Solids and Structures* 11.2 (2014): 185-199.

[24] Veeredhi, Lakshmi Shireen Banu, NV Ramana Rao, and Vasudeva Rao Veeredhi. "Effect of Plate Curvature on Blast Response of Structural Steel Plates." *Journal of The Institution of Engineers (India): Series A* 99.3 (2018): 463-471.

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Feasibility Study of Epoxidised Rice Bran Oil as Cutting Fluid

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***Abstract*— Cutting fluids are extensively utilized in machining operations for reducing the metal to metal contact and temperature generated during machining. Most of the cutting fluids commonly available are derived from mineral oil. The mineral oil-based lubricants are harmful to the operators because of their toxic nature and they are non-biodegradable which causes several health hazards to living things. The development of biodegradable cutting fluid is thus necessary. Vegetable oil-based lubricant is one of the alternates for mineral oil-based lubricants because they are biodegradable, renewable, less toxic and have good lubricating properties. Their use is limited because, vegetable oils have poor thermal-oxidative stability and poor cold flow properties. Chemical modifications and additives can overcome these disadvantages. Among different vegetable oils available, Rice Bran Oil (RBO) is found to be a better option as potential base-stoke because of its fatty acid composition. The chemical modification is done to improve the oxidative stability of RBO. Therefore, this study focused mainly on the epoxidation of RBO (ERBO). The thermal, chemical and tribological properties of RBO, ERBO and commercially available cutting fluid (servo cut s) are evaluated and compared as per ASTM and international standards. Organic emulsifier is used to emulsify RBO and ERBO in this work. Performance test on lathe machine is conducted for RBO, ERBO, Servo cut s and results are compared.**

Keywords— vegetable oils, bio cutting fluid, mineral oil, epoxidation, water soluble cutting fluid.

I. INTRODUCTION

Lubricants are introduced to reduce friction and wear between two relatively moving surfaces which are in contact. Lubricants are extensively used in all manufacturing and automobile industries to lubricate their machines. In 2005, reports indicate 38,000,000 tonne of lubricants were globally utilized [1]. 85% of lubricants utilized globally are petroleum derivatives [2]. Extensive utilization of petroleum-based oils creates lot of environmental issues. Toxicity of mineral oils result in air pollution, surface and ground water contamination, soil pollution which leads to agricultural product and food contamination [3].

Cutting fluids or Metal Working Fluids (MWF) are employed in high speed machining. The function of the MWF is to pretend as a lubricant, in order to minimize the friction and keep the heat generated to least. Under higher temperature and stresses, the work piece and tool weld together, so MWF should have the properties to restrict this problem [4]. Cutting fluids increase the productivity and provide good surface finish by cooling and lubricating during machining process [5]. Because of this, the usage of MWF is growing rapidly in machinery industries. Reports indicated that European Union yearly consume 320,000 tons of MWF.out of this around one third can be reused and the remaining has to be thrown out because of the high cost associate with its recycling [6]. MWF create ailments to humans and environmental issues to the nature. Studies show that approximately eighty percent of the workers exposed to lubricants are facing skin cancer, cough, occupational asthma, etc [7]. Cutting fluids are irritant

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or allergic to the human skin. Commonly water-soluble MWF poses more threat to the workers.

To get over these hurdles, scientists and tribologists are currently searching to find out alternatives to petroleum based cutting fluids. Synthetic, solid and vegetable oil derived lubricants are the examples for those alternatives [8]. Vegetable oils are suitable replacement for mineral oil lubricants due to their eco-friendly nature, low toxicant, and sustainability. So, works are conducted to create a new ecofriendly MWF from globally accessible vegetable oils.

Vegetable oils mainly contains triglyceride molecule structure. Triglycerides are basically glycerol molecules attached to triple fatty acid chains through ester linkage [9]. Because of triglyceride structure these oil shows the excellent boundary lubrication behavior. Long and polar fatty chains of vegetable oils impart high strength to lubrication films formed. These films have the ability to adhere to the contact surfaces and minimize the surface contact. This results in minimization of friction as well as wear. The carbon chain having one, two and three double bond C-C atoms are known as oleic, linoleic, and linolenic fatty acids respectively. More oleic content is good for lubricant properties. These oils show inferior cold-flow properties as well as poor resistance against rancidification. This can be solved by chemical modification such as hydrogenation, epoxidation, and transesterification. Epoxidation is one of the important reactions because of the epoxides formed as the byproduct of this reaction has a wide range of application. It perhaps directly used as lubricant, plasticizers and polymer stabilizers, and also used for producing alcohols, glycols, alkanolamines, polyols and polymer [10]. On manufacturing level, the epoxidation process is done by reacting percarboxylic acid obtained from in-situ reaction with oil. Percarboxylic acid is formed by acid catalyzed peroxidation of respective acids with hydrogen peroxide. Water dissolvable mineral acids such as sulfuric acid act as catalyst.

The present work is an attempt to compare mineral oil based (servo cut S) and vegetable oil-based cutting fluids. In this work Rice bran oil (RBO) is considered for the study. RBO is extracted from husk of the rice. The fatty acid composition is, Oleic acid (38.4%), Linoleic acid (34.4%), Linolenic acid (34.4%), Palmitic acid (21.5%), Stearic acid (2.9%). India is the second largest producers of rice. Annual production RBO in India is over 1.62 million tons, so it is a readily available lubricant base stock. High oleic acid content in RBO make it as a better candidate for bio-lubricant base stock. As compared to SAE20W40, RBO has better friction properties but has high wear characteristics compared to it [11]. The lubricant properties of RBO is improved in this work by epoxidation process. The performance analysis of RBO, ERBO and servocut s was conducted to evaluate the cutting forces during lathe turning operation.

II. MATERIALS AND METHODS

A. Materials

The refined RBO was purchased from pavizham Healthier Diet Pvt. Ltd. Chemicals such as acetic acid, Sulfuric acid, Hydrogen peroxide, etc are purchased from Sarabhai chemicals, Tvpm. MS rod and HSS lathe tool was brought from Shakthi tools. The organic emulsifier was bought from Y K laboratories.

B. Epoxidation of RBO

Epoxidation of vegetable oil is a reaction in which C-C double bonds reacts with highly reactive oxygen to form an epoxy ring (fig 1). On large scale, the vegetable oil is reacting with percarboxylic acid formed by in-situ reaction. Water soluble acids act as catalysts in this reaction [12]. The process of epoxidation is influenced by reaction variables such as volume of reactants and products, selected catalyst, temperature, stirring speed etc. The degree of conversion of unsaturation to oxirane rings are characterized by the iodine value.

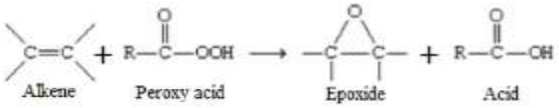

Figure 1: Epoxidation reaction

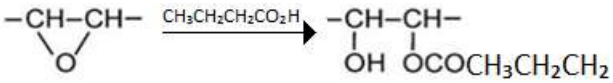

Figure. 2. Ring Opening Reaction

In a round bottom flask, 150 g of RBO is mixed with acetic acid, H_2SO_4 (catalyst) and H_2O_2 stoichiometrically. The sample is stirred in water bath at temperature about 70ºC for 6 hours. After 6 hours of stirring, the epoxidized RBO sample is made ready. The sample is washed with water and allowed to separate in a gravity separating funnel. The sample is washed with water to remove unreacted acid and then heated to remove water content. After epoxidation, the sample is mixed with suitable amount Butanoic acid and is stirred for 4 hours. Then it was again washed with water and heated to remove water content in it. Finally, the ring opened product of ERBO is obtained. The ring opened reaction is shown in fig 2.

Figure. 3. Epoxidation setup

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C. Preparation of Emulsifier Mixture

From the literature, 40% emulsifier is found to be stable hence 40% by wt. emulsifier is added to the RBO. Oil in water emulsion is made in the ratio of 1:20 and mixed for 5min in magnetic stirrer.

D. Chemical Properties

The main properties evaluated are acid value and iodine value

1) Acid Value

Acid value represents the quantity of potassium hydroxide needed to neutralize the free fatty acids (FFA) within the sample. It indicates the number of FFA in the sample.

Figure 4: Acid value setup

Acid value should be less for a good lubricant. The acid value is determined based on IS: 548 (Part 1) –1964. Take 5g oil in conical flask and then add 30 ml methanol along with four drops of phenolphthalein indicator. Titrate this mixture against potassium hydroxide in the burette till pink colour is appeared as shown in fig 5. The experimental set up for determining the acid value is shown in fig 4.

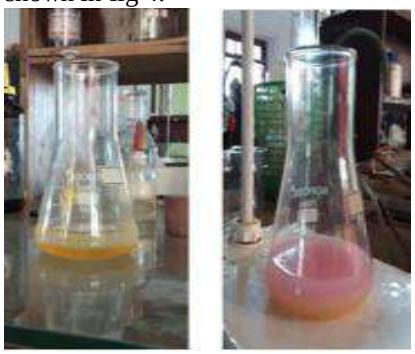

Figure 5: Acid test stages a) before b) after titration

The titration volume was noted and the acid value is determine using following (1):

$$Acid\ value = \frac{56.1 \times V \times N}{W} \quad (1)$$

Where,

V = Volume of potassium hydroxide in ml

N= Normality of potassium hydroxide

W = Weight of the sample in g

2) Iodine Value

The iodine value represents the quantity of double carbon bonds present within the oil. Iodine value is denoted as the quantity of iodine that gets absorbed in 1 gram of oil [12]. A solution of 0.1N sodium thiosulphate is prepared. Starch solution is prepared in a test tube. Adequate heating is done using gas flame. 25 ml chloroform is taken in a conical flask and add 0.283g oil to it. Pippet out 20ml wijs's iodine solution to the mixture of oil and chloroform. Keep this solution in dark atmosphere for 30 minutes. After 30 minutes Potassium iodide solution and 50 ml water is added to it. Then this mixture is titrated against 0.1N Sodium thiosulphate solution. When the colour changes from yellow to pale yellow, starch solution is added. Continue titration till the solution becomes colourless and take the corresponding readings.

E. Tribological Properties

The coefficient of friction and wear characteristics of samples have been evaluated as per the ASTM D-4172 by using a fourball tribometer (DUCOM Instruments) as shown in the fig.6. The four-ball tester is an equipment which is used to test tribological characteristics of lubricants.

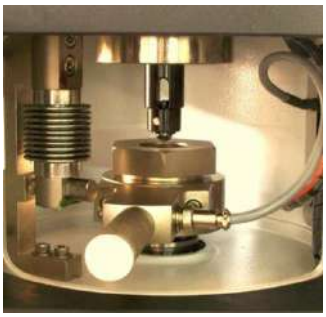

Figure 6: Four ball tester

Figure 7: Optical microscope

There are four balls of diameter 12.7 mm made of chromium steel and hardness value of 64 HRC in which three of the balls are kept in a ball pot and test sample is poured over it and the fourth ball is fixed to a collect which is attached to the rotating spindle. The load is given by pneumatic source and is sensed by load cell fixed in the machine.

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As per the standard ASTM D-4172, the spindle speed was set to 1200rpm and the load applied is 392N. The test was carried out for a duration of 3600 seconds at a temperature of 75ºC. After the test, the wear scar diameters were measured using an optical microscope which is shown in fig 7.

F. Thermal Properties

The temperature below which oil becomes hazy when cooled at a specific rate is known as cloud point. Pour point is the temperature below which the oil ceases to flow. The pour point and cloud point are evaluated using physical techniques.

G. Machining Performance

The performance tests for the metal working fluid were evaluated by conducting machining operation (turning) on a lathe (Kirloskar, Model 1330) by analyzing the cutting forces using a lathe tool force indicator (UIL-15) as shown in fig 8. The machining was performed with mild steel rod of diameter 50 mm and 150 mm long using HSS lathe cutting tool. The forces were noted for a duration of 1 minute. The cutting forces were obtained in the unit of kgf. The setup for performance test is shown in the fig 9.

Figure 8: Lathe tool force indicator

Figure 9: Lathe setup with tool dynamometer

The longitudinal cutting forces are obtained from the lathe tool dynamometer. For analyzing the performance, the cutting forces were determined at different depth of cut and speed. The feed is maintained constantly at 0.22mm/rev is applied for each machining operations. The metal working fluid is supplied continuously at a rate of 10 ml/sec using an external pump and the cutting forces were analysed for different depths of cut at 0.1 mm, 0.2 mm and 0.3 mm and speed at 140rpm, 224rpm, 315rpm.

III. RESULTS AND DISCUSSIONS

A. Evaluation of Chemical Properties

The chemical properties such as acid value and iodine value were evaluated by conducting the tests as explained and the results are shown in the Table 1.

Table 1: Results showing chemical properties of RBO and ERBO.

Sample	**Acid value**	**Iodine value**
RBO	1	93
ERBO (Ring opened)	0.6	53

Acid value for ERBO is lesser than RBO. For an excellent lubricant, acid value must be low. The acid value indicates the quantity of base required to neutralize the given sample. This indicates the free fatty acid content within the oil. Acid number increases with the free fatty acid content.

Iodine value of ERBO is less compared to RBO. For an excellent lubricant iodine value should be less. Iodine value is inversely proportional to oxidation stability.

B. Evaluation of Tribological Properties

The tribological properties of RBO and ERBO are evaluated as per ASTM D-4172 which is explained earlier and the results are given in the Table 2.

Table 2: Tribological properties comparison of RBO and ERBO.

Sample	**Coefficient of friction**	**Wear scar diameter (mm)**
RBO	0.0738	0.589
ERBO	0.0542	0.568

From the Table 2, it is found that the ERBO has lower coefficient of friction and wear scar diameter compared to RBO. As the acid number increases, the coefficients of friction decreases. The oils having a high acid number contain more free fatty acids. The reduction in coefficient of friction is due the presence of free fatty acids. The vegetable oils mainly consist of triglycerides and are polar in nature. This triglyceride chain provides the high strength lubricant film and low frictional properties. The same triglycerides are the primary cause for less oxidative stability of vegetable oils. The properties of vegetable oil are mainly depending on the fatty acid content of the oil.

C. Evaluation of Thermal Properties

The thermal properties such as cloud point and pour point are evaluated for ERBO and RBO and the results are given in the Table 3. The cloud point and pour point of ERBO are lesser than that of RBO, which indicates that ERBO can also be used in low temperature applications. The thermal properties of ERBO are sufficient for developing an eco-friendly cutting fluid.

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So that formulated cutting fluid from ERBO can be kept in storage close to -14ºC.

Table 3: Thermal properties of RBO and ERBO

Thermal property	**RBO**	**ERBO**
Cloud point	-10.4ºC	-11.5 ºC
Pour point	-13.2 ºC	-14ºC

D. Evaluation of Machining Performance

The performance test is carried out in lathe and the cutting forces are measured using a lathe tool dynamometer by observing the forces on Z-axis. The forces are obtained in kgf from the dynamometer. The tests are carried out for servo cut, RBO based MWF and ERBO based MWF and the results obtained are given in the Table 4.

Table 4: Results obtained on conducting performance test.

Sl.no	**Speed (rpm)**	**Depth of cut (mm)**	**Cutting Forces (kgf)**		
			Servo cut	**RBO**	**ERBO**
1	140	0.1	21	24	20
		0.2	23	27	22
		0.3	24	29	24
2	224	0.1	20	25	21
		0.2	22	28	22
		0.3	26	31	25
3	315	0.1	23	28	22
		0.2	25	31	26
		0.3	27	34	28

By using these results, graphs between speed and cutting forces for each depth of cuts are shown in fig 10 - 12.

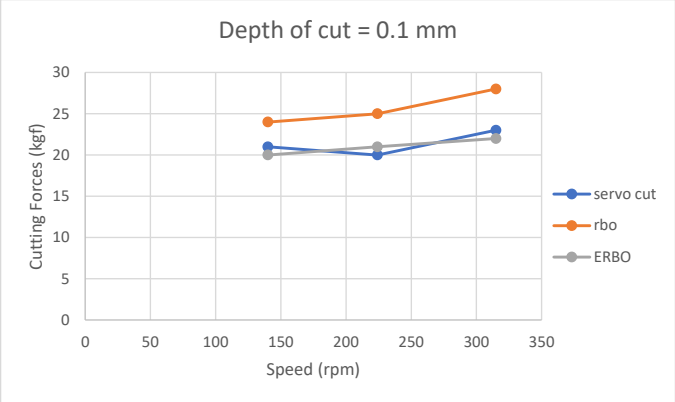

Figure 10: Speed vs cutting forces for depth of cut equals to 0.1mm

Figure 11: Speed vs cutting forces for depth of cut equals to 0.2mm

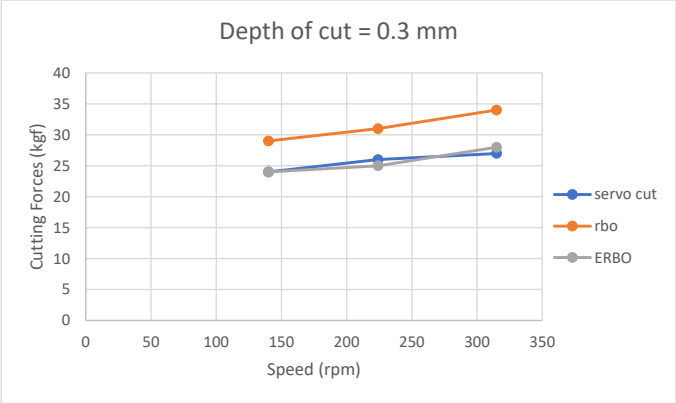

Figure 12: Speed vs cutting forces for depth of cut equals to 0.3mm

From fig 10-12, it is clear that machining performance of Servo cut s and ERBO are similar. In all the cases, ERBO performs much better than RBO. In general, at higher speeds, cutting forces will be less because of higher cutting temperature tends to soften the work piece material ahead of cutting tool made it easy to machine. In this work, lower speeds are only considered. ERBO has low coefficient of friction compared to RBO. So, it can provide better lubricity at the cutting zone. Because of this cutting force gets reduced. This increases tool life of the cutting tool as well as a good surface finish can also achieved.

IV. CONCLUSIONS

The development of an eco-friendly cutting fluid based on RBO is accomplish in this work. The mineral oil based cutting fluids are non-biodegradable and toxic which creates imbalance in ecological system. The literature survey shows that RBO has better oxidative stability compared to other vegetable oils due to the presence of gamma oryzanol which is a natural anti-oxidant. Organic emulsifier is selected for this work. Epoxidation is done to increase oxidation stability of RBO. Butanoic acid is used for ring opening of ERBO. Chemical and

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tribological properties of RBO and ERBO are compared. Emulsions of RBO and ERBO are prepared and performance test is conducted on a lathe machine and compared with servo cut S.

- Epoxidation of RBO improves its oxidative stability, cloud point and pour point.
- Tribological characteristics of ERBO is better than RBO
- Formulated ERBO MWF outperforms RBO MWF and gives performance almost same as that of servo cut.

The properties of vegetable based cutting fluid can be further improved by using additives and implementing other types of chemical modifications.

REFERENCES

1. Kline & Company, Inc. Competitive intelligence for the global lubricants industry, 2004–2014. Kline & Company, Inc., 2006.
2. Loredana P, Cosmina P, Geza B, Gabriela V, Remus N. "Basestock oils for lubricants from mixtures of corn oil and synthetic diesters". J Am Oil Chem Soc 2008;85:71–6.
3. Birova A, Pavloviova A, Cvengro J. "Lubricating oils based on chemically modified vegetable oils". J Synth Lubr 2002(18):291. 4. Abdalla HS, Patel S. "The performance and oxidation stability of sustainable metalworking fluid derived from vegetable extracts". Proc ImechE Part B: J Eng Manuf 2006;220.
5. Julieb Z, Andres F, Kimf H, Steven J. "Design of hard water stable emulsifier systems for petroleum and bio-based semi-synthetic metalworking fluids". Environ Sci Technol 2003;37:5278–88.
6. Abdalla HS, Baines W, McIntyre G, Slade C. "Development of novel sustainable neat-oil metal working fluids for stainless steel and titanium alloy machining". Part 1.Formulation development. J Adv Manuf Technol 2007;34:21–33.
7. Bennett EO. "Water based cutting fluids and human health". Tribol Int 1983;45–60.
8. Y.M. Shashidhara , S.R.Jayaram. "Vegetable oils as a potential cutting fluid—An evolution", Tribology International 2010:43; 1073–1081.
9. Fox NJ, Stachowiak GW. "Vegetable oil based lubricants–A review of oxidation". Tribol Int 2007;40:1035–46.
10. Snezana Sinadinovi Fiser, Milovan Jankovi, "Epoxidation of castor oil with peracetic acid formed in situ in the presence of an ion exchange resin" Chemical Engineering and Processing 62 106– 113, 2012.
11. S. Rani, M.L. Joy, K. Prabhakaran Nair, "Evaluation of physiochemical and tribological properties of rice bran oil – biodegradable and potential base stoke for industrial lubricants"Industrial Crops and Products 65 (2015) 328–333.
12. Marlena Musik, Eugeniusz Milchert, "Selective epoxidation of sesame oil with peracetic acid", Molecular Catalysis 433,170–174, 2017.

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Fabrication and Performance Analysis of a Grease formulation setup

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***Abstract*—This work deals with the fabrication and performance analysis of a grease formulation setup. In this work, vegetable oil based greases were formulated using the fabricated setup. From the literature survey, it was noted that various parameters influence the formulation of grease. Among the different parameters, temperature was identified to be a very important factor in the formulation process. Hence a grease formulation setup was fabricated and a temperature control system was designed to control the temperature of the grease formulation process. Performance analysis of the temperature control system was undertaken to identify the optimized power input and the Tribological properties of grease formulated with and without using the temperature control system were also evaluated as per ASTM standards. The Tribological properties of the grease formulated with temperature control system were slightly better compared to the grease formulated without temperature control system. It was also noted that the use of temperature control system prevented the over-heating of oil, thus it prevented smoke formation. The wear scar diameter improved by 6.56 micro meter and coefficient of friction by 0.0036 after implementing the temperature control system.**

Keywords— Grease; Vegetable oil; Grease formulation setup; Temperature control system; Tribological properties.

I. INTRODUCTION

Lubricants have always been an integral part of our lives. The function of an effective lubricant is to reduce friction, wear and corrosion of the material parts as well as to transmit heat from the surface. Based on their structure, lubricants can be classified into Solid lubricants, Semi liquid lubricants, and Liquid lubricants. Greases come under the category of Semi liquid lubricants.

A simple definition of grease can be given as a semi solid lubricating structure with base oil filled within a Soap matrix which forms a three dimensional network and holds the base oil trapped inside it. The major components of grease include the base oil, thickener which forms the soap matrix and additive for improving the properties of the grease. The commonly used base oils are mineral oils, synthetic oils and vegetable oils while the commonly used thickeners are soap based and non soap based. Since mineral resources are quickly being depleted, the use of mineral oils as base oils is being replaced by vegetable oils. The non biodegradability, high toxicity and scarcity of these mineral resources are the main reason why mineral oils are being replaced by vegetable oils as base oils [1].

Many attempts have been done to produce eco friendly greases with various base oils like karanja oil [2], castor oil [3], jatropha oil [4], etc. Some of these oils have good lubricating properties compared to mineral oil greases. Very few studies based on lubricating grease, focuses on rice bran oil as base oil. Since rice is being effectively cultivated in Indian subcontinent and it also possess high lubricating properties compared to other vegetable oils, Rice bran oil is selected as the base oil in this work.

The second most important component of grease is the thickener [5]. The most commonly used soap thickeners are lithium and calcium based soap thickeners. But since lithium being a scarcely available resource and since it has various bio compatibility concerns calcium based soaps are selected as thickener in this study. Calcium 12-hydroxy stearate is used as thickener in this study.

It was noted from the literature survey that various parameters such as soap concentration, temperature, saponification time, heating rate, etc affect the effective formulation of grease [6]. From these parameters, the heating temperature is considered as the most important parameter [7]. Therefore, the study focuses mainly to control this parameter and effectively formulate grease.

This work consists of formulating a setup for effective grease manufacturing and also designing a temperature control system to control the heating rate and maximum temperature during grease manufacturing. A setup was fabricated using readily available items such as double walled vessel and induction heater. This setup was used to formulate grease using rice bran oil as base oil and calcium 12-hydroxy stearate as thickener. A temperature control system was designed using PID controller to control the heating rate and maximum temperature during grease formulation. Performance analysis of the setup with temperature control system was conducted. The Tribological analysis of both the greases formulated with

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and without temperature control system was undertaken to determine the coefficient of friction and wear scar diameter.

II. Materials And Methods

A. Materials

Rice bran oil was purchased from Kalady Rice Millers Consortium Pvt, Ltd. Angamaly. Calcium hydroxide was purchased from Qualikems Fine Chem Pvt. Ltd, Vadodara. and 12-hydroxy stearic acid was supplied by Rajaji Chemicals, Chennai.

B. Fabrication and Performance Analysis of Grease Setup with Temperature Control

A double walled vessel was used for making grease. Silicon oil present in between the walled layers act as the heat conducting medium. Induction heater was used to heat the mixture. Initially saponification process was done using a magnetic stirrer with hot plate, then the mixture is transferred to the experiment setup shown in Fig 1.

Fig. 1 Grease Formulation Setup without Temperature controller

The temperature control circuit consists of a digital temperature control, a solid state relay module and a Resistance Temperature Detector (RTD) sensor for temperature measurement. The electrical circuit used for temperature control system is shown in Fig 3. The temperature control system created using the above mentioned materials is shown in Fig.4 and this system is connected to the induction heater for controlling the temperature of the grease. The complete grease formulation setup with the temperature control system is shown in Fig 2.

Fig. 2 Grease Formulation Setup with Temperature Controller.

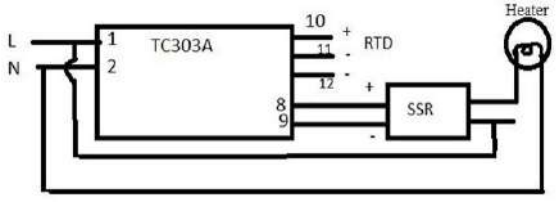

Fig. 3 Circuit of Temperature Control System

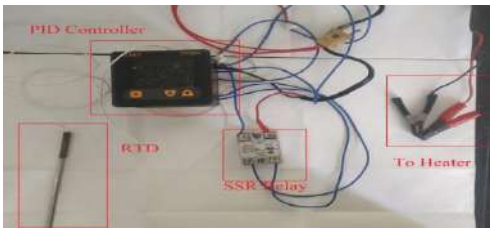

Fig. 4 Temperature Control System

For the performance analysis of the temperature control system, rice bran oil was heated in the grease setup under various input power conditions of the induction heater. For each power input various pre set temperature points were set in the temperature controller and then the oil was heated. The time taken to reach a particular pre set temperature was noted as ramp time. It was also observed that excess heating and an increase in temperature occurs even after reaching the pre set temperature and the maximum reached temperature was also noted for each power input. In this way the performance analysis of the temperature controller was undertaken and optimum input power was selected.

C. Grease Formulation

For grease formulation, calcium hydroxide and 12- hydroxy stearic acid was mixed in the ratio of 1:1 and then this mixture was added to the required amount of rice bran oil, heated and mixed together using magnetic stirrer with hot plate. This process is known as saponification. The saponified oil was then transferred to the double walled vessel and heated using an induction heater to a higher temperature. After heating, it was held at the maximum temperature for about 10 minutes and then cooled. On cooling, the mixture solidifies to form grease. The heating was undertaken with and without using the temperature control system. A sample of grease formulated using this setup is shown in Fig.5.

Fig. 5 Grease Formulated using the fabricated Setup

D. Four Ball Tester

The coefficient of friction and wear characteristics of the greases have been evaluated as per ASTM D- 2266 by using a four ball tribometer (DUCOM TR-30L-KRL-PNU-IAS) as shown in Fig.6. The four ball tester is used to test tribological characteristics of lubricants. There are four balls of diameter 12.7 mm made of chromium steel with hardness value of 64 HRC in which 3 balls are kept in a ball pot and test sample is applied to it. The fourth ball is fixed on a collet which is attached to a rotating spindle. Load is given by pneumatic source and is sensed by a load cell.

As per ASTM D-2266 the spindle speed is 1200 rpm and load applied is 392N. The test is carried out for duration of 3600

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seconds at a temperature of 75℃. After the test is conducted, wear scar diameter will be measured using an optical microscope.

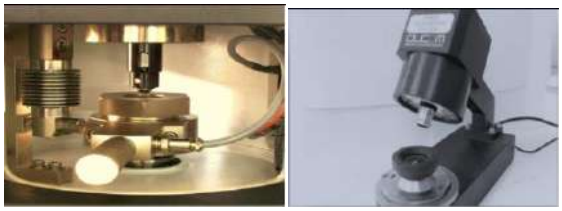

Fig. 6 Four Ball Tester and Optical Microscope

III. RESULTS AND DISCUSSIONS

A. Performance Analysis

The performance analysis of the temperature control system was conducted for different power input such as 100W, 300W, 600W and 1000W. No previous works were observed related to performance analysis of grease formulation setup during literature survey. After discussion with various tribologists across India, It was realised that the major drawback, they faced during their setup formulation was over-heating of the oil during grease formulation. To prevent this a temperature control system was designed and implemented to control the grease formulation temperature. In this work, 300 gm of Rice bran oil was heated in the double layered vessel during the performance analysis of grease formulation setup without temperature control. The temperature (Temp) was continuously monitored with the help of temperature sensor. The range of temperature for performance analysis was taken from 60-180℃ because saponification process of soap usually takes place at the range of 80-90℃ and maximum temperature for grease formulation is 150-180℃. Therefore the performance analysis was undertaken from 60-180℃.

Temp. Range (℃)	Preset Temp (℃)	Ramp Time (Min)	Maximum Temp. (℃)
60-70	70	02:25:03	74
70-80	80	02:01:34	82
80-90	90	01:54:44	93
90-100	100	02:16:76	102
100-110	110	02:22:76	113
110-120	120	02:22:09	122
120-130	130	02:34:83	131
130-140	140	02:49:33	141
140-150	150	04:56:45	152
150-160	160	05:11:45	162
160-170	170	06:50:17	172
170-180	180	14:42:29	182

Table 1: Performance Analysis of setup at 100W

From Table 1, it was noted that if the preset temperature is above 120^0C, the difference in preset temperature and maximum temperature attained was only $\pm2^0$C.

Temp. Range (℃)	Preset Temp. (℃)	Ramp Time (Min)	Maximum Temp. (℃)
60-70	70	00:39:95	73
70-80	80	00:40:33	83
80-90	90	00:40:21	93
90-100	100	00:40:78	103
100-110	110	00:41:20	113
110-120	120	00:44:46	124
120-130	130	00:49:62	134
130-140	140	00:47:57	144
140-150	150	00:50:51	154
150-160	160	00:48:06	164
160-170	170	00:46:25	174
170-180	180	00:49:41	184

Table 2: Performance Analysis of setup at 300W

From Table 2, it was noted that if the difference in preset temperature and maximum temperature attained was only $\pm4^0$C and the ramp time was also considerably low.

Temp Range (℃)	Preset Temp (℃)	Ramp Time (Min)	Maximum Temp. (℃)
60-70	70	00:28:47	79
70-80	80	00:30:91	89
80-90	90	00:34:14	100
90-100	100	00:34:33	109
100-110	110	00:37:03	117
110-120	120	00:39:83	128
120-130	130	00:38:61	138
130-140	140	00:39:88	147
140-150	150	00:39:54	157
150-160	160	00:38:67	167
160-170	170	00:38:60	178
170-180	180	00:42:26	185

Table 3: Performance Analysis of setup at 600W

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Temp Range (℃)	Preset Temp (℃)	Ramp Time (Min)	Maximum Temp. (℃)
60-70	70	00:29:68	80
70-80	80	00:30:66	88
80-90	90	00:37:30	96
90-100	100	00:36:95	106
100-110	110	00:34:52	113
110-120	120	00:36:02	125
120-130	130	00:36:94	135
130-140	140	00:37:01	145
140-150	150	00:36:32	155
150-160	160	00:41:47	164
160-170	170	00:42:89	173
170-180	180	00:44:90	184

Table 4: Performance Analysis of setup at 1000W

From Table 3 and Table 4, it shows that as power input increases, the ramp time decreases but the maximum temperature attained was more deviated than the preset value.

Based on the performance analysis it was found out that 300W power shows the most optimized result. Hence initially 300W input power will be selected for the grease formulation. When the solid state relay cuts the power supply to induction heater then the input power will be reduced to 100W. So that the maximum temperature can be maintained properly.

B. Tribogical Test

Two different greases were formulated with and without using temperature control system. Both these greases were subjected to four ball test to determine their Tribological properties such as coefficient of friction and wear scar diameter. The result for grease formulated without temperature controller is shown in Table 5.

Coefficient of Friction	Wear Scar Diameter(micro meter)			
	Ball 1	Ball 2	Ball 3	Average WSD
0.0893	571	564	565	566.66
0.0733	567	564	543	558
0.0706	582	602	589	591

Table 5: Grease formulated without temperature control

From Table 5, it was noted that the average Coefficient of friction was 0.073 and the average Wear Scar Diameter was 571.89 micro meter.

Coefficient of Friction	Wear Scar Diameter(micro meter)			
	Ball 1	Ball 2	Ball 3	Average WSD
0.057	580	563	578	573.66
0.0786	560	543	510	537.66
0.0727	576	589	589	584.66

Table 6: Grease formulated with temperature control

The Table 6 shows the result of grease formulated with temperature controller. It was noted that the average 1Coefficient of Friction was 0.0694 and the average Wear Scar Diameter was 565.33 micro meter

The major reason for improvement of tribological properties when temperature control system was used is due to better control of temperature range. During heating without the temperature control system, the temperature of the grease cannot be easily maintained at a constant temperature and overheating occurs but effective control is observed when temperature control system is used. This is the reason for improvement of properties.

IV. CONCLUSION

- The grease formulating setup was fabricated successfully with a temperature control system.
- The Performance Analysis of the temperature control system for grease preparation system was conducted and the initial power input to induction heater was selected as 300W and once the solid state relay cuts the power supply then the power input will be reduced to 100W.
- The greases formulated using the setup with and without the temperature control system were tested to determine its tribological properties and it was observed that grease formulated using temperature control system showed better properties.

REFERENCES

1. Tirth M. Panchal et al, A methodological review on bio-lubricants from vegetable oil based resources, Renewable and Sustainable Energy Reviews 70 (2017) 65–70
2. Tirth Panchal et al, Bio based grease A value added product from renewable resources, Industrial Crops and Products,63 (2014) 48-52
3. R. Sanchez et al, Rheological and mechanical properties of oleogels based on castor oil and cellulosic derivatives potentially applicable as bio-lubricating greases:Influence of cellulosic derivatives concentration ratio, Journal of Industrial and Engineering Chemistry 17 (2011) 705-711
4. Ponnekanti Nagendramma et al, Eco-Friendly Multipurpose Lubricating Greases from Vegetable Residual Oils, Lubricants,3 (2015) 628-636

ISBN 978-93-89105-41-4

5. Craig J. Donahue et al, Lubricating Grease: A Chemical Primer, Journal of Chemical Education, 83 (2006)
6. David Morgan et al, Critical Variables in Lithium Complex Grease Manufacturing, Conference paper, NLGI Spokesman,77 (2013) 1-12
7. Anoop Kumar et al, How Friendly Are Bio-Based Greases with Other Greases? NLGI Spokesman, 77 (2013) 34-47

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Feasibility study on the Formulation of rice bran oil based Bio-grease

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***Abstract*— Friction and wear loss is inevitable in machine parts in motion. In order to control them the industry uses different type of lubricants. Grease is a semi solid type of lubricant which is widely used for this purpose. Majority of the grease manufactured are using mineral oil as base oil and lithium soap as thickener, which are not only non-biodegradable but also scarce. They create many health issues also. Biodegradable grease is an eco-friendly and healthy alternative product. Grease formulated using vegetable oils with required lubricant properties may be able to bring revolutionary changes.**

This work is an attempt to formulate an eco-friendly vegetable oil based greases with soap based thickener and optimize their process parameters such as thickener concentration, saponification time, maximum temperature, etc for consistency of grease. In this work, Rice bran oil is used as base oil due to its superior properties like high biodegradability, low toxicity, high flash and fire point. Calcium 12-hydroxy stearate is used in this work as thickener due to its water resistance property. The study may lead to the best process for manufacturing the particular greases. The Cone penetration test was carried out for characterization of the optimum grease as per NLGI grading. The tribological properties of formulated grease was evaluated using a four ball tester as per ASTM standards. The newly formed greases may be a good substitute for conventional type of grease

Keywords— Bio grease; Rice bran oil; Calcium soap; Optimization; Tribological properties; NLGI grading.

I. INTRODUCTION

Any machine parts in contact experiences friction and wear loss, which is the main causes of mechanical failure. Even though they cannot be avoided completely, they can be reduced significantly by the use of lubricants. Lubricants are available in liquid, solid, and semi solid form. Grease, waxes, petroleum jelly etc. are different types of semi solid lubricants. Grease can be considered as a colloidal dispersion which contains a thickener in the form of a three dimensional network and the lubricating oil will be trapped inside this network [1, 2].Unlike the oils, grease possess the ability to stick to the contacting surface. So it has been using widely for semi-permanent lubrication. They reduce both friction, wear and also possess good load carrying capacity and reduces the corrosion by sealing the work surfaces.

Grease contains 75-95 wt. % base oil and 5-25 wt. % thickener mainly. The oils used can be classified as mineral oil, synthetic, and bio-compatible oils. Oil imparts the major share of lubrication effect. Corrosive and oxidative stability, flash and fire points are the major lubricant properties[3]. Thickeners can be soap based, inorganic and organic materials. They are responsible for the formation of the colloidal structure, rheological properties, and thermal stability. The thickener also helps in imparting proper lubrication[2].

Around 90% of the grease manufactured worldwide is based on mineral oil, which is non-biodegradable and only about 1% of the grease produced is biodegradable[4]. This is harmful to the nature, especially to aquatic life[5]. Since mineral oil reserve is limited, we have to find an eco-friendly

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alternative which we can rely on. Many attempts have been done in this field and some of the eco-friendly lubricant oils have been developed based on Karanja oil, Jatropha oil, sunflower oil, rice bran oil[3, 4, 6-8] etc., and found to be an effective alternative to commercial lubricants. Many attempts have been made to formulate grease from vegetable oil[9-14]. Usage of locally available oils is the key to low cost lubricant production. Since rice is widely cultivated around Indian subcontinent, rice bran oil is a potential base stock for lubricant in India. It has superior lubricants properties over other vegetable oils[7]. So rice bran oil is used as the base oil for grease in this work.

The second most important constituent of a grease is thickener. The most commonly used thickener is lithium and calcium soap based. The availability and bio-compatibility of lithium is a big concern and the focus is on calcium based thickeners. The simplest of them is calcium 12-hydroxy stearate. Since it is bio compatible and widely available, it is a good thickener for the modern world needs.

It was noted from the literature survey, that so many factors have effects on the grease formulation. Some of them are thickener percentage, maximum temperature, ratio of $Ca(OH)_2$ and 12-hydroxy stearate, saponification time, heating rate, holding time and ramp time during formulation, and shelf time before testing. Most influencing four parameters among them is selected for this study.

This work focused on the formulating of a bio grease based on rice bran oil as base oil and calcium 12-hydroxy stearate as a thickener, and process optimization using the parameters such as thickener percentage, maximum temperature, ratio of $Ca(OH)_2$ and 12-hydroxy stearate, saponification time to find the best combination of these parameters, Taguchi optimization technique[8] is employed with L16 array. Optimization is carried out based on consistency of the grease using cone penetration. The tribological properties of the formulated grease were evaluated as per ASTM standards.

II. MATERIALS AND METHODS

A. Materials Used

Rice bran oil was purchased by Kalady Rice Millers Consortium Pvt, Ltd. Angamaly. Calcium hydroxide was purchased from Qualikems Fine Chem Pvt. Ltd, Vadodara. and 12-hydroxy stearic acid was supplied by Rajaji Chemicals, Chennai.

Figure 1: Grease formulation setup

B. Grease formulation set up

The setup consists of a double walled vessel filled with silica oil, an induction plate with PID temperature controller and a mechanical stirrer as shown in figure 1. The double walled vessel helps in distributing heat more uniformly and thereby avoiding overheating. Stirrer helps in uniform heating and breaking down the agglomeration if any. PID temperature controller was able to provide an accuracy of $\pm 2^{o}$ C and also reduced the smoke formation during grease formulation. The grease formulation setup with temperature control system was fabricated and validated.

C. Procedure for grease formulation

The grease is manufactured in two steps. First step focuses on saponification and second step on grease formation. Calcium hydroxide is mixed with 10 g of water and desired amount of 12-hydroxy stearic acid (12 HSA)and rice bran oil was added to it and mixed well. Then the mixture is heated at 90^{o}C and stirred for a period of time as specified in the table 1.

Then the mixture is heated to the specified maximum temperature and this temperature is maintained for 10 minute and finally the mixture is left undisturbed for cooling and solidification. The grease obtained is milled to the final form. The ratio of Calcium hydroxide to 12-hydroxy stearic acid, and the maximum temperature and weight percentage of thickener are given in the table 1.

D. Consistency measurement

Grease is available in a wide variety of fluidity. It varies from consistency of tomato sauce to brick. Majority of multipurpose and commercially available grease falls under the consistency of NLGI GRADE 2 or 3. The Consistency of a grease is measured by cone penetrometer (ASTM D 217) shown in figure 2. It measures depth of penetration of a standard cone in the sample material in 5 seconds. It is measured in deci milli meters per 5 seconds. The consistency result can be used to identify the application of certain grease.

Figure 2: Cone penetration apparatus

E. Optimization

There are many factors influencing the grease formation. Most important among them are thickener percentage,

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maximum temperature, ratio of $Ca(OH)_2$ and 12-Hydroxy stearic acid, saponification time, heating rate, and shelf time before testing. By varying these parameters consistency of the grease can be varied. So it is important to know how these parameters effects the grease formation.

Taguchi L16 parameter optimization technique was implemented to study the effect of these thickeners and predicting the best combination of them for multipurpose grease. In this work four important parameters have been selected. They are thickener percentage, maximum temperature, ratio of $Ca(OH)_2$ to 12-Hydroxy stearic acid and saponification time. Table 1 shows the factors and levels selected for this work. The taguchi optimization technique reduced the complexity of experiments and it has also helped in analysing the effect of each parameter. The most influential to least influential parameters can also be found out with the help of analysis of variance.

Table 1: Factors and Levels selected for this work

Factors	Levels			
Saponification time in hr	1	1.5	2	2.5
Wt. % of Thickener	8	12	16	20
$Ca(OH)_2$:12 HSA	0.5	0.57	0.67	0.8
Max Temp (^{0}C)	150	160	170	180

F. Tribological properties:

Greases are commonly used for the lubrication of bearings. It is essential to know the lubricating effect of the formulated greases. Thus the tribological properties of greases such as coefficient of friction, wear scar diameter generated were evaluated using a four ball tester as per ASTM D 2266. The four ball tester consists of three balls locked in a ball port and another rotating ball pressed against them as shown in figure 3. The grease to be tested will be filled in the ball port.

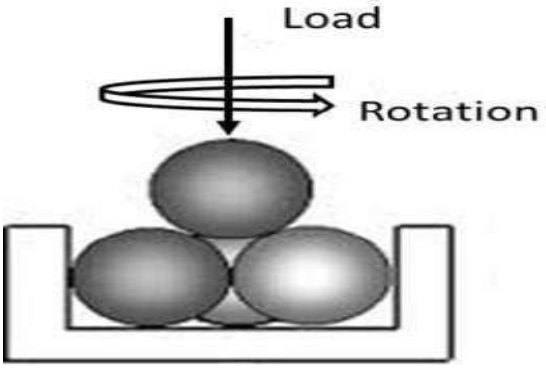

Figure 3: Four ball tester [15]

III. RESULTS AND DISCUSSION

A. Consistency measurement

The 16 different combination of greases have been formulated and tested for consistency using cone penetration equipment and the results have been tabulated in table 2. A sample of the formulated grease is shown in figure 4.

Figure 4: Sample of grease formulated (sample no 9)

Table 2: Taguchi L16 Orthogonal array with response

Sl. no	Saponification time in hr	wt. % of thickener	$Ca(OH)_2$:12 HSA	Max temp (^{o} C)	Penetration (dmm)
1	1	8	0.8	150	205
2	1	12	0.67	160	109
3	1	16	0.57	170	67
4	1	20	0.5	180	36
5	1.5	8	0.67	170	192
6	1.5	12	0.8	180	96
7	1.5	16	0.5	150	75
8	1.5	20	0.57	160	34
9	2	8	0.57	180	212
10	2	12	0.5	170	76
11	2	16	0.8	160	49
12	2	20	0.67	150	63
13	2.5	8	0.5	160	227
14	2.5	12	0.57	150	230
15	2.5	16	0.67	180	60
16	2.5	20	0.8	170	33

From the results, seven of the samples has cone penetration values in the range of 90-265, which comes under NLGI

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grading. The remaining samples have penetration values below 90. So the seven combination which comes under NLGI grading can be considered as grease.

B. Optimization

Since the grease obtained is harder than the NLGI GRADE 2, which is the general purpose grease. The final optimization was carried out for higher value of cone penetration. So analyzing the mean signal to noise ratio of cone penetration value by applying larger the better concept, the trend of the behavior of each parameters and their influence in altering the properties was observed and it was noted that the maximum value of the signal to noise ratio in each parameters gives a softer grease.

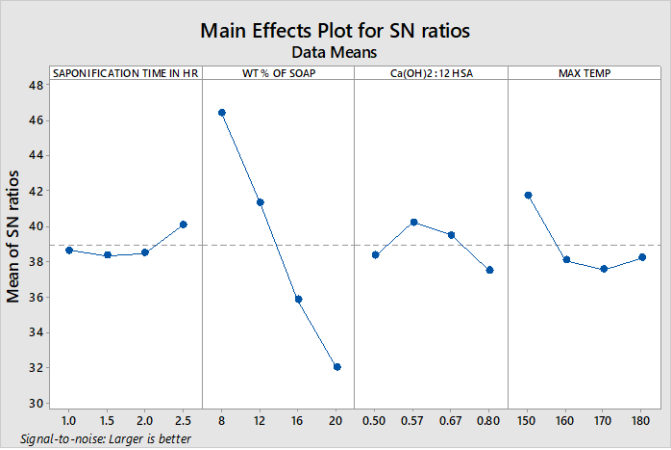

Figure 5: Mean effects plot for s-n ratios vs levels of each parameters

In order to formulate a softer grease, the saponification time should be increased to 2.5 hr, weight percentage of thickener should be decreased to 8%, ratio of $Ca(OH)_2$ and 12-Hydroxy stearic acid should be kept as 1: 1.75 and the maximum temperature should be lowered to 150^{O} C as shown in figure 5. The table 3 shows the influence of parameters in grease formulation.

Table 3: Response table based on Signal to Noise ratio

Level	saponification time in hr	Wt. % of thickener	$Ca(OH)_2$: 12 HSA	max temp (^{0}C)
1	38.66	46.39	38.34	41.74
2	38.36	41.31	40.23	38.08
3	38.48	35.85	39.49	37.54
4	40.07	32.03	37.51	38.22
Delta	1.71	14.36	2.71	4.2
Rank	4	1	3	2

The most influential parameter is weight percentage of thickener and least important parameter is saponification time. But one should note that this trend may not be repeating in any other range of these parameters. The best combination of these parameters for softer grease is as mentioned above.

C. Tribological properties:

The coefficient of friction and wear scar of the seven NLGI graded greases were evaluated and the results are shown in tZable 4. The lowest coefficient of friction is obtained for the 9th sample. The lowest wear scar is obtained for 14th sample but it is only marginally lower than that of the 9th sample. The 9th sample can be considered as the best sample based on the results of tribological properties.

Table 4: Tribological properties evaluated

Sl. No	Coefficient of friction	Average wear scar diameter (µm)
1	0.0444	677
2	0.0356	579
5	0.0309	604
6	0.0335	542
9	0.0264	517
13	0.0628	628
14	0.0411	512

IV. CONCLUSION

This study was conducted with the help of taguchi orthogonal array method. The results obtained only considered certain distinct points and most of the results were interpolated. Hence it may not depict the exact scenario of the experiment. However, they are able to provide good predictions about the possible results, as they reduce the amount of experiments considerably. From the above mentioned experiments the following conclusions are derived:

- Bio greases of different NLGI gradings were formulated and combination for formulating softer bio grease was also noted.
- The formulated grease 13th and 14th samples can be categorised as multipurpose grease NLGI grade 3.
- Thickener percentage is the most influential parameter among the four parameters considered and saponification time was the least influential parameter for the formation of grease.
- Tribological results indicates that the selected parameters have some correlations.

REFERENCES

1. Delgado, M.A., et al., *Relationship Among Microstructure, Rheology and Processing of a Lithium Lubricating Grease.* Chemical Engineering Research and Design, 2005. **83**(9): p. 1085-1092.

ISBN 978-93-89105-41-4

2. Fan, X., et al., *Probing the effect of thickener on tribological properties of lubricating greases.* Tribology International, 2018. **118**: p. 128-139.
3. Zainal, N.A., et al., *A review on the chemistry, production, and technological potential of bio-based lubricants.* Renewable and Sustainable Energy Reviews, 2018. **82**: p. 80-102.
4. Panchal, T.M., et al., *A methodological review on bio-lubricants from vegetable oil based resources.* Renewable and Sustainable Energy Reviews, 2017. **70**: p. 65-70.
5. Tamada, I.S., et al., *Biodegradation and toxicological evaluation of lubricant oils %J Brazilian Archives of Biology and Technology.* 2012. **55**: p. 951-956.
6. Nagendramma, P. and S. Kaul, *Development of ecofriendly/biodegradable lubricants: An overview*. Renewable and Sustainable Energy Reviews, 2012. **16**(1): p. 764-774.
7. Rani, S., M.L. Joy, and K.P. Nair, *Evaluation of physiochemical and tribological properties of rice bran oil – biodegradable and potential base stoke for industrial lubricants.* Industrial Crops and Products, 2015. **65**: p. 328-333.
8. Suhane, A., et al., *Optimization ofWear Performance of Castor Oil based Lubricant using Taguchi Technique.* Materials Today: Proceedings, 2017. **4**(2): p. 2095-2104.
9. Panchal, T., et al., *Bio based grease A value added product from renewable resources.* Industrial Crops and Products, 2015. **63**: p. 48-52.
10. Sánchez, R., et al., *Development of new green lubricating grease formulations based on cellulosic derivatives and castor oil.* Green Chemistry, 2009. **11**(5).
11. Nagendramma, P. and P. Kumar, *Eco-Friendly Multipurpose Lubricating Greases from Vegetable Residual Oils.* Lubricants, 2015. **3**(4): p. 628-636.
12. García-Zapateiro, L.A., C. Valencia, and J.M. Franco, *Formulation of lubricating greases from renewable basestocks and thickener agents: A rheological approach.* Industrial Crops and Products, 2014. **54**: p. 115-121.
13. Florea, O., et al., *The influence of lubricating fluid type on the properties of biodegradable greases.* 2003. **19**(4): p. 303-313.
14. Sánchez, R., et al., *Rheological and mechanical properties of oleogels based on castor oil and cellulosic derivatives potentially applicable as bio-lubricating greases: Influence of cellulosic derivatives concentration ratio.* Journal of Industrial and Engineering Chemistry, 2011. **17**(4): p. 705-711.
15. tribonet. *Four Ball Tester*. [cited 2020 Jan 25]; Available from: https://www.tribonet.org/wp-content/uploads/2019/03/four-ball-1-275x300.jpg.

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VIBRATION ANALYSIS OF A RECTANGULAR PLATE IMMERSED IN A FLOWING FLUID

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***Abstract*—Vibration and acoustic analysis of flexible structures such as beams and plates, immersed in fluids and subjected to external excitation is of great significance in various engineering applications, especially in submarines. Sensors which are mounted externally to the hull of the submarine to capture various signals usually get affected by the structure borne vibrations. Numerical analysis of free vibration responses of rectangular plates, immersed in flowing fluids, using the software ANSYS is performed in this paper. Effects of viscosity and velocity of the fluid on the free vibration responses of the plate are studied. Though experimental studies have been done by several researchers, a numerical investigation of the vibration characteristics of rectangular plates in flowing fluids has not been found reported.**

***Index Terms*—Flow induced vibration, submarine, vibration analysis, fluid-loaded plate**

I. INTRODUCTION

Fluid structure interaction(FSI) is the interaction that occurs between rigid bodies placed in a fluid flow. The fluid flow causes deformation on the immersed body due to the pressure exerted by the fluid on it,which in turn modifies the fluid flow. FSI is encountered in many cases and has to be seriously dealt with. Some areas in which FSI becomes important is in the designing of aircraft wings, pipes conveying fluid, components for turbo machinery,bridges,tall buildings and so on [1]. Thus, the area covered under FSI ranges from the design of high rise buildings to the design for atomic force microscope components [2].

The effect of flowing fluid on the immersed body could be in the form of vibrations,deflections and aerodynamic noise generation.These effects are highly undesirable mainly in aerospace industry for appropriate functioning of the various components.As the flow velocity is high,there may be large amplitude vibrations and fluttering which may result in the failure of wings [3]. Even though these vibrations are of smaller amplitudes for low velocities they may get amplified for higher flow velocities. Inspite of these drawbacks they could also be used to harvest small amount of energy from these vibration by bonding suitable piezoelectric materials to the vibrating body [4-9]. Rigorous research works are still continued in this area for developing methods and identifying the optimum conditions for potential and efficient energy harvesting.

Fluid structure interaction becomes important in the case of submarines. Usually sensors are mounted on plates. At higher velocities significant flow induced vibrations may happen which affects the proper functioning of the sensors. As a result of which it may not be able to capture signals effectively. Thus proper selection of the boundary conditions is very important for reducing the vibration of plates that get transmitted to the submarines. The levels of vibration may be amplified if the inherent vibrations in the submarines and flow induced vibrations become in phase. Flow induced vibrations have been experimented rigorously in the past. One of the most common methods of experimentation is by placing a bluff body upstream of a flexible plate or a structure [10-11]. The vortices generated move downstream and induce vibration into the plate that is placed downstream (vortex induced vibrations) [12-15]. The flow velocity, plate stiffness and the gap between the bluff body and the downstream plates were all the parameters taken under the studies.

Experimental works were also carried out to find the noise or the acoustic wave field generated due to the fluid structure interaction [16]. Experiments were carried out to find the vibration and acoustic behavior of a plate placed in a wind tunnel and excited by means of an external shaker [17]. They found that external and flow induced excitation's have significant impact on plate vibrations. Reference [18] depicts how the author calculated the sound generated from a flexible plat kept behind a forward backward step. Similar study was carried out to analyse the vibration characteristics of a flexible plate,placed in a free flow and excited harmonically. The forcing amplitude, frequency,plate stiffness and Reynolds number were taken as the parameters [19].

From literature we can see that numerous experiments have been done on fluid structure interaction mainly in the area of flow induced vibrations. Numerical analyses using commercial software are found to be very rare. Thus,a numerical analysis using ANSYS software is done in the present work for the first time. The flow velocity and the fluid viscosity are the two parameters considered for this analysis. The effects of these parameters on the plate vibrations are studied. Simulations provide us a means to study the vibration characteristics as a function of various parameters rather than the experimentation,which incurs a lot of cost,time and effort.

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II. DESCRIPTION OF MODEL

The model for the present simulation consists of a cantilevered flat plate made of aluminium,having density 2770 kg/m^3, Young's Modulus 71 GPa and Poisson's ratio of 0.33. The plate is having a dimension of 100 mm x 50 mm x 2 mm and is aligned in the direction of flow. The plate is fixed in an enclosure of dimension of 1000 mm x 500 mm x 100 mm in x,y and z axes respectively. One of its six faces is fixed, whereas the remaining five faces are exposed to fluid flow. The face having the dimension 50 mm x 2 mm in the upstream direction is fixed. The resulting vibrations are measured at the edge of the plate downstream of the flow.

In the present model the fluid domain and the structural domain are modeled independently and are coupled using the system coupling. The fluid domain is modeled using FLUENT while for structural analysis TRANSIENT STRUCTURAL is used. For the flow computation domain the boundary conditions chosen are velocity inlet for inlet, pressure outlet for the outlet and boundary walls for the four sided walls of the enclosure. Flow conditions chosen are the laminar and steady flow. Analysis is carried out for 20 sec with a coupling time step of 0.05 sec. The fluid solver variable is pressure/force, while mechanical solver variable is displacement. Fig. 1 shows the flow computation domain details.

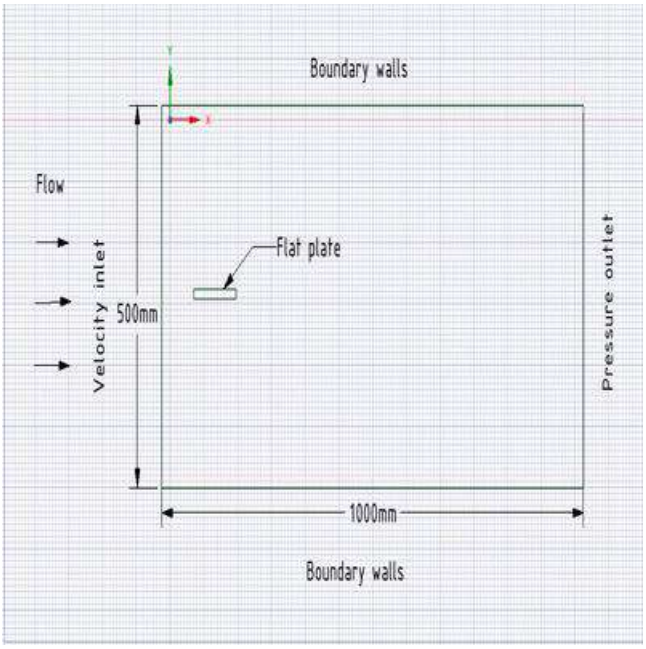

Fig. 1. Flow computation domain and boundary conditions

III. VALIDATION OF THE PROPOSED MODEL

The inlet velocity is varied in the range of10m/s to 150m/s. Corresponding to each velocity the tip displacement of the plate is noted. A peak in the displacement–velocity plot is found at a velocity of 70m/s and a second peak at a velocity of 120m/s. These peaks may correspond to the 1stand 2nd vibration modes of the plate. The variation of plate displacement as a function of flow velocity is shown in the Fig. 2. The critical velocity ($\bar{U}$),a non-dimensional term at which resonance occurs for a cantilever plate [20] of breadth b, depth h, density is analytically given by(1)

$$\bar{U} = b \times \sqrt{\frac{\rho \times h}{k}} \times U \tag{1}$$

where U represents the flow velocity and k represents the bending stiffness. The non dimensional critical velocity obtained from the present model and the analytical critical velocity as given by (1) for mode 1 are 1.14 and 1.49 while for mode 2 it is 2.2 and 3.73 respectively. The difference in the values obtained may be due to the errors during simulation. Errors in a coupled system may have errors accumulated from the transient structure module and fluent module. However, with some reasonable accuracy the present model can predict the critical velocity for resonance.

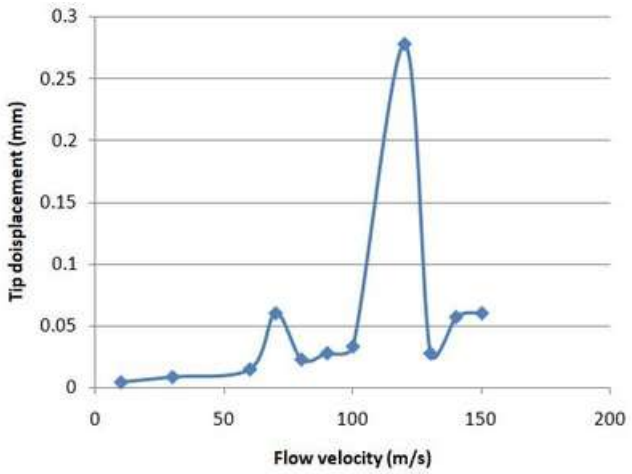

Fig. 2. Displacement as a function of flow velocity

IV. RESULTS

A. Influence of fluid velocity

It could be observed that as the flow velocity is increased from 10m/s to 150m/s there is a corresponding increase in the tip displacement. Tip displacements as a function of time, at flow velocity of 10 m/s and 30 m/s, are shown in Figs. 3 and 4. This maybe accounted due to the increased flow induced force or pressure on the plate surface. It is also observed that from Fig. 5, two resonant peaks are observed at velocities 70 m/s and 120m/s which correspond to the 1st and 2nd vibration modes of the flat plate. The plate displacements at the time of resonance are shown in Fig. 5

B. Influence of fluid viscosity

Simulations are carried out with two arbitrarily chosen fluids of different viscosities i.e., water and glycerin at a flow velocity of 70m/s.The viscocity values are 0.89 and 950cP for water and glycerine respectively. The results shows that as

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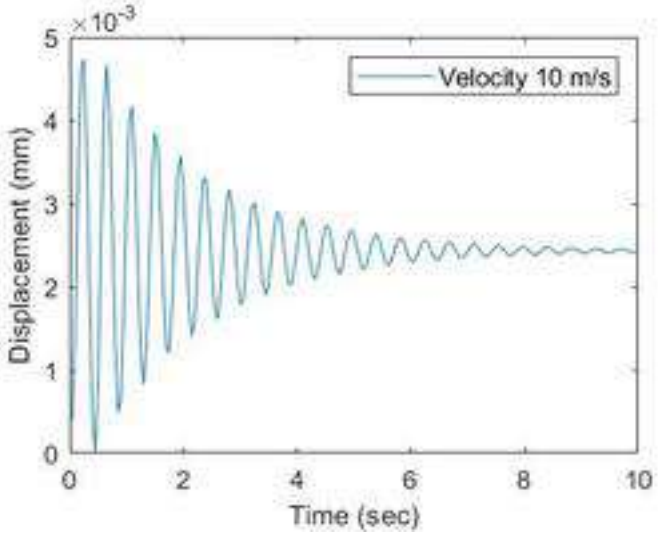

Fig. 3. Tip displacement at flow velocity of 10 m/s

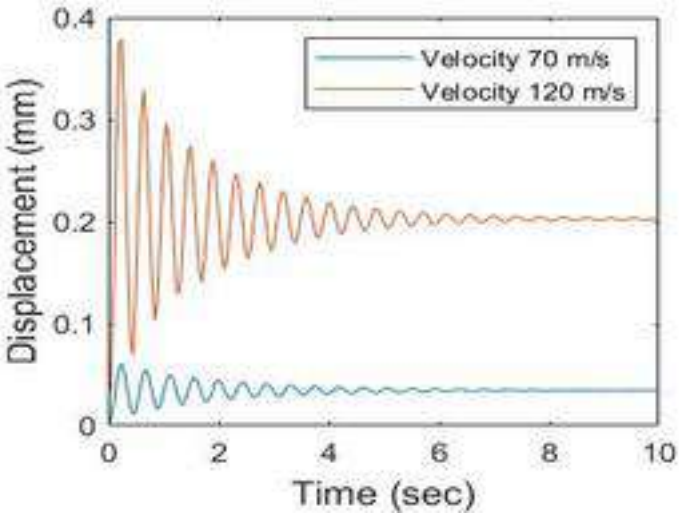

Fig. 5. Tip displacements at the time of resonance

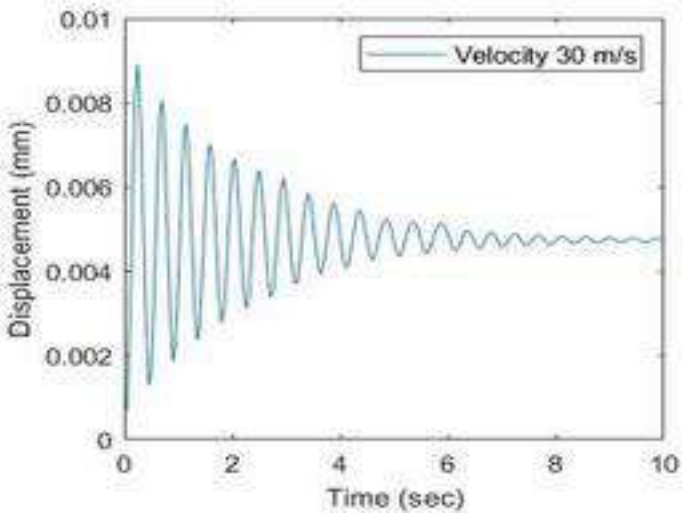

Fig. 4. Tip displacement at flow velocity of 30 m/s

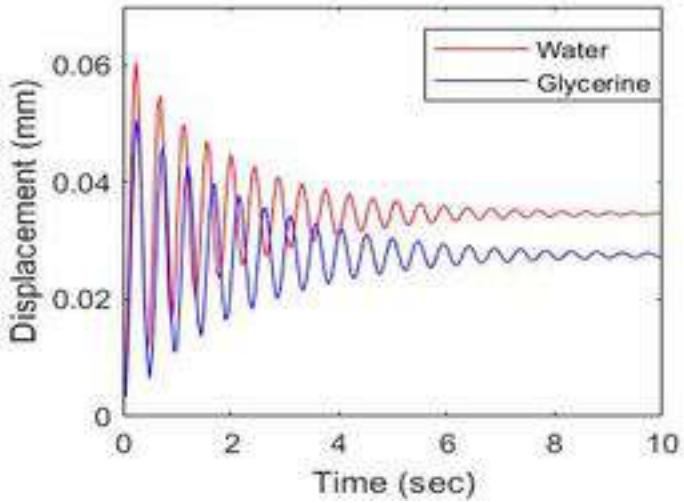

Fig. 6. Displacement as a function of viscosity

the viscosity of fluid is increased the tip displacement gets reduced.The reduction in the amplitude is due to the fluid induced damping effect. As the density of water (1g/cm^3) and glycerine (1.26g/cm^3) are almost the same, the added mass effect is negligible hence the frequency of vibration in both fluids appears to be the same as shown in Fig. 6. The variation in the tip displacement with viscosity is shown in Fig. 6

V. CONCLUSIONS

In this work, vibration analysis of a flat plate in fluid flow is numerically investigated using commercial software ANSYS, whereas most of the reported works in this area are purely experimental. By simulations we can study the vibration characteristics as a function of various parameters with ease rather than experimentation which requires much effort, time and cost. Thus, in this present work vibration characteristics of a cantilevered aluminium plate in steady, laminar and uniform flow is analysed. Velocity and viscosity of fluids taken as the parameters under consideration and are studied. Fig. 6. Displacement as a function of viscosity. As the flow velocity is varied form 10m/s to 150 m/s the tip displacement is also increased correspondingly. Two resonant peaks are observed at velocities of 70 and 120 m/s. The simulations also carried in glycerine to study the influence of fluid viscosity. It is observed that as the fluid viscosity increases the tip displacement gets decreased which may be attributed to the damping effect exerted by the fluid on the plate.

REFERENCES

[1] R. Parameshwaran, S. J. Dhulipalla, and D. R. Yendluri, "Fluid-structure Interactions and Flow Induced Vibrations: A Review," Procedia Eng., vol. 144, pp. 1286–1293, 2016.

ISBN 978-93-89105-41-4

[2] C. A. Van Eysden and J. E. Sader, "Frequency response of cantilever beams immersed in viscous fluids with applications to the atomic force microscope: Arbitrary mode order Frequency response of cantilever beams immersed in viscous fluids with applications to the atomic force microscope:," J. Appl. Phys., vol. 101, no. 15, pp. 044908-0,044908-11, 1998.
[3] R. Kamakoti and W. Shyy, "Fluid-structure interaction for aeroelastic applications," Prog. Aerosp. Sci., vol. 40, no. 8, pp. 535–558, 2004.
[4] H. J. Jung and S. W. Lee, "The experimental validation of a new energy harvesting system based on the wake galloping phenomenon," Smart Mater. Struct., vol. 20, no. 5, 2011.
[5] F. R. Liu et al., "Performance enhancement of wind energy harvester utilizing wake flow induced by double upstream flat-plates," Appl. Energy, vol. 257, no. October 2019, p. 114034, 2020.
[6] M. M. Bernitsas, K. Raghavan, Y. Ben-Simon, and E. M. H. Garcia, "VIVACE (Vortex Induced Vibration Aquatic Clean Energy): A new concept in generation of clean and renewable energy from fluid flow," J. Offshore Mech. Arct. Eng., vol. 130, no. 4, pp. 1–15, 2008.
[7] J. Wang et al., "Energy harvesting from flow-induced vibration: a lumped parameter model," Energy Sources, Part A Recover. Util. Environ. Eff., vol. 40, no. 24, pp. 2903–2913, 2018.
[8] Y. Yu and Y. Liu, "Flapping dynamics of a piezoelectric membrane behind a circular cylinder," J. Fluids Struct., vol. 55, pp. 347–363, 2015.
[9] L. Tang, M. P. Païdoussis, and J. Jiang, "Cantilevered flexible plates in axial flow: Energy transfer and the concept of flutter-mill," J. Sound Vib., vol. 326, no. 1–2, pp. 263–276, 2009.
[10] Y. L. Lau, R. M. C. So, and R. C. K. Leung, "Flow-induced vibration of elastic slender structures in a cylinder wake," J. Fluids Struct., vol. 19, no. 8, pp. 1061–1083, 2004.
[11] N. M. Maruai, M. S. M. Ali, M. H. Ismail, and S. A. Zaki, "Flow-induced vibration of a square cylinder and downstream flat plate associated with micro-scale energy harvester," J. Wind Eng. Ind. Aerodyn., vol. 175, pp. 264–282, 2018.
[12] H. Wang, Q. Zhai, and J. Zhang, "Numerical study of flow-induced vibration of a flexible plate behind a circular cylinder," Ocean Eng., vol. 163, no. September 2017, pp. 419–430, 2018.
[13] T. Massai, J. Zhao, D. Lo Jacono, G. Bartoli, and J. Sheridan, "The effect of angle of attack on flow-induced vibration of low-side-ratio rectangular cylinders," J. Fluids Struct., vol. 82, pp. 375–393, 2018.
[14] P. Rojratsirikul, M. S. Genc, Z. Wang, and I. Gursul, "Flow-induced vibrations of low aspect ratio rectangular membrane wings," J. Fluids Struct., vol. 27, no. 8, pp. 1296–1309, 2011.
[15] Y. Z. Xu, L. H. Feng, and J. J. Wang, "Experimental investigation on the flow over normal flat plates with various corner shapes," J. Turbul., vol. 16, no. 7, pp. 607–616, 2015.
[16] A. Purohit, A. K. Darpe, and S. P. Singh, "A study on aerodynamic sound from an externally excited flexible structure in flow," Comput. Fluids, vol. 103, pp. 100–115, 2014.
[17] A. Purohit, A. K. Darpe, and S. P. Singh, "Experimental investigations on flow induced vibration of an externally excited flexible plate," J. Sound Vib., vol. 371, pp. 237–251, 2016.
[18] M. Springer, C. Scheit, and S. Becker, "Fluid-structure-acoustic coupling for a flat plate," Int. J. Heat Fluid Flow, vol. 66, pp. 249–257, 2017.
[19] F. Paraz, C. Eloy, and L. Schouveiler, "Étude Expérimentale De La Réponse D'Une Plaque Flexible À Un Forçage Harmonique Dans Un Écoulement," Comptes Rendus - Mec., vol. 342, no. 9, pp. 532–538, 2014.
[20] Y. Kerboua, A. A. Lakis, M. Thomas, and L. Marcouiller, "Modelling of Plates Subjected to Flowing Fluid Under Various Boundary Conditions," Eng. Appl. Comput. Fluid Mech., vol. 2, no. 4, pp. 525–539, 2008.

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Performance Evaluation of Vegetable Oils as Metal Cutting Fluids

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***Abstract*— The depletion of petroleum-based resources and non-biodegradable nature of mineral oils resulted in the requirement of an alternate source for lubricants such as cutting fluid. The literature survey indicated that the vegetable oils are potential candidates to replace mineral oils. They have some limitations such as low oxidative stability which can be rectified. In this work, Bio based cutting fluids are derived from vegetable oils such as rice bran oil (RBO), jatropha oil (JO), and coconut oil (CO). The tribological properties, emulsion stability, rheological properties, corrosion stability and performance evaluation of all the samples were evaluated as per ASTM standard. It was noted that the tribological properties, viscosity, corrosion stability for RBO was better compared to CO & JO. The emulsion stability test indicated that 40% emulsifier has shown no layer separation. The performance analysis was conducted by a standard lathe machine incorporated with lathe tool dynamometer. The turning operation was performed on mild steel work piece with high speed steel tool and flood cooling was implemented for the experimentation. The cutting forces were evaluated and it was observed that as speed and depth of cut increases, the cutting forces are increasing gradually.**

Keywords—vegetable oils, bio cutting fluid, mineral oil, bio degradable, water soluble cutting fluid.

I. INTRODUCTION

One of the most important process used in industries is metal cutting process. The friction between the two surfaces which are in relative motion can be reduced by using different types of lubricant. The cutting fluids are commonly applicable in machining process for reducing friction and wear thereby minimizing the cutting forces and energy consumption. They also improves the tool life, surface quality, washes away the chips from cutting zone and protects the workpiece from corrosion. Approximately 85% of working fluids being used around the world are petroleum-based oils. Mineral oil based lubricants are prominent in most of the industries because of its superior quality and ease of availability at low price (1). Due to environmental concerns and pollution caused by mineral oils there is a requirement for renewable and biodegradable lubricants, hence the manufacturing industries are trying to find an alternative solution to change their direction towards an eco-friendly biodegradable cutting fluid in place of mineral oil based cutting fluid. Bio-based lubricants are mostly derived from vegetable oils, since they are bio degradable in nature (2), possess good lubricating properties, better thermal stability (3), low toxicity, higher viscosity and high flash point (4). The major disadvantages of vegetable oils are its poor low temperature behaviour and low oxidative stability. These problems can be improved by the usage of proper eco-friendly additives and chemical modifications(5). Modifying the vegetable oils chemically via Transesterification or epoxidation helps in improving the oxidative stability(6).

The composition of fatty acids in vegetable oil is an important aspect in the cutting fluids formulation. The carbon chain length present in fatty acids determines the wear and coefficient of friction. The effect of saturated fatty acids in

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sunflower oil helps in the reducing the coefficient of friction and wear(7). Coconut oils which contains high percentage of saturated fatty acids has the highest pour point among the other vegetable oils and showed lower weight gain, as an indicator of oxidative stability(8). Linoleic acid of the soybean oil helps to attribute the lower abrasion rate and coefficient of friction (CoF) (9). Due to the presence of natural anti-oxidants such as gamma oryzanol, the wear is less in rice bran oil as compared to other vegetable oils(10). Both Palm Kernal Oil and Cotton Seed Oil based cutting fluids are better alternatives when compared with commercial cutting fluids (11). Avocado oil has shown good tribological properties with the lowest friction and wear when compared with other selected oils like canola (rapeseed), corn, olive, peanut, safflower, sesame, and soybean oils (12). Ground nut oil was also converted into oil-water emulsion, which is nontoxic and safe to the surrounding ecosystem (13).

This research work was an attempt to compare mineral oil based and vegetable oil-based cutting fluid. Rice bran oil (RBO), Jatropha oil (JO) and Coconut oil (CO) were considered in this study. The mineral oil based cutting fluid used for the study was servo cut S, which is a water soluble cutting fluid purchased from supraja agencies, coimbatore. The refined RBO was procured from Kalady Rice Mill Consortium Pvt.Ltd, Kerala. The Coconut oil was bought from the local market. The crude jatropha oil was purchased from Jatropower Bio-Trading Private Limited, Coimbatore. The organic emulsifier with polysorbate as main ingredient was bought from Y K laboratories, Hyderabad.

II. METHODOLOGY

A. Tribological Properties

The tribological properties such as wear scar and CoF were evaluated as per ASTM D – 4172. The four ball tester used for this study is shown in figure 1. The experiment was conducted at a temperature of 75˚C for 60 min duration with a speed of 1200 rpm by using chrome steel balls having a diameter of 12.7 mm. A steel ball, which is rotating at the specified speed, is kept in contact against three steel balls, with the given load of 392 N. The wear scar generated on the bottom three balls were analysed by using optical microscope.

Ball pot

Spindle running unit

Figure 1: Four ball tribometer

B. Emulsion Stability

The emulsion stability was examined as per the ASTM D-3707. The emulsions were prepared with oil to water ratio of 1:20. For this test, 100 ml of test sample was taken in a container and closed using stopper and then it was kept in an oven at 85ºC for 48 hours. Then the samples were examined visually for observing the separation layer of oil and water.

C. Rheological properties

The viscosity of the oils was evaluated using Cannon-Fenske Opaque Viscometer as per the ASTM D446 standard. The oil sample was taken in a Cannon-Fenske tube and kept in the viscometer bath as shown in Figure 2. After reaching the required temperature, the time taken for the oil to reach the marking was noted and the viscosity was evaluated using the equation 1. The kinematic viscosity in centiStokes (cSt) is obtained for temperatures ranging for 40 – 80℃ with 10℃ interval.

$$\text{Viscosity (cSt)} = \text{Time (sec)} * 0.10235 \quad \ldots (1)$$

Figure 2: Cannon-Fenske Viscometer with oil sample

D. Corrosion Stability

The corrosion stability test was conducted as per ASTM D 4627 standard. In this test, 4-5g of cast iron chips was placed in a petri dish containing filter paper. The test sample was then filled into the petri dish such that all the cast iron chips are submerged. Petri dish was closed with a lid and left for 24hrs incubation time. After 24 hours, the test sample and cast iron chips were removed carefully. The test setup was shown in Figure 3.

Figure 3: Petri dish with filter paper

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The filter paper was rinsed under fresh water for 5 secs. The amount of area stained on the filter paper was visually inspected. Similar procedure was carried out for all the samples and the amount of stained area was visually observed.

E. Machining Performance

The work piece used was mild steel rod of 30 mm diameter and 80 mm length and the tool used was High Speed Steel (HSS). The performance analysis for the present study was conducted using kirloskar lathe (Model - 1330) attached with tool dynamometer (Model – UIL -15) on the tool post as shown in figure 4.. This dynamometer can measure the forces produced during machining in X, Y and Z directions.

Figure 4: Lathe tool dynamometer

The turning operation was performed on the work piece by using mineral oil and vegetable oil-based cutting fluid in flood cooling mode. A recirculating cutting fluid mechanism was adopted for performing the flood cutting operation with a flow rate of 10ml/min. In this operation, the parameters varied during the turning operation are speed and depth of cut (DOC). The feed was maintained constant (0.22mm/rev). By selecting the different ranges for speed and depth of cut, an L9 Taguchi orthogonal array was developed using the Minitab software. Similar arrays were developed for the different test samples and the corresponding cutting forces was noted. The cutting forces were compared and the corresponding graphs were obtained.

III. RESULTS AND DISCUSSIONS

The experiments conducted in the present study were as per ASTM and international standards and all the set of experiments were repeated 3 times and the average results were taken.

A. Evaluation Of Tribological Properties

The tribological properties such as CoF and wear scar diameter of RBO, JO and CO were evaluated by a four-ball tester as per ASTM D-4172 standards. The results of the tribological tests obtained from four ball tester were shown in Table 1.

Table 1: CoF and wear scar of RBO, JO and CO

Oil	CoF	Wear Scar Dia (mm)
RBO	0.0508	0.574
Jatropha Oil (JO)	0.0684	0.604
Coconut Oil (CO)	0.0854	0.626

The graphical representation of CoF for three different samples were shown in Figure 5.

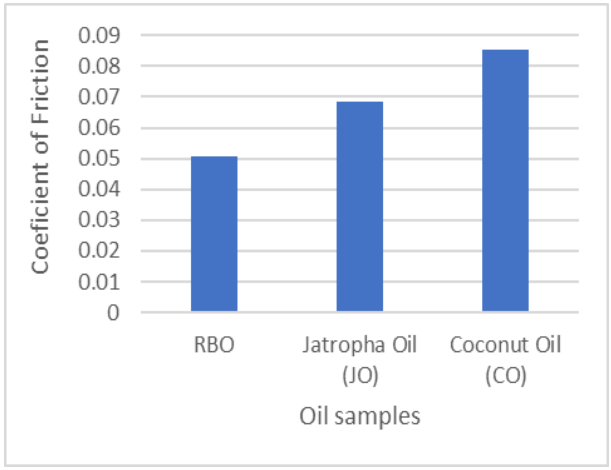

Figure 5: CoF for RBO, JO & CO

By observing the coefficient of friction graph, it can be understood that coefficient of friction for RBO is low and for CO it is high. The graphical representation of wear scar for different samples are shown in Figure 6.

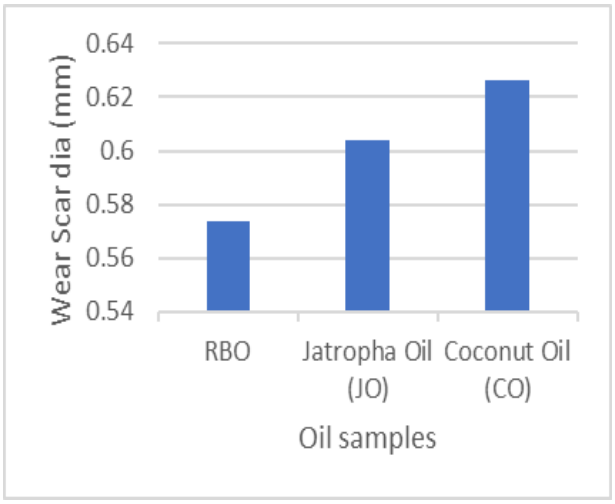

Figure 6: wear scar for RBO, JO & CO

By observing the wear scar graph, it can be seen that the wear scar diameter for RBO is low compared to JO, CO. This is due to the presence of Gamma oryzanol which is the natural anti-oxidant present in the RBO.

B. Evaluation Of Emulsion Stability

Evaluation of emulsion stability was done as per ASTM D-3707 standard. Three different samples using 20%, 30% and 40% of emulsifiers were prepared initially. The emulsions were prepared with an oil to water ratio of 1:20. The organic emulsifier was used to make the emulsion. The three samples were kept in the oven at 85 degree centigrade for 48 hrs. After 48 hours visual inspection was done for identifying layer separation of oil and water.

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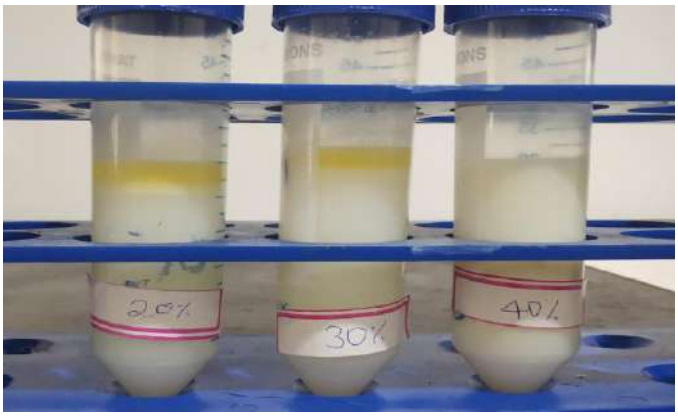


20% emulsifier 30% emulsifier 40 % emulsifier

Figure 7: 20%, 30% & 40% emulsifiers of RBO oil

From the Figure 7, a layer of separation can be observed for 20% and 30% emulsifiers. It can also be seen that 40% emulsifier has no layer of separation. Hence 40% of emulsion is considered as optimum.

C. Evaluation of Rheological Properties

The rheological properties of all the oil samples were evaluated as per ASTM D446 standard. The viscosity of all the oil samples at different temperatures are shown in the Figure 8. It is observed that the viscosity decreases with increase in temperature. This may be due to the high thermal movement among oil molecules which reduces intermolecular forces, making the flow among them easier and reduces viscosity. RBO shows high viscosity among all the oil samples. The viscosity index of the vegetables oils showed better results compared to that of commercially available mineral oil based lubricant.

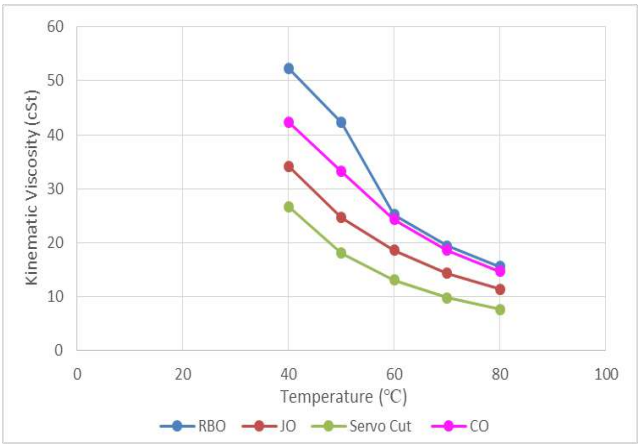
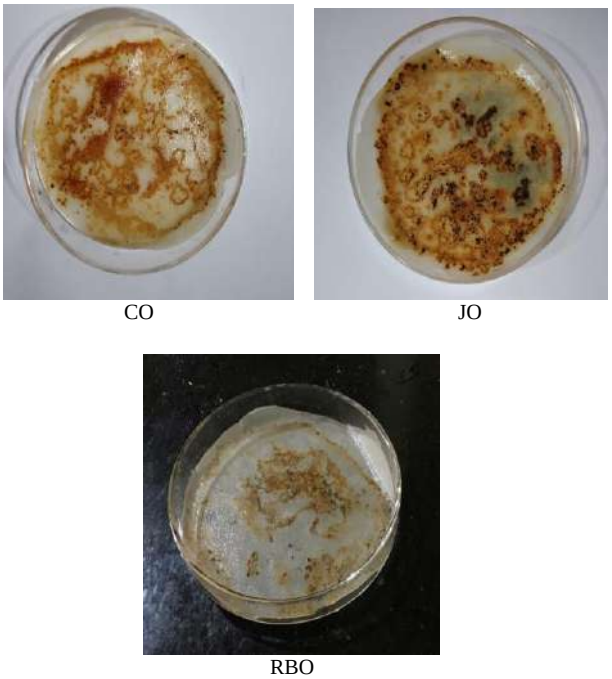


Figure 8: kinematic Viscosity of all oil samples

D. Evaluation Of Corrosion Stability

The corrosion test is carried out as per ASTM D-4627 standard. As per the standard 4-5g of cast iron chips and metal working fluid (RBO, JO & CO) was placed in a petri dish. The corrosion stability test was conducted for all the samples in different petri dishes. The test duration is about 24 hrs.



CO JO

RBO

Figure 9: Filter paper for RBO, JO & CO

Figure 9 shows the stain marks on filter paper observed after 24hrs for JO, RBO and CO. It can be seen that rust stain area is very less for RBO when compared to JO and CO.

E. Evaluation Of Machining Performance

The turning operation was performed on the lathe machine. The speed and depth of cut (DOC) were varied while feed (0.22mm/rev) was kept constant and the cutting forces were evaluated. The results of the cutting forces for the L9 orthogonal array experimental trails are shown in Table 2

Table 2: cutting forces for dry, RBO, JO and CO at different speeds and different DOCs.

SPEED (rpm)	DOC (mm)	CUTTING FORCE (kgf)			
		SERVO CUT	RBO	JO	CO
140	0.1	21	24	25	24
140	0.2	23	27	26	26
140	0.3	24	29	28	29
224	0.1	20	25	26	25
224	0.2	22	28	29	27
224	0.3	26	31	32	30
315	0.1	23	28	27	28
315	0.2	25	31	32	31
315	0.3	27	34	35	35

The experimental results from table 2 was used to create the main effects plot for means of cutting force vs speed and DOC. The Figure 10-13 shows the plot for different samples such as servo cut, RBO, JO, CO.

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1) Servo cut cutting graph

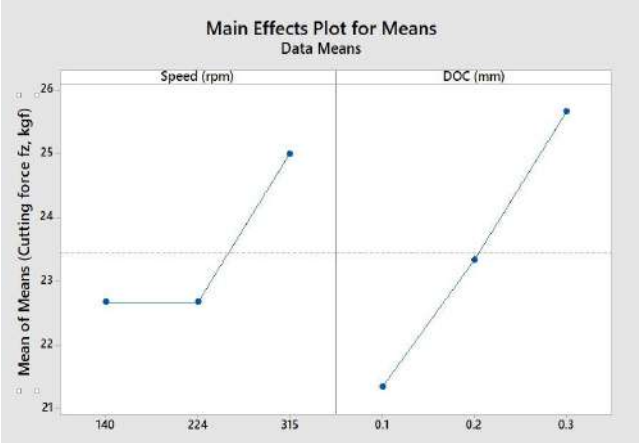

Figure 10: Speed vs MOM graph and DOC vs MOM graph for Servo cut

2) RBO cutting graph

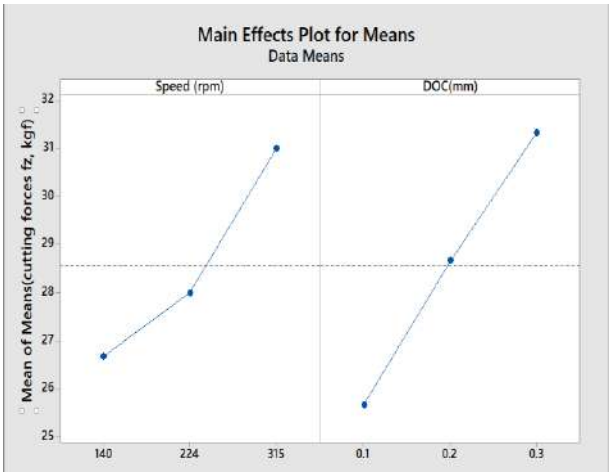

Figure 11: Speed vs MOM graph and DOC vs MOM graph for RBO

3) JO cutting graph

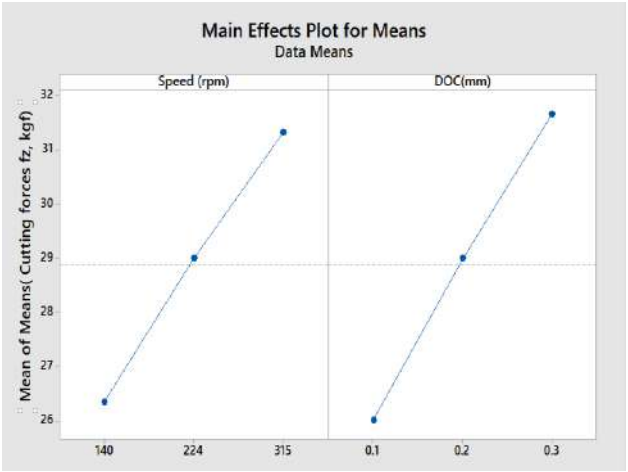

Figure 12: Speed vs MOM graph and DOC vs MOM graph for JO

4) CO cutting graph

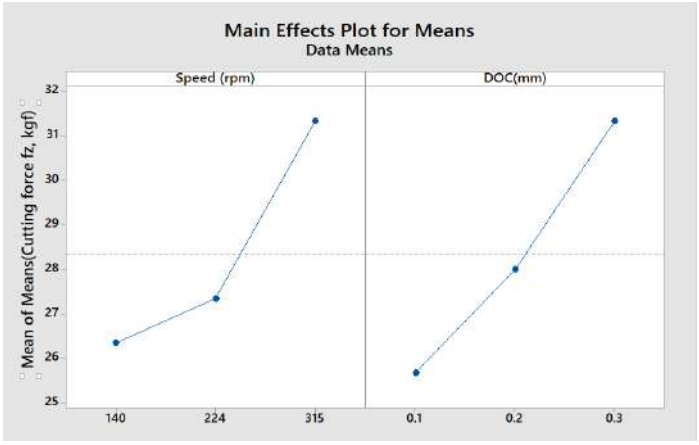

Figure 13: Speed vs MOM graph and DOC vs MOM graph for CO

It was observed that as speed and depth of cut increases, the cutting forces were increasing. With increase in the depth of cut, the load on the work piece and tool also increased, thus the cutting forces are increasing. The cutting forces are less for mineral oil when compared to vegetable oil based cutting fluid. It was also noted that at low speed, the cutting forces are gradually increasing as a result of work piece surface hardening.

IV. CONCLUSIONS

In this work, three different vegetable based cutting fluids namely RBO, JO and CO were used. The feasibility study of these oils as base oil for cutting fluid was done. From the study the following results are concluded

- The wear scar and CoF of RBO was lower than JO and CO.
- The viscosity of RBO was noted to be higher than that of other oils. The viscosity index of the vegetable oils were high compared to the commercially available mineral oil.
- The RBO has shown lesser stain area than JO & CO which attributes to its better corrosion stability.
- At high speeds, RBO based cutting fluids results in lesser cutting forces than CO & JO.
- At higher depth of cuts, RBO & CO based cutting fluids has shown lower cutting forces than JO.
- The cutting force values of the selected vegetable oils are high when compared to the mineral oil.

The feasibility study concludes that RBO is better compared to other vegetable oil for the formulation of bio cutting fluid. The properties of these vegetable oils can be improved further by

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addition of suitable additives or by chemical modifications. Future studies are planned to include experiments in a broader range of cutting parameters and worked materials, as well as other methods of application of machining fluids for cooling and lubrication.

REFERENCES

1. *Acharya N, Nanda P, Panda S, Acharya S. Analysis of properties and estimation of optimum blending ratio of blended mahua biodiesel. Engineering Science and Technology, an International Journal. 2017;20(2):511-7.*
2. *Rani S, Joy ML, Nair KP. Evaluation of physiochemical and tribological properties of rice bran oil – biodegradable and potential base stoke for industrial lubricants. Industrial Crops and Products. 2015;65:328-33.*
3. *Ruggiero A, D'Amato R, Merola M, Valašek P, Müller M. Tribological characterization of vegetal lubricants: Comparative experimental investigation on Jatropha curcas L. oil, Rapeseed Methyl Ester oil, Hydrotreated Rapeseed oil. Tribology International. 2017;109:529-40.*
4. *Lawal SA, Choudhury IA, Nukman Y. Evaluation of vegetable and mineral oil-in-water emulsion cutting fluids in turning AISI 4340 steel with coated carbide tools. Journal of Cleaner Production. 2014;66:610-8.*
5. *Rahim EA, Sani ASA, Talib N. Tribological Interaction of Bio-Based Metalworking Fluids in Machining Process. Lubrication - Tribology, Lubricants and Additives2018.*
6. *Saikiran M, Ravali G, kumar P. Comparative study of vegetable based and conventional cutting fluids in machining of copper alloys. Materials Today: Proceedings. 2019;19:611-4.*
7. *Boyde S. Green lubricants. Environmental benefits and impacts of lubrication. Green Chemistry. 2002;4(4):293-307.*
8. *Sevim Z. Erhan SA. Lubricant basestocks from vegetable oils. Industrial Crops and Products. 2000:277-82.*
9. *Quinchia LA, Delgado MA, Franco JM, Spikes HA, Gallegos C. Low-temperature flow behaviour of vegetable oil-based lubricants. Industrial Crops and Products. 2012;37(1):383-8.*
10. *Adhvaryu A, Erhan SZ, Perez JM. Tribological studies of thermally and chemically modified vegetable oils for use as environmentally friendly lubricants. Wear. 2004;257(3-4):359-67.*
11. *N.J. Fox BT, G.W. Stachowiak. Boundary lubrication performance of free fatty acids in sunflower oil. Tribology Letters,. 2004;16:275-81.*
12. *Jayadas NH, Nair KP. Coconut oil as base oil for industrial lubricants—evaluation and modification of thermal, oxidative and low temperature properties. Tribology International. 2006;39(9):873-8.*
13. *Siniawski MT, Saniei N, Adhikari B, Doezema LA. Influence of fatty acid composition on the tribological performance of two vegetable-based lubricants. Journal of Synthetic Lubrication. 2007;24(2):101-10.*

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Futures Portfolio Optimization of Energy and Non-Energy Commodities

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***Abstract*— Investors consider trading in commodities as risky process. The complexity and volatility of commodity markets discourage people from investing in commodity market. But a well-planned commodity investment can be beneficial for investors. Diversification is a risk management method that blends a wide array of portfolio investments. This paper explores the asymmetric short-term and long-term relationships between energy and non-energy resources, and draws inferences on potential opportunities for diversification. The financialization process has stepped up the correlation between energy and non- energy commodities, thus allocation decisions for portfolios become more challenging. In this paper gold, silver, copper, aluminum and cotton were taken as non energy commodities to analyze the effect of energy commodities like crude oil and natural gas on these commodities. Data used was the weekly prices of commodity futures of energy and non-energy commodities during a period of January 2011 to October 2019. The short-run and long-run commodity relationships are analyzed using the nonlinear autoregressive distributed lag technique (NARDL) along with robustness analysis using the causality-in-quantiles method. Once the diversification strategy is identified for energy and non energy assets, the portfolio will be optimized using Markowitz portfolio optimization method.**

Keywords—Energy commodities, Non-energy commodities, NARDL, Causality-in-quantiles approach

I. INTRODUCTION

Commodity market is a market that trade in primary economic sector. It is a virtual market where buying, selling and trading of raw or primary products are taking place. Commodity markets have a very important role in economic growth and progress of country. An organized derivative market was developed in India in the middle of 19th century. Initially cotton trade association started trading in futures in1875 [8]. Later more derivative markets were developed for different commodities in India. After Cotton, in 1900 trading of oil seed started in Bombay and during the period of 1912 raw jute and jute goods traded in Calcutta. Later, it is followed by trading of wheat in Hapur (1913) and Bullion in Bombay (1920). In global market, trading takes place in four categories of commodities. They include energy commodities, metals, livestock and meat and agricultural commodities. One of the key issues associated with commodities is the rapid upward or downward change of prices. Price volatility may result from erratic production and harvesting, as well as from changes in demand and supply. Volatility poses risk to producers as well as customers. Volatile markets can have serious economic repercussions. In global commodity markets a variety of domestic and international factors drives prices. In recent years, the rapid growth in China and India's production and consumption has contributed to a massive surge in commodity demand from energy to minerals. Therefore, heavy trading activity by financial firms, geopolitical conditions and tight supply capacities also has a significant effect. The complexity and volatility of commodity markets discourage people from investing in commodity market. In order to minimize risk, investors diversify portfolio of investment as a number of different investments than one large investment. Commodity markets are of two types. One is spot market and other is derivative market. In a spot market, the buyers and sellers trade their commodities at a negotiated price. The buying and selling of physical commodity is taking place in spot market with immediate delivery of cash. On the other hand, in derivative market trading is made with the help of pre-determined and standardized contracts like futures contract. The futures contract is a contract made for a future date where buyers and sellers agree to purchase or sell the goods at a specific price.

The purposes of this work are to establish the relationship between non-energy &energy commodities and to identify potential possibilities for diversification. This research will also seek to optimize the energy and non-energy resources portfolio.

The reason behind this research is that by learning about a diversification strategy, investors and portfolio managers will rebalance their assets on the market.

II. LITERATURE REVIEW

This review focuses on summarizing previous reports published, that are relevant and supportive to the overall

improvement in knowledge about asymmetrical relationship between energy and non energy commodities.

Dutta, Elie & David(2018)[1] used nonlinear ARDL bound and nonlinear Granger causality tests to investigate the cointegration and nonlinear causality between the global crude oil and precious metals markets. The data used for the analysis was crude oil volatility indices and valuable metals, such as miners of copper, silver and gold. The linear ARDL model is used initially to determine the long term relationship between the commodities under study. But the test failed to do so. Later, they are able to capture long-term relationship between oil and metals using non–linear ARDL models. The Granger causality test helped assess the symmetric effect between the markets of crude oil and gold.

In studying the causal relationship between oil and gold prices, Sathish Kumar(2017)[2] used nonlinear Granger causality tests and nonlinear autoregressive distributed lag tests and found that gold prices shows high sensitivity to rising oil prices. Linear causality experiments showed unidirectional Granger causality for both short-run and long-run, from oil prices to gold prices. The result shows that there is no proof that the price of gold Granger caused the price of oil. A strong, non-linear, bi-directional causality between oil and gold is observed.

Saban & Soyatas(2011)[3] examined the long-run and short-run relationship between the world oil price, interest rate inTturky, Turkish lira–US dollar exchange rate, and spot prices of silver and gold. The analysis showed that there is no much relation between world oil price and precious metals in Turkish market. Hence the price of metals, interest rate or exchange rate in the long run in Turkish market won't help to predict world oil prices.

The spillover effects in commodity futures markets were analyzed by Sang, Ron & Seong(2016)[4] using the multivariate DECO-GARCH model and the spillover index. Six commodity futures market returns were taken as data for analysis. They've taken gold, silver, West Texas Intermediate crude oil, corn, wheat, and rice as commodities. The analysis of data provided that there is a positive equicorrelation between commodity returns. They also found that this effect increases during the period of financial crisis. This effect can reduce the benefits for investors of diversifying the international portfolio.

Algeri & Leccadito(2017)[5] attempted to examine the contagion risk from commodity markets towards the economy as a whole and through sectors. They selected energy, food and metal commodities for study. Contagion risk means adverse shocks that affect one or more commodity markets and spread across the entire economic system. They identified the contagion risk for commodities by using Conditional Value-at-Risk approach based on quantiles regression. The analysis concludes that financial and economic factors affecting the commodity markets are the reason for contagion risks. Oil market cause more contagion risk than food market.

Bouri, Gupta, Lahiani & Shahbaz(2018)[6] done analysis on commodity index, gold prices and price of Bitcoin. They established the asymmetric, nonlinear and quantiles effects of commodity index and gold prices on the price of Bitcoin. Using non-linear ARDL model they investigated the long and short-run asymmetries in commodities. The quantiles ARDL model was used to determine the distributional asymmetry within commodities under study. The final result indicates that by using price information of commodity index and gold prices the Bitcoin price movements can be predicted.

III. METHODOLOGY

The short-run and long run commodity relationships are analyzed using the nonlinear autoregressive distributed lag technique (NARDL) along with robustness analysis using the causality-in-quantiles method.

(i) Non-linear ARDL model

The basic theory behind the NARDL model is the Error Correction Model (ECM) and the linear ARDL (Autoregressive Distributed Lag) model. ECM does not take into account short-run and long-run asymmetrical behavior. The NARDL method allows modeling asymmetric or non-linear cointegration in a single equation, which performs better in small samples. The NARDL system allows for the study of hidden cointegration in variables not accounted for in linear models. This approach allows a distinction to be made between linear co-integration, non-linear co-integration and lack of co-integration. The basic ARDL model can be formulated as:

$$\Delta y = \mu + \rho y_{t-1} + \theta x_{t-1} + \sum_{j=1}^{p-1} \alpha_j \Delta y_{t-1} + \sum_{j=0}^{q-1} \pi_j \Delta x_{t-j} + \varepsilon_t$$

Δy & μ are difference operators. Δy is dependent variable and μ is the intercept. xt is k×1vector of explanatory variables. ρ & θ are long run coefficients and j , j are short run coefficients. p and q are the respective lag orders for the dependent and explanatory variables and εt is the error term. ARDL model tests the null hypothesis of no cointegration between variables (ρ= θ = 0) and alternate hypothesis of linear cointegration between variables (ρ≠ θ ≠ 0). The validation of the hypothesis is performed using non-standard F-test. If the test results are above the critical value of the upper bound, the null hypothesis (no cointegration) can not be accepted. If the test statistic is below the lower bound, the null hypothesis cannot be rejected.

(i) Non- linear causality in-quantiles test

Nonlinear causality is a type of causation where cause and effect between two or more elements can flow in a bidirectional fashion. The key feature of nonlinear causality is the concept of feedback that can create a cause and this cause can then feedback in the first mechanism to produce an effect. It is possible to contrast nonlinear causality with linear causality where the direction of the effect flows in a specific direction. Nonlinear causation leads to a variety of nine significant results that are not feasible when considering simpler linear causal circumstances. Nonlinear causality can lead to processes of self-reinforcement or self-amplification through feedback, thereby allowing for difference between initial cause and final result. The second

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result of nonlinear causality is the bidirectional flow of causation within a system between the macro and micro-levels, thereby allowing causation downward. Thirdly, it can allow timely reversal causality that can set future goals to react to current events.

Fig.1. Time trend of sample period

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IV. DATA AND PRELIMINARY ANALYSIS

This study uses weekly prices of certain commodities from energy and non-energy sector. The Forward Markets Commission (FMC) has authorized the Indian markets to trade 113 commodity futures contracts. Out of this most frequently traded commodities are selected. The commodities selected for this study are: Crude oil and Natural gas (energy commodities), Gold, Silver, Copper, Aluminium and Cotton (non- energy commodities). Data are sourced from Multi Commodity Exchange of India limited (MCX) and chosen the period January 2011 to October 2019. Fig. 1 shows time span of commodity data series over sample period. The time trends of energy commodities shows similar trends throughout the period.

Table1 shows the logarithmic return series of energy and non energy commodities. Oil and natural gas shows negative average return. Gold has highest return and copper has the least average return. Gas shows the highest volatility and gold shows least volatile commodity. Most assets returns of selected commodities are negatively skewed. This indicates the symmetrical distribution of oil, gas, silver, and cotton with tail extending towards more negative values. Kurtosis measures the peakedness of a distribution. Since the kurtosis for all commodities are greater than 3, the data sets has heavier tails than normal distribution. All the commodities under study are leptokurtic. In order to check the normality of data series Jarque-Bera test is used. Since the probability value exceeds the absolute value, the null hypothesis of normal distribution is rejected both at 5% and 1% significance level. The significant values for both energy and non energy commodities under study are below 0.05 in Shapiro- Wilk test. Hence data significantly deviate from normal distribution. The Q statistics for autocorrelation shows that all the commodity series are independently distributed. ARCH effect is visible for all commodities except oil and copper. This table also shows correlation between energy and non-energy commodities. Oil is linked positively to the non-energy commodities. Natural gas is in a negative correlation with silver and gold.

Table 2 presents the test result of unit root test with structural break in order to find whether the test series are stationary or non-stationary. Here the test statistics is less than the P-value; hence reject the null hypothesis of unit root. All the test series are stationary series.

ARDL bound testing procedure is used to obtain the cointegration between energy and non-energy commodities. The test result in Table 3 shows that the F_{stat} is greater than the upper bound, rejecting the null hypothesis of no cointegration. Since the model does not capturing the asymmetrical relationship, NARDL model is further used.

Table 1
Descriptive statistics

	OIL	GAS	GOLD	SILVER	ALUMINIUM	COPPER	COTTON
Mean	-0.000031	-0.000093	0.001374	0.000103	0.000337	.0000302	0.0000346
Median	0.001461	0.001141	0.000836	-0.00014	-0.001343	-0.000465	0.001284
Maximum	0.132655	0.180692	0.097428	0.178317	0.118618	0.113355	0.090992
Minimum	-0.131288	-0.271587	-0.08808	-0.27600	-0.108782	-0.132220	-0.114367
Std. Dev	0.041864	0.058115	0.020317	0.034395	0.025457	0.027323	0.025238
Skewness	-0.210040	-0.214161	0.070409	-1264012	0.674009	0.132595	-0.246949
Kurtosis	3.823908	4.112239	5.397576	16.06796	5.448787	4.910859	4.691623
Jarque-Bera	16.39308	27.22692	110.5572	3395.615	149.7628	71.33272	54.34665
Shapiro-Wilk test	0.987405	0.990772	0.974581	0.883633	0.96307	0.981942	0.982316
Q stat.	88.655	62.425	113.85	66.591	87.323	33.58	21.853
ARCH(1)	-0.600239	3.664980	4.717805	4.674297	2.579667	-0.140822	3.567468
Correlation							
Oil	-	-	0.117713	0.1348778	0.2061045	0.2487674	0.0575348
Gas	-	-	-0.010801	-0.017895	0.1437274	0.0749436	0.0357521

Table 2
Unit root test with structural break

	At level	
Non-Energy Commodities	Statistics	Break point
Gold	-19.94759	3/06/2011
Silver	-19.83659	2/20/2011
Aluminium	-22.33736	5/01/2011
Copper	-22.07799	1/30/2011
Cotton	-20.06589	8/14/2016
Energy commodities		
Oil	-19.00826	2/16/2011
Gas	-22.13271	2/20/2018

Table 3
ARDL bound testing cointegration test

Commodities	F_{stat}	Lag order
Gold	137.0614	(1,0,0)
Silver	139.3571	(1,0,0)
Aluminium	170.8566	(1,1,1)
Copper	184.6877	(1,0,0)
Cotton	130.9050	(1,0,0)

REFERENCES

[1] Nazlioglu, S., Soytas, U., 2011. World oil prices and agricultural commodity prices: evidence from an emerging market. Energy Econ. 33 (3), 488–496.

[2] Dutta, A., Bouri, E., Roubaud, D., 2019. Nonlinear relationships amongst the implied volatilities of crude oil and precious metals. Resour. Policy 61, 473–478.

[3] Kang, S.H., McIver, R., Yoon, S.M., 2017. Dynamic spillover effects among crude oil, precious metal, and agricultural commodity futures markets. Energy Econ. 62, 19–32.

[4] Kumar, S., 2017. On the nonlinear relation between crude oil and gold. Resour. Policy 51, 219–224.

[5] Algieri, B., Leccadito, A., 2017. Assessing contagion risk from energy and non-energy commodity markets. Energy Econ. 62, 312–322.

ISBN 978-93-89105-41-4

[6] Bouri, E., Gupta, R., Lahiani, A., Shahbaz, M., 2018b. Testing for asymmetric nonlinear short-and long-run relationships between bitcoin, aggregate commodity and gold prices. Resour. Policy 57, 224–235.

[7] Mahajan, N., Singh, K. (2015). A beginner's guide to indian commodity futures markets. New Delhi: Madhyam research institute.

[8] Bhagwat, S., Maravi, A. S. (2016). A study on commodity market vs multi commodity exchange of india limited (MCX). International journal of research in management, economics and commerce. Vol.6, Issue 04.27-41.

[9] Shin, Y., Yu, B., Greenwood-Nimmo, M., 2014. Modeling asymmetric cointegration and dynamic multipliers in a nonlinear ARDL framework. In: Festschrift in Honor of Peter Schmidt. Springer, New York, NY, pp. 281–314.

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Numerical analysis of heat transfer and flow friction characteristics of curved longitudinally finned-tube heat exchanger

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Abstract— **The thermo-hydraulic characteristics of a compact double pipe heat exchanger with curved longitudinal fins is numerically studied. Three dimensional, Computational Fluid Dynamics analysis is performed using Ansys Fluent software in laminar flow regime for rectangular longitudinal fins and curved longitudinal fins with three thickness to height ratios. The numerical model of the flat fin is validated with experimental data. Comparative analysis of heat transfer and flow friction characteristics in terms of Colburn j factor and friction factor for different configurations of curved fins and rectangular fins were conducted. The numerical study was carried out for different laminar flow Reynolds number ranging from 100 to 1000, for different thickness to height ratio ranging from 0.0769 to 0.0909. It was found that the j factor decrease with an increase in air flow Reynolds number and thickness to height ratio ratio of fins. The f factor decrease with increase in Reynolds number but increase with thickness to height ratio. Making the fins curved rather than rectangular will increase the heat transfer in general. The j/f ratio is significantly higher for 0.0769 configuration than that of rectangular finned geometry. The thermo-hydraulic performance of an annular longitudinal fin geometry can be improved by adopting curved geometry.**

Keywords— Colburn j factor, f factor, compact heat exchanger

I. INTRODUCTION

Heat transfer enhancement in a double pipe heat exchanger is possibly achieved by several methods. It can widely be classified into Active and Passive methods. Active methods require external input for enhancement of heat transfer like induced vibrations, injection and suction of fluids and jet impingement etc. Passive methods make use of surface coating, surface roughness & extended surfaces. In order to intensify heat transfer from heat exchanger surface to fluid, we can increase surface area across which convection occurs. Extended surfaces in form of longitudinal or radial fins are commonly used where the need to enhance heat transfer between a surface and an adjacent fluid exists. The finned tube heat exchangers are used in variety of fields, mainly in heating, ventilating, air-conditioning and refrigeration systems, petrochemical industry, electronics cooling etc. as they have compact structure and higher effective heat transfer performance. Compact heat exchangers are most commonly used in refrigeration systems for providing more heat transfer since they have higher surface area to volume ratio greater than 700 m^2/m^3.

A Agarwal et al. [1] studied the heat transfer inside a finned tube annulus for laminar flow. They used an isothermally heated finned tube and assumed since fins are highly conducting, convection heat transfer should be alone studied. They found out the flow recirculation takes place at the wake of the fin. Even though it increases mixing, the fins cause main flow to move away from the heated wall. As the height of fins increase both heat transfer & pressure drop increases. At higher Reynold's no, the flow separates at fin tip & reattaches near the tip of the downstream fin. Under highly conductive thin wall assumption, the isothermal boundary maybe considered and to be imposed at the interface of fluid & thin wall assembly.

Syed et al. [2] numerically simulated laminar convection flow in the fully developed region of finned double pipe subjected to constant heat flux boundary conditions. Hydraulic diameter alone cannot be used or correlation of friction factor and Nusselt number. As the no. of fins are increased, the fin parameters like height, number and radius ratio exert much influence on the system.

Shiva Kumar K et al. [3] conducted a numerical study on heat transfer process in a given heat exchanger for different

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longitudinal fin profiles to find out fins promote boundary layer separation & disturb the whole bulk flow field inside the tube. This separation & restarting of the boundary layer increase the heat transfer rate. Bulk of fluid layer is being disturbed and rise of temperature is also uneven along the length of tube. The results showed thermal performance for rectangular geometry is higher than parabolic and triangular geometries, while pressure drop was least for parabolic geometry. They also added the fin shape not only affect the mass of heat exchanger, but also it affect flow direction that cause the temperature change on fin contact surfaces.

helical fins is superior to that of longitudinal fins at the cost of pressure drop.

T. C. Carnavos [5] studied heat transfer performance of internally finned tubes in turbulent flow. The main objective was to experimentally determine the heat transfer performance in turbulent flow using internal longitudinal and spiral fins in tube & to compare with a smooth tube datum. The experimentally determined correlating equations can be used to predict the turbulent flow pressure loss and heat transfer performance for those particular profiles mentioned in the study.

Table 1

Nomenclature

d_i = Inner pipe inner diameter (m)
D_o = Outer pipe outer diameter (m)
d_o = Inner pipe outer diameter (m)
D_i = Outer pipe inner diameter (m)
t = Fin thickness(m)
h = Height of the fins (m)
N = No of fins
A_s = Total heat transfer area (m^2)
V = Volume occupied by air flow side (m^3)
Re = Reynolds number
Nu = Nusselt number
D_h = Hydraulic diameter (m)
k = Thermal conductivity (W/mk)
V = Velocity of air flow (m/s^2)
h = heat transfer coefficient (W/km^2)
j = Colburn factor
f = friction factor
T_{ci} = cold fluid inlet temperature (K)
T_{co} = cold fluid outlet temperature (K)
T_w = Average water temperature
T_a = Average air temperature
T_m = Mean fluid temperature
A_f = Fluid flow area (m^2)
P_a = Air wetted perimeter (m)
C_p = Specific heat (J/kgK)
L = Length of heat exchanger (m)
Pr = Prandtl number

Greek symbols

ρ = Density of air(Kg/m^3)
μ = Coefficient of viscosity(Ns/m^2)

Abbreviation

SAD = Surface area density (m^2/m^3)
CHE= Compact Heat Exchanger

Anas El Maakoul et al.[4] numerically investigated thermo-hydraulic performance of air to water double pipe heat exchanger with helical fins. They found the coefficient of heat transfer at annular side controls 72-89% of overall heat transfer coefficient. So all efforts towards improving thermal performance must be focused on h_a. The increase in pressure drop may be due to two reasons; sudden change in flow field or a large annular surface area. The heat transfer performance of

A Karapaka Harendra [6] conducted an experimental study for heat transfer and flow friction characteristics on a rectangular finned tube heat exchanger with external fins with water flowing through inner tube and air flowing through annular space. It was found that the effectiveness, NTU, Colburn j factor and friction f factor decreases with increase in mass flow rate whereas pressure drop increases with increase in mass flow rate.

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In this numerical study, compact heat exchanger with rectangular and curved longitudinal fins on its annulus with surface area density greater than 700m^2/m^3 are modelled. The numerical results obtained for the reference configuration with rectangular fins is validated with experimental data. Then the CFD model is used to compute the results for various configurations of curved fin model. Comparative analysis of heat transfer and flow friction characteristics in terms of Colburn j factor and friction factor for different configurations of curved fins and rectangular fins were conducted.

II. METHODOLOGY

A. *Designing the heat exchanger*

An air to water double pipe compact heat exchanger is designed. Since the coefficient of heat transfer at annular side controls 72-89 % of overall heat transfer coefficient [4], the longitudinal fins are designed for the annular side where cold air is passed. The fin is considered to be uniform and fins are equally spaced on the outer surface of the inner tube. Surface area density was a major constraint in designing since compact heat exchangers should have SAD greater than 700 m^2/m^3. The dimensions of the pipe were chosen from the experimental work by A Karapaka Harendra [6]. Both the number of discs and fin thickness were changed to obtain the required surface area density. The fixed dimensions are Do = 62 mm, Di = 60 mm, do = 32 mm, di = 30 mm h= 13 mm, L= 300 mm.

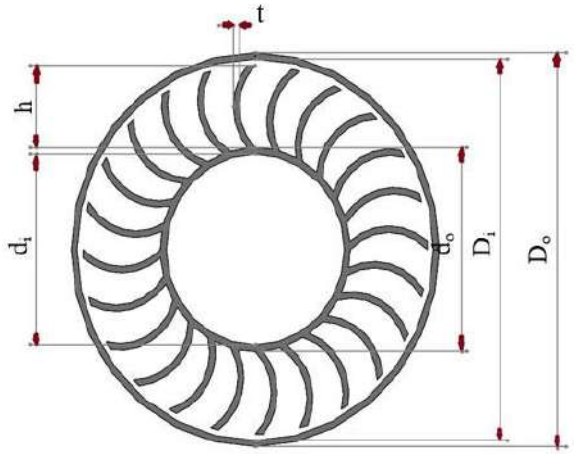

Figure 1. Curved fin tube heat exchanger cross section

From case study, it is observed that in order to increase SAD it is desirable to increase fin width and increase the number of fins. Therefore, the final values of t, N are 1 mm, and 24 respectively and the D_h values of CHE used in this study is 7.38 mm.

Surface area density be

$$SAD = \frac{A_s}{V} \quad (1)$$

Hydraulic diameter of heat exchanger annular side is given by

$$D_h = \frac{4A_f}{P_a} \quad (2)$$

The surface area density of heat exchanger using this values of parameters is 772.64 m^2/m^3. Four annular fin configurations are considered, one with rectangular fins to validate the numerical model and three with variable fin thickness to height ratio of 0.0769, 0.0833, and 0.0909.

B. *Numerical modelling*

ANSYS Fluent 17.0 was used to conduct a parametric study of heat transfer characteristics of external curved finned-tube geometry. The finned tube heat exchanger consisting of 24 external fins of 1mm thickness on the inner pipe having a length of 300 mm was modeled using ANSYS Fluent 17.

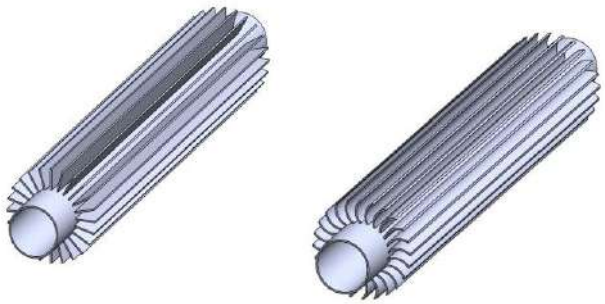

Figure 2. Rectangular finned and Curved finned tube heat exchanger geometries

The meshing was done using ANSYS ICEM CFD which is inbuilt in FLUENT. Automatic meshing was given for finned wall and multi-zone meshing with hexa-prism mapped mesh type was given for cold fluid air region for the successful meshing of the finned tube heat exchanger.

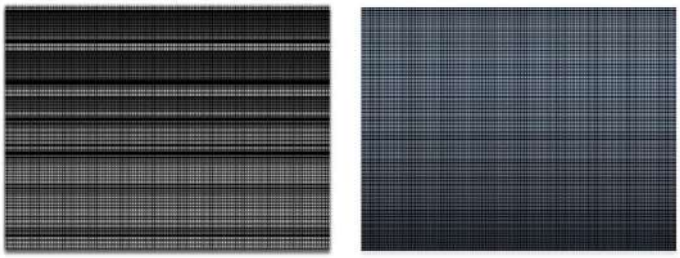

Figure 2 Meshed model of (a) pipe & (b) fluid domain

The inner wall of heat exchanger was assumed isothermal. Under highly conductive thin wall assumption, the isothermal boundary may be imposed at the interface of fluid and wall fin assembly [2]. Also since the study focuses on the convective heat transfer on the annular side, the complexity of conduction heat transfer can be relaxed by choosing isothermal wall. The temperature of inner wall was assumed to be 343K which is the inlet temperature of water in the experiment [6]. The numerical study was done for Reynolds no. ranging from 100 to 1000. A steady laminar model was used for solving the governing equations. The mass flow

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corresponding to each Reynolds number was given for the mass flow inlet. Outlet boundary condition was made as pressure outlet. The outlet is assumed to have a pressure of zero so the inlet pressure is equal to pressure drop across the fins. At the walls, no slip boundary condition was applied. Outermost wall was considered as adiabatic.

At mass flow inlet,
m= m_a, T = T_{ci} = 300 K
At pressure outlet,
P = Po (gauge pressure zero)
At inner wall,
T = T_{hi} = 343 K
At outer wall,
q. = 0 W/m^2.

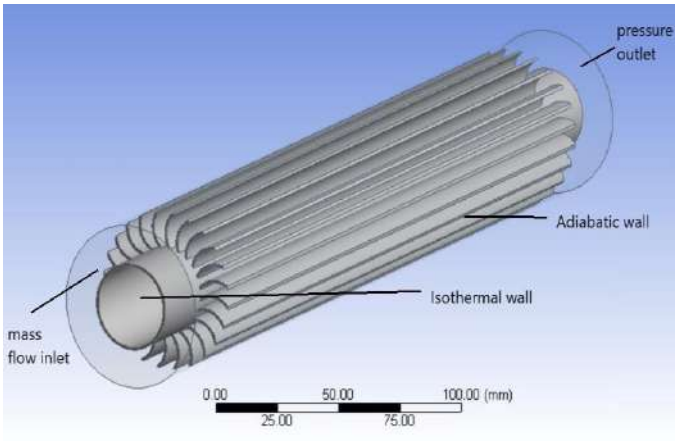

Figure 3 Boundary conditions

CFD simulations were carried for all the configurations for different Reynolds number. Since we deal with incompressible flow where **ρ** is constant, hence pressure is a function of temperature only, so pressure based solver is used. The pressure-based solver employs an algorithm which belongs to a general class of methods called the projection method. In the projection method, wherein the constraint of mass conservation (continuity) of the velocity field is achieved by solving a pressure (or pressure correction) equation. Pressure-velocity coupling scheme was used in all computations. Using Fluent, the governing equations are iteratively solved by finite volume method by SIMPLE (Semi Implicit Method for Pressure Linked Equations) algorithm. The manner in which the governing equations are linearized may take an "implicit" or "explicit" form with respect to the dependent variable (or set of variables) of interest. In Implicit form, for a given variable, the unknown value in each cell is computed using a relation that includes both existing and unknown values from neighbouring cells. Second order upwind discretization method was used in both energy and momentum equations for accurate results since unstructured mesh was used. The pressure term is treated with second order scheme. The convergence criteria used for continuity equation and energy equation are 10^{-4} and 10^{-6} respectively.

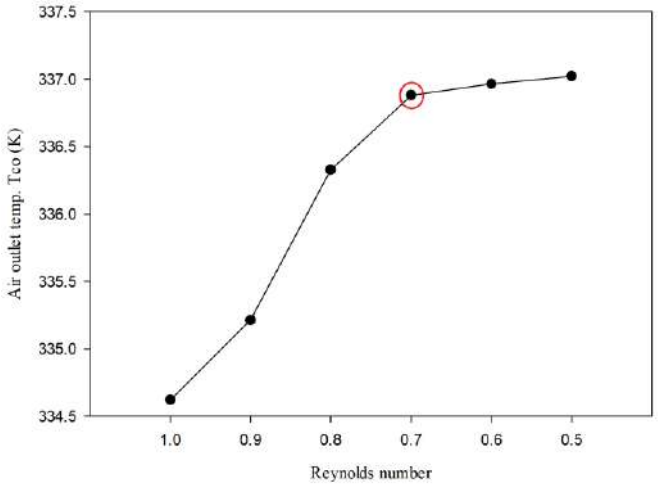

Figure 4 Grid independence study

Grid independence study was carried out for Re=500, wall temperature on water side is 343 K while air inlet temperature is 300 K for element size between 0.5 mm and 1 mm. The outlet temperature was recorded for different element sizes. Element size was reduced in steps and corresponding outlet temperatures were noted down. For the 4th and 5th observations the results became close. The result corresponding to grid size 0.7 was taken for the further study. The maximum skewness and average skewness value of the mesh are 0.58104 and 0.14223 respectively with 2322177 elements.

C. Equations used

Mass flow rate of air is given by

$$\dot{m}_a = \frac{\mathrm{Re}.\mu_a.\mathrm{A_f}}{\mathrm{D_h}} \quad (3)$$

The air properties were taken from fluid property tables corresponding to inlet temperature T_{ci}. The heat transfer coefficient, h was calculated from the heat balance equation in the numerical study.

$$\mathrm{h}_a = \frac{\dot{m}_a \mathrm{C_p}(\mathrm{T_{co}} - \mathrm{T_{ci}})}{\mathrm{A}_a(\mathrm{T_w} - \mathrm{T_a})} \quad (4)$$

The hot side wall temperature in the numerical study was taken as same as that of the inlet temperature of water (T_w=343K) as in [6] and considered as isothermal wall. The fluid properties were calculated corresponding to mean fluid temperature.

$$\mathrm{T_m} = \frac{\mathrm{T_w} + \mathrm{T_a}}{2} \quad (5)$$

Non dimensionalised form of heat transfer co-efficient, Nusselt number is calculated using

$$\mathrm{Nu} = \frac{\mathrm{h}_a.\mathrm{D_h}}{\mathrm{k}_a} \quad (6)$$

Colburn j factor is given by

$$\mathrm{j} = \frac{\mathrm{Nu}}{\mathrm{Re}.\mathrm{Pr}^{(\frac{1}{3})}} \quad (7)$$

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The friction f factor for the finned tube heat exchanger is calculated using

$$f = \frac{2\Delta p D_h}{\rho_a L V^2} \quad (8)$$

III. RESULTS AND DISCUSSION

A. Model validation

A numerical model with rectangular fins is used to evaluate the heat transfer and flow friction characteristics of the compact heat exchanger. This numerical model was validated against the experimental data from [6].

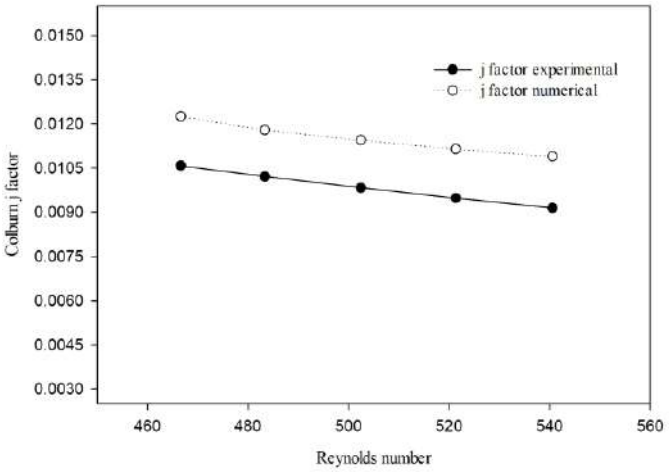

Figure 5. Colburn j factor versus Re for rectangular fins.

The Colburn j factor obtained from both experiment and numerical study are plotted against corresponding mesh Reynolds number in Figure 6. The j factor from experimental data is less than the j factor from numerical data. In numerical scheme, the outer wall is assumed to be adiabatic, but in reality it is not completely adiabatic and heat is lost to surroundings. The maximum percentage change was found to be 19.056.

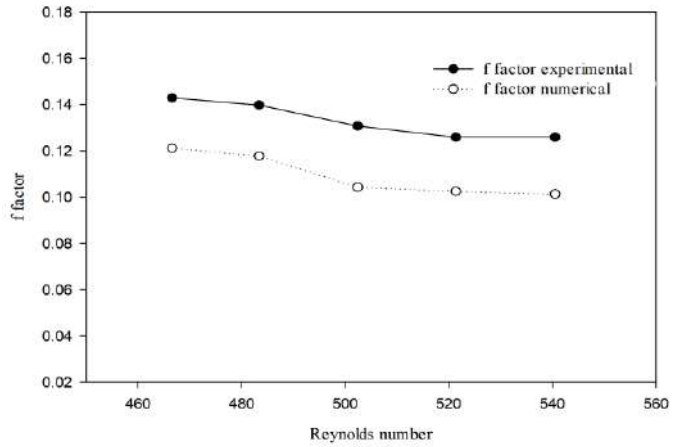

Figure 6. Friction factor versus Re for rectangular fins

Figure 6 shows a comparison of friction factor obtained by the numerical model and the experiment. The maximum percentage change in friction factor is 19.552. The value of friction factor from experiment is higher than that from numerical study. This might be due to the roughness of pipe and fins and the fabrication procedure. So the pressure drop became higher than the usual value and hence resulted in a rise in friction f factor.

From the above comparisons, it can be concluded that the numerical model provide reliable results and has a reasonable precision. The model is next used to evaluate the thermo-hydraulic performance of different configurations of curved fin heat exchanger.

B. Thermal performance

The variation of temperature in the r-z plane and r-Θ plane at air outlet side is shown in figure.

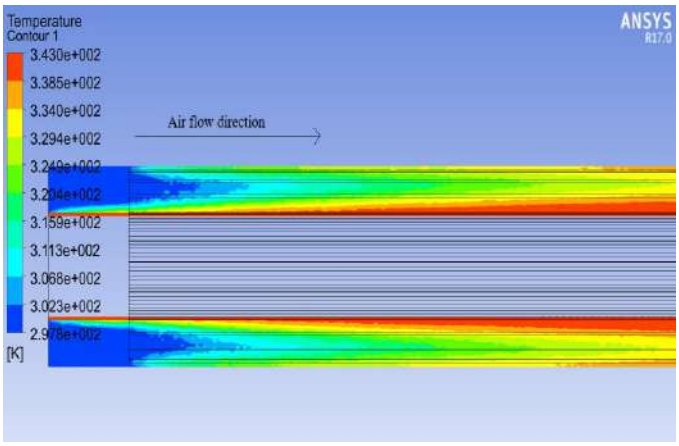

Figure 7. Temperature profile in the y-z plane for Re= 100 and t/h=0.0769

Figure 7 shows the buildup of thermal boundary layer along flow direction. At inner pipe wall, the temperature remains constant. The outlet temperature is measured using area weighted average method.

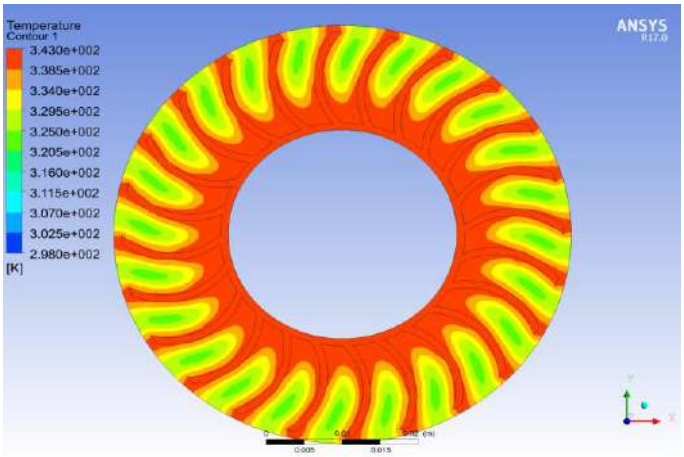

Figure 8. Temperature profile in x-y plane at centre of pipe for Re= 100 and t/h=0.0769

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The temperature of air near outer surface of inner pipe and the fins is same as that of wall temperature. The temperature of air close to these regions are almost same as that of wall temperature. The air temperature decreases along the radial direction.

The variation of Colburn j factor for both rectangular and curved fin (t/h=0.0769, t/h= 0.0833 and t/h =0.0909) is compared in the following curves for Reynolds number from 100 to 1000. This gives a straightaway comparison between the two geometries. It is assumed that the mass flow rate and inlet temperature are same for all the three configurations.

The Colburn j factor decreases with the increase in Reynolds number since it is inversely proportional to Reynolds number.

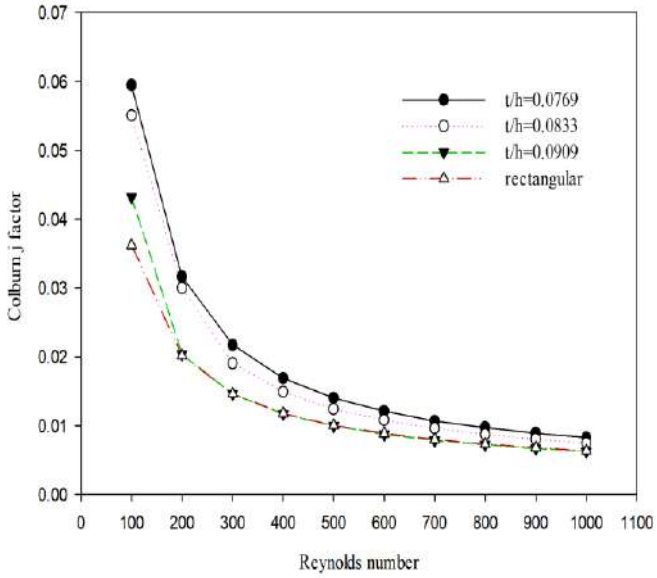

Figure 9 j factor vs Re for rectangular and curved fin geometries

The Colburn factor for both rectangular and curved fins decrease with increase in Reynolds number. As Reynolds number is increasing, the outlet temperature is also decreasing and so is the effectiveness of heating. The j factor for curved fin geometry is higher than rectangular fin geometry. This is due to increase in total heat transfer area. The percentage increase decreases with increase in Reynolds number. When thickness to height ratio is increased from t/h=0.0769 to t/h=0.0909 the j factor tend to be decreasing due to the reduction in total heat transfer area. Much increase in j factor is observed at low Reynolds numbers. The maximum increase in j factor is 39.075% for t/h=0.0769 observed at Re= 100 which reduces to 23.183% at Re= 1000.

C. Hydraulic performance

The variation of friction factor f for both rectangular and curved fin (t/h=0.0769, t/h= 0.0833 and t/h =0.0909) is compared in the following curves for Reynolds number from 100 to 1000.

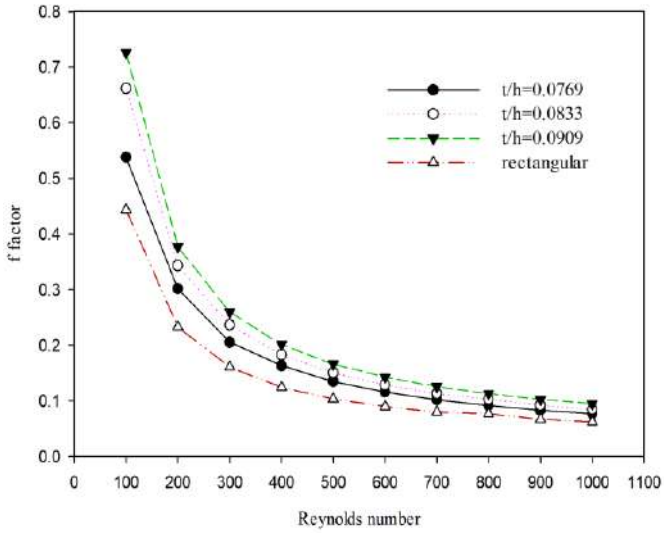

Figure 10 f factor vs Re for rectangular and curved fin geometries

The friction factor for all geometries decrease with increase in Reynolds number since f is inversely proportional to square of mean velocity of flow. The friction factor for rectangular finned geometry is less than that of curved fin geometry. Friction factor also increases with increase in pressure drop, which is high at larger Reynolds numbers. But effect of air velocity variation is influencing more than pressure drop. So net effect is decrease in friction factor with Re. With increase in t/h, hydraulic diameter also increases. Friction factor f being proportional to hydraulic diameter, increases with friction factor.

D. Thermal-hydraulic performance

The ratio of Colburn factor to friction factor express the thermo-hydraulic performance.

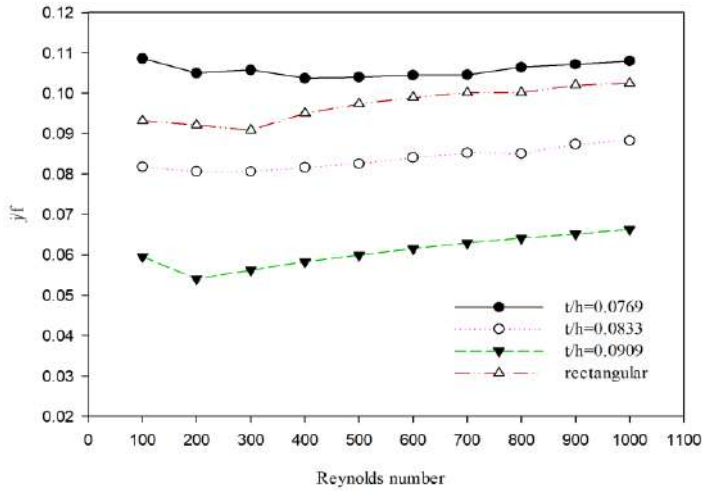

Figure 11 j/f vs Re for rectangular and curved fin geometries

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The j/f ratio is higher for curved configuration t/h=0.0769 than rectangular finned geometry. The maximum percentage increase in j/f value is 26.066. The maximum increase in j/f ratio is at lower Reynolds numbers. At higher Reynolds numbers, the rectangular fin geometry increase the thermo-hydraulic performance while that of t/h=0.0769 tend to decrease.

The j/f performance of both t/h= 0.0833 and t/h=0.0909 is below rectangular geometry, owing to the lower value of j factor and higher value of friction factor. So with increase in t/h value, the thermo-hydraulic performance drops.

IV. CONCLUSION

A finned tube heat exchanger with a rectangular and curved longitudinal fins on outer surface of inner pipe was numerically modelled using Computational Fluid Dynamics package ANSYS 17. The numerical results obtained for the reference configuration with rectangular fins is validated with experimental data. Then the CFD model was used to compute the results for various configurations of curved fin model. Comparative analysis of heat transfer and flow friction characteristics in terms of Colburn j factor and friction factor for different configurations of curved fins and flat fins were conducted for varying flow Reynolds number.

From the study it was found out that.

1) The Colburn factor for both rectangular and curved fins decrease with increase in Reynolds number. The j factor for all curved fin configurations are higher than rectangular fin geometry. So making the fins curved rather than rectangular will increase the heat transfer due to increase in heat transfer area. The Colburn j factor was highest for t/h=0.0769 curved configuration.

2) The friction factor for all geometries decrease with increase in Reynolds number. All curved fin configurations have frictional factor greater than that of rectangular fin geometry. Friction factor also increases with increase in t/h, due to increase in hydraulic diameter.

3) The j/f ratio is significantly higher for t/h= 0.0769 than that of rectangular finned geometry. The maximum increase in j/f value is 26.066%. The j/f performance of both t/h= 0.0833 and t/h=0.0909 is below rectangular geometry

4) The thermo-hydraulic performance of an annular longitudinal fins can be improved by adopting curved geometry.

REFERENCES

[1] Ajay K. Agrawal, Subrata Sengupta, “Laminar fluid flow and heat transfer in an annulus with an externally enhanced inner tube,” International Journal of Heat and Mass Transfer, Vol. 11, 1993, 54-59

[2] K. Syed, M. Ishaq, M. Bakhsh, “Laminar convection in the annulus of a double-pipe with triangular fins,” Computers and Fluids, 2011, 44: 43-55.

[3] Shiva Kumar, K. Vasudev Karanth, Krishna Murthy, “Numerical study of heat transfer in a finned double pipe heat exchanger” World Journal of Modelling and Simulation, Vol. 11 (2015), pp. 43-54

[4] Anas El Maakoul, Mustapha El Metoui, Abdellatif Ben Abdullah, “Numerical investigation of thermos hydraulic performance of air to water double-pipe heat exchanger with helical fins,” Applied Thermal Engineering, 127:127-139 December 2017

[5] T C Carnavos, “Heat transfer performance of internally finned tubes in turbulent flow,” Heat Transfer Engineering, vol. 1, No.4, 1990, 32-37

[6] A Karapaka Harendra, “Experimental study of heat transfer and flow friction characteristics of rectangular finned tube heat exchanger with external fins,” unpublished.

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Predicting Exchange Rates using Commodity Prices in the Indian Market

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***Abstract*— Since the exports and economic growth are related directly to the domestic industry of a country, there is a natural proneness to associate commodity prices with certain currencies. The commodity-currency correlation can help the traders understand and forecast those market movements. The research attempts to evaluate the effect of commodity prices on the exchange rates and vice versa and seeks to forecast the relationship between the exchange rate and commodity prices. The variables employed are major commodity prices and exchange rates. Monthly data on commodity prices and exchange rates have been selected. The preliminary analysis is performed in which the data is plotted and co-movements observed. The test for the existence of serial correlation in the predictors is completed, stationarity is evaluated using Augmented Dickey Fuller test and break dates have been established using break point unit root test.**

Keywords*— *commodity prices, asymmetry, structural breaks, exchange rate, co-movement, currency pairs, gold price index

I. INTRODUCTION

Exchange rates play an important role in the degree of exchange or trade of a nation that is vital almost every free market economy in the world today. Exchange rates are therefore among the economic measures that are most controlled, assessed and manipulated by government and further impact the real return on investments of investors, competitiveness of companies, and development of specific sectors among various other economic determinants. The exchange rate is a focal point in the level of trade in any region. Exchange rate-volatility affects the international trade thereby impacting trade-related industries resulting in foreign investment outflows. Exchange rate consideration have been the subject of a detailed study, not only for policy making circles, but also for business houses.

Commodities traded worldwide are subject to the exchange rates. Generally, the course of relationship between the commodity prices and exchange rates is dependent on the nature of the economy concerned. The commodities can be fairly easy to trade because their value is usually based on the demand and supply and hence its trend is more predictable. Trading in commodities and currencies can be very profitable and consistent, however the forex market is more consistent in comparison to the commodities trading. There will be times when the commodity-currency relationship breaks down, at such times it can be very costly for a trader that doesn't know what's occurring. Being aware of a correlation, tracking it and timing it is critical for effective trading based on the intermarket research provided by examining currency and commodity relationships. Understanding which currency is associated with what commodity will help traders understand such market movements and forecast them. The objectives of the study are as follows :

a) To understand the direction of relation between prices of commodities and exchange rates.

b) To account for statistical features of the predictors, i.e. commodity prices, such as standard deviation, skewness, kurtosis, autocorrelation and account for presence of stationarity and to identify structural breaks.

II. LITERATURE REVIEW

This review focuses on summarizing published previous reports that are relevant and supporting the overall improvement of knowledge about commodity based exchange rate prediction. The main objective of the review is to examine and evaluate the various factors considered for prediction of exchange rates and to have a brief outline of the development in various techniques that are used in prediction of exchange rates using commodity prices.

Yu Chin Chen et.al (2010) [1] focused on the structural relation between currencies and prices of commodity through the trade terms and income effects, and the resulting complex relationship between commodity price movements and exchange rate fluctuations was empirically studied. This study supported the notable role of commodity prices in forecasting exchange rate forecasts for both in-sample as well as out of sample. This suggested that return predictability is primarily in-sample and that out-of-sample tests are not robust.

Domenico Ferraro et.al (2015)[2] concluded that commodity prices would forecast daily currency exchange rates. At all frequencies, the relation between oil price and exchange rate is

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statistically significant. The predictive ability at quarterly and monthly frequencies is however not evident. The study also confined itself to a single commodity price and a single exchange rate.

Westerlund et.al (2015)[3] concluded that the initial tests provided good predictability data, but the subsequent research found that much of the evidence was due to bias created by incorrect predictor assumptions and showed that this is costly analytically and numerically, and the inclusion of the irrelevant information found in the heteroskedasticity can result in significant performance gains, not only in terms of power but also in terms of size accuracy while combining with important sub-sample values.

Yu Chin Chen et.al (2016)[4] investigated the effect of crude oil shocks on US dollar exchange rates against currencies in the OECD countries and analyzed the non-linear relationships between oil price changes and currencies. Consequently, Value at Risk model was used to examine their particular dynamics. The study established that the exchange rate responses to the oil price changes depended on the driving force that affected changes in oil price. The study concluded that the oil price changes in the pre-crisis and post crisis periods were not consistent.

Yang et.al (2017)[5] used daily data to investigate the dynamic relationship between exchange rates and the price of crude oil over time and frequency space. It was found, with the help of wavelet coherence, that the extent of co-movement between price of crude oil and the exchange rate differed over time and for all countries a strong but not homogenous link around 2008. In addition, there is a negative relation between the crude oil price and the oil-exporting countries' exchange rates while the relation between the crude oil price and oil-importing countries' exchange rates is unclear.

Afees A Salisu et.al (2018)[6] concluded that US inflation is best modelled by the predictive model (multi factor) and that oil price shifts, in the presence of asymmetries, are essential to forecast inflation. It can be noted from the study that the major traded currency pairs reacted in a different manner to shocks and therefore cannot be used to generalize the results of a single currency pair.

III. Data and Methodology

A. Data Collection and Relevance

The most traded currencies in India includes US dollar, British Pound, Japanese Yen, Euro. The monthly exchange rates of US dollar, British Pound, Japanese Yen, Euro against the Indian Rupee are taken. Monthly prices of Gold (per gram in INR) and Crude Oil have been considered. The monthly prices are obtained from gold.org and investing.com. The monthly closing prices of the companies listed on the Nifty Commodities Index and Nifty Energy Index have been selected. These are thematic indices that aim to reflect the performance and behavior of a diversified portfolio of companies which represent the commodities segment.

Nifty Commodities Index is an index of the 30 companies that are listed on the National Stock Exchange. Such companies belong to different sectors like Oil, Cement, Petroleum products, Power, Sugar, Chemicals, Metals etc. It is measured using the periodic capped free float market capitalization.

Nifty Energy Index is an index of 10 companies which are listed on the National Stock Exchange. These companies belong to Petroleum, Gas and Power sectors. It is determined using market capitalization(free float) process, in which the index reflects the total market value (free float) of all the stocks in the index compared to particular base market capitalization value. Both these indices can be used for a variety of purposes such as the launch of index funds, benchmarking fund portfolios, structured goods and exchange traded funds. The monthly closing prices are tracked from January 2011 to October 2019 over the entire period.

B. Preliminary Analysis

The steps involved are as follows :

(i) Collect the data, i.e., the monthly closing prices of Nifty Commodities Index, Nifty Energy Index; the monthly prices of Gold (per gram in INR), Crude oil and exchange rate of US dollar, Japanese Yen, British Pound and Euro against Indian Rupee.
(ii) Graphical Representation : to explore the co-movements between the four most exchanged currency pairs and the commodity prices.
(iii) Descriptive Statistics : Mean, Standard Deviation, Skewness, Kurtosis, Jarque Bera statistics
(iv) Autocorrelation Test (Ljung Box test Q statistics)
(v) Unit Root Test (Conventional ADF test and Breakpoint Unit root test)

C. Results and Discussion

The results of the preliminary analysis are provided in this section. The results of the following steps are included :

1. Graphical Representation
2. Descriptive Statistics
3. Autocorrelation
4. Unit root test

1. Graphical Representation

The course of the movements between the 4 currency pairs and all the commodity prices is explored. As shown in Fig.1, the co-movements between commodity prices and Euro/Indian Rupee is positive for gold, Nifty commodities index and Crude oil whereas for Nifty energy index, the direction is initially inverse, but positive co-movement was obtained later. In Fig.2, there is positive movement between commodity prices and British pound/Indian rupee. In Fig. 3, the co-movements are in opposite direction in the case of commodity prices and US dollar/Indian

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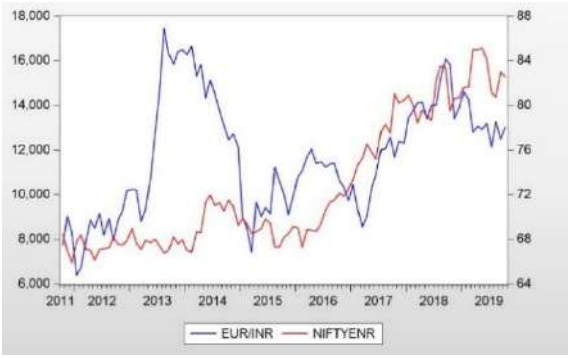
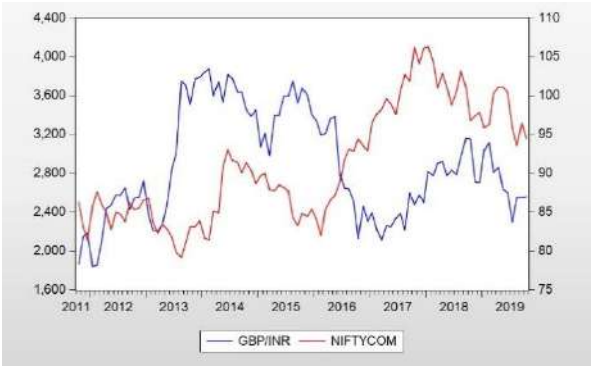
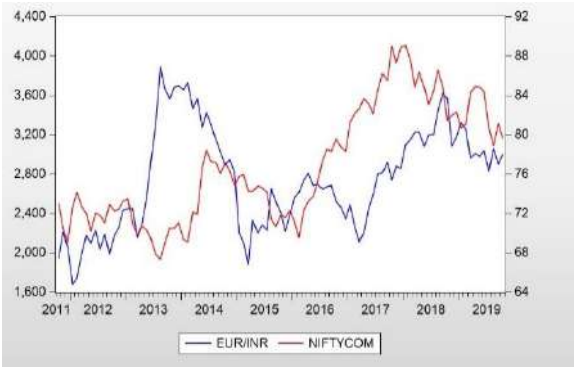
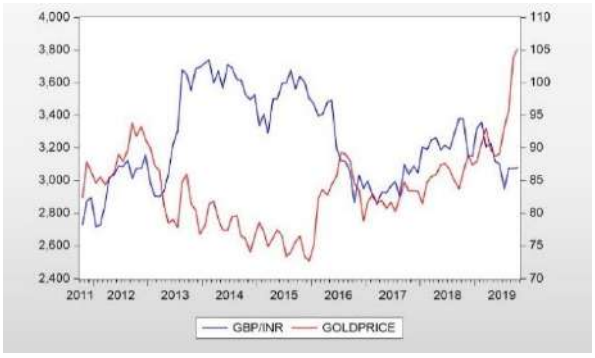
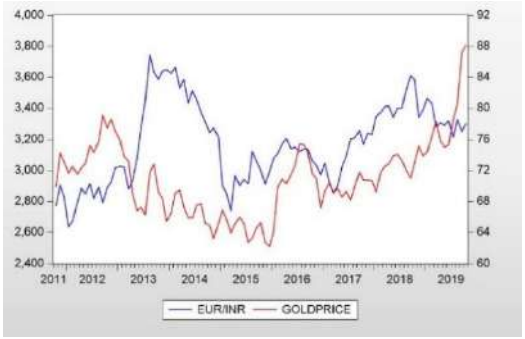
rupee. In Fig. 4, the commodity prices and Japanese yen/Indian rupee move in opposite direction.

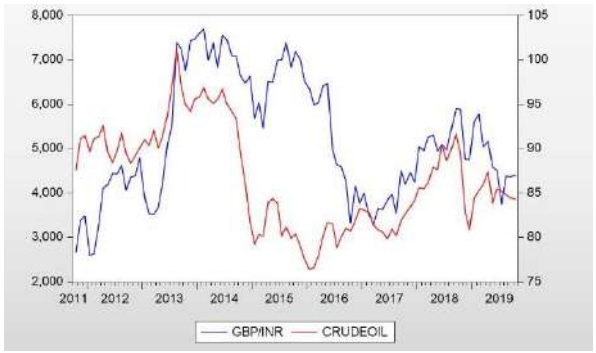


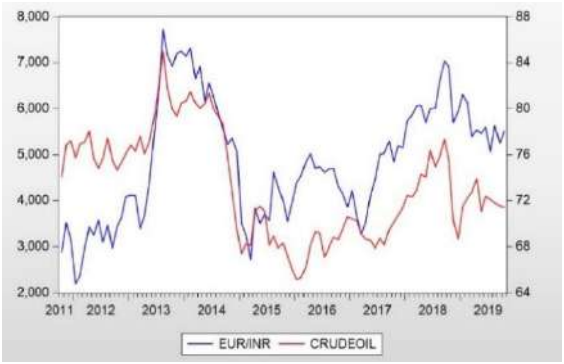












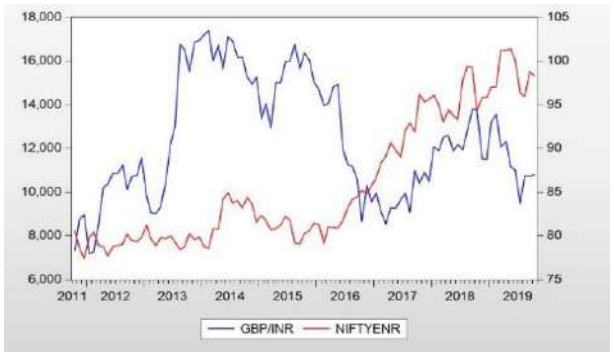


Fig.1 Commodity prices and Euro- Indian Rupee exchange rate

Fig.2 Commodity prices and British pound- Indian Rupee exchange rate

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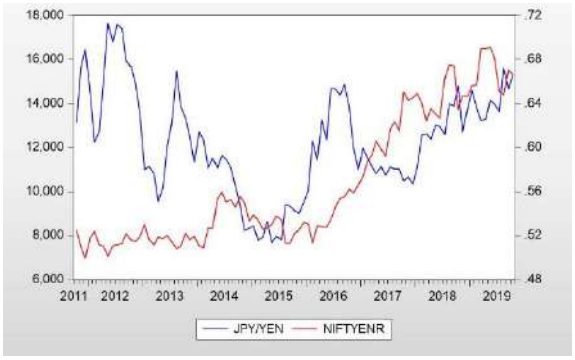
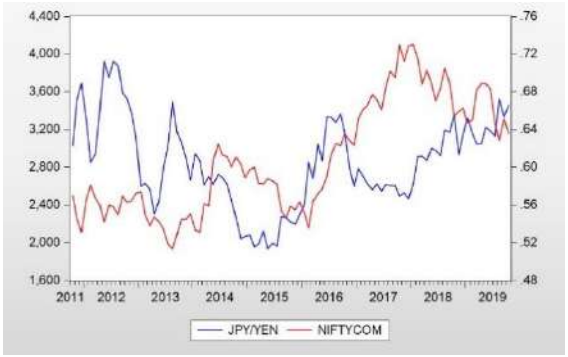
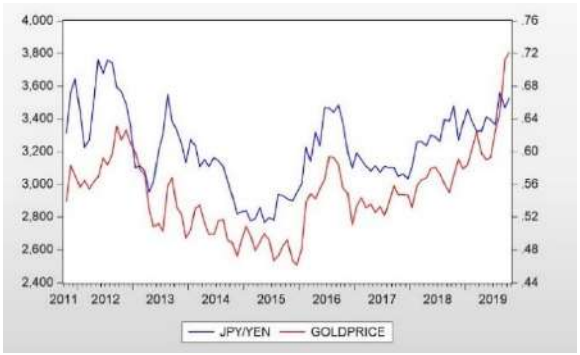






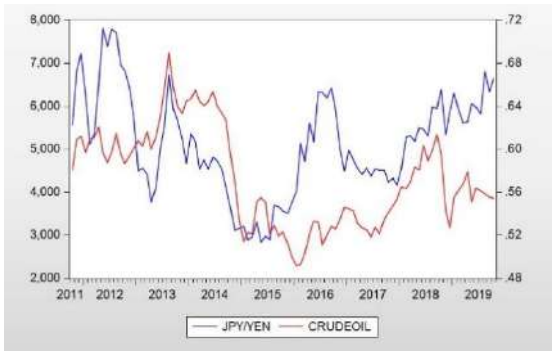
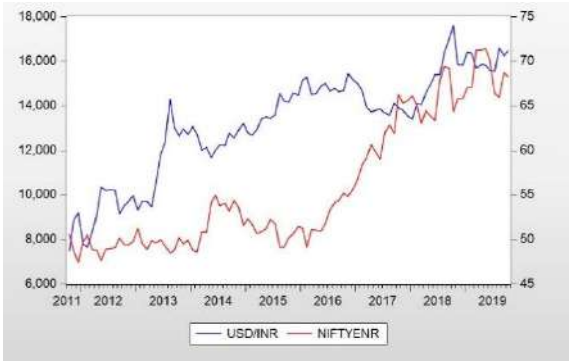
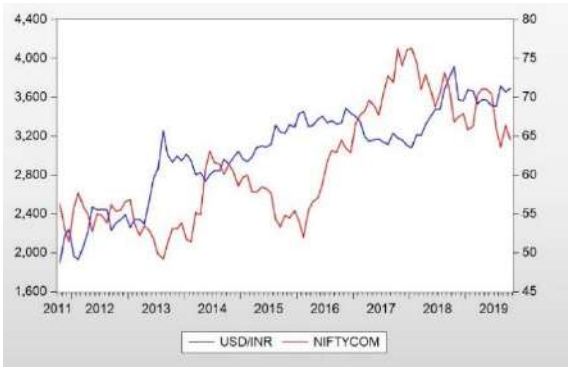
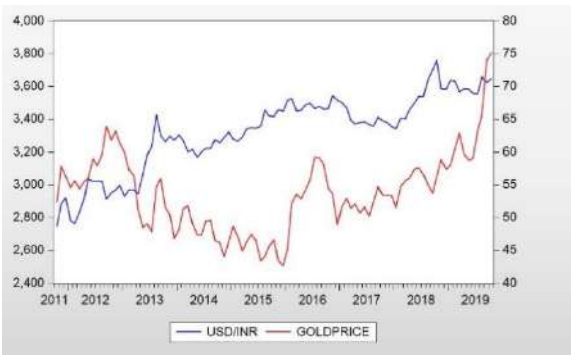


Fig.3 Commodity prices and US dollar- Indian Rupee exchange rate







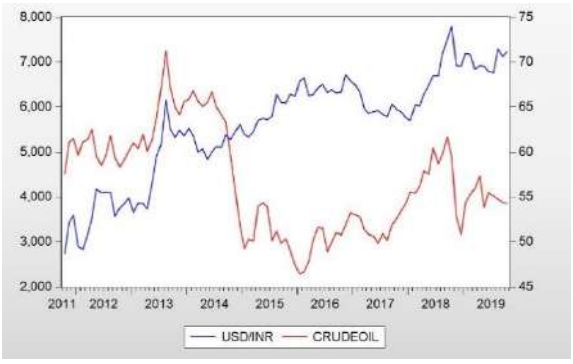


Fig.4. Commodity prices and Japanese yen- Indian Rupee exchange rate

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2. Descriptive Statistics

The most volatile of the commodities as for standard deviation (std. dev), is the Nifty Energy index whereas the least volatile is price of gold. Likewise, the mean monthly exchange rate for currency pairs is higher for British pound when compared to other currencies, and GBP/INR still tends to be most unpredictable. Moreover, with respect to the statistical characteristics of the series, the statistics on skewness is positive for all commodity price and exchange rates (excluding US dollar- Indian Rupee exchange rate). The statistics on kurtosis is mainly platykurtic over commodity prices except gold. The kurtosis statistics is platykurtic for exchange rates. Therefore, Jarque Bera statistics (JB stats), which uses the skewedness and kurtosis information for normality imply that all the commodities prices and exchange rates are non-normal.

Table 1. Descriptive Statistics

EXCHANGE RATES	MEAN	STD. DEV	SKEWNESS	KURTOSIS	JB STATS
EUR	75.4916	5.2375	0.1634	2.1450	3.3857
GBP	91.0444	6.9375	0.1950	1.8871	5.6208
YEN	0.6053	0.0479	0.0695	2.4868	1.1441
USD	63.0331	5.9246	-0.645	2.6319	7.2798

COMMODITIES	MEAN	STD. DEV	SKEWNESS	KURTOSIS	JB STATS
GOLD	2947.242	244.5174	0.69464	4.2094	13.7127
CRUDE OIL	4330.423	1154.924	0.2935	2.1108	4.5885
NIFCOM	2889.590	594.4522	0.3863	1.8958	7.3408
NIFENR	10348.05	2498.153	0.7432	2.0263	12.7620

3. Autocorrelation

Autocorrelation test is conducted using the Ljung Box test Q statistics. In this, three separate lag(K) of lengths were considered, which were of four, eight and twelve. This is done for robustness and the results show the there is substantial serial dependence for the commodity prices at lower as well as higher orders. There is a major serial dependency for the exchange rates at lower as well as higher orders. For autocorrelation test, null hypothesis is that there exists no serial correlation. Rejection of null hypothesis is conducted at level of significance of 1% and 5%.

Table 2. Autocorrelation results of exchange rates and commodities

EXCHANGE RATES	K=4	K=8	K=12
EUR	138.34	143.48	152.88
GBP	102.53	106.37	110.48
YEN	81.379	84.980	98.012
USD	176.18	223.14	237.16

COMMODITIES	K=4	K=8	K=12
GOLD	98.279	135.04	140.05
CRUDE OIL	69.55	77.735	78.326
NIFCOM	239.98	288.99	294.35
NIFENR	241.29	292.00	294.91

4. Unit root test

The traditional unit root type Augmented Dickey Fuller (ADF) test and Breakpoint unit root test is performed. The outcome of unit root testing of ADF implies that all the eight variables are, at level, non-stationary but achieve stationarity after 1st difference which implies that they are integrated of order 1. This is further verified with structural breaks by the breakpoint unit root test. The variables considered are all in their log forms. The test regression for all unit roots involves trend and intercept and dismissal of a unit root's null hypothesis occurs at 1%, 5% and 10% levels of significance.

Table 3. Unit root test and break points of exchange rates and commodities

VARIABLES	ADF TEST			BREAKPOINT TEST			
	LEVEL	FD	I(d)	LEVEL	FD	I(d)	BREAK DATES
EUR	-2.1572	-9.5375	I(1)	-3.1095	-10.5203	I(1)	2013M08; 2014M11
GBP	-2.3886	-10.879	I(1)	-3.976	-11.800	I(1)	2013M04; 2013M08
YEN	-1.9787	-9.578	I(1)	-3.2836	-10.1181	I(1)	2012M05; 2012M11
USD	-3.2184	-9.7976	I(1)	-5.005	-10.713	I(1)	2013M04; 2013M08

VARIABLES	ADF TEST			BREAKPOINT TEST			
	LEVEL	FD	I(d)	LEVEL	FD	I(d)	BREAK DATES
GOLD	-1.0668	-8.8678	I(1)	-2.8445	-9.4377	I(1)	2013M10; 2016M02
CRUDE OIL	-2.2083	-8.1039	I(1)	-5.1551	-8.8275	I(1)	2014M09; 2018M11
NIFCOM	-2.4349	-9.3820	I(1)	-3.5423	-9.8345	I(1)	2016M02
NIFENR	-2.8634	-10.5289	I(1)	-4.448	-11.0163	I(1)	2015M08; 2016M12

CONCLUSION

The currency pair co-movements with the commodity price indices, gold price and crude oil are analyzed. From Jarque Bera Q statistics, it is found that at both higher and lower orders there is significant serial correlation in the predictors. The findings of Augmented Dickey Fuller test on the eight variables showed that at level, the variables are non-stationary but attain stationarity after first difference. This implies that they are integrated of order 1. The break point unit root test further confirms the non-stationarity and break dates are identified.

REFERENCES

[1] Y.C. Chen, K.S. Rogoff, B. Rossi, 2010. *Can exchange rates forecast commodity prices?* Q. J. Economics, Vol. 125 (3), pg.1145–1194.I.S.

[2] D. Ferraro, K. Rogoff, B. Rossi, 2015. *Can oil prices forecast exchange rates? An empirical analysis of the relationship between commodity prices and exchange rates.* J.Int. Money Finance. Vol.54, pg. 116–141.[7] Kohlscheen, E., Avalos, F., Schrimpf, A., 2016. *When the Walk Is Not Random: Commodity Prices and Exchange Rates.* Bank for Settlement (BIS) Working Papers Series No. 551.

[3] Westerlund, J., Narayan, P.K., 2015. *Testing for predictability in conditionally hetoroscedasticity stock returns.* Journal of Finance Economics, Vol. 13, pg. 342–375.

[4] H. Chen, L. Liu, Y. Wang, 2016. *Oil price shocks and US dollar exchange rates.* Energy,Vol. 112, pg. 1036–1048.

[5] Yang, L., Cai, X.J., Hamori, S., 2017. *Does the crude oil price influence the exchange rates of oil-importing and oil-exporting countries differently? A wavelet coherence analysis.* International Revenue Economics Finance, Vol. 49, pg. 536–547.

[6] A.A. Salisu, K.O. Isah, 2018. P*redicting US inflation: evidence from a new approach.* Economic Modelling, Vol. 71, pg. 134–158

Modal Analysis of a Launch Vehicle

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Abstract **- Recently, a lot of breakthroughs has been seen in engineering theory and applications. The recent trend is combining modeling, theoretical analysis and computer simulation. Conventional mathematical modeling techniques for structures for vibration analysis are tedious. As an alternative, the finite element (FE) method is increasing in popularity because of its simplicity and feasibility of using for real life applications. Applications such as ANSYS use the FE method to effectively solve problems that is otherwise tedious to solve. In this study a preliminary study is first conducted in ANSYS 2019 to find out the natural frequencies and mode shapes of a launch vehicle structure. For this purpose, a model of a launch vehicle was first created using a combination of Solidworks and AutoCAD. This model was then studied in ANSYS using the Modal Analysis module. Post importing, the model was meshed with a mesh size of 0.5mm (Three noded mesh elements), and solved for the first twenty five mode shapes.**

Keywords-Classical Modal Analysis; Experimental Modal Analysis; Operational Modal Analysis; Vibration Measurements

I. Introduction

Modern design of engineering structures requires them to become lighter, yet more flexible and strong owing to space and mass constraints. These demands have created new challenges to the scientific understanding of engineering structures. Where the vibration of a structure is concerned, the challenge lies on having a basic understanding of its dynamic properties using analytical, numerical or experimental means, or a combination of all three. As the significance of dynamic behavior of different structures are better appreciated; it becomes important to design them with proper consideration of dynamics. The experimental study of structural dynamics has always been a big part of our efforts to understand and control the vibrations that are encountered in practice.

Of late, modal analysis has gained importance in the quest for determining, improving and streamlining dynamic characteristics of various structures. Along with being identified as a major method for solving problems in Mechanical and Aerospace Engineering, it has found new applications in civil structures, biomechanical problems, space structures etc.

The natural modes of vibration are unique to a particular system and it stems in its physical properties. Modes are described by its modal parameters, viz, natural frequency, modal damping factor and mode shape. The frequencies at which a structure resonates strongly, even for a small amplitude excitation is known as its natural frequency. The relative position of points on a structure at a given natural frequency is known as mode shape.

II. Literature review

Practical ways of doing modal analysis has been discussed in this section. There are mainly two methods that are used for modal analysis: Operational Modal Analysis and Experimental Modal Analysis.

Brain J Schwartz [1], in his work, reviewed modern techniques for experimental modal analysis. Modal testing, FRF measurement techniques, excitation techniques and modal parameter estimation techniques were discussed.

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Peter Avitabile [2] in his paper Experimental Modal analysis, uses simple explanantions to describe structural vibration, as well as the use of some tools for solving structural dynamic problems, without the use of complex mathematical relationships.

[3] investigated the feasibility of a SSI- data based approach to separate structural damping from aerodynamic damping. They have used nonlinear regressions instead of linear ones to achieve this. This approach tried to eliminate, to a certain extent, the arbitrariness of the user's decision making. It also dealt with the non-whiteness of the wind excitation. They succeeded in separating structural damping from aerodynamic damping.

A De Vivo et al. [4] implemented Natural Excitation Technique (NEXT) for modal shape identification of large structures like a launcher vehicle for small and medium satellites exposed to wind excitation. Modal parameters obtained are compared with those achieved using Experimental Modal Analysis (EMA). The results showed good correlation. This validated OMA as a reliable tool to analyze dynamic behavior of large structures. Pintelon et al. [5] calculated uncertainty bounds on the estimated modal parameters by means of a simulation and an experiment performed on an ach bridge.

OMA is nowadays used widely in mechanical engineering as well. Kindt et al. [6] performed experimental analysis on a passenger car tire to study structure-bone tyre/road noise due to road discontinuity. The output response of their state-of-the-art experimental setup is used as input to the OMA code LMS Test Lab to extract modal parameters. A laser Doppler vibrometer is used to capture vibration response.

Palanivelu et al. [7, 8] did similar works. They established a procedure to find the modal parameters of a rolling tire using a combination of Finite Element Analysis (FEA) and OMA. FEA software named Abaqus Explicit is used to simulate an experiment of a tire rolling over a straight and an inclined cleat. The vibration response data obtained from these simulations is used as an input to LMS Test Lab.

III. Numerical Analysis

The 3D CAD model of a Launch Vehicle was constructed in Solidworks. The diameter of the model was set as 10.66mm and overall length of the model is 213.21mm. Such as model was selected so that further analysis in ANSYS would be feasible.

Fig 1: Modelling in Solidworks

This model was then imported into ANSYS. Since free-free boundary condition was desired, no boundary condition was specified in the software.

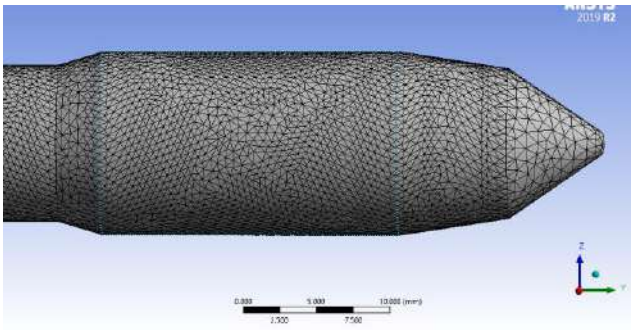

Fig 2: Meshing in SpaceClaim

After importing the model, a mesh was generated in Ansys SpaceClaim. The mesh size was set to a maximum of 0.5mm and 3 noded triangular elements were used. A total of 254604 nodes and 147125 elements was generated while meshing.

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IV. Results and discussions

The computational time of the analysis can be influenced with a change in the number of mode shapes specified. The first twenty-five mode shapes and natural frequencies were obtained. All obtained mode shapes were as expected. Mode shapes 13,19,23 were observed to have breathing mode shape and mode 22 was observed to have a pulsating mode shape. All four mode shapes are plotted here.

Table I: Natural Frequencies of particular mode shapes

Mode	Frequency (Hz)
1	0
2	0
3	0
4	0
5	0
6	0
7	1118.
8	1118.
9	3104.4
10	3104.5
11	6052.7
12	6052.8
13	7160.6
14	9872.9
15	9873.2
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22	23187
23	24421
24	25393
25	25396

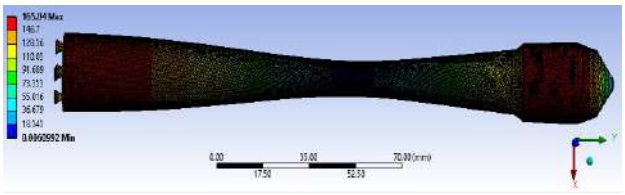

Fig 3: Thirteenth mode shape

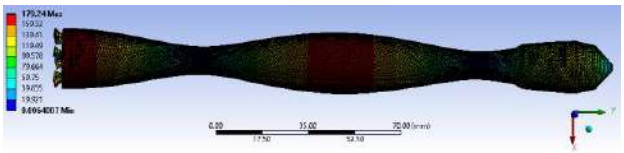

Fig 4: Nineteenth mode shape

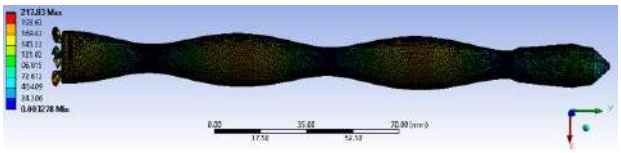

Fig 5: Twenty second mode shape

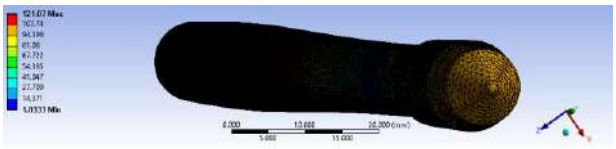

Fig 6: Twenty third mode shape

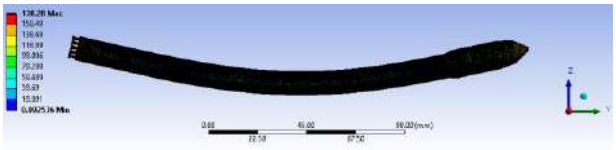

Fig 7: Seventh mode shape

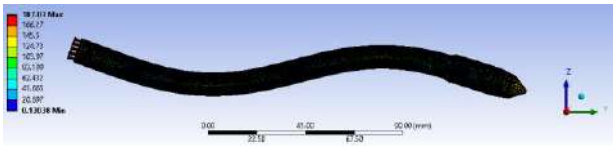

Fig 8: Ninth mode shape

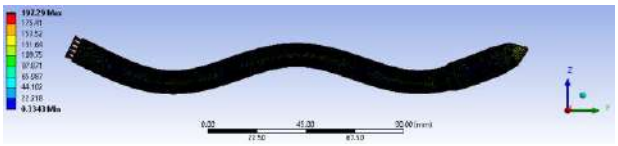

Fig 9: Eleventh mode shape

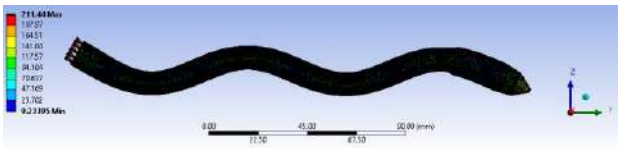

Fig 10: Fourteenth mode shape

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V. Conclusions

The model of a Launch Vehicle was modelled in Solidworks. This model was then imported into the Modal analysis module of ANSYS and meshed with three noded mesh elements of minimum size 0.5mm. After this, modal analysis of the structure was executed.

The first twenty-five mode shapes were successfully plotted. The first six natural frequencies were zero due to the Free-free boundary condition that was applied. These six modes are actually free motion of the model in the 3 spatial directions, viz x, y and z, and rotations about these 3 axes.

Three modes that involve the breathing mode shape are considered here. The thirteenth mode shape with breathing mode and one node occurs at 7160.6 Hz, the nineteenth mode shape with two nodes and breathing mode occurs at 14957 Hz, and the twenty second mode shape with three modes occur at 23187 Hz.

Figures 7,8,9 and 10 represent seventh, ninth, eleventh, and fourteenth mode shapes. All these mode shapes can be easily obtained by conducting 2D modal analysis on a simple cantilever beam. However, in order to obtain the breathing mode shapes as presented above, one needs to model in 3D.

Although these modes occur at very high frequencies, it can be very destructive to sensitive payloads in the cargo hold. High frequency excitation can occur during the launch stage of the rocket, right from lift-off up to Max Q, viz, point of Maximum dynamic pressure.

REFERENCES

[1]. Brian J. Schwarz, "EXPERIMENTAL MODAL ANALYSIS", CSI Reliability Week, Orlando, FL,1999

[2] Peter Avitable, "Experimental Modal Analysis", University of Massachutts Lowell

[3]. Ubertini, F. Hong, A L, Betti, R, Materazzi, A L, "Estimating aeroelastic effects from full bridge responses by operational modal analysis", Journal of Wind Engineering and Industrial Acrodynamics, Vol.99, pp.786-797, 2011

[4]. De Vivo, A, Brutti, C, Leofanti, J L, Modal shape identification of large structure exposed to wind excitation by operational modal analysis technique", Mechanical Systems and Signa Processing, Vol.39, pp.195-206, 2013.

[5]. Pintelon, R, Guillaume, P, Schoukens, J, "Uncertainty calculation in (operational) modal analysis", Mechanical Systems and Signal Processing, Vol.21, pp.2359-2373, 2007.

[6]. Kindt. P, Berckmans D, F Sas, Ramarathnam, K K, "Determination of rolling tyre modal parameters using finite element techniques and operational modal analysis", Mechanical Systems and Signal Processing, Vol.64-65, pp.385-402, 2015

[7]. Palanivelu, S, Narasimha Rao, K V, Ramarathnam, K K, "Determination of rolling tyre modal parameters using finite element techniques and operational modal analysis", Mechanical Systems and Signal Processing, Vol.64-65, pp.385-402, 2015

[8]. Sakthivel, P, Narasimha Rao, K V, Krishna Kumar, R, "Operational Modal Analysis of tyre road interaction using Abaqus Explicit and Operational Modal Analysis", in Proceedings of the ISMA 2012 International Conference on Noise and Vibration Engineering, Leuven, Belgium, September 2012.

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ANALYSIS OF HAND-ARM VIBRATION IN HAND-HELD POWER TOOL OPERATORS

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Abstract— **Hand-held power tool operators experience various health problems associated with hand-arm vibration (HAV). Repeated or prolonged HAV exposures can lead to a group of medical conditions in the hands and lower arms known as Hand-Arm Vibration Syndrome (HAVS). Vibration energy waves that transmit through the body tissues and organs of the operator lead to various critical effects on the body. This work aims to study the prevalence of HAVS among hand-held angle grinder operators. In this study, Standardized Nordic Questionnaire (SNQ) is used to identify the musculoskeletal disorders among the operators. Results indicate that the operators experience more pain at wrists and hands. Number of operators who reduced the work activities is more due to the pain and worsening of their heath. Repetitive works and more exposure to HAV can lead to critical health conditions of these operators. Proper ergonomic interventions can be developed to reduce these vibration exposure based on the magnitude of vibration.**

Keywords—power tools; angle grinder; HAV; HAVS; Standardized Nordic Questionnaire

I. INTRODUCTION

Several hand-held power tools like hand drillers, grinders, hammer drillers and riveters are used in various field of manufacturing [1]. Operators use this power tools for continuous and repetitive works. Angle grinders are commonly used in welding shops for metal making and metal fabrication works. They are hand-held power tools which are attached with consumable stone disks or blades. Such disks or blades spin to grind, polish or cut metals at high speeds. Angle grinders are extremely useful for removing rust, smooth welds, grinding grooves and cutting metals. While working with this power tools, some vibration waves enter to the body through the hands. A long time exposure to vibration in hands may cause disorders to the muscles and skeletons [2]. These disorders may lead to hand-arm vibration syndrome (HAVS) like "vibration white finger". In its advanced stages, white finger syndrome is characterized by a blanching of the finger extremities caused by damage to the arteries and nerves.

In-order to analyze the factors leading to vibration experienced by hand-held power tool operators, a Standard Nordic Questionnaire was developed with a team of Nordic researchers [3]. Their main aim was to make an easy and standardized questionnaire to evaluate disorders in muscles and skeletons of the workers. The results showed that workers experience pain in hands while operating hand-held power tools. Literature shows the effect of hand arm vibration among hand tool operators.

Vergara et al. [6] reported that the levels of vibration produced by tools of the same kind may differ. In this study, an accelerometer was mounted on the hands of the operators handling the power tools for the measurement of vibration. Renolds et al. [7] developed a method for calculating the power transmitted to the hands of the operators who uses the vibrating hand tools. The measurement was done on the chippers and grinder workers who use pneumatic hand tools. Joshi et al. [8] carried out a study on the measurement of hand arm vibration on fastening operations. Two fastening power tools were used. The results determined the number of years required to reach the maximum level of hand arm vibration exposure.

The intensity of the hand-arm vibration is more compared to the whole body vibration. The hand-arm vibration causes severe pain in shoulders and wrists. Continuous exposure to this vibration can lead to disorders in hand-arm muscles and skeletons as well as neurological or vascular disorders [8]. Problems in muscles and skeletons are the primary or secondary signs of hand-arm vibration syndrome (HAVS). Literature explains in detail about the effects of vibration on human body [9].The parameters which are influencing the human body vibration are the duration of exposure, repetitive works and personal factors [10]. The intensity of these factors may lead to the cause of hand arm vibration syndrome. However, in literature, it is not explained about the risk of hand arm vibration among angle grinder operators. Hence this study was concentrated on the factors effecting hand arm vibration in these operators. The objective of the study is to investigate the prevalence of HAVS among angle grinder operators and to identify the important signs and symptoms of HAVS.

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II. SUBJECTS AND METHODS

Angle grinders used in the welding workshops were chosen as the hand-held power tool in this study. Almost all the welding workshop uses angle grinders for the finishing of the joints/work. Operators work with angle grinder in different convenient and inconvenient postures to complete the work. Data were collected from 18 welding workshops in Trivandrum, Kerala. The study participants include 100 male hand-held power tool operators. The participants were aged between 22 and 50 years. The physiological details of the subjects are shown in the TABLE I. The operators considered for this study have a minimum experience of two years.

TABLE I. DEMOGRAPHIC DETAILS OF SUBJECTS

Basic Statistics	Variables			
	Age (years)	Experience (years)	Height (cm)	Weight (Kg)
Mean	32.4	30.1	161.2	71
Standard Deviation	6.8	5.7	4.04	5.5
Range	22-50	2-15	154-175	55-85

The Standardized Nordic Questionnaire consists of multiple choice questions including the basic characteristics of the subjects such as height, weight, experience etc. Questions were based on the pain in mainly nine parts of the body (elbows, shoulders, neck, wrists/hands, lower back, upper back, knees, hip/thighs and ankles/feet). The questions were based on severity, symptoms and prevalence of pain experienced by the subjects. Also the questions deal with numbness, tingling or dullness in the fingers, palms or feet. In-order to know their current health condition, questions based on the symptoms was also included. A body map that shows the important anatomic regions of risk was used for the collection of data (Fig.1). Structured interview was conducted among the angle grinder operators with the help of the questionnaire.

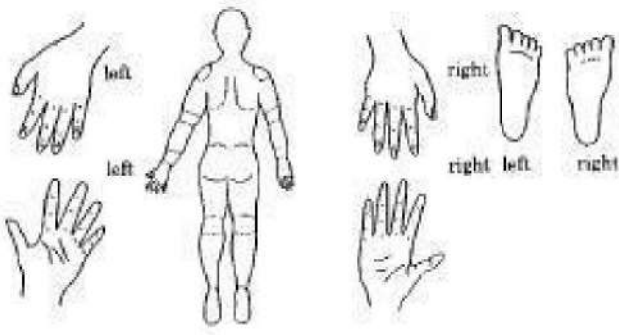

Fig.1. Body map for marking the pain experienced [1]

III. RESULTS AND DISCUSSIONS

Results of data collected using the standardized Nordic questionnaire is presented in this section. The prevalence of pain reported by the angle grinder operators is shown in the Fig. 2. The operators experienced more pain at wrists/hands compared to other body parts. The prevalence of pain at shoulders, elbows and low back of the operators indicated a higher value while working in different postures. The angle grinder operations with uncomfortable working postures may be the reason for this higher risk at body parts.

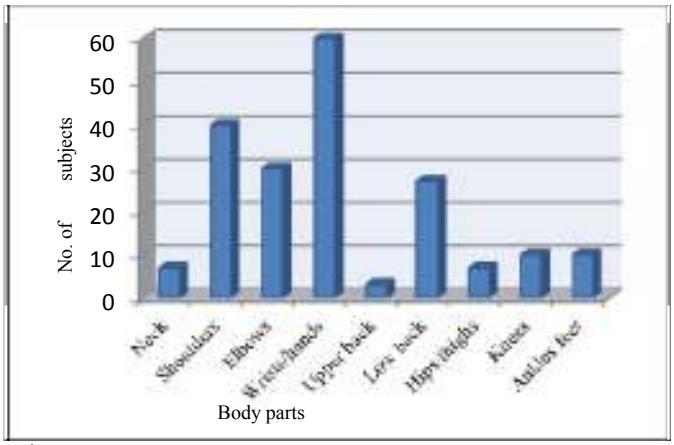

Fig.2. Prevalence of pain among angle grinder operators

The occurrence of musculoskeletal symptoms for a period of one year among angle grinder operators is shown in the Fig.3. The operators experienced more pain at wrists and hands during the last one year. The operators had pain in the joints, bones, muscles, ligaments and tendons. These symptoms may become intense with the duration and severity of vibration exposure.

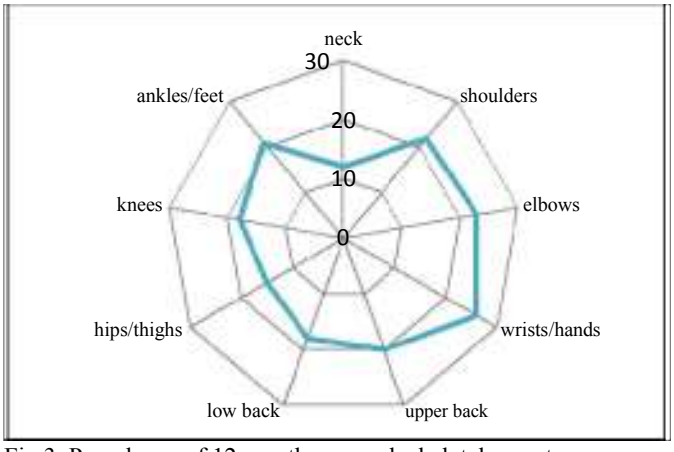

Fig.3. Prevalence of 12 months musculoskeletal symptoms

The number of subjects who distorted jobs, decreased job and free time activities and who were hospitalized due to symptoms of muscles and skeleton disorders are shown in the Fig.4. Also the number of subjects who left the work activities is more due to the pain. The operator's leisure activities are also reduced.

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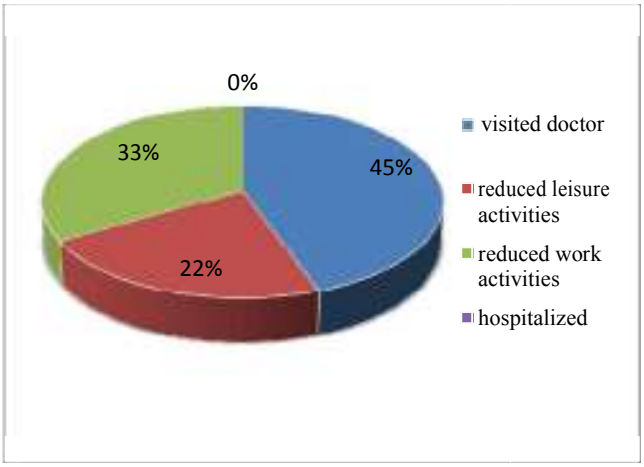

Fig. 4. Severity of troubles among angle grinder operators

Using vibrating hand tools for a long time may result in a condition of vibration syndrome called phenomenon of Reynaud. Numbness of fingers is a common indication, caused by vibration sensitivity, which continues for a long period [11]. Blanching of finger is often another symptom where chronic exposure tends to occur. Early identification is important to prevent the disease from becoming critical.

The SNQ can be modified with a few more questions to review the symptoms of finger numbness and blanching of the finger to be relevant to workers bare to hand-arm vibration [8]. It can also include questions regarding the length of the symptoms over the last one year. It should also include questions about the severity of symptoms in terms of their effect on work and leisure actions, as well as the overall period of symptoms and ailing leave during the previous one year.

The results from the qualitative analysis done by using the questionnaire reveal the parameters which causes the vibration. It also explains the importance of conducting this study. The major region in the human body which was affected by the vibration was found out by this analysis. Hand arm vibrations are more prominent than the whole body vibrations [12]. The regions which are affected by the pain are wrist, elbow and shoulders.

Compared to the results obtained from the done in [2], it is found that the angle grinder operators experience more pain in the wrists and hands. Analyzing the prevalence of vibration disorders among angle grinders revealed that the operators reported pain mainly in the hand-arm regions. The number of operators complaining about the numbness in finger is decreasing. But the symptoms leading to HAVS are experienced by the operators while working. So it is very important to pay attention to avoid these symptoms. Preventive measures have to be adopted to maintain better health conditions of the workers in the field of welding.

IV. CONCLUSION

Several studies have been done for analyzing the effects of vibration in grinding machines for long term works. This study focus on the operators of angle grinder, those who have a minimum of two year experience. The results obtained from this study show that the angle grinder operators experience more pain in the hands and wrists. These operators also have to work in different postures which may be uncomfortable for them. This study can be extended to do the measurement of hand-arm vibration magnitude among these operators.

Different postures of the operators may be considered while working with the angle grinder. So that it will help to find out the optimal working posture for the operators. This study of HAV would provide necessary information for the reduction of HAV symptoms and musculoskeletal disorders. Also to provide more comfortable, safer and healthier work conditions for the hand-held power tool operators. The findings of this study suggest that evidence exists for the presence of HAVS among angle grinder operators. The key signs and symptoms are hand numbness, hand ache, headache, and the irregular vibration sensation rate and the frequency of these signs and symptoms increases with the number of years of work and the daily exposure amount. Additionally, operators should be equipped with more safe operating procedures for occupational HAV exposure. A future study conducted among a larger population of angle grinder operators will enable them to develop better health and safety programs.

REFERENCES

[1] J.E Hansson and S. Kihlberg, “A test rig for the measurement of vibration in hand-held power tools”, Applied Ergonomics,1983, pp.11-18.

[2] O. Kaewbooncho, H. Yamamoto, N. Miyai, S.M Mirbod,I. Morioka, and K. Miyashita. “The standardized nordic questionnaire applied to workers exposed to hand- arm vibration”,Journal of Occupational Health,1998, 40, pp. 218-222.

[3] K.T Palmer, M.J.Griffin, and Holly Syddall,. “Risk of HAVS according to occupation and sources of exposure to hand-transmitted vibration: a National survey”, 2001, 39 , pp. 389-396.

[4] L.Burstrom, R.Lundstrom, and M.Hagberg, “Comparison of different measures for HAV exposure”, 2000, 28, pp. 3-14.

[5] V Margarita, J.L Sancho, P. Rodriguez, and A.P Gonzalez, “Hand-Transmitted vibration in power tools: Accomplishment of standards and user’s perception”, International Journal of Industrial Ergonomics, 2008, 38, pp. 652-660.

[6] D D Reynolds, R. Basel, D E Waserman, and W Taylor (1984),”A study of hand vibration on chipping and grinding operators,part iii:power levels into the hands of operators of pneumatic tools used in chipping and grinding operations”, Journal of Sound and Vibration, 1984, 94(4), pp. 515-524.

[7] A. Joshi, M. Leu, and S. Murray, “Ergonomic analysis of fastening vibration based on ISO Standard 5349-2001”, Applied Ergonomics, 2001, 43, pp. 1051-1057.

ISBN 978-93-89105-41-4

[8] L.M.Roseiro, Maria F, Paulino, and Maria A Neto,n, “Analysis of Hand arm vibration syndrome in drummers”, 2018, 66, pp. 110- 118.

[9] S.Maedaa, M.D.Taylorb, L.C. Andersonc, J. Mc Laughlinc, “Determination of hand- transmitted vibration risk on the human”, 2019,70, pp 61-65.

[10] X.Xu, Z. Yuan, M. Gong, L. He, R. Wang, J.Wang, Q. Yang and S.Wang, “ Occupational hazards survey among coal workers using hand-held vibrating tools in northern China coal mine”, International ournal of Industrial Ergonomics,2016,pp.1-6.

[11] T.W McDowell, X.S Xu, C. Warren, D.E Welcome, R,G Dong, “The effects of feed force on rivet bucking bar vibration”, International Journal Of Industrial Ergonomics,2018, pp.145-158.

[12] D.Suiqi, Xiong Xingfu, W. Wenhua, “The analysis of hand drill security psychology design”, Procedia Engineering, 2011, pp. 4461-4464.

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FRICTION AND WEAR CHARACTERISTICS OF RCO DERIVED BIODIESEL

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ABSTRACT

The interest in using biofuels for power generation and transportation has seen a massive increase in recent years due to the growing energy safety and environmental concerns. In the coming years, it is projected that the use of non-fossil fuels will continue to grow. In India, the national policy on bio-fuels aims to increase the usage of biofuels in the energy and transportation sectors of the country during the coming decade. A major aim of the policy is to increase the blending percentage of biodiesel with mineral diesel. Currently, the biodiesel blending percentage in diesel is less than 0.1%. An indicative target of five percent blending of biodiesel in diesel is proposed by 2030. However, increased use of these fuels on a long term basis in current IC engines without any modifications is a cause for concern. Various concerns associated with using biodiesel and its blends in engines have been reported. They include higher emission of nitrogen oxides, high viscosity, high density, inherent unsaturation, lower volatility, tendency to absorb water, oxidative instability etc. This research tries to address the concerns regarding oxidative instability of biodiesel and its subsequent effects on fuel lubricity. The oxidative stability of biodiesel is worse than diesel. This is a significant problem in the industry because it affects the quality of the fuel and the materials in contact with it. In this study, the lubrication behavior of oxidized and pure biodiesel blends is investigated using a four-ball tribometer. Friction characteristics were compared for biodiesel, oxidized biodiesel, and various blends. Resulting wear scars were quantified using optical microscopy. Elemental analysis of fuel was carried out through gas chromatography-mass spectroscopy to determine any compositional changes that might affect the lubricity of the fuel. Highest wear and friction was observed in diesel. Friction, deformation, and wear decreased as the biodiesel blend percentage increased. Oxidized biodiesel blends showed a better reduction in friction and wear compared to pure biodiesel and diesel. It was also noted that the lubricity of oxidized biodiesel decreased as its concentration increased in the blend.

Keywords— Biodiesel; Lubricity; Oxidation.

I. INTRODUCTION

A major factor affecting engine life is the lubricity of the fuel being used. In addition to the ability of the fuel to reduce energy consumption by reducing the friction between moving parts, it has the additional responsibility of lubricating the fuel injectors and high-pressure fuel pumps in automobile engines (Serrano et al. (7)). Although every fuel has its inherent lubricity, its performance is influenced by the temperatures it experiences(Sarvi et al. (15)). Biodiesel possesses better lubrication properties than diesel fuel. In fact, some researchers (Dave et al(16)) have suggested biodiesel can be used as an additive to increase the lubricity of diesel fuel.

Numerous studies have been conducted to assess the tribological characteristics of biodiesel derived from various sources using tribometers. Many results indicate that wear and friction decrease with increasing biodiesel concentration. Masjuki et al. (1) used steel ball bearings in a four-ball wear testing machine to assess the tribological characteristics of biodiesel derived from palm oil with different loads at 1500 rpm and at ambient temperature for a test duration of 1 min. It was reported that biodiesel worked as an additive and improved the overall lubricity of the fuel. Tribological properties of rapeseed oil derived biodiesel were studied by Sulek et al. (2) by using high-frequency reciprocating rig tribometer and it was observed that all biodiesel blends produced lower friction coefficient compared to diesel fuel

Fazal et al. (3) investigated the friction and wear characteristics of palm biodiesel at different blend percentages by using four-ball tribometer at 75^0C under a normal load of 40 kg for 1 h at four different speeds, viz., 600, 900, 1200, and 1500 rpm. Both wear and friction decreased inversely with biodiesel concentration and rotating speed. Mosarof et al. (4) studied the tribological characteristics of diesel, Calophyllum inophyllum derived biodiesel, palm biodiesel, and their blends using a four-ball tribotester under varying temperatures and loads. They reported that a 20% blend of biodiesel exhibits lower wear when compared with pure diesel and other blends. Habibullah et al. (5) also studied the friction and wear characteristics of Calophyllum inophyllum biodiesel. They also found that a 20% blend displayed the best lubricity.

Haseeb et al. (6) studied the effect of temperature on the tribological performance of palm biodiesel using a four-ball wear machine. Tests were conducted at varying temperatures, under a constant load of 40 kg for 1 h at speed 1200 r/min. It was observed that friction was proportional to increasing temperature. Also at higher test temperatures, it was indicated that biodiesel gets oxidized. Fazal et al. (3) also reported some major issues related to the use of biodiesel like oxidation, moisture retention, and corrosiveness.

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Thus even though biodiesel has good lubricity compared to diesel it is also subject to various other issues that have a negative impact on its tribological properties. More research is needed in this area to evaluate the effect of these issues on the tribological characteristics of biodiesel to enable its wider use in engines. One major concern addressed in this research is the tendency of biodiesel to get oxidized, which can result in changes in its chemical composition, thereby affecting friction and wear characteristics leading to tribological issues.There is no literature available regarding the oxidative stability of RCO derived biodiesel. In this investigation, the lubrication behavior of oxidized and pure biodiesel blends is studied using a four-ball tribometer.

II. EXPERIMENTAL DETAILS

Biodiesel(B100) derived from rendered chicken oil(RCO) was provided by Kerala Veterinary and Animal Sciences University(KVASU). Biodiesel was produced at the School of Bio-Energy and Farm Waste Management at KVASU through a two-step process: acid-catalyzed esterification of free fatty acids followed by base-catalyzed transesterification of triglycerides using transesterification process. (John et al(8)).The produced biodiesel complied with Indian biodiesel specifications. A magnetic stirrer (ROTEK) was utilized to prepare blends of biodiesel and oxidized biodiesel. Different blends were prepared with volume concentrations of biodiesel at 10% (B10), 20% (B20), 30% (B30),50% (B50) and 100% (B100). Biodiesel was heated on electrical heaters at 75 °C for 2 h to oxidize and oxidized biodiesel blends (OxB10, OxB20, OxB30, etc) were prepared using the same methodology.

A four-ball tribotester (TR30L, Ducom, India) was used to determine the lubrication properties of various blends of biodiesel. This tribotester is widely used in the lubricant industry to determine the lubrication characteristics of greases and oils (Zulkifli, et al. (9)), but it has been used by researchers (Fazal, et al. (3)), (Haseeb, et al. (6)) to investigate the tribological characteristics of diesel fuel. A schematic diagram of the device is shown in Figure 1. Details of the four-ball tester are shown in Table 1.

The steel balls utilized for the test were constituted of carbon chromium alloy steel with a surface roughness of 0.1 μm and hardness of 62 HRc. The four balls are placed in the tester in such a way that an equilateral tetrahedron is formed. Three fixed steel balls were kept in a steel oil cup. A collet at the base of a constant speed vertical spindle holds the fourth ball. This upper ball is in three-point contact with the other three balls when it is rotated against them. Different loads can be applied to the balls and the frictional torque exerted on the three lower balls can be recorded. The steel balls were cleaned with toluene and thoroughly dried. 10 ml of test fuel was filled into the oil cup till it covered the three balls to at least 3mm depth. The test parameters were formulated based on ASTM D4172 used for the evaluation of the anti-wear properties of fluid lubricants. The test conditions of 1200 rpm, runtime of 1 hour, and constant 40 kg load match the standard with the exception of temperature, which was maintained at ambient. After each test, the three bottom balls were collected to measure its wear scar diameter and conducting SEM/EDX analysis. The changes in the chemical composition of fuel were analyzed by gas chromatography-mass spectroscopy (GCMS).

Table 1:Details of the four-ball tester (TR30L, Ducom)

Specification	Unit	Description
Test speed	rpm	300-3000
Test load	N	100-10000
Frictional torque	Nm	0-16
Temperature	^{0}C	Ambient to 120
Power	V/Hz/ ∅	415/50/3
Test ball(dia)	mm	12.7

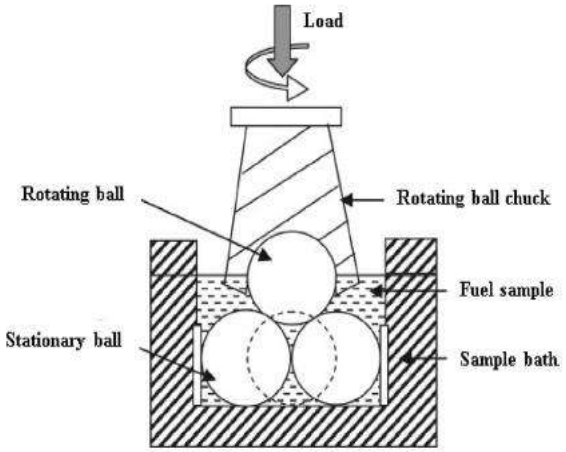

Figure 1: Schematic diagram of a four-ball tribometer (Adapted from Fazal et al(3))

III. RESULTS AND DISCUSSION

The coefficient of friction was calculated from the mean friction torque recorded by the four-ball tester. The friction torque measured by a load cell is multiplied by the spring constant to obtain the coefficient of friction.

$$\mu = \frac{T\sqrt{6}}{3Wr}$$

where μ is the coefficient of friction, T is the frictional torque (Kg-mm), W is the applied load (N) and r is the distance from the center of the contact surface on the lower balls to the axis of rotation, which was found to be 3.67 mm.

The friction torque came to a steady-state after a few minutes from the start of the test for all fuels The highest coefficient of friction for all fuels tested was observed for diesel. A general trend observed was that the coefficient of friction decreases with the increase of biodiesel concentration in the blend. Low friction coefficients were also observed for pure and oxidized biodiesel blends. The ability to maintain a steady lubricant film between the contacting metals is a requirement of a good lubricant Biodiesel is expected to provide good lubricity due to their inherent ester component and the presence of long-chain fatty acids. The hydrocarbon chain of fatty acids provides a sliding surface when the ester end of the chain adsorbs to the

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metal surface layer thereby permitting a thin film to form with the hydrocarbon end of fatty acids facing outwards from the metal surface. This stops direct metal to metal contact (Sharma, et al(10)). The absence of lubrication may result in increased temperatures at the contact points of moving parts causing adhesion and scuffing. As the concentration increases in the blend, biodiesel provides better lubrication performance. In all testing conditions, the friction and wear of biodiesel lubricated surface are consistently lower than that of diesel as shown in Figures 2 and 3.As the biodiesel blend percentage increases the wear scar diameter (WSD) decreases. Greater WSD is observed in diesel fuel. Every biodiesel blend yields lesser WSD compared with diesel. The decreasing trend in the WSD of biodiesel is inversely proportional to the blend percentage. The friction coefficient and wear are reduced as a result of the development of the covering layer of adsorbed biodiesel molecules on the steel surface. This results in reduced wear scar surfaces compared to that of diesel.

In oxidized biodiesel and blends, the WSD decreases until OxB30, and an increase is subsequently observed.OxB100 shows a higher scar diameter compared with OxB30 and Ox B50.Fig.ure 4 displays the graphical representation of the WSDs of diesel, biodiesel, oxidized biodiesel, and blends. A pronounced increase is observed with the addition of oxidized B50. The reduction in the wear scar diameter for oxidized B50 compared to lower blends can be attributed to a change in wear regime from adhesive to abrasive wear. The decrease in friction and wear characteristics for oxidized biodiesel is greater than pure biodiesel up to oxidized B30. During the oxidation of biodiesel, epoxides, ketones, and polymers are produced. This increases the viscosity of biodiesel since these are of higher molecular weight and this, in turn, enhances the lubricity of biodiesel.(Fox et al(11)).It has also been reported (Pereira et al(12)) that biodiesel becomes more polar and hence more affinitive to the metal as the by-products of oxidation absorb even more oxygen. Further, the formation of an oxide layer on the metal contact surfaces contributes to a reduction in wear.

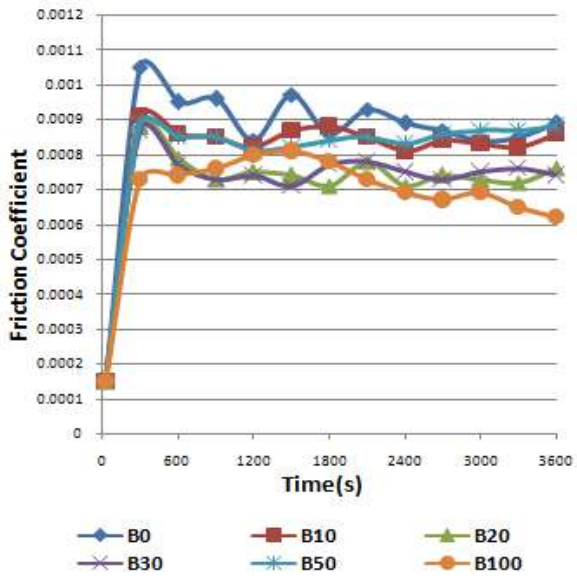

Figure 2: Coefficient of friction for biodiesel blends

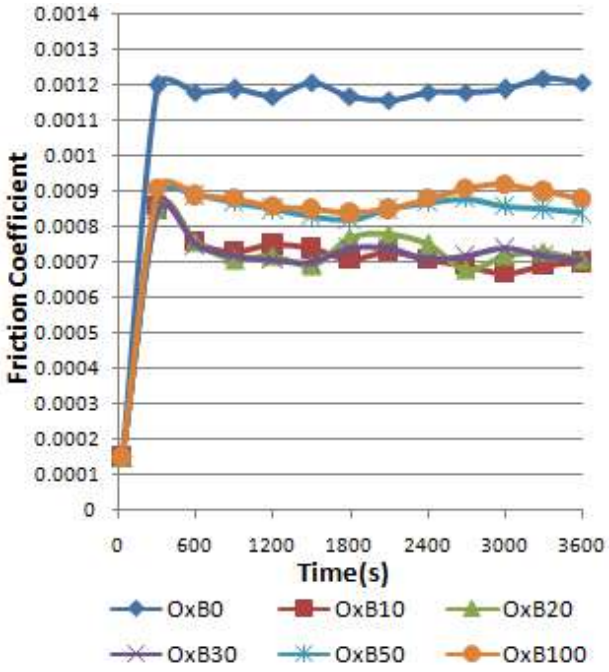

Figure 3:Coefficient of friction for oxidized biodiesel blends

In higher blends of oxidized biodiesel, we can observe an increase in friction and wear characteristics. This could be due to the formation of transitional oxidative compounds that increase wear. The formation of corrosive acids during oxidation increases wear. (Wu et al(13)) The presence of dark spots on the contacting metal surfaces denotes the presence of oxidative corrosion. However, the wear observed in oxidized biodiesel is lesser than that of pure diesel.

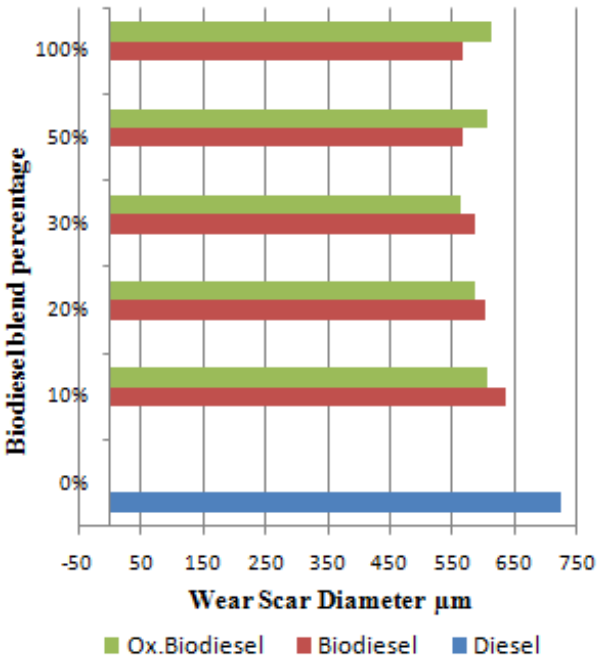

Figure 4:Wear scar diameter for diesel, biodiesel, oxidized biodiesel and various blend

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Table 2:Chemical constituents of biodiesel and oxidized biodiesel from GCMS

Fatty Acids	B100	B100 after exp	OB100	OB100 after exp
Oleic 18:1	44.12	33.35	31.93	33.10
Palmitic 16:0	23.56	21.35	19.44	26.89
Linoleic 18:2	14.64	13.63	4.54	2.56
Palmitoleic 16:1	6.40	7.45	5.40	3.79
Stearic 18:0	7.32	9.50	3.85	1.24
Lauric 12:0	0.68	0.58	2.78	2.94
Linolenic 18:3	1.38	1.25	0.21	0.10
Myristic 14:0	0.78	3.45	2.56	5.87

The composition and hence properties of biodiesel derived from animal fats are mainly influenced by constituent fatty acids and their degree of unsaturation. They have a major influence on the wear and friction characteristics of the fuel.(Geller et al(14)) GCMS analysis (Table 2) indicates that the main constituents of RCO derived biodiesel are methyl oleate(18:1, 44.12%) methyl palmitate (16:0; 23.56%) and methyl linoleate (18:2,14.64%) esters.This is in agreement with the reported literature. Other dominant components found in the analysis include palmitoleic acid (6.40%) and stearic acid (7.32%). Table 2 shows the changes in major constituents of biodiesel and oxidized biodiesel before and after conducting the four-ball experiment. It was observed that the concentration of unsaturated fatty acids decreased upon oxidation. This could negatively impact the lubricity of the oxidized fuel and thereby affect its performance

IV. CONCLUSIONS

The following conclusions can be derived from this experimental investigation:

Both wear and friction decreased with increasing blend percentages of biodiesel. Oxidized biodiesel blends exhibited a decrease in wear scar diameter up to OxB30 and then increased with increasing blend percentages.

However, they were still lesser than the wear scar diameter of pure diesel. For blending, percentages of less than 40 oxidized biodiesel demonstrated up to a 20% reduction in wear scar diameter when compared to corresponding biodiesel blends. The wear scars indicate a reduction in surface deformation with an increasing biodiesel blend. However higher blends of oxidized biodiesel revealed increased surface wear. This was evident from the presence of dark spots, which might have developed due to the formation of corrosive acids and due to oxidation.

The compositional analysis revealed the differences between oxidized and pure biodiesel with various blend percentages. These compositional differences might have a major influence on the lubricity of the fuel. Higher blends of oxidized biodiesel showed a negative impact on tribological performance in this short term test. It is necessary to develop additives to counter the adverse effects of oxidation on tribological characteristics.

V. ACKNOWLEDGMENTS

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VI. REFERENCES

[1] Masjuki, H., Maleque, M., Kubo, A. and Nonaka, T. (1999), Palm oil and mineral oil-based lubricants:their tribological and emission performance, Tribol Int 32, 6, pp.305-314

[2] Sulek, M. W., Kulczycki, A., and Malysa, A. (2010), Assessment of lubricity of compositions of fuel oil with bio components derived from rape-seed,Wear 268, 1–2, pp.104-108.

[3] Fazal, M., Haseeb, A., Masjuki, H., 2013. Investigation of friction and wear characteristics of palm biodiesel. Energy Convers. Manage. 67, 251–256.

[4] Mosarof.M.H,Kalam,M.A,Masjuki.HH,Habibullah M,Arslan, A. and Monirul, I. M. (2016), Assessment of friction and wear characteristics of Calophyllum inophyllum and palm biodiesel, Ind Crop Prod 83, pp. 470-483

[5] Habibullah, M., Masjuki, H. H., Kalam, M. A., Zulkifli, N. W. M., Masum, B. M., Arslan, A. and Gulzar, M. (2015), ―Friction and wear characteristics of Calophyllum inophyllum biodiesel,‖ Ind Crop Prod 76, pp. 188-197.

[6] Haseeb, A.S.M.A., Sia, S.Y., Fazal, M.A., Masjuki, H.H., 2010. Effect of temperature on tribological properties of palm biodiesel. Energy 35, 1460–1464.

[7] Serrano,L.M.V.,Câmara, R.M.O., Carreira, V.J.R., Gameiro da Silva, M.C., 2012.Performance study about biodiesel impact on buses engines using dynamometer tests and fleet consumption data. Energy Convers. Manage. 60,2–9.

[8] John Abraham and Ramesh Saravan Kumar, "Biodiesel Production from Broiler Chicken Waste", World Academy of Science, Engineering and Technology International Journal of Biological, Biomolecular, Agricultural, Food, and Biotechnological Engineering Vol:9, No:12, 2015.

[9] Zulkifli, N. W. M., Kalam, M. A., Masjuki, H. H., Shahabuddin, M. and Yunus, R.(2013), ―Wear prevention characteristics of a palm oil-based TMP (trimethylolpropane) ester as an engine lubricant, Energy 54, pp. 167-173.

[10] Sharma BK, Doll KM and Erhan SZ. Ester hydroxy derivatives of methyl oleate: tribological, oxidation and low-temperature properties. Bioresour Technol 2008; 99: 7333–7340.

[11] Fox NJ and Stachowiak GW. Boundary lubrication properties of oxidized sunflower oil. Lubric Eng 2003;59: 15–20.

[12] Pereira GG, Marmesat S, Barrera-Arellano D, et al. Evolution of oxidation in soybean oil and its biodiesel under the conditions of the oxidation stability test. Int J Fats Oils 2013; 64: 482–488.

[13] Wua Y, Li W, Zhang M, et al. Oxidative degradation of synthetic ester and its influence on tribological behavior.Tribol Int 2013; 64: 16–23.

[14] Geller, D. P., and Goodrum, J. W. (2004), Effects of specific fatty acid methyl esters on diesel fuel lubricity, Fuel 83, 17, pp. 2351-2356.

[15] Sarvi, A., Fogelholm, C.-J., Zevenhoven, R., 2008. Emissions from large-scale medium-speed diesel engines: 2. Influence of fuel type and operating mode.Fuel Process. Technol. 89, 520–527.

[16] Dave, H., Stoldt, S.H., 1998. Esters derived from vegetable oils used as additives for fuels. Google patents.

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Comparative Study on Application of Hybrid Algorithms for Portfolio Optimization

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***Abstract*—Portfolio optimization models are of great importance for the investors in making safe investments with high returns in the form of stocks and bonds. Markowitz portfolio model is the most commonly used method for finding best solutions for portfolio management problems, which is based on a number of assumptions. The traditional Markowitz mean-variance model has been extended over the recent decades to incorporate the tracking-error, active share and asset cardinality constraints for overcoming the limitations of the traditional Markowitz model. The newly formed portfolio management problems were complex and therefore difficult to solve. So the requirement of robust algorithms for solving complex portfolio optimization problems became necessary which lead to the study of application of various nature-inspired algorithms and hybrid algorithms in financial modeling. The main objectives of this paper are to study the scope of various hybrid algorithms as well as to propose a hybrid model involving the ant colony optimization (ACO) and genetic algorithm (GA) for solving complex portfolio optimization problems.**

Keywords—Portfolio Optimization; Markowitz Portfolio Model; Nature-Inspired Algorithms; Ant Colony Optimization; Genetic Algorithm

I. INTRODUCTION

In the modern era, investment became an attractive prospect in the condition that income is derived from unused capital or money. Investments are, however, also very risky; high risk of loss or failure will follow with great profit expectations. Investors will typically consider the risk and make their choices based on some risk level intervals. Many buyers, though, will not make high-risk investments, even if it is expected to deliver a big profit. Experts have suggested some methods and study because of investment management but further work is needed to determine a better outcome. Portfolio optimization is one of the most common types of investments, including the collection of the best financial assets to deliver the highest return and the lowest risk. Diversification is a common way of reducing risk. The concept of diversification is to split investment from different firms. If some of the shares held suffered a decline, the others wouldn't reduce profits. Industries, economies, asset forms and so on can contribute to diversification. One of the world's most popular theories about portfolio optimization is the mean-variance theory proposed by Harry Markowitz [1]. The portfolio optimization problem is defined as a constrained issue of profit maximization. It is defined as the estimated return of portfolio (net of investment and funding cost) minus the risk costs by traditional terminology of portfolio utility functions. The latter, risk prices are the risk management exposure compounded by the parameter of risk reduction (or the price unit of risk present). Practitioners also add additional restrictions to increase diversification and reduce more risk. The stock, sector and national portfolio weight limits are examples of such restrictions. Portfolio optimization occurs mostly in two stages: weight optimization of asset classes to be carried, and weight optimization of assets within the same asset class. One example of the former would be to select the right equity and debt ratios and one example of the latter would be to select stock sub-portfolio ratios of stocks X, Y, and Z. Equities and bonds have essentially different financial characteristics and distinct operational uncertainties, and can therefore be considered as independent asset groups; having some of the portfolio in each class gives some diversification, and holding different specific assets in each class provides more diversification. By using such a two-step method, one reduces non-systematic threats on both the asset and asset class level. Another approach to portfolio optimization is to determine a von Neumann – Morgenstern utility function defined over the wealth of the final portfolio; the estimated utility value should be maximized. This target function is growing in wealth to reflect a desire for higher rather than lower returns, and is concave to reflect aversion to risk. This method, while technically the most defensible, can be computationally intensive for practical utility functions in the face of many properties which can be carried.

Harry Markowitz [1] has developed the "critical line method" a general quadratic programming methodology capable of meeting certain linear constraints on holdings and the upper and lower boundaries. The technique also provides a method for calculating the entire range of profitable portfolios.

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. It was explained later on by William Sharpe. The Markowitz portfolio model has evolved over the recent decades in such a way to overcome the drawbacks of the traditional model. Additional constraints were incorporated in the modern Markowitz portfolio model to improve diversification and limit the risk further. The newly formed optimization problems were complex and hence their solving became difficult using traditional algorithms. Financial practitioners were in search of alternate algorithms having robust features and better problem solving abilities, this lead to the study of application of various nature inspired algorithms and modern hybrid algorithms in the field of financial modeling.

Nature-inspired algorithms like Firefly Algorithm (FA), Particle Swarm Optimization (PSO) algorithm, Artificial Bee Colony (ABC) algorithm, Ant Colony Optimization (ACO) algorithm, Genetic Algorithm (GA) etc. finds an extensive application in the field of financial modeling and optimization problems. These algorithms overcome some of the drawbacks of traditional Markowitz portfolio model and hence they can be used as an alternate algorithm for finding solutions for complex portfolio management problems. Hybrid algorithms are the combination of various optimization techniques which can be either nature-inspired algorithm or logic based algorithm. Some of the examples of hybrid algorithms that can be used for solving portfolio management problems are the combinations of:

- K-means clustering and ACO
- Generative Adversarial Networks (GAN) and Mathematical Programming (MP)
- Firefly Algorithm (FA) and Imperialist Competitive Algorithm (ICA)
- PSO and Hopfield Neural Network (HNN)
- Self-Organizing Maps (SOM) clustering and GA

II. Literature Review

Literature review focuses on summarizing previous reports published, that are relevant and supportive to the overall improvement in knowledge about on Markowitz mean-variance portfolio model, nature-inspired algorithms and hybrid algorithms for financial data modeling.

A. Markowitz Mean-Variance Portfolio Model

Harry Markowitz [1] proposed a new portfolio selection model which provided theoretical framework for risk and return analysis and their interrelationships. It used the statistical analysis in an efficient manner for risk assessment and mathematical programming for asset collection in a portfolio. This concept contributed to the idea of portfolio efficiency. An optimal portfolio is supposed to yield the maximum return for a given risk level, or the least risk for a specified return level. In a given amount of money or property, Markowitz created a variety of investments, and provided investor expectations for risk and return. Individuals vary widely in their expectations for risk tolerance and properties. Their criteria for the means, cost and income differ from individual to individual. The fund collection, despite the interests, is not a simple choice of any stocks or bonds, but a suitable mix of securities.

M. Ivanova and L. Dospatliev [2] explained about the application of Markowitz mean-variance model on Bulgarian stock market. The paper gives a brief idea about the various features of traditional Markowitz portfolio model. The data being used are the weekly closing prices of 50 stocks traded between January 2013 and December 2016 on Bulgarian Stock Exchange. In addition to three optimal portfolios (maximum portfolio return for a given level of risk, minimum risk portfolio and maximum Sharpe ratio portfolio) the efficient frontier was developed using the Markowitz portfolio theory. It was pointed out that Markowitz model's efficient portfolios performed better than any other domestic individual security during the period of study. Such ideal portfolios function as a choice for Bulgarian investors, maximizing the rate of return on portfolios with regard to their risk preferences.

M. Radović, S. Radukić and V. Njegomir [3] studied about the application of the Markowitz's portfolio model in forming efficient portfolio on the capital market in the Republic of Serbia. This research was based on previous theoretical and empirical research already done in the world. Statistical methods for evaluating the return and risk, variance matrix and co-variance by add-in software solver included in the Microsoft Excel package, consistent with Markowitz model limitations. The results of the analysis showed that the set of efficient portfolios can be formed, which fulfills the criterion that they give minimal risk for the return given on the capital market in Serbia. The results showed that the Markowitz model allows investors to choose an efficient portfolio, but only for liquid securities, depending on the risk they are willing to accept. The findings of this paper suggested that the descriptive illiquidity on the Serbian market and the inadequate number of shares for diversification by sector make it difficult for the research results to be implemented in practice.

Ihsan Kulali [4] explained about the portfolio optimization using the Markowitz mean-variance portfolio model. In this work, Markowitz portfolio model was applied on the Istanbul Stock Exchange (BIST).They analyzed 252 days of data corresponding to the year 2015. First, a conceptual portfolio was developed that contained ten equally weighted stocks. To reduce portfolio risk they were selected from three different industries. Yet the total number of shares alone was not enough to form a well-diversified portfolio. This model takes into consideration a connection between the rates of return on assets invested in portfolios. They adopted the empirical analysis mean-variance approach, and they developed several portfolios. The formula has been modified here as a least deviation from a given expected rate of return. Investors can opt for either of these as their risk priorities. Eight assets with different weights create an optimum portfolio, because they are all efficient. It has delivered better returns compared with a portfolio of ten equal-share stocks.

B. Hybrid Algorithms for Financial Data Modelling

A. Brabozan and M. O'Neill [5] performed a research on the subject of biologically inspired financial modeling algorithms, where they provide a various array of biologically based algorithms along with their financial modeling implementations. It is split into 3 parts, which contains a total of 21 pages. The first, Part I, provides short introductory descriptions of three types of Artificial Neural Networks (multi-layer perceptron-MLP, self-organizing maps and radial-based process network), evolutionary computational algorithms

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(GA, differential adaptation, genetic engineering, and variations of MLPs), artificial immune systems and social systems (ant colony simulations, particle swarm simulations and their MLP hybrids). Part II is the smallest of the three which concentrates on the stock trading systems development. Topics of discussion spread from targets determination and the data collection to develop design and its validation. A brief chapter is dedicated for the technical analysis of equity market. Part III contains several case studies. Most of them examine stock market index forecasts, some cases focus on stock returns and price estimates, and the remaining others discuss exchange rate forecasting, business loss and bond ratings. This tracks their potential as templates for financial-market assessment and classification techniques. Few lines of programming tools are given in the last chapter.

W. T. Lin and G. F. Deng [6] undertook a research on the topic of solving Markowitz mean-variance portfolio model using Ant Colony Optimization (ACO) algorithm. This paper introduces ACO, which was initially proposed as a meta-heuristic framework portfolio optimization to solve the Markowitz mean-variance model constraints (nonlinear mixed quadratic type programming problem). For analyzes, the weekly price data and numerical solutions were obtained for the following indices over the period from March 1992 to month of September 1997: Hang Seng 31 in Hong Kong, , Nikkei 225 in Japan FTSE 100 in the UK, DAX 100 in Germany and S&P 100 in the USA. The model results show that the ACO algorithm is much more effective and reliable than the Particle Swarm Optimization (PSO), particularly for portfolios with reduced risk investments.

S. Abolmaali and F. R. Roodposhti [7] conducted a case study on the Tehran stock exchange was performed on the subject of portfolio optimization using ant colony process. This thesis aims to create portfolios embedded in constraints regarding the total number of assets or stocks included on a particular portfolio inspired by the Ant Colony Algorithm; however, the analysis was aimed at finding the best efficient frontier for the algorithm proposed. First, Sharpe ratio was employed as the portfolio's fitness function which attempts to maximize portfolio selection by optimizing the Sharpe ratio. Furthermore, an efficient frontier for ant colony algorithm has been set, and it has been shown that the algorithm works more efficiently when we limit the number of assets to a precise number.

A. Steven, B. D. Handari and G. F. Hertono [8] conducted a research on the topic of weighing of clustered stocks using K-means clustering for portfolio optimization using ant colony optimization. Here portfolio optimization involving different stocks is discussed where stock data is converted to some score parameters using various financial parameters like EPS ratio and P / E ratio and then clustered with K-means clustering algorithm. The reason, K-Means Clustering has been selected since it is the most effective clustering algorithm due to its robustness and simplicity over time. Some securities are selected for the portfolio after clustering. The weight of each cluster of stocks will be calculated in such a way as to achieve the objective. The weight of each stock is calculated using the Ant Colony Optimization algorithm. Quality of the portfolio will be measured on the basis of some actual data sets. They demonstrate important facts that an exercise function's value is an important function in selecting the resulting weighted stock present in a portfolio and empirical results often indicate how to decrease portfolio risk.

A. N. Sadigh, M. Iranpoor, S. M. T. Fatemi Ghomi and H. Mokhtari [9] conducted a research on the topic of application of hybrid algorithm involving Hopfield neural network and particle swarm optimization for solving cardinality constrained portfolio optimization problems. This paper addressed a problem of portfolio optimization with certain restrictions such as cardinality and boundary that were more suitable to actual world situations. The optimization problem was identified as a mixed integer type quadratic programming paradigm in which the optimal solution can't be sought easily by exact methods. A Hopfield neural network (HNN) was considered and hybridized with a particle swarm optimization (PSO) algorithm to figure out the efficient Frontier. PSO is an optimal search algorithm which is computationally effective; meanwhile HNN is a type of repeating type artificial neural network used in data science. Multiple factors regarding the algorithm proposed were estimated using a statistical method based on Taguchi methodology. Mathematical results obtained using a benchmark problems indicates that the proposed algorithm exceeds the conventional meta-heuristic algorithms formerly introduced to solve cardinal-restricted portfolio question.

Wei Chen, Yong-Jun Liu and Dandan Li [10] proposed a new hybrid ICA-FA algorithm based on multiple parameters for multi-period unpredictable portfolio optimization process. This research explains a multi-period portfolio allocation problem on an unpredictable market environment, where stock return is considered to be an unknown factor and calculated by the subjective evaluation of the specialist. They presented a novel multi-objective, multi-period, mean-variance-skewness model based on uncertain theory by taking into consideration, the multiple realistic investment constraints like transaction costs, holding boundaries and cardinality etc. The existing multi-objective programming model was transformed to a single-objective one using a weighted type max-min fuzzy target programming strategy. Subsequently, a new combination of imperialist competitive algorithm and firefly algorithm was designed to find solution for it, named ICA-FA. Ultimately a computational analysis was presented to represent the efficacy of newly developed model and subsequent algorithm.

Y. Kim, M. Jeon, D. Kang and Chungmok Lee [11] proposed a GAN-MP based hybrid algorithm for finding solutions for non-convex portfolio optimization problems. To cover the disadvantages of the traditioanl Markowitz model, the new Markowitz model has been expanded for asset cardinality, tracking-error and active share constraints. Nevertheless, the corresponding problems of optimization are often very complex to solve while those of the original mean-variance model can be easily solved. A novel algorithm was built here, integrating GAN (Generative Adversarial Networks) with mathematical programming for solving the portfolio management problem for the latest extensions: the GAN-MP based hybrid algorithm. It was the first effort to combine the neural networks and statistical programming to address actual-world portfolio optimization problems. Statistical tests with real time stock data indicate that this method substantially outperforms the current solvers for nonlinear optimization.

S. Goudarzi, Amir Afsar and M. J. Jafari [12] proposed a hybrid portfolio optimization method based on stock clustering and numerous investment decisions. The goal of this research was to assist shareholders, specialists and intermediate managers in building personalized stock portfolios in line with investment strategy. The proposed method used the five parameters such as risk, skewedness,

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price, liquidity and current ratio indices of 66 companies listed on the Tehran stock exchange market and then grouped multiple companies using the composite clustering algorithm. Afterwards, the clusters were ranked using the TOPSIS process. Ultimately, the portfolio, using genetic algorithm, is designed for different classes of investors about their level of risk-taking. The results show that the proposed method is better compared to the index of 50 more companies involved.

III. Markowitz Mean-Variance Portfolio Model

In Markowitz model [1], the problem regarding selection of portfolio is split into two stages: first, identifying mean-variance effective portfolios and second, choosing one of those portfolios. Investors don't like risk, and the higher the risk of returns on an investment, the greater the returns investors expect. A trade-off is present between the return and risk that has to be expressed in the rates of return on investment opportunities required. The standard deviation (or variance) of return tests an investment's overall risk. An investor doesn't have to consider the total risk of an individual security. Investors can and do diversify for risk reduction. As the number of holdings approaches larger, the diversification eliminates a good deal of the total risk. It is a common phenomenon that portfolio investment diversification will lead to a reduction in yield variance, even for the same level of expected return. The analysis took into account investment-related uncertainties-using volatility or standard return deviation.

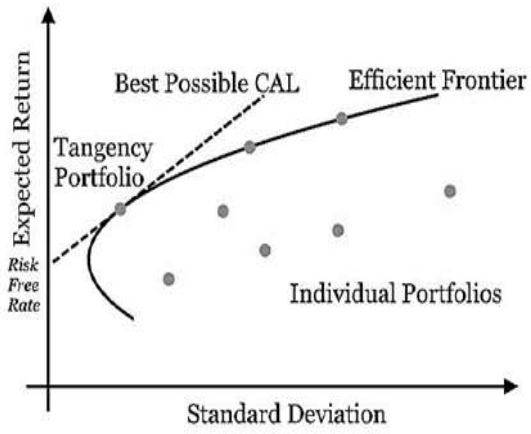

Fig. 1 Efficient Frontier [1]

Efficient frontier comprise of a set of optimized portfolios that provide the maximum expected rate of return for a specified level of risk or the low level risk for the expected return amount. Beneath the efficient frontier curve, portfolios are sub optimal, as they don't have adequate risk level value. Portfolios clustering to the right of the efficient frontier are sub-optimal, as they have a high level of risk for the defined return rate.

Assumptions

The assumptions of Markowitz model are:

1. The return from an investment describes the result of the investment appropriately.
2. Investors may interpret a distribution of return rates in probability.
3. Risk expectations by investors are equal to the volatility of risk expected by them for a security or portfolio.
4. Investors make their investment decisions on two factors, i.e. returns forecast and return volatility.
5. All investors are averse to risk. He recommends taking lowest risk for a given expected rate of return; naturally the investor wants to get optimum expected return for a specified level of risk.
6. Investors are supposed to be reasonable in so far as, given equal or lower risk and risk averse, they will choose greater returns to lesser ones.
7. Return could be any appropriate measure of monetary inflows such as NPV, but yield was the most widely applied return indicator in this sense, so that where the standard deviation of returns is related to, we say the standard deviation of yield from the expected value of the return.

IV. Portfolio Optimization Using Hybrid Algorithms

Hybrid algorithms are the combination of various optimization techniques which can be either nature-inspired algorithm (like PSO, FA, ACO, ABC, GA etc.) or logic based algorithm. Hybrid algorithms find an extensive scope in the field of financial modeling and portfolio management [8] [9] [10] [11] [12]. These algorithms overcome some of the limitation of traditional Markowitz mean-variance model and therefore they can be used as an alternate algorithm for finding solutions for modern portfolio optimization problems.

The various steps involved in the development and implementation of hybrid algorithms for finding the best solution of complex portfolio optimization problems are discussed below.

A. Combination of K-means clustering and ACO

The procedure for implementing the hybrid model comprising of k-means clustering and ant colony optimization algorithm [8] is given in below steps:

- The historical data of various financial ratios (EPS and P/E) of stocks are collected.
- The financial ratios are converted to score values.
- The stocks are clustered based on the score values using K-Means clustering.
- The clustered stocks are given weights using the ACO algorithm.
- The optimal model is selected by comparing the determined outputs with the actual value.

B. GAN- MP Hybrid Algorithm

The hybrid algorithm comprising of Generative Adversarial Networks and Mathematical Programming [11] is explained in below steps:

- The Mathematical model of corresponding problem is developed.
- Initial sets of stocks to make investment are generated using GAN.

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- Feasible solutions for given set of assets is found out.
- Local search using Bisection method is done for finding improved solutions.

C. Combination of PSO and HNN

The procedure for implementing the hybrid model involving the Hopfield neural network and particle swarm optimization [9] is given in below steps:

- The portfolio management problem with cardinality constraints is formulated.
- PSO-HNN algorithm is developed to optimize the cardinality constrained problem.
- The statistical performance analysis on benchmark data sets is conducted.

D. ICA- FA Hybrid Algorithm

The steps for implementing the ICA-FA hybrid algorithm [10] are explained in below steps:

- Criteria such as return, skewness, transaction cost, risk, cardinality and holding bounds are considered.
- The proposed multi-objective model is converted to a single-objective one using a weighted max-min fuzzy logic programming strategy.
- ICA-FA based hybrid algorithm is used to solve the function.
- Effectiveness of the proposed approach is determined.

E. Combination of SOM clustering and GA

The procedure for implementing the hybrid algorithm involving the combination of SOM clustering and Genetic Algorithm [12] is explained in below steps:

- Data gathering and normalization of data is done.
- The normalized data is clustered using Self-Organizing Maps (SOM) clustering.
- The clustered data is given ranks using the technique for order of preference by similarity to ideal solution (TOPSIS) method.
- Portfolio Optimization is done using Genetic Algorithm.

V. Proposed Hybrid Algorithm Based On GA And ACO

The Genetic Algorithm (GA) is one of the powerful methods of solving optimization problems that rely on the natural evolution process. The survival of the best choice is implemented to provide a different search strategy that examines the possible solution selected to achieve good outcomes. Due to the performance problems in GA during the search many works were done aimed at it, such as the growth of the selection mechanism technique, the probability of adaptive mutation and the enhancement of GA operators, and the improvement of the elitism selection mechanism across successive generations utilizing threshold values.

Biological evolutionism enlightens both ACO and GA. In GA, the solution as the chromosome performing fitness enhancement is evolved and improved in each generation. Meanwhile the solution in ACO is improving from the search process for the productive route between nests and food supply. To achieve the best answer, therefore, both approaches are combined use not just the propensity of the ant colony to find a route, as well as the particular fitness capabilities

A. Genetic Algorithm

Genetic algorithm (GA) is an analytical tool developed to replicate natural selection and evolution processes in organisms following the series as initial population growth, study, selection, fusion, mutation and regeneration, as shown in fig. 2.

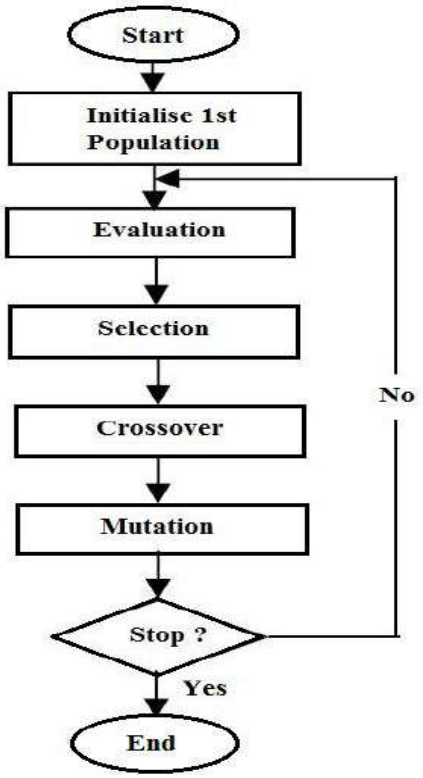

Fig. 2 Flowchart of GA

The preliminary population is critical because this is the problem, and is typically created at random. The population is then analyzed using a problem-specific function. GA can select most of them in the next stage, based on a certain likelihood of matting. It will be carried out on fusion and transformation to obtain a new and better version. GA's vision is to make the new process phase better than the one before it. The process will be repeated until certain conditions for the stoppage are met.GA is generally applicable to many success problems, as this approach does not involve a good initial understanding of the subject solved in nature; it is known to be GA's pros. This algorithm is further found to be globally efficient and well suited to the problem. On the other side, GA is likely to fall into early regression, which makes it difficult to achieve optimal solution; and GA often requires longer time for processing, as its disadvantages are generally considered to be large data issues.

B. Ant Colony Optimization

Ant colony optimization (ACO) is a statistical approach inspired from the way the ant colony finds the shortest route

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from the food source to the nest without using any visual aid. Ants inject a certain amount of pheromone throughout their quest, as they move in form of a line and interact with other ants. Those who couldn't smell the pheromones continue to travel randomly. Some path's pheromones intensify when more ants watch it attractively to get the shortest one. The flowchart of ACO is depicted in fig. 3.

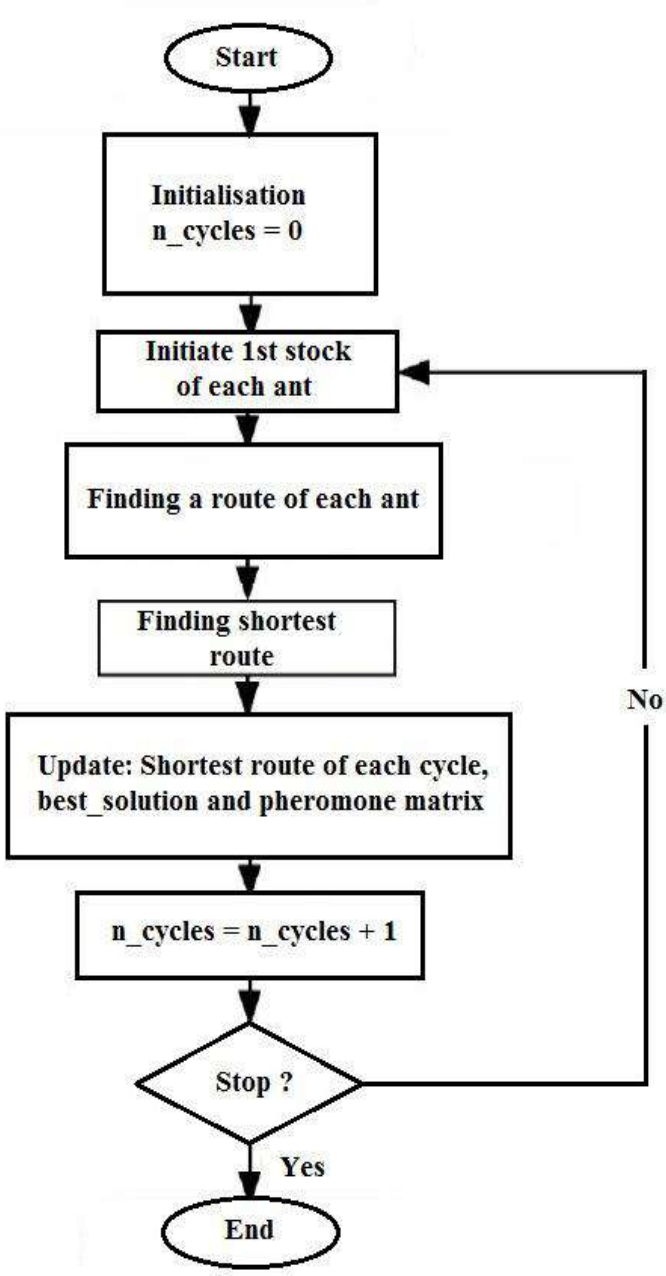

Fig. 3 Flowchart of ACO

The ACO algorithm for solving Traveling Salesman Problem (TSP), with slight modifications can be used to find solutions to complicated portfolio management problems. The ant algorithm is initiated by randomly spreading the ants to each stock that is to be set as the initial stock for the ant. Such ant will choose the next stock based on some probability. This probability is a function of the matrix of pheromones, the matrix of distances and the parameters. Repeat this selection until each ant has visited each stock once. That's the first cycle in the algorithm, and the cycle continues until the stop criteria are reached. The overall route shifts methodically in each cycle, as the matrix of pheromones is changed. This algorithm has several limitations, as its performance is highly dependent on the preceding cycle, easy to converge and stagnant, and requires a long processing time. This reality causes ACO's challenge, search space, and calculation time.

C. Hybridization of GA and ACO

In GA and ACO based hybrid model [20], ant colony optimization is used to aid GA to remove the presence of null movement while the GA is used for solving the pheromone matrix dependence present in ACO. Here the GA chromosomes are used for optimizing the number of next stocks from each stock already visited by ants, in order to avoid dependence on the preceding cycle. Of these chromosomes it is possible to preserve the variability with ant's motion. The proposed method introduces GA's evolution steps into ACO's calculation step as shown in the fig. 4.

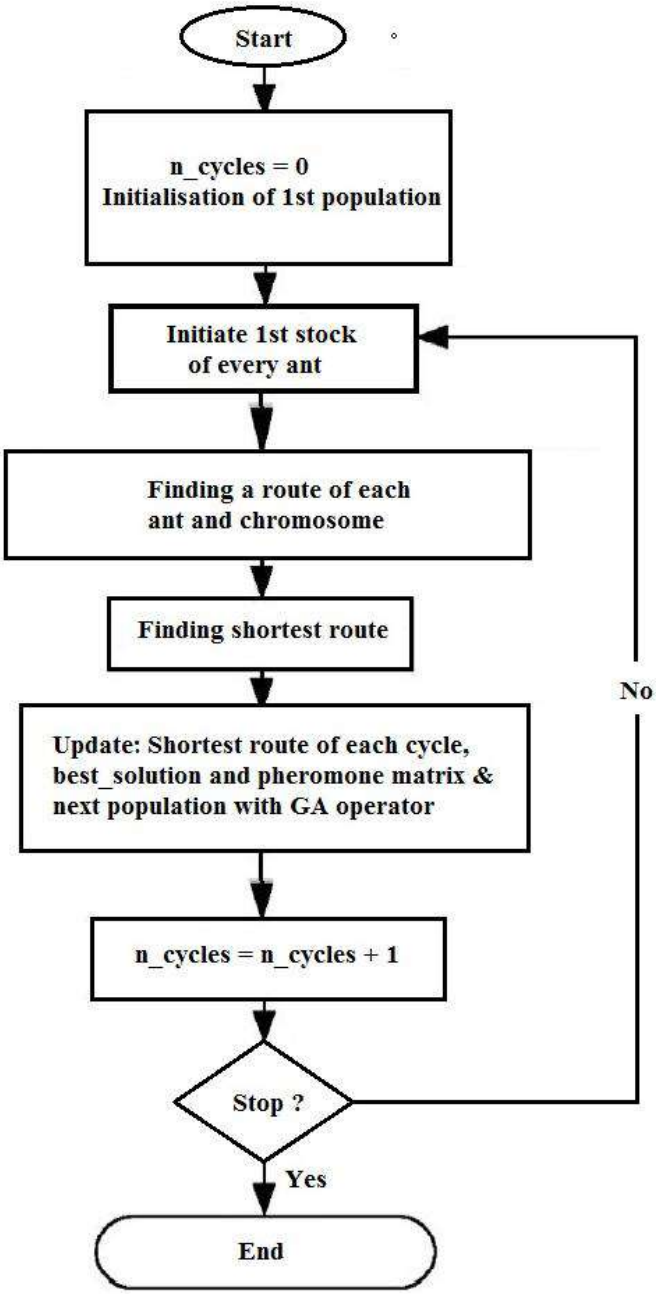

Fig. 4 Flowchart of Hybrid GA-ACO model

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Hybridization can also be applicable to certain factors and variables of ACO or GA which share the same computational features, i.e. the number of generation parameter in GA and the number of cycles present in ACO, size of population in GA and the number of aunts parameter in ACO and the number of chromosomes in genetic algorithm and Tabu parameter in ACO.

<table>
<tr><th>GA</th><th>ACO</th><th>GA-ACO</th></tr>
<tr><td colspan="3">Hybridization on variables and parameters of the algorithms</td></tr>
<tr><td>Number of generations</td><td>Number of cycles</td><td>Number of cycles</td></tr>
<tr><td>Population size</td><td>Number of ants</td><td>Number of ants; it is equal to the population size.</td></tr>
<tr><td>Chromosome</td><td>Tabu list</td><td rowspan="2">Tabu list and Chromosome. Tabu list is the representation of solution. Chromosome is indirect representation of solution. It represents the remaining stock to be visited by the ant.</td></tr>
<tr><td colspan="2">Chromosome & Tabu list are the representations of solution</td></tr>
<tr><td colspan="3">Hybridization on steps of the algorithms</td></tr>
<tr><td>Initialization: First population</td><td>Initialization: Pheromone</td><td>Initialization: Pheromone and first population</td></tr>
<tr><td></td><td>Initiate first stock of each ant</td><td>Initiate first stock of each ant</td></tr>
<tr><td></td><td>Finding a route of each ant</td><td>Finding a route of each ant & chromosome</td></tr>
<tr><td></td><td>Finding shortest route</td><td>Finding shortest route</td></tr>
<tr><td>Evaluation</td><td></td><td>Evaluation process is hybridized on finding a route</td></tr>
<tr><td>Updating population</td><td>Updating pheromone matrix and shortest route of each cycle</td><td>Updating population, pheromone matrix and shortest route of each cycle</td></tr>
</table>

Table 1 Comparison of GA, ACO & GA-ACO models

Advantages of GA-ACO model

The advantages of proposed GA-ACO hybrid model over conventional and established portfolio optimization models are discussed below.

1. Improved performance with time complexity fairly equal compared to the GA and ACO.
2. Bi-objective portfolio optimization problems can be easily solved.
3. Tracking-error and active share constraints can be incorporated.

VI. Conclusion

The scope of various hybrid algorithms for solving portfolio optimization problems has been studied. This study concludes that the hybrid algorithms can be used for solving complex portfolio optimization problems involving active share, asset cardinality and tracking-error constraints, which cannot be solved using traditional optimization algorithms. Also a hybrid model involving the ACO and GA has been proposed for finding solutions for portfolio optimization problems.

VII. Acknowledgment

First of all, I would like to thank God Almighty for bestowing me with wisdom, courage and perseverance which had helped me to complete this work. This work has been a reality as a result of the help given by a large number of personalities. I would like to remember with gratitude Dr. A. Samson, Head of Department of Mechanical Engineering, College of Engineering Trivandrum for the encouragement and guidance rendered.

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References

[1] Harry Markowitz, “Portfolio selection”, The Journal of Finance, Vol. 7, No. 1, pp. 77-91, 1952

[2] M. Ivanova and L. Dospatliev, “Application of Markowitz Portfolio Optimization on Bulgarian Stock Market from 2013 to 2016”, International Journal of Pure and Applied Mathematics, Vol. 117, No. 2, pp. 291-307, 2017

[3] M. Radović, S. Radukić and V. Njegomir, “The Application of the Markowitz's Model in Efficient Portfolio Forming on the Capital Market in the Republic of Serbia”, Economic Themes, 2018

[4] I. Kulali, “Portfolio Optimization Analysis with Markowitz Quadratic Mean-Variance Model”, European Journal of Business and Management, Vol. 8, No. 7, 2016

[5] A. Brabozan and M. O’Neill, “Biologically Inspired Algorithms for Financial Modeling”, New York: Springer, pp. 103-104, 2007

[6] G. F. Deng and W. T. Lin, “Ant Colony Optimization for Markowitz Mean-Variance Portfolio Model”, B. K. Panigrahi et al. (Eds.): SEMCCO 2010, LNCS 6466, pp. 238–245, 2010

[7] S. Abolmaali1 and F. R. Roodposhti, “Portfolio Optimization Using Ant Colony Method a Case Study on Tehran Stock Exchange”, Journal of Accounting, Finance and Economics, Vol. 8, No. 1, pp. 96 – 108, 2018

[8] A. Steven, G. F. Hertono and B. D. Handari, “Clustered Stocks Weighting with Ant Colony Optimization in Portfolio Optimization”, Proceedings of the 3rd International Symposium on Current Progress in Mathematics and Sciences, 2017

[9] A. N. Sadigh, H. Mokhtari, M. Iranpoor and S. M. T. Fatemi Ghomi, “Cardinality Constrained Portfolio Optimization Using a Hybrid Approach based on Particle Swarm Optimization and Hopfield Neural Network”, Advanced Science Letters, Vol. 5, pp. 1–10, 2012

[10] W. Chen, Dandan Li, and Yong-Jun Liu, “A Novel Hybrid ICA-FA Algorithm for Multi-Period Uncertain Portfolio Optimization Model Based on Multiple Criteria”, Journal Of Latex Class Files, Vol. 14, No. 8, August 2015

[11] Y. Kim, D. Kang, M. Jeon and Chungmok Lee, “GAN-MP Hybrid Heuristic Algorithm for Non-Convex Portfolio Optimization Problem”, The Engineering Economist, Vol. 64, No. 3, pp. 196–226, 2019

[12] S. Goudarzi1, M. J. Jafari and A. Afsar, "A Hybrid Model for Portfolio Optimization Based on Stock Clustering and Different Investment Strategies", International Journal of Economics and Financial Issues, pp. 602-608, 2017

[13] K. F. Haqiqi and T. Kazemi, "Ant Colony Optimization Approach to Portfolio Optimization – A Lingo Companion", International Journal of Trade, Economics and Finance, Vol. 3, No. 2, April 2012

[14] D. Maringer, "Portfolio Management with Heuristic Optimization", 2005, Netherlands: Springer, pp.1-37

[15] J. Branke, B. Scheckenbach, M. Stein, K. Deb, and H. Schmeck, "Portfolio Optimization with an Envelope-Based Multi-Objective Evolutionary Algorithm", European Journal of Operational Research, no. 199, pp.684-693, 2009

[16] H. M. Markowits, "Portfolio Selection", The Journal of Finance, vol. 7, no. 1, pp. 77-91, 1952

[17] A. J. T. Lee, M. C. Lin, R. T. Kao, and K. T. Chen, "An Effective Clustering Approach to Stock Market Prediction", PACIS 2010 Proceedings 54 (Association for Information Systems, Atlanta, 2010), pp. 345- 354

[18] Chang, T.J., Yang, S.C., Chang, K.J. (2009), "Portfolio Optimization Problems In Different Risk Measures Using Genetic Algorithm", Expert Systems with Applications, pp. 10529-10537

[19] G. E. Bidgoli, J. V. Sani, M. Alizadeh, and S. Bajalan, "Portfolio Optimization and Examining the Effect of Diversification on Its Performance through Using Ant Colony Algorithm", Quarterly Journal of Securities Exchange, vol. 2, no. 5, pp. 57-75, Spring 2009

[20] Z. Zukhri and I. V. Paputungan, "A Hybrid Optimization Algorithm Based on Genetic Algorithm and Ant Colony Optimization", International Journal of Artificial Intelligence & Applications (IJAIA), Vol. 4, No. 5, September 2013

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Price Prediction Using Machine Learning Algorithm on Daily Stock Prices

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***Abstract*—Predictive stock price systems play an important role in financial markets. They serve to provide sufficient information regarding the trend of stock prices. The complexity and uncertainty of stock markets make it difficult to develop an efficient forecasting method in order to help potential investors in financial decision making processes. Predictive stock price systems form the fundamental in investment strategies and risk management tools. Consistency in anticipating market movements is difficult to achieve but machine learning algorithms and hybrid models can develop efficient predictive stock market systems.**

It is proved by many researchers that integration of technical analysis along with machine learning can be used to identify trading opportunities. This is possible by analysing statistical trends from trading activities, such as price movements, volatility and volume. Thus, valuation of technical analysis (TA) is important while making trading decisions. Technical analysis indicators commonly used are Simple Moving Average (SMA), Weighted Moving Average (WMA), Relative Strength Index (RSI) and Moving Average Convergence Divergence (MACD). In this work we will be exploring several technical indicators which will be used as input to a supervised machine learning algorithm (Support Vector Regression) to forecast stock prices.

***Keywords—Machine Learning Algorithm, Stock Price, Technical Analysis Indicators, Support Vector Regression*.**

I. INTRODUCTION

Stock market investment has been the aim of professionals due to its high risk - high return policy. Therefore, predicting stock price became the primary goal of every investor. Complexities of modelling market dynamics due to its non-linearity and chaotic system, increases difficulty in prediction of stock prices. Besides, many external parameters such as liquid money, human behaviour, politics and financial news could also pose challenges towards trend forecasting. Price prediction of stocks traded on an exchange could yield significant profit and provide information regarding the trend of stock prices. Investment strategies and risk management models are developed on the basis of stock market price prediction mechanisms. This forms the basis of various financial decision making processes. Market behaviour indicates rise and fall of companies. Accurate prediction of market movement will augment chances of better trading strategies. Several machine learning algorithms and models have gained importance over recent years which were used to map market trends consistently. Estimation of future asset values of companies has become possible due to computational advancement in the field of trend forecasting. Stock market prediction refers to exploring the potentiality of various stock parameters such as high/low prices, open/ close prices, adjusted closing prices and trading volume.

Stock market research for analysing securities and making investment decisions can be categorised into two: Fundamental Analysis and Technical Analysis. Fundamental analysis is a traditional approach that determines value of a security by analysing its current transactions and future prospects. It evaluates financial statements, assets, liabilities, annual growth rates and current ratios to forecast profit and loss regarding the movement of a company's stock price.

Technical analysis refers to evaluation of a security by analysing statistical trends (such as past price and volume) due to market activities and relies on historical data to forecast future earnings. Use of technical analysis can help investors to determine appropriate time for buying or selling or holding stocks of a company in order to maximise profit. Fundamental analysis is favoured for long- term investment schemes while technical analysis is evaluated better for short-term trading.

II. LITERATURE SURVEY

Stock market has a complex structure and decision making in financial sector is very difficult. The reason is that stock market fluctuates according to a numerous factors and it has a non-linear and chaotic system. Recent studies in the field of stock price prediction have been based on trend analysis, pattern recognition, time series forecasting, machine learning, deep learning and neural networks.

Technical Analysis proposes a set of investment rules for the investor. Sharmila and Ramaswami [1] explained about the types of technical indicators and their effectiveness in Indian stock market. They analyzed the use of each technical analysis indicator and interpreted the crossovers, trend of market, strength of trend, moving averages and rolling

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forecasting. Pushpa, Sumithra and Madhuri [2] examined the analysis of technical indicators and investment decisions based on Indian stock market. They estimated that trading and investment decisions are purely based on fundamental and technical analysis. But, their paper focused only on the technical analysis of 9 companies in different sectors of NSE Nifty 50 index. Jelana and Ivana [3] examined the efficiency of predictive modelling and technical analysis in order to determine optimal trading strategies for an investor in emerging markets across the world. These trading strategies are set using various moving averages and returns on stock indices.

Support vector regression is characterized by the use of number of support vectors, kernels, sparse solution, and Vapnik-Chervonenkis (VC) dimension control of the margin. SVR has been proven to be an effective tool in real-value function estimation. Ballings [4] and Gerlein [5] have obtained good results in predictions when applying classifiers such as SVM, k-Nearest Neighbours (KNN), neural networks and decision trees. Henrique, Sobreiro & Kimura [6] used a machine learning technique called Support Vector Regression (SVR) to predict stock prices for large and small capitalisations in three different markets (American, Brazilian and Chinese). They employed prices with daily and up to minute frequencies of three blue chip and three small cap stocks, totalling 18 assets. Pan& Liu [7] focused on the potentiality of moving trends of Google Inc. stock prices over 4 different time periods (5, 15, 30 and 45 trading days). Kumar [8] and Kim [9] applied SVM-based systems to technical analysis (TA) indicators and the authors proposed a predictor variable selection method and applied decision tree and neural network mechanisms. Tsai and Wang [10] created a stock price prediction model by integrating Decision Tree (DT) and Artificial Neural Network (ANN). They used ANN for good forecasting performances and DT to generate forecasting decision rules.

III. Methodology

The methodology used in this study is bifurcated as technical analysis of the stock market data and the development of machine learning algorithm for price prediction.

A. Technical Analysis (TA)

Technical analysis is a trading technique used to evaluate investment strategies and identify trading opportunities in stock price patterns and trends based on historical data. Technical analysis monitors past trading activities and price trends and provides valuable information regarding stock's future price movement. The effectiveness of technical analysis to analyse financial performance of a stock over a period of time depends on data quality and data mining techniques. Investors can base their financial decisions, whether to buy or sell stocks, upon interpreting each technical indicator and thereby increase profit in their venture. These TA indicators act as predictor variables for SVR model. Technical analysis can be categorised into four:

1. Trend Indicators
2. Momentum Indicators
3. Volatility Indicators
4. Volume Indicators.

B. Support Vector Regression (SVR)

Price forecasting of stock is based on estimating actual prices of the stock. This paper focuses to build a regression model for short-term price prediction of asset prices. SVR is best suitable for smaller datasets as it takes large processing time. It examines non-linearity in datasets in contrary to Simple Linear Regression (SLR). Thus, SVR is superior to SLR as a prediction model.

Support Vector Regression is a supervised machine learning algorithm which was developed by Vapnik in 1995. He used training datasets to construct a linear model by applying non-linear classification constraints and mapping target variables to a higher dimension. The model is characterized by use of kernels and optimal hyperplane identification. SVR uses a technique called kernel trick to perform complex data transformations. Commonly used kernels for SVR model are linear, polynomial, radial basis function (RBF) and sigmoid. The main objective behind SVR is to find an optimal separating hyperplane from the input data so as to maximize the margin of training data. It classifies existing data as well helps in predicting the values of unseen data.

IV. Experimental Design

A. Research Data

The dataset used for stock market price prediction is obtained from the National Stock Exchange (NSE). NSE Junior Nifty is selected and historical daily prices of SBI Life Insurance Company Ltd., a finance company, is chosen for training and testing the model. The dataset for technical analysis is obtained for a period of 1 year from 1st January 2019 to 31st December 2019. The dataset for SVR is divided into training and test set. Training data is collected for trading period of 1month from 1st December 2019 to 31st December 2019. Test dataset is taken for a period of 14 days from 1st January 2020 to 14th January 2020.

Selection of stock from Junior Nifty is based on following criteria:

1. High liquidity cost – Stocks in Junior Nifty has high liquidity cost which is directly measured by the cost incurred in executing a transaction of the given stock in proportion to its weightage in portfolio under consideration. It represents most liquid securities after the first 50 securities of NIFTY50
2. Market Capitalization - Companies included in Junior Nifty have a six month average market capitalization of 200 crores or more.
3. Incubator for Nifty 50 – Companies in Nifty Next 50 represents potential candidates for inclusion in Nifty 50.
4. Free float capitalization - It represents 11.9 % of the free float capitalizations of the 1600 stocks listed on NSE.

The data obtained from NSE website comprises of several stock parameters such as Date, Open/ Close prices, High/ Low

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prices, Adjusted Close price, Volume of stocks traded. Closing price and Date are used for experimental analysis. Fig. 1 shows the actual price for SBI Life Insurance Company for technical analysis.

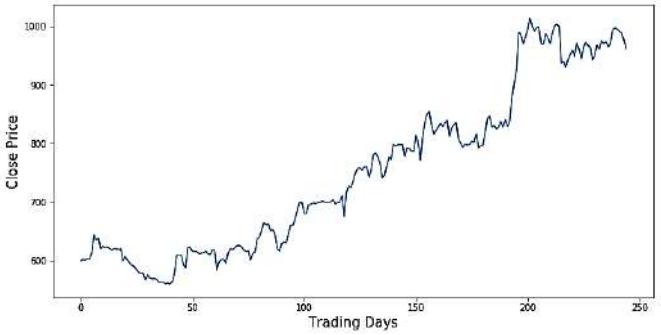

FIG. 1 CLOSING PRICE VS TRADING DAYS

B. Technical Analysis (TA)

The various technical analysis indicators used in this experiment are discussed in this section.

Notations used:
A_i- Actual Closing Price
F_i – Forecasted Closing Price
T- Total test samples
Cl_i – Closing price for the period
n - Total samples
P – Period (days)
U_p – Number of price rises
D_w – Number of price reductions.

1. Simple Moving Average (SMA)

SMA is the arithmetic mean of closing price for a particular period. It provides equal weightage to all days. Standard moving average periods are 20 days and 50 days. It can be calculated by using the following equation:

$$SMA = \frac{\sum_{i=1}^{T} Cl_i}{T}$$

2. Weighted Moving Average (WMA)

Unlike SMA, WMA gives particular weightage to important days and higher weightage is given to more recent prices. The level of importance can also be decided by the trader. WMA can be calculated by using the following equation:

$$WMA = \frac{PCl_i + (P-1)Cl_{i-1} + \ldots\ldots + Cl_{i-p}}{P + (P-1) + \ldots\ldots + 1}$$

3. Relative Strength Index (RSI)

RSI compares the losses and gains of a stock in the market in order to determine whether it is an overbought or oversold market. It evaluates a ratio of upward price movements to absolute price movement. RSI can be calculated by using the following equation:

$$RSI = 100 - \frac{100}{1 + \frac{\sum_{i=0}^{P-1} U_{p_{t-i}}/n}{\sum_{i=0}^{P-1} D_{w_{t-i}}/n}}$$

4. Moving Average Convergence Divergence (MACD)

MACD is a momentum oscillator that determines the strength of trend and dynamics and it oscillates around zero line in positive and negative directions. It is the best technical indicator because it can indicate potential market reversals. It is unique in a way that it has both lagging (trend following moving averages) and leading (momentum) elements. MACD consists of three moving averages (12 day, 26 day and 9 day Exponential Moving Averages (EMA)). MACD line represents the difference between 12 day and 26 day EMA's and signal line represents 9 day EMA of MACD line.

C. Support Vector Regression (SVR)

SVR algorithm learns the pattern from input data to forecast stock price as output. This study can be categorized into training phase and testing phase. The model is developed by fitting training dataset such that it predicts the next day stock price. The developed model is repeatedly trained with rolling values of the closing price to forecast subsequent stock prices. Here, four different kernels are used (linear, polynomial, radial basis function and sigmoid). The parameters of SVR for different kernels (c, γ, d) are optimized using gradient search. Accuracy of the model can be determined by evaluating the error rates of predicted and actual prices. For this, mean absolute deviation (MAD) and root mean squared error (RMSE) are calculated.

$$MAD = \frac{\sum_{i=1}^{n} |A_i - F_i|}{n}$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n} (A_i - F_i)^2}{n}}$$

V. EXPERIMENTAL ANALYSIS AND RESULTS

A. Technical Analysis Indicators

a. Simple Moving Average (SMA)

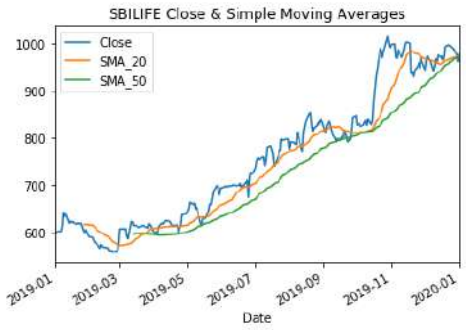

FIG. 2 SIMPLE MOVING AVERAGE (SMA)

Fig. 2 shows 20 day (SMA_20) and 50 day (SMA_50) simple moving averages and corresponding closing prices. In this curve, a buy signal is indicated when

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closing price is above its moving average and a sell signal is indicated when closing price is below its moving average. Thus, above result identifies the presence of a bullish or bearish market. The uptrend momentum (rising moving average) indicates a bullish crossover and vice versa.

b. Weighted Moving Average (WMA)

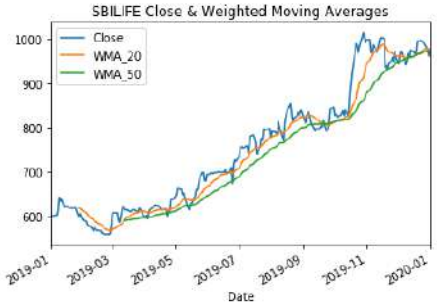

FIG. 3 WEIGHTED MOVING AVERAGE (WMA)

Fig. 3 shows 20 day (WMA_20) and 50 day (WMA_50) weighted moving averages and corresponding closing prices. In the above curve, particular weightage is given to more recent prices in contrast to SMA. If the moving average lines are below the closing price of the stock, the company can be identified to be performing well and vice-versa.

c. Relative Strength Index (RSI)

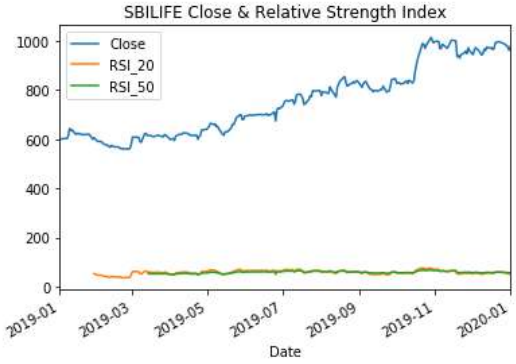

FIG. 4 RELATIVE STRENGTH INDEX

Fig. 4 shows 20 day (RSI_20) and 50 day (RSI_50) relative strength index and the corresponding closing prices. RSI value of 50 and above indicates an overbought market, which indicates a good signal to sell the stocks. If the RSI value falls to 40 and below, it indicates an appropriate moment for investors to buy the stocks.

d. Moving Average Convergence Divergence (MACD)

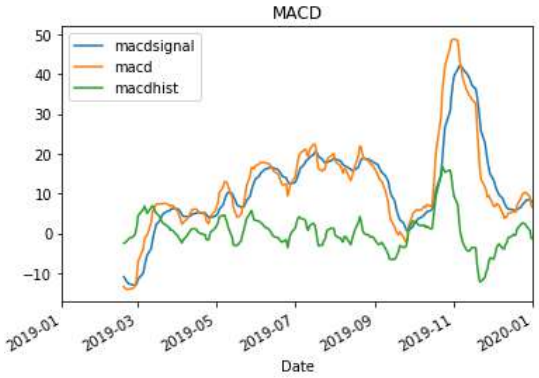

FIG. 5 MOVING AVERAGE CONVERGENCE DIVERGENCE

Fig. 5 shows moving average convergence divergence indicator. A technically strong company can be recognized when the MACD lines show maximum movement above zero line. Trading strategies is based on the crossovers of zero line and signal line. Zero Line Crossover is the trading strategy to sell the stock when MACD line crosses below zero line and to buy the stock when MACD line crosses above zero line. Signal Line Crossover is the trading strategy to sell the stock when MACD line crosses below signal line and to buy the stock when MACD lines crosses above signal line.

B. Support Vector Regression (SVR)

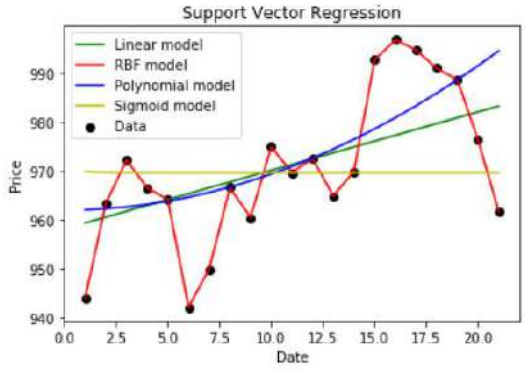

FIG. 6 SUPPORT VECTOR REGRESSION

The SVR model is trained with 1 month dataset of SBI LIFE Insurance Company Ltd. from 1st December 2019 to 31st December 2019 (21 trading days). Fig. 6 shows support vector regression model fitted with training set. This model is used to predict the next day stock price.

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TABLE I. OPTIMAL SVM PARAMETERS

Kernel	Kernel Parameters		
	C	***γ***	***d***
Linear	1000	-	-
Polynomial	1000	-	2
RBF	100	8.2	-
Sigmoid	1000	10.5	-

Note : C: Required parameter for all kernels, γ: Radial and Sigmoid kernel parameter, d: Polynomial kernel parameter.

Table I shows the optimal SVM parameters of different kernels, obtained using gradient search method, employed in this experiment.

Table II shows the predicted price for test data period using different kernels and the corresponding actual closing prices. Initially, the model is trained with 1 month training dataset ('n' days) to predict the stock price on (n+1)th day. After analysing the result, the model is trained using closing price of n days and actual closing price on (n+1)th day to forecast the stock price on (n+2)th day. Subsequent price predictions are carried out by considering the rolling values of closing prices.

TABLE II. PREDICTED PRICE VS ACTUAL PRICE

Date	Predicted Price using different kernels				Actual Price
	Linear	Polynomial	RBF	Sigmoid	
01/01/2020	984.38	997.6197	970.59	969.55	976.4
02/01/2020	979.75	989.3125	970.86	969.65	969.35
03/01/2020	979.27	981.3833	970.79	969.55	975.1
04/01/2020	978.48	979.8068	970.97	969.65	975.1
05/01/2020	978.48	979.8068	970.79	969.65	975.1
06/01/2020	978.48	979.8068	970.79	969.65	983.1
07/01/2020	980.78	984.3	971.46	969.75	984.9
08/01/2020	983.18	986.0681	971.97	971	987.75
09/01/2020	985.84	988.1457	972.56	972.25	988.5
10/01/2020	987.02	990.1982	973.13	972.4	989
11/01/2020	989.07	991.7391	973.68	972.55	989
12/01/2020	989.07	991.7391	973.68	972.55	989
13/01/2020	989.07	991.7391	973.68	972.55	989.85
14/01/2020	990.8	992.9123	974.21	973.73	987.8

TABLE III. MEAN ABSOLUTE DEVIATION (MAD) AND ROOT MEAN SQUARED ERROR (RMSE)

Kernels	MAD	RMSE
Linear	3.656207	4.56579
Polynomial	5.463307	8.421358
RBF	10.95901	12.20891
Sigmoid	11.86251	13.11061

Table III shows the MAD and RMSE values of various kernels. This study shows that smaller prediction errors are obtained when a linear kernel was used. Linear kernels shows lowest MAE and RMSE values among the four kernels used. Upon comparing the errors produced by various kernels of SVR, linear kernel has a superior predictive power. The polynomial kernel has also predictive errors close to that of linear kernel.

VI. CONCLUSION

Stock market supplies great opportunity for informed investors and professionals for both short term and long term trading. Investors will be able to gain sufficient knowledge using the technical analysis of stock prices which increases their chances of profitable trading and identification of better trading opportunities. The fundamental step for price prediction is analysing statistical trends (such as price movements, volatility and volume) from past trading activities. Thus, implementation of technical analysis helps investors to understand trend, volume, volatility and momentum indicators. Technical analysis can be extended towards forecasting as it is taken as input for price prediction model. Technical analysis is very important for trading as it can identify short-term fluctuations of a stock. The predictive variables for forecasting are estimated using technical analysis indicators on stock prices.

Various technical analysis indicators used in this experiment provide strong information regarding the direction in which a company is heading. This helps in the identification of an oversold or overbought stock and also determines chances of trend reversals. The study analyses various kernels in an SVR algorithm for forecasting stock prices. The predicted stock prices using SVR algorithm are estimated using rolling moving averages of close prices for a short-term. Four different kernels are compared to identify the most appropriate one. Error rates of different kernels are estimated. From the results, it can be inferred that a linear kernel has a better predictive power among the four kernels used.

REFERENCES

[1] J Sharmila Vaiz, M Ramaswami, "Forecasting Stock Trend Using Technical Indicators with R", International Journal of Computational Intelligence and Informatics, Vol. 6: No. 3, December 2016.

ISBN 978-93-89105-41-4

[2] Pushpa BV, Sumithra C.G, Madhuri Hegde ,"Investment Decision Making Using Technical Analysis: A Study on Select Stocks in Indian Stock Market", IOSR Journal of Business and Management (IOSR-JBM) ISSN: 2278-487X, p-ISSN: 2319-7668. Volume 19, Issue 9. Ver. VI. (September. 2017), PP 24-33

[3] Jelena Stankovic, Ivana Markovic and Milos Stojanovic, "Investment Strategy Optimization Using Technical Analysis and Predictive Modelling in Emerging Markets",The Economiess of Balkan and Eastern Europe Countries in the changed world,EBEEC 2014, Nis, Serbia, Prrocedia Economics and Finance (2015), Pg 51-62.

[4] Ballings M, Van Den Poel D, Hespeels N, Gryp R. "Evaluating Multiple Classifiers for Stock Price Direction Prediction". Expert System Appl. 2015; 42(20):7046-7056.

[5] Gerlein EA, McGinnity M, Belatreche A, "Coleman S. Evaluating machine learning classification for financial trading: an empirical approach". Expert Syst Appl. 2016;54(1): Pg: 193-207.

[6] B M Henrique, V A Sobreiro, H Kimura, "Stock Price Prediction Using Support Vector Regression on Daily and up to the Minute Prices", The Journal of Finance and Data Science 4 (2018) 183-201, Science Direct, 27 April 2018.

[7] Liu Pan, Xuan Liu, "Prediction of The Moving Direction of Google Inc. Stock Price Using Support Vector Classification and Regression", doi:10.5296/Ajfa.V6i1.5485, June 1, 2014.

[8] Kumar D, Meghwani SS, Thakur M. "Proximal support vector machine based hybrid prediction models for trend forecasting in financial markets". J Computer Science. 2016;17(1): Pg:1-13.

[9] Kim K. "Financial time series forecasting using support vector machines". Neuro- computing. 2003;55(1e2): Pg: 307-319.

[10] Tsai, C.-F., Wang, S.-P, "Stock Price Forecasting by Hybrid Machine Learning Techniques" Proceedings of the International MultiConference of Engineers and Computer Scientists 2009 Vol I IMECS 2009, March 18 - 20, 2009, Hong Kong

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Different Approaches in Playground Equipment Design to Bring Inclusiveness

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***Abstract*— Inclusive park can bring social integration among children. This could help the cognitive and physical development of children through a variety of play equipment. Design methods of play equipment have a significant role in bringing inclusiveness. The purpose of the study is to prioritize universal and accessible design methods used in play equipment. In this study, a comparison matrix of the design methods was formed based on interview conducted among parents and playground keepers. The attributes of age-appropriateness, safety, equitable use, maintenance and activity rate were considered in the interview. SWOT analysis was conducted to prioritize the design method in various play equipment such as swings, merry-go-round and sensory equipment. The study revealed the difficulty in prioritizing the design methods. It advocates that there is a need in blending the design methods to bring maximum inclusiveness without ruining the fun factor. The work can be extended to more equipment to verify the results.**

Keywords—inclusive park, universal design, accessible design, SWOT analysis

I. INTRODUCTION

An inclusive park is the one which helps children with any ability to play together and satisfy their physical, psychological and social needs [1]. The public sports sector is committed to helping young people develop their social and physical skills and improve their skills [2]. Through sports, young people learn many psychological specialties in a very relaxed environment. All young people should have equal rights to play live areas. However, many existing playgrounds do not have comprehensive facilities to meet the needs of disabled children. An inclusive park helps to mend this gap.

However the existing designs of inclusive parks are insufficient to achieve the real intention of inclusive parks i.e., helping all children play together [3]. In many cases it comply purely on accessible design or on universal design concept. This takes away the real essence and benefits of play. The Indian constitution lays down the principle of right to life with dignity to every individual. Thus is complies that children are given opportunities and facilities to develop in a healthy manner [1]. India has ratified the United Nations convention on rights of children, 1989 and the United Nations convention on persons with disabilities, 2006 of this aspect. Despite this a lot obstacles come across when it comes to the children with ability to play together [2].

The fundamental principles guiding the development and maintenance of public play spaces may include factors that bring in maximum inclusiveness [3]. The play space must be in the near proximity of children so that they can aces it without any difficulty. All play spaces must be inclusive and accessible. They need to have universally accessible features in space as well as play equipment. The features must pertain to all abilities. A common play space for all age group from 0 to 18 years need to be created and must be free of cost [1]. A non-abusive environment with well trained staff members is to be employed [3].

The basic designs while preparing an inclusive park in the public sphere are universal design and accessible design. Universal design is the one in which the accessibility to every equipment is available to anyone irrespective of their size, age, sex, ability etc. [4]. This in turn provides for a barrier free play space for any person. The concept of universal design was originally developed by the Center for Universal Design at North Carolina State University. There are mainly seven guiding principles of a universal design which enable in the effective implementation of the design. These ensures equitable, flexible, simple use of equipment with the help of minimum errors, maximum safety factors and lowers physical effort [5].Thus the universal design calls for a good design to accommodate everyone. But studies show that these inclusive parks at times don't give the real essence of play to the users.

On the other hand an accessible design provides for special designs for differently abled people and making it easier for them to use play spaces [5]. This includes segregating children on the basis of age, abilities and accessibility by zoning parks and equipment. This helps the differently abled child to easily Access Park [6]. On the other hand this curbs the chances of social mingling and creates a barrier between children. Moreover the maintenance in these parks are difficult as children may not use age appropriate equipment as per guidelines. Imparting the real benefit of play is also very difficult in these type of parks [7]. The universal and accessible design has its own pros and cons. Hence it is important to absorb the best of both design and select equipment that best suit the needs of an inclusive public park [8]. The case studies discuss in this paper consists of equipment with universal and accessible design methods in

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various parts of India. The objective of the study is to prioritize these methods for play equipment design.

IV. METHODOLOGY

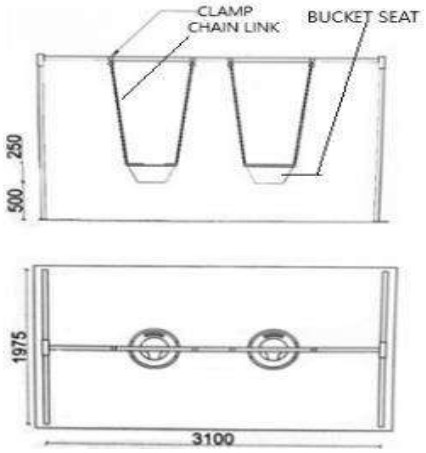
The study methodology includes the formulation of comparison matrix using the design attributes such as age-appropriateness, equitable use, safety, and maintenance and activity rate. The technical details of equipment presently used in inclusive parks in India were obtained from the Kilikili technical manual [1]. The comparison of equipment was done on the basis of universal and accessible approaches of design. The parameters for comparison were obtained with the help of the interview conducted among parents and playground keepers who frequents the area and from the literature.

V. CASE STUDIES

The case studies are made on different designs of swings, merry-go-round, and sensory integration equipment [8]. All the equipment were designed taking the average anthropometric dimensions of the particular age group of 3 to 14 years of all categories of abled children. The parameters for evaluation were selected based on the interview conducted on parents and playground keepers [9]. SWOT analysis helped to understand the strengths and weakness of equipment. This helped in arriving at a conclusion in every case. The best equipment was selected based on design attributes in comparison matrix and SWOT analysis.

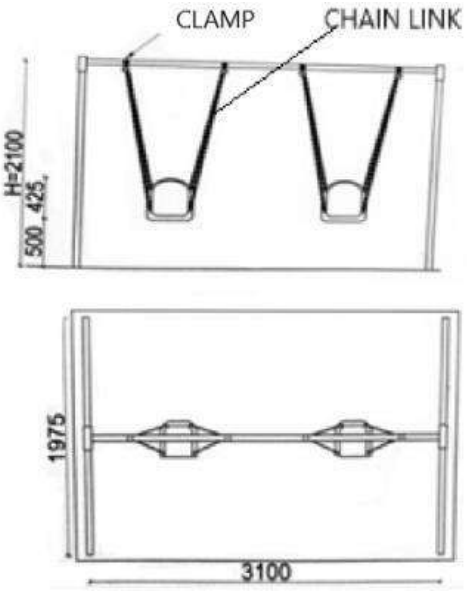
1) Case study 1: SWINGS

Swing designs from used in different inclusive parks were collected and categorized into accessible swing as in Fig. 1 and universal swing design as in Fig. 2. The inclusiveness of swing were evaluated on the basis of age appropriateness, safety, equitable use, maintenance and activity rate as shown in the TABLE I [10]. The details of various swings and the SWOT conducted are given in TABLE II.



All dimensions are in mm

Fig. 1 Design of accessible swing [1]



All dimensions are in mm

Fig. 2 Design of universal swing [1]

TABLE I. COMPARISON MATRIX FOR SWING

Design type	Age appropriateness (years)	Safety (low, moderate, high)	Equitable use (low, medium, high)	Maintenance (low, medium, high)	Activity Rate (low, moderate, high)
Accessible	4-10	High	Low	High	Medium
Universal	4-14	moderate	Medium	Low	Medium

TABLE II. SWOT ANALYSIS FOR SWING

SWOT	Accessible design	Universal design
Strength	• Safe • Physical activity involved	• Equitable • Maintainable
Weakness	• Unequitable	• Unsafe
Opportunities	• Can be made more inclusive	• A seat belt can improve safety features
Threats	• External help required to mount	• Child may fall

A safe swing accessible model swing with high safety features and back rest. This makes the children with special care comfortable in using the equipment. The main drawback is that it can only accommodate a very small population due to its restricted size. Moreover it always

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require an external help to access the swing. A high back swing on the other hand is a universal swing [11]. This ensures more inclusiveness. The main drawback of the design is its safety which can be rectified using a seat belt.

From the above cases it can be noted that safe swing is designed to accommodate children from 4-10 years with low equitable use medium activity rate, and high safety and maintenance. A high back swing can be used for children who need high back support and offers accessibility to the age group of 4-14 years. This offers moderate safety features with medium equitable use and activity rate and low maintenance. The SWOT analysis clearly says that when the accessible equipment shows strengths like higher safety, the universal design is accessible to a wider section of children [12]. Thus the universal design can be made more accessible by bringing more safety features like a seat belt.

2) Case study 2: MERRY- GO-ROUND

Merry-go-round used in different inclusive parks are taken and evaluated. The different type taken for study include high backed merry-go-round (universal design) as in Fig. 3 and wheelchair accessible merry-go-round (accessible deign) as in Fig. 4.

The merry-go-round helps children develop their fine and gross motor skills [13]. This helps them improve their balancing skills. The inclusivity and accessibility of merry-go-round are evaluated using its age appropriateness, safety features, equitable use, and maintenance and activity rate. The TABLE III shows the comparison matrix of both merry-go-rounds. The SWOT analysis as in TABLE IV of both are also given. The comparison matrix and the SWOT analysis give a fair idea on which equipment can be used in an inclusive park, what modifications need to be made for its betterment, the weakness of each equipment and how it is different from its counterpart.

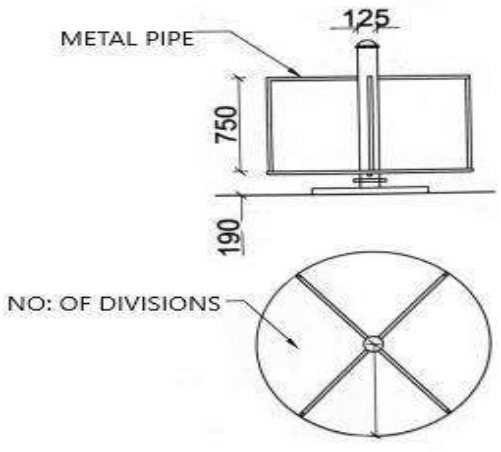

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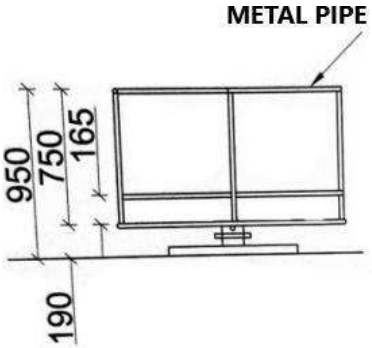
Fig. 3 Design of universal merry-go-round [1]



All dimensions are in mm

Fig. 4 Design for accessible merry-go-round [1]

TABLE III.COMPARISON MATRIX FOR MERRY GO ROUND

Design type	Age appropriateness (years)	Safety (low, moderate, high)	Equitable use (low, medium, high)	Maintenance (low, medium, high)	Activity rate (low, medium, high)
Universal	3-8	moderate	Low	Low	Medium
Accessible	3-12	moderate	High	medium	Medium

TABLE IV.SWOT ANALYSIS FOR MERRY-GO-ROUND

SWOT	Accessible design	Universal design
Strength	• Equitable use	• Low maintenance • Higher back support
Weakness	• High maintenance	• Lack safety • Unequitable use
Opportunities	• Selection of materials and better engineering	• A seat belt can improve its safety
Threats	• Regular monitoring required	• Child may fall

In this case an accessible merry-go-round out performed its universal counterpart. The accessible design approach was able to accommodate more population than the universal design approach. However the maintenance was higher in case of an accessible design as compared to the universal design. Hence better engineering is to be done in this aspect. The universal go round can be used by the age group

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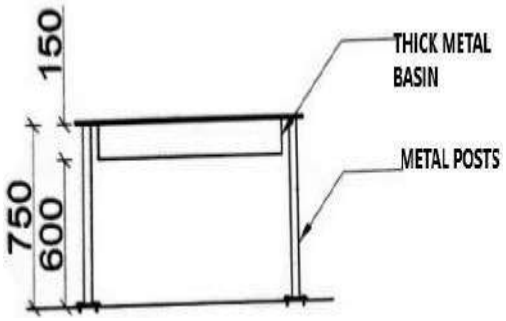
from three to eight. Thus it automatically gets restricted to a minority use [14]. Thus the equitable use of the equipment falls low compared to the accessible merry-go-round which can accommodate all categories in a relatively safer manner compared to a high backed merry-go-round [14]. The SWOT analysis conducted also shows the same result. A better engineering and material selection can help the accessible model more usable in this case.

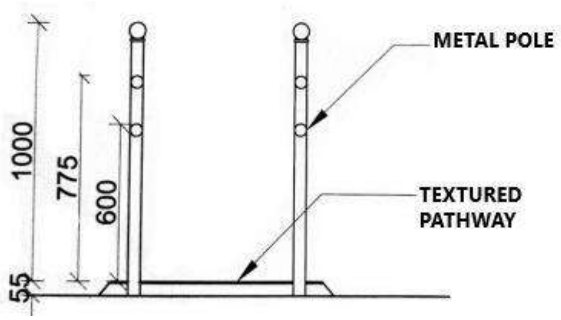
3) Case study 3: SENSORY INTEGRATION EQUIPMENT

Here we opted accessible sand pit (accessible design) as in Fig.5 and sensory pathway (universal design) as in Fig.6, for the purpose of study. They were employed in different inclusive parks. The comparative study of various attributes are as shown in the TABLE V in the comparison matrix. The dimensions of equipment and the SWOT analysis conducted is as shown in TABLE VI.



All dimensions are in mm

Fig. 5 Design for accessible sand pit [1]



All dimensions are in mm

Fig. 6 Design for universal pathway [1]

The sand pit provides a play space where children can use their hands and understand the senses. On the other hand the sensory pathway provides sensory input to legs. Thus helping children to understand the different textures. The sensory pathway is add on to children with poor eyesight. They can feel and understand different textures.

TABLE V. COMPARISON MATRIX OF SENSORY EQUIPMENT

Design type	Age-appropriateness (years)	Safety (low, moderate, high)	Equitable use (low, medium , high)	Maintenance (low, medium, high)	Activity rate (low, medium, high)
Universal	2-10	high	high	low	High
Accessible	1-8	high	high	low	high

TABLE VI.SWOT ANALYSIS FOR SENSORY EQUUIPMENT

SWOT	Accessible design	Universal design
Strength	• Equitable • Safe • Fun	• Equitable • Safe • Fun
Weakness	• Sand may blow away	• Deformation of pathway
Opportunities	• Use good quality sand	• Use better engineering in making pathways
Threats	• Dust allergy	• Leg injury

The evaluation shows that both inclusive sand pit and sensory pathway offers high equitable use, safety and activity rate with low maintenance. The age range also lies in almost equal range. Thus both account highly employable equipment. The SWOT analysis conducted on both shows the same result. More fun can be brought to the equipment by incorporating challenges to the design [15]. Hence both can be invariably included in any park.

VI. DISCUSSION

The analysis was done for different equipment using design attributes in comparison matrix. Referring to the literature review it clearly shows that there is a great need for improving the park design to bring maximum inclusiveness for children at public playgrounds [16]. Literature also shows that bringing inclusiveness can help children of all kind in their overall cognitive development [17]. Thus a public playground must be non-discriminatory [18]. From the literature, it is evident that a universal design method or an accessible design method as such won't stand alone to bring maximum inclusiveness with desired benefits [19].

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Case studies were conducted on three different equipment using both universal and accessible design approaches. It can be observed from the comparison and SWOT analysis that in the swing design the universal swing performed better over the accessible design. The design could be made more inclusive by incorporating a seat belt to the universal design. On the other hand the accessible design in merry-go-round showed better performance in bringing inclusivity over the universal design used. The accessible design could be more effective if some engineering corrections were given to the design. In case of sensory equipment, both universal as well as accessible design performed almost equally. Hence both could be employed with little alterations in design in any playground. This could in turn help in eliminating social skill deficits among children [20].

VII. CONCLUSION

It is every kid's right, to play without any barriers. A poorly designed park makes it difficult to achieve this goal. Making the public playgrounds inclusive helps break the social barrier and help every child integrate into the normal social life boosting their overall cognitive development. The two design methods of universal and accessible design help to achieve this goal to a large extent. But implementing equipment belonging to a single model in a park will ruin the real fun of the play space. The study infers us that it is very important to integrate the two designs to bring maximum inclusiveness. This ensures maximum safety, equitability in use, lower maintenance and maximum activity rate for everyone. The scope of the work is limited to the extent that the anthropometric data of children with different abilities is lacking. This makes it difficult for the designer to develop a better design which could satisfy the demands of children with equal abilities and provide a better ergonomic design. An extensive anthropometric data collection is to be done in this field to help them provide with a better design and make the play spaces more inclusive.

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REFERENCES

[1] Breaking barriers through play, Policy guidelines and a technical manual for making play spaces inclusive, KiliKili, Chennai, India, October 2016.

[2] K. Siua, Y. Wonga, M Lamb, "Inclusive Play In Urban Cities: A Pilot Study Of The Inclusive Playgrounds In Hong Kong",Urban Transitions Conference, Shanghai, September 2016.

[3] K. Skulski, "Designing for Inclusive Play", Applying the Principles of Universal Design to the Playground October 1, 2007.

[4] H. Lynch, A. Moore And M. Prellwitz, "Children From Policy To Play Provision: Universal Design And The Challenges Of Inclusive Play, Youth And Environments," vol. 28, No. 2, Unleashing The Power Of Play: Research From The International Play Association 20th Triennial Conference 2018.

[5] M..Roderick, "The Ergonomics of Children in Playground Equipment Safety"Community Parks and Playgrounds Journal of Safety Research-vol. 35, pp 249, 2004.

[6] M. Emmett, "Universally Designed Playgrounds: An Outdoor Play Place for All ", Universally Designed Playgrounds, 2012.

[7] American Society of Landscape Architects,"Accessible Play Areas-A Summary of Accessibility Guidelines for Play Areas", 2005.

[8] Courtney, Fernelius, "Playgrounds That Support Peer Interactions among Children with All Abilities",Evidence Based Practices for The Design Of Inclusive, 2017.

[9] S. Dewi," How Does The Playground Role In Realizing Children-Friendly City" Asia Pacific International Conference On Environment-Behaviour Studies, 2010.

[10] Https://Www .Access- Board. Gov/ Guidelines and Standards/ Communications- And-It/26-255- Guidelines/825- Principles-Of-Universal-Design

[11] J. Ohrnbergera, E. Ficherab, M. Suttona," The relationship between physical and mental health: A mediation analysis"-Social Science & Medicine, vol. 195, pp 42-49, 2017.

[12] B. Phadermrod, "Importance-Performance Analysis based SWOT analysis" International Journal of Information Management vol. 44, pp 194-203, February 2019.

[13] D. Singh, Information Needs of Differently Abled: New Challenge for LIS Professionals Conference Paper, January 2015.

[14] S. Khaliefeh Disabled Children in Public Playgrounds: A Pilot Study-Procedia "- Social and Behavioral Sciences vol. 36, pp 670-676, 2012.

[15] M. Kretzmann, W. Shih, C. Kasari,-"Improving Peer Engagement of Children with Autism on the School playground: A Randomized Controlled Trial"- Behavior Therapy vol 46(1), pp 20-28-January 2015.

[16] K. Wu, L. Song-"A case for inclusive design: Analyzing the needs of those who frequent Taiwan's urban parks"- Applied Ergonomics vol. 58, pp 254-264, January 2017.

[17] E. Grande," Disseminating good practices for inclusive schooling in Catalonia"- International Medical Review on Down syndrome vol. 12(1), pp 12-15, March 2008.

[18] F. Gliga, M. Popa-"In Romania, parents of children with and without disabilities are in favor of inclusive education"- Procedia - Social and Behavioral Sciences vol. 2(2), pp 4468-4474-2010.

[19] L. Koegel, R. Freden, R. Lang, R. Koegel, " Interventions for Children With Autism Spectrum Disorders in inclusive School Settings" Cognitive and Behavioral Practice vol. 19, pp 401-412,August 2012.

[20] U. Sanrattana, T. Maneerat, K. Srevisate," Social Skills Deficits of Students with Autism in inclusive Schools" vol. 116-pp 509-512, 21 February 2014.

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Application of nature inspired algorithms for optimizing water distribution system post disaster; A review

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***Abstract*— Disaster, the sudden occurrence of an event that causes loss of lives and property, may be man-made or natural. The degree of impact of these disasters is related to the way the people, affected by the event are able to cope up with the aftermath. Proper management and effective distribution of the available resources reduces the scale of impact of the calamity. Proper distribution of fresh and clean water for both drinking and other purposes is a key challenge faced by the administration after a disaster. The optimization of water delivery system hence plays an important role in relief activities. Providing adequate quantity of good quality water at reasonable cost is very important in this regard.**

The dynamicity of the situation and the scarcity of available resources, makes the problem very complex and challenging. Conventional optimization methods may not be effective to tackle the situation. Hence the research focusing on the application of nature inspired algorithms like Ant colony optimization, non dominated sorting algorithm II (NSGA II), multi objective differential evolution (MODE) and Multi objective particle swarm optimization (MOPSO) etc. gained momentum. This paper is a review on the application of nature inspired algorithms for optimizing the water distribution problems post disaster.

Keywords: Genetic Algorithms, MODE, Disaster response, Differential evolution.

1. INTRODUCTION

The degree of impact of natural disasters depends on the ability of people to cope up with the post event situations. The disaster will have greater impact on the poor and marginalized, and their ability to adapt or recover post disaster is seriously limited by their social and economical conditions. The prompt and effective decision making is to be the priority for the disaster management group to bring them back to their normal life in reasonable time. The quality decisions taken should be backed by intensive coordination between the various government departments and NGO's.

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The effective optimization tools provide the decision makers an extra edge in planning and scheduling of relief activities. This is applicable to the design and deployment of water distribution systems also, once a calamity has occurred. This forms an integral part of survival help to be provided to the victims post disasters.

In this paper a review on how various tools, non-traditional ones, can be effectively used for optimizing the water distribution system post disaster. The application of various nature inspired algorithms in planning and distribution of materials post disaster, in order to optimize the number of facility locations to enhance the area covered during relief activities is considered taking the cost factors into consideration.

2. CURRENT WORK IN THE AREA

Over the past decade there has been an increasing interest in applying the concepts of nature inspired algorithms to plan and schedule the delivery of goods and services post disaster. The following section briefly summarizes various studies done in the field. These works are primarily focused on minimizing the delivery time, and the distance traveled. The tools and methodologies followed by the researchers were also reviewed.

2.1 Optimization model objectives

(a) Minimization of time

Time minimization is one of the primary objectives to be considered during disaster response. Timely response can help in reducing the impact of the event.

Hu et al. (2016b) developed an emergency model with the objective of reducing the time of distribution of supplies. The paper focused on the road network connectivity and analyzed the vehicle connectivity in each network. They used genetic algorithm to formulate an optimized model. Yan and Guo (2016) studied the emergency response model considering the time varying complex conditions of the road and followed by dynamic allocation of paths to arrive at the shorted path between the nodes. The paper addressed real time supplies distribution post an emergency.

Wex et al. (2014) tried to model the problem of effective arrangement of rescue units for accessing the nodal points within a short span of time. The work addresses a Rescue Unit Scheduling and assignment problem using binary quadratic optimization problem. Then Monte Carlo simulation, five improvement heuristics, eight construction heuristic and GRASP heuristic were considered to solve the problem. The solutions obtained by these heuristics were compared. The result suggests that the heuristics deployed to solve the problem were successful in reducing the economic losses post disaster to a certain extend. Furthermore that GRASP

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was found to improve solution quality of both construction and improvement heuristics. These meta-heuristics diversify the search paths and, consequently, require significantly more computation time.

Hamedi et al. (2012) in his paper developed a scheduling model for the delivery of goods like water, food etc. with the primary objective of determining shortest delivery time. The model developed was solved using genetic algorithm. The performance of this algorithms were then evaluated by model networks. The results suggested that the model was successful in delivery of goods while maintain the quality of the solutions. Ahmadi et al. (2015) proposed a multi-nodal location-routing model. The cases of network failure, uses of vehicles for delivery purposes were the parameters considered. The model identifies the local routs and warehouses available. Last mile distribution model was developed. The deterministic model developed was then solved using neighborhood search algorithm. The study suggests that the demands can be satisfied by increasing number of local warehouses and the number of vehicles used.

(b) Minimization of distances

Developing or realizing the shortest path to be followed is another important objective to be considered during emergency disaster response.

Ma and Wang (2014) developed a model with a single distribution centre supplying multiple disaster affected nodes and produced a two way distribution model. The work suggest that the tool produces efficient solutions.

Liu (2010) further developed a model for deployment of emergency response materials, considering minimization of the total distance traveled by the vehicles as the primary objective. The model for the optimal delivery of goods and supplies also provides directions for the victims to flee from the affected zone, thus helping in effective rescue. Ferrer et al. (2018) built a compromise programming model for last mile distribution-multi objective problem. The paper developed a multi criterion transportation model for Last mile distribution that incorporates security as a performance measure. The model when applied forces the vehicle to travel together as convoys. By deploying vehicles as convoys, the work establishes the enhancement in security aspects. The new system takes a larger waiting time which is the main pitfall of the model.

Batmetan et al. (2017) in his study delved into problem of determining the shortest path. The distance, speed, depots etc. were considered as the constraints. Multi objective Ant Colony Optimization (MO-ACO) algorithm was used to develop the model and determine the shortest route to travel. The results obtained from the study showed promise in developing optimal solutions with short path as well as reducing the time span of response. Yuan and Wang (2007) in his study developed an emergency supply model were the complexity of the different paths to be

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travelled as well as time requirement per path were considered. Real time data was taken into account. The model developed was successful in reducing the travel time. The model considered the travel speed on each arc as a continuous decreasing function of time.

2.2. Nature Inspired Tools for Optimization

(a) Genetic algorithms (GA)

Genetic algorithms are based on the theory of biological evolution. It considers or bring about biological aspects like developing next generation solutions by replication, duplication, mutation and cross over and gradually eliminate weak solutions i.e. solutions that have small or weak fitness value, hence the solution developed would be one in which solutions would have high fitness value Deb et al (2002). The distribution of water post disaster being a Multi objective problem and genetic algorithms can act as an effective tool to provide smart solutions. Zhao (2012) developed an improved GA to obtain solutions for Multi Objective Emergency Supply models. The algorithm successfully introduced both the mutation and crossover operators while maintaining the diversity and uniqueness of the solutions. The simulated models showed that the improved form of GA was able to attain the optimized solutions in minimum number of iterations.

(b) Non - Dominated sorting genetic algorithm-II (NSGA-II)

Deb et al (2002) developed the concept that removed the problems or drawbacks of Multi objective evolutionary algorithms. The author considered the computational complexity, lack of elitism approach and the lack of specification of parameters as major drawbacks of Multi Objective Evolutionary Algorithms. The work presented a novel approach to overcome these drawbacks. The algorithm developed, produced a faster solutions. By ranking the solutions based on non-dominated sorting the method ensures well distributed and diverse set of solutions. The results shows that the solutions produced by NSGA-II were well distributed over the pareto front and got better convergence compared to other MOEAs namely Pareto-archived evolution strategy (PAES) and Strength-Pareto Evolutionary Algorithm (SPEA). It is reported that that the diversity preserving mechanisms in NSGA-II were better compared to PAES and SPEA.

Kasat and Gupta (2003) further introduced the concept of jumping genes (JG) into the NSGA-II and developed more sophisticated NSGA-11-JG. The jumping genes concept incorporated the effect of elitism into the NSGA-II making the NSGA-11-JG more effective in attaining the optimal solution.

(c) Multi-objective particle swarm optimization (MOPSO)

The algorithms were developed by drawing inspiration from behavior of flock of birds. The order of the arrangement's taken by the birds after scattering was used as the inspirational model for developing this algorithm. Kennedy (2011) developed and proposed the basic PSO methodology. The study found the algorithm to be simple

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and efficient and could be applied to solve optimization problems.

Lin and Xu (2008) applied the PSO model on to an Emergency medical and transportation system and found the results to be promising. Unlike the previous works on distribution of relief materials, the work analyzed the relation between the system time and the associated cost. The multi objective problem was transferred into a single objective problem by ideal point method. Then the PSO algorithm was used to obtain the solution. The solution sets obtained on solving the model were found to be able to reduce the system time and the associated cost. Yu (2014) developed an improved more robust version of PSO to solve Multi-Objective model with an objective of minimizing the transportation charge and time delays.

The research in the field of PSO shows that it has better advantage of faster convergence and producing quality solutions for solving both multi-objective and dynamic target optimization. The major drawback of PSO is that even if it has faster convergence it has tendency to get entrapped in local optima. Currently researchers are focused on developing hybrid models incorporating PSO's to overcome this drawback.

(d) Multi objective differential evolution

The differential evolution algorithm draws inspiration from the NSGA-II. The algorithm was proposed by BV Babu (2008) and introduced the concept of dominated differential evolution to solve multi objective problems. The author compared the performance of MODE with NSGA-II on four different mathematical problems. Results obtained shows that the solutions obtained possesses diversity compared to its counterpart NSGA-II. Hence MODE can be applied to more complicated problems where diversity of the solution is the priority. The major drawback of the algorithm is its run time complexity.

H. Momsef et.al (2018) considered the practical applications of the three genetic algorithms namely Non-dominated sorting genetic algorithm-II, Multi objective differential evolution and Multi Objective Particle Swarm optimization for optimizing water distribution systems. The paper analyzed the performance of these three algorithms over 4 water distribution networks in cities of New York, Hanoi, Pescara and Modena each time increasing the complexity of the problem. Minimum cost and network reliability were considered as the primary objectives. the results obtains shows that both MODE and NSGA-II were able to provide optimal solutions in the initial cases, but as the complexity of problem increased the MODE algorithm had better convergence with associated runtime complexity.

3. CONCLUSION

The available research result in the field of Multi Objective Optimization (MOO) focuses on tackling the complexity of real life situations in unanticipated situations such as the occurrence of disasters. The timely

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action reduces the impact of the event. As the previous work suggests, the application of non-traditional optimization tools that produce smart solutions can help the administration to effectively manage the situation. The solutions in this regard depends on the nature and locality of the event and involves complexity because of the novelty of the situation. Hence this field is promising area for researchers. The analysis of various nature inspired algorithms to solve the issues faced by natural calamities in different areas can help in developing a generic tool that can be effectively implemented for future planning and disaster management activities.

REFERENCES

[1] Hu, F., Tian, C., Zhao, M., & Han, X. (2016). Research on hierarchical linkage scheduling emergency supplies based on genetic algorithm. *Application Research of Computers*, *33*(2), 339-440

[2] Junai, Y., & Yiyuan, G. (2016). Unconventional emergency aid delivery path optimization research. *Journal of Catastrophology*, *1*(1), 193-200.

[3] Wex, F., Schryen, G., Feuerriegel, S., & Neumann, D. (2014). Emergency response in natural disaster management: Allocation and scheduling of rescue units. *European Journal of Operational Research*, *235*(3), 697-708

[4] Hamedi, M., Haghani, A., & Yang, S. (2012). Reliable transportation of humanitarian supplies in disaster response: model and heuristic. *Procedia-Social and Behavioral Sciences*, *54*, 1205-1219.

[5] Ahmadi, M., Seifi, A., & Tootooni, B. (2015). A humanitarian logistics model for disaster relief operation considering network failure and standard relief time: A case study on San Francisco district. *Transportation Research Part E: Logistics and Transportation Review*, *75*, 145-163.

[6] Batmetan, J. R., & Santoso, A. (2017). A Multiple-Objective Ant Colony Algorithm for Optimizing Disaster Relief Logistics. *Advanced Science Letters*, *23*(3), 2344-2347.

[7] Yuan, Y., & Wang, D. (2007, August). Multi-objective path selection model and algorithm for emergency evacuation. In *2007 IEEE international conference on automation and logistics* (pp. 340-344). IEEE.

[8] Hu, H., He, J., He, X., Yang, W., Nie, J., & Ran, B. (2019). Emergency material scheduling optimization model and algorithms: a review. *Journal of traffic and transportation engineering (English)*

[9] Alem, D., Clark, A., & Moreno, A. (2016). Stochastic network models for logistics planning in disaster relief. *European Journal of Operational Research*, *255*(1), 187-206.

[10] Ma, R., Xie, G. Z., & Zhang, C. (2014). Design and implementation of agricultural logistics distribution vehicle scheduling system based on LBS. In *Advanced Materials Research* (Vol. 989, pp. 5504-5507). Trans Tech Publications Ltd.

[11] Hu, H., He, J., He, X., Yang, W., Nie, J., & Ran, B. (2019). Emergency material scheduling optimization model and algorithms: a review. *Journal of traffic and transportation engineering (English edition)*.

[12] Ferrer, J. M., Martín-Campo, F. J., Ortuño, M. T., Pedraza-Martínez, A. J., Tirado, G., & Vitoriano, B. (2018). Multi-criteria optimization for last mile distribution of disaster relief aid: Test cases and applications. *European Journal of Operational Research*, *269*(2), 501-515.

[13] Deb, K., Agrawal, S., Pratap, A., & Meyarivan, T. (2000, September). A fast elitist non-dominated sorting genetic algorithm for multi-objective optimization: NSGA-II. In *International conference on parallel problem solving from nature* (pp. 849-858). Springer, Berlin, Heidelberg.

[14] Kasat, R. B., & Gupta, S. K. (2003). Multi-objective optimization of an industrial fluidized-bed catalytic cracking unit (FCCU) using genetic algorithm (GA) with the jumping genes operator. *Computers & Chemical Engineering*, *27*(12), 1785-1800.

[15] Lin, H., & Xu, W. S. (2008). Research of Emergency Materials Scheduling Solved by Binary PSO. *Computer Knowledge and Technology*, *3*(7), 1503-1505.

[16] Bonyadi, M. R., & Michalewicz, Z. (2017). Particle swarm optimization for single objective continuous space problems: a review.

[17] Xiao-bing, Y. (2014). Mult-objective Emergency Supplies Scheduling Based on Improved Particle Swarm Optimization. *Industrial Engineering Journal*, *17*(3), 18.

[18] Gan, X., Wang, Y., Yu, Y., & Niu, B. (2013, July). An emergency vehicle scheduling problem with time utility based on particle swarm optimization. In *International Conference on Intelligent Computing* (pp. 614-623). Springer, Berlin, Heidelberg.

[19] Monsef, H., Naghashzadegan, M., Jamali, A., & Farmani, R. (2019). Comparison of evolutionary multi objective optimization algorithms in optimum design of water distribution network. *Ain Shams Engineering Journal*, *10*(1), 103-111.

[20] Babu, B. V., & Anbarasu, B. (2005, December). Multi-objective differential evolution (MODE): an evolutionary algorithm for multi-objective optimization problems (MOOPs). In *Proceedings of International Symposium and 58th Annual Session of IIChE*.

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Advancements in Stock Price Prediction using Long Short Term Memory (LSTM) Neural Network: A Review

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Abstract **— Utilizing deep learning is gaining popularity in the area of stock price prediction and algorithmic trading. The artificial neural network can continuously improve itself without human interaction until it reaches a level of acceptable accuracy. Within the type of neural networks, there are more advanced systems called Deep Neural Networks (DNNs) Deep learning networks has the capability of multiple hidden layers. The applications of deep learning technology are endless in various fields, and recently, research about artificial intelligence and deep learning has increased. Long short Term Memory networks (LSTMs) observed as the most effective solution for many data science problems found in the sequence prediction.**

LSTM neural network compared with various other models, neural networks to highlight its importance. Therefore a review is made to explain the advancements in the LSTM approach in recent years, which makes the problem of stock price prediction more effective.

Keywords— Deep Learning, Neural Network, Long Short Term Memory, Stock Price Prediction.

I. INTRODUCTION

For years, stock price prediction has been a focus as it can yield maximum profits. The two traditional methods used for forecasting stock prices are fundamental analysis and technical analysis. Stock price prediction makes many investors and traders keep hoping for the best stock investment. Due to the characteristics and dynamic nature, it isn't very easy to find the financial time series data, the data representation of stock price. In recent years many studies regarding the stock price prediction are experimented for overcoming the forecasting problems faced by the financial experts using deep learning. Deep Learning has proven success in the fields of image recognition, speech recognition, or sentiment analysis. These models are capable of learning from large-scaled unlabeled data, forming non-linear relationships, forming recurrent structures, and can be easily changed to avoid over-fitting.

Similarly, in the discipline of finance too, the applications are far and wide — these models used in pricing, some portfolio construction, risk management, and also in high-frequency trading. For modeling stock prices over time near-perfectly, there are no proper, consistent patterns in the data as the stock market prices are volatile and highly unpredictable. For many years Recurrent Neural Networks (RNNs) were used for sequence prediction problems in many fields. But it has some gradient vanishing problems. Long Short Term Memory (LSTM) neural networks explicitly designed to avoid the long-term dependency problem. Therefore LSTMs have been used recently in many experiments because of their exciting features. There have been more advances in LSTM neural networks by improving there working mechanism. Some of the recent advancements in LSTMs reviewed.

Long Short Term Memory (LSTM) Neural Network

Long Term Short Memory neural network is a type of Recurrent Neural Network, designed to overcome the long term dependency problems in recurrent networks. LSTMs initially conveys the vanishing gradient problem of the recurrent neural network and then allows training of long term dependencies. The typical LSTM module has four neural network layers interrelating uniquely. The blade has three gate functions, namely the input gate, the output gate, and the forget gate. Cell state, the fundamental component of LSTM allows the details to proceed straight down the line. The cell state in LSTM acts like a conveyor belt that runs along through the entire chain, with only some minor sequential interactions. The network has the control over the amount of previous data to be transmitted. The LSTM do have the ability to add or remove the details from the cell states. LSTMs have been well known for their promising performance in sequence prediction like, language modelling, image captioning, speech recognition, translation etc. In finance, the price movement in the stock markets are extremely complex and volatile. LSTMs

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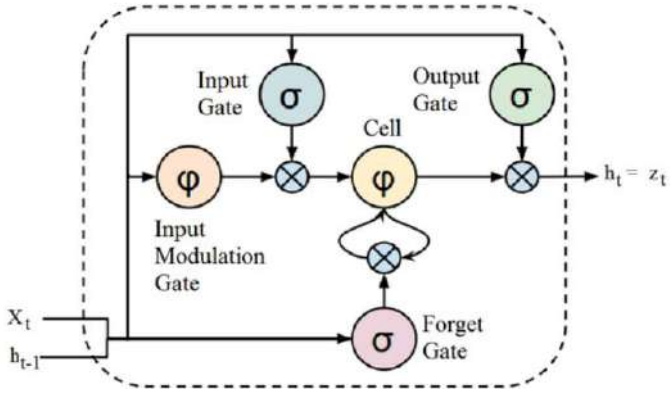
due to its unique storage unit structure, avoids long term dependence issues and helps in predicting financial time series. Thereby, guiding the investors to effective and accurate stock trading.



Flowchart of LSTM Neural Network

II. Literature Survey On The Tool And Technique Long Short Term Memory neural network

A. Stock Price Prediction

1). LSTM – for denoising

Usually, due to the large number of instantaneous changes in the market and trading area, a complex system of irregularities and roughness are configured in the financial data. These irregularities are known to be noise. The noises employed in the financial data usually demonstrate heavy tracking; that is, the primary time series data reveals a huge number of random jumps. Ignoring these irregularities in the financial data can conveniently lead to inaccurate conclusions.

The solution to the problem of noising in the financial time series can be; Xiaodan Liang et al. [1] introduced wavelet denoising method into the data preprocessing. The original data to be used as an input in LSTM is preprocessed with a new multi optimal combination wavelet transform (MOCWT) method and is used as the training data, thus suggesting a way for denoising. Thomas Fischer et al. [2] used LSTM neural network for extracting a sequence of standardized raw returns, even though the portfolio consists of stocks with below mean momentum, high volatility, beta, and reliable short term reversal characteristics. Also, these findings relate to existing capital market anomalies to some extent. Thereby meaningful information are effectively extracted from the noisy form of financial time series data by the successfully demonstrated LSTM neural network.

2). Comparison of LSTM with other methods

As already mentioned, LSTMs can add the information or remove it to the cell state. Therefore, LSTMs outperformed various other traditional methods using their promising performance in sequence prediction. In recent years different research has been made in stock price prediction using LSTM against some particular benchmark sequence prediction methods. Some such studies examined for focusing the outperformance of LSTM.

Therefore, Kai Chen et al. [3] has modelled and predicted the Chinese stock returns using LSTM Algorithm. They randomly predicted the stock price by chance and compared the results with the LSTM Algorithm method using different features. They then suggested that different market indexes affect the stock returns, concerning the accuracy of prediction. Similarly, Thomas Fischer et al. [2] compared LSTM to random forests, standard deep nets, and logistic regression. They suggested better prediction accuracy for daily returns was achieved for LSTM after transaction costs. Chawalit Jeenanunta et al. [4] investigated the prediction of everyday stock prices of the topmost companies in the Thai SET50 index. Five companies are selected to compare the performance of the model with different stocks having various volatility to analyze how the model performs in different conditions. They compared LSTM with Deep belief Network (DBN), and the results suggested LSTM has better prediction accuracy. Divit Karmiani et al. [5] provided a comparative analysis between Back propagation, Support Vector Machine (SVM), and LSTM algorithms based on accuracy, variation, and time required for different numbers of epochs. They made a comparative approach using Back propagation, Support Vector Machine (SVM), LSTM algorithms based on accuracy, variation, and time required for the different number of epochs in order to obtain optimal technique for stock market prediction under different circumstances. According to their results, they suggested that the choice of algorithm entirely depends on requirement of parameters like time, variance, and mean accuracy. If the demand is having high accuracy and low variance, then LSTM would be a better choice.

3). Advancements in LSTM Neural Network

Since the beginning of the LSTM neural network, there have been various researches carried out for further improving the existing algorithm by conducting experiments by changing multiple factors in it. Some of such changes adopted are listed. QiLyu, JunZhu [6] proposed a matrix-based batch learning method for LSTM with full Back propagation Through Time (BPTT). Then, state drifting issues are solved and the overall performance for LSTM is improved using revised activation functions for gates. Leonardo dos Santos Pinheiro et al. [7] used a simple LSTM neural network with character level embeddings for stock market forecasting using only financial news as predictors. They proposed the use of

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character-level embeddings in their experiment and said it is more promising with more complex models that use technical indicators and event extraction methods besides the use of news articles.

Raghav Nandakumar et al. [8] has proposed an online learning algorithm that utilizes Long Short Term Memory (LSTM), a kind of recurrent neural network (RNN), where stochastic gradient descent used for adjusting individual data point weights. Thus, more accurate results were produced in comparison to existing stock price prediction algorithms. Svetlana Borovkova [9] proposed an ensemble of long short term memory (LSTM) neural networks for the intraday stock predictions, which used a large set of technical analysis indicators as network inputs. The predictive power of the model on several US large-cap stocks was evaluated and benchmarked against lasso and ridge logistic classifiers. The author found that the proposed model performs better than the benchmark models.

Manish Agrawal et al. [10] predicted the price and price trend of stocks by adopting optimal Long Short Term Memory (O-LSTM) deep learning and adaptive Stock Technical Indicators (STIs). Their concept is based on deriving adaptive STIs and passing them as correlation tensor. The tensor then supplied to the LSTM model. So, many such types of research conducted to date for improving the LSTM neural network for attaining the best model in deep learning. Therefore, further, many studies in the field are expected for precise stock price prediction accuracy.

III. CONCLUSION

Various models used for making a comparison with LSTM neural network to make it apparent. LSTM neural network, when compared with the Deep Belief Network for analyzing the performance of the model in different stocks with various volatility, has better prediction accuracy. Also, when stocks from different markets are used together in LSTM as an input, it affected the accuracy in prediction. LSTMs have the capability of extracting meaningful information from noisy financial time series data.

In LSTM, when the individual data point weights are adjusted using stochastic gradient descent provides results much accurately. In recent advances made in LSTM, data preprocessing carried out using a multi optimal combination wavelet transform for denoising. The stock technical indicators sometimes used for deriving and are used as a correlation tensor in LSTMs for getting excellent precision in price movement. Therefore, the advancements in LSTM keep ongoing for acquiring much better prediction accuracy than before.

REFERENCES

[1] Xiaodan Liang ,ZhaodiGe ,LilingSun ,MaoweiHe ,HanningChen (2019) “LSTM with Wavelet Transform Based Data Preprocessing for Stock Price Prediction” Hindawi Mathematical Problems in Engineering Volume 2019, Article ID 1340174, 8 pages.

[2] Thomas fischer and Christopher krauss (2018), “Deep learning with long Short Term Memory networks for financial market predictions” European Journal of Operational Research

[3] Kai Chen, Yi Zhou, Fangyan Dai (2015)” A LSTM-based method for stock returns prediction : A case study of China stock market” 2015 IEEE International Conference on Big Data (Big Data)

[4] Chawalit Jeenanunta, Rujira Chaysiri, Laksmey Thong (2018) “Stock Price Prediction with Long Short-Term Memory Recurrent Neural Network” School of Management Technology Sirindhorn International Institute of Technology Thammasat University, Thailand

[5] Divit Karmiani, Ruman Kazi, Ameya Nambisan, Aastha Shah, Vijaya Kamble (2019) “Comparison of Predictive Algorithms: Backpropagation, SVM, LSTM and Kalman Filter for Stock Market” 978-1-5386-9346-9/19/$31.00 ©2019 IEEE

[6] Qi Lyu, Jun Zhu (2013) “Revisit Long Short-Term Memory: An Optimization Perspective” State Key Laboratory of Intelligent Technology and Systems (LITS) Tsinghua National Laboratory for Information Science and Technology (TNList) Department of Computer Science and Technology, Tsinghua University, Beijing 100084, China

[7] Raghav Nandakumar, Uttamraj K, Vishal, Y V Lokeswari (2018) “Stock Price Prediction Using Long Short Term Memory” International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 05 Issue: 03.

[8] Leonardo dos Santos Pinheiro, Mark Dras (2017) “Stock Market Prediction with Deep Learning: A Character-based Neural Language Model for Event-based Trading”

[9] Svetlana Borovkova, Ioannis Tsiamas (2019) “An ensemble of LSTM neural networks for high-frequency stock market classification” School of Business and Economics, Vrije Universiteit

[10] Manish Agrawal, Asif Ullah Khan, Piyush Kumar Shukla (2019) “Stock Price Prediction using Technical Indicators: A Predictive Model using Optimal Deep Learning” International Journal of Recent Technology and Engineering (IJRTE) ISSN: 2277-3878, Volume-8 Issue-2

Numerical study on heat transfer augmentation in a tube heat exchanger with symmetrical airfoil shaped insert

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Abstract— In this study, the effect of an airfoil shaped insert in a heat exchanger tube is numerically studied. The insert is added to increase the heat transfer rate and improve the thermal performance of the heat exchanger. The insert is modelled as a straight tape with modified NACA0024 arranged along the axial direction. ANSYS Fluent package is used for the simulation. The inclination angle of the airfoil and the pitch to tube ratio is fixed in the present study. To evaluate the performance of the insert, the CFD results are presented in dimensionless form such as Nusselt number(Nu), friction factor (f), and thermal enhancement factor (TEF).The accuracy of the CFD results are ensured by conducting grid independence test and model validation study against previously published experimental data

Keywords—Numerical study, heat exchanger, insert, Nusselt number, friction factor

I. INTRODUCTION

Heat exchangers find applications in many industrial and engineering processes. Heat transfer augmentation in heat exchangers is necessary in today's scenario as it helps to save energy, increase thermal performance and reduce size. The techniques employed for heat transfer augmentation can be classified as active and passive methods. Active methods employ external energy to enhance heat transfer whereas passive methods introduce surface or geometrical modification to the flow passage with the help of inserts or additional devices. A lot of study has been conducted on passive techniques for heat transfer improvement

Xu et al. [1] numerically studied the effect of winglet vortex generators on heat transfer performance in a circular tube. The different sets of delta winglets were characterized by four attack angles β (0^o, 15^o, 30^o and 45^o) and three blockage ratios B (0.1, 0.2 and 0.3). The combination β 45^0 - B 0.3 generated the highest heat transfer increase and the highest frictional effect as well. However, the configuration β 30^0 – B 0.1 generated the highest thermal performance enhancement which was about 1.3 .

Mahfouz et al. [2] conducted a numerical study on twisted tape inserts on a heat exchanger tube. Heat transfer and pressure drop through a tube with twisted tape inserts were numerically investigated for different twist ratios. It was found that inserts with lower twist ratio provided significant heat transfer enhancement. The effect of addition of a rod to twisted tape geometry was studied. The modified geometry yielded higher thermal performance compared to twisted tape.

Gururatana et al. [3] carried out an experiment using a new type of insert in a circular tube. The insert was an aluminum tape having modified symmetric airfoils arranged centrally along its length. The experiment was carried for inclination angles 0^o, 30^o, 45^o. It was found that the insert with inclination angle 45^o gave Nusselt number approximately thrice that of plane pipe. However the friction factor was also higher for that insert. Maximum heat transfer enhancement performance obtained was 1.45

Skullong et al. [4] experimentally and numerically studied a tubular heat exchanger with delta wing tape inserts. The experiment was conducted for turbulent flow. The delta wings were in a forward-wing arrangement with different inclination angles, ratios of wing-pitch to tube-diameter. The results indicated that the delta wing tape provided increased Nusselt number and friction factor up to 5.05 and 69 times over the smooth tube. Maximum heat transfer performance was 1.49

Ibrahim et al. [5] did a computational study of conical insert in circular tube. Conical ring inserts were applied through three configurations of; convergent conical rings (CR), convergent–divergent conical rings (CDR) and divergent conical rings (DR). RNG-k − ε turbulence model with enhanced wall functions was used to model the turbulent flow regime. The friction factor ratio decreased with increase of pitch ratio. The best enhancement tube efficiency was found to be 1.291 for the divergent ring with d/D.

Chokphoemphun et al. [6] Winglet vortex generators (WVG) with an attack angle of 30^o at four different winglet pitch ratios and three winglet-width or blockage ratios were tested for turbulent flow. It was established that smaller pitch ratio yields higher heat transfer rate than the larger one but the smaller blockage ratio provides an opposite trend. Friction factor of the WVGs was found to be 2.07-5.63 times above that of the plain tube. Friction factor tends to decrease with the

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Nomenclature

D = Diameter of tube (m)
L = Length of tube (m)
w = Width of tape (m)
l = Length of tape (m)
t_a = Air foil thickness(m)
t = Tape thickness (m)
p = Pitch length (m)
PR = Pitch ratio (p/D)
Re = Reynolds number
Nu = Nusselt number
k = turbulent kinetic energy (m^2/s^2)
V = Velocity of air flow(m/s)
h = heat transfer coefficient(W/km^2)
f = friction factor
T_i = Air inlet temperature(298K)
T_o = Air outlet temperature(K)
T_{surf} = Average tube surface temperature (K)
T_b = Bulk temperature of air(K)
Pr = Prandtl number
Δp = Pressure drop along length of tube
$C_{1\varepsilon}$ = constant (1.42)
$C_{2\varepsilon}$ = constant (1.68)
Nu_o = Nusselt number for plain pipe
f_o = friction factor for plain pipe
G_k = generation of turbulence kinetic energy due to the mean velocity gradients

Greek symbols

α = Inclination angle (0^o)
ε = dissipation rate (m^2/s^3)
ρ = Density of air(Kg/m^3)
σ_k= turbulent Prandtl number for k
σ_ε= turbulent Prandtl number for ε
μ = dynamic viscosity (kg/s m)
μ_t= turbulent viscosity (kg/s m)
i, j = Cartesian coordinates in x and y direction
λ = thermal conductivity of fluid (W/m K)

Abbreviations

TEF = thermal enhancement factor

rise of pitch. The thermal performance index was found to be in the range of 1.35-1.59

It is evident from literature that winglet type inserts improve the heat transfer rate with less frictional loss compared to other vortex generators. In this paper a numerical study is conducted to analyze the effect of insert with airfoil geometry on heat transfer and friction loss.

II. METHODOLOGY

A. Physical model

The domain of interest is a circular tube with an insert in the form of a straight tape with modified NACA0024 airfoils placed along its axis. In order to reduce computational time symmetry of the model is utilized and therefore the computational domain is only half section of the pipe and insert.

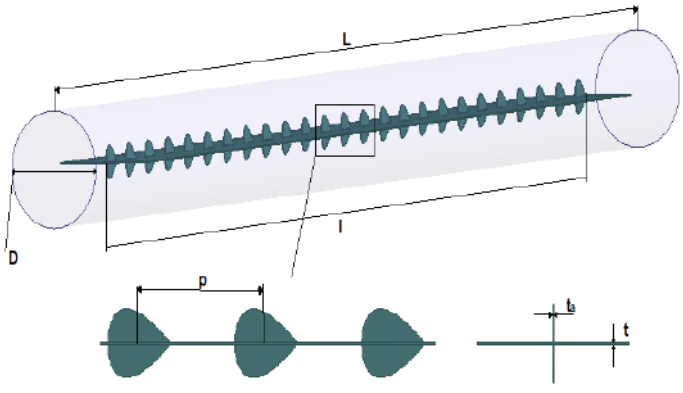

Fig. 1 Schematic of tube with airfoil shaped insert

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The geometrical parameters and their values are D = 50.2mm, L = 1200mm, w = 50mm, l = 1000, t = 0.5mm, t_a = 0.5mm. Initially α = 0 and PR = 1 for validation. Later these are varied for analysis. Air is used as the working fluid and the insert material is aluminum. Turbulent flow with Reynolds number ranging 4196 to 8610 is considered.

B. Mathematical modeling and boundary conditions

The flow is three-dimensional, steady and incompressible. RNG k – ε turbulence model with enhanced wall treatment is chosen for numerical simulation of tube with insert. The set of governing equations consists of (1) continuity
(2) Momentum, (3) energy, (4) k and (5) ε and are given below:

$$\frac{\partial(\rho u_i)}{\partial x_i} = 0 \tag{1}$$

$$\frac{\partial\left(\rho\overline{u_i u_j}\right)}{\partial x_j} = -\frac{\partial p}{\partial x_i} + \frac{\partial}{\partial x_j}\left(\mu\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)\right) - \frac{\partial(\rho\overline{u_i' u_j'})}{\partial x_j} \tag{2}$$

$$\frac{\partial}{\partial x_j}\Big(u_j(\rho e + p)\Big) = \frac{\partial}{\partial x_j}(\lambda\frac{\partial T}{\partial x_j}) \tag{3}$$

$$\frac{\partial}{\partial x_j}(\rho k u_i) = \frac{\partial\left(\left(\mu + \frac{\mu_t}{\sigma_k}\right)\lambda\frac{\partial k}{\partial x_j}\right) + G_k - \rho\varepsilon}{\partial x_j} \tag{4}$$

$$\frac{\partial}{\partial x_j}(\rho\varepsilon u_i) = \frac{\partial}{\partial x_j}\left(\left(\mu + \frac{\mu_t}{\sigma_k}\right)\lambda\frac{\partial k}{\partial x_j}\right) + C_{1\varepsilon}\frac{\varepsilon}{k}G_k - C_{2\varepsilon}\rho\frac{\varepsilon^2}{k} \tag{5}$$

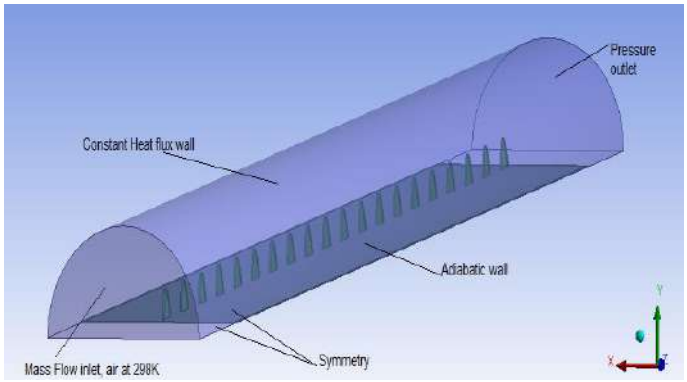

Fig. 2 Boundary conditions applied for numerical study.

The inlet is set as mass flow inlet with air entering at 25 °C and outlet is set as pressure outlet condition with zero gauge pressure. The no-slip wall conditions are given on the tube wall as well as on the insert surface. The tube wall is assigned a constant heat flux condition and the walls of the insert are made adiabatic. Symmetry is set on the bottom part of semi cylindrical domain. The working fluid properties were considered at its mean temperature.

C. Modeling strategy and solution method

The unstructured grid is generated in the computational domain using ANSYS Meshing. To capture the boundary layer phenomenon near the wall, the prism layers are generated with maintaining wall y+ below 4. ANSYS FLUENT software is used for solving the governing equations. Coupled algorithm is employed for pressure velocity coupling. Second order upwind scheme is employed for energy, momentum, while first order upwind scheme is used turbulent kinetic energy, and turbulent dissipation rate equations.

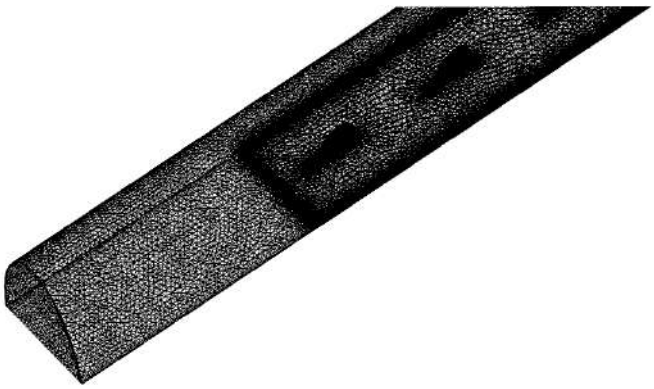

Fig. 3 Computational domain of tube with insert

D. Parameter definition

The parameters of interest in this paper are Nusselt number, friction factor and thermal enhancement performance which relates to the heat transfer rate, friction loss and effectiveness of heat transfer enhancement in the tube with insert for given flow conditions.

Friction factor refers to dimensionless pressure drop for internal flow, which is calculated by:

$$\mathrm{f} = \frac{2\Delta\mathrm{p}\mathrm{D}}{\rho\mathrm{L}\mathrm{V}^2} \tag{6}$$

The heat transfer coefficient is given by:

$$q = h(T_{surf} - T_b) \tag{7}$$

Bulk temperature is the mean of inlet and outlet temperature.

$$T_b = \frac{T_o + T_i}{2} \tag{8}$$

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Nusselt number can be obtained by the equation:

$$Nu = \frac{hD}{\lambda} \quad (9)$$

The TEF, which is the ratio used to evaluate the thermo hydraulic performance:

$$TEF = \frac{Nu/Nu_o}{(f/f_o)^{1/3}} \quad (10)$$

III. Results and Discussion

The results of numerical simulations are discussed in this section. Firstly the grid independence is discussed followed by validation of tube with insert

A. Grid independency test

Grid independence test was carried out by using five different grids with 2.82, 3.02, 3.61, 4.42 and 5 Million elements. Each grid case was created with the same mesh topology. The mesh size was varied from biggest size to small and stopped where the corresponding results converge. The study was carried out for Re = 4190 and pitch ratio, PR = 1. The outlet temperature for each grid case was noted. It was found that the solution became grid independent beyond 3.61 million elements. For further analysis this grid was selected.

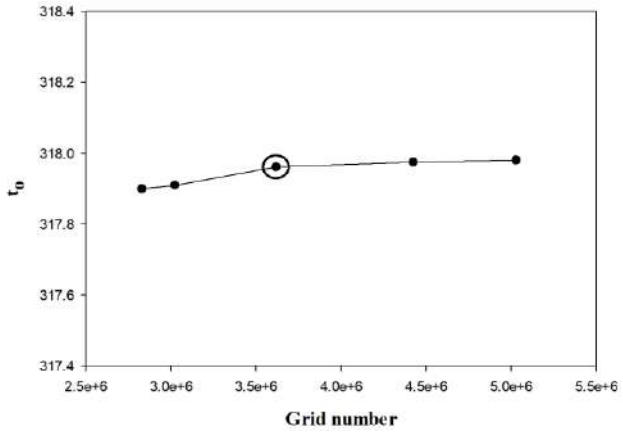

Fig. 4 Grid independence study

B. Validation

The numerical results for the tube with airfoil insert are compared with the experimental results of Gururatana [3]. These results are shown in fig. 5. It is observed that the maximum error between numerically computed Nu and experimental value is 8.4% and the average error is 4.2%. In the case of f, the maximum error between numerical and experimental value was 19% with average relative error being 16.8%.

From Fig. 5 it can be seen that Nu increases and f decreases with Re. As the flow become more turbulent more mixing occurs enhancing the heat transfer resulting in higher Nu. As f is inversely proportional to square of velocity and as a result reduction in flow area due to presence of insert, the mean velocity of flow will be greater causing reduction in f.

The results for a plain pipe in terms of Nu and f are also compared with correlations of Dittus-Boelter and Blasius and also with experimental values from literature. These correlations are expressed as follows;

Dittus – Boelter correlation: $Nu = 0.023\, Re^{0.8} Pr^{0.4}$ (11)

Blasius's correlation: $f = 0.316\, Re^{-0.25}$ (12)

C. Thermal enhancement factor

TEF is defined as the ratio of the heat transfer coefficient of an augmented surface, to that of a smooth surface at an equal pumping power. Here this ratio is related between the tube with insert and plain tube. TEF is plotted against Re as shown in fig. 7. For the given range of Re, the value of TEF is above one which indicates that the tube with insert is advantageous over plain tube. It is also seen that TEF decreases with Re. This is because the ratio, Nu/Nu_o decreases with increase in Re and f/f_o increases with Re but the effect of increase in friction factor ratio is more dominant leading to reduction in TEF at higher values of Re.

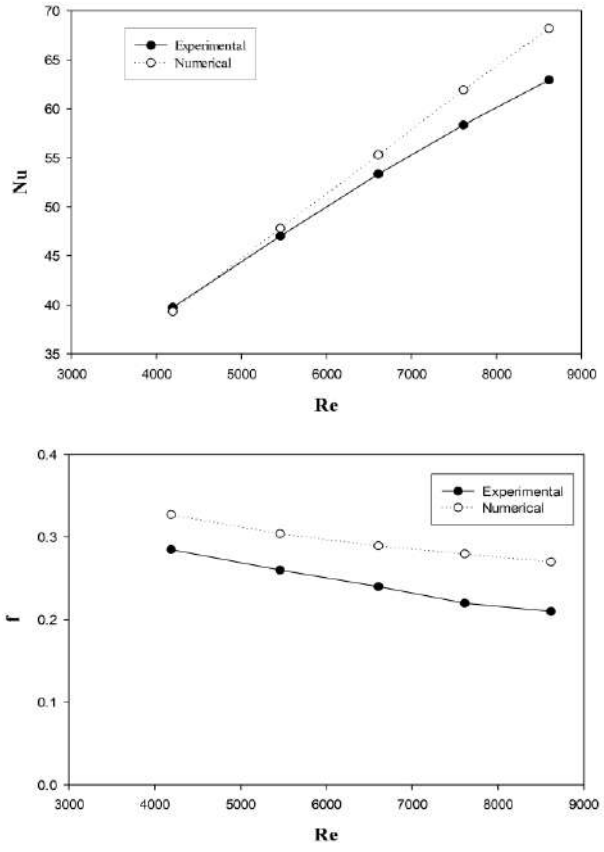

Fig. 5 Validation of numerical study using experimental results of Gururatana et al.

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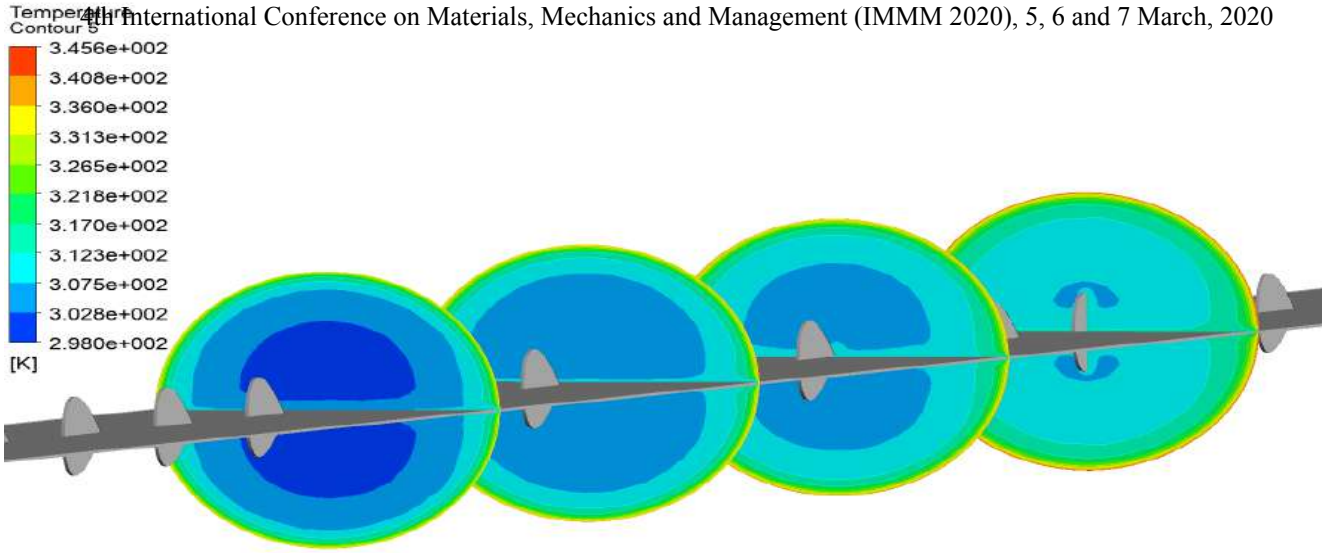

Fig. 6 Temperature contours in transverse planes for the insert at Re = 4910

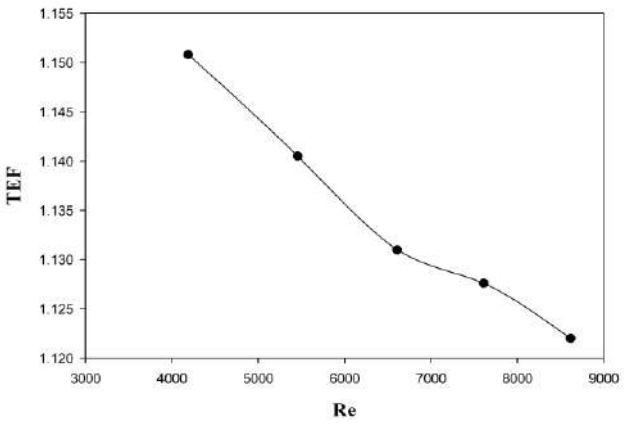

Fig. 7 Variation of TEF against Re for the tube with insert

Fig. 6 displays the temperature distribution along various transverse planes for the present model at Re = 4910 and the evolution of temperature field can be observed. As the flow progresses along the insert, longitudinal vortices are produced and they enable better mixing in the core region of flow. This results in more uniform temperature distribution.

IV. CONCLUSION

A numerical study has been conducted to determine the thermo-hydraulic characteristics of turbulent flow in a tube with airfoil insert of PR = 1 and $\alpha = 0^{o}$. The conclusions are as follows:

1) Heat transfer is improved by the addition of the airfoil insert as it alters the flow pattern by generating vortices. This enables better mixing in the core region of flow and helps in reducing the boundary layer thickness

2) Nusselt number is increased by twice compared to plain tube. However friction factor increases by six times.

3) TEF values for the present model was above unity for the tested range of Re. The maximum obtained value was 1.15 at Re = 4910.

Further analysis needs to be conducted with varying inclination angles of airfoil and pitch ratios to see if better configuration is possible.

REFERENCES

[1] Y. Xu, M.D. Islam, N. Kharoua "Heat Transfer and Fluid Flow Characteristics in a Heat Exchanger Tube Fitted with Inserts", Journal of Thermal Science and Engineering Applications 112 (2017) 304 -317

[2] A. E Mahfouz, E.E khalil "Heat Transfer and Fluid Flow Characteristics in a Heat Exchanger Tube Fitted with Inserts", Journal of Thermal Science and Engineering Applications , 10(3) (2018)

[3] S. Gururatana, S. Skullong "Experimental investigation of heat transfer in a tube heat exchanger with airfoil-shaped insert", Case Studies in Thermal Engineering 14 (2019)

[4] S. Skullong, P. Promvonge, N. Jayranaiwachira C. Thianpong "Experimental and numerical heat transfer investigation in a tubular heat exchanger with delta-wing tape inserts", Chemical Engineering and Processing 109 (2016) 164-177

[5] M. M. Ibrahim, M. A. Essa, N. H. Mostafa "A computational study of heat transfer analysis for a circular tube with conical ring turbulators", International Journal of Thermal Sciences 137 (2019) 138–160

[6] S. Chokphoemphun, M. Pimsarn, C.Thianpong, P. Promvonge, "Heat transfer augmentation in a circular tube with winglet vortex generators", Chinese journal of chemical engineering 23 (2015) 605-614

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Effect Of Data Uncertainties in the Thermal Analysis of a Printed Circuit Board Using Monte Carlo Method

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Abstract— Electronic devices, components are normally mounted on printed circuit boards (PCBs). Such components generate heat in operation, which must be conducted away efficiently from the small mounting areas to frames where the PCB is mounted. The temperature of the components depends on heat dissipation rate, type of mounting, component location in PCB and finally effective thermal conductivity (k_{eff}) of the board. Nowadays, accurate prediction of heat generation in semiconductor devices is very critical for spacecraft avionics system. An electro-thermal analysis is an attractive method to predict heat generation in devices. The reliability of electronic components is directly related to operating temperature, so the thermal analysis should be able to provide a correct temperature prediction of all PCB components under the hottest operational condition. The accuracy of thermal analysis greatly depends on the uncertainties in input data. Data uncertainty in thermal analysis can be analysed using Monte-Carlo Methods. This study focused on the effect on peak temperature of an electronic component due to the uncertainties present in the thermal properties of a Printed Circuit Board (PCB) where it is mounted. PCB thermal properties measurements have some uncertainties due to the method of measurements because it is a highly composite material.

In Monte Carlo (MC) method, a large number of thermal models are created and each model is constructed with each value of thermal properties are given as an input data and solve this model. A MC study with data uncertainty in two input parameters of PCB namely thermal conductivity and emissivity are presented. The Effect of uncertainties present in these thermal properties of PCB with the peak temperature of SMT (Surface mounting technology) device has been predicted for a particular DC-DC convertor for the ground level testing conditions. The correlation of these uncertainties with the peak temperature of this system is calculated. It is found the there is a uncertainty of ±2.7K in the peak temperature of PCB due to the 20% uncertainty in these two input parameters.

Keywords—PCB, Monte Carlo, Effective Thermal Conductivity, Uncertainty, SMT

I. INTRODUCTION

In recent years, miniaturization of the electronics devices is the major breakthrough in the electronics industry. So the electronics internal heat generation is a major problem faced by the package designers. Semiconductor devices are the most dominant heat source in electronic equipment[3], and Si MOSFETs (Metal-Oxide-Semiconductor Field Effect Transistors) are widely used as semiconductor devices. These Si MOSFETS are mounted on the Printed Circuit boards. So that PCB will be the major heat carrier from the heat source to the ambient. Printed circuit board consists of highly conductive material (Cu) and highly non-conductive material (FR4). So the thermal properties of this PCB have great influences in the temperature levels of this electronic device.

Currently there are a lot of research were carried out in the field of electronics thermal management. The main heat transfer mode in electronic devices is conduction only. So the role of Printed circuit board in heat transfer of electronic packages is very crucial because the main heat source is mounted on the PCB. Various types of mounting technologies were present to enhances the heat transfer .They are PBGA,FBGA,SMT,etc.., The current study focused on the Surface mount technology were the MOSFET are directly mounted on the PCB with a thermal paste[10]. So that heat generated is directly transferred to PCB as well as Heat sink through the conduction only. To carry out thermal analysis of such system a one dimensional heat transfer code is developed in FORTRAN95.

Reliability of any thermal analysis is greatly depending upon the uncertainty in the input data[1]. Since PCB, MOSFETs are highly composite materials the thermal properties of these components may have uncertainties. So these data uncertainties can be treated with various methods. One of the strongest and commonly used method is Monte Carlo simulation method [2]. In this, large number of thermal models were developed and in each thermal model, randomly chosen uncertain values given as an input. This process repeated a number of times and will get the thermal profile of peak temperatures. So generation of random space of uncertain parameter is essential for a Monte Carlo problem[1]. In this study, we assumed thermal conductivity and emissivity of PCB as uncertain parameters and generate a random space of this parameters with 20% uncertainty with mean value.

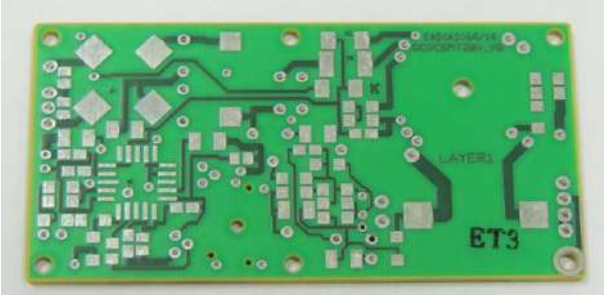

Fig.1 Typical Printed Circuit board

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II. METHODOLOGY

This study is an attempt to simulate heat transfer in a SMT Mosfet System, which is used in a DC-DC converter. The domain of interest to be solved is represented by a schematic diagram.

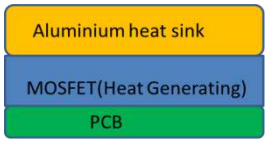

Fig 2 Package configuration

As the figure illustrated, a one dimensional transient heat conduction problem is modelled with a heat generating component is placed in between PCB and aluminium heat sink. Since the top side aluminium heat sink and bottom side of the printed circuit board is open to atmosphere these points are subjected to the conduction, convection and radiation mode of heat transfer. Other elements of system subjected to conduction mode only. This One dimensional transient problem is solved by the Finite difference Method.

II.A. GOVERNING EQUATIONS

It is a case of pure conduction problem. Heat generation in mosfet is considered as uniform. mosfet, and aluminium assumed as isotropic material. In PCB heat transfer is possible only along the thickness because the heat generation area in PCB is protected by FR4 materials for protecting nearby electronic devices from the thermal cycling. So that one dimensional energy conservation, momentum conservation were used. Hence one dimensional heat balance equation makes key role for forming the programme to solve this model.

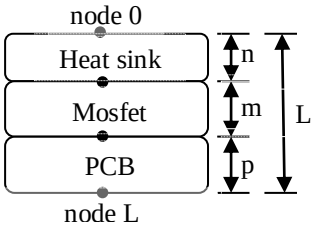

Fig 3 Computational Model

$$T(x,0) = T_0 \qquad 0 < x < L \quad time, t = 0 \qquad (1)$$

$$-K(T)\frac{\partial T}{\partial X} = q_c + q_h + q_r \qquad x = 0 \quad t > 0 \qquad (2)$$

$$-K(T)\frac{\partial T}{\partial X} = q_c + q_h + q_r \qquad x = L \quad t > 0 \qquad (3)$$

$$-\rho Cp(T)\frac{\partial T}{\partial X} = \frac{\partial T}{\partial X}\left(K(T)\frac{\partial T}{\partial x}\right) + q(t)''x \quad at \quad n < x < m \quad t > 0 \qquad (4)$$

$$\rho Cp(T)\frac{\partial T}{\partial X} = \frac{\partial T}{\partial X}\left(K(T)\frac{\partial T}{\partial x}\right) \quad 0 < x < n \quad t > 0 \qquad (5)$$

Where t is the time step, L is the total thickness of the components T_0 is the initial temperature of system. In this problem took it as the ambient temperature. q''(t) is the heat generation and q_c, q_h, q_r are the heat transfer by the conduction, convection, radiation respectively. The time step taken for computational model is taken as 0.1s for the consistency of result.

II.B. MONTE CARLO SIMULATION

Monte Carlo methods, or Monte Carlo experiments, are a broad class of computational algorithms that rely on repeated random sampling to obtain numerical results[1]. The underlying concept is to use randomness to solve problems that might be deterministic in principle. They are often used in physical and mathematical problems and most useful when it is difficult or impossible to use other approaches[8]. Monte Carlo methods are mainly used in three problem classes. Optimization, numerical integration, and generating draws from a probability distribution. Monte Carlo simulation is now a much-used scientific tool for problems that are analytically intractable and for which experimentation is too time-consuming, costly, or impractical. Simulation also has disadvantages: it require huge computing resources; it doesn't give exact solutions; results are only as good as the model and inputs used; and simulation software, like any software, is prone to bugs[8]. The main idea behind this method is that the results are computed based on repeated random sampling and statistical analysis .The quality of MC analysis is greatly depends on the size of random space of uncertain parameters[7].

II.C. DATA UNCERTINITIES

These data uncertainties can be treated in various methods. In worst case analysis, all uncertain parameters are given the extreme values that lead to sufficient overdesign to compensate the uncertainties[2]. If the number of uncertain parameter is more, this approach results gross over design of the system. A simple system with one or two data uncertainties can be treated by experimental method. But for complex problems, it is difficult to make test setup for treating the data uncertainties. Another method of determining the effects of data uncertainties is "sensitivity analysis." In this method, the statistical equation is applied for the effect of uncertainties in parameters x_i on the variable y

$$dy = \left(\frac{\partial y}{\partial x_1}\right)dx_1 + \left(\frac{\partial y}{\partial x_2}\right)dx_2 + \ldots\ldots\ldots\ldots \qquad (6)$$

If dx_1, dx_2 are the uncertainties in x_1,x_2, then the effect of each uncertainty on y is seen by examining each term on the right. In thermal analysis, y might be the temperature at a point and the x_i is the various conduction and radiation path conductance between nodes. This technique allows the analyst to see the important network conductance that affect a given temperature and thus to see which factors introduce the most uncertainty[1].

II.D. Thermal conductivity of PCB

Thermal conductivity can be defined as the amount of heat conducted per unit time across unit area through unit thickness when a temperature difference of unit degree is maintained across the bounding surface. Thermal conductivity is the major parameter that determines the heat transfer pattern through materials. Since PCB is a composite material many researchers introduced the methods to find effective thermal conductivity of composites and there will be some uncertainty in the result due to the changes in methods. . As an illustration purpose we choose this uncertainty as 20%.

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II.E. Emissivity of PCB

It is a surface property of a material. Emissivity is defined as the ratio of the energy radiated from a material's surface to that radiated from a perfect emitter, known as a blackbody, at the same temperature and wavelength and under the same viewing conditions. It is a dimensionless number between 0 (for a perfect reflector) and 1 (for a perfect emitter). The emissivity of a surface depends not only on the material but also on the nature of the surface.

A sample space of size 10000 is generated for thermal conductivity and emissivity to carryout MC simulation.

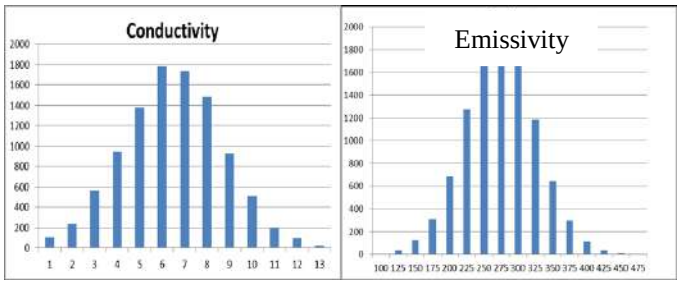

Fig 4. Sample Space of thermal conductivity and emissivity

III. NUMERICAL CODE GENERATION

In the present study, thermal model is discretized into a number of nodes and applied the FDM technique to solve the each node for a Δt time step. To get the accurate results the PCB and MOSFET is discretized into more number of nodes. For each node i we have the heat balance equation that

$$m_i C_i \frac{dT}{dt} = C_{ij}(T_j - T_i) + h_{rad} A_{ij}[T_j - T_i] + q_i \qquad (6)$$

Where $h_{rad} = 5.67 F_{ij} A_{ij} \left[\left(\frac{T_j}{100}\right) - \left(\frac{T_i}{100}\right)\right]^4$

$C_{ij} = \frac{KA}{\Delta x} + \frac{hA}{1}$

Now the above equation can be solved by the Finite Difference Method. We have used the implicit method. So for N number of nodes we obtain N number of equations for the time T^i . That N number of equation we can categorized as in the form of matrix as

$$[A][T] = [C] \qquad (7)$$

In this [A]is the co-efficient matrix [C] is known vector and [T] is the unknown vector[11]. The co-efficient matrix is a tri-diagonal matrix. The above system of equation is solved by tri-diagonal matrix algorithm. In the present study we use the Thomas algorithm to solve this equation.In this method the co-efficient matrix is transformed into an upper triangular matrix by systematic application of some algebraic operations under which the solution to the system of equations remains invariant. It takes the advantage of the zero of tri-diagonal co-efficient matrix. This method is extremely efficient method to solve such equations.

The steps involved in this work are outlined as follows:

i) Input variables are identified and 3-σ uncertainties are assigned. Gaussian probability functions are built based on these uncertainties.

ii) Random numbers are used to sample input parameter values based on their probability distribution function.

iii) A program run is made with the selected input parameters and the output values of interest (temperature) are collected.

iv) Steps (ii) and (iii) are repeated with different random numbers for 10,000simulations.

IV. RESULT AND DISCUSSION

The thermal response of a SMT device in a DC-DC converter is studied. The heat generation in the MOSFET is given as a volume heat generation in the generated code. Initially code is run without MC simulation. The temperature on top of the Aluminum heat sink is compared with the values that are measured. The results of the generated programme comparatively mimic the measured values.

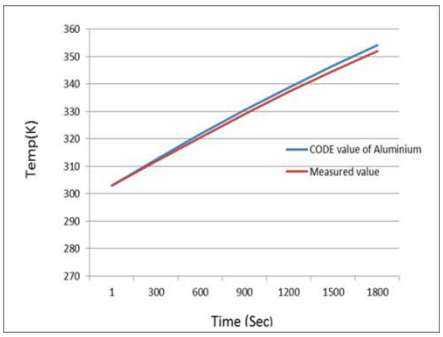

Fig 5. Programme validation

To carry out the monte carlo analysis, property values of parameters, which are identified as uncertain are varied as per their uncertainties in each run of the programme. The finite difference equations are then solved. The resulting peak temperatures obtained at the front and back walls as well as the time at which this occurs is noted. The process is repeated for 10,000 runs. Thus a distribution of the peak front wall and peak back wall temperatures are obtained. Temperature band can now be predicted for the maximum temperatures with 99% confidence level. The same can be done to predict their time of occurrence also

Description	Time (Sec)	Temperature		Temperature		Temperature	
		20% Uncertainty in Conductivity		20% Uncertainty in emissivity		20% Uncertainty in emissivity& K	
		Mean	std	Mean	Std	Mean	Std
FRONT WALL (Aluminium)	1800	354.17	0.083	354.16	0.202	354.23	0.55
	900	330.46	0.026	330.45	0.106	330.53	0.32
BACK WALL (PCB)	1800	351.47	0.595	351.59	0.23	351.61	0.91
	900	329.13	0.34	329.20	0.14	329.20	0.65

Table 1 : Peak temperature in the front and back wall with uncertainties in emissivity and thermal conductivity.

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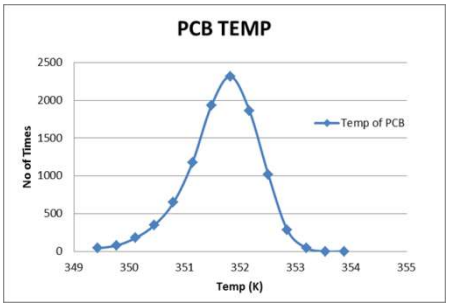

Fig 6. Peak PCB temp.

- Peak Temp of Aluminium heat sink with 99% Confidence limit is found between 352.86K and 355.02K with 353.83K as most probable value.
- Peak Temp of PCB with 99% confidence limit is found between 350.10K and 353.7K with 351.47 as most probable value

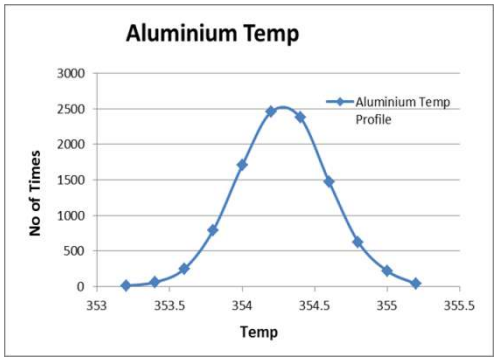

Fig 7. Peak aluminium temp

IV.A. EFFECTS OF INITIAL CONDITIONS AND BOUNDARY CONDITIONS

Uncertainity in initial conditions may also affect the final result. This section discuss about the effect of uncertainty in initial temperature of the model and Convection heat transfer co-efficient. For the illustration purpose the 20% uncertainty is taken in initial values.

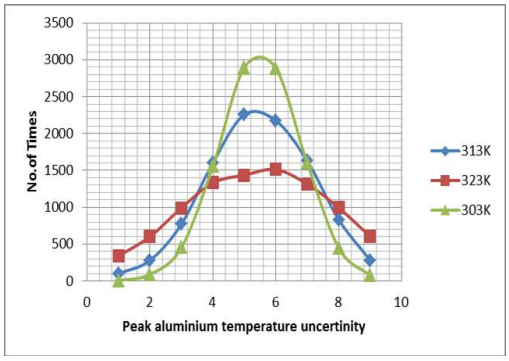

Fig 8. Effect of initial temperature

Initial	Peak aluminium	Standard deviation
303	354.20K	0.31
313	363.4K	0.42
323	372.6K	0.64

From the result it is found that the uncertainty in peak aluminium temperature is only ±2.1K with 20% uncertainty in the input thermal parameters of PCB with 99% confidence limit. Also specific heat of PCB is contributing more uncertainty to the peak temperature of aluminium heat sink. But in the case of peak temperature of PCB, it is observed that variation is ±2.7K with 20% uncertainties in thermal properties of PCB.

V. CONCLUSION

A thermal analysis coupled with monte carlo simulation of a printed circuit board is presented. The result obtained by simulation is compared with the measured values. It found that with 20% uncertainties in two thermal properties of PCB leads only 1% uncertainties in the peak temperature of the electronic system. Thermal conductivity has more effect with the variation of peak temperature. The effect of uncertainties in the evaluation of emissivity of PCB can be neglected because it causes less effect in the peak temperature of the system.

REFERENCES

1. John R. Howell "Monte Carlo Treatment of Data Uncertainties in Thermal Analysis" J. Spacecraft, Vol. 10, No. 6, June 1973.
2. MJ Chacko, Leelamma Mani and K. N. Shukla "Transient thermal analysis for electronic packages" J.Spacecraft, Vol. 24, No. 2,March-April 1987.
3. Rafael Lopes Costa, ValeriVlassov "Evaluation of Inherent Uncertainties of the Homogeneous Effective Thermal Conductivity Approach in Modeling of Printed Circuit Boards for Space Applications". Journal of Electronics Cooling and Thermal Control, 2013, 3, 35-41
4. H. Shaukatullah and Michael A. Gaynes "Experimental Determination of the Effect of Printed Circuit Card Conductivity on the Thermal Performance of Surface Mount Electronic Packages".10th IEEE SEMI-THERM™ 1998
5. J.RichardCulham and Michael Yovanovich "Factors Affecting The Calculation Of Effective Conductivity In Printed Circuit Boards". Intersociety Conference on Thermal Phenomena 1998
6. W. Nakayama, "Heat Conduction in Printed Circuit Boards A Meso scale Modeling Approach", Proc. Thermal Issues in Emerging Technologies (ThETA 1), Cairo, Egypt, Jan. 3-6, 2007,pp.59-66.
7. Brent.ACullimore, "Dealing with Uncertainties and variations in Thermal design". Proceeding in Interpack'01, july2001
8. ISRO-VSSC-SP-21-86 "Proceedings of the workshop on the Monte-Carlo Simulation Techniques". November 2-5, 1979, Published by Indian Space Research Organization,January, 1986.
9. Yih-Kanq Chen, Thomas Squire, Berbard Laub and Michael Wright "Monte Carlo Analysis for Spacecraft Thermal Protection System Design" AIAA paper 2006-2951
10. Dr. N.V, Srinivasulu , "Thermal Analysis Of Printed Circuit Board (PCB) Of Avionics Equipment", Journal of Advanced Research in Computer Engineering& Technology, Vol-1,issue-6, Aug2012
11. Text book of Heat and Mass Transfer by Yunus cengel,Afshin j ghajar

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Identification of risk due to RSI among auto rickshaw drivers

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***Abstract*— Auto rickshaws are the most commonly used public transportation system in India. It is also considered as one of the economic modes of transportation. Drivers of auto rickshaws are exposed to repetitive actions of hands and improper postures during their riding. These exposures cause a lot of health problems like repetitive strain injuries (RSI) among them. The present study aims to determine the exposure level to physical risk factors that leads to the health problems among auto rickshaw drivers. The physical risk was evaluated using Strain Index (SI). Results indicate that the occurrence of RSI are high for drivers in dense traffic region. A greater prevalence of risk at left hand of drivers were also identified in this study. SI scores of both hands of the drivers indicate a positive correlation with their experience. The higher risk at left hand of drivers may be due to repetitive actions for engaging clutch and twisting motions for changing gears. The level of RSI risk can be reduced by distribution of these exposures to right hand as well as to lower extremities with proper ergonomic interventions.**

Keywords*— Physical exposures, distal upper extremity, RSI, strain index.

I. INTRODUCTION

In India, different types of public transportation systems are being used such as cars, auto rickshaws, trucks, buses, two-wheelers etc. Auto rickshaws are the most convenient and economical transportation mode for short distances. Auto rickshaws have a crucial role in both urban and rural transport in India. Data from various cities of India shows that 10- 20% of the daily transportation requirement are met by auto rickshaws [1]. Two- wheelers and auto rickshaw drivers are subjected to various occupational health hazards such as heat, noise, vibration, repetitive actions etc. [2-3]. Repetitive strain injuries (RSI) are injuries caused by repetitive actions and muscle/joint overuse, affecting muscles, nerves and tendons of human body [4-5]. The symptoms of RSI begins with mild pain in the body parts and develops gradually into severe pain. Intensity of these injuries can be reduced by early detection of risks and proper medical treatments. Auto rickshaw driving is one such job where chances for occurrence of RSI are high due to repetitive actions and improper wrist posture involved in the job. Repetitive actions involved in auto rickshaw driving job include gear changing and acceleration operations using left hand and right hand respectively. The human body parts which are mostly affected by RSI include forearms and elbows, wrists and hands, neck and shoulders (distal upper extremities) [6-7]. Symptoms of RSI include pain, tenderness, stiffness, numbness, weakness, cramp in upper extremities of the body. Other causal factors which increase the risk of RSI are activities requiring forceful exertions for prolonged time without rest or recovery period, improper ergonomic posture, working in low temperature conditions and vibrating equipment [8]. Improper ergonomic postures for prolonged duration causes stress on muscles and tendons. These exposures leads to lumbar pain, tendinitis, and damage to joints, when combined with unhealthy postures [9]. Different posture-based ergonomics methods are currently being used to assess the physical risks involved in a job. Some of them are Moore-Garg strain index (SI), rapid upper limb assessment (RULA), occupational repetitive actions (OCRA) and rapid entire body assessment (REBA) [10-13]. These assessment methods quantify the risk factors involved in the process and eventually prioritize the need for ergonomic improvement techniques. The criteria for selection of proper risk assessment tools for a research work include the objective of research work, depth of assessment details needed, the reliability and validity of measured values, time needed for the assessment as well as the experience of the evaluator with the assessment tool [14]. The OCRA checklist would be more suitable for risk assessments focusing on the shoulder, elbow and wrist of the subjects. However, risk assessment using SI was found to be effective for determining the effects of carpal tunnel syndrome and other RSI injuries on the wrist/hand of the drivers.

The level of training required for an effective risk assessment using OCRA checklist were more than twice when compared with SI. Also, the training time required for risk assessment using OCRA checklist is much higher than that required for SI Comparatively, the time required for completing risk assessment using the OCRA checklist was found to be four times higher than SI. Thus, OCRA checklist requires more time for conducting RSI risk assessment compared to SI [15-16].

RSI is the most common occupational health hazard and has significant negative impact for the organization. It will affect the productivity and work quality of occupational drivers. The present study can increase the awareness of RSI injuries among the drivers and provide evidences on occurrence of symptoms of RSI. The objective of this study was to evaluate ergonomically the job of auto rickshaw driving. It also tries to determine the RSI risk in both upper limbs of the selected population as well as the hazardous level of the job.

II. METHODOLOGY

The study was carried out using strain index (SI) method through direct observation of occupational drivers. The

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identification of population, research instrument, procedure and data collection are discussed in following sections.

A. Population Identification

The requirement for transport infrastructure and services has been increasing by around 10% a year with the current infrastructures being not able to meet these growing demands. Development of road infrastructure are lagging with sudden increase in vehicle number [3, 8]. This has resulted in traffic congestion and the chances of RSI risk has been increased. Hence, in this study, subjects were selected from dense traffic region (Trivandrum city) and less traffic region (Enathu). The College of Engineering Trivandrum (CET) junction, medical college junction, chavadimukku auto stand were selected for the study in dense traffic region. Society junction and moolakkada junction auto stand in Enathu were selected for conducting the study in less traffic region. A total sample of 50 drivers were selected for evaluation by convenience sampling method. 25 subjects were selected from each locations for the study. All the values required for the evaluation were collected by direct observations [17]. Drivers having experience below 30 years were selected for the study as above 30 years, the chance for occurrence of RSI will be high due to ageing and the intensity of repetitive actions done in all these years.

B. Research Instrument

SI is used to assess if the repetitive actions and other physical risk factors expose workers to increased chance for developing distal upper extremity musculoskeletal disorders [18]. In order to define hand exertion level, Strain index uses exertion intensity, time period of exertion, exertions per minute, posture of hand/wrist, work speed, and time duration/day. These 6 task variables are converted into internal physical strain (dose values) by connecting functional values that define multiplier values for the task variable value as shown in TABLE I and II [19]. Strain index score is the product of these six multiplier values.

C. Data collection

Manual data collection using direct observation method was employed for collecting the data regarding the six ergonomic parameters in the SI score sheet. The vehicles were checked for their gear lever condition, clutch play and acceleration play for determining qualitatively the hand exertion intensity and work speed. Information regarding time duration of hand exertion and repetitive efforts required per minute were provided by the drivers itself based on their experience and by travelling a distance of 3 km from the stand. Right and left hand of the drivers were assessed individually during the ride. Hand/wrist posture were determined by asking them to do their jobs using both hands.

D. SI score calculation procedure

The physical risk associated with the work was assessed by direct observation [17]. Right and left side of the operator are assessed separately. Work can be characterized as hazardous or not, based on the SI scores.

The 5 steps involved in risk assessment using SI are:

1. Determine data regarding six task variables.
2. Provide ordinal ratings with the ratings table (TABLE 1).
3. Determine multiplier values with the multiplier table (TABLE II)
4. Determine the SI score (SI score = product of the 6 multiplier values).
5. Interpretation of obtained SI score to determine whether job is hazardous or not.

TABLE I. RATINGS TABLE [19]

Rating values	Exertion Intensity	Efforts /min.	Period of exertion (%)	Wrist posture	Work Speed	Period /day (hours)
1	Light	<4	<10	Very good	Very slow	<=1
2	Somewhat hard	4-8	10-29	Good	Slow	1-2
3	Hard	9-14	30-49	Fair	Fair	2-4
4	very hard	15-19	50-79	Bad	Fast	4-8
5	Near maximal	>=20	>=80	Very bad	Very fast	>=8

TABLE II. MULTIPLIER TABLE [19]

Rating values	Exertion intensity	Efforts /min	Period of exertion (%)	Wrist posture	Work speed	Period /day (hours)
1	1	0.5	0.5	1	1	0.25
2	3	1	1	1	1	0.5
3	6	1.5	1.5	1.5	1	0.75
4	9	2	2	2	1.5	1
5	13	3	3	3	2	1.5

Moore and Garg in 1995 [16] proposed that a value of SI score 5.0 can differentiate between safe and hazardous works. Jobs having SI score less than 5 is considered as “safe” and SI score greater than 5 concluded as “hazardous.” However, a revised hazard classification criteria was developed in 2005 with 3 groups for interpreting SI score (TABLE III) [20]. When a risk is predicted for a particular job, critical evaluation of the SI scores can provide some rectifying strategies that would make the job safer for the worker.

TABLE III. MODIFIED SI SCORE TABLE [20]

SI Score	Inference
SI <=3	WORK IS FOUND TO BE SAFE
3<SI<7	WORK CAN CAUSE INCREASED RISK FOR DISTAL UPPER EXTREMITY DISORDERS.
7 <=SI	WORK IS FOUND TO BE HAZARDOUS

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III. Results and Discussion

This section includes the results of the descriptive statistics and the correlation test conducted on the data using IBM SPSS software.

A. Risk assessment of left hand

The mean value of Strain index score for left hand in dense traffic and less traffic region were 9.1 and 8.8 respectively as shown in Fig. 2. According to modified SI score criteria for interpreting the computed job, it's clear that the job of auto rickshaw driving is hazardous for left hand in both dense traffic as well as less traffic region. SI Score of left hand is higher in dense traffic region compared to less traffic region which implies that the chance for occurrence for RSI is high in drivers from dense traffic regions.

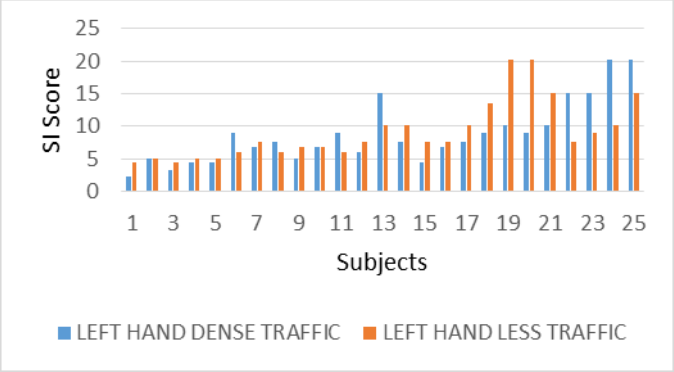

Fig. 2. SI score for left hand in different traffic conditions

B. Risk assessment of right hand

The mean value of SI score for right hand in dense traffic and less traffic region were 5.12 and 4.54 respectively as shown in Fig. 3. According to modified job strain index score, it's clear that the job of auto rickshaw driving may place the worker in increased chance for occurrence of RSI. It can also be seen that value of SI for right hand in dense traffic is also slightly higher than that in less traffic area, which implies the effect of traffic density on SI score eventually on RSI risk.

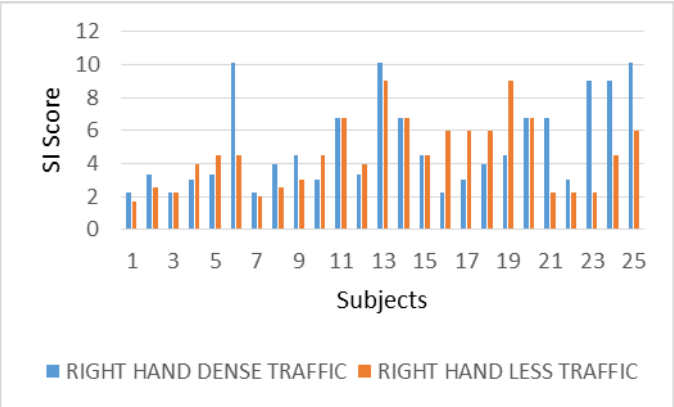

Fig. 3. SI score for right hand in different traffic conditions

C. Correlation of SI scores

Spearman rank correlation coefficient was conducted between SI scores of right and left hand in dense as well as less traffic region. In order to determine the relation between experience and SI score also, the correlation coefficients were determined.

1) Dense traffic region

Spearman rank correlation coefficient was found as '1' for SI score values of both hands in dense traffic region.SI scores in both hands indicates an increase with experience of the drivers in dense traffic region [Fig. 4]. This can be validated by the correlation coefficient value obtained between SI score and experience of drivers. Correlation coefficient of '0.879' was obtained between SI score of left hand and experience of drivers in dense traffic region. Similarly, a correlation coefficient of '0.74' was obtained between SI score of right hand and experience of drivers in dense traffic region

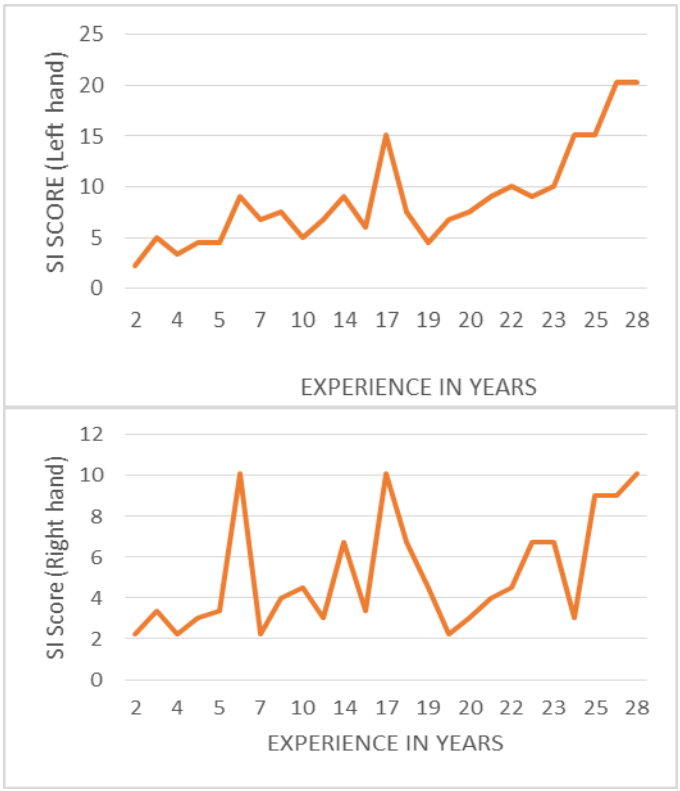

Fig. 4. Variation of strain index with experience of drivers in dense traffic region.

2) Less traffic region

Spearman rank correlation coefficient was found as '0.8' for SI score values of both hands in less traffic region. SI scores in both hands indicates an increase with experience of the drivers in less traffic region [Fig. 4]. This can be validated by the correlation coefficient value obtained between SI score and experience of drivers. Correlation coefficient of '0.633' was obtained between SI score of left hand and experience of drivers in dense traffic region. Similarly, a correlation coefficient of '0.58' was obtained between SI score of right hand and experience of drivers in less traffic region

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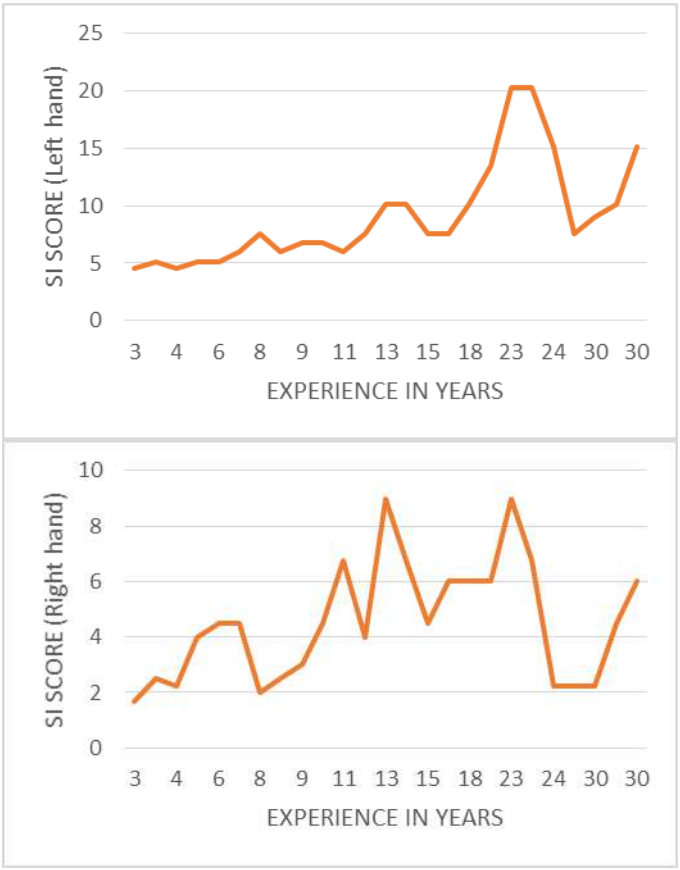

Fig. 5. Variation of strain index with experience of drivers in less traffic region.

A high value of SI score (SI score >7) has been obtained for left hand of auto rickshaw drivers. It may be attributes to the highly repetitive actions and improper posture of this dominant hand. The literature also reports a higher risk in dominant hand among automotive spray painters due to improper arm posture [5]. A medium range of SI score (3<SI score >7) has been obtained for the right hand of the drivers. This may be attributes to the work speed and increased number of efforts per minute.

IV. CONCLUSION

In this paper, an assessment of RSI risk among auto rickshaw drivers was conducted using job strain index method. It is evident form the study that chance for occurrence of repetitive strain injuries for the drivers are high due to the large number of repetitive actions involved, efforts done per minute, and speed of the work. The risk was found to be high for left hand compared to right hand. Also, as experience of the driver increases, the risk of RSI also increases. This increased risk of RSI will affect the productivity and quality of work life of the drivers. Implementations of proper ergonomic interventions can reduce RSI risk factors in auto rickshaw driving. Proper hand/wrist posture and distribution of repetitive actions to other body parts such as lower extremities can minimize the occurrence of future health problems for these drivers. Future works can be done to quantify the risk by analysing force exertions, working posture and muscle activities of drivers. Other occupational health hazards such as vibration, thermal effects can also be determined.

REFERENCES

[1] K.P. Sayoojkumar, "Socio-economic and health status of auto rickshaw drivers of Calicut city", Journal of Emerging Technologies and Innovative Research (JETIR), pp. 981-987, 2017.

[2] G.A. Anoop and S.A. Binoosh, "A study on musculoskeletal disorders among two-wheeler riders of Kerala state in India", Kerala Technological Congress- KETCON 2019, Vol. 6, pp. 411-418, 2019.

[3] L.P. Singh, "Musculoskeletal disorders and whole body vibration exposure among auto rickshaw drivers: a case study in Northern India", Ergonomic International Journal, ISSN: 2577-2953, 2019.

[4] H. Mohammadpour, M. Jalali, S. Ali, M. Najarkola, S. Farhadi, M. Kangavari, and A.G. Sartang, "Ergonomic Risk Assessment of distal upper extremity by job strain index in carpet weavers", Health Scope- 64182, 2018.

[5] S.K. Sajithkumar and S.A. Binoosh, "Ergonomic assessment of musculoskeletal risk in automotive spray painting task", Kerala Technological Congress- KETCON 2019, Vol. 6, pp.441-447, 2019.

[6] A. Calvo, E. Romano, C. Preti, G. Schillaci, R. Deboli, "Upper limbs disorders and hand arm vibration risks with hand held olive beaters", International Journal of Industrial Ergonomics, pp. 36-45, 2018.

[7] A. Calvo, E. Romano, C. Preti, G. Schillaci, R. Deboli, "Upper limb disorders and hand-arm vibration risks with hand held olive beaters", International journal of industrial ergonomics, pp. 36-45, 2018.

[8] M. Jalali, "The risk assessment of related factors of hand activities in automotive industry", Iran occupational health, vol. 9 (2), 2012.

[9] A.R. Proto, "Risk assessment of repetitive movements in the citrus fruit industry", Journal of agricultural safety and health, pp. 219-228, 2010.

[10] N. Stanton, A. Hedge, K. Brookhuis, E. salas, H. Hendrick, Handbook of human factors and ergonomic methods.

[11] E. Occhipinti, "OCRA: a concise index for the assessment of exposure to repetitive movements of the upper limbs", Ergonomics, pp. 1290-1311, 1998.

[12] J.S. Moore and A. Garg, "The strain index - a proposed method to analyze jobs for risk of distal upper extremity disorder", American Industrial Hygiene Association Journal, pp. 443-458, 1995.

[13] P. Drinkaus, R. Sesek, D. Bloswick, T. Bernard, B. Walton, B. Joseph, G. Reeve, J.H. Counts, "Comparison of ergonomic risk

ISBN 978-93-89105-41-4

assessment outputs from Rapid Upper Limb Assessment and the Strain Index for tasks in automotive assembly plants", Work, vol. 21 (2), pp. 165-172, 2003.

[14] A. Antonucci, "Comparative analysis of three methods of risk assessment for repetitive movements of the upper limbs: OCRA index, ACGIH(TLV), and strain index", International Journal of Industrial Ergonomics, pp 9–21, 2019.

[15] J. Rosecrance, R. Paulsen and L. Murgia, "Risk assessment of cheese processing tasks using the Strain Index and OCRA Checklist", Industrial Journal of Industrial Ergonomics, pp. 142-148, 2017.

[16] R. Paulsen, T. Gallu, D.P. Gilkey, R.F. Reiser, L. Murgia, J. Rosecrance, "The inter-rater reliability of Strain Index and OCRA Checklist task assessments in cheese processing," Applied Ergonomics, pp. 199-204, 2015.

[17] P. Spielholz, B. Silverstein, M. Morgan, H. Checkoway, J. Kaufman, "Comparison of self-report, video observation and direct measurement methods for upper extremity musculoskeletal disorder physical risk factors", Ergonomics, pp. 588-613, 2001.

[18] A. Garg, J.S. Moore and J.M. Kapellusch, "The strain index to analyze jobs for risk of distal upper extremity disorders: Model validation", IEEE International Conference on Industrial Engineering and Engineering Management, pp. 497-499, 2008.

[19] K. Knox, and J.S. Moore, "Predictive validity of the strain index in Turkey processing", Journal of Occupational Environment Medicine, pp. 451-462, 2001.

[20] A. Garg, J.S. Moore, J.M. Kapellusch, "The revised strain index: an improved upper extremity exposure assessment model, Ergonomics, pp. 912-922, 2017.

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Preparedness for E-pharmacy in Rural India: A Quantitative Analysis Using DEA

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***Abstract*— An E-pharmacy or online pharmacy is an internet-based vendor that sells medicines. E-pharmacy is one of the modern innovative developments that will probably connect the gap between the services of retail pharmacies and mainly the end rural customers by giving simple and moderate access of medicines at the doorstep of the patient just by the click of a finger.**

The rural population of India is about 68.85 percent. The demand for E-pharmacy in the rural area increases mainly due to the rising number of people with unmet medical needs because of the large population. The E-pharmacy is expected to account for 5-15 percent of the total pharmaceutical revenue in India, largely by improving quality and accessibility to medicines for a lot of underserved population. There are numerous other factors apart from the large population that influence the need for E-pharmacy in rural India.

The objective of this work is to identify the factors influencing E-pharmacy in rural India. A quantitative analysis of these factors is done using Data Envelopment Analysis(DEA) in order to understand the preparedness of various states in India with respect to E-pharmacy.

Keywords*— *E-pharmacy; Data Envelopment Analysis; Rural India

I. INTRODUCTION

India is one of the rapidly developing nations that is home to over 1.1 billion people, out of which 68.85 percent population live in rural areas[17]. Retail pharmacies are the prime source of medicines for all patients. In most of the developing countries, private retail pharmacies are often seen as a source of inexpensive medical care; India is of no exception. But the idea of accessible and affordable medicines is as remote as their homes in rural area and an estimated 65 percent of Indian population even do not have access to healthcare.

Online marketing or digital marketing or internet marketing has become a trend these days and most of the companies promote their business through digital platforms. Online purchase of medicine is gaining popularity among people worldwide due to its convenience. The Indian healthcare market is growing rapidly and was approximately USD27.57 billion in 2016 and is expected to reach USD55 billion by 2020[8]. E-pharmacy is emerging as the new format for buying medicines and it has attracted customers due to its convenience factor, thus increasing the pharmaceutical industry business. Around sixty E-pharmacy companies have developed in the past few years, but most of them have not reached up to the scale of other E-commerce ventures. In India, E-pharmacy is still in its budding stage and it is still an unknown useful service specially to the rural people. E-Pharmacy is an innovative progression which will connect the service gap of retail pharmacies and the end customers by giving simple and moderate access of medicines to the customer just by the click of a finger. The demand for E-pharmacy in the rural area increases mainly due to the rising number of patients with unmet medical needs because of the large population. Around 5-15 percent of the total pharmacy sales in India is expected from online sale of medicines, largely by improving adherence and access to medicines for a lot of under-served population[5]. Apart from large population, there are many other quantitative and qualitative factors that can enhance E-pharmacy in rural India. The motivation of the present work is that majority of Indian population resides in rural parts. Providing proper healthcare to this deprived population is a major challenge. Various means are sought by the government to address this concern. Here, an online framework for providing medicines to rural population is studied. Absence of proper vehicle facility, long waiting and travel time and the cost associated with it influences the patient's access to medicines. So once a proper E-pharmacy model is developed, it will be convenient because the patient need not hop from one pharmacy to another for a medicine and the same will be provided at the doorstep of the patient.

The present work addresses the quantitative factors that directly affects the E-pharmacy. An analysis of these factors is done using DEA for 29 states of India with specific reference to E-pharmacy market in rural India. The data for four inputs and three outputs are used to estimate the efficiency of the states for preparedness of E-pharmacy market in rural India.

This paper consists of the following sections: Section II explains the factors affecting E-pharmacy for different states and the application of DEA methodology. Section III gives an analysis of various factors with respect to the efficient and inefficient states identified by DEA. The results are discussed in section IV along with conclusion in Section V.

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II. Literature Review

This section discusses the literature on E-pharmacy and DEA. The popularity of E-pharmacy is very low in Saudi Arabia. But a survey conducted by the author shows that the respondents are ready to purchase medicines online once the FDA of the country sets guidelines and monitor the procedures(Norah Anbanmy)[14]. Due to the huge promotion of information technology by the European Union, the online pharmaceutical market is gaining interest in Europe. The study by the author shows that legal online pharmacies will only benefit the consumers. Proper national regulations will not hinder the market from the online purchasing community (Mia, Paivi, Jari)[11]. In India, there is a lack of clear cut regulations and guidelines for the proper working of E-pharmacy. The authorities find it difficult to control, monitor and track the sale of medicines through internet. According to the review by the authors, the E-pharmacy model is a promising business but the drawbacks hurdle the success of the model. As of 2015, E-pharmacy is a dangerous trend in India, if not regulated (Priyanka, Ashok)[16]. According to Mohd. Ayub and M. Mustafa[13], online delivery of medicines is estimated at $10million at its nascent stage in India. With adoption of E-commerce, this industry will grow among Indian consumers and has emerged to be the greatest challenge for unorganized retail pharmacy in India. Prabal and Alok [15] addresses the present scenario of E-pharmacy, the rules and regulations and the suggestions for improving the market among common people. Not much literature is available for E-pharmacy and the existing research articles presents the concern on the guidelines and regulations to be followed for the legalization of E-pharmacy and the acceptance of the service by the people.

The generalized form of output oriented DEA model is presented by Ma Sheng-yun and Ma Zhan-xin [10], and the model has been used to evaluate the efficiency of energy consumption and GDP in China. An Xun, Bao and Zhu [1] has studied the economic and social contribution of NOC (national oil company) using DEA model. The two stage NOC model-micro production and macro- contribution are studied using the model. The paper by Bruno [3] measured the efficiency of the district hospitals of Uganda using super- efficiency DEA model which solves the problems of standard DEA. Gholam and Toloo [6] proposed an improved integrated DEA model to find the efficient DMUs(Decision Making Units). In this case, the DMUs are evaluated using the common values of weight and the formulation of LP is simplified. An application of DEA to evaluate how well the regions of Serbia utilize their resources is presented by (Milan and Gordana)[12]. An output oriented CCR model is used and a study to combine DEA and LDA(linear discriminant analysis)is done. Yan, Gongbing and Liang [20] presents a model to find out the appropriate input and output variables for DEA model based on the concept of cash value added. This model has been used to evaluate 14 Chinese banks. The input-output variables can include both quantitative and qualitative factors, but the qualitative factors needs to be quantified. Wade, Moshe and Lawrence [19] presents a framework to include the qualitative factors for DEA calculation. There are many research articles that addresses DEA and its different variants.

III. Methodology

A. Factors affecting E-pharmacy

The identified factors affecting the performance of E-pharmacy are:

1) Literacy rate: Education is a key factor that influences any business. Helping out the rural population to read and write in their own language will help in proper communication about the products. This will help the rural consumers to safely access E-pharmacy portals. Educated consumers will be able to identify the reliability of legal E-pharmacy. It also helps in protection of consumer rights, security and confidentiality of information exchanged and security of financial transactions. E-pharmacies provides value-added information to consumers, such as drug interactions, side effects, medicine reminders and information on cheaper substitutes[5]. This power of knowledge will increase the trust of rural population to online pharmacies. Literacy rate is taken as per the 2011 census of India.

2) Teledensity: Telephone density or Teledensity is defined as the number of telephone connections, including wire line and wireless, for every hundred individuals living within an area. The source of data is Telecom Regulatory Authority of India[18].

3) Number of Patients: As per reports, the leading causes of death and disability in India are chronic diseases such as diabetes, cardiovascular diseases, mental health disorders, cancer and injuries and it accounts for around 60 percent of the total death[5]. Other health issues due to lifestyle such as pain, obesity, stress, diabetes, hypertension, cancers, etc are also increasing. The number of inpatients in rural healthcare centers per thousand population is taken for calculation. The data is obtained from Rural Healthcare Statistics[17].

4) Length of surfaced roads: Delivery of required drugs at exact location (at doorstep) is one of the important challenge of E-pharmacy. People living in remote villages are required to travel to nearby towns to access the healthcare services[5]. The other major problem perceived by consumers is the delay in delivery of medicines. With a long way to travel and no proper road network, it is tough to transport temperature sensitive drugs such as insulin. With proper road networks in the rural area, the demand and supply of medicines will be met, which will also help in reducing the transportation costs, which will be acceptable to the rural community. The statistics of rural roads is collected from Basic Road Statistics of India[2]. The ratio of length of surfaced roads in rural area to the length of total surfaced roads of the state is taken for calculation.

5) Number of medicine outlets: In addition, another major factor which directly impacts the access to medicines is the unavailability of retail pharmacy in rural areas forcing the patients or customers to travel long distances and visit multiple stores for acquiring all the prescribed drugs. E-pharmacies helps in accessing the rural areas where there is limited presence of retail pharmacies. The only available

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facility is the dispensaries. Also more the number of retail pharmacies available, more efficient will be the E-pharmacy model. The data for number of medicine outlets per thousand population is collected from Rural Healthcare Statistics[17].

6) Number of Medical staffs: Just like doctors, pharmacists too have a role in dispensing prescription medicines. The E-pharmacy model enhances the services of the pharmacist to the consumers by answering the questions regarding medications using e-mail or other chat options. An E-pharmacy will have a team of qualified pharmacists for verification of prescriptions and for handling any drug related queries of the patients[5]. The data includes the total number of doctors, specialists and pharmacists available for thousand population in primary and community health centers. The source of data is Rural Healthcare Statistics[17].

7) Number of internet subscribers: The increased number of citizens using Internet fuel up the of E- pharmacy market. The numbers of internet users have been increasing continuously since 2000 in rural areas. This increase in netizens and smart phone users will help in the growth of online pharmacy business. Under the Digital India initiative, the Internet and broadband services are being expanded to every remote corners of the country[5]. The number of internet subscribers data is collected from Telecom Regulatory Authority of India[18].

The data source for 29 states are consolidated for each of these factors. A DEA approach is used for analyzing these factors for all the states in order to have a comparative study of the preparedness for E-pharmacy.

B. Methodology

DEA was first used by Charnes [4] to evaluate the relative efficiency of organizational units that has multiple inputs to produce multiple outputs. The DEA is defined as the efficiency of the quantity under evaluation as the ratio of the sum of its weighted outputs to the sum of its weighted inputs. The problem of assessing the efficiency is that it is formulated as a fractional equation and the solving process is complicated. Therefore the application procedure for DEA consists of solving linear programming for each of the DMUs under assessment.

The reason to choose DEA over other approaches is its objectivity, that is, DEA provides the efficiency ratings based on numerical data and not by using subjective data. DEA makes the maximum possible use of the available objective data. One of the main advantages of DEA is its ability to accommodate a multiple number of inputs and outputs and the data can be measured in different units. Also DEA is a non-parametric tool because it does not require an equation relating the inputs to the outputs.

The following steps are used for the analysis:

Step 1: Identification of factors affecting the performance of E-pharmacy in rural India and classifying the factors into input and output factors.

Step 2: Collection of data for those factors for 29 states of India from census data.

Step 3: Conduct an output oriented DEA to find the efficiency score of each DMUs(Decision Making Units). Each state is considered as a DMU.

Step 4: Conduct sensitivity analysis on the inefficient states.

Fig. 1 shows the flowchart of the methodology used.

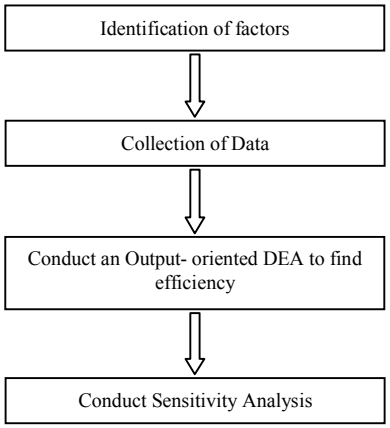

Fig. 1. Methodology

When a variable is considered for DEA, it is necessary to determine whether that variable should act as an input or an output. Some variables can be pre-specified as inputs or outputs based on the expert knowledge of the analyst or the production conversion mechanism of a DMU[7].

The set of inputs are:

- Rural literacy rate(x1)
- Rural Teledensity(x2)
- Number of patients per thousand population in rural India(x3)
- Length of surfaced roads in rural India.(x4)

The set of outputs are:

- Number of medicine outlets per thousand population in rural India(y1)
- Number of medical staffs per thousand population in rural India (y2)
- Number of Internet subscribers in rural India (y3)

Table I shows the selected inputs and outputs. The 29 states of India are considered and therefore there are 29 DMUs. The correlation between input factors, between output factors and between input and output factors are calculated. The pair of inputs are negatively correlated and the output-input pair are well correlated.

Since the input data is fixed and is not controllable, an output oriented DEA model is used to find the efficiency score of each DMUs[9]. In an output-oriented model, an inefficient

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DMU is made efficient through the proportional increase of its outputs, while the inputs remain unchanged.

The objective function of the output oriented model as per [12] is

$$\text{Max } \varphi \quad (1)$$

subjected to

$$\sum \lambda_{ij} * x_{ij} \leq x_{io} \qquad i=1,2,3,4 \quad (2)$$

$$\sum \lambda_{ij} * y_{rj} \geq y_{ro} \qquad r=1,2,3 \quad (3)$$

$$\sum \lambda_j = 1 \quad (4)$$

$$\lambda_j \geq 0 \qquad j=1,2,3\ldots..,29 \quad (5)$$

i is the number of inputs

r is the number of outputs

j is the number of DMU

φ is the efficiency

λ is the dual that provides weight to the DMUs.

x_{ij} and y_{rj} denote the values of the i^{th} input criterion and r^{th} output criterion for k^{th} DMU.

TABLE I. SELECTED INPUTS AND OUTPUTS WITH DATA

States	(x1) (%)	(x2) (%)	(x3)	(x4) (%)	(y1)	(y2)	(y3) (%)
Andhra Pradesh	60.4	63.9	61	48.3	0.0074	0.09	38.2
Arunachal Pradesh	59.9	82.3	36	35.3	0.0675	0.20	28.6
Assam	69.3	44.5	9	76.3	0.0185	0.12	24.5
Bihar	59.8	44.2	12	79.3	0.0062	0.02	21.6
Chhattisgarh	66.0	50.9	18	53.7	0.0082	0.06	43.5
Delhi	81.9	201.6	34	85.6	1.1693	0.06	176.6
Goa	86.6	164.9	32	76.8	0.0670	0.21	37.8
Gujarat	71.7	73.3	21	50.4	0.2195	0.08	34.7
Haryana	71.4	74.4	28	51.5	0.0147	0.05	37.3
Himachal Pradesh	81.9	113.8	45	76.8	0.0427	0.16	55.2
Jammu & Kashmir	63.2	53.3	23	47.2	0.0761	0.21	18.7
Jharkhand	61.1	43.1	11	57.1	0.0068	0.02	21.6
Karnataka	68.7	68.7	29	45.6	0.0267	0.13	38.2
Kerala	93.0	79.4	114	59.6	0.0160	0.13	58.8
Madhya Pradesh	63.9	41.2	20	68.7	0.0107	0.05	32.5
Maharashtra	77.0	69.9	31	63.5	0.1381	0.08	37.9
Manipur	76.2	33.1	19	47.2	0.0374	0.20	22.6
Meghalaya	69.9	50.9	17	41.3	0.0206	0.12	9.3
Mizoram	84.1	91.2	26	46.6	0.0418	0.21	45.1
Nagaland	75.3	37.1	13	61.9	0.0241	0.17	26.8
Odisha	70.2	59.7	34	81.4	0.0450	0.07	30.1
Punjab	71.4	81.4	31	77.6	0.0934	0.07	42.6
Rajasthan	61.4	58.9	24	63.7	0.0164	0.08	33.5
Sikkim	78.0	73.5	29	64.4	0.3260	0.07	25.8
Tamil Nadu	73.5	90.1	31	58.3	0.0240	0.13	36.2
Tripura	84.9	40.7	57	87.9	0.2337	0.09	16.0
Uttar Pradesh	65.5	47.6	14	41.3	0.0004	0.04	23.9
Uttarakhand	76.3	88.3	21	65.0	0.3416	0.07	22.9
West Bengal	72.1	54.4	40	35.2	0.0147	0.04	25.9

Table II gives the efficiency score (φ) of each states obtained using the equations 1 to 5 and the ranks based on ratings are allotted.

TABLE II. EFFICIENCY SCORE AND RANK OF DMUS

STATES	(φ)	RANK
Andhra Pradesh	0.74	3
Arunachal Pradesh	1.00	1
Assam	1.00	1
Bihar	0.57	12
Chhattisgarh	1.00	1
Delhi	1.00	1
Goa	1.00	1
Gujarat	0.65	7
Haryana	0.59	11
Himachal Pradesh	1.00	1
Jammu & Kashmir	1.00	1
Jharkhand	0.59	11
Karnataka	1.00	1
Kerala	1.00	1
Madhya Pradesh	1.00	1
Maharashtra	0.66	6
Manipur	1.00	1
Meghalaya	0.69	5
Mizoram	1.00	1
Nagaland	1.00	1
Odisha	0.62	9
Punjab	0.63	8
Rajasthan	0.69	5
Sikkim	1.00	1
Tamil Nadu	0.71	4
Tripura	1.00	1
Uttar Pradesh	0.60	10
Uttarakhand	0.76	2
West Bengal	0.56	13

IV. Sensitivity Analysis

It is possible for a DMU to obtain a value of unity by just improving its performance in terms of only one particular output ignoring others. The DMU will be considered efficient even though it has not improved its performance in terms of all outputs. The sensitivity analysis is done on the rest 12 inefficient states to improve its performance and the new values for each output are presented in Table III.

V. Results and Discussion

The results obtained from the DEA analysis for each state under consideration using the output oriented DEA model are presented in this section. The inputs for the analysis are rural literacy rate, rural Teledensity, number of patients per thousand population and length of rural surfaced roads and the outputs are number of medicine outlets per thousand population, number of medical staff per thousand population and the number of internet subscribers. The results are presented in Table II based on the efficiency score and rankings. The DEA model selected is an output oriented model, which seeks to identify the efficiency by maximizing output factors because the input factors considered in this paper are fixed and cannot be changed as per human desire.

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TABLE III. THE NEW OUTPUT VALUES.

STATES	Y1	Y2	Y3 (%)
Andhra Pradesh	0.278	0.1942	40.2
Bihar	0.1264	0.1033	23.6
Gujarat	0.263	0.08743	42.1
Haryana	0.2807	0.1028	63.7
Jharkhand	0.1328	0.087	31.3
Maharashtra	0.168	0.1228	69.2
Meghalaya	0.028	0.298	15
Odisha	0.145	0.1118	40.8
Punjab	0.2904	0.095	63
Rajasthan	0.208	0.098	58.2
Tamil Nadu	0.198	0.1866	62.2
Uttar Pradesh	0.116	0.0902	33.9
Uttarakhand	0.693	0.091	67.2
West Bengal	0.215	0.5521	49.9

From the Table II, it was found that 15 states of India were efficient for E-pharmacy market and 14 states inefficient. Results show that West Bengal, Bihar, Haryana and Jharkhand are the most inefficient states for E-pharmacy.

The new values for all the three outputs of each inefficient states are obtained from sensitivity analysis and is presented in Table III. From the analysis, it is found that the output factor (y1) that is the number of medicine outlets per thousand population in rural area causes a major impact on the efficiency score of most states. The states Andhra Pradesh, Haryana, West Bengal, Punjab and Uttarakhand are inefficient because of lack of medicine outlets. An increase of medicine outlets to 0.278, 0.2807, 0.215, 0.29 and 0.693 per thousand population respectively will result in an efficiency score of one. With increase in number of patients, the need for medicine outlets also increases. An increase in retail pharmacies will make the E-pharmacy model to provide its service to more number of under-served population.

The second reason for inefficiency is the number of internet subscribers in rural area(y3). Haryana, Tamil Nadu, Rajasthan, West Bengal, Punjab and Maharashtra are those states that are affected by output y3. If Tamil Nadu is considered for evaluation, from Table I, the Teledensity is 90.1 percent but the number of internet subscribers is just 36.2 percent. Now considering one of the efficient states such as Delhi, the Teledensity is 201.6 percent and the number of internet subscribers is 176.6 percent, which shows that almost every individual having phone connection has access to net connectivity as well. Since having access to internet is an important factor for an E-pharmacy model to work, an increase in the subscribers will increase the efficiency of E-pharmacy. An increase of number of internet subscribers to 62.2 percent will make Tamil Nadu efficient.

The second output factor(y2), that is the number of medical staffs per thousand population has large impact on states West Bengal, Meghalaya and Andhra Pradesh. An increase of value to 0.55, 0.298 and 0.1942 in the number of medical staffs per thousand population, respectively will make these states efficient. The number of medical staffs is also another unavoidable factor because E-pharmacy dispenses medicines only if E-prescription is available and the prescription can be provided by doctor and pharmacists only. With increase in number of patients, the number of doctors need to increase as well. A shortfall in any of the following could be the reason for inefficiency: doctors, specialists or pharmacists.

VI. CONCLUSION

The paper analyses factors affecting the performance of E-pharmacy in rural India using the data available in public domain. E-pharmacy has a huge potential to grow in business once the untapped rural population is made aware of the service provided. An output oriented DEA model is used to find out the efficiency score of the states based on data for four inputs and three outputs. As discussed in results, 12 states were inefficient. The obtained results indicated that the main reason for inefficiency is the lack of medicine outlets per thousand population followed by the number of internet subscribers in rural India. One of the solutions to increase the number of internet subscribers is by increasing the net connectivity and educating the people to use the facilities. Since it is difficult to reach every household, the government can start internet kiosks connecting multiple villages. Also availability of smart phones at cheaper rates will augment the net subscribers. And considering the pharmaceutical outlets, opening a common distribution centre for multiple villages will improve the E-pharmacy model in rural area.

The limitation of the work is that the present work is done on the data available on public domain and the results largely depends on the correctness of the states. Also the data for Andhra Pradesh and Jammu and Kashmir are considered before bifurcation.

The work can be further expanded by including more qualitative factors and the causes of inefficiency can be further analyzed for all the states.

ACKNOWLEDGMENT

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REFERENCES

[1] An Xun, Bao Hanrui, Zhu Xiaoyang, "A DEA approach to evaluate economical and social roles of NOCs, Energy Procedia, (05) (2011), 763-767.

[2] Basic Road Statistics of India, 2017.

[3] Bruno Yawe, "Hospital performance evaluation in Uganda", Zambia Social Science Journal, Vol1, No.01 (6) (2010).

[4] Charnes A., W. W. Cooper, E. Rhodes, "Measuring the efficiency of decision making units", European Journal of Operational Research 2(6) (1978) 429-444.

[5] "E-pharmacy in India: Last mile access to medicine", Frost and Sullivan Report.

[6] Gholan R. Amin, M. Toloo, "Finding the most efficient DMUs in DEA: An improved integrated model", Computers and Industrial Engineering (52) (2017), 71-77.

[7] Hiroshi Morita, Necmi K. Avkiran, "Selecting inputs and outputs in data envelopment analysis by designing statistical experiments", Journal of Operations Research (52) (2009), 163-173.

[8] Indian healthcare industry report, November 2019.

[9] Manolis N. Kritikos , "A full ranking methodology in data envelopment analysis based on a set of dummy decision making units", Expert Systems With Applications (2017), unpublished.

[10] Ma Sheng-Yun, Ma Zhan- xin, "The efficiency of Chinese energy consumption and GDP", Energy Procedia, (05) (2011), 1727-1731.

[11] Mia Maria Makinen, Paivi Tuire Rautava, Jari Johannes Forstorm, "Do online pharmacies fiteuropean internal markets", Health Policy 72,(2005), 245-252.

[12] Milan Martic, Gordana Savic, "An application of DEA for comparative analysis and ranking of regions in Serbia with regards to socio-economic development", European Journal of Operational Research 132(2001), 343-356.

[13] Mohd. Ayub, M. Mustafa, "An overview of unorganized retail pharmacy in Indian pharmaceutical industry", International Journal of Development Research, Vol 07, Issue 08(2017), 14394-14401.

[14] Norah Anbany,"The extent of online pharmacies in Saudi Arabia", Saudi Pharmaceutical Journal (25) (2017), 891-899.

[15] Prabal Chakraborty, Prof. (Dr) Alok Satsangi, "Online pharmacy in India: A study on digital marketing perspective", International Journal of Research in Engineering, IT and Social Sciences (02) (2019), 232-242.

[16] Priyanka V P, Ashok B K, "E-pharmacies regulation in India: Bringing new dimensions to pharma sector", Review Article, Pharmaceutical Regulatory Affairs, Vol 05, Issue 02(2016).

[17] Rural Healthcare Statistics 2018.

[18] Telecom Regulatory Authority of India, 2018.

[19] Wade D Cook, Moshe Kress, Lawrence M. Seiford, "Data analysis in the presence of both quantitative and qualitative factors", Journal of the Operational Research Society (47) (1996), 945-953.

[20] Yan Luo, Gongbing Bi, Liang Liang, "Input/ output indicator selection for DEA efficiency evaluation: An empirical study of Chinese commercial banks", Expert Systems With Applications (39) (2012), 1118-1123.

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Effect of Variable Deterioration Rate on Perishable Food Supply Chains

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Abstract—Customer satisfaction is the back bone of any business entity and supply chain optimization plays a vital role in customer satisfaction efforts. Supply chain inventory control is one of the scientific supply chain optimization methods for determining the inventory levels at proper levels in different stages or echelons of the supply chain to meet the requirements of the customers. The aim is to supply right type of material at right time in the right quantities and at competitive rates. Supply chain inventory costs include costs to store, track and insure materials. Inventories that mismanaged create significant financial problems for a business, whether the mismanagement results in an inventory glut or an inventory shortage. Therefore an investigation of the right quantities to be kept in stock to meet the requirements, the strategic location, storage facilities and recordings of the goods or items should be done systematically such that the desired degree of service can be provided at competitive prices or at minimum ultimate cost. Major objective of inventory control in a multi echelon supply chain is to optimize inventory cost elements like transportation cost, carrying cost, holding cost and all other inventory related costs at all supply chain stages with an elevated service level at the end customer point. The supply chain inventory control becomes difficult when the handling material is a perishable one as its deterioration rate is variable rather than constant. This article describes a study which reveals the deterioration rates for perishable edible goods and same helps for perishable inventory management.

Keywords—*supply chain; deterioration rate; shelf life.*

I. INTRODUCTION

The research in inventory control of perishable goods or deteriorating inventory is becoming more important and popular because perishable goods like milk, blood, drugs, food and vegetables do deteriorate significantly. Deterioration is defined as decay, damage, wastage, vaporization, obsolescence, pilferage and loss of utility or loss of marginal value of a commodity that results in decreasing utility from the actual one. It is significant to point out that the management of perishable items is intricate as it involves the deterioration of the goods, additional and often complex cost factors such as cost of deterioration, cost of transportation and holding cost. The involvement of cost of deterioration makes the optimization problems related with perishable inventory complicated because the deterioration rate of such items are not constant. It may or may not vary slightly after procurement followed by a rapid deterioration. The transportation cost should also be considered carefully because special enhancements should be presented to counter the deterioration of perishable inventory during its interaction with the logistics systems. Po-Chung Yang and Hui-Ming Wee" (2003) developed a multi-lot-size production and inventory model of deteriorating items with constant production, demand rates and constant deterioration rate. The major advantage of the model was that it introduced an optimal policy using the integrated approach which had reduced the total joint cost for the producer and the buyer. The model had limitations that the producer's cost was higher and it considered a constant deterioration rate for the inventory. Chamansingh (2011) introduced an integrated supply chain model for the perishable items with fuzzy production rate and fuzzy demand rate. In his mathematical model the optimization of supply chain was by assuming demand rate and production rate as fuzzy numbers. Probability distributions are obtained with historical data. In several cases, especially for new products, the probability will not be easily obtainable because of the lack of historical data and realistic information. Therefore this work exploited the advantage of fuzzification for the modeling with unknown data.H. Rau, B.C. OuYang (2008) developed an optimal batch size model for integrated production–inventory policy in supply chains. The model was a mathematical one for optimizing the supply chain for a vendor and buyer with an objective to minimize the total cost of the system. This model was based on a single buyer and a single vendor with a single item with constant demand rate.AdityaShastria et al. (2013) developed a multi-echelon supply chain model for deteriorating items with partial backordering under an Inflationary Environment. The advantage of this model was that it gave the optimum number of deliveries which minimized the total cost and considered the shortages of the deteriorating inventory and the influence of inflation. Liang-Hsuan Chen , Fu-Sen Kang, (2007) developed Integrated vendor–buyer cooperative inventory models with variant permissible delay in payments .The advantage of this work

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was that it introduced integrated models with the permissible delay in payments while determining the optimal replenishment time interval and replenishment frequency.

Most of the researchers made their works in the perishable goods by assuming constant demand and constant deterioration rates for the perishable goods. But the demand rate and deterioration rate are not usually constant and it will vary under the influence of external factors. Almost all edible goods are subjected to variable deterioration and the factors influencing the deterioration are environmental factors like temperature, humidity etc.Therefore this regime opens a significant research opportunity since the research works conducted under this assumption are comparatively less. This paper aims at the investigation of the deterioration rate of a perishable edible inventory subjected to a set of major parameters which make it perishable.

II. INVENTORY DETERIORATION IN MULTI ECHELON DISTRIBUTION CHAIN

In a multi echelon distribution chain the very significant and primary echelon is the one which is associated with the manufacturer. The flow of goods commences from the manufacturer to the subsequent echelons. Therefore supply chain management faces a major challenge to begin the optimization process from this echelon by estimating the stock level at this echelon which reduces the total cost of the chain with due considerations on the deterioration rate and demand rate of the inventory. The figure 1 shows the inventory model of manufacturer for a perishable inventory having constant deterioration rate. Inventory level increases from zero for the producer at a finite rate (p-d) and descends at a fixed deterioration rate θ for duration 0 to T_1.At this point the production comes to an end. Then, the inventory level decreases due to the constant demand rate' d' units per unit time and at a constant deterioration rate for a period of time 0 toT_2 at which the inventory level reaches zero again.

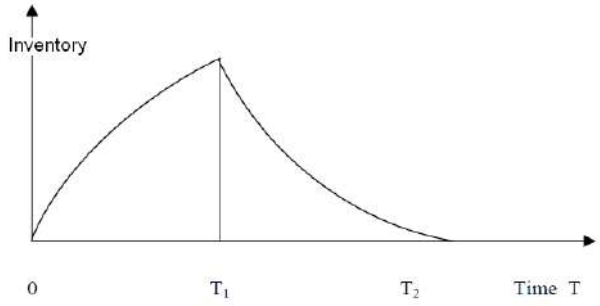

Fig.1 Manufacturer's Inventory Model

The equations governing the single echelon for the producer for different time durations are as below

$$I! p1 (t1) = P\text{-}d\text{-}\theta\ Ip1 (t1),\ 0 \le t1 \le T1$$

$$I! p2 (t2) = P\text{-}d\text{-}\theta\ Ip2 (t2),\ 0 \le t2 \le T2$$

Where $T=T_1+T_2$ subjected to boundary conditions

$$I_{p1} (0) =0,\ I_{p2} (0) =Q_P \text{ and } I_{p2} (T_2) = 0$$

III. INVENTORY DETERIORATION OF EDIBLE PERISHABLE GOODS

The assumption made generally for the management of inventory is that goods can be stored for a long time. But this assumption is not justifiable for deteriorating inventory. This is due to the fact that the items which are perishable lose their value with respect to time. This is assumed as the deterioration. The usefulness of such edible items is represented by their shelf lives. These limited shelf lives of such inventories escalate the complexity of their management. Also there are some major factors such as temperature and humidity which results in the variation of their shelf life. The products depart the manufacturers with a certain shelf life, but may have a changed shelf life when they reach subsequent echelons. The shelf lives will certainly vary with respect to products.

Thus the inventory management systems for the nonperishable items cannot be used for the perishable items because of the above mentioned reasons. In order to extent the shelf life of perishable goods, prevention of microbe friendly environment and addition of preservatives are the common practices these days. But from a supply chain perspective the spoilage reduction of goods by effectively optimizing stock levels at every echelon is relevant.i.e the ultimate objective of perishable edible good's supply chain is to supply the exactly needed quantity of goods to the echelons on time when and where they are needed without keeping excess stock.

IV.EFFECT OF VARIABLE DETERIORATION ON EDIBLE PERISHABLE GOODS

Most of the recent studies and researches about the supply chain management of perishables assume that their deterioration rates are constant. But real time data from experiments reveal that deterioration rate for perishable goods do not follow a constant pattern. Inventory models for different echelons of the supply chain for these items are entirely different from those of the non perishable items. The inventory models will be so complex for each echelon as the build up in the system will not actually follow a straight line. The environmental conditions can significantly influence the inventory system, safety stock, maximum inventory level and reorder level.

For example in the manufacturer's Inventory model as shown in the Fig.1 the deterioration rate 'θ' is assumed as constant. The inventory buildup pattern and consumption pattern after the time period T_1 will be different if the deterioration rate of the inventory is variable. Since the deterioration pattern is different, mathematical equations for the deterioration rate should be formulated based on the variability of deterioration rate. As temperature and relative humidity are the major parameters which influence the shelf life of edible goods, the

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shelf lives of them varies with different combinations of these parameters which makes the analysis lot more complex.

V.SHELF LIFE STUDY ON AN EDIBLE PERISHABLE GOOD

With a view to learn the deterioration pattern of a perishable edible item, an experiment was conducted on it. The items selected for study were homely made bread samples which had no added preservatives in them. The bread is selected because it is a frequently consuming item and the deterioration is quite reasonable because the deterioration will not be very fast like other perishable items like milk, meat or blood. The deterioration of the bread is mainly due to the microbes like bacteria, yeast and molds .The mold formation in the bread is the major factor which makes the bread inedible compared to others and the focus of the study is on the rate of mold formation for a selected set of variables viz.Temperature and humidity

VI.METHODOLOGY

For studying the shelf life, bread samples were placed in an environmental chamber which could simulate the real environmental conditions. The variable parameters taken for shelf life study were the temperature and relative humidity. These parameters were strategically varied such that some of their combinations could represent the environmental conditions of different locations like coastal areas, high altitude regions, urban areas and villages. Then the mold formations in the bread samples were studied for these combinations. The selected environmental conditions were
a) 40% Relative humidity (RH) and temperature 20^0C b) 50% relative humidity and temperature 30^0C c) 60% relative humidity and temperature 40^0C and d) 80% Relative humidity and temperature 45^0C. The bread loses edibility when the mold formation exceeds 10 Cfu/g (colony forming unit per gram) and the duration to have a mold growth of 10Cfu/g can be accounted as the shelf life of the bread for the selected environmental conditions.
The tables below show the observations from the experiments conducted on bread samples at the above mentioned environmental conditions. Such environmental conditions were simulated with the environmental chamber and the mold colony formation units per gram were estimated at regular time intervals.

Sl.no	Time (hrs)	Cfu/g
1	18	3
2	24	4
3	38	6
4	45	7
5	58	9
6	65	10
7	66	12
8	90	46

Table 1. Shelf life of Sample at 40% RH and 20^0C

Sl.no	Time (hrs)	Cfu/g
1	12	2
2	48	3
3	49.5	5
4	50.5	6
5	51	7
6	52	8
7	55	12
8	62	20

Table .2 Shelf life of Sample at 50% RH and 30^0C

Sl.no	Time (hrs)	Cfu/g
1	24	2
2	30	3
3	39	4
4	47	5
5	54	6
6	60	10
7	65	13

Table .3 Shelf life of Sample at 60% RH and 40^0C

Sl.no	Time (hrs)	Cfu/g
1	10	2
2	19	3
3	23	6
4	27	9
5	30	12
6	42	23

Table .4 .Shelf life of Sample at 80% RH and 45^0C

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Graphical representations of the test results at the selected set of environmental conditions are as shown below. Almost all the graphs are somewhat similar in shapes though the parameters are different.

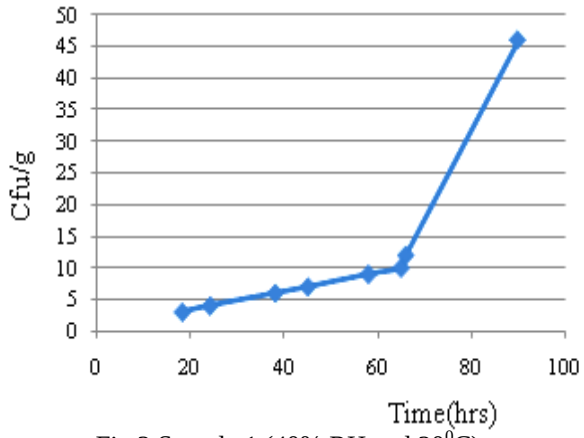

Fig.2 Sample 1 (40% RH and 20^0C)

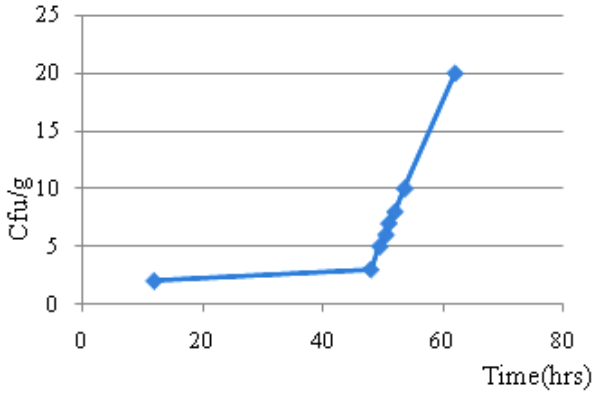

Fig.3 Sample 2 (50% RH and 30^0C)

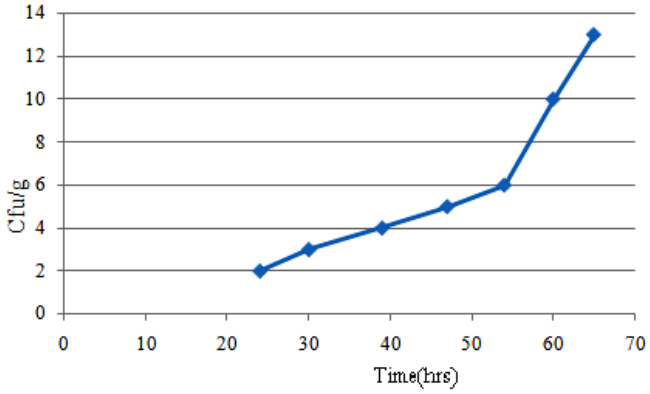

Fig.4. Sample 3 (60% RH and 40^0C)

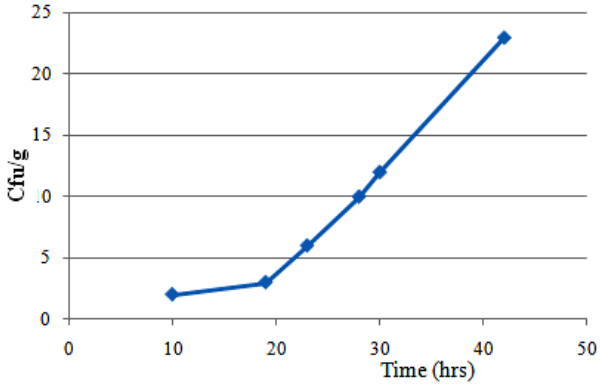

Fig.5 Sample 4 (80% RH and 45^0C)

VII.RESULTS

For the sample1 kept at 40% RH and 20^0C the deterioration is very slow up to 65 hours, reaches a mold formation rate of 10Cfu/g and then increases at a faster rate.

For the sample 2, kept at 50% RH and 30^0C, mold formation of 10cfu/g reaches at 53.6 hours and increases rapidly to 20 Cfu/g after 62 hours. The shelf life is estimated as 53.6 hours.

For the sample 3, kept at 60% RH and 40^0C mold formation of 10cfu/g reaches at 60 hours and follows an increasing trend. The shelf life is estimated as 60 hours.

For the sample 4 kept at 80% RH and 45^0C mold formation of 10 Cfu/g reaches at 28 hours and follows an increasing trend. The shelf life is estimated as 28 hours.

From Analysis the patterns of mold formation for the samples were obtained as follows

Sample 1; $y = 1.555e^{0.033x}$

Sample 2; $y = 0.964e^{0.039x}$

Sample 3; $y = 0.754e^{0.042x}$

Sample 4; $y = 0.850e^{0.082x}$

Where y is the Colony formation units per gram and x is the

Time in hours

VIII.CONCLUSION

The study revealed that the deterioration rates for perishable edible goods are variable rather than constant. The deterioration rates vary with respect to the environmental conditions. It is observed that the deterioration rate increases gradually at the beginning followed by a rapidly increasing trend almost for all the samples tested at different environmental conditions. For the analyzed inventory the useful shelf life is the time exactly taken for a mold formation of 10 colony formation units/gram. As the variable deterioration rate is very much significant in the optimization of the stock levels to be maintained at various echelons of a distribution chain, this study results contribute to the

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mathematical modeling of the inventory models for different echelons of a distribution chain and their optimization with a view to reduce the total cost associated with the chain. This methodology can also be expanded to learn the variation of shelf life by allowing one parameter to remain constant and the other to vary. i.e. Shelf life of the sample can be analysed by keeping the relative humidity constant and by varying the temperature and vice versa. This methodology may also be useful for the investigation of the shelf lives for an array of similar kinds of perishable goods. The advantage of this study is that it can portray the real behavior of perishable inventory when it is subjected to a set of different climatic conditions and can provide realistic data regarding the shelf life and deterioration rate which increases the accuracy of subsequent efforts to design the inventory models based on variable deterioration rates. But this method is time consuming and challenging. It requires expensive equipments, accurate methods to collect data and service of micro biological experts.

REFERENCES

[1] Po-Chung Yang, Hui-Ming Wee, "An integrated multi-lot-size production inventory model for deteriorating item, Computers & Operations Research", 30, 2003,pp. 671–682

[2] Chamansingh, "An integrated supply chain model for the perishable items with fuzzy production rate and fuzzy demand rate", Yugoslav Journal of Operations Research, 21, 2011, pp. 47-64

[3] H. Rau, B.C. OuYang, "An optimal batch size for integrated production–inventory policy in a supply chain", European Journal of Operational Research, 185, 2008, pp. 619–634

[4] AdityaShastria, S.R. Singh, DharmendraYadav, ShalleyGupta,"Multi-Echelon Supply Chain Management for deteriorating items with Partial Backordering under Inflationary Environment" ProcediaTechnology,10, 2013,320–329

[5] Liang-HsuanChen, Fu-SenKang, "Integrated vendor–buyer cooperative inventory models with variant permissible delay in payments", European Journal of Operational Research, 183, 2007, pp. 658–673

[6] Jian Li, T.C. Edwin Cheng, Shouyang Wang, "Analysis of postponement strategy for perishable items by EOQ-based models", International journal of production economics, 107, 2007, pp. 31-38

[7] Mohammad Rahdar , Ali S. Nookabadi, "Coordination mechanism for a deteriorating item in a two-level supply chain system", Applied Mathematical Modeling, 38, 2014,pp. 2884–2900

[8] Liang-Hsuan Chen, Fu-SenKang, "Integrated inventory models considering permissible delay in payment and variant pricing strategy", Applied Mathematical Modelling, 34, 2010, pp. 36–46

[9] Chamansingh, S.R.Singh, "Integrated Supply Chain Model for Perishable Items with Trade Credit Policy under Imprecise Environment", International Journal of Computer Applications, 48, 2012, pp.36-40

[10] A. NagoorGani,G. Sabarinathan, "Optimal Policy for Vendor-Buyer Integrated Inventory Model within Just In Time in Fuzzy Environment", International journal of fuzzy Mathematical Archive, 2,2013,pp.26-35

[11] R. Kalaiarasi, W.Ritha, "Optimisation of fuzzy Integrated two stage vendor-buyer Inventory System", International Journal of Mathematical Sciences and Applications, 1, 2011, pp.659-670

[12] Derrien.R.Jansen, ArjenvanWeert, AdrieJ.M.Beulens, RuudB.M.Huirne, "Simulation model of multi compartment distribution in the catering Supply chain", European Journal of Operational Research, 133, 2001, pp.210-224

[13] Sameer Kumar, AnvarNigmatullin, "A system dynamics analysis of food supply chains – Case study with non-perishable products", Simulation Modelling Practice and Theory, 19, 2011, pp. 2151–2168

[14] Rob A.C.M.Broekmeulen, KarelH.vanDonselaar, "A heuristic to manage perishable inventory with batch ordering, positive lead-times, and time-varying demand", Computers& Operations Research, 36, 2009, pp. 3013 – 3018

[15] YongruiDuan, JiazhenHuo, Yanxia Zhang, JianjunZhang, "Two level supply chain coordination with delay in payments for fixed Lifetime Products", Computers& Industrial Engineering, 63, 2012, pp. 456–463

[16] Kyu Hun Hahn, Hark Hwang, SeongWhanShinn, "A returns policy for distribution channel coordination of perishable items", European Journal of Operational Research, 152, 2004, pp. 770–780

[17] PrzemysławIgnaciuk, "Dead-time compensation in continuous-review perishable inventory systems with multiple supply alternatives", Journal of Process Control, 22, 2012, pp. 915– 924

[18] KanchanaKanchanasuntorn, AnularkTechanitisawad, "An approximate periodic model for fixed-life perishable products in a two-echelon inventory–distribution system", International Journal of Production Economics, 100, 2006, pp.101–115

[19] JunxiuJia, QiyingHu, "Dynamic ordering and pricing for a perishable goods supply chain", Computers& Industrial Engineering, 60, 2011, pp. 302–309

[20] Amir H. Masoumi, Min Yu, Anna Nagurney, "A supply chain generalized network oligopoly model for pharmaceuticals under brand differentiation and perishability", Transportation Research Part E, 48, 2012, pp. 762–780

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Tool Pin Profiles and the Quality of Welds in Friction Stir Welding of Aluminium Alloys

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***Abstract*—Aluminium alloys are successfully used to construct lightweight and durable structures in high precision areas such as marine industry, aircraft industry and railway industry. The major aluminium alloys used in these industries belong to 2000, 6000 and 7000 series. These are precipitation hardened alloys. The fusion welding of these alloys is difficult because of the crack and defect formation at the time of solidification. Friction Stir Welding (FSW) is a type of solid-state welding which eliminates the formation of defects that usually occur during the conventional welding methods for aluminium alloys. In the process of FSW, a rapidly rotating non-consumable high strength tool plunges in the faying surfaces and rotational and forward movement of the tool plastically deforms the material to form the joint. The workpiece to be joined is firmly clamped with the work table. Frictional heating is produced out of the rotation between shoulder and the workpiece. This review paper is an attempt to describe the state-of-the-art tool profiles used in FSW and their effects on the weld properties and weld defects. The types of microstructure evolving with different tool profiles are also discussed. The review reveals that square pin tool gives better joint strength than other types of tools and FSW can produce joints even stronger than GMAW for certain dissimilar welds. In the case of AA7075-O, the weld strength is more than even the base material. The crack propagation rate in certain dissimilar welds made by FSW is reported to be less than that in the constituent base materials.**

Keywords—Friction Stir Welding, tool profile, aluminium alloy

I. INTRODUCTION

Aluminium has a wide range of applications; it is used from packing foil for the food industry to aerospace and shipbuilding industries [1]. The main advantages of the aluminium and its alloys are high strength-to-weight ratio and good corrosion resistance [2]. It is a non-ferrous material and is highly sensitive to the heat and temperature. It is not possible to use all types of manufacturing processes for aluminium. Mostly the aluminium alloys are hard through precipitation hardening [3] and hence the fusion welding cannot be applied to them because the high heat generated during these processes causes loss of some of its properties and leaves it unable to serve the intended functions.

In 1991, a new technology in welding processes was invented by The Welding Institute (TWI) [4] and it was named as Friction Stir Welding (FSW). The FSW is a solid-state welding process in which the workpieces are joined together at the solidification temperature. It is a type of green welding so that there are no hazardous fumes or flames produced during the welding process. The main components of the FSW machine are the rotating spindle, the movable bed and the control system. This is the most energy-efficient welding technique and it is used to weld aluminium alloys and other kinds of ferrous and non-ferrous metals.

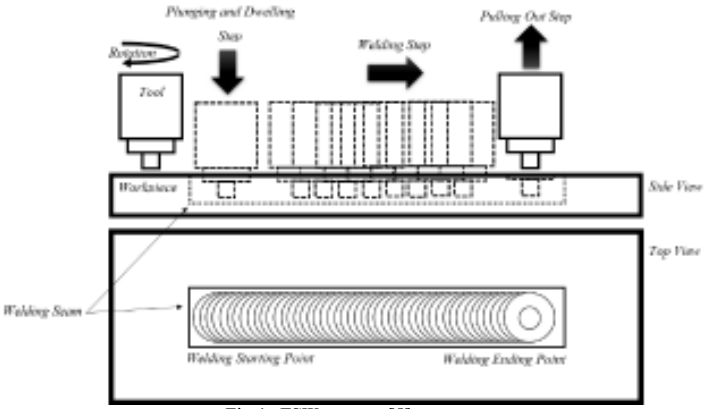

Fig.1. *FSW process* [5]

The tool, that consists of pin and shoulder, rotates at high rpm and is made to plunge into the workpiece and move at a specific speed to realize the process of welding. The Fig. 1 shows the schematic of FSW process. The important parameters to be considered for achieving a good quality defect-free weld joint in FSW are tool rotational speed, welding speed, axial force, pin profile, tool tilt angle, shoulder diameter and pin diameter [6] [7]. If these parameters are not properly selected and maintained, the defects such as voids, hooks, onion ring and tunnel defects may arise. The incorrect speed range, welding speed and axial force may even lead to the damage of the tool. The cross-sectional area of an FSW weld joint is characterized by the different zones such as Heat Affected Zone (HAZ), Thermo-Mechanically Affected Zone

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(TMAZ) and Weld Nugget Zone (WNZ). Also, there are Advancing Side (AS) and Retreating Side (RS), which are the two sides relative to the weld centre line. The rotational motion and linear motion of tool pin are in the same direction in AS and they are opposite in direction in the RS. The Fig. 3 shows the different weld zones in FSW.

II. TYPES OF TOOLS FOR FSW

There are different types of tools used for performing FSW. Important of them are – straight cylindrical pin tool, tapered cylindrical pin tool, trapezoidal tapered pin tool, triangular pin tool, straight square pin tool, threaded pin tool, tapered threaded pin tool, pentagonal shaped pin tool and hexagonal shaped pin tool. The Fig. 2 shows the geometry of triangular, square and cylindrical shaped tools. The Fig. 4 shows the profiles for concave and convex type shoulder. The Fig. 5 shows the cylindrical, cylindrical tapered, cylindrical threaded, trapezoidal tapered and cylindrical grooved tools. The Fig. 6 shows tapered cylindrical, straight cylindrical and straight square pin tools. The Fig. 7 shows the pentagonal and hexagonal tool pin profiles. The tools used for FSW of aluminium alloys are generally made of Stainless Steel (SS), High Speed Steel (HSS), H13, C40 or High carbon High Chromium Steel (HCHCr). The Table I details the types of tools and their main features. The Table II is a summary of major findings from FSW of different aluminium alloys using different types of tools.

A. FSW with Cylindrical Pin Tool

Cylindrical pin tool is the simplest type of tool and has been widely used by several researchers. The 2XXX, 5XXX, 6XXX, 7XXX series of aluminium alloys were reported to have been welded by using the cylindrical tool. A non-consumable cylindrical pin tool was attached with the robot to conduct a flexible friction stir welding process for making defect-free weld joints with better mechanical properties [2]. The plates of aluminium 6005-T5 alloys, used for making the floor, roof, and wall panels of railway vehicles, were welded in FSW by cylindrical tool [1]. The tensile strength of the welded joint increased with the increase in the welding speed whereas the fatigue strength decreased with the increase in welding speed. The aluminium 6061-T6 alloys were spot welded using the cylindrical tool, to get the better weld results in the 700 Kg/550 rpm/2 S welding parameters. By this condition, the cross-sectional part of the stir zone (SZ) gave finer grains [9].

Fig.2. *Triangular, Square, Cylindrical pin profile* [10]

The 7075-T6 aluminium alloy plates of different thicknesses (1.6 mm and 0.8 mm) were welded as a lap joint

Fig. 3 *Different weld zones in FSW* [8]

and the quality of the weld was estimated by using optical microscope and scanning electron microscope [11]. The strength capacity of the weld joint was calculated by tensile/pure shear loading tests. The microstructural study gave a clear picture of the quality of joint-related to the tool plunge depth. Also, the alloy was welded as a square butt joint using the 15 mm shoulder diameter, 5 mm pin diameter, and 45 HRC tool. The best results were obtained at the tool rotational speed of 1400 rpm, welding speed of 60 mm/min and an axial force of 8 KN and they were yield strength of 315 MPa, tensile strength of 373 MPa, hardness of 203 HV and a joint efficiency of 77%.

TABLE 1. Tool pin profiles and their main features

No.	Tool pin profile	Literature	Major features
1	Cylindrical pin tool	[2][1][9][11][12] [3][13][14][4][15] [16][17][18][19]	Simplest design; moderate fine grains are produced; high stirring force required
2	Square pin tool	[10][6]	Gives better joint strength; very fine grains produced at the nugget zone.
3	Cylindrical tapered tool	[6]	Gives finer grains than straight cylindrical tool
4	Triangular pin tool	[10]	Higher joint strength than cylindrical tool; joint strength decreases at higher than 2000 rpm
5	Threaded pin tool	[20][21][22][23]	Gives fine grains at the nugget zone; dissimilar welds are also performed.
6	Tapered threaded pin tool	[24][25][26][8]	Better joint strength than threaded pin; mainly used for dissimilar welds
7	Hexagonal pin tool	[14]	Used in similar welds; better joint strength at lower rpm.
8	Pentagonal pin tool	[14]	Used in similar welds; better joint strength at lower rpm.

Defect-free and fine-grained microstructure was obtained at NZ and finer $MgZn_2$ particles in the NZ contributed to the strength of joint [12]. This alloy was welded at the rotational speed of 1600 rpm and welding speed of 63 mm/min with a cylindrical tool and the tunnel, kissing bond and zigzag defects were found to be formed in the microstructural analysis of the weld joint. [10]. The 7055 aluminium alloy was welded under two conditions with the cylindrical tool, one with air cooling and the other with water cooling. In this experiment, water cooling gave the finer recrystallized grains at the nugget zone (NZ). The minimum value of hardness was rising from 134 HV for the air-assisted cooling to 142 HV for the water-assisted cooling joint. The ultimate strength and elongation efficiency were increased from 0.68 and 0.26 for air-assisted cooling to 0.73 and 0.31 for the case of water-

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assisted cooling respectively [3]. The aluminium 7449 alloys microhardness was measured. The better result were with the naturally aged alloys [13]. The series of aluminium alloys which possesses higher corrosion resistance is the 5XXX series [14]. The aluminium alloy 5052 was welded at the of various thicknesses were welded and the property of rotational speed of 700 rpm, welding speed of 75mm/min and at a tilt angle of 2^0 to get a moderate value of tensile strength for the joint.

TABLE II. Summary of major findings from FSW of different aluminium alloys using different types of tools

No.	Material	Tool pin profile	Major findings
1	AA 6005-T5	Cylindrical [1]	Tensile strength of weld joint increases and its fatigue strength decreases with increase in welding speed [1] .
2	AA 6061-T6	Cylindrical [9]; square [6]	Square pin gives finer grains in nugget zone; the nugget/stirred zone has higher strength compared with HAZ and TMAZ because of the formation of smaller grain size at this zone due to stirring of tool; the observed failure mode was a ductile fibrous fracture [6]
	AA 7075-T6	Cylindrical [11][10][12]; square [10]; triangular [10]; threaded tool [24] [21] [22] [23]	Defects like tunnel, kissing bond, zig-zag occur [10]; important parameters affecting the quality of the joint are the duration of welding time and tool plunge depth [11]
4	AA 7055	Cylindrical [3]	Water assisted cooling gives better strength [3]
5	AA 7449	Cylindrical [13]	Natural ageing is very effective at improving the strength of the welds [13]
6	AA 7075-T6 and AA 6061-T6 (Dissimilar weld)	Cylindrical [4] [16]; tapered cylindrical [27]	Tool offset increases the tensile strength due to a good flow of AA7075-T651 material in retreating side to AA6061 in advancing side; good mixing of material in the weld nugget zone; The material mixing is much more effective when AA6061alloy is located in advancing side [4]; dynamic recrystallization and grain size in both alloys decrease significantly with the increase of welding speed [16]; taper cylindrical tool exhibits good tensile strength [27];
7	AA 7075-O	Threaded pin tool [26][25]	The joint strength is higher than the base material [25]
8	AA 6082-T6 and AA 7075-T6 (Dissimilar weld)	Cylindrical [15]	AA7075 alloy being placed on the advancing side increases welding heat generation, peak temperature and degree of material mixing [15]
9	AA 7050 and AA 6061 (Dissimilar weld)	Cylindrical [17]	Material intermixing and joint strength increase with the increase in tool rotational speed [17]
10	AA 7075 and AA 2024 (Dissimilar weld)	Cylindrical [18]	UTS, YS and percentage elongation increase with increase in velocity ratio (tool rotational speed/tool traverse speed) [18]
11	AA 5052	Cylindrical tapered [14]; Pentagonal tool [14]; hexagonal tool [14]	Tool tilt angle has a significant role in determining the tensile strength of the weld joint [14]
12	AA 2219 -T62	Threaded pin tool [20]	Water cooling led to more grain refinement in weld nugget zone than air cooling [20]
13	AA 2024-T3 and AA 7075-T6 (Dissimilar weld)	Threaded pin tool [28]	Microhardness increases with increase in velocity ratio [18]
14	AA 6061-T6 and AA 6082-T6 (Dissimilar weld)	Threaded pin tool [8]	Crack propagation rate in weld joint less than that of base materials [8]
15	AA 7050 and AA 7075 (Dissimilar weld)	Cylindrical tool [29]	Tensile and yield strengths of weld joint increased with decrease in plate thickness due to faster workpiece cooling rate and higher tool travel speed [29]

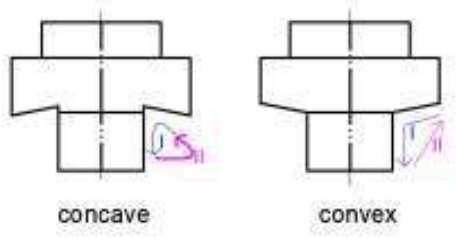

Fig.4. *Concave and Convex type shoulder* [19]

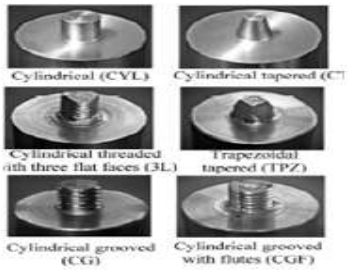

Fig.5. *Tool pin profiles* [30]

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By the cylindrical tool, dissimilar FSW was also performed. The aluminium 7075-T6 and 6061-T6 alloys were butt-welded by FSW. The tool had a pin diameter of 6 mm, shoulder diameter of 20 mm, pin length of 6 mm and a tilt angle of 3^0 [4]. Also, the tool has the dimensions of 25 mm shoulder diameter, 6 mm probe diameter and 6 mm probe height. This tool was used to weld the aluminium alloy and the microstructure of the joint was analysed. The abnormal shape of the stir zone was equally noticed in all the samples [15]. These alloys can be welded at different process parameters using a straight cylindrical tool. While the welding speed is high, the 6061 alloys placed in the advancing side gives better microstructure as well as good mechanical properties [16]. The aluminium 6061 and 7050 alloys were welded using the tool having 18 mm shoulder diameter and 10 mm pin diameter. The 4 mm thickness plate was welded where the tool rotational speed was found to be affecting the welding process. Better mixing of the material was observed at the high rotational speed [17]. Plates made of aluminium 7075 and 2024 alloys with a thickness of 6 mm were subjected to friction stir butt welding where the tool shoulder diameter was 24 mm, pin diameter was 8 mm and pin length was 5.8 mm and tilt angle was 1.5^o. A constant axial force of 5 KN was employed. It was observed that microhardness value increased as the velocity ratio was increased. Also, the tensile properties and hardness of welds were found to be related to the microstructure [18]. The 5052-H32 and 6061-T6 aluminium alloys were welded by changing the shoulder geometry as concave and convex keeping the same pin profile. The effects of shoulder profile on weld quality were assessed. As the FSW progressed, the convex type shoulder needed high Z force and torque as compared to the concave type shoulder. High heat was developed in the area of convex type shoulder which led to poor weld quality. The shoulder with concave geometry is termed to be more weld energy efficient [19].

B. FSW with Square Pin Tool

The 5XXX, 6XXX, 7XXX series of aluminium alloys are mostly welded by the square tool. Maximum mixing and minimum defect at the weld region were reported when 7075 aluminium alloy was welded using the square pin tool with a rotational speed of 1600 rpm and welding speed of 63 mm/min [10]. The 5XXX series alloy plate of size 6mm was welded with a straight square pin having a 5.7 mm pin length, 25 mm shoulder diameter, and 6 mm square side length. The weld joint exhibited better strength with this tool at the NZ as compared with the Heat-Affected Zone (HAZ) and Thermo-Mechanically Affected Zone (TMAZ) when the rotational speed was 1000 rpm and welding speed was 40 mm/min [6].

C. FSW with Tapered Pin Tool

The 5XXX series alloy plate of size 6 mm was welded using tapered pin tool with 5.7 mm pin length, 24 mm shoulder diameter and 3 mm pin diameter. Higher hardness value was obtained at the NZ and the lowest value was obtained at HAZ [6]. Higher degree of mixing and good strength for weld joint was observed when aluminium 5052 alloy plates were welded at a rotational speed of 600 rpm, welding speed of 65 mm/min and tilt angle of 1.5^0 [14].

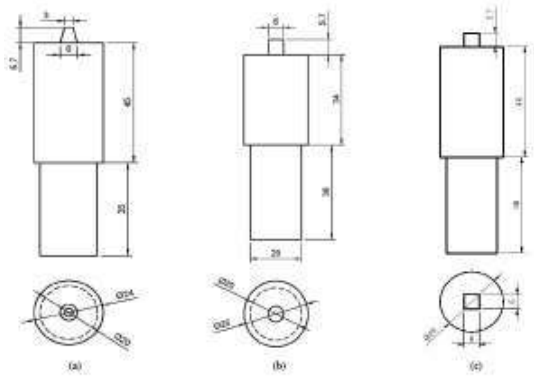

Fig.6.*Different tool profiles used (a) tapered cylindrical (b) straight cylindrical (c) straight square* [6]

The dissimilar welds were also performed by this tapered tool. The plates made of aluminium 7075-T6 and 6061-T651 alloys were welded with a tapered cylindrical threaded tool rotating at 900 rpm and at a welding speed of 100 mm/min and the resulting Ultimate Tensile Strength (UTS) was 205.3 MPa. When tapered square threaded tool was used at 900 rpm and 90 mm/min, the UTS was 178.01 MPa. This lower value is thought to be because of the less amount of mixing of the material at the time of welding. The tapered cylindrical tools could produce better results than the other tools like tapered square and tapered threaded tools [27].

D. FSW with Triangular Pin Tool

The aluminium 7075 plates were welded at the rotational speed of 1600 rpm and welding speed of 63 mm/ min and it was observed that crack and tunnel defects developed at the weld joint [10]. The thickness of the plates was 5 mm and the triangular tool had a shoulder diameter of 15 mm, pin diameter of 5 mm and pin length of 3.8 mm. The increase in rotational speed led to increase in tensile strength, but the tensile strength decreased for rotational speed above 2000 rpm.

E. FSW with Threaded Pin Tool

Aluminium 2XXX, 6XXX, 7XXX series are commonly welded by the threaded pin tool. The 20 mm thick AA2219-T62 aluminium alloy plates were welded using threaded pin tool where the shoulder diameter was 34 mm, the diameter of threaded cone-shaped pin was 13.5 mm and the diameter of tip was 9.3 mm. It was a left-hand threaded screw which rotated clockwise. The tilt angle was decided to be 2.8^0. It was observed that the microstructure of AA2219 alloy had pancake-shaped grains. The failure of the joints occurred at the borders of the HAZ and TMAZ, similar to cracks [20].

A tapered threaded tool was used to weld 7075 aluminium alloy with the assistance of a compressed air-cooling system. The tool gave rise to fine symmetrical grain microstructure in the Stir Zone (SZ). The compressed air-assisted FSP produced a very good microstructure at the SZ which helped to achieve the super-plastic behaviour of the 7075Al alloy [24]. The aluminium alloy was welded with the tool of 18mm shoulder diameter, 4.7 mm pin length, and 6 mm pin diameter. In

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water-assisted cooling, the traverse speed could be increased as compared with an air-assisted cooling system. The weld strengths obtained in the water-cooled and air-cooled system were 396 MPa and 360 MPa respectively [21]. For plates made of aluminium 7075-T6 alloy of 5 mm thickness, the tool used was of 15 mm shoulder diameter, 5 mm pin diameter and 25 mm pin tip diameter. The tensile strength of weld portion was found to be increasing with increase in rotational speed below 2000 rpm. Over and above 2000 rpm, the tensile strength was found to be decreasing [22]. A tapered pin with a threaded line having 7 mm root diameter, 5 mm tip diameter and 5 mm height was used to weld plates made of aluminium 7075-T651 alloy with a thickness of 6.35 mm, length of 110 mm and width of 60 mm [23]. When the fluidity of metal was less, cavity and tunnel defects were reported to have been formed. The property of the weld material was different at various thickness layers. In order to weld plates of 7075-O aluminium alloy, the tool with 30 mm shoulder diameter, 5.7 mm pin diameter and 4.8 mm threaded pin length was employed [25]. The welding was conducted at the rotating speed of 630 rpm and welding sped of 32 mm/min. In contrast to 7075-T6 aluminium alloy for which the tensile strength decreases when welded, the 7075-O aluminium alloy achieved better hardness and tensile strength. A tool with concave double-ring shoulder of 16 mm diameter and threaded probe with 7 mm root diameter, 6.2 mm pin tip diameter and 6 mm length was used to weld 12 mm thick 7085 aluminium alloy plates keeping the angle of tilt at 2.5^{o} [26]. There was a remarkable reduction in the yield strength, ultimate tensile strength, and % elongation for the weld portion. Also, tunnel defect occurred at the NZ.

The dissimilar alloys were also weld by using this kind of tools. The dissimilar plates of 2024-T3 and 7075-T6 aluminium alloys of 3 mm thick were welded in FSW using the tool (SKD61) having a 12 mm shoulder diameter and 4 mm threaded pin [28]. It was observed that the weld quality deteriorates with increase in welding speeds. Kissing bond defect was said to be developed at the retreating side. The maximum tensile strength of the weld joint was 423 MPa and this was achieved at a welding speed of 1.7 mm/s and when the 2024 alloy was placed at the advancing side of the weld.

The crack propagation rate in the weld joint was lower than that of the base material when the plates were welded with threaded in tools [8]. The aluminium 6082-T6 alloy plates were welded with threaded pin tool of 6 mm diameter and 15 mm shoulder diameter. The 6061-T6 aluminium alloy plates were welded with threaded pin tool of 4 mm diameter and 10 mm shoulder diameter. The Fig. 8 shows the profiles for square, threaded cylindrical and threaded square tool.

F. FSW with Miscellaneous Shaped Tool

The pentagonal and hexagonal shaped pin profiles were used to weld the aluminium 5052 alloys [14]. Pentagonal tool was employed to perform FSW at the rotational speed as 500 rpm, welding speed of 55 mm/min and tool tilt angle of 1^{0} for maximum performance. FSW with hexagonal tool was conducted for the best performance at the rotational speed as 400 rpm, welding speed of 45 mm/min and tool tilt angle of 0.5^{0}.

Fig.7. *Hexagonal and pentagonal pin profile* [14]

The Fig. 9 shows the details of weld hardness obained by using different tools in FSW for aluminium alloys. The Fig. 10 depicts the weld tensile strength values obtained with different types of FSW tools. The Table III summarizes the tool-specific details of various types of tools and the range of process parameters used in the respective FSW processes.

G. Important Observations From the Literature Review

The important observations fom the literature review are listed below:

- The square pin tool gives the better joint strength for aluminium alloys compared to other types of tools. This is because of the very fine grains produced at the weld nugget zone by square pin tool.
- The FSW can produce weld joints even stronger than that by GMAW for certain combinations of dissimilar materials.
- In the case of AA7075-O, the weld strength is more than even the base material.
- The crack propagation rate in certain dissimilar welds made by FSW is reported to be less than that in the constituent base materials.
- In the case of 7XXX series aluminium alloys, water assisted cooling gives better strength than air assisted cooling.

Fig.8. *square, threaded cylindrical and threaded square tool* [27]

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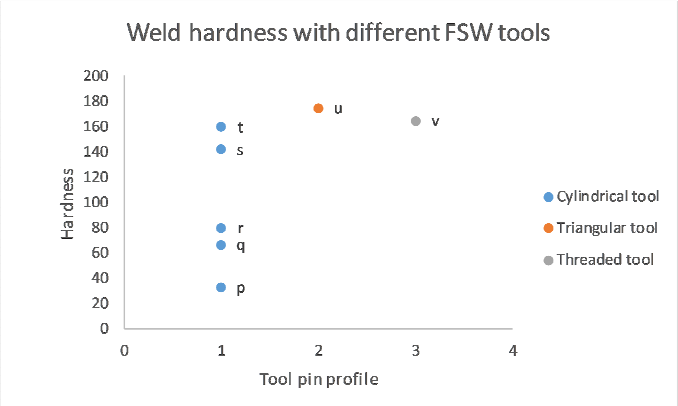
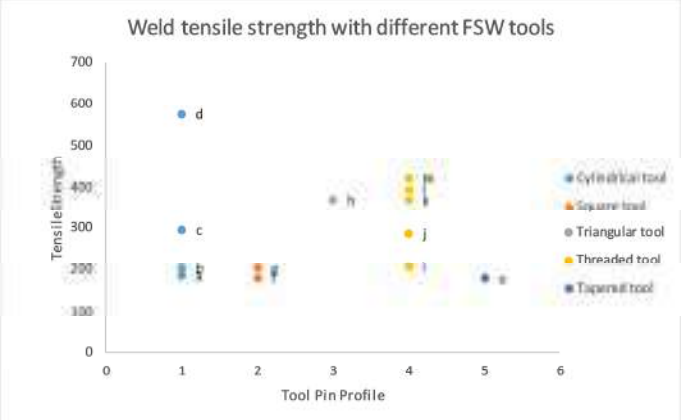


Points	Literature
a	[31]
b	[32]
c	[33]
d	[34]
e, h, n o	[35]
f	[36]
g, j, t, u	[37]
i, s	[38]
k, p	[39]
l	[40]
m, q	[41]
r	[42]

Fig. 9. *Details of weld hardness obained by using different tools in FSW for aluminium alloys.*



Points	Literature
a	[31]
b	[32]
c	[33]
d	[34]
e, h, n o	[35]
f	[36]
g, j, t, u	[37]
i, s	[38]
k, p	[39]
l	[40]
m, q	[41]
r	[42]

Fig. 10. *Details of weld tensile strength obtained by using different tools in FSW for aluminium alloys.*

TABLE III. Summary of tool-specific details of various types of tools and the range of process parameters

No.	Tool pin profile	Details of tool	Range of parameters
1	Cylindrical tool	SD- 8 mm, the PD-2.0mm, PL-1.7 mm.[43]; SD-20 mm and PL-6 mm, PD-3mm [34]; SD-25mm, PL-5.7mm, PD-6mm [44];SD-12mm, PD-4mm, PL-1.8 mm[45];SD-25 mm, PD-6mm, PL-6mm [46]	S- 1200 rpm ,WS- 100 mm/min, α-1°[43]; PD-4,5,6,7 and 8 mm, ,TO-0.3, 0.6, 0.9, 1.2 and 1.5 mm, α-1^0,2^0, 3^0, 4^0 and 5^0[34]; S- 800, 900, 1000, 1100, and 1200 rpm, WS- 20, 30, 40, 50 and 60 mm/min [44]; WS- 63 mm/min, S-1600 rpm[40]; S-900 rpm, WS-20 mm/min[47]; S- 950 and 1000 rpm, WS- 80 and 100 mm/min [46]; S- 270, 340 and 410 rpm, WS- 114 mm/min[31]
2	Square pin tool	PL-5.7 mm, SD-25 mm, SSL-6 mm [44]	S- 800, 1000 and 1200 rpm, WS- 20, 40 and 60 mm/min [44]
3	Cylindrical tapered tool	A concave (7^0 taper), SD-19.1mm, PD-7.87mm , PL-5.85 [48]; PL-5.7mm, SD-24mm, PD-3mm [44]	S-200-600 rpm, WS-101.6 and 109 mm/min [48]; S-800, 1000 and 1200 rpm, WS- 20, 40 and 60 mm/min [44];S- 600 rpm, WS- 65 mm/min and α-1.5^0[36];
4	Triangular pin	SD-15mm, PD-5mm, PL-3.8mm[37]	S- 1600 rpm and WS- 63mm/ min [40]; S- 765 rpm, WS- 765 rpm [37];
5	Threaded pin tool	SD-9,12 ,15, 18, 21mm , PD-3, 4, 5, 6, 7mm [49]; PD-10mm , SD-18mm[31]; SD-20 mm, PL-0.5 mm, PD-3 mm [50]; PD-4mm, SD- 10mm [51]; SD-12mm, PD-4mm[42];SD-17mm,PD-5mm, PL-5mm [52]; SD-18mm, PL-4.7mm, PD-6mm [39]; SD-30, PD-5.7 mm [38]	S- 900-1800 rpm, WS- 20-100 mm/min [49]; S- 270, 340 and 410 rpm, WS- 114 mm/min[31]; S- 900 rpm and WS- 100 mm/min [50]; WS-800 mm/min; β-2^0; S- 1500 rpm [51]; S- 600 rpm and WS-47.5 mm/min [52]; S- 800 and 1200 rpm, WS- 25 and 300 mm/min [39]; S- 630 rpm, WS- 32 mm/min [38]; S- (800, 1000, 1250 and 1600 rpm), WS- (63, 80, 100 and 125 mm/min) [37]

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6	Tapered threaded pin tool	SD-34mm, RPD- 13.5mm, PTD- 9.3mm [53]; SD-16mm , RPD-7mm , PTD-6.2mm, PL- 6mm [41]	S- 300 rpm, WS- 80 mm/min, $\alpha=2.8^0$[53];
7	Hexagonal tool	PL-5.7 mm [36]	S- 400 rpm, WS- 45 mm/min, α=0.5[36]
8	Pentagonal tool	PL-5.7 mm [36]	S- 500 rpm, WS- 55 mm/min, $\alpha= 1^0$ [36]

(S- rotational speed , WS- welding speed, α- tool tilt angle, SD- shoulder diameter, PD- pin diameter, PL- pin length, SSL- square side length, RPD- root pin diameter, PTD-pin tip diameter, TO- tool offset, β- pitch angle)

H. Directions for Future Research

- The backing plate has a significant role in FSW as it ensures the required uniform temperature throughout the weld nugget zone. Hence, selection of material and design for backing plate is important. Only limited number of literatur is reported in this area so far.
- The pentagonal and hexagonal tool pin profiles have been tried by only a few researchers. The number of cutting edges in these tools are higher than that in conventional cylindrical and square tools. The more the number of cutting edges, the finer will be the grains in nugget zone. Hence, authors find a great scope in exploring pentagonal and hexagonal tools.
- Another very less explored area in FSW is the study on the effects of changing the axial force. Study on axial force neessitates the thorough understanding of the behaviour of backing plate and they together make this study promising.

III. CONCLUSION

In the FSW process, one of the most important parameters is the tool pin profile. The weld quality is largely depending on the type of tool pin profile and shoulder diameter. Larger the shoulder diameter, higher will be the surface area in contact and the frictional heat developed in the weld region becomes higher which leads to easy mixing of material and finer grains at the NZ. Hence, the mechanical properties like tensile strength and hardness improve much. The cylindrical pin profile is the most commonly used type and it gives a moderate tensile strength and hardness. The straight square pin profile produces better mechanical properties in comparison with cylindrical pin profile. The use of straight square pin tool stirs the nugget zone very much which makes finer grains at the NZ. In general, the tapered square threaded pin profile produces the most defect-free joint. It gives the best values for the mechanical properties such as tensile strength and hardness. The future scope of FSW includes its use as the most energy efficient joining process, process of welding non-metals and temperature sensitive materials and less hazardous joining technique.

REFERENCES

[1] W. K. Kim, S. T. Won, and B. C. Goo, 'A study on mechanical characteristics of the friction stir welded A6005-T5 extrusion', *Int. J. Precis. Eng. Manuf.*, vol. 11, no. 6, pp. 931–936, 2010, doi: 10.1007/s12541-010-0113-1.

[2] K. Wang, F. Léonard, and G. Abba, 'Dynamic model identification of axial force in robotic friction stir welding', *IFAC-Pap.*, vol. 28, no. 3, pp. 1936–1941, 2015, doi: 10.1016/j.ifacol.2015.06.370.

[3] H. Lin, Y. Wu, S. Liu, and X. Zhou, 'Effect of cooling conditions on microstructure and mechanical properties of friction stir welded 7055 aluminium alloy joints', *Mater. Charact.*, vol. 141, no. February, pp. 74–85, 2018, doi: 10.1016/j.matchar.2018.04.029.

[4] K. P. Yuvaraj, P. Ashoka Varthanan, and C. Rajendran, 'Effect of friction stir welding parameters on mechanical and micro structural behaviour of AA7075-T651 and AA6061 dissimilar alloy joint', *Int. J. Comput. Mater. Sci. Surf. Eng.*, vol. 7, no. 2, pp. 130–149, 2018, doi: 10.1504/IJCMSSE.2018.092553.

[5] B. Meyghani, M. B. Awang, S. S. Emamian, M. K. B. Mohd Nor, and S. R. Pedapati, 'A comparison of different finite element methods in the thermal analysis of friction stir welding (FSW)', *Metals*, vol. 7, no. 10, pp. 1–23, 2017, doi: 10.3390/met7100450.

[6] A. Chandrashekar, B. S. Ajaykumar, and H. N. Reddappa, 'Effect of Pin Profile and Process Parameters on the Properties of Friction Stir Welded Al-Mg Alloy', *Mater. Today Proc.*, vol. 5, no. 10, pp. 22283–22292, 2018, doi: 10.1016/j.matpr.2018.06.594.

[7] G. Ugrasen, G. Bharath, G. K. Kumar, R. Sagar, P. R. Shivu, and R. Keshavamurthy, 'Optimization of Process Parameters for Al6061-Al7075 alloys in Friction Stir Welding using Taguchi's Technique', *Mater. Today Proc.*, vol. 5, no. 1, pp. 3027–3035, 2018, doi: 10.1016/j.matpr.2018.01.103.

[8] P. M. G. P. Moreira, A. M. P. de Jesus, A. S. Ribeiro, and P. M. S. T. de Castro, 'Fatigue crack growth in friction stir welds of 6082-T6 and 6061-T6 aluminium alloys: A comparison', *Theor. Appl. Fract. Mech.*, vol. 50, no. 2, pp. 81–91, 2008, doi: 10.1016/j.tafmec.2008.07.007.

[9] Y. Sun, H. Fujii, S. Zhu, and S. Guan, 'Flat friction stir spot welding of three 6061-T6 aluminum sheets', *J. Mater. Process. Technol.*, vol. 264, pp. 414–421, 2019, doi: 10.1016/j.jmatprotec.2018.09.031.

[10] S. M. Bayazid, H. Farhangi, and A. Ghahramani, 'Effect of Pin Profile on Defects of Friction Stir Welded 7075 Aluminum Alloy', *Procedia Mater. Sci.*, vol. 11, pp. 12–16, 2015, doi: 10.1016/j.mspro.2015.11.013.

[11] A. Kubit, M. Bucior, D. Wydrzyński, T. Trzepieciński, and M. Pytel, 'Failure mechanisms of refill friction stir spot welded 7075-T6 aluminium alloy single-lap joints', *Int. J. Adv. Manuf. Technol.*, vol. 94, no. 9–12, pp. 4479–4491, 2018, doi: 10.1007/s00170-017-1176-2.

[12] S. Rajakumar, C. Muralidharan, and V. Balasubramanian, 'Influence of friction stir welding process and tool parameters on strength properties of AA7075-T6 aluminium alloy joints', *Mater. Des.*, vol. 32, no. 2, pp. 535–549, 2011, doi: 10.1016/j.matdes.2010.08.025.

[13] N. Martinez, N. Kumar, R. S. Mishra, and K. J. Doherty, 'Effect of tool dimensions and parameters on the microstructure of friction stir welded aluminum 7449 alloy of various thicknesses', *Mater. Sci. Eng. A*, vol. 684, no. December 2016, pp. 470–479, 2017, doi: 10.1016/j.msea.2016.12.077.

[14] S. SHANAVAS and J. EDWIN RAJA DHAS, 'Parametric optimization of friction stir welding parameters of marine grade aluminium alloy using response surface methodology', *Trans. Nonferrous Met. Soc. China Engl. Ed.*, vol. 27, no. 11, pp. 2334–2344, 2017, doi: 10.1016/S1003-6326(17)60259-0.

[15] S. T. Azeez, E. T. Akinlabi, S. V. Kailas, and S. D. Brandi, 'Microstructural properties of a dissimilar friction stir welded thick aluminum aa6082-t6 and aa7075-t6 alloy', *Mater. Today Proc.*, vol. 5, no. 9, pp. 18297–18306, 2018, doi: 10.1016/j.matpr.2018.06.168.

[16] J. F. Guo, H. C. Chen, C. N. Sun, G. Bi, Z. Sun, and J. Wei, 'Friction stir welding of dissimilar materials between AA6061 and AA7075 Al alloys effects of process parameters', *Mater. Des.*, vol. 56, pp. 185–192, 2014, doi: 10.1016/j.matdes.2013.10.082.

[17] R. I. Rodriguez, J. B. Jordon, P. G. Allison, T. Rushing, and L. Garcia, 'Microstructure and mechanical properties of dissimilar friction stir

welding of 6061-to-7050 aluminum alloys', *Mater. Des.*, vol. 83, pp. 60–65, 2015, doi: 10.1016/j.matdes.2015.05.074.

[18] B. Srinivas and A. Devaraju, 'Investigation of velocity ratios on mechanical and microstructural characterization of friction stir welded dissimilar 2024 and 7075 aluminium alloy', *Mater. Today Proc.*, vol. 5, no. 9, pp. 19250–19254, 2018, doi: 10.1016/j.matpr.2018.06.282.

[19] J. R. Kim *et al.*, 'Effect of tool geometry and process parameters on mechanical properties of friction stir spot welded dissimilar aluminum alloys', *Int. J. Precis. Eng. Manuf.*, vol. 18, no. 3, pp. 445–452, 2017, doi: 10.1007/s12541-017-0053-0.

[20] W. F. Xu, J. H. Liu, D. L. Chen, G. H. Luan, and J. S. Yao, 'Improvements of strength and ductility in aluminum alloy joints via rapid cooling during friction stir welding', *Mater. Sci. Eng. A*, vol. 548, pp. 89–98, 2012, doi: 10.1016/j.msea.2012.03.094.

[21] R. Rouzbehani, A. H. Kokabi, H. Sabet, M. Paidar, and O. O. Ojo, 'Metallurgical and mechanical properties of underwater friction stir welds of Al7075 aluminum alloy', *J. Mater. Process. Technol.*, vol. 262, pp. 239–256, 2018, doi: 10.1016/j.jmatprotec.2018.06.033.

[22] M. Mohammadi-pour, A. Khodabandeh, S. Mohammadi-pour, and M. Paidar, 'Microstructure and mechanical properties of joints welded by friction-stir welding in aluminum alloy 7075-T6 plates for aerospace application', *Rare Met.*, pp. 1–9, 2016, doi: 10.1007/s12598-016-0692-9.

[23] W. Y. Li, J. F. Li, Z. H. Zhang, D. L. Gao, and Y. J. Chao, 'Metal Flow during Friction Stir Welding of 7075-T651 Aluminum Alloy', *Exp. Mech.*, vol. 53, no. 9, pp. 1573–1582, 2013, doi: 10.1007/s11340-013-9760-3.

[24] V. V. Patel *et al.*, 'Experimental Investigation on Hybrid Friction Stir Processing using compressed air in Aluminum 7075 alloy', *Mater. Today Proc.*, vol. 4, no. 9, pp. 10025–10029, 2017, doi: 10.1016/j.matpr.2017.06.314.

[25] K. Dehghani, R. Ghorbani, and A. R. Soltanipoor, 'Microstructural evolution and mechanical properties during the friction stir welding of 7075-O aluminum alloy', *Int. J. Adv. Manuf. Technol.*, vol. 77, no. 9–12, pp. 1671–1679, 2015, doi: 10.1007/s00170-014-6574-0.

[26] W. Xu, H. Wang, Y. Luo, W. Li, and M. W. Fu, 'Mechanical behavior of 7085-T7452 aluminum alloy thick plate joint produced by double-sided friction stir welding: Effect of welding parameters and strain rates', *J. Manuf. Process.*, vol. 35, no. July, pp. 261–270, 2018, doi: 10.1016/j.jmapro.2018.07.028.

[27] S. R. Kumar, V. S. Rao, and R. V. Pranesh, 'Effect of Welding Parameters on Macro and Microstructure of Friction Stir Welded Dissimilar Butt Joints between AA7075-T651 and AA6061-T651 Alloys', *Procedia Mater. Sci.*, vol. 5, pp. 1726–1735, 2014, doi: 10.1016/j.mspro.2014.07.362.

[28] S. A. Khodir and T. Shibayanagi, 'Friction stir welding of dissimilar AA2024 and AA7075 aluminum alloys', *Mater. Sci. Eng. B Solid-State Mater. Adv. Technol.*, vol. 148, no. 1–3, pp. 82–87, 2008, doi: 10.1016/j.mseb.2007.09.024.

[29] C. B. Fuller, M. W. Mahoney, M. Calabrese, and L. Micona, 'Evolution of microstructure and mechanical properties in naturally aged 7050 and 7075 Al friction stir welds', *Mater. Sci. Eng. A*, vol. 527, no. 9, pp. 2233–2240, 2010, doi: 10.1016/j.msea.2009.11.057.

[30] M. Raturi, A. Garg, and A. Bhattacharya, 'Joint strength and failure studies of dissimilar AA6061-AA7075 friction stir welds: Effects of tool pin, process parameters and preheating', *Eng. Fail. Anal.*, vol. 96, no. August 2018, pp. 570–588, 2019, doi: 10.1016/j.engfailanal.2018.12.003.

[31] R. I. Rodriguez, J. B. Jordon, P. G. Allison, T. Rushing, and L. Garcia, 'Microstructure and mechanical properties of dissimilar friction stir welding of 6061-to-7050 aluminum alloys', *Mater. Des.*, vol. 83, pp. 60–65, 2015, doi: 10.1016/j.matdes.2015.05.074.

[32] W. K. Kim, S. T. Won, and B. C. Goo, 'A study on mechanical characteristics of the friction stir welded A6005-T5 extrusion', *Int. J. Precis. Eng. Manuf.*, vol. 11, no. 6, pp. 931–936, 2010, doi: 10.1007/s12541-010-0113-1.

[33] B. Srinivas and A. Devaraju, 'Investigation of velocity ratios on mechanical and microstructural characterization of friction stir welded dissimilar 2024 and 7075 aluminium alloy', *Mater. Today Proc.*, vol. 5, no. 9, pp. 19250–19254, 2018, doi: 10.1016/j.matpr.2018.06.282.

[34] K. P. Yuvaraj, P. Ashoka Varthanan, and C. Rajendran, 'Effect of friction stir welding parameters on mechanical and micro structural behaviour of AA7075-T651 and AA6061 dissimilar alloy joint', *Int. J. Comput. Mater. Sci. Surf. Eng.*, vol. 7, no. 2, pp. 130–149, 2018, doi: 10.1504/IJCMSSE.2018.092553.

[35] S. R. Kumar, V. S. Rao, and R. V. Pranesh, 'Effect of Welding Parameters on Macro and Microstructure of Friction Stir Welded Dissimilar Butt Joints between AA7075-T651 and AA6061-T651 Alloys', *Procedia Mater. Sci.*, vol. 5, pp. 1726–1735, 2014, doi: 10.1016/j.mspro.2014.07.362.

[36] S. SHANAVAS and J. EDWIN RAJA DHAS, 'Parametric optimization of friction stir welding parameters of marine grade aluminium alloy using response surface methodology', *Trans. Nonferrous Met. Soc. China Engl. Ed.*, vol. 27, no. 11, pp. 2334–2344, 2017, doi: 10.1016/S1003-6326(17)60259-0.

[37] M. Mohammadi-pour, A. Khodabandeh, S. Mohammadi-pour, and M. Paidar, 'Microstructure and mechanical properties of joints welded by friction-stir welding in aluminum alloy 7075-T6 plates for aerospace application', *Rare Met.*, pp. 1–9, 2016, doi: 10.1007/s12598-016-0692-9.

[38] K. Dehghani, R. Ghorbani, and A. R. Soltanipoor, 'Microstructural evolution and mechanical properties during the friction stir welding of 7075-O aluminum alloy', *Int. J. Adv. Manuf. Technol.*, vol. 77, no. 9–12, pp. 1671–1679, 2015, doi: 10.1007/s00170-014-6574-0.

[39] R. Rouzbehani, A. H. Kokabi, H. Sabet, M. Paidar, and O. O. Ojo, 'Metallurgical and mechanical properties of underwater friction stir welds of Al7075 aluminum alloy', *J. Mater. Process. Technol.*, vol. 262, pp. 239–256, 2018, doi: 10.1016/j.jmatprotec.2018.06.033.

[40] S. M. Bayazid, H. Farhangi, and A. Ghahramani, 'Effect of Pin Profile on Defects of Friction Stir Welded 7075 Aluminum Alloy', *Procedia Mater. Sci.*, vol. 11, pp. 12–16, 2015, doi: 10.1016/j.mspro.2015.11.013.

[41] W. Xu, H. Wang, Y. Luo, W. Li, and M. W. Fu, 'Mechanical behavior of 7085-T7452 aluminum alloy thick plate joint produced by double-sided friction stir welding: Effect of welding parameters and strain rates', *J. Manuf. Process.*, vol. 35, no. July, pp. 261–270, 2018, doi: 10.1016/j.jmapro.2018.07.028.

[42] S. A. Khodir and T. Shibayanagi, 'Friction stir welding of dissimilar AA2024 and AA7075 aluminum alloys', *Mater. Sci. Eng. B Solid-State Mater. Adv. Technol.*, vol. 148, no. 1–3, pp. 82–87, 2008, doi: 10.1016/j.mseb.2007.09.024.

[43] H. Lin, Y. Wu, S. Liu, and X. Zhou, 'Effect of cooling conditions on microstructure and mechanical properties of friction stir welded 7055 aluminium alloy joints', *Mater. Charact.*, vol. 141, no. February, pp. 74–85, 2018, doi: 10.1016/j.matchar.2018.04.029.

[44] A. Chandrashekar, B. S. Ajaykumar, and H. N. Reddappa, 'Effect of Pin Profile and Process Parameters on the Properties of Friction Stir Welded Al-Mg Alloy', *Mater. Today Proc.*, vol. 5, no. 10, pp. 22283–22292, 2018, doi: 10.1016/j.matpr.2018.06.594.

[45] Y. Sun, H. Fujii, S. Zhu, and S. Guan, 'Flat friction stir spot welding of three 6061-T6 aluminum sheets', *J. Mater. Process. Technol.*, vol. 264, pp. 414–421, 2019, doi: 10.1016/j.jmatprotec.2018.09.031.

[46] S. T. Azeez, E. T. Akinlabi, S. V. Kailas, and S. D. Brandi, 'Microstructural properties of a dissimilar friction stir welded thick aluminum aa6082-t6 and aa7075-t6 alloy', *Mater. Today Proc.*, vol. 5, no. 9, pp. 18297–18306, 2018, doi: 10.1016/j.matpr.2018.06.168.

[47] J. R. Kim *et al.*, 'Effect of tool geometry and process parameters on mechanical properties of friction stir spot welded dissimilar aluminum alloys', *Int. J. Precis. Eng. Manuf.*, vol. 18, no. 3, pp. 445–452, 2017, doi: 10.1007/s12541-017-0053-0.

[48] C. B. Fuller, M. W. Mahoney, M. Calabrese, and L. Micona, 'Evolution of microstructure and mechanical properties in naturally aged 7050 and 7075 Al friction stir welds', *Mater. Sci. Eng. A*, vol. 527, no. 9, pp. 2233–2240, 2010, doi: 10.1016/j.msea.2009.11.057.

[49] S. Rajakumar, C. Muralidharan, and V. Balasubramanian, 'Influence of friction stir welding process and tool parameters on strength properties of AA7075-T6 aluminium alloy joints', *Mater. Des.*, vol. 32, no. 2, pp. 535–549, 2011, doi: 10.1016/j.matdes.2010.08.025.

[50] V. V. Patel *et al.*, 'Experimental Investigation on Hybrid Friction Stir Processing using compressed air in Aluminum 7075 alloy', *Mater. Today Proc.*, vol. 4, no. 9, pp. 10025–10029, 2017, doi: 10.1016/j.matpr.2017.06.314.

[51] P. M. G. P. Moreira, A. M. P. de Jesus, A. S. Ribeiro, and P. M. S. T. de Castro, 'Fatigue crack growth in friction stir welds of 6082-T6 and

6061-T6 aluminium alloys: A comparison', *Theor. Appl. Fract. Mech.*, vol. 50, no. 2, pp. 81–91, 2008, doi: 10.1016/j.tafmec.2008.07.007.

[52] W. Y. Li, J. F. Li, Z. H. Zhang, D. L. Gao, and Y. J. Chao, 'Metal Flow during Friction Stir Welding of 7075-T651 Aluminum Alloy', *Exp. Mech.*, vol. 53, no. 9, pp. 1573–1582, 2013, doi: 10.1007/s11340-013-9760-3.

[53] W. F. Xu, J. H. Liu, D. L. Chen, G. H. Luan, and J. S. Yao, 'Improvements of strength and ductility in aluminum alloy joints via rapid cooling during friction stir welding', *Mater. Sci. Eng. A*, vol. 548, pp. 89–98, 2012, doi: 10.1016/j.msea.2012.03.094.

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Finite element simulation of roll bending process of cylindrical waffle structure

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Abstract—**The process of roll bending is an efficient process in manufacturing sheet panels to cylindrical and conical shapes because of its simple configuration. In the present paper, simulation of rolling process for a cylindrical panel is done using ABAQUS Finite element model and the effect of different parameters on rolling radius is studied. The panel is modeled using 3D shell elements and then subjected to end moment to simulate rolling. Different parameters of waffle configuration were varied to find the effect of each on rolling radius.**

Keywords—Rolling; spring back; finite element simulation, waffle, cylinder

I. INTRODUCTION

Roll forming is a plane strain bending process and materials with high strength and limited ductility is formed at room temperature. "Fe Han et al" studied about the Q&P980 steel sheet which is passed through a series of continuous stands. The plastic deformation mechanism of roll forming was analyzed using the stress and strain distribution at the corner of a hat-type profile [1].The roll bending process is a type of roll forming process which is widely used method for forming a metal sheet or plate into curved shapes. Cylindrical and conical shapes can be manufactured using the process [2]. The plates are generally of monocoque, isogrid or waffle configuration. Waffle structure is orthogonally stiffened shell structure, where the shell is stiffened by the use of longitudinal stiffeners and circumferential rings. The stiffeners can be oriented at 45^0or 90^0. The waffle structure is made by milling rectangular pockets in metal plate and then rolled to achieve required radius. An ABAQUS finite element model and analytical model of three roll bending process was done by "Zemin Fu et al" .The relation between downward inner roller displacement and the desired spring back radius (unloaded curvature radius) of the bent plate is derived using both methods.[3]. 3D ABAQUS finite element model is used to form a semi elliptical work piece and the simulation of multiple-step incremental air-bending forming and spring back processes is carried out by "Zemin Fu et.al". The elasto-plastic constitutive model using plain strain condition is modeled [4]. The three roll bending process is used to study the simulation of U shaped work piece .The relation between the position of rolls and final curvature of work piece is determined [5]. In this paper simulation is done to determine the relation between radius at which the plate is rolled and waffle parameters. This study is useful when curved cylindrical or conical sections for different applications such as tubular sections and large steel structures.

In this paper FEM simulation of rolling process is carried out using ABAQUS CAE. The 4 node shell element is chosen and the waffle structure is modeled as bilinear elasto-plastic constitutive model. The simulation is aimed at finding the minimum radius to which a waffle plate can be rolled without buckling of ribs. In this paper the variation of rolling radius with various waffle parameters is studied and effect of each parameter has been brought out.

II. ROLL BENDING PROCESS

A process in which the sheet is stretched to different shapes by action of tensile forces in the plane in which the sheet is to be bent is known as metal forming process. The roll bending process is performed in a three roller bending machine. The Metal strip bent as it passes through a series of rolls. The process is performed on a roll forming line in which the sheet metal stock is fed through a series of roll stations. Each station has a roller, referred to as a roller die, positioned on both sides of the sheet. The roller dies may be above and below the sheet, along the sides, at an angle, etc. As the sheet is forced through the roller dies in each roll station, it plastically deforms and bends. Each roll station performs one stage in the complete bending of the sheet to achieve the desired radius. The

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schematic representation of roll bending is shown in "Fig 1". The model consists essentially of a plate, one inner roll, and two outer rolls. The two outer rolls in symmetrical position are identical, with a constant distance between their axes. The inner roll is able to move in the vertical direction in order to press down the plate to reach a desired curvature radius.

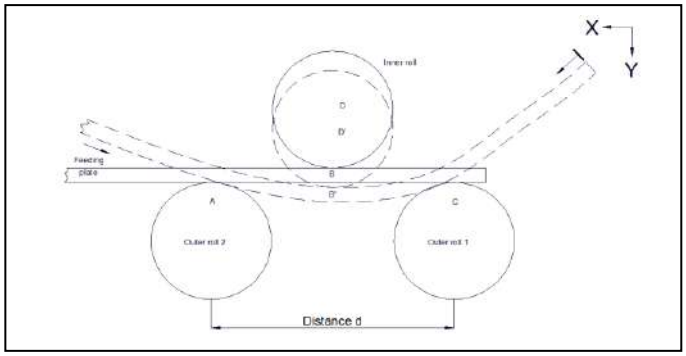

Fig. 1. Schematic representation of roll bending process

III. SIMULATION SETUP

A. Mechanical properties

The material used is Aluminum Alloy plate AA7075-T7351. It is a high strength material with zinc as primary alloy element and it is used for highly stressed parts. The T7351 temper improves stress corrosion cracking resistance and fracture toughness. The source of material properties is from "Metallic Materials Properties Development and Standardization (MMPDS)-09") .Mechanical properties of the material are shown in "Table 1" . The stress strain values, utilized for analysis, is shown in "Table II".

TABLE I. MECHANCAL PROPERTIES

Item	Value
Material	7075 Aluminum Alloy Sheet
Yield Strength(Mpa)	393
Ultimate Tensile Strength(Mpa)	475
Percent Elongation	7
Young's Modulus(Mpa)	71000
Poisson's Ratio	0.33

TABLE II. YIELD STRESS-PLASTIC STRAIN

Yield stress (MPa)	Plastic strain (%)
393	0
475	7

B. Finite element modeling

The material used for plate is isotropic and the model was assumed as elasto-plastic and of constant yield stress. The structure is idealized as 3D deformable shell. The rolling process is simulated by modelling a part of full waffle, hence utilizing the symmetric nature a cylinder. The S4R (4 node shell element) is used in the rolling process. The modeling of plate is done in the form of waffle structure in which pockets are milled. Each pocket has length, width and depth as parameters to be analyzed. Since length (Normal to rolling direction) is not going to affect the rolling radius, it has been excluded from this study. Rib thicknesses for horizontal and vertical ribs and skin thickness are also considered for the study.These are known as waffle parameters as shown in "Fig. 2"and increments of each parameter is shown in "Table III".

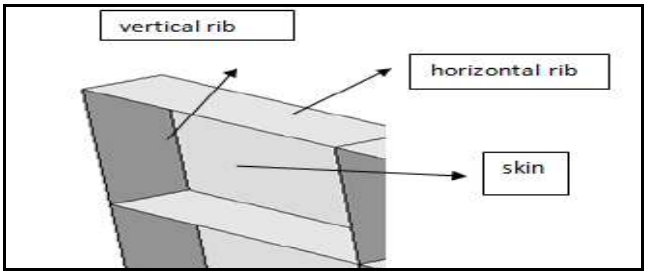

Fig.2. Waffle pocket

For each increment of the different parameters two analyses is carried out. In the first analysis the magnitude of the load is given the highest value such that the structure will fail. From the results the buckling load at failure can be determined which is the product of step time and the load applied during the particular analysis. In the second analysis the modified magnitude of load is applied such that it is decreased from the load at failure to zero. But the panel does not come to its initial position because of plasticity but some amount of permanent deformation will be present in structure. The aim is to find the final rolling radius after spring back.

1) Boundary condition

The boundary condition is applied such that the panel undergoes buckling. In the top and bottom of the panel Y symmetric boundary condition is applied. It is restrained against translational motion in Y direction and rotational motion in X and Z direction. In the left side of the panel X symmetric boundary condition is applied. It is restrained against translational motion in X and Z direction and rotational motion in Y and Z direction. It is shown in "Fig. 3".

2) Load application

Bending of waffle is simulated by applying moment around neutral plane of waffle on the free edge of model. Direction of moment is to roll cylinder with waffle on inner surface. Moment is applied as equivalent pressure having distribution in the form of 1/ (Z/2) * (1-1/ (Z/2)) along depth direction. (Z corresponds to the depth of pocket) Same is shown in "Fig. 3,".

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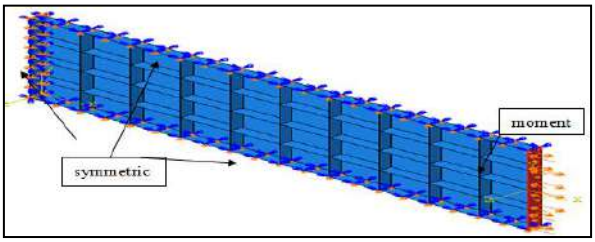

Fig.3. Load and boundary condition

TABLE III. VARIATION OF WAFFLE PARAMETERS

Waffle parameter	Range(mm)	Increment(mm)
Horizontal rib thickness	1-4	0.25
Vertical rib thickness	1-4	0.25
Skin thickness	1-4	0.25
width	100-200	10
depth	15-50	5

The rolling radius is determined by plotting graph of nodal co-ordinates of the deformed structure. The co-ordinates in rolling direction which is the z-direction is plotted in Y-axis and the co-ordinate in x-direction is plotted in X-axis of the graph. The above graph is superimposed with a graph of known co-ordinates and the rolling radius. The value of radius at which the ideal circle coincides with the radius of panel after spring back is the required rolling radius. The determination of rolling radius for horizontal rib of 2.25 mm thickness is shown in "Fig. 7". The rolling radius obtained is 3500 mm which is the minimum value for given set of parameters.

2) FE Results of rolling panel

a) Maximum equivalent stress for horizontal rib of 2.25mm thickness

The maximum equivalent stress is 343.9N/mm^2 for the horizontal rib of thickness 2.25 mm. When the H-rib thickness is varied from 1 to 4 mm the 2.5 mm rib gave the minimum rolling radius of 3500 mm**.** The results are shown in **"**Fig. 4**".**

b) Deformation for H-rib of 2.25mm thickness

The deformation of Horizontal rib in Y-direction is 0.021mm. The load is not applied in Y-direction but deformation occurs in circumferential direction. This shows that rib buckled in circumferential direction. The magnitude of total deformation is 145.4mm. The results are shown in "Fig5"

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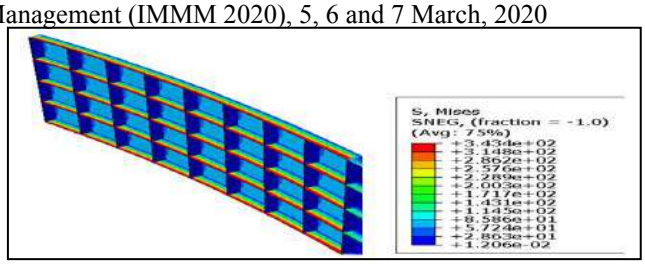

Fig.4. Maximum equivalent stress in N/mm^2 at collapse for horizontal rib of 2.5mm thickness with minimum rolling radius of 3500 mm

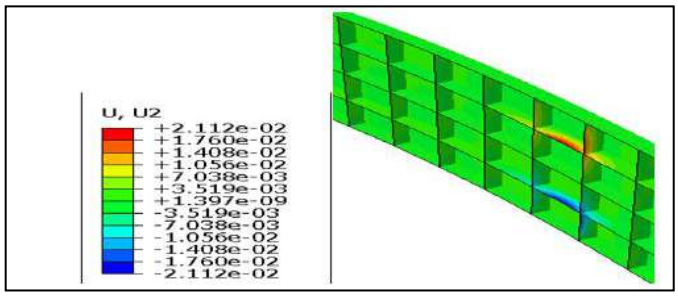

Fig. 5. Deformation in Y direction at collapse for H-rib of 2.25 mm thickness

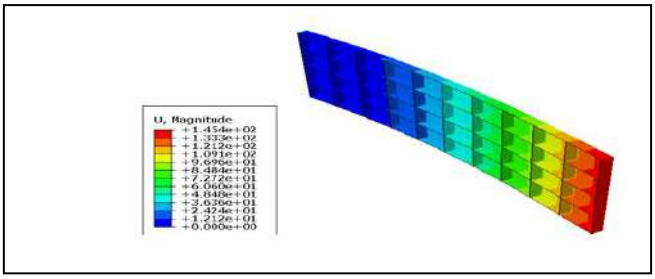

Fig. 6. Total Deformation in mm for H-rib of 2.25mm thickness

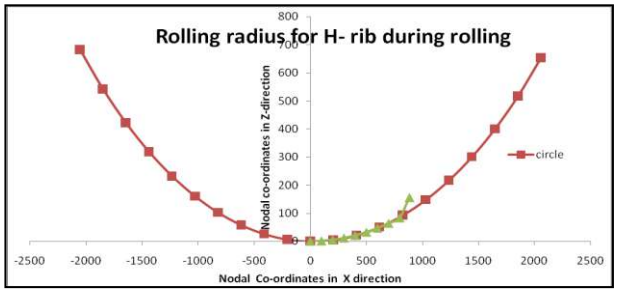

Fig.7. Rolling radius of 3500mm

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III. VARIATION OF ROLLING RADIUS AND WAFFLE PARAMETERS

The horizontal rib thickness is varied from 1 to 4mm at 0.25 increments and rolling radius is determined by the procedure explained above. Similarly, vertical rib and skin thickness, width and depth is also varied. The variation of rolling radius and waffle parameters is studied by plotting a graph with rolling radius on X axis and waffle parameter in Y axis. In "Fig 8" the variation of rolling radius and Horizontal rib thickness is plotted. The thickness of horizontal rib is varied from 1 to 4mm at increments of 0.25 mm. The rolling radius is decreasing but after 3 mm it is showing slight increase.

In "Fig 9" the variation of rolling radius and skin thickness is plotted. The skin thickness is varied from 1 to 4mm at 0.25 increments. The rolling radius is varying in haphazard manner. So the graph does not give any inference.

In "Fig 10" the rolling radius and vertical rib thickness is plotted. The rolling radius is almost constant. It is around 2750mm and 3000mm.But for 2mm rib there is a sudden increase. The reason for the increase is to be studied further.

In "Fig 11" The variation of rolling radius and width is plotted. The width of horizontal rib is varied from 100 to 200mm at 10mm increments. The rolling radius is increasing uniformly.

In "Fig 12" the variation of rolling radius depth and is plotted. The depth of ribs is varied from 15 to 50mm at 5mm increments. The rolling radius is increasing uniformly with rib depth.

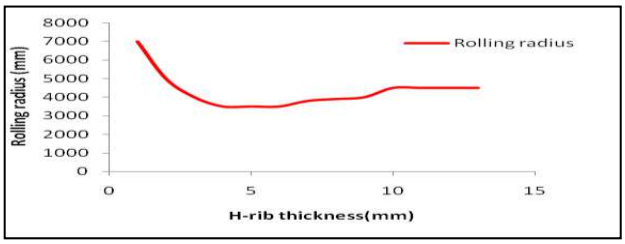

Fig.8. Rolling radius-Horizontal rib thickness

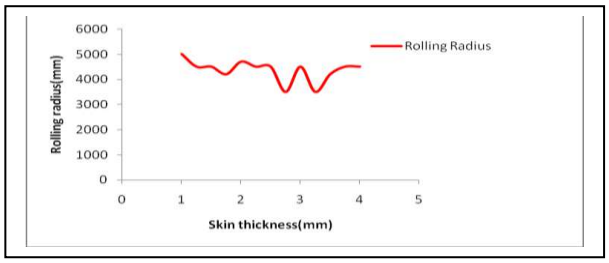

Fig. 9. Rolling radius-skin thickness

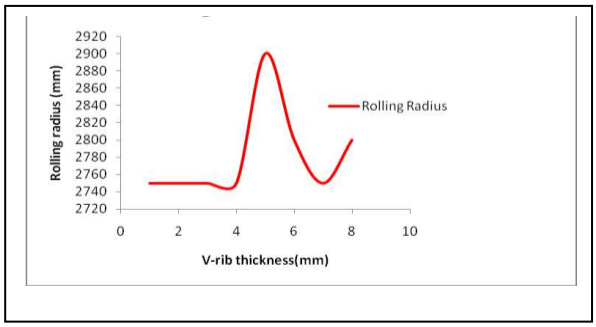

Fig. 10. Rolling Radius-Vertical rib thickness

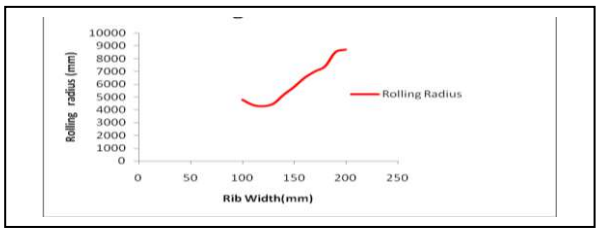

Fig. 11. Rolling radius- rib width

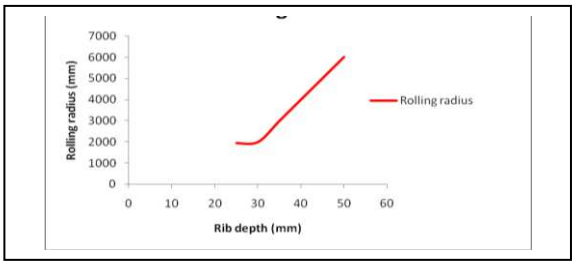

Fig. 12. Rolling radius- rib depth

TABLE IV. Effect of rolling radius for waffle parameters

Sl no	Parameter	Effect
1	Horizontal rib	Uniformly decreasing
2	skin	No effect
3	Vertical rib	No effect
4	width	Uniformly increasing
5	depth	Uniformly increasing

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V. CONCLUSION

The variation of waffle parameters with rolling radius is shown in "Table IV". The rolling radius is decreasing uniformly with increase in horizontal rib thickness up to a value of 2.75mm and then it is slightly increasing. This increase is due to buckling mode changing to plastic collapse than elastic buckling of rib. The rolling does not change much by changing skin thickness. Small variations are due to change of neutral plane during bending. The rolling radius remains almost constant with increase in vertical rib thickness except for 2mm thickness. This peak needs further detailed study. Increase in rib width and rib depth increase rolling radius uniformly.

All these observations prove that maximum rolling radius which can be achieved is limited by buckling strength of horizontal ribs which align with rolling direction. Hence to achieve a lower radius, waffle of lower depth, higher horizontal rib thickness and smaller pocket width in rolling direction is required.

The present study can be effectively considered for deciding waffle parameters for structures which are planned to make using rolling process.

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REFERENCES

[1] Fei. Han, Yung. Wang, and Li-li Niu, "Deformation mechanism analysis of roll forming for Q&P980 steel based on finite element simulation," Journal of iron and steel research International , vol. 26, pp. 1172-1187, March 2019.

[2] J. Paralikas , K . Salonitis, G . Chryssolouris, "Investigation of the effect of roll forming pass design on main redundant deformations on profiles from AHSS," International Journal of Advanced Manufacturing Technology, vol . 56,pp. 475–491, March 2011.

[3] Zemin Fu, Xiuli Tian , Wei chan, Bingkhun Hu and Xingyan Yao"Analytical modeling and numerical simulation of three roll bending forming of sheet metal," International Journal of Advanced Manufacturing Technology, vol. 69, pp. 1639-1647, November 2013.

[4] Zemin. Fu, Wei. Chen, Xiuli. Tian and Bingkun. Hu "Modeling and simulation for multiple-step incremental air-bending forming of sheet metal," The International Journal of Advanced Manufacturing Technology, vol 72, pp.561-570, 2014.

[5] M.Yang, S. Shima "Simulation of pyramid type three-roll bending process." Int J Mech Sci, vol.30, pp.877–886, August 1988.

[6] D.E. Hardt, E. Constantine and A. Wright" A model of the sequential bending process for manufacturing simulation, "Laboratory for Manufacturing and Productivity, Eng Ind, vol.114, pp.181–187.

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Experimental Investigation on Mechanical Properties of Sustainable Concrete Incorporated with Fly ash, GGBS and Recycled Aggregate

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***Abstract* – The use of recycled aggregates from construction and demolition wastes as partial or full substitution of natural aggregates and supplementary cementitious materials as a substitute for the cement in concrete is accepted worldwide as a sustainable technology. This study aims to investigate experimentally the workability and mechanical performance of ground granulated blast furnace slag (GGBS) and fly ash based alkali activated sustainable geopolymeric recycled aggregate concrete (GRAC) under ambient curing. In this study, the recycled aggregates were used to replace different levels (0%, 20%, 40%, 60% and 100%) of natural aggregates, and GGBS and fly ash based geopolymer was used to replace 100% of ordinary Portland cement. Results of this innovative research indicated that the workability of fly ash and GGBS based geopolymer recycled aggregate concrete is very low but the sustainable concrete produced exhibited excellent compressive and tensile strength for mix upto 40% replacement of recycled aggregate.**

Keywords*— Recycled aggregate, supplementary cementitious materials, ground granulated blast furnace slag, fly ash, workability, compressive strength, tensile strength

I. INTRODUCTION

Concrete is the most commonly used man-made construction resources, where cement is a core ingredient in it. In recent decades, urbanisation and industrial growth depend mainly on the construction sector. Building industry provides 5% to 10% of worldwide employment and generates 5% to 15% of GDP. But the built environment accounts for 40% of energy consumption, 40% of CO_2 emissions, 30% of the consumption of natural resources, 30% of waste generation and 20% of water consumption [1].

In this regard, the use of by-products from other industries as supplementary cementitious materials in concrete has been well known for its enhanced properties and ability to minimize the impact on the environment. Geopolymer is an inexpensive and sustainable binding material, derived from industrial by-products such as fly ash, ground granulated blast furnace slag (GGBS) etc. [2].

Also, most of the construction and demolition (C&D) wastes consists of waste concrete, which can be used as a renewable material. Hence using recycled aggregates from C&D wastes as partial or full substitution of natural aggregates in concrete is accepted as a sustainable technology [3].

Reuse of recycled aggregates, which are from construction and demolition wastes,and fly ash and GGBS, which are from industry by-products in geopolymeric recycled aggregate concrete (GRAC) could provide a sustainable solution to deal with the increasing construction waste and to reduce the CO_2 emission from OPC production [3[.

Geopolymer (Inorganic alumino-silicate polymer concrete) is an evolving type of cementitious material and could be the next generation concrete for civil infrastructure applications. This innovative technology provides a new opportunity for urban society to develop sustainably in the coming decades. These materials can be replaced to the binder in concrete as a major construction material. As compared with Portland cement, geopolymers have low CO_2 emission. Geopolymer concrete have high early strength, good freeze-thaw resistance, low shrinkage, sulphate resistance and corrosion resistance [4].

Low-calcium fly ash (Class F) has been found as a suitable material for geopolymer because of its wide availability, low cost, pertinent silica and alumina composition and less water demand. Fly ash is a by-product from burning pulverized coal in electric power generating plants. Fly ash-based geopolymer concrete (GPC) are hardened by heat curing, which is considered as a limitation for cast in situ applications at low ambient temperatures. Fly ash based GPC requires heat curing due to less calcium content in fly ash. To overcome this limitation of GPC, material containing high calcium content can be used as a binder with fly ash. Ground Granulated Blast Furnace Slag (GGBS) is a by-product material from steel industry which contains high calcium, silica and alumina content thus it is usually used as a binder material in concrete. Inclusion of GGBS with fly ash helped in achieving required strength at ambient curing [2].

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In order to reduce the CO_2 emission caused by OPC, it is necessary to find substitutions of OPC. Geopolymers, can be used to fully replace OPC in concrete and hence it is a good application to make use of the waste byproducts. There have been many literatures on geopolymer binders activated by alkaline solutions, which reported that the geopolymer binders can result in better physical and durability properties than OPC paste. This improvement is because that the matrix in geopolymer binder is much denser than the cement matrix in OPC paste. Geopolymer binder was also reported to form a much stronger interfacial transition zone (ITZ) between the matrix and aggregates than OPC [3]. These advantages could improve the properties of recycled aggregate geopolymer concrete.

The objective of this work is to create a sustainable concrete mix by fully replacing cement with flyash and GGBS and natural aggregate by recycled aggregate at various percentages. To effectively use the GGBS and fly ash based geopolymeric recycled aggregate concrete (GRAC) in structural application, it is essential to study fresh and hardened properties of GRAC.

II. EXPERIMENTAL DESIGN

A. Materials

1) Coarse aggregate

Coarse aggregate used for the study is having nominal size 12 mm. The properties of coarse aggregate used are given in Table 1. The particle size distribution of natural coarse aggregate is shown in Figure 1.

2) Fine aggregate

Fine aggregate used for this study was M sand conforming to Zone II as per IS 383. Specific gravity of fine aggregate was 2.54 and fineness modulus was 3.03.

3) Recycled aggregate

The crushed recycled C&D wastes of nominal size 12 mm were used as coarse aggregates. The properties of recycled aggregate used are given in Table 2. The particle size distribution of RA is shown in Figure 2.

4) Fly ash

Low calcium fly ash obtained from the thermal power plants at Tuticorin in Tamil Nadu were used for the study. The specific gravity was obtained as 2.1.

5) Ground granulated blast furnace slag (GGBS)

GGBS was obtained from JSW cement limited. The specific gravity was obtained as 2.93.

6) Alkaline activator

The alkaline activator used in this study was a mixture of NaOH and Na_2SiO_3 solution. NaOH used is available in pellet form and Na_2SiO_3 is in gel form. Specific gravity of NaOH is 1.37. Specific gravity of Na_2SiO_3 is 1.59. Molarity of NaOH solution was taken as 8 M. The mass ratio of Na_2SiO_3: NaOH was taken as 2.5.

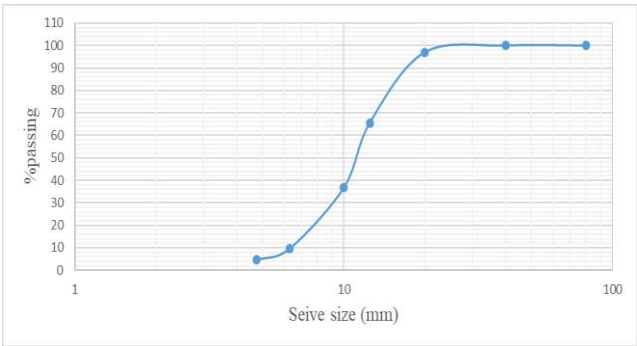

Figure 1. Gradation curve of coarse aggregate

Table 1. Properties of coarse aggregate

Sl No	Property	Result
1	Specific gravity	2.71
2	Fineness modulus	7.86
3	Impact value	25.3%
4	Crushing strength	27.5%
5	Water absorption	1.1%

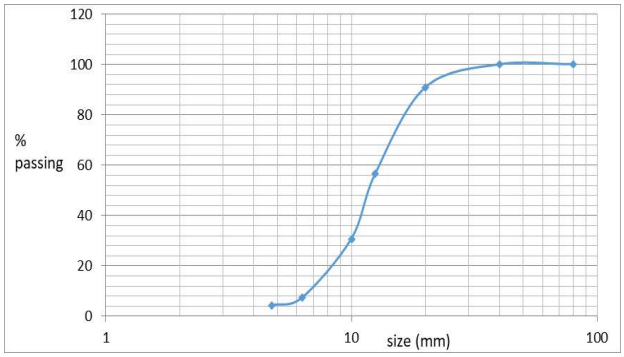

Figure 2. Gradation curve for recycled aggregate

Table 2. Properties of recycled aggregate

Sl No	Property	Result
1	Specific gravity	2.5
2	Fineness modulus	8.1
3	Impact value	38.3%
4	Crushing strength	34.5%
5	Water absorption	5.9%

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7) Superplasticiser

The action of super plasticizer in concrete is to reduce the surface tension of water by increasing the wetting ability as well as internal friction of solid components of concrete. The super plasticizer used in this study was Ceraplast 300.

B. Mixture proportions

Due to the absence of an established comprehensive design method, mixes are designed to achieve required target strength based on trial and error method [1]. Mix design was prepared for M30 geopolymer concrete

In geopolymer concrete mixes the ratio of flyash :GGBS was kept constant as 7:3. In order to produce geopolymeric recycled aggregate concrete, the recycled aggregates were introduced into the geopolymer mix by replacing coarse aggregate with varying percentages of recycled aggregate. The recycled aggregates were introduced at 0%, 20%, 40%, 60% and 100% replacement of coarse aggregate. The designation for identifying the mixes are given in Table 3. The mix proportion for M30 mixes are given in Table 4.

Table 3. Mix designation

Mix designation	% replacement of recycled aggregate
RGPO	0
RGP20	20
RGP40	40
RGP60	60
RGP100	100

Table 4. Mix proportion for various mixes (in kg/m^3)

Sl no	Material	RGP 0	RGP 20	RGP 40	RGP 60	RGP 100
1	Coarse aggregate	1248	998.4	748.8	499.2	-
2	Fine aggregate	600	600	600	600	600
3	Recycled aggregate	-	249.6	499.2	748.8	1248
4	Fly ash	285.6	285.6	285.6	285.6	285.6
5	GGBS	122.4	122.4	122.4	122.4	122.4
6	Na_2SiO_3 Solution	103	103	103	103	103
7	NaOH solution	41	41	41	41	41
8	Super plasticizer	10.2	10.2	10.2	10.2	10.2
9	Water	14.5	14.5	14.5	14.5	14.5

C. Specimen preparation and curing

The recycled aggregates were immersed in water on the day before casting so that the pores on the surface of the aggregate does not absorb water added to it during casting. NaOH solution of molarity 8 M was also prepared 24 hrs before casting.

Experimental work include casting of specimen with 5 different mixes RGP0, RGP20, RGP40, RGP60, RGP100. In each set, cube specimen of standard size 150mm and cylinder specimen of size 150mm diameter and 300mm height were prepared. Coarse aggregates in saturated surface dry condition is first mixed with sand, fly ash and GGBS for about three minutes. After this alkaline solution, superplasticizer and extra water is added to it and mixing continued for four minutes. Immediately after mixing, the fresh properties of the mix were found out by conducting slump test.

The specimens were demoulded after 24 hrs and were kept for ambient curing for 7 days.

D. Testing

After 7 days of ambient curing, specimens were tested for compressive strength and split tensile strength

1) Compression testing

In geopolymer concrete most of the geopolymerisation reaction happens within the first few days of the curing. Hence, Compressive strength of 5 mixes were tested after 7 days of ambient curing to study the effect of various percentage replacement of recycled aggregate on geopolymer concrete.

The 3 cube specimens were tested for each mix in the compression testing machine of capacity 200T. The failure load was noted. From the failure load the cube compressive strength was calculated.

2) Split tensile strength testing

To determine the split tensile strength, cylinder specimen of size 150mm diameter and 300mm height were used. The load was applied continuously at the rate of 10 to 15 tons/minute until the specimen fails. The maximum load applied at failure was noted. The magnitude of the tensile stress is given by $2P/\pi DL$, where P is the applied load and D, L are the diameter and length of cylinder respectively.

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III. RESULTS AND DISCUSSIONS

A. Slump test

The slump is basically a measure of the consistency of fresh concrete or its workability. The slump is calculated by measuring the distance from the top of the slumped concrete to the level of the top of the slump cone. When slump test was conducted, notable slump was not obtained. This shows that GRAC is of low workability.

A geopolymer mixture's rheology is generally different from an OPC mixture's. For this reason, conventional geopolymer slump test results do not lead to the same degree of workability as in OPC mixtures [2]. All the geopolymer concrete and mortar mixtures were formulated with alkaline solution as the main liquid component in the mixture. A small amount of additional water and superplasticizer were added.

The mixture of sodium hydroxide and sodium silicate solutions constituted 35% of total binder the mixtures. The combined alkaline solution produces a sticky mixture due to high viscosity of sodium silicate. In the absence of substantial amount of additional water or superplasticizer, this solution usually forms a thick and cohesive paste with fly ash and GGBS [2]. Thus, the mixture of aggregates and geopolymer paste becomes highly cohesive. The mixture can be quite stiff when the liquid content is relatively low.

GGBS also accounts for stiffness of the concrete. The increased resistance of mixture is most likely due to the accelerated reaction and setting process of slag blended mixture.

Extra water or superplasticizer may be added to improve workability, however this will affect the mechanical properties of the hardened concrete.

B. Compressive strength

Compressive strength of 5 mixes were tested after 7 days of ambient curing. Testing apparatus and test specimen is shown in Figure 3 and Figure 4.

Figure 3. Compression testing machine

The experimental results at the age of 7 days are shown in Table 5. From the experimental results it was understood that the compressive strength of the concrete gets decreased with the increase in the percentage replacement of recycled coarse aggregate .Graphical representation is shown in Figure 5 and Figure 6. For 20%, 40%, 60% and 100% recycled Coarse aggregate geopolymer concrete the decrement was 10%, 16%, 40% and 56% respectively. The fall in the strength of recycled coarse aggregate geopolymer concrete most likely can be because of the adhered mortar present in the recycled aggregate.

Figure 4. Testing of specimen

Table 5. Compressive strength of RGP mixes

Mix	Compressive strength (N/mm^2)
RGP0	43.5
RGP20	39.5
RGP40	37.5
RGP60	27
RGP100	19

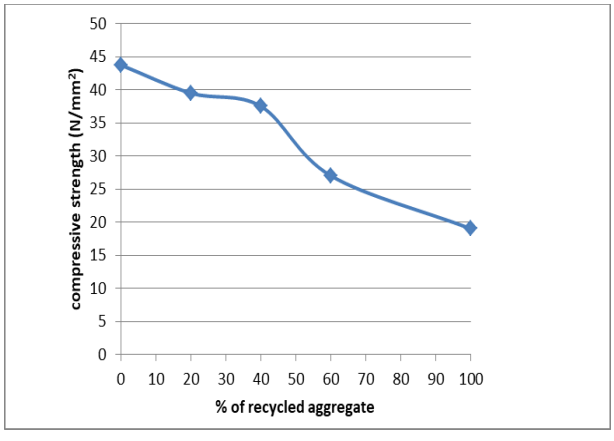

Figure 5. Compressive strength of RGP concrete with different % of recycled aggregate

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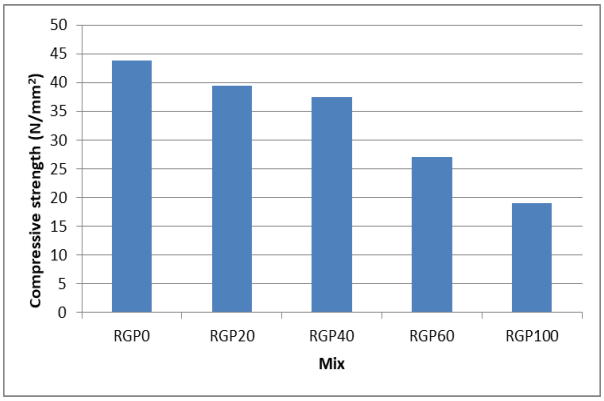

Figure 6. Comparison of compressive strength of RGP mixes

C. Split tensile strength

Split tensile strengths for various mixes were obtained from the cylinder specimens at the age of 7 days under ambient curing temperature with various replacement percentage of RA. Testing apparatus is shown in Figure 7. The obtained results are tabulated in Table 6. A similar trend like compressive strength was also observed in case of the split tensile strength (Figure 8). The split tensile strength of the geopolymer concrete was decreased with the increase in the percentage replacement of recycled aggregate as shown in Figure 9.

Figure 7. Tension testing apparatus

Table 6. Split tensile strength of RGP mixes

Mix	Split tensile strength (N/mm^2)
RGP0	3.19
RGP20	2.85
RGP40	2.64
RGP60	2.15
RGP100	1.11

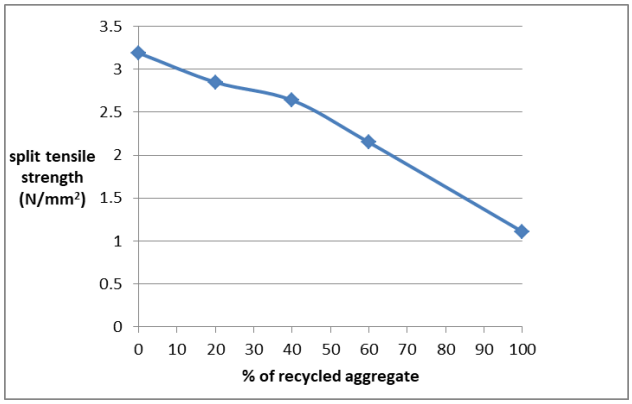

Figure 8. Split tensile strength of RGP concrete with different % of recycled aggregate

For 20%, 40%, 60% and 100% replacement of recycled aggregate, the decrement of split tensile strength was 10%, 17%, 33% and 65% respectively comparing to geopolymer mix with 100% natural coarse aggregate.

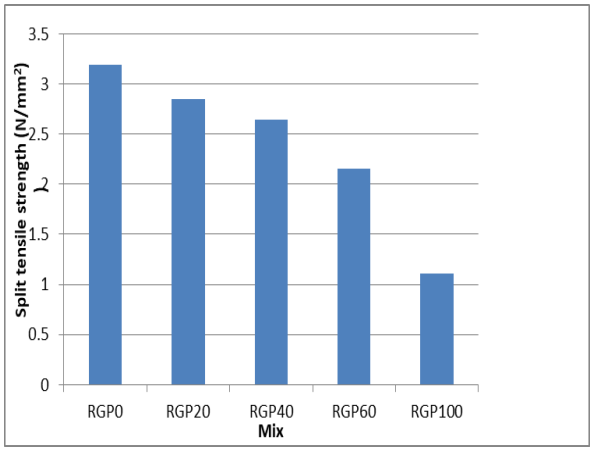

Figure 9. Comparison of split tensile strength of RGP mixes

In general, the fall in the strength of GRAC concrete most likely be because of the adhered mortar present in the recycled aggregate [5]. The bonding between the old and new mortar (new ITZ) forms another weak link in the concrete, which in turn results in a lower strength. The other reason is that there were defects such as cracks and voids existed in the recycled aggregate, leading to lower strength than natural aggregate [3]. Also the crushing and impact value of recycled aggregate is more compared to natural coarse aggregate. This will also results in reduction in strength.

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IV. CONCLUSION

The paper is based on the experimental investigation conducted to study the behaviour of geopolymeric recycled aggregate concrete. The main aim of the study was to investigate the usability of geopolymeric recycled aggregate concrete for sustainable and environmental friendly construction. The following conclusions were made

- Workabilkity of geopolymeric recycled aggregate concrete was very low. The handling time also reduced considerably with diminished workability.
- Geopolymer concrete attains it strength at higher rate in early stages.
- The compressive and tensile strength of concrete get decreased, as the recycled aggregate content increases.
- The optimum replacement percentage of recycled aggregates was 40% with respect to mechanical properties as compressive strength obtained for 40% replacement was 37.5 MPa.
- For 100% replacement of coarse aggregate with recycled aggregate, the compressive strength and split tensile strength obtained were very low compared to control mix RGP0 (56% and 60% decrement respectively).

The target strength for M30 mix was achieved for mixes with replacement of natural aggregate with recycled aggregate upto 40%. The combination of geopolymer binder and recycled coarse aggregate can exhibit an excellent compressive resistance (upto 40% replacement of recycled aggregate). The GGBS and fly ash based geopolymeric recycled concrete is a promising sustainable building material for the construction industry.

REFERENCES

[1] Ganesh P. and Murthy A Ramachandra.,(2019) "Tensile behaviour and durability aspects of sustainable ultra-high performance concrete incorporated with GGBS as cementitious material" *Construction and Building Materials 197*, pp.667–680

[2] Nath Pradip and Sarker Kumar Prabir., (2014), "Effect of GGBFS on setting, workability and early strength properties of fly ash geopolymer concrete cured in ambient condition*", Construction and Building Materials 66*, pp.163–171

[3] Xie Jianhe, Wang Junjie, Zhang Bingxue et al., (2019), "Physicochemical properties of alkali activated GGBS and fly ash geopolymeric recycled concrete*", Construction and Building Materials 204*, pp.384–398

[4] Ganesan N., R Abraham, S Deepa Raj,(2015) "Effect of fibres on the stress strain behaviour of geopolymer concrete".

[5] Saravanakumar P. (2018), "Strength and Durability Studies on Geopolymer Recycled Aggregate Concrete" *International Journal of Engineering & Technology*, pp 370-375

[6] Gedam A Banti , Bhandari N., Upadhyay et al., (2015), "Influence of Supplementary Cementitious Materials on Shrinkage, Creep, and Durability of High-Performance Concrete", *Journal of Materials in Civil Engineering ASCE*

[7] Parthiban K. and Saravana R.M.K. (2015), Influence of recycled concrete aggregates on the flexural properties of reinforced alkali activated slag concrete, *Construction and Building Materials, 102*, pp.51-55

[8] Sengul Ozkan and Tasdemir Ali Mehmet., (2009), "Compressive Strength and Rapid Chloride Permeability of Concretes with Ground Fly Ash and Slag*" Journal of materials in civil engineering ASCE*, pp. 494-501

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Calibration of Water Distribution Network using Genetic Algorithm

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***Abstract*— The paper focuses on the modelling and calibration of a sample pipe network with genetic algorithm. Before a network model is used for operation and planning studies, it must be ensured that the model would predict, with reasonable accuracy, the behavior of the network under different conditions. Such a process is termed as calibration. Higher the accuracy of field data better will be the calibrated results. The calibrated network can be useful in operational studies and planning. In the present study, a GA-based optimization approach is used for optimal calibrated parameters in which square of the difference between modelled and observed pressure values are minimized. The entire methodology is illustrated with a real pipe network taken from the literature. Better calibrated results are observed with the proposed methodology**.

Keywords—calibration, genetic algorithm, EPANET

I. INTRODUCTION

One of the most essential commodities required to maintain life on earth is water. Thus the supply of water also became crucial in the day to day life. The water from a source is to be conveyed to the distribution points by use of pipes, flow control devices, tanks, pumps etc. called as Water Distribution System. Once installation is over, actual field measurement of the data regarding these components is very tedious. Thus, models of these networks are to be formulated for predicting the behaviour of network for further analysis. Before a network model is used, it must be ensured that the model would predict, with reasonable accuracy, the behaviour of the network. Such a process is termed "calibration" of the model (Bhave 1988).

A. Calibration

Calibration is a combination of two processes: (1) comparison of pressure and flows predicted with observed pressures and flows for known field conditions; and (2) input data adjustment to make a good match between observed and predicted parameters (Walski 1983b). The process of calibration generally involves a series of field tests during which pressures and flows are recorded at critical locations in the system, usually continuously over one or more days, and then followed by the adjustment of the roughness and demand. If going for a traditional trial and error manual approach, selection of good set of roughness values can be a laborious task. Therefore use of automated calibration approaches using computer based technique will surely reduce the working time, efforts and increase the efficiency. Generally, automated calibration approaches can be grouped into three categories: (1) Iterative procedure models (2) Explicit models (3) Implicit models. Nowadays implicit models or optimization models are of greater importance.

B. Calibration using Genetic Algorithm

Several methods, based on implicit approach or the explicit approach are available for calibration of network model. These methods can be classified into two categories (1) Methods in which only the pipe roughness coefficients (C values) are adjusted and (2) methods in which both pipe roughness coefficients (C) and nodal demands (q values) are adjusted. In the first method, the assumed nodal demands are considered accurate and are taken as such in calculations. Methods proposed in (Rahal and Sterling 1980) and Ormsbee and Wood 1986 are based on the adjustment of C values only, whereas the methods proposed by Walski 1983b, Bhave 1988, Lansey et al. 1991 etc. are based on both C and q values. In this study, both nodal demand d the pipe head loss coefficient are adjusted. All the methodologies till now follow either trial and error approach or manual calculations for calibration. In this study, conventional methods are replaced with latest optimization tools, i.e. Genetic Algorithm. The initial Hazen–Williams (HW) coefficients are assigned group wise on the basis of pipe material, age of installation in years, and clustering.

Genetic Algorithms are search and optimization tools which work on a global perspective. A general source code is developed by IIT Kanpur GA laboratory in which objective and constraints can be modified and optimal parameters can be obtained. This GA program is used in this work and clubbed

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with hydraulic model EPANET. The hydraulic model provides modeled value of pressure heads throughout the day using an extended period simulation. Pressure loggers are installed at few locations to note observed field pressure throughout the day. Pipe roughness and nodal demands are considered as parameters to be adjusted to match the model results with field results. GA optimizes the same.

II. Illustrative Example

The area selected for illustration is the zone of Ramnagar GSR located at the western part of Nagpur city (Jadhav and Gupta 2018). The Ramnagar GSR supplies water to both residential areas and commercial areas including slums. The WDN as shown in Figure 1 consists of 410 nodes and 434 links. Valves, 59 numbers, are considered as separate component to incorporate proper head loss through them during calibration. Other details can be obtained from Jadhav and Gupta (2018).

III. Data Collection

Data collection and preparation include: (1) network skeletonization; (2) source heads and supply at source nodes; (3) nodal demands; (4) pipe and valve details. Various details of the Ramnagar zone are taken from Jadhao and Gupta (2018). Pressures were observed at two points through pressure loggers at an interval of every 1 hour. These points are the points where less pressure is observed and termed as critical measurement points CMP-1 and CMP-2.

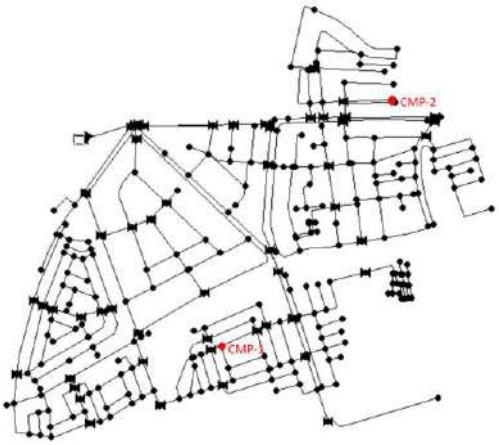

Fig. 1. Ramnagar GSR operational water distribution network

IV. Clustering Of Data

The number of uncertain parameters for nodal demands at each node is 410 and the same for pipe roughness are 434. Considering them independently would increase the size of problem manifold. Hence, it is desirable to cluster them in groups. Pipes can be grouped based on the age, material and diameters. Increase in C value of one pipe may increase or decrease the pressure at the observational node. Hence, it may produce different type of impact in direction and magnitude at different observational points. Therefore, besides age, material and diameter, a fourth parameter, impact of change in pressure on observational node for unit change in C value of pipe is also considered for clustering. In the study, there are two critical measuring points. Therefore, pipes are first divided into 2 groups based on the magnitude of change in roughness coefficient of pipe on pressures at both the CMPs. Pipe that produced higher change at the CMP-1 is allocated to first group and rest to other. Now, based on material and diameter, these are further grouped as shown in Table 1.2

Table I. Grouping of pipes

Group No.	Impact on	Pipe Material	Age of installation in Years & Diameter in mm	Assigned Hazen Williams C-values	Number of pipes
1	CMP-1	Cast Iron	>30 (dia<100)	75	2
2	CMP-2	Cast Iron	>30 (dia<100)	75	9
3	CMP-1	Cast Iron	<30 (dia>=100)	90	79
4	CMP-2	Cast Iron	<30 (dia>=100)	90	137
5	CMP-1	Ductile Iron	<10	115	9
6	CMP-2	Ductile Iron	<10	115	40
7	CMP-1	HDPE	<10	125	64
8	CMP-2	HDPE	<10	125	94

The difference in observed and measured pressure at CMP-1 is minimized by adjusting C values of odd number of groups (Group No. 1, 3, 5, 7) as they have more impact on pressure at CMP-1 as compared to that at CMP-2.Similarly, C values of even number of groups (Group No. 2, 4, 6, 8) are adjusted to minimize the difference in pressure at CMP-2. Initially, the results are obtained by adjusting C values only. Later, both C values of pipe pipes and nodal demands were adjusted. For adjusting the nodal demands, a demand multiplier is changed which was used to generate initial demand pattern. The same pattern is considered at all the nodes.

V. Calibration Results

The observed and modelled values of pressures at CMP-1 and CMP-2 are shown in Figures 2(a) and 2(b), respectively after assigning suitable values of the roughness coefficient from the Manual based on pipe material. The variation in

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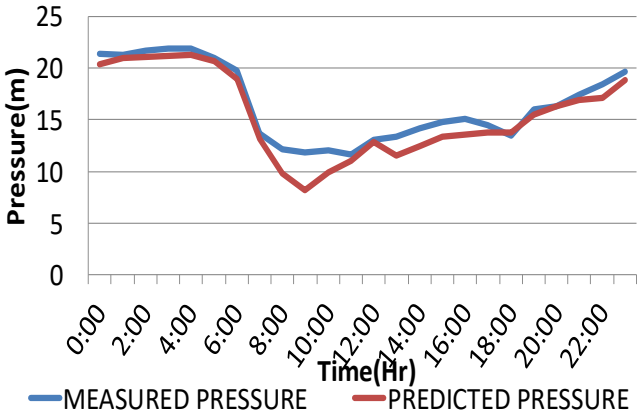
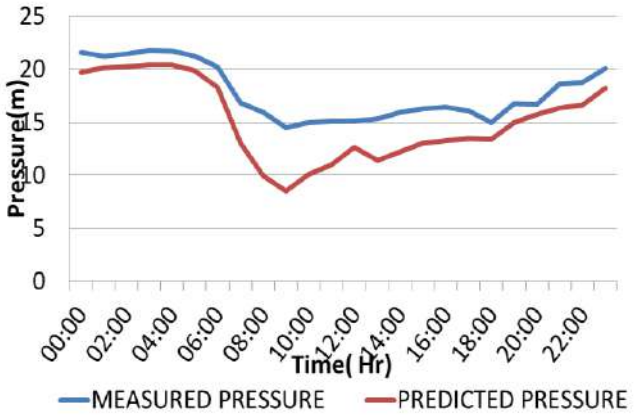
demand is considered at an interval of 1 h and outflow as measured through water meter through data logger is used to generate a demand pattern. On comparison with the observed pressure, it is found that the maximum difference between observed and the model calculated pressures is 5.98 m, which is not acceptable. The model should accurately predict hydraulic grade line to within 1.5-3 m at calibration data points (Walski 1983b).



(a)



(b)

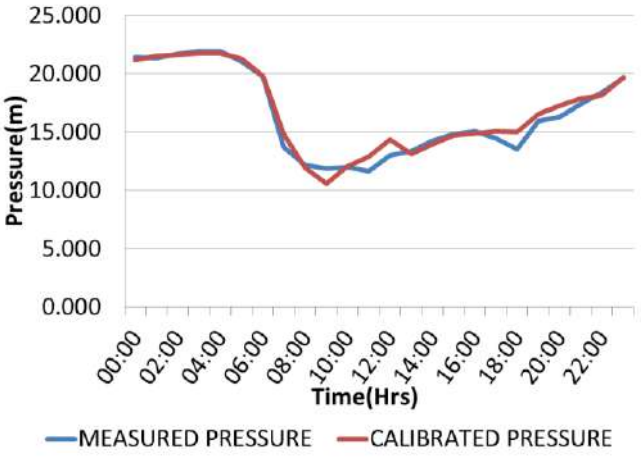
Fig. 2. Comparison of simulated pressure heads with those measured in the field before calibration for CMP-1 and CMP-2 respectively

A. Results of Jadhav and Gupta(2018)

Jadhav and Gupta (2018) considered adjustment of C values considering that measurement of nodal demands is very accurate. Further, pipes were grouped based on the material and diameter. By knowing the impact of group of pipes on pressure observation points, the C values were altered using trial and error process to minimize the objective function. This provided the value of summation of the square of the difference between the observed pressure and simulated pressure as 18.32. Only roughness coefficient was adjusted in their study. Obtained roughness coefficients are given in Table 2. The graph showing the measured pressure and calibrated pressure is shown in Figures 3(a) and 3(b).

Table 2. : Obtained roughness coefficient after manual calibration

Group No.	Material, age and diameter	Calibrtaed C Values Jadhav and Gupta (2018)
1	Cast Iron (>30 (dia<100))	79
2	Cast Iron(<30 (dia<100))	94
3	Ductile Iron	119
4	HDPE	129



(a)

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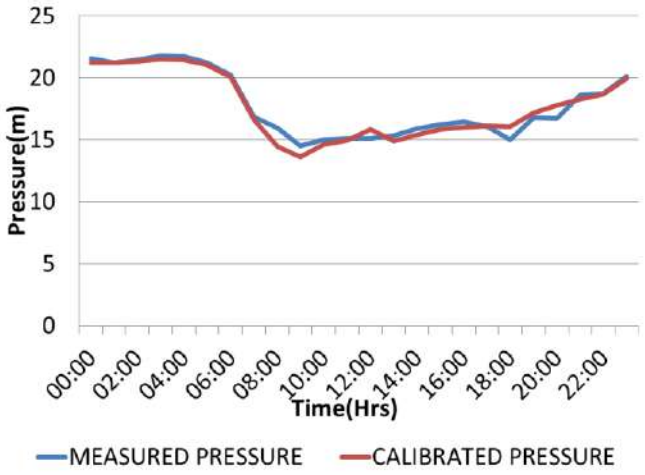

(b)

Fig. 3. Comparison of simulated pressure heads with those measured in the field after calibration by Jadhav and Gupta (2018) (CMP-1 and CMP-2 respectively)

B. Results using proposed methodology using GA

The calibration process is now carried out using GA. Both C values and q values are adjusted in the method. The GA parameters are selected as: population size - 100, number of generations - 100, cross over probability - 0.95, and mutation probability - 0.05. The results obtained from GA are 24 optimal demand multipliers and 8 optimal roughness coefficients (Table 3). The pressure values obtained from EPANET, when run with optimal results shows a good match between field data and the model simulated pressure (Figures 4a and 4b). The objective function value was 9.67. Maximum difference observed between the field data and the model simulated data was 1.2 m, which is in the acceptable range.

Table 3. Obtained demand multipliers and roughness values after calibration using GA

Time (Hrs)	Demand Multiplier	Group No.	Roughness value
00:00	0.976854	1	71.990447
01:00	1.027189	2	80.826718
02:00	0.993548	3	99.006973
03:00	0.971477	4	82.838830
04:00	0.966470	5	101.810673
05:00	1.021614	6	117.382807
06:00	1.004004	7	127.270037
07:00	1.049086	8	139.171067
08:00	0.977171		
09:00	0.967196		
10:00	1.009531		
11:00	1.050239		
12:00	1.088906		
13:00	0.994893		
14:00	0.989591		
15:00	0.996430		
16:00	0.990453		
17:00	1.047414		
18:00	1.099997		
19:00	1.061873		
20:00	1.099997		
21:00	1.026660		
22:00	0.995323		
23:00	1.011827		

VI. CONCLUSION

Genetic algorithms are an extremely powerful technique which is capable of finding the optimal solution in relatively less time. Trial and Error based method of calibration is usually tedious and time consuming. In this study, the objective function is to minimize the summation of square of the difference between observed pressure and calibrated pressure. By Jadhav and Gupta (2018) method, the minimum objective function value was 18.32 from an initial solution of 31.13. By calibration using GA, the objective function reduced up to 9.67. This shows the efficiency of using GA, the effect

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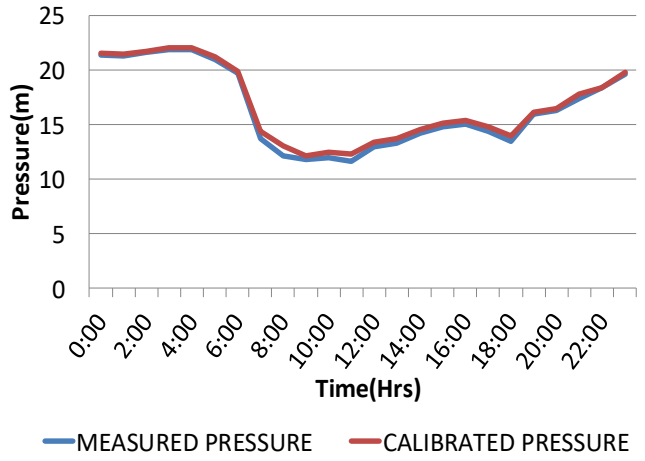
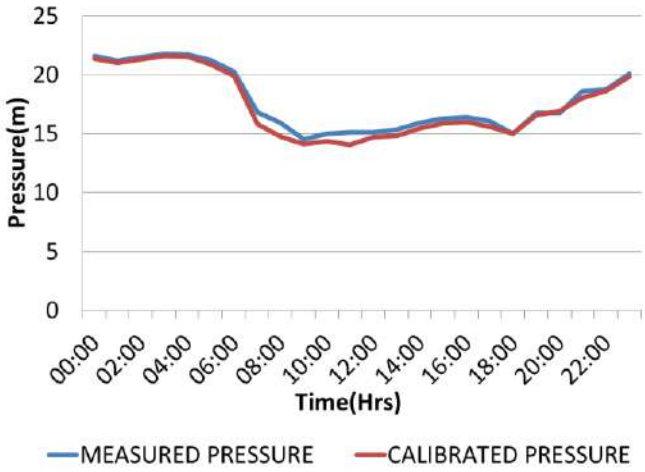
of inclusion of demand pattern and the clustering process in the calibration process.



(a)



(b)

Fig. 4. Comparison of simulated pressure heads with those measured in the field by calibration using GA

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REFERENCES

[1] Bhave.P. R. (1988). "Calibration of water distribution network models." 114(1), 120–136.

[2] Bhave, P. R. Gupta, R. (2006) Analysis of Water Distribution Networks.5th edn. Narosa Publishing House Pvt.Ltd. New Delhi

[3] Bhave P.R (2003). Optimal Design of Water Distribution Networks.Narosa Publishing House Pvt Ltd. New Delhi

[4] Jadhao, R. D., and Gupta, R. (2018). "Calibration of water distribution network of the Ramnagar zone in Nagpur City using online pressure and flow data." *Applied Water Science*, Springer Berlin Heidelberg, 8(1), 1–10.

[5] Lansey, B. K. E., Member, A., and Basnet, C. (1991). "Parameter estimation for w a t e r distribution n e t w o r k s 8." 117(1), 126–144.

[6] Ormsbee and Wood. (1986). "Explicit pipe network calibration." *Journal of Water Resources Planning and Management*, 113(4), 591–593.

[7] Rahal, M., and Sterling, M. J. H. (1980). "models of water distribution networks." 751–762.

[8] Deb, K. (1999). "An introduction to genetic algorithms." *S ā dhan ā*, *24*(4), 293-315.

[9] Rossman(1997),"EPANET Programmer's Toolkit".

[10] Walski TM (1983b), Using water distribution system models. J Am Water Works Assoc 75:58–63.

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Pond Ash as Partial Replacement of Fine Aggregate in Concrete

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***Abstract*—Pond ash is the ash extracted from the ash ponds at coal based thermal power plants. It is coarse in nature with particle size varying between 300 microns to 1 mm. Restrictions imposed on dredging of sand are fast leading to scarcity of natural sand in many parts of India which has considerably affected the construction industry. The construction industry is looking for cost effective alternate aggregate to replace conventional fine aggregate. Use of pond ash to partially replace conventional fine aggregate in concrete mix, not only provides an effective solution to scarcity of sand / crushed stone, but also helps reduce the impact of coal ash disposal on the environment.**

To establish suitability of pond ash as replacement of fine aggregate in concrete, two grades of concrete M30 and M40 were selected. For each grade, concrete mixes were prepared replacing 15%, 17.5%, 20%, 22.5% and 25% of conventional fine aggregate with pond ash. Concrete specimen thus prepared were tested for compressive strength and flexural strength at the end of twenty-eight days curing. Results of tests showed significant difference between strengths of conventional concrete and concrete with pond ash. Amongst specimens with pond ash, the specimens with replacement level of 20% showed maximum strength.

Keywords—coal ash, pond ash, fine aggregate, alternate aggregate, concrete

I. INTRODUCTION

Nearly 70% of the electricity in India is produced from fossil fuels, i.e., coal and gas. Burning of thermal coal in power plants produces two types of ash, one which falls down in the bottom hopper of the furnace, commonly termed as bottom ash and the other that is extracted from flue gases by deploying electro static precipitators, termed as fly ash. Total ash produced comprises 70% fly ash and 30% bottom ash. Fly ash is commonly used as an additive to concrete to make it homogeneous and impervious, or mixed with cement to produce Portland pozzolana cement or processed aggregates for use in concrete. Bottom ash which is lot more coarser, is either disposed off in form of a slurry into the ash ponds along with un-utilised fly ash, or used for land filling.

A. Issues Faced by Power Generation Industry

Ministry of Environment and Forests (MOEF) has stipulated utilization of 100% ash within six years of commissioning of a thermal power project. However, this is hard to achieve and most power plants end up disposing off the unutilised ash in the ash ponds. This ash is then extracted and dumped on the bunds of the pond to increase its height and thereby the capacity. This ash is known as pond ash. In power plants having capacity more than 500 MW, ash ponds consume huge area of precious land for accommodating the unutilised ash.

B. Issues Faced by Construction Industry

Construction industry in India is growing at fast pace and the size of the industry is likely to be US$ 200 billion by year 2020. The basic material resources required to meet this fast pace of growth are however depleting. In addition, many state governments have imposed restrictions of dredging of sand, thus affecting their availability. Sand is an important ingredient of cement concrete and also cement mortar which is used in masonry and plastering. People have resorted to manufactured sand which is derived from natural stone, as an alternative to natural sand, but this is a costly alternative, as it requires processing of natural stone.

C. Connect Between the Two Sectors

Small portion of coal ash in form of fly ash is utilised by cement industry in cement production and construction industry as additive to concrete. This essentially comprises the finest particles of ash having an average size of 40-45 microns. The coarser particles dumped in the ash ponds and that are higher in quantity. These can be used as partial replacement of fine aggregate in concrete or cement mortar to be used for masonry. Thus the waste product of power industry can be utilised in an effective manner by the construction industry, thereby reducing the environmental hazard and saving precious land resource.

II. REVIEW OF LITERATURE

From the earlier discussion, it is necessary to know more about total thermal coal consumption, ash generation through combustion of coal (both fly ash and bottom ash) and its utilization so as to get an idea of the volumes of ash that are required to be handled. Central Electricity Authority of India (CEA) in their Report on Fly Ash Generation at Coal/Lignite Based Thermal Power Stations and its Utilization in the Country for the year 2016-17 (http://www.cea.nic.in/tcd.html, December 2017)

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have presented the following data for generation of fly ash during the year –

No. of thermal power stations	155
Installed capacity (MW)	157377
Coal consumed (million MT)	509
Fly ash generation (million MT)	169.25
Fly ash utilisation (million MT)	107.10
Unutilised fly ash (million MT)	62.15
Percentage average fly ash content	33.22
Percentage average bottom ash	24.80
Bottom ash generation (million MT)	56.00

From the above information, pond ash quantity generated works out to (62 + 56) 118 million MT.

Tumingan, Tjaronge M, Djamaluddin R and Sampebulu.V [1] carried out experimentation to check the effect of replacement of fine aggregate with varying percentages of pond ash and concluded that up to 20% replacement, compressive strength of concrete remains unaffected, whereas at 50% replacement, the same decreases by 18.19%. They also concluded that coal ash waste material can be utilized as replacement of sand thereby reducing dependence on natural sand material.

Phanikumar B., Sofi A. [2] carried out experiments on concrete specimens prepared using pond ash and discrete steel fibres. Concrete samples were prepared using 0%,10%, 20% and 30% pond ash along with 0%, 0.5% and 2% steel fibres. They observed an increase in the compressive strength of concrete to the extent of 12% when a combination of 20% pond ash and 0.5% steel fibre were used. However the same was reduced by 5% when 30% pond ash was used.

Verma A., Kumar A., Mishra A., Verma A.[3] in their review paper, have cited references to 11 papers and concluded that generally with replacement of fine aggregates with pond ash to the extent of 20%, increase in compressive strength was observed, however, reduction in the compressive strength with additional replacement was observed.

Sreelakshmi R, Reshmi P. [4] performed experiments on concrete specimen to check the strength characteristics after replacement of fine aggregates with various percentages of pond ash. They conclude that the best compressive strength is obtained at 20% replacement of fine aggregates. They also performed RCPT on concrete samples using pond ash along with triethanolamine as inhibitor. Results show reduction in charge passed on till 2% inhibitor is added and increase in the charge passed on after increase in the inhibitor in excess of 2%.

Sharma S., Ritu B.[5] performed experimentation on concrete prepared using varying percentages of pond ash and found that till 15% replacement of fine aggregate with pond ash, the compressive strength remained unaffected. They also observed reduction of unit weight in the range of 18 to 20%. Another observation recorded by them is that increase in the pond ash content led to increase in the flow characteristics of concrete.

Sharma P. et al, [6] and Madheswaran R., et al, [7] have performed experimentation to get similar results.

The above are representative papers. Most researchers found that compressive strength of concrete improves or at-least remains unaffected up to 20% replacement of fine aggregate by pond ash, which therefore appears to be the optimum percentage replacement.

III. EXPERIMENTATION DONE

It was decided to carry out experimentation on two most commonly used grades of concrete in India, M30 and M40 designated by IS 456:2000 [8]. Here M stands for concrete mix and the number indicates characteristic compressive strength of concrete when tested at 28^{th} day after casting. Following materials were used for preparation of concrete specimens –

Cement	43 grade ordinary portland cement
Fine aggregate	Natural sand conforming to Zone II of IS 383:2016[9] having specific gravity of 2.72
Coarse aggregate	Natural (basalt) stone with maximum nominal size of 20 mm with specific gravity of 2.78
Pond ash	Sample collected from Dahanu Thermal Power Plant, having a specific gravity of 1.53.
Super-plasticizer	Carboxylated Acrylic Easter Co Polymer type, with specific gravity 1.25

A. Concrete Mix Design

With above information, concrete mix design was performed considering severe exposure conditions as per IS456:2000[6] and proportioning method as per IS10262:2009 [10] for Grades M30 and M40, with different percentages of fine aggregate replacement. Mix proportions obtained are given in Table I (for M30 grade) and Table II (for M40 grade).

TABLE I: Mix proportions for M30 grade concrete with varying proportions of pond ash

Pond Ash %	Cement kg/m^3	Water kg/m^3	Coarse Aggregate kg/m^3	Fine Aggregate kg/m^3	Pond Ash kg/m^3	Super plasticizer kg/m^3
0	362	145	1272	765	0	3.80
15	362	145	1272	650	64	3.80
17.5	362	145	1272	632	75	3.80
20	362	145	1272	611	85	3.80
22.5	362	145	1272	593	96	3.80
25	362	145	1272	574	107	3.80

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TABLE II: Mix proportions for M40 grade concrete with varying proportions of pond ash

Pond ash %	Cement kg/m^3	Water kg/m^3	Coarse aggregate kg/m^3	Fine aggregate kg/m^3	Pond ash kg/m^3	Super plasticizer kg/m^3
0	382	145	1259	758	0	3.80
15	382	145	1259	645	64	3.80
17.5	382	145	1259	626	74	3.80
20	382	145	1259	607	85	3.80
22.5	382	145	1259	588	95	3.80
25	382	145	1259	569	106	3.80

B. Sample Preparation

Taking clue from the literature survey, concrete specimens were prepared by replacement of 0%, 15%, 17.5%, 20%, 22.5% and 25% fine aggregate with pond ash for both M30 and M40 grades.

Specimens for compressive strength test in form of concrete cubes of size 150mm x 150mm x 150mm and specimens for flexural strength in form of beams of size 150mm x 150mm x 700mm were prepared. Specimens prepared were kept submerged under water for curing and tested after 28 days. Results of tests conducted are tabulated below in Table III (for M30 grade concrete) and Table IV (for M40 grade concrete):

TABLE III: Test results for grade M30 concrete specimen

Pond ash %	Average compressive strength MPa	Average flexural strength MPa
0	50.40	7.18
15	41.63	4.07
17.5	41.40	5.20
20	44.30	6.03
22.5	41.70	6.48
25	42.90	6.29

TABLE IV: Test results for grade M40 concrete specimen

Pond ash %	Average compressive strength MPa	Average flexural strength MPa
0	56.76	7.76
15	43.43	5.66
17.5	44.90	6.37
20	47.93	6.71
22.5	45.03	6.16
25	43.23	6.11

IV. ANALYSIS OF RESULTS AND DISCUSSION

A. M30 Grade Concrete

- All the specimens of grade M30 concrete meet the target mean strength requirement of 38.5 MPa. As per IS456:2000[8], target mean strength of concrete is given by

$$f_{ck}' = f_{ck} + 1.65 \text{ x } S \quad (1)$$

where

f_{ck}'- target mean strength of concrete mix

f_{ck} – characteristic compressive strength of concrete

S – standard deviation which for M30 grade is 5

- It is observed that the average compressive strength of cube specimens with pond ash is maximum at 20% replacement level. However, there is no specific trend showing definite increase in compressive strength up to this level of replacement and gradual decrease thereafter. It may not therefore be appropriate to designate 20% as the optimum replacement percentage as many of the researchers have done.
- All beam specimens satisfy the theoretical flexural strength value of 3.83 MPa derived from equation given by IS456:2000[8]

$$f_r = 0.7 \sqrt{f_{ck}} \quad (2)$$

where

f_r – flexural strength of concrete

f_{ck} - characteristic compressive strength of concrete

- It is seen that flexural strength of conventional concrete is significantly higher than the concrete with pond ash content. However, amongst the specimens with pond ash content, flexural strength goes up with increase in the replacement percentage. A definite trend in this respect is observed up to a replacement percentage of 22.5 after which the flexural strength decreases marginally. This improvement in flexural strength cannot be attributed to improvement in concrete microstructure as the same should have first resulted into improvement in compressive strength. This is also evident from equation (2) in which flexural strength is shown as a function of compressive strength. Variation in strengths with respect to variation in pond ash content is represented in Fig. 1 below.

B. M40 Grade Concrete

- All concrete specimens with pond ash content show significant reduction in compressive strength.
- It may be seen that none of the concrete specimen with pond ash content meet the target mean strength of 48.25 MPa (worked out from equation (1)) for M40 concrete although all of them exhibit a strength more than 40 MPa.

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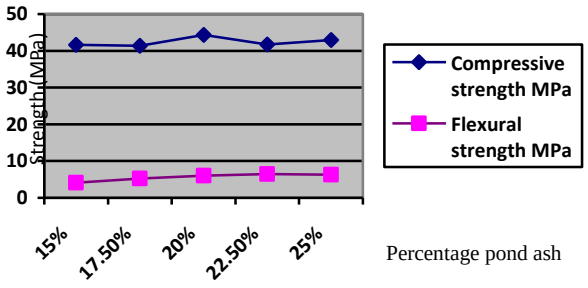
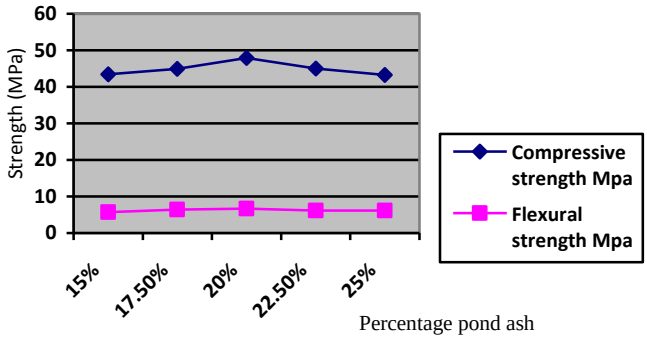
Fig.1: Variation in strength with % variation in pond ash content for M30 grade concrete



- All the specimens except the one with 20% replacement with pond ash have a consistent compressive strength in the range of 43 to 45 MPa. This therefore appears to be a problem of mix design rather than effect of replacement of fine aggregate with pond ash.
- Similar to the specimens for M30 concrete, the specimen with 20% replacement level gives the highest compressive strength amongst specimens with pond ash content.
- Similar to the specimens for M30 grade concrete, flexural strength of conventional concrete is significantly higher than the concrete with pond ash content. However, amongst the specimens with pond ash content, flexural strength goes up with increase in the replacement percentage. A definite trend in this respect is observed up to a replacement percentage of 20 after which again the flexural strength decreases significantly. However, all the specimens meet the theoretical flexural strength 4.5 MPa (worked out using equation (2)) for M40 grade concrete.

  Variation in strengths with respect to variation in pond ash content is represented in Fig. 2 below.

Fig. 2: Variation in strength with % variation in pond ash content for M40 grade concrete



V. CONCLUSION

Partial replacement of conventional fine aggregate with pond ash was seen to considerably reduce the compressive and flexural strength of concrete. There is no definite trend of increase or decrease in the compressive strength of concrete specimens prepared with replacement of fine aggregate with pond ash. In general, however, amongst the specimens with pond ash, a replacement to the extent of 20% of fine aggregate shows maximum compressive strength. Flexural strength of concrete specimens with pond ash increases with pond ash content. However, there is no specific trend of increase or decrease. One can in general infer, that pond ash can be used in concrete as a partial replacement of conventional fine aggregate taking care of the compressive and flexural strength requirements in the mix design. This is in line with the studies done so far wherein various researchers have identified a limit of 20% on replacement of conventional fine aggregate.

This type of replacement is beneficial from the point of view of –

- Effective utilisation of coal ash waste and reduction in requirement of natural aggregates.
- Reduction in cost of concrete.

More efforts are however required to standardize the mix design process for replacement of fine aggregate so that the strength characteristics are not affected. This may also call for study related to other mechanical properties like modulus of elasticity and studies related to durability.

Even more efforts will be required after this, to create awareness amongst the construction industry players and make this material acceptable so as to reduce load on natural resources and environment.

REFERENCES

[1] Tumingan,Tjaronge M,Djamaluddin R and Sampebulu.V, “Compressive strength of concrete with pond ash as replacement of fine aggregate”, ARPN Journal of Engineering and Applied Sciences., April 2015

[2] Phanikumar B., Sofi A.,“Effect of pond ash in concrete as replacement of sand”, Ain Shams Engineering Journal 2016, pp 89-99J.

[3] Verma A., Kumar A., Mishra A., Verma A., “Utilization of pond ash as partial replacement of cement concrete mix”, International Journal of Engineering and Technology, Vol. 3 issue 3, March 2016.

[4] Sreelakshmi R., Reshmi P.(2016), “Durability performance of concrete replaced with pond ash as fine aggregate”, IOSR Journal of Mechanical and Civil Engineering, pp 12-18K.

[5] Sharma S., Ritu, “Characterization and use of pond ash in concrete as replacement of sand”, International Journal of Technical Research, Vol.4,Issue 3, Nov.-Dec. 2015.

[6] Sharma P., Himani, Dabas A., “Experimental study with pond ash as partial replacement of fine aggregate in concrete with superplasticizer”, International Journal of Engineering and Technology, Vol. 7 issue 7, July 2018

[7] Madheswaran R., Bharath M., Anjalidevi M., “Utilization of pond ash as fine aggregate”, International Research Journal in Advanced Engineering, Vol. 3, Issue 3, June 2017

[8] IS 456:2000, “Plain and reinforced concrete – Code of practice” Beauro of Indian Standards, 2000.

[9] IS 383:2016, Coarse and fine aggregate for concrete”, Beauro of Indian Standards, 2016.

[10] IS 10262:2009, “Concrete mix proportioning – Guidelines”, Beauro of Indian Standards, 2009

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Analysis of Groyne Orientation in Meanders with Permeable Groynes – a Laboratory Study.

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***Abstract*— The use of groynes is proved to be an effective way of reducing erosion of rivers. This paper presents a flume study carried out to find the effect of the orientation angle of permeable groynes in meanders on reducing erosion. The experimental flume used in this study is a scaled model of a meandering section of the river Vamanapuram in Trivandrum district of Kerala. In this study, permeable groynes (cocologs) were placed at a S/L ratio of 2.5 at different orientation angles like 45^0, 60^0, 90^0, 135^0 and 150^0 and the corresponding change in erosion was observed. After each experiment, the erosion pattern was analyzed by calculating the volume of sediment eroded. The orientation angle of 45^0 showed the least erosion making it a suitable option to be used in erosion prevention measures. There is a reduction of around 6% in erosion when compared with 90^0 oriented cocologs. Also around groyne field (section 6), scouring depth for 150^0 orientation is about 4.5 times larger than with 45^0 orientation. In case of section 4, upstream of first groyne in second bend, maximum scour depth observed with 90^0 orientation is more than twice the scour depth obtained with 45^0.**

Keywords—cocologs, erosion; orientation; permeable groynes; sediment transport

I. INTRODUCTION

Erosion has always been a major issue to be dealt with when it comes to the management of rivers. Though various measures have developed by many researchers worldwide, groynes are proved to be an effective solution in meanders. A number of studies have investigated the details of the flow near groynes. The performance of groynes is usually studied by setting up a physical model of a river with groynes at suitable positions and configurations and observing various related parameter variations. Studies have been carried out on different aspect of groyne placement including type of materials with which groynes are made (permeable and impermeable groynes), permeability, different plan forms and shapes of the groynes, single and multiple groynes, submerged and emerged groynes and with different orientations (spacing, length, inclination etc.) of groynes. Most studies on groynes have been carried out on straight line form or "I"-shaped groynes, and there are only few studies on transformed groynes. Flow patterns around straight groynes were conducted by Bhuiyan et al., (2010), Ahmed et al., (2010), Uijttewaal (2005),Yossef and Vriend (2011) etc. Whereas the flow patterns around specially shaped groynes were studied by Martinez, et al., (2002), Mohsen et al., (2008) , Kang et al., (2011), Jamieson et al., (2013), and Alauddin et al., (2011). Experiments on the installation angle and penetration rate of the Hook groyne was done by Martinez, et al., (2002), and experiments on the move concerning the "I", "T", and "L"-shaped groynes were done by Mohsen et al., (2008).

Uijttewaal (2005) studied the relation between groyne shapes and flow in a groyne field. Four different types of schematized groynes arranged in an array of five identical groyne fields were tested. Groyne types include standard reference groynes, groynes with a gentle sloped head and extending into the main channel, permeable groynes consisting of pile rows, and hybrid groynes consisting of a lowered impermeable groyne with a pile row on top. Vortex formation and detachment near the groyne head were studied. By changing the permeability and slope of the groyne head, turbulence properties near and downstream of the groyne can be manipulated. Teraguchi et al., (2008) conducted a study on the effects of groynes on the flow and bed deformation in non-submerged conditions in which they found that scour hole produced by the impermeable groynes are deeper than permeable groynes. Recirculation flow around the upstream groyne causes bed erosion around the groynes.

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Kang et al., (2011) conducted studies on the effect of changes in the arm angle (θ) and length (AL) on the flow around the refraction groynes and developed relation between length of the recirculation area and projected length. The length of the recirculation area showed a gradual uptrend as the arm length of the groyne increased. Such area was formed at the range of 29% - 47%. For the length of the recirculation area, it was observed to be 10.2-14.7 times (URG), 8.4-12.7 times (DRG), and 10.6-13.8 times (right angle groyne) the projection length (L') incensement. Yeo et al (2005) conducted a study on tip velocity and downstream recirculation zone of single groynes of different permeability and was found that tip velocity was noticed to increase from 1.25 times to 1.7 times for the impermeable type and the smallest 1.1 times for the permeable type. In case of permeable groyne, downstream velocity is found to be reduced since the flow penetrate partly through the structure. Thus resistance to flow is less for permeable groyne compared to that of impermeable one. Hence the permeable groyne has the advantages of excellent stability and relatively easy maintenance (Yeo 2005 and Kang 2011). So performance wise permeable groyne is proved to be better than impermeable groynes.

Anil et al (2004) conducted field experiment on permeable groynes (cocologs) using coir geotextiles for riverbank protection in Southern Kerala, India. Cocologs were placed at an interval of 20 meters with angle of 45^{o}. This technology is effective in preventing riverbank erosion and also helps in depositing the soil particles carried with the flood water along the river bank. It was noted that, natural vegetation was established on rear side of spurs which consolidated the soil along the riverbank within a period of 14 months. After 30 months the spurs constructed with cocologs started biodegrading and by that time strong vegetation was established along river bank capable of arresting the erosion from bank completely. Thus Most of the studies deal with groynes in straight channels. Studies related to meandering channels using permeable groynes are comparatively less. So this study is an attempt to find the performance of cocolog groynes in a meandering channel.

Objective of this study is to find a suitable orientation angle with which permeable groynes can be aligned in meanders so as to reduce the erosion.

II. STUDY AREA

Vamanapuram River located in Southern Kerala with a catchment area of 781 square km is the study area. In order to develop a physical model in the laboratory, the channel planform change over a period of 50 years were analysed using river bank lines and the areas prone to erosion and deposition were identified. The river bank lines were digitized from the NDWI image and the Survey of India Toposheet. NDWI image was prepared from the pre-processed Landsat 7 ETM+ image of 2016. These layers of the river bank lines were then overlaid on top of one another to identify the channel planform change over the years as shown in Fig. 1.

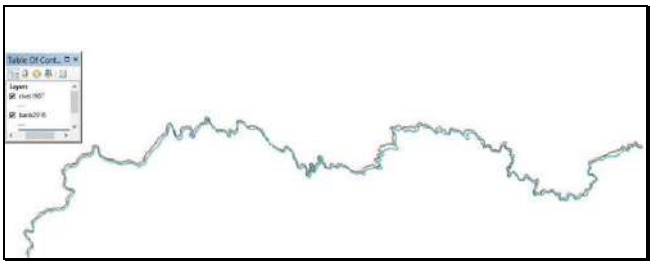

Figure 1. River banklines of 1967 and 2016

The banklines were exported as CAD file and a 5km X 5km grids were drawn covering the entire river and these grids were imported to ArcGIS for the grid wise assessment of riverbank erosion. The area eroded within each grid for the time period was found out, to prioritize grids based on the area eroded. The area of river and the surrounding banks are divided into 11 grids of size 5km X 5km for simplifying the analysis of factors causing the riverbank erosion as shown in Fig.2.The areas of erosion and deposition were digitised as polygon features. The total area of erosion and deposition within each grid was then found out.

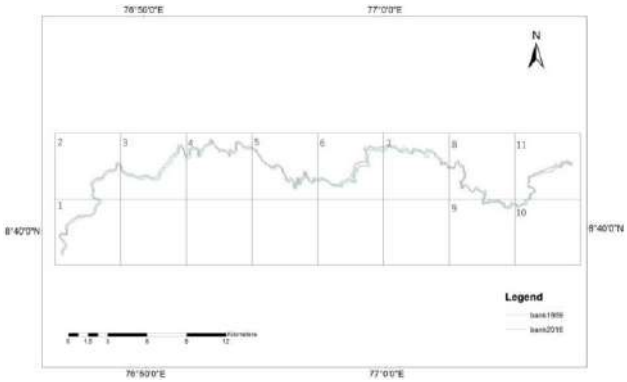

Figure 2. Grid wise assessment of channel planform change

From the river change detection studies, a curved portion on Grid 4 was selected for conducting physical model study. The curved portion selected for the physical model is shown in Figure 3. From the plot, it is seen that grid 6 has the largest erosion record and grid 10 has the least erosion record. This shows that the eroded soil in the grid also is deposited on the some other point on the same 5km grid. The river in Grids 4, 5, and 6 takes up extremely irregular and curved paths.

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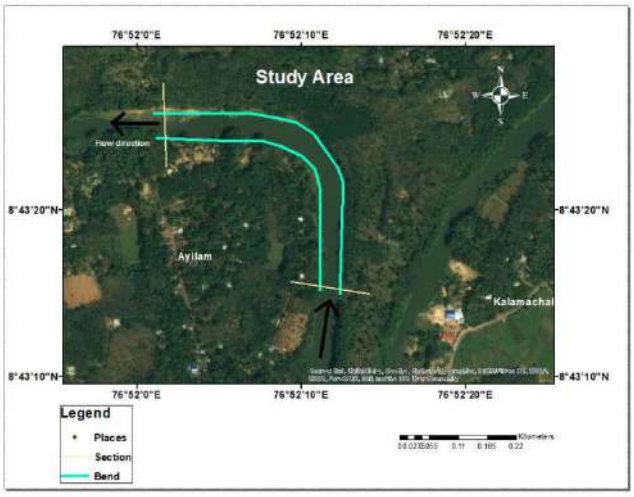

Figure 3. The river reach selected for physical model

A. *Channel Layout and Design*

The curved portion of the river was scaled down to a horizontal scale ratio of 1:60 and vertical scale ratio of 1:20 with three consecutive and opposite bends and its plan details are presented in figure 4. The first bend which is a right hand curve has a central angle of 67˚ denoted as Bend 1. It is followed by a left hand curve of central angle 134˚, denoted as Bend 2. The third bend which is a right hand curve of central angle 67˚ is denoted as Bend 3. The central angle of 134˚ represents typical meander geometry.

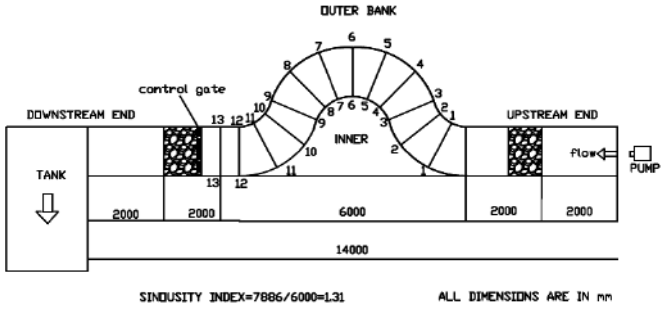

Figure 4. Plan view of curved flume

The curved channel has a sinuosity index of 1.31. The length of the channel reach taken for study is 12m. It has a bottom width of 0.5 m and a depth of 250 mm. A sediment layer of 100 mm was used in the channel. Figure 5 shows the dimensions of the channel as well as the sediment layer.

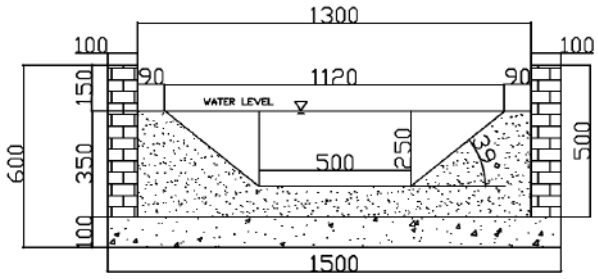

Figure 5 Cross section of the designed flume (All dimensions in millimeters)

A sediment basin was designed to allow the sediment to settle after being washed out of the channel. The sediment settling basin was designed to have a drop of 600 mm to the laboratory floor to reduce the velocity of the water, so that sediment settling would occur more readily. Since the study deals with river bank protection, the side slopes were maintained in prototype. Velocity and bed profile measurements were taken radially at specified grids (section 1 to 13), after the flow is stabilized. Calculation of eroded volume was done by plotting velocity contour with the help of Surfer 15 software. The hydraulic conditions were chosen to fulfill the sediment transport requirements of sediment mobility and suspension in all test cases. An approach channel was designed to ensure a smooth transition of the inflow water at the beginning of the sediment layer. As per King (2009), the first groyne must be positioned before the commencement of the first bend. To ensure that flow was fully developed at the first groyne, a 2m straight channel section was included before the first bend. A 2m straight portion was provided at downstream that helps to determine scour effects immediately downstream of the last groyne. Four groynes were placed on Bend 1 and six groynes at Bend 2 as in shown figure 6.

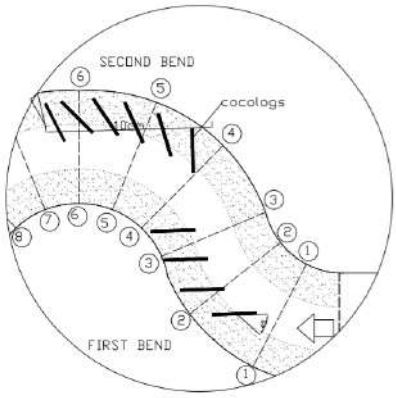

Figure 6. Arrangement of groynes in bends 1 & 2

III. METHODOLOGY AND MATERIALS

Various parameters that affect the performance of groynes are projected length, aspect ratio, density of the cocolog and orientation angle. In this study keeping projected length, aspect ratio and density of the cocolog constant, orientation angle was changed for finding out suitable value of the orientation angle

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which will help in reducing erosion effectively. Experiments were conducted in the curved flume using permeable groynes of density 140kg/m^3 for a discharge of 27.07lps for various orientation angles (45^0, 60^0, 90^0, 135^0 and 150^0). The repelling groynes are usually provided at angle of 60^0 to 80^0 range and attracting groynes are provided with 120^0 to 150^0 (Sharma, 2017). Hence the experiment was conducted for angles ranging from 45^0 to 150^0. After each experiment, velocity and bed profile measurements were taken and analysed using Surfer 15 software. From the analysis, the eroded volume of sediment is calculated. Using this and change in cross section after and before the experiment at selected sections 4 and 6, conclusions were drawn regarding the erosion pattern in each case. The sediment used in this study was uniformly distributed sand with a median grain size, d_{50}, of 0.56mm and a geometric standard deviation, σ_g, of 1.3. Cocologs were used as permeable groynes. Cocologs were made for a density of 140kg/m^3 for this study

A. Preparation of cocologs

Groynes made of cocologs were used for the experimental study. Standard sizes of cocolog available in the market are of diameters 300mm, 400mm and 600mm. For this study, 600mm diameter was selected. By the scale ratio of 1:20, 30mm diameter groyne was used for the physical model. Polypropylene geotextile of opening size 1.96mm was used as the outer covering. Cocologs were prepared by filling coir fibres inside the outer covering of diameter 30mm to achieve the desired density. As per IS 8408:1994, effective length should not exceed 1/5th of width of the flow. Therefore a projected length of1 85mm was used for the study. Figure 7 shows the scaled model of cocolog used for the study.

B. Preparation of Flume

The modelled flume is made ready for the experiment by properly filling and levelling the bed material similar to the cross section shown in fig 5. Adequate side slopes are provided and maintained in the cross section of the channel

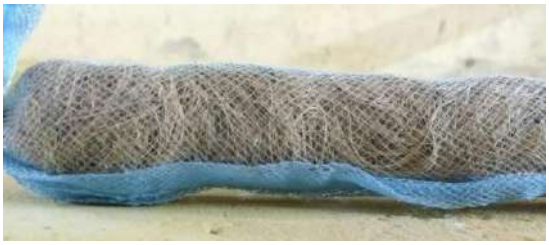

Figure 7 Scaled model of cocolog

IV. RESULTS AND DISCUSSION

For selecting the best possible value of inclination of groynes which will offer maximum protection of the bed and bank of river from erosion, various alternatives were tried in the laboratory flume. Angles used were 45, 60, 90, 135 and 150 degrees. After each experiment, bed levels were taken and bed contour maps were plotted using Surfer 15 software. Sediment eroded volume and its percentage value were obtained from the contour maps and the experimental results are presented in Table 1. The best orientation angle is selected based on the bed contours erosion, cross-sectional profiles and physical examination of erosions and depositions.

TABLE I. EXPERIMENT DETAILS FOR VARIOUS INCLINATIONS

Expt. No	Angle (Degrees)	Sediment Eroded volume (%)
1	45	8.33
2	60	9.71
3	90	14.08
4	135	14.10
5	150	16.86

From the experimental data shown in table 1, it is found that least erosion is when the orientation angle was 45^0 and for 150^0 orientation, erosion is maximum. Also an increasing trend is observed in erosion with the increase in orientation angles.

Figure 8 shows the bed contours obtained for five different orientation of groynes. Here bed and banks were more protected in case of orientation angle of 45^0. It is evident from erosion contour that experiment 1 is least eroded at the places where cocologs are placed as in Figure 8.

Figure 9 shows the bed profile after experiment. For experiment 1, when the orientation angle was 45^0, erosion is less compared to 60^0 and 90^0 cases. Even though scouring can be seen in all cases, scouring depth is very less in experiment 1. For experiment 2, with 60^0 angle, bed as well as bank eroded considerably and stability of the groyne also affected. In experiment 3, with orientation angle of 90^0, scouring is severe eroding entire thickness of bed material.

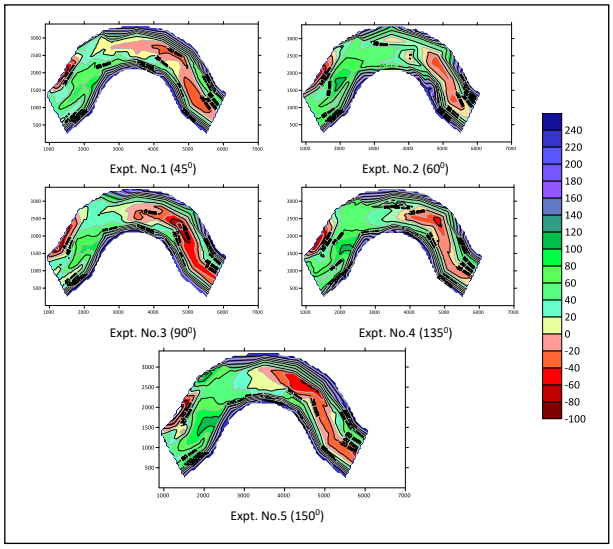

Figure 8 Bed contour maps for different orientation angles

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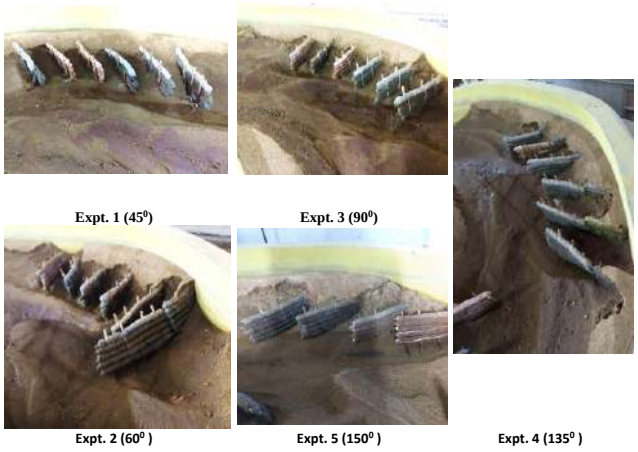

Figure 9 Bed profile after experiment

Cocolog groynes when placed at 45° showed less erosion of bed and bank. So from all these findings 45° can be selected as the best inclination. Also it is observed that erosion is more for large inclination angles.

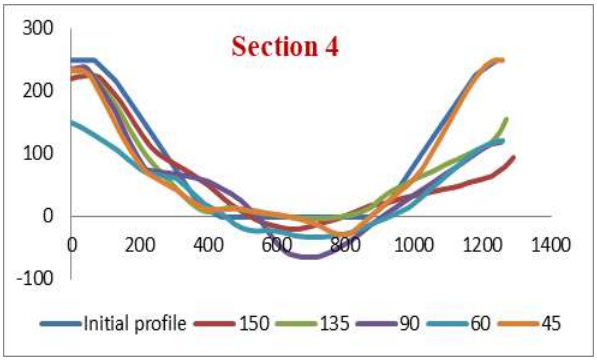

Figure 10 Change in C/S at Section 4 for various inclinations

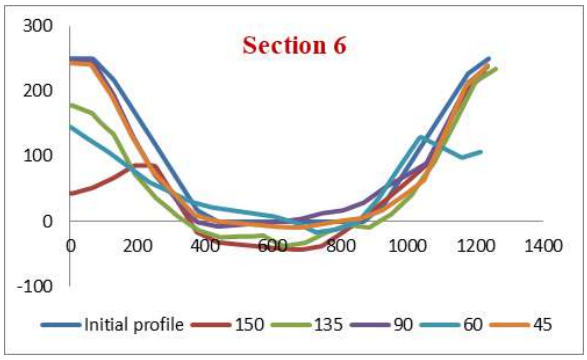

Figure 11 Change in C/S at Section 6 for various inclinations

The cross sectional profile of the experimental flume was plotted at two different sections, at section 4 and 6 respectively and is shown in Figure 10 and 11. At section 4,more scouring was noticed with 90^0 orientation which is found to be about 65mm. For 45^0 inclination, scouring depth obtained was 28mm which is less than half the value obtained with 90^0. Bank erosion is severe in all the cases except with 45^0 at section 4.

At section 6, 150^0 and 135^0 orientation showed maximum scouring depth values as 44 and 38mm respectively. Bank also eroded completely in case of 150^0 orientation at section 6.

The 45^0 cocolog is identified as the best orientation with least erosion from the cross sectional profile. Cross section was maintained well at almost all section for 45^0 orientated cocologs when compared to 60^0 and 90^0. Bed and banks were protected when cocologs were placed at an inclination of 45^0 and it is considered as the best orientation for meanders.

The graphs were plotted for percentage sediment eroded versus orientation angle as shown in Figure 12. It is clear from the figure that for a constant S/L ratio and density of cocolog the percentage of sediment eroded is less in case of 45 degree oriented cocologs.

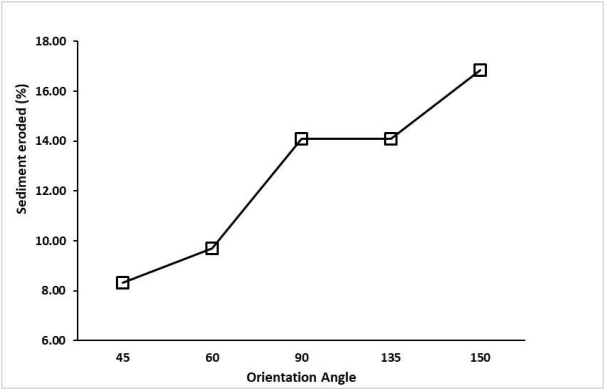

Figure 12 Percentage Sediment eroded Vs Orientation Angle

V. CONCLUSIONS

Experiments were conducted in the laboratory flume and the experimental results were analysed. It was noted that erosion was comparatively less for small angles and as angles increased erosion also increased. The orientation angle of 45^0 showed the least erosion making it a suitable option to be used in erosion prevention measures. There is a reduction of around 6% in percentage erosion when compared with 90^0 oriented cocologs. Also at section 6, scouring depth for 150^0 orientation is about 4.5 times larger than with 45^0 orientations. In case of section 4, maximum scouring depth observed with 90^0 orientation is more than twice the scouring depth obtained with 45^0.In this study, bed contours were taken for a 5cm interval. More accurate results would be obtained if smaller intervals were used.

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REFERENCES

[1] Ahmed, H. S., Hasan, M.M., Tanaka, N, (2010). Analysis of flow around impermeable groynes on one side of symmetrical compounded channel: An experimental study, Journal of water science and engineering, Vol.3 No. 1, pp 56-66

[2] Alauddin, M, Tashiro, T., and Tsujimoto, T., (2011).,Experimental investigations of channel response against different configurations of groynes, Advances in river engineering. JSCE, Vol 17. pp 335-340

[3] Anil, K. R, Rani George, Reji Rani, (2004). Eco-friendly river bank protection technologies using coir geotextiles, Price. Of the 42nd Conference , International erosion control association, pp 276-283.

[4] Beebe, J.T, (2000). "Flume Studies of the Effect of Perpendicular Log Obstructions on Flow Patterns and Bed Topography"., Vol. 7, No. 1. The Great Lakes Geographer, pp 9-25.

[5] Bhuiyan, F., Hey, R. D., and Wormeaton, P. R, (2010). "Bank attached vanes for Bank erosion control and Restoration of River Meanders", Vol. 136, No. 9, ASCE Journal of Hydraulic engineering , pp 583-596

[6] Bhuiyan, F., Hey, R. D., and Wormeaton, P. R, (2010). "Bank attached vanes for Bank erosion control and Restoration of River Meanders", Vol. 136, No. 9, ASCE Journal of Hydraulic engineering , pp 583-596

[7] Dr S K Sharma (2017), "Irrigation Engineering And Hydraulic Structures", S. Chand Publishing,

[8] Hans King (2009)," The use of groynes for riverbank erosion protection", https://www.researchgate.net/publication/267434540

[9] Jamieson,E. C., Rennie,C.D, and Townsend,R. D., (2013). "3D flow and Sediment Dynamics in a Laboratory Channel Bend with and without Stream Barbs", Vol 139, No.2, ASCE Journal of Hydraulic Engineering, pp 154-166

[10] Kang, J., Yeo, H and Kim, S., (2011). Experimental Study on the Flow Characteristics of around the Refraction Groyne, Journal of Scientific Research, Vol 3, pp 8421-850

[11] Martinez, E., Ettema, R and Lachhab, A.,(2002). "Scour Experiments on Dike Angle, Porosity, and Hook for a Thin Dike," 1st ICSF-1, College Station, Texas, pp 364-372.

[12] Mohsen, F., Ramin, D. A., Ahmad and Mirkhalegh, Z. A.,(2008). "Experimental Investigation of Local Scouring around a Series of L-Head Groynes," 8th ICHE, Nagoya, pp 383-384.

[13] Teraguchi, H., Nakagawa, H., Muto, Y., Baba, Y., and Zhang, H. 2008. Effects of groins on the flow and bed deformation in non-submerged conditions. Annuals of Disaster Prevention Research Institute of Kyoto University, 51B, 625-631.

[14] Uijttewaal, W, S.,(2005). "Effects of groyne layout on the flow in groynes fields; laboratory experiments",Vol. 131, No. 9., ASCE Journal of hydraulic engineering pp 928-936

[15] Yeo H K, Kang J G and Kim S J (2005) An Experimental study on tip velocity and downstream recirculation zone of single groynes of permeability change. KSCE, Journal of Civil Engineering, 9(1), 29-38.

[16] Yossef,M. F. M., and Vriend, H. J. D., (2011). "Flow Details near River Groynes: Experimental Investigation", Vol. 137, No. 5, ASCE Journal Of Hydraulic Engineering pp 504-5160

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Buckling Analysis of Stiffened Functionally Graded Material Plates under Uniaxial Compression

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***Abstract*—Functionally Graded Materials (FGMs) are a relatively new class of materials with continuously changing volume fraction of the constituents from one component to the other through the thickness direction which results in continuous and gradual changes in the material properties. Due to the continuous change in material properties of FGMs, the stress singularity at the interface between the two different materials is eliminated and thus the bonding strength is enhanced. FGMs are widely used in high temperature environment such as nuclear reactors and rocket heat shields. In order to achieve higher strength for FGM plates and shells either the thickness should be increased or stiffeners should be attached. With increasing thickness the weight of the structure will become higher, but addition of stiffener plate will reduce the weight as well as the cost of the structure. For this reason, using stiffeners is the best method in special cases such as ship building, bridge construction, aerospace, marine, etc. This work deals with the study of buckling behavior of stiffened FGM plates under uniaxial compression. The effect of volume fraction index and aspect ratio on the buckling load is also discussed.**

Keywords—stiffeners; volume fraction index; aspect ratio

I. INTRODUCTION

Functionally Graded Materials (FGMs) are advanced composite materials. They are made of two or more constituent materials with continuous and smoothly varying composition. These advanced materials with gradients of composition in the preferred direction are superior to homogeneous materials. The mechanical properties such as Young's modulus, Poisson's ratio, shear modulus, and material density, vary smoothly and continuously in preferred directions, mainly along thickness direction. FGMs have been developed by combining the advanced engineering materials in the form of particulates, fibers, whiskers, or platelets. These materials possess numerous advantages that make them appropriate in potential applications. It includes a potential reduction of in-plane and through-the thickness transverse stresses, improved thermal properties, high toughness, etc. FGMs consisting of metallic and ceramic components are well-known to enhance the properties of thermal-barrier systems, because cracking or de-lamination, which are often observed in conventional multi-layer systems are avoided due to the smooth transition between the properties of the components. In the continuous drive to improve structural performance, FGMs are being developed to tailor the material architecture at microscopic scales to optimize certain functional properties of structures. These materials are gaining wide applications in various branches of engineering and technology with a view to make suitable use of potential properties of the available materials in the best possible way. This has been possible through research and development in the area of mechanics of FGMs for the present day modern technologies of special nuclear components, spacecraft structural members, and high temperature thermal barrier coatings, etc.

Ramu and Mohanty (2014) investigated the buckling behavior of rectangular FGM plates under compression using classical plate theory (CPT). The critical buckling load of the rectangular plate under uniaxial compression was found to be greater than the biaxial compression. Chi and Chung (2006) studied the behavior of rectangular FGM plate of medium thickness subjected to transverse loading. The Poisson's ratios of the FGM plates were assumed to be constant, but their Young's modulus varied continuously throughout the thickness direction according to the material distribution defined by power-law, sigmoid, or exponential function. Based on the classical plate theory and Fourier series expansion, the solutions were obtained. Kumar et al. (2018) carried out a finite element analysis of stiffened and un-stiffened plates with three different types of composite materials with a view of predicting the buckling load. They found that the buckling load increases with increase in the number of stiffeners. Bhandari and Purohit (2014) considered Power law, sigmoid law and exponential distribution for the volume fraction distributions. The FGM plate was subjected to transverse uniformly distributed load and point load and the response was analysed. Bending response for S-FGM remained closer for various values of "n" as compared to that of the P-FGM. Gehlot et al. (2018) presented the harmonic and vibration analysis of stiffened functionally graded plates using Finite element method. Two functionally graded plates-Al/Al2O3 and Ti - 6Al - 4V/Aluminium oxide were considered in the study. They reported that with increase in eccentricity of stiffeners, the natural frequency also increases considerably at each mode. Udupa et al. (2014) presented an overview on research and application of functionally graded composite materials in broad. They also considered a simple case study based on CNT reinforced Al functionally graded composite by power metallurgy technique.

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From various literature it was found that only limited studies are done so far on the buckling behavior of stiffened FGM plates. The objective of the present work is to study the buckling behavior of FGM plates with stiffeners under uniaxial compression.

II. MATERIAL PROPERTY OF FGM PLATE

FGM plate made up of a mixture of silicon nitride (ceramic) and stainless steel (metal) was considered. The plate was rectangular having length a, width b and thickness h, as shown in Fig. 1.

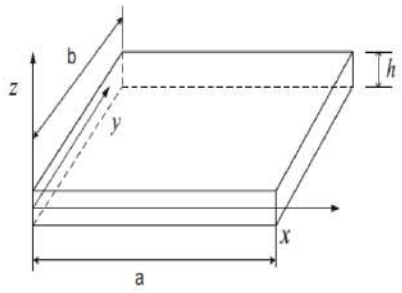

Fig. 1. Geometry of plate

The functionally graded material can be continually produced by varying the constituent multi-phase materials in a predetermined profile. The constitutive material property which varies with a given direction is expressed using volume fraction variation. This volume fraction variation can be described using power law function, sigmoid function or exponential function. Power law variation was considered for the present work.

The volume fraction is assumed to obey a power-law function.

$$g(z) = \left(\frac{z + h/2}{h}\right)^n \quad (1)$$

where n is the material parameter and h is the thickness of the plate. Once the local volume fraction $g(z)$ has been defined, the material properties can be determined by the rule of mixture.

$$E(z) = g(z)\,E_1 + [1 - g(z)]\,E_2 \quad (2)$$

where E_1 and E_2 are the Young's modulus at upper surface $(z = h/2)$ and lower surface $(z = -h/2)$ of the FGM plate, respectively. The variation of Young's modulus in the thickness direction of the plate is depicted in Fig. 2.

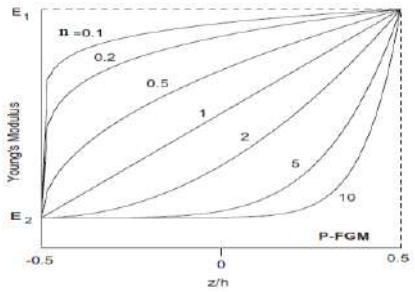

Fig. 2. The power law variation of Young's modulus

The material properties of silicon nitride and stainless steel metal are as in TABLE I.

TABLE I. MATERIAL PROPERTIES

Material	Density (kg/m^3)	Modulus of Elasticity (Pa)	Poisson's ratio
Silicon Nitride	2370	3.23×10^{11}	0.24
Stainless Steel	8166	2.08×10^{11}	0.32

III. FINITE ELEMENT FORMULATION

Finite element model of FGM plate without stiffener was generated using the software package ABAQUS 6.13. The plate was assumed to have dimensions a=b=1m (a/b=1)and h=0.01m. S4R element with six degrees of freedom at each node was used to model the plate geometry. The plate was modeled with a finite number of elements. The fully metal bottom surface was gradually varied along the thickness direction (z-axis) to the fully ceramic top surface by the power law distribution. The overall thickness of the plate was approximated to have finite number of layers having isotropic and homogenous material property using the volume fraction. The Poisson's ratio was assumed to be a constant [12]. From the convergence study, an optimum for the number of elements and layers were obtained as 10x10 elements and 20 layers. Fig. 3 shows the comparison of present results with that of literature values [6].

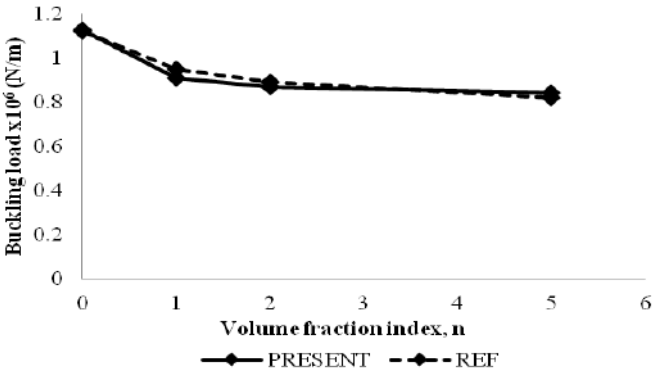

Fig. 3. Comparison of present results with literature results

The stiffener plate was attached to the bottom surface, which was fully metallic. Thus the material of stiffener and the bottom surface was the same. The height (h_s) and width (b_s) of the plate as shown in Fig. 4 was assumed as h_s=0.025m and b_s=0.0m (h_s /h=2.5 and b/ b_s =100). The element chosen for modeling was the same as for the FGM plate. Fig. 5 shows the model of stiffened plate generated using the software.

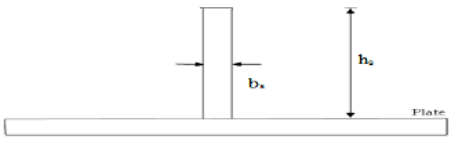

Fig. 4. Geometry of stiffener plate

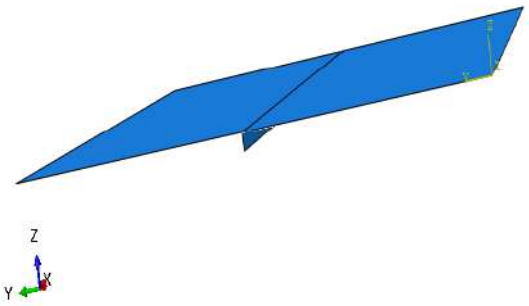

Fig. 5. Stiffened FGM plate modeled in ABAQUS

IV. ANALYTICAL INVESTIGATIONS

The buckling behavior of the stiffened plate is influenced by several factors. In this paper, the effect of volume fraction index (*n*) and aspect ratio (a/b) on the buckling of stiffened FGM plate subjected to uniaxial compression is studied.

A. Effect of Volume Fraction Index

The plate was assumed to have a/b=1 and h=0.01m. The stiffener was centrally placed along the x-axis and was assumed to have h_s /h=2.5 and b/ b_s =100. All the edges of the plate were simply supported. Uniaxial compression was applied along the x-axis. The value of n was varied from 0.1 to 10. The results obtained are shown in Fig. 6.

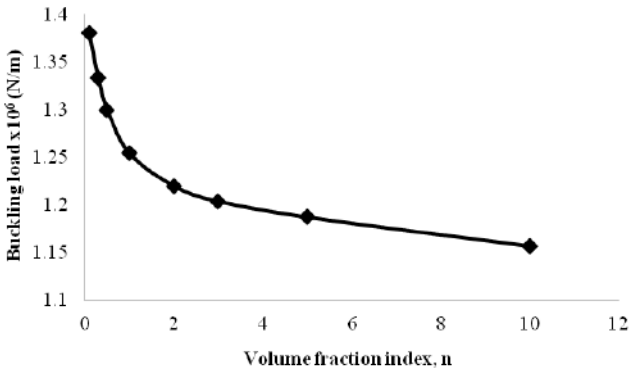

Fig. 6. Buckling loads of stiffened plate with various *n*

The buckling strength of the plate reduces with the increasing value on n. For values *n*<1, the ceramic content is high. As the *n* value approaches to zero, the plate approaches to fully ceramic condition. For values *n*>1, metallic content becomes higher. Young's modulus is higher for ceramic. The buckling strength increases with Young's modulus. Hence the strength decreases with increasing *n* value.

B. Effect of Aspect Ratio

The thickness of the plate, dimensions of stiffener and the boundary condition was assumed same as before. The *n* values considered were 0.3, 1 and 3. The aspect ratio of the plate was varied from 0.25 to 4. The buckling loads obtained for uniaxial compression along x-axis for different *n* values are shown in Fig. 7.

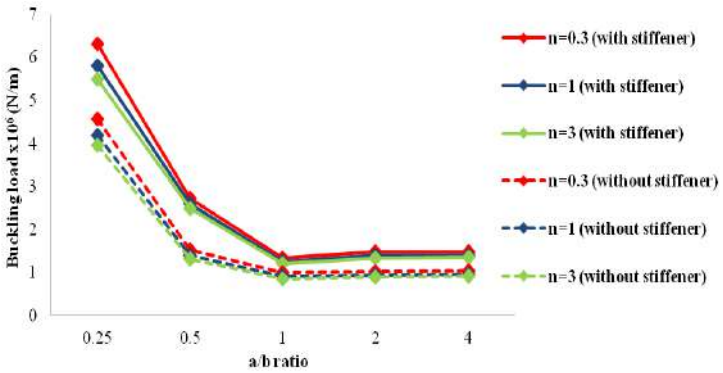

Fig. 7. Buckling load of stiffened and un-stiffened plate with various aspect ratio for different values of *n*

For a stiffened plate, the buckling strength decreases as a/b ratio increases up to a/b=1 and a gradual increase from then for the considered *n* values. At a/b=0.25, the strength of stiffened plate was about five times of that at a/b=1. As the plate approaches a rectangular geometry, the plate becomes less susceptible to buckling. But the strength is less for higher ratios. Increased aspect ratio increases the length in direction along the load applied. Same behavior was observed in the absence of stiffeners also. In all the cases, the presence of stiffener enhanced the buckling strength. This increase between a stiffened and un-stiffened plate is more at lower aspect ratios.

V. CONCLUSIONS

Buckling behavior of stiffened FGM plate subjected to uniaxial compression was evaluated under the influence of volume fraction index and aspect ratio of plate. The volume fraction exponent has a significant effect on the buckling strength. Variation in *n* value produces variation in metallic content. As the metallic content in the plate reduces, the buckling strength becomes higher. The buckling load increases at a high rate for a/b<1. The length of plate along the compression axis significantly affects the buckling strength of the plate. The strength of stiffened plate was higher compared to un-stiffened plate for the cases considered. The increase in strength for a stiffened plate becomes significant at lower aspect ratios. Hence a considerable increase in buckling strength for FGM plates can be obtained at lower *n* values or lower aspect ratios with the addition of stiffener plates.

REFERENCES

[1] Pranshu Gehlot, Avadesh, K. Sharma, Aishwary Singh Rajawat, "Harmonic Analysis of Stiffened Functionally Graded Plate using FEM," Materials Today: Proceedings, vol. 5, pp. 5145 – 5153, 2018

[2] P. Ravi Kumar, Ganesh Gupta, Shamili, G. K. , Anitha, D. , "Linear Buckling Analysis and Comparative Study of Unstiffened and Stiffened Composite Plate," Materials Today: Proceedings, vol. 5, pp. 6059 – 6071, 2018

[3] Farhad Riahi, Alaeddin Behravesh, Mikaeil Yousefzadeh Fard, Arasto Armaghani, "Buckling Stability Assessment of Plates with Various Boundary Conditions under Normal and Shear Stresses," Engineering, Technology & Applied Science Research, vol. 7, issue. 5, pp. 2056-2061, 2017

[4] Akshaya Awari, "Static Stress Analysis of Functionally Graded Circular Cylindrical Shell Subjected to Internal Pressure," International Research

Journal of Engineering and Technology, vol.3, issue.11, pp. 431 – 437, 2016

[5] U. Parvathy and K. P. Beena, " Linear Static Analysis of Functionally Graded Plate using Spline Finite Strip Method," Composite Structures, vol. 117, pp. 309 – 315, 2014

[6] Manish Bhandari and Kamlesh Purohit, "Static Response of Functionally Graded Material Plate under Transverse Load for Varying Aspect Ratio," International Journal of Metals, 2014

[7] I. Ramu and S. C. Mohanty, "Buckling Analysis of Rectangular Functionally Graded Material Plates under Uniaxial and Biaxial Compression Load," Procedia Engineering, vol. 86, pp. 748 – 757, 2014

[8] Gururaja Udupa, S. Shrikantha Rao, K. V. Gangadharan, "Functionally Graded Composite Materials: An Overview," Procedia Materials Science, vol. 5, pp. 1291 – 1299, 2014

[9] D. K. Jha, Tarun Kant, R. K. Singh, "A Critical Review of Recent Research on Functionally Graded Plates," Composite Structures, vol. 96, pp. 833 – 849, 2013

[10] X. Zhao, Y. Y. Lee, K. M. Liew, "Mechanical and Thermal Buckling Analysis of Functionally Graded Plates," Composite Structures, vol. 90, pp. 161 – 171, 2009

[11] Shyang-Ho Chi and Yen-Ling Chung, "Mechanical Behavior of Functionally Graded Material Plates under Transverse Load - Part I: Analysis," International Journal of Solids and Structures, vol. 43, pp. 3657 – 3674, 2006

[12] Shyang-Ho Chi and Yen-Ling Chung, "Mechanical Behavior of Functionally Graded Material Plates under Transverse Load - Part II: Numerical Results," International Journal of Solids and Structures, vol. 43, pp. 3675 – 3691, 2006

[13] F. Delale and F. Erdogan (1983) The Crack Problem for a Non-homogeneous Plane, Journal of Applied Mechanics, Vol. 50, 609 – 614

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ADDITION OF GLASS POWDER AND EGG SHELL POWDER: A GREEN SOLUTION FOR IMPROVING THE MECHANICAL PROPERTIES OF CONCRETE

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***Abstract*— It has been reported in literature that glass can be added (in grounded form) to concrete to improve its mechanical and durability characteristics. Studies have been reported in which the cement was part replaced by adding broiler hen egg shell powder and found improvement in compressive strength. The objective of the study reported in this paper is to assess the effect of addition of glass powder(GP) and egg shell powder(ESP) to concrete. The test was conducted on M30 grade concrete.**

Keywords—Concrete technology; Egg shell powder; Glass powder.

I. INTRODUCTION

Concrete is a composite material composed of coarse granular material embedded in a hard matrix of material (the cement or binder) that fills the space among the aggregate particles and glues them together. Concrete, a primary building construction material, is the world's most consumed man made material. About 800 million tons of concrete was consumed in the US in 2007, and the world consumption was estimated at 11 billion tones or approximately 1.7 tons for every living human being [1]. Production of cement (the binder in concrete) is energy intensive and highly polluting process, which contributes about 5-8% to global CO2 emissions [2]. Chemical compounds have been added when making concrete to improve its performance. As can be read in literature, several hundred years before Christ, Roman masons were adding blood and eggs to the lime and pozzolanas when making concrete [3]. Solid waste materials or industrial by-products can partly replace cement in concrete which reduces the use of Portland cement and thus reducing the environmental and energy impacts of concrete production [4]. According to Federico and Chidiae and Jin et al [5,6], mixed color waste glass offers desired chemical composition and reactivity for use as supplementary cementitious material which can benefit the chemical stability, moisture resistance and durability of concrete. To realize this potential, waste glass needs to be milled to micro scale particle size in order to accelerate its beneficial chemical reaction in concrete. Concrete compressive strength, tensile strength, absorption, voids ratio and density are improved as a result of using 10% glass powder (GP) as cement replacement [7].In 2004 ASTM international C150 allowed incorporation of up to a 5% mass fraction of limestone in ordinary Portland cement [8]. Hawkins et al (2003) reported that use of up to 5% limestone does not affect performance of Portland cement [9]. Limestone powder substitution for cement makes sense in concretes saving money and energy and reducing carbon dioxide emission [10].

Quarrying of natural limestone and its processing are energy intensive, water consuming and lead to many environmental issues. Hence it is advisable to use analogues material from waste in concrete production. An ideal alternative to limestone is egg shell which has the chemical composition nearly same as that of limestone. Utilizing the poultry egg shell waste in the making of concrete is a sustainable option for waste recycling.

This study is aimed to use glass powder (GP) and eggshell powder (ESP) in conventional concrete as part replacement of cement. No study has been reported in literature to assess the properties of concrete that combined incorporation of ESP and GP. Addition of ESP and GP are expected to improve the properties of concrete, and reduce the unit cost of cement production..

II. SIGNIFICANCE OF THE RESEARCH

Although various research findings are available on concrete and mortars incorporating waste glass powder and egg shell independently as supplementary cementitious material (SCM) the ones that have these two combined are not found in literature. Independent studies have shown that 10 % Glass powder replacement (major portion being silica) in concrete improves the strength properties, and anything below or above this value does not aid any improvement but rather diminish the quality. Egg shell (major portion being lime) can be used about 5% as SCM which improves the properties of concrete. The current study combines the GP & ESP and uses it as SCM in M30 concrete mix. The trial mix constitutes various proportions of ESP and GP. Samples are tested for compression, flexure and Ultrasonic Pulse Velocity (UPV). Based on the results, optimal proportion is suggested for the case when these two are combined (i.e. ESP and GP).

III. REVIEW OF LITERATURE

Incorporation of egg shell powder and glass powder is expected to benefit concrete production in many ways. Various

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studies reported in literature on the effect of addition of glass powder and eggshell is listed below in chronological order.

1. Based on the early and later age compressive strength, it was observed that 10 % replacement of cement with the Glass powder is advantageous in cementitious system [15].

2. The 28-day compressive strength of concrete with 10 % glass powder replacing cement is found to be higher than that of fly ash Concrete at the same replacement level [15].

3. Glass powder as a cement replacement material demonstrated the potential to reduce deleterious expansion due to alkali silica reaction [15].

4. It was found that conventional cement can be replaced with 5 % egg shell powder plus 20% micro-silica without any reduction in compressive strength properties. [20].

5. Experiments to determine the pozzolanic reaction of glass powder in cement paste and its influence on mechanical and durability properties of concrete indicated that the Portlandite continuously decreased with more glass powder replacement beyond 30%. However, water permeability would be consistently reduced with increasing glass powder content because of the reduced water accessible porosity as well as the refined capillary pore system [16].

6. The eggshell concrete has shown significant reduction in water absorption and water penetration [22].

7. Egg shell powder has been successfully used as partial replacement of cement in concrete production. It was observed that at 5% ESP replacement the strength was higher than control concrete and that 5% ESP is an optimum content for maximum strength [18].

8. The addition of white and brown eggshell powder in mortar reduced the compression and flexural strength at all levels of limestone Portland cement replacement. Although eggshell based limestone Portland cement replacements led to inferior mechanical properties, mortar projects where strength may not be the principle requirement, could potentially be used [19].

9. The concrete compressive strength with eggshell powder as cement replacement material was found to increases up to 15%. The flexural strength of concrete increased with the addition of egg shell powder up to 15% [21].

10.Studies revealed that 0.25 % natural admixture (whole eggs) dosage has very significant effect on compressive strength and splitting tensile strength of all concrete mixes at all curing periods [23].

11. The use of glass powder up to 10 % enhanced the mortar compressive strength by about 9 % [13].

12. Concrete compressive strength, tensile strength, absorption, void ratio and density were found to improve as a result of using 10 % glass powder cement replacement [13].

13. The substitution of GP improved the mechanical resistance (compressive and flexure strength) especially at later age of 91 days and beyond. The GP inclusion in the RCC induces a positive impact on durability properties. The water porosity and volume of permeable voids of the hardened RCC can be reduced by designing the RCC with GP [14].

14. Waste glass powder is a promising admixture of preparing alkali activated slag mortar. The mixture of waste glass and sodium hydroxide can be used as activators [12].

15. A study illustrated the feasibility of using waste shell powder on attractive natural bio filler in the production of gypsum plaster. A highly flow able and self-compactable gypsum plaster was obtained even at low water binder ratio [17]

IV. INGREDIENTS OF CONCRETE

Properties of various ingredients of concrete used in the study are listed in Table :1. Mix design was done by Indian Standard Method (IS 10262:2009). Mix proportion of M30 grade concrete is obtained as 1:1.742:2.99 with water- cement ratio of 0.5.

V. PROCESSING OF ADDITIVES

A. Glass powder

Waste glass is an ingredient having about 70% of SiO_2 and possessing pozzolanic activity. It has been reported to lower the permeability of concrete [11]. The resulting performance improvement of concrete reduces end user costs and repair/ maintenance cost by decreasing the period/ interval of maintenance.

TABLE I. PROPERTIES OF VARIOUS INGREDIENTS OF CONCRETE

Ingredient /Property	Value
1.Cement	
Type	PPC
Fineness	2%
Standard consistency	31%
Initial setting time	125min
Final setting time	360min
Specific gravity	3015
2.Coarse Aggregate	
Bulk density (compacted/loose)	1.59kg/l,1.44kg/l
Fineness modulus	6.83
Water absorption	1%
Specific gravity	2.9
3.Fine Aggregate	
Bulk density (compacted/loose)	1.83kg/l,1.48kg/l
Fineness modulus	3.78
Water absorption	0.4%
Specific gravity	2.53
4.Glass powder	
Specific gravity	2.29
Particle size	70microns
5.Egg Shell Powder	
Specific gravity	1.78
Particle size	300microns
6.Water	
Potable	

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Waste glass can be used as inert filler aggregates (when used in larger sized particles) or supplementary cementing material (SCM) (when finer particle gradation is used) by replacing some weight fraction of cement with it. Latter one is expected to improve the mechanical properties of cement, which is the focus of this study. Commercially purchased glass powder of particle size 70 micron was used for the study.

B. Eggshell powder

Calcium rich egg shell is a poultry waste with chemical composition nearly same as that of limestone. Use of eggshell waste instead of natural lime to replace cement in concrete can have benefits like minimizing use of cement, conserving natural lime and utilizing waste material. The broiler hen egg shells were collected locally from restaurants. The eggshell contained kitchen wastes like chilly, onion peals etc., which was manually removed by hand picking. It was then cleaned in a bucket of water and then dried in sunlight for one day. The organic membrane in the shell is devoid of lime (CaO) and may have adverse effect on the quality of concrete. The cleaned, dried eggshells along with its attached membrane were first grounded using a 750-watt table top kitchen blender for 10 seconds. Then it was taken out and sieved through 0.5 mm sieve and the major part of membrane got separated at this stage. As was observed, grinding for more 45 seconds or so makes both eggshell and membrane to reduce to very fine sizes and the process of sieving out these two becomes even cumbersome. The passing eggshells contain some membrane material (approximately < 20% of initial membrane content). This was then grounded for one minute at invariable speed and its contents were sieved through 300 µ sieve. Particles passing through the sieve were used in the study.

VI. DETAILS OF MIXES AND SPECIMEN

Compression test, split tensile test and UPV test were conducted on standard specimens. Specifications of mixes are given in Table 2. Mix 1 with 0% GP and 0% ESP is the control specimen. Three standard cubes (150×150×150 mm) and three standard cylinders (150 mm diameter and 300 mm height) were cast with each mix. Ultrasonic pulse velocity (UPV) test and compression test were done on cubes; split tensile test was done on cylinders. All tests were done after 28 days of curing.

TABLE II. SPECIFICATION OF MIXES

Mix	% GP	% ESP
Mix 1	0	0
Mix 2	0	5
Mix 3	0	15
Mix 4	5	10
Mix 5	10	5
Mix 6	15	0
Mix 7	10	0

VII. RESULTS AND DISCUSSION

Observations of various tests are listed below and results are plotted in fig.1 to fig.4.

[1] Mix 2 having 5% ESP replacement showed 2.22 MPa increase in compressive strength when compared to control mix (Mix 1). Mix 3 with 15% ESP and 0% GP showed a slight increase of compressive strength about 0.75 MPa over mix 1. Mix 4 with 10 % ESP and 5% GP showed an increase of 2.23MPa in compressive strength over mix 1.

Mix 5 (5% ESP, 10% GP), mix 6 (0% ESP, 15% GP) and mix 7 (0% ESP, 10% GP), showed a decrease in compressive strength by an average of 2.66 MPa.

[2] The slump value of control mix is 75 mm, which is reduced to 60 mm for mix 2 (5% ESP), and 55 mm for Mix 4 (5%GP, 10%ESP). Mix 5 (5% ESP 10% GP) showed highest slump value of 90 mm among all mixes.

[3] All mixes showed a lower tensile strength than conventional mix by an average of 0.33 MPa. The lowest tensile strength was shown by mix 7 (10% GP, 0% ESP)) varying from the standard mix by about 0.59 MPa. The least deviation from the tensile strength of standard mix was shown by two mixes, mix 2 (0%GP, 5% ESP) and mix 4 (5% GP 10% ESP) by about 0.15 and 0.17 MPa respectively.

[4] Except for mix 7 (10% GP, 0% ESP)) every mix showed a significant reduction in ultrasonic pulse velocity by an average of 108.4 m/s when compared to the control mix. Mix 7 showed an increase in pulse velocity by 59 m/s. All specimens got UPV more than 4500m/s which indicates excellent quality of concrete as per IS 13311 Part (1).

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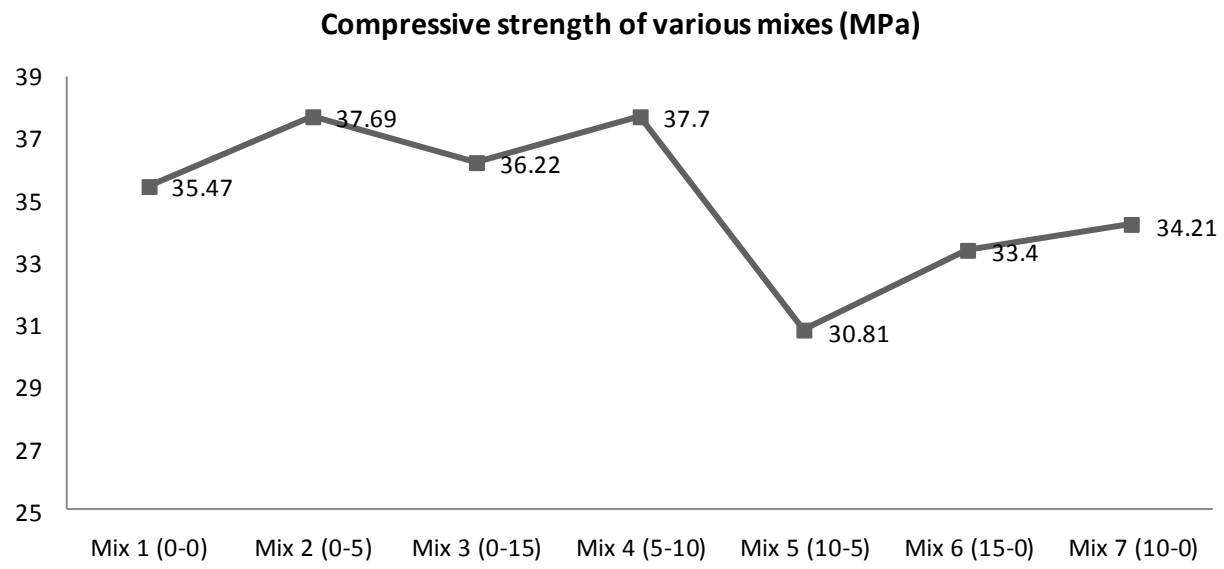

Fig. 1. Different mixes and Compressive Strength

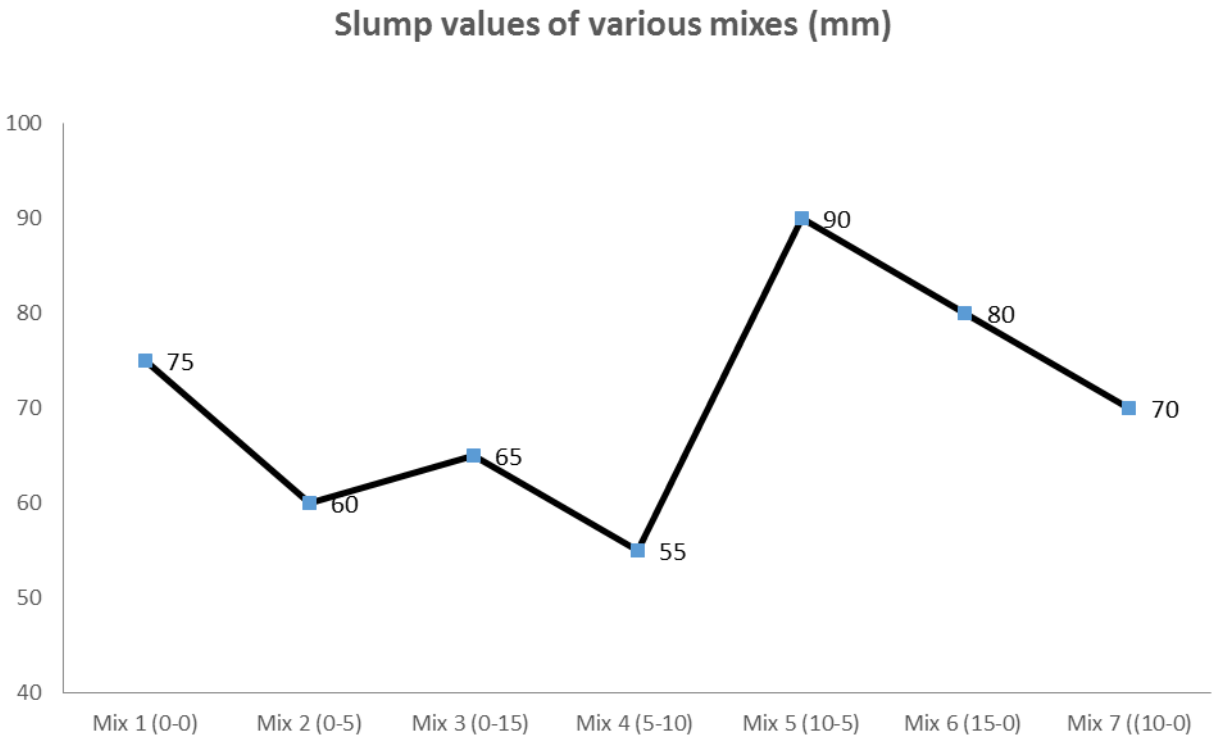

Fig. 2. Graph showing slump values of various mixes

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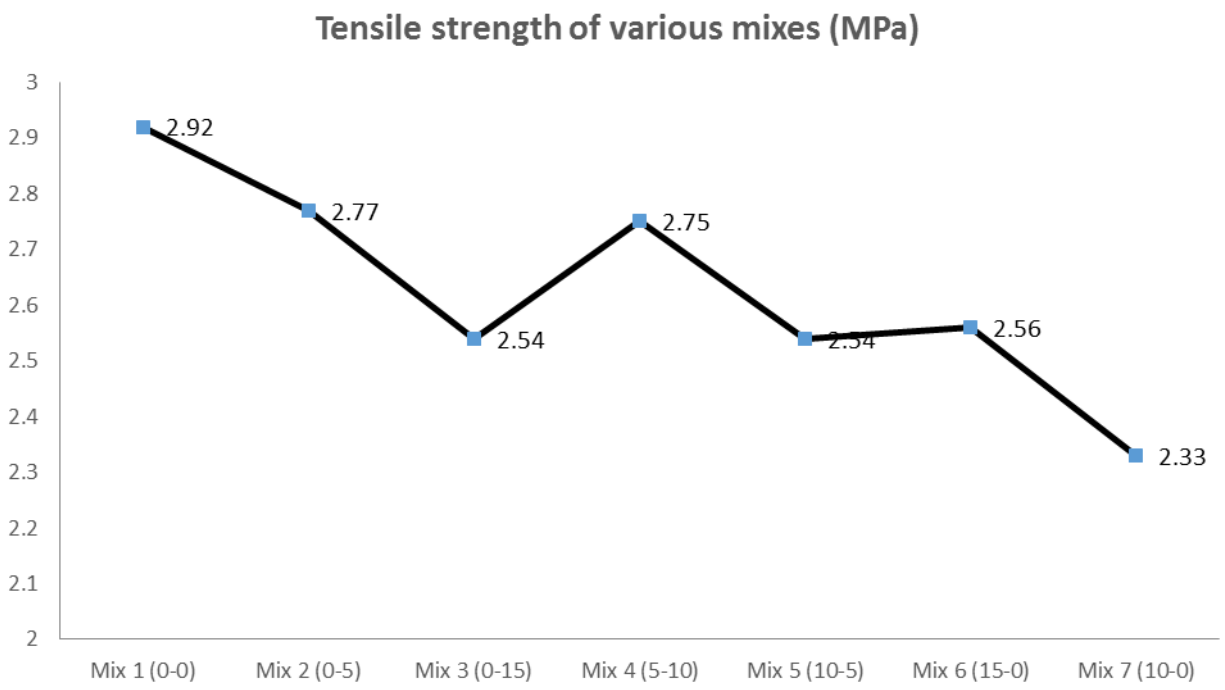

Fig. 3. Graph showing tensile strength of variation of mixes

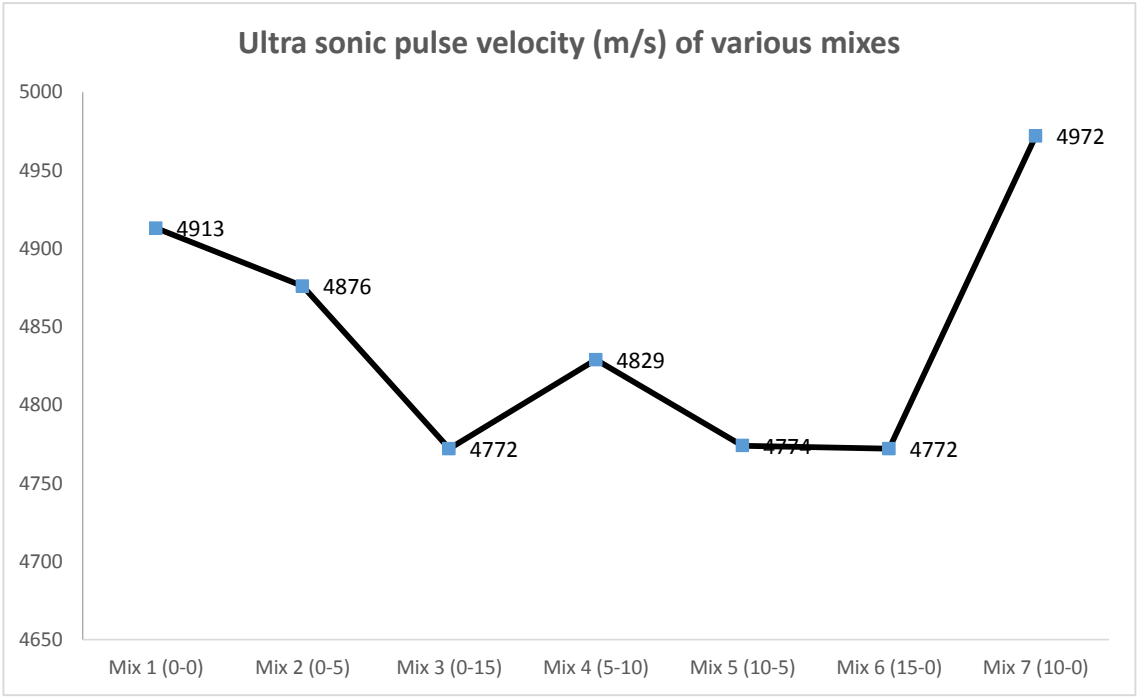

Fig. 4. Ultrasonic Pulse velocity of various mixes

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Based on the above observations following conclusions can be made:

[1] Mixes 2, 3 and 4 which showed increased compressive strength have a range of 5 to 15% ESP and least or no GP included (only mix 4 has 5% GP and other two has 0% GP). Hence it can be concluded that 5-10 % of ESP (lime) along with maximum of 5% silica (GP) is optimal as far as compressive strength is considered.

[2] In the tensile strength tests, all the mixes showed reduced strength compared to the control mix. But two mixes, 2 and 4 showed the least deviation, viz., by 0.15 and 0.17 MPa respectively. It can be noted that mixes 2 and 4 also were two among the three mixes (other being 3) that showed increased compressive strength.

[3] A study [24] showed that the ratio of the splitting tensile strength to compressive strength of concrete is influenced by the level of concrete strength. The ratio decreases with increasing compressive strength. This trend has been observed in current study also, as shown in fig.5. The plot of ratio of split tensile strength to compressive strength has a negative slop.

[4] A plot of workability of various mixes (fig.6) shows that mixes having higher percentage of GP has more workability; more content of ESP increases the compressive strength, but reduces workability.

[5] The plot in fig.7 shows that mixes with lower percentage of ESP have higher UPV values (except for mix 5 and 6).

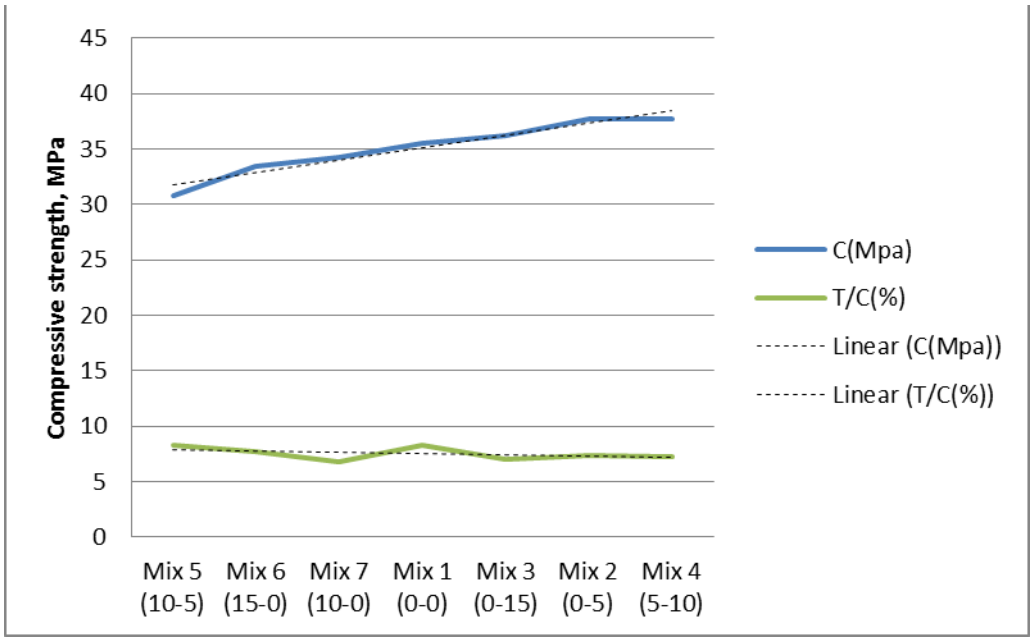

Fig. 5. Relation between Compressive strength and T/C ratio

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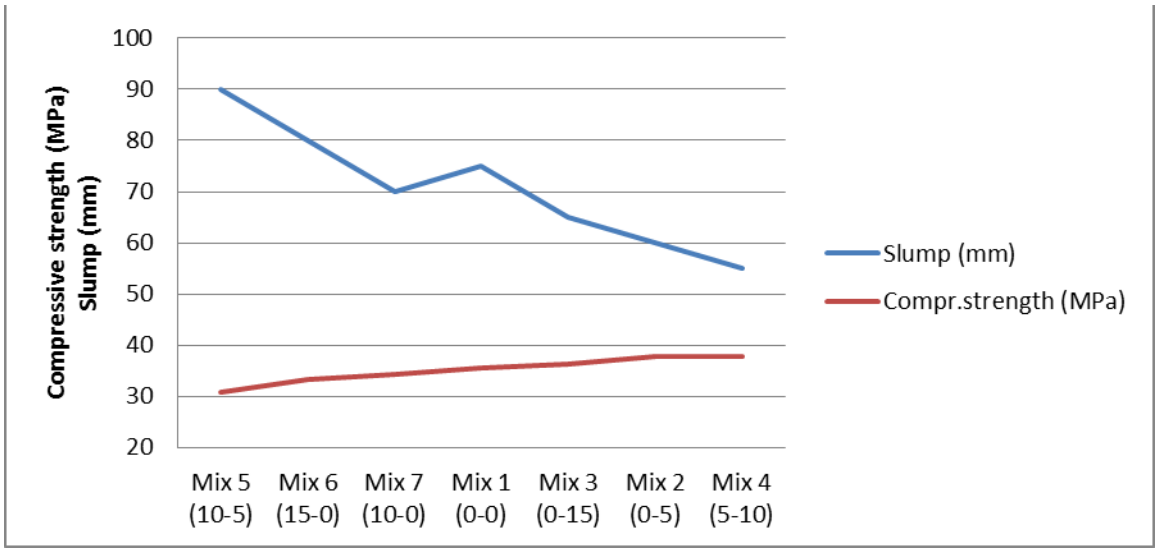

Fig. 6. Relation between workability and Compressive strength

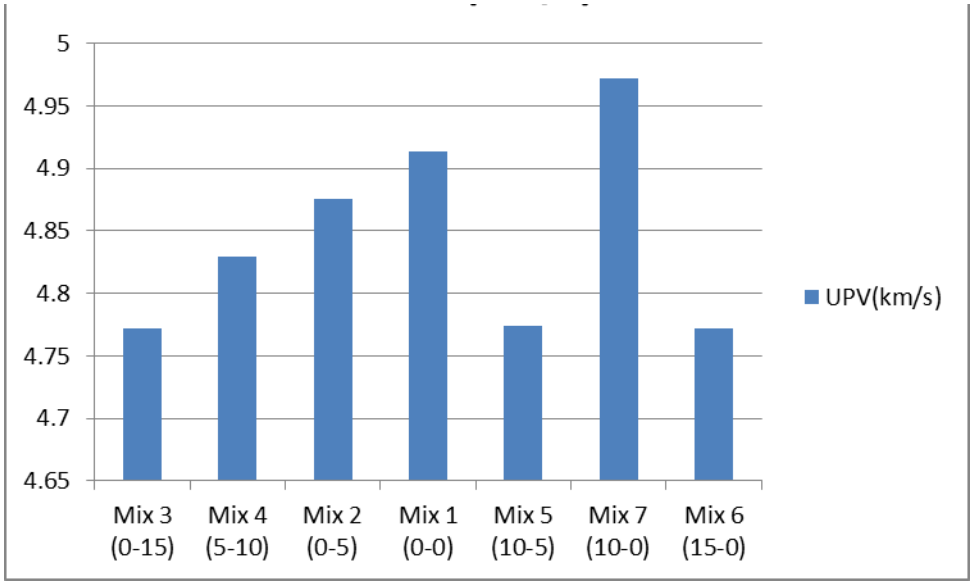

Fig. 7. Relation between GP-ESP and UPV

VIII. CONCLUSION

Both ESP and GP incorporation reduces the overall concrete production cost, reduce carbon foot print and contribute less to global warming. Hence, addition of glass powder and egg shell powder proves to be a prospective green solution for improving the mechanical properties of concrete.The study reported here shows increase in compressive strength for mixes with ESP and GP ratio of 5%-0%, 10%-5%, 15%-0%. It can be concluded that ESP and GP can be beneficially and safely used with ESP 5-15% and GP 5%, for M30 concrete using PPC cement. Higher percentage of ESP with little or no GP enhances compressive strength, due to the additional calcium input. On the other hand, higher percentage of GP with little or no ESP enhances workability as GP acts as a sort of lubricant. However, due to reduced tensile strength it would be suitable to use GP &ESP cement replacement in plain cement concrete works, mass concrete works etc. More number of specimen need to be tested at different ages to get more extensive information.

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REFERENCES

[1] T.R. Naik, G. Moriconi, Environmental – friendly durable concrete made with recycled materials for sustainable concrete construction,in international symposium on sustainable development of cement, concrete and concrete structures, Torento,Ontario, October, 2005,P-5-7..

[2] C. Pade, M. Guimaraes. The CO2 uptake of concrete in a 100-year perspective. Cem. Concr. Res. 37 (9) (2007) 1348- 1356.

[3] Young, J.F. and Mindess, S. (1981) Concrete. Prentice-Hall, New Jersey.

[4] R. Gopalakrishnan, D. Govindarajan, compressive strength and electron paramagnetic resonance studies on waste glass admixture cement. New J. glass ceram. 1 (03) (2011) 119.

[5] LM. Federico, S.E. chidiac, waste glass as a supplementary cementitious material in concrete – critical review of treatment methods, cement concr. Compor. 31(8)(2009) 606 – 610.

[6] W. Jim, C. meyer, S. Baxter, Glascrete- concrete with glass aggregate, ACI Mater. J 97 (2)(2000).

[7] Ali A. Aliabdo, Ahd Elmoaty M. Abd Elmoaty, Ahmed Y. Aboshama " Utilization of waste glass powder in the production of cement and concrete" in journal construction and building materials (2016).

[8] ASTM Annual Book of standards (2004) cement; Lime; Gypsum, west conshohockon PA, vol. 04.01.

[9] Hawkins, P., Tennis, P. and Detwiler, R(2003) The use of limestone in Portland cement; a state-of-the-art review, EB 227, Portland cement association, Skokie, IL,44.

[10] Bonavetti, V, Donaza, H., Menedez, G. Cabreva , O and ivassar, E.F. (2003) Limestone filler cement in low w/c concrete : A rational use of energy, cement and concrete research, 33: 865-871.

[11] Bignozzi et al., 2015; Gopalakrishnan, 2011; shi et al., 2005.

[12] Lanfang zhang, Yu Yue " Influence of waste glass powder usage on the properties of alkali activated slag mortar based on response surface methodology", Journal of construction and building materials (2018) P-534.

[13] Ali A aliabdo, Abd Elmoaty M. Abd Elmoaty, Ahmed Y. Aboshama "Utilization of waste glass powder in the production of cement and concrete". In journal of construction and building materials (2016) P-877.

[14] Ahmed omran, David Harbec, Arezki Tagnit – Hamou, Richard Gagne " Production Of roller – compacted concrete using glass powder : Field study". Journal of construction and building materials (2016) P-457.

[15] Nathan Schwarz, Hieu cam, Narayanan Neithalath "Influence of a fine glass powder on the durability characteristics of concrete and its comparison to fly ash". Cement and concrete composites (2008) P-495.

[16] Hengjian Du, Hangchen Jacey Gao, WeiLi "Pozzolanic reaction of glass powder and its influence on concrete properties". 23rd Australian conference on the mechanics of structures and materials.

[17] M Sophia, N. Sakthieswaran "Waste shell powder as valuable Bio-filler in gypsum Plaster – Efficient waste management technique by effective utilization". Journal of cleaner Production.

[18] Amarnath Yerramala "Properties of concrete with eggshell powder as cement replacement "The Indian Concrete Journal (2014). P- 94.

[19] P. Pliya, D. Cree "Limestone derived eggshell powder as a replacement in Portland cement mortar" Construction and building materials 2015, P-8.

[20] D. Dowsika, S. Sarankokila, K.Sargnan " Experimental investigation of egg shell powder as potential replacement with concrete". International Journal of engineering trends and technology (2014) P-68.

[21] Praveen kumar R, Vijaya Sarathy R, Jose Ravindraraj – B "Experimental study on partial replacement of cement with egg shell powder" International journal of innovations in engineering and technology (2015) P-340.

[22] DOH shulng, CHIN siew choo "Egg shell powder : potential filler in concrete" (conference paper) 8th MUCET 2014, November 2014, Melaka, Malaysia.

[23] T.S. Ramesh Babu, D. Neeraja "A Experimental study of natural admixture effect on conventional concrete and high volume class F fly ash blended concrete". J. Case studies in construction materials (2016). P-43.

[24] Mutiu A. Akinpelu a , Samson O. Odeyemi a , Oladipupo S. Olafusi b, Fatimah Z. Muhammed a "Evaluation of splitting tensile and compressive strength relationship of self-compacting concrete" Journal of King Saud University – Engineering Sciences (January 2017).

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Effect of Fly Ash Replacement on Strength and Durability Properties of Slag Based Geopolymer Concrete

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***Abstract* - This paper focuses on the strength and durability properties of slag based geopolymer concrete. In spite of fact that there are a number of studies have been published that have evaluated the feasibility of geopolymer as the binder in concrete, the prime objective of this study has been the evaluation of strength and durability properties of slag based geopolymer concrete. The amount of fly ash in slag based geopolymer concrete has been the variable for the comparative study of different mixes. For evaluation of strength and durability property several test has been carried out in the laboratory. The concrete test includes compressive strength, split tensile strength, water absorption and permeable voids.**

In this study, the concentration of sodium hydroxide was kept constant at 12 Molar and the ratio of sodium silicate and sodium hydroxide was also kept constant at 1.5. The specimens were cured in oven dry at 65ºC temperature. The amount of fly ash kept varying from 0-40%. The results revealed that the strength of geopolymer concrete depends upon the proportion of GGBS and fly ash in the concrete mix. The use of 90% GGBS and 10% fly ash gives the maximum compressive strength and also maximum split tensile strength as compared to the different proportion of fly ash used in slag based geopolymer concrete. The water absorption and permeable voids result found satisfactory.

I. INTRODUCTION

Concrete is the second most-consumed material by the person in the world after water (Gagg 2014). Normally Portland cement has been utilized generally as a binding material for the preparation of concrete. The worldwide utilization of cement is accepted to rise exponentially driven by the infrastructural advancement occurring in China and India. One tone of carbon dioxide is estimated to be discharged to the environment when one ton of Portland cement is manufactured. Additionally, the emission of CO2 due to the manufacturing of cement contributes to 7% of the global carbon dioxide outflow (Mehta, P. Kumar2001). So we need to find an alternative that is environmentally friendly and less carbon footprint as compared to CO2. The proportion of CaO in clinkers is 64-67%. The remainder consists of silicon oxides, iron oxides, and aluminum oxides. Therefore, CO2 emission from clinker production amounts to about 0.5 kg/kg. The CO2 emission per tonne of cement depends on the ratio of clinker to cement. This ratio varies normally from 0.5 to 0.95 (Worrell et al. 2001).To carry out a complete overhaul of the OPC from construction activities an alternative cementitious binder, termed geopolymer, comprising of an alkali-activated Fly Ash and GGBS, has been considered as a substitute for OPC. This new class of material known as geopolymer was developed in 1978 by a French scientist Joseph Davidovits. Geopolymer is a family of amorphous alkali or alkali-silicate activated aluminosilicate binders of composition $M_2O{\cdot}mAl_2O_3{\cdot}nSiO_2$, usually with $m \approx 1$ and $2 \leq n \leq 6$ (M usually is Na or K). In this process of geopolymerisation involved a chemical reaction between various alumino-silicate oxides with silicates under highly alkaline conditions, yielding polymeric Si – O – Al – O bonds. (Turner and Collins 2013) carried out a comparative study of the carbon footprint of OPC & geopolymer concrete with the help of a term defined as CO2-e emitted (kg CO2-e/kg). The amount of energy utilized in activities necessary to construct 1 m3 of concrete and the calculation of CO2-e was based on the collective contributions of CO2, CH4, NO2, and synthetic gases evolved during each activity, taking into account the energy content of the fuel, the global warming gas types produced, and the respective gas global warming potential (GWP), when the fuel is fully combusted.

A. Reaction Mechanism of Geopolymer Concrete

The reaction of geopolymer concrete is different from ordinary cement concrete reaction. Three main steps are involved in a geopolymer concrete reaction.

- Dissolution of any pozzolanic compound or source of silica and alumina that is readily dissolved in alkaline solution, with the formation of mobile precursors of alumino-silicate oxides through the complex action of hydroxide ions.
- The partial orientation of mobile precursors as well as the partial internal restructuring of the alkali poly-sialates.
- Re-precipitation of the particles from the initial solid-phase where the whole system hardens to form an inorganic polymeric structure.

In this process reaction of alumina, silicate resources occur with alkali solution thereby leading to dissolution

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and precipitation of Al & Si complex. After dissolving alumina silicate particles from their surfaces, precipitation of gel begins & Al and Si complex penetrates into the gel phase. After that reorganization of the complex formed occurs followed by subsequent condensation of the complex formed.

B. Research objectives & significance

The overall objective of this paper focuses on the strength and durability properties of slag based geopolymer concrete. In spite of fact that there is a number of studies have been published that have evaluated the feasibility of geopolymer as the binder in concrete, the prime objective of this study has been the evaluation of strength and durability properties of slag based geopolymer concrete. The amount of fly ash in slag based geopolymer concrete has been the variable for the comparative study of different mixes. For evaluation of strength and durability property number of the test has been carried out in the laboratory. The concrete test includes compressive strength, split tensile strength, water absorption and permeable voids.

II. EXPERIMENTAL INVESTIGATION

The properties of various materials used for making GPC concrete mixes were determined in the laboratory as per relevant IS codes of practice. The materials used in the present experimental study undertaken for the development of GPC were flyash, coarse aggregates, fine aggregates, and NaOH solution, in addition, to fly ash and GGBS in varying proportions. The importance of the study of the various properties of the material is used to check the acceptance of materials with the codal provision requirements and to enable an engineer to design a concrete mix for a particular strength. The description of various materials along with their investigated properties which were used in this study are detailed in the following sub-sections.

A. Fly ash

Fly ash utilized in this study was obtained from Guru Gobind Singh Super Thermal Power Plant, Punjab, India. The chemical composition of the fly ash as shown in Table I, was determined X-Ray Fluorescence (XRF) analysis.

TABLE I ROPAR FLY ASH AS CLASS F FLY ASH

Criteria	SiO_2 + Al_2O_3+ Fe_2O_3(%)	SO3 (%)	Na2O (%)	LOI (%)
ASTM C 618	≥70.0	≤5.0	≤1.5	≤6.0
Utilized Fly Ash	72.9	0.27	0.31	4.6

B. Blast furnace slag

The blast furnace slag utilized in this study was supplied by ASTRA Chemicals, Chennai, India. The properties of this slag conformed to (BS 6699 1992). As can be seen from Table II. The blast furnace slag utilized in this study has CaO /SiO2 ratio = 1.12, Al2O3/SiO2 ratio = 0.53. The fineness of blast furnace slag was 97.10% passing 45-micron sieve and the specific surface area was 390 m2 /Kg as shown in Table II.

TABLE II. PHYSICAL AND CHEMICAL CHARACTERISTICS OF BLAST FURNACE SLAG

Characteristics	Test Result
Specific surface area	390 m^2/Kg
Specific Gravity	2.85
Particle size (cumulative %)	97.10
Moisture content (%)	0.10
Insoluble residue (%)	0.499

C. Aggregates

Locally available aggregates, comprising 12.5 mm, 10 mm, 4.75 mm above coarse aggregates and natural fine aggregates, in saturated surface dry condition, were utilized. The coarse aggregated were natural crushed type aggregate and the fine aggregate was coarse sand.

D. Coarse aggregates

The coarse aggregates utilized were crushed natural aggregate. The gradation of coarse aggregate followed the nominal size of 12.5 mm conforming to (IS 383 2016) as shown in Table III.

TABLE III PHYSICAL PROPERTIES OF COARSE AGGREGATE

Sr. No	Characteristics	Value
1	Type	Crushed Natural
2	Specific Gravity	2.60
3	Water Absorption	1.12

E. .Grading of aggregates

The aggregates were washed to remove dust and dirt and were dried to surface dry condition. Some physical properties that are calculated in the laboratory for utilization in the manufacturing of geopolymer concrete are given in Table IV.

F. Fine aggregates

The grading of fine aggregate as shown in Table V, confirms the Zone II of IS 383: 2016. The sand was first sieved through 4.75 mm sieve to remove any particles greater than 4.75 mm and then was washed to remove the dust. Properties of the fine aggregate used in the experimental work are tabulated in Table 5.

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TABE IV GRADING OF COARSE AGGREGATES

Sieve Size	Weight Retained (gm)	% Retained	% Cumulative Retained	% Passing	IS 383: 2016
40 mm	0	0	0	100	-
20 mm	0	0	0	100	-
12.5 mm	200	10	10	90	90-100
10 mm	700	35	45	55	40-85
4.75 mm	1100	55	100	0	0-10
Pan	0	0	100		

TABLE V CHARACTERISTICS OF FINE AGGREGATES

Sr. No.	Characteristics	Value
1	Specific gravity	2.79
2	Bulk density	1.46 kg/m3
3	Fineness modulus	2.66
4	Water absorption	0.76 %
5	Grading Zone	Zone II

The aggregates were sieved through a set of sieves to obtain sieve analysis and the same is presented in Table VI.

TABLE VI SIEVE ANALYSIS

Sieve Size	Retained	% Retained	% Cumulative Retained	% Passing	IS383: 2016
10 mm	0	0	0	100	-
4.75 mm	56	5.6	5.6	94.4	90-100
2.36 mm	150	15	20.6	79.4	60-95
1.18 mm	126	12.6	33.2	66.8	55-90
600 µm	80	8	41.2	58.8	30-70
300µm	298	29.8	71	29	8-30
150µm	240	24	95	5	0-10
Pan	50	5	-	0	

G. Alkaline liquid

The liquid segment utilized in making Geopolymers is typically called the alkali activator solution (AAS), it is sometimes additionally called catalytic liquids solution (CLS). The alkaline activator utilized in this study was a sodium silicate based solution which implies that the alkaline activator contained sodium silicate and sodium hydroxide. The properties of Industrial grade-52 sodium silicate (Na2SiO3) supplied by local suppliers are shown in Table VII.

TABLE VII CHEMICAL AND PHYSICAL PROPERTIES OF LIQUID SODIUM SILICATE

Characteristics	Result
SiO_2/Na_2O (by weight)	2.0
% Na_2O	15.3
% SiO_2	36.7
Density @ 20ºC (g/cc)	1.53
pH	12.8
Visual appearance	Clear to opalescent liquid

The sodium hydroxide (NaOH) flakes were also purchased from a local supplier in bulk with purity 97-98%. The sodium hydroxide pellets in deionized in the water at least before mixing (as the disintegration of NaOH flakes in water is an exothermic reaction bringing about increased temperature promptly on dissolution) and permitted to achieve room temperature. Sodium silicate is mixed homogeneously with a sodium hydroxide solution only before concrete mixing. It should be noted here that dissimilar to water in Portland cement concrete, AAS contains a specific amount of solid, and AAS likewise instigates viscosity in concrete. Henceforth to accomplish fresh state properties, the water content in AAS ought to be considered as the parameter and not AAS as entirely. The viscosity incited by AAS has a gainful impact on since it actuates a sense of homogeneity into the geopolymer concrete mix, this reduces the segregation of concrete, and anyway, higher water content is required to accomplish the desired fresh state properties

H. Mixture Proportion

For alkali-activated fly ash–slag based geopolymer concrete, the variables considered in this study were:

- Molarity of sodium hydroxide, which is the ratio of a mole of sodium hydroxide to the volume of water.
- The mass ratio of sodium silicate to sodium hydroxide.

It was found that the range of 6-14 molarity of sodium hydroxide and the ratio of sodium silicate and sodium hydroxide in the range of 1-2.5 gave good workability and acceptable strength. Therefore, it was decided to adopt this range for fly-slag based geopolymer concrete manufacturing as given in Table-VIII and Table IX. Also, curing at high temperature was needed for fly ash-slag based geopolymer concrete.

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TABLE VIII MIX QUANTITIES OF FLY ASH-SLAG BASED GEOPOLYMER CONCRETE (PER M3)

Mix ID	Mix Notation	GGBS (Kg)	Fly Ash (Kg)	Fine Aggregate (Kg)	Coarse Aggregate (Kg)	Activator	
						Na2SiO3	NaOH
Mix 1	G12-2	412	0	784	1039	100	50
Mix 2	G12-2	370.8	32.37	784	1039	100	50
Mix 3	G12-2	329.6	64.74	784	1039	100	50
Mix 4	G12-2	288.4	97.11	784	1039	100	50
Mix 5	G12-2	247.2	129.48	784	1039	100	50

III. MANUFACTURING OF TEST SPECIMEN

A. Preparation of liquid

The sodium hydroxide flakes were mixed in water to make the solution. The mass of sodium hydroxide flakes differs depending on the concentration (molarity) requirement of the respective mix. For example, the solution of an 8M concentration of sodium hydroxide solution consisted of 8x40 = 320 grams of sodium hydroxide flakes per liter of the solution, where 40 grams is the molecular weight of sodium hydroxide. The mass of sodium hydroxide flakes was measured 260 grams for 8 Molarity, 310 grams for 10 Molarity and 360 grams for 12 Molarity concentration of sodium hydroxide solution for making 1 Kilogram solution. The sodium hydroxide solution was prepared at least one day before the casting of the specimen. As the addition of sodium hydroxide flakes and water undergoes exothermic reaction and temperature of solution rises. On the day of the casting of the specimen, sodium silicate solution and sodium hydroxide solution were mixed together and left for 4 hours to cool down naturally.

B. Manufacture of concrete and casting

The surface saturated dry coarse aggregates and fine aggregate was first mixed together in 80-liter capacity laboratory drum mixer for 1-2 minutes. After that, the fly ash and blast furnace slag was added and mixing continued for further 2-3 minutes. Moulds have been oiled before casting as shown in Figure-1.

The mix of sodium hydroxide solution and sodium silicate solution were then added to dry material and mixing continued for 3-4 minutes to manufacture the fresh concrete. The manufacture concrete poured into the container and was cast into the moulds immediately, in two layers for cubic specimens. For compaction, each layer was given 20-25 manual strokes using a rod bar and then vibrated for 15 to 18 seconds on a vibrating table. The mould has been filled and left for 10-12 hours for expelling out of water before putting into the oven.

Figure 1 Specimens mould before and after casting

C. Curing of Test Specimen

After casting and expelling out of the water from the specimen, the test specimens were dry heat cured in an oven cured at 65ºC for 24 hours. After the 24 hours of the curing period, the test specimens were left in the moulds for at least 4 hours to avoid the effect due to a drastic change in the environment. After de-moulding, the specimens were left to air dry curing in the laboratory until the day of the test.

IV. RESULTS AND DISCUSSION

A. Compressive Strength

The specimen of each mix were tested at a curing age of 3 days, 7 days and 28 days. The results of compressive strength with increasing curing age for every mix are shown in Table 9.

TABLE IX COMPRESSIVE STRENGTH TEST DATA WITH AGE

Mix ID	Compressive Strength (MPa)		
	3 Days	7 Days	28 Days
M1	57.30	61.50	67.07
M2	60.87	66.08	72.13
M3	53.47	57.23	63.30
M4	45.91	50.73	57.97
M5	44.86	47.07	52.83

The slag was replaced with fly ash in the proportion of 0%, 10%, 20%, 30%, and 40%. It was observed from the results (Table-IX) that with substitution of fly ash there as an increase in compressive strength up to 10% replacement. Mix M2 containing 10% fly ash achieved maximum compressive strength 60.87 MPa, 66.08 MPa and 72.13 MPa for 3, 7 and 28 days respectively. The increase in 28 days compressive strength of mix M2 was about 7.5% from the mix containing no fly ash. Geopolymer concrete strength development depends on the silica-alumina ration and amount of silicate and aluminate (Si4+) and aluminate ion (Al3+) into the activator gel which influences the synthesis of aluminosilicate oligomers and consequently polymerization. The dissolution of silicate and aluminate ion from source material into the activator gel

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depends on the concentration of alkali activator and chemical composition of source materials and ease with which dissolution of silica and alumina ion favors by the source material. In this study, GGBS replaced with fly ash which alters the silicate and aluminate ion into the activator due to the differences in the chemical composition of fly ash and GGBS. Replacement of GGBS with fly ash improves the geopolymerization due to increment in silicate ion and inactivator gel compared to GGBS binder which improves the compressive strength of geopolymer concrete (Görhan and Kürklü 2014). It has been observed from Table-4.1 that compressive strength deteriorates beyond the 10% fly ash replacement.

This may be due to excess flyash in mix reduces the silica-alumina ratio and which decelerates the synthesis of manufacturing of aluminosilicate oligomer and consequently geopolymerization rate and strength of geopolymer concrete. Compressive strength deteriorates with the increase in replacement of GGBS with fly ash and compressive strength mix M5 was marked lowest among all the mixes with a magnitude of 44.86 MPa, 47.07 MPa and 52.83 MPa for 3, 7 and 28 days respectively which had highest replacement level. The reduction in compressive strength is also due to the reduction in calcium oxide amount in the matrix which decreases the synthesis of calcium alumina silicate hydrate (CASH) gel which was added advantage to the geopolymer concrete in spite of geopolymerization.

B. Split Tensile Strength

The specimen of each mix were tested at a curing age of 3 days, 7 days and 28 days. The results of split tensile strength with increasing curing age for every mix are shown in Table-X.

TABLE X SPLIT TENSILE STRENGTH DATA WITH AGE

Mix ID	Split Tensile Strength (MPa)		
	3 Days	7 Days	28 Days
M1	7.60	8.32	9.27
M2	8.40	9.32	10.20
M3	7.40	8.10	8.90
M4	6.60	7.20	7.75
M5	5.41	6.20	6.90

The slag was replaced with fly ash in the proportion of 0%, 10%, 20%, 30%, and 40%. It was observed from the results (Table-XI) that with substitution of fly ash there as an increase in split tensile strength up to 10% replacement. Mix M2 containing 10% fly ash achieved maximum split tensile strength 8.40 MPa, 9.32 MPa and 10.20 MPa for 3, 7 and 28 days respectively. The increase in 28 days split tensile strength of mix M2 was about 10.03% from the mix contains no fly ash. Strength development in geopolymer concrete depends on the extent of geopolymerization and calcium alumina silicate hydrate (CASH) gel synthesis if calcium oxide available in abundant. Geopolymerization rate relies on the number of silicate aluminates ion present in the activator gel. The framework of aluminosilicate silicate oligomer depends on the ratio of silicate and aluminate dissolve from source material by the alkali activator solution. In this study, GGBS replaced with fly ash which alters the silicate and aluminate ion into the activator due to the differences in the chemical composition of fly ash and GGBS. Initially, fly ash replacement improves geopolymerization but beyond the 10% replacement, it reduces the silica-alumina ratio and which adversely affects the strength development. The increase in the amount of fly ash in binder reduces the silica-alumina ratio simultaneously and the split tensile strength of mix M5 was marked lowest among all the mixes with magnitude of 5.41 MPa, 6.20 MPa and 6.90 MPa for 3, 7 and 28 days respectively which had a maximum level of replacement among all other mixes.

The strength was also reduced due to a reduction in the synthesis of CASH gel in the matrix. CASH gel synthesis depends on the amount of calcium oxide in the binder. The replacement of GGBS with fly ash which has less amount of oxide of calcium than the GGBS. The reduction in the oxide of calcium reduces the CASH gel synthesis. After the replacement, the strength development depends on the silica-alumina ratio and their amount in activator gel. The increase in replacement level reduces the silica-alumina ratio and amount of calcium oxide. Initially, replacement with fly ash improves the strength slag based geopolymer concrete due to an increase in the amount of silicate and aluminate ion accelerates the oligomer synthesis and less impact on the silica-alumina ratio. But beyond the 10% replacement, the oligomer synthesis highly depending on the ratio of silicate and aluminate ion into the activator gel, ultimately deteriorate the split tensile strength of slag based geopolymer concrete.

C. Water Absorption and Permeable Voids

Water absorption and permeable voids of any concrete play an important role in the durability of the structure.

TABLE XI WATER ABSORPTION AND POROSITY

Mix ID	Dry Weight (W1)	Saturated Weight (W2)	Boiled Weight (W3)	Apparent Weight (W4)	Percent Absorption	Percent Voids
M1	2420	2517.5	2526.75	1482.25	4.41	10.22
M2	2400	2489	2497.25	1463.75	4.05	9.41
M3	2345	2453.5	2464.75	1432.75	5.10	11.60
M4	2360	2485	2498	1454.5	5.45	12.34
M5	2380	2447	2509.75	1458	5.85	13.22

Ingress of water deteriorates concrete and in the reinforced concrete structure, corrosion of the bars took place which results in it no cracking and spalling of the

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concrete and ultimately reduce the life span of the structure.

Water absorption and permeable voids test results of fly ash–slag based geopolymer concrete is shown in Table XI. The comparative representations of water absorption for all the mixes are given in Figure-2.

Figure 2 Oven drying and boiling of water for transport properties

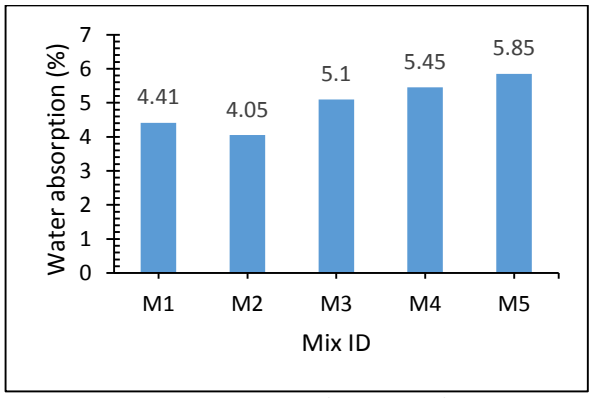

Figure 3 Water absorption after 28 days of casting

Water absorption is measured by measuring the increase in mass as a percentage of dry mass. Saturated water absorption test is carried out after 28 days on 100 mm cubes in accordance with (ASTM C 642-13 2013). The slag was replaced with fly ash in the proportion of 0%, 10%, 20%, 30%, and 40%. It was observed from the results (Table-4.1) that with substitution of fly ash there as an increase in water absorption up to 10% replacement. Mix M5 containing 40% fly ash performed worst against water absorption of 5.85%. Mix M2 containing 10% fly ash had shown the best performance against water absorption of 4.05% only. This is due to the extent of geopolymerization and synthesis of calcium alumina silicate hydrate (CASH) gel. Initially, the geopolymerization improved by the addition of extra aluminate and silicate ion and had less impact on the silica-alumina ratio. Comparative study of water absorption of different mixes as shown in Figure-3 reveals that as the replacement level increases the ratio of silicate and aluminate ion into the activator gel reduces and it deteriorates the slag based geopolymer concrete matrix and reduces the performance against the water absorption.

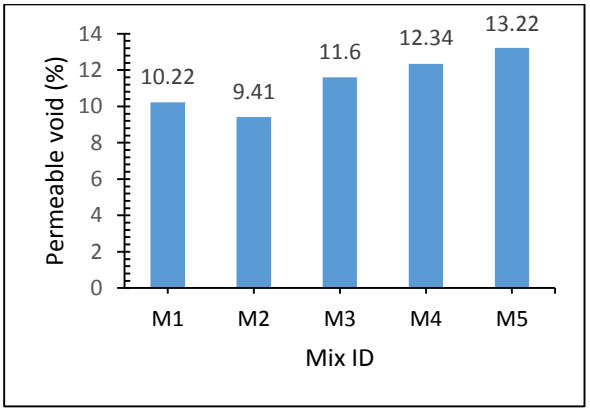

Figure 4 Voids after 28 days of casting

The generation of permeable voids supports the trends observes in the comparative study of water absorption (Figure-4.) It was observed from the result that the replacement of GGBS with fly ash reduces the permeable void up to 10% due to improvements in the geopolymerization rate. Mix M2 incorporates the minimum amount of permeable void of 9.41% but permeable voids increase with the increase in replacement level of fly ash and Mix M5 containing 40% fly ash marked maximum incorporation of the permeable void of 13.22%.

The trend of voids presents into the concrete matrix is similar to the water absorption of the matrix. Maximum voids present in Mix 5, which is due to the minimum silica-alumina ratio in the mix and minimum synthesis of calcium alumina silicate hydrate (CASH) gel in the matrix due to oxides of calcium in fly ash is less compared to GGBS. 10% replacement improves the geopolymer, and Mix M2 marked minimum incorporation of the permeable void into the concrete matrix but as the replacement level increases impact the extent of geopolymerization and less dense structures slag based geopolymer concrete has been manufactured.

The framework of aluminosilicate oligomers depends on the ratio of silicate and aluminate ion into the activator gel. Higher silica- alumina ratio manufactures a dense structure of geopolymer concrete. The increase in replacement level of GGBS with fly ash reduces the silica-alumina ration and consequently the denseness of slag based geopolymer concrete.

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V. CONCLUSIONS

- Compressive strength of slag based geopolymer concrete increased with fly ash substitution in mix initially but later on compressive strength reduces progressively with an increase in replacement level. It has been concluded that minor replacement of GGBS with fly ash shows no impact on the silica-alumina ratio but assisted the geopolymerization rate with the increase in the amount of silicate and aluminate ion into the activator.
- Mix 5 marked the lowest compressive strength which has maximum fly ash in the mix. Fly ash replacement influences the silica-alumina ratio and it goes decreasing with an increase in the amount of fly ash in the mix. That is why mix 5 marked the lowest compressive strength had a minimum silica-alumina ratio. An increase in fly ash in the mix also reduces the calcium alumina silicate hydrate (CASH) gel because of less amount of calcium oxide compares to GGBS and that reduces compressive strength.
- Split tensile strength development shows a similar trend to compressive strength development. Mix M2 marked maximum split tensile strength development as minor replacement increase the amount of silicate and aluminate ion into the activator gel and consequently assisted the geopolymerization rate and strength development.
- An increase in replacement level of fly ash consequently reduces the split tensile strength beyond the 10% replacement and mixes M5 marked lower split tensile strength. Fly ash replacement level increases the amount of silicate and aluminate ion into the activator gel but reduces the silica-alumina ratio into the activator gel and consequently reduces the split tensile strength. An increase in fly ash in the mix also reduces the calcium alumina silicate hydrate (CASH) gel because of less amount of calcium oxide compares to GGBS and that reduces the split tensile strength.
- Slag based geopolymer concrete tested for water absorption. Water absorption decreases with fly ash intrusion up to 10% due to improvement in geopolymer concrete matrix due to improved geopolymerization rate. Mix M2 marked lowest water absorption among all other mixes as fly ash intrusion assisted the geopolymerization without showing much impact on the silica-alumina ratio of the activator gel. As the replacement level of fly ash increases water absorption goes increasing as silica-alumina ration reduces with an increase in fly ash and also the synthesis of CASH gel goes decreasing. It deteriorates the structural matrix and the durability of slag based geopolymer concrete goes deteriorating.
- The generation of permeable voids generated into the concrete matrix has been calculated. It has been observed that mix M2 incorporated the lowest porosity among all the mixes. Permeable voids incorporation in the concrete matrix goes decreases with fly ash content in mix beyond the 10 percent.

REFERENCES

[1] ASTM C 642-13. (2013). "Standard test method for density, absorption, and voids in hardened concrete." *ASTM International, West Conshohocken, PA*.

[2] ASTM Standards C618. (2015). "Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use." *Annual Book of ASTM Standards*.

[3] Bakharev, T., Sanjayan, J. G., and Cheng, Y. B. (1999). "Effect of elevated temperature curing on properties of alkali-activated slag concrete." *Cement and Concrete Research*, 29(10), 1619–1625.

[4] Barbosa, V. F. F., Mackenzie, K. J. D., and Thaumaturgo, C. (2000). "Synthesis and Characterization of Sodium Polysialate Inorganic Polymer Based on Alumina and Silica." *Geopolymer International Conference*, 2, 65–78.

[5] BS 6699. (1992). "Specification for Ground granulated blastfurnace slag for use with Portland cement." *British Standard*.

[6] Davidovits, J. (2002). "30 Years of Successes and Failures in Geopolymer Applications . Market Trends and Potential Breakthroughs ." *Geopolymer 2002 Conference, October 28-29, 2002, Melbourne, Australia*, 1–16.

[7] Deb, P. S., Nath, P., and Sarker, P. K. (2014). "The effects of ground granulated blast-furnace slag blending with fly ash and activator content on the workability and strength properties of geopolymer concrete cured at ambient temperature." *Materials and Design*.

[8] Elchalakani, M., Dong, M., Karrech, A., Li, G., Mohamed Ali, M. S., Xie, T., and Yang, B. (2018). "Development of Fly Ash- and Slag-Based Geopolymer Concrete with Calcium Carbonate or Microsilica." *Journal of Materials in Civil Engineering*, 30(12), 04018325.

[9] Fernández-Jiménez, A., Palomo, J. G., and Puertas, F. (1999). "Alkali-activated slag mortars: Mechanical strength behaviour." *Cement and Concrete Research*, 29(8), 1313–1321.

[10] Görhan, G., and Kürklü, G. (2014). "The influence of the NaOH solution on the properties of the fly ash-based geopolymer mortar cured at different temperatures."

ISBN 978-93-89105-41-4

Composites Part B: Engineering, 58, 371–377.

[11] IS-516. (2004). "Method of Tests for Strength of Concrete." *Bureau of Indian Standards,New Dehli*.

[12] IS 383. (2016). "Coarse and fine aggregate for concrete - Specification." *Bureau of Indian Satandards*.

[13] Islam, A., Alengaram, U. J., Jumaat, M. Z., and Bashar, I. I. (2014). "The development of compressive strength of ground granulated blast furnace slag-palm oil fuel ash-fly ash based geopolymer mortar." *Materials and Design*.

[14] Kupwade-Patil, K., and Allouche, E. N. (2012). "Impact of Alkali Silica Reaction on Fly Ash-Based Geopolymer Concrete." *Journal of Materials in Civil Engineering*, 25(1), 131–139.

[15] Kürklü, G. (2016). "The effect of high temperature on the design of blast furnace slag and coarse fly ash-based geopolymer mortar." *Composites Part B: Engineering*.

[16] Nath, P., and Sarker, P. K. (2014). "Effect of GGBFS on setting, workability and early strength properties of fly ash geopolymer concrete cured in ambient condition." *Construction and Building Materials*.

[17] Naidu, G., Prasad, A. S. S. N., Adiseshu, S., and Satayanarayana, P. V. V. (2012). "A Study on Strength Properties of Geopolymer Concrete with Addition of G . G . B . S." *International Journal of Engineering Research and Development*.

[18] Pasupathy, K., Berndt, M., Sanjayan, J., Rajeev, P., and Cheema, D. S. (2018). "Durability Performance of Precast Fly Ash–Based Geopolymer Concrete under Atmospheric Exposure Conditions." *Journal of Materials in Civil Engineering*.

[19] Provis, J. L., Palomo, A., and Shi, C. (2015). "Advances in understanding alkali-activated materials." *Cement and Concrete Research*, Elsevier Ltd, 78, 110–125.

[20] Shaikh, F. U. A. (2014). "Effects of alkali solutions on corrosion durability of geopolymer concrete." *Advances in concrete construction*.

[21] Supraja, V., and Kanta Rao, M. (2011). "Experimental study on geopolymer concrete incorporating GGBS." *International Journal of Electronics, Communication & Soft Computing Science and Engineering*.

[22] Turner, L. K., and Collins, F. G. (2013). "Carbon dioxide equivalent (CO2-e) emissions: A comparison between geopolymer and OPC cement concrete." *Construction and Building Materials*.

[23] Venkatesan, R. P., and Pazhani, K. C. (2016). "Strength and durability properties of geopolymer concrete made with Ground Granulated Blast Furnace Slag and Black Rice Husk Ash." *KSCE Journal of Civil Engineering*.

[24] Worrell, E., Price, L., and Martin, N. (2001). "Energy efficiency and carbon dioxide emissions reduction opportunities in the US iron and steel sector." *Energy*.

[25] Zabihi, S. M., Tavakoli, H., and Mohseni, E. (2018). "Engineering and Microstructural Properties of Fiber-Reinforced Rice Husk–Ash Based Geopolymer Concrete." *Journal. of Materials in Civil Engineering*, 30(8), 04018183.

[26] Zhuang, X. Y., Chen, L., Komarneni, S., Zhou, C. H., Tong, D. S., Yang, H. M., Yu, W. H., and Wang, H. (2016). "Fly ash-based geopolymer: Clean production, properties and applications." *Journal of Cleaner Production*, Elsevier Ltd, 125, 253–267.

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Performance Study of Clay mixture amended with Activated carbon as Clay liner

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Abstract **– Clay amended with activated carbon was developed for possible use as a barrier material as an alternative to bentonite-kaolinite mix. The percentages of activated carbon 1, 2, 4 and 10% were added to the kaolinite bentonite mix and its effect was observed by comparing the results with the untreated soil. The results showed that unconfined compressive strength decreased with the addition of carbon. Hydraulic conductivity of clay mix with 2% activated carbon is less than 1 x 10^{-9} m/s, which meets the common regulatory requirement of clay liner. From the test results, threshold ratio of kaolinite - bentonite - activated carbon mix is obtained as 80:18:2.**

Keywords—Clay liner; Activated carbon; Permeability

I. INTRODUCTION

Waste disposal has become one of the most serious modern environmental problems in developed and developing countries all over the world. One of the preferred methods of dealing with this kind of environmental problem is to dispose of the waste in sanitary landfills. To safeguard the groundwater and environment from pollutants originating from landfill an effective liner system is required. Clay liners limit the infiltration of moisture due to rainfall or water migration through the barrier into the waste and limit the release of leachate and gasses from the waste. Because of low hydraulic conductivity and high adsorption capacity compacted clay soil are traditionally used within liners to prevent subsurface contamination. Generally bentonite clays are preferred for liner contruction. However, the limited availability of high quality bentonite may be supplemented with bentonite kaolinite mixes. Compacted clays undergo large changes in physicochemical properties when exposed to shrink-swell and/or freeze-thaw cycling. Blended bentonite with coarser particles is used to reduce the problem of development of shrink swell cracks. Geosynthetic Clay Liners (GCLs) are factory manufactured hydraulic barrier consists of a dry bentonite placed between two geotextile or glued to a geomembrane. When it exposed to water bentonite in GCLs hydrates and swells to form a thin layer having low hydraulic conductivity. But they are not preferred because of high cost and uncertainty in the future performance.

General requirements of a compacted clay liner are coefficient of permeability should be less than 1 x 10^{-9} m/s, unconfined compressive strength greater than 200kPa, minimum clay content of 10% and liquid limit not more than 90%.

Earthen barrier materials can also be susceptible to chemical attack by permeating contaminants. A method of enhancing pollutants adsorption and thus minimizing the flux of leachate pollutants through liners is to amend the liners with materials capable of strongly adsorbing pollutants. Activated carbon is powerful adsorbents for contaminants. In this study activated carbon (AC) is mixed with kaolinite bentonite mix and tests were done to check the suitability of carbon as a liner material.

The main objectives of this study are determination of optimum percentage of activated carbon in kaolinite bentonite mix and study its effect in compacted liner based on hydraulic conductivity and unconfined compressive strength.

II. METHODOLOGY

A. *Materials*

1 Kaolinite

The Kaolinite used in this investigation was and laboratory tests were done to find soil properties. The soil is classified as CH as per Indian standards. The physical and compaction properties of soil are summarized in Table.1

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Table.1 Geotechnical properties of Kaolinite

Property	Value
Colour	White
Specific gravity	2. 53
Liquid limit (%)	72
Plastic limit (%)	25
Plasticity Index (%)	47
Shrinkage limit (%)	17.3
Clay (%)	64.2
Silt (%)	28.4
Sand (%)	7.4
Maximum dry density(g/cc)	1.4
Optimum moisture content (%)	34.48
Unconfined Compressive Strength (kN/m^2)	103.1

2 Bentonite

Bentonite is naturally occurring clay having 70 to 90 percentage of the clay mineral as sodium montmorillonite. It has high affinity for water and swells up to about 15 times its dry bulk volume. Figure 2 shows the bentonite used for the study. The properties of the bentonite are listed in Table 2.

Table.2 Geotechnical properties of Bentonite

Property	Value
Specific gravity	2.79
Liquid limit (%)	355
Plastic limit (%)	40
Plasticity Index (%)	315

3 Activated Carbon

Specific gravity activated Carbon used for this study was obtained as 2.1.

B. *Methodology*

The study was conducted on kaolinite clay with different percentages of bentonite (B) and activated carbon (AC). The bentonite percentge on kaolinite (K) was varied as 10%, 20% and 30%, and AC as 1%, 2%, 4% and 10%. The clay - carbon mixture was subjected to various tests to determine the suitability of soil mix as clay liner material.

III. RESULTS AND DICUSSION

A. *Compaction Characteristics*

It is necessary to find the optimum dosage of bentonite for the addition of activated carbon in the kaolinite. For this, compaction test were conducted with various dosages of bentonite such as 10%, 20% and 30%. The variation of maximum dry density (MDD) and OMC with increase in bentonite dosage is illustrated in Table3. From that optimum dosage of bentonite in kaolinite was obtained as 20%.

Table 3.Variation of OMC and MDD with respect to dosage of bentonite

K:B	Max dry density (g/cc)	OMC (%)
100:0	1.4	34.48
90:10	1.42	35.61
80:20	1.45	36.11
70:30	1.43	38.24

In order to find the optimum dosage of activated carbon in the kaolinite bentonite with 80% kaolinite, compaction test were conducted with various dosages of activated carbon such as 1%, 2%, 4% and 10%. Figure 1 and Figure 2 shows the variation of maximum dry density and omc with different percentage of carbon.

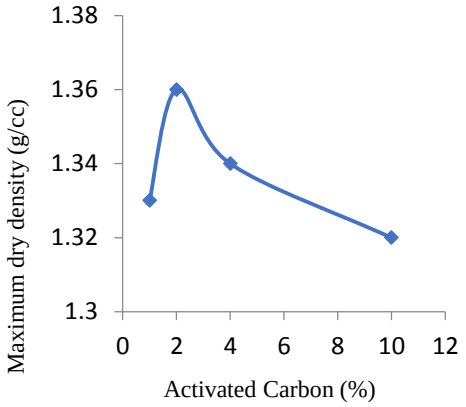

Figure 1.Variation of maximum dry density with different percentage of Activated Carbon

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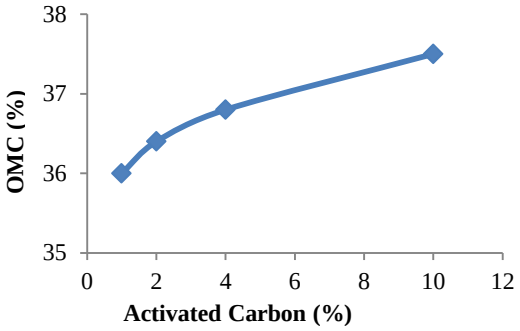

Figure 2.Variation of OMC with different percentage of Activated Carbon

From the test results, optimum percentage of kaolinite, bentonite and activated carbon was obtained as 80:18:2. The variation of maximum dry density (MDD) and OMC with increase in AC is illustrated in Table 4.

Table 4.Variation of OMC and MDD with respect to dosage of activated carbon

Dosage (%)			Max dry Max dry density (g/cc)	OMC OMC (%)
Kaolinite	Bentonite	Activated Carbon		
80	20	0	1.41	31.11
80	19	1	1.33	36
80	18	2	1.36	37.5
80	16	4	1.34	36.99
80	10	10	1.32	36.25

Results show that addition of carbon content cause decrease in MDD and increase in OMC. The decrease in MDD can be attributed to the replacement of soil by activated carbon in the mixture which has relatively lower specific gravity. It may also be attributed to coating of the soil by the AC which result to large particles with larger voids and hence less density. The reason behind increasing in optimum moisture content (OMC) with increase in AC contents is that increase in AC content causes adsorption of a high amount of water which expels the clay particles and the water takes its place.

B. *Unconfined compressive strength*

The axial stress and strain relationship that obtained from unconfined compressive strength test is shown in figure 3. The study of test results reveals that the unconfined compressive strength (UCS) decrease with the addition of activated carbon content. There is no clear variation in UCS for the clay with activated carbon content above 4%.

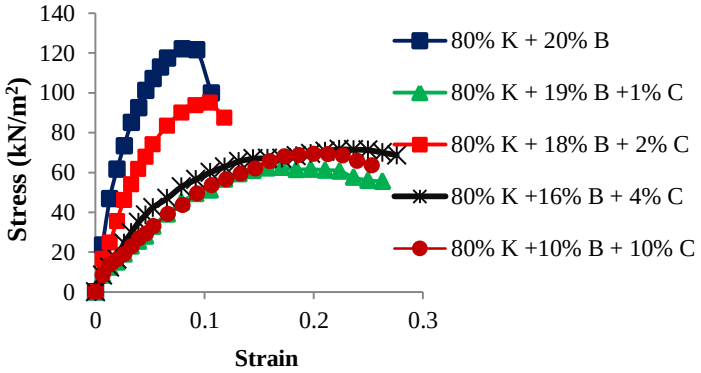

Figure 3: Stress-strain behaviour of soil

For 80% kaolinite with various combinations of bentonite and carbon, maximum unconfined compressive strength is obtained for 2% carbon. The unconfined compressive strength of the soil sample is shown in Table 5.

Table 5. Unconfined compression strength of tested samples

Dosage (%)			Unconfined Compressive Strength (kN/m^2)
Kaolinite	Bentonite	Activated Carbon	
100	0	0	103.1
80	20	0	122.084
80	19	1	62.513
80	18	2	94.97
80	16	4	71.56

Variation in UCS with curing time period from 0 to 14 days at the optimum mix combination is shown in figure 4.

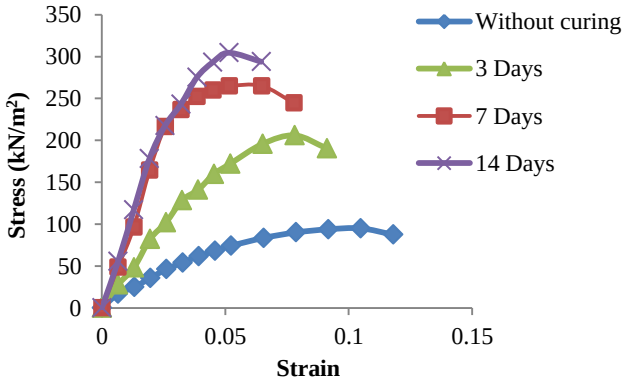

Figure 4: Stress-strain behavior of soil mixed with 2% activated carbon with different curing periods

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The unconfined compressive strength of the soil sample with curing is shown in Table 6. Test results show that stiffness of soil is increases with curing period. The increase in stiffness of the model test cured for 7 days as compared to the corresponding model test cured for 3 days is due to hardening process that developed during curing period.

Table 6: Unconfined compression strength of soil mixed with 2% activated carbon with different curing periods

Kolinite : Bentonite : Activated carbon	**Curing Period (Days)**	**Unconfined Compressive Strength (kN/m^2)**
80 : 18 : 2	0	94.97
	3	205.913
	7	265.055
	14	304.568

C. *Hydraulic Conductivity*

The hydraulic conductivity of soil mix was determined using 1-D consolidation apparatus. The coefficient of permeability (k_v) of kaolinite with distilled water as a permeant was very close to l x 10^{-8} m/s which is not with in the permissible limit of 1 x 10^{-9}m/s. The coefficient of permeability (k_v) did not change significantly when 20% kaolinite was replaced with bentonite. 80% Kaolinite with 18% Bentonite and 2% Activated Carbon shows k_v less than 10^{-9} m/s. Permeability test results are summarised in table 7.

Table 7. Hydraulic conductivity of soil mixes

Soil mix	**Hydraulic Conductivity (m/s)**
Kaolinite	1.02 x 10^{-8}
Bentonite	1.96×10^{-10}
80% Kaolinite + 20% Bentonite	7.065×10^{-9}
80% Kaolinite + 18% Bentonite + 2% Activated Carbon	1.65×10^{-10}

D. *Properties*

The index properties of 80% Kaolinite with 18% Bentonite and 2% Activated Carbon are presented in table 8. Liquid limit was obtained as 82% which is less than permissible liquid limit of 90%. Clay content is obtained as 64% which is greater than minimum clay content of 10%. Soil mixes are supposed to sustain certain amount of static load applied by the overlying waste materials. In this regard barrier material must have adequate strength for stability. Daniel and Wu (1993) mentioned that soil used as a barrier material should have minimum unconfined compressive strength of 200kPa. Test results show that unconfined compression strength of cured samples is greater than 200kPa.

Table 8.The index properties of 80% Kaolinite with 18% Bentonite and 2% Activated Carbon

80% Kaolinite +18% Bentonite + 2% Activated Carbon	**Properties**
Liquid Limit(%)	82
Plastic Limit (%)	29
Plasticity Index (%)	53
Clay content (%)	64
Hydraulic Conductivity (m/s)	1.65×10^{-10}
Max dry density (g/cc)	1.36
Optimum moisture content (%)	37.5

IV. CONCLUSION

The objective of this study was to investigate the possible use of activated carbon to replace part of bentonite and kaolinite in environmental containment applications, the main focus being to identify the threshold ratio of kaolinite - bentonite - activated carbon mix that can be used as liner material. Hence, its properties, strength and permeability were studied.

The conclusions drawn from the study include:

- Addition of carbon causes decrease in MDD and increase in OMC.
- The unconfined compressive strength (UCS) decrease with the addition of activated carbon.
- Threshold ratio of kaolinite - bentonite - activated carbon mix that can be used as liner material is 80:18:2. Unconfined compression strength of cured samples with 2% carbon is greater than 200kPa and hydraulic conductivity less than $1x10^{-9}$ m/s.

The results in this paper lead to the conclusion that 80:18:2 kaolinite-bentonite-activated carbon mix could be used as an effective barrier system.

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REFERENCES

[1] Abidin Kaya; and Seda Durukan. (2004). "Utilization of Bentonite-Embedded Zeolite as Clay Liner". Applied Clay Science, Vol 25, Issue 1, pp. 83-91.

[2] Anil Kumar Mishra; Loretta Li; Masami Ohtsubo; and Takahiro Higashi.(2005). "Effect of Salt Concentrations on the Permeability and Compressibility of Soil-Bentonite Mixtures". Journal- Faculty of Agriculture Kyushu University, Vol 50, Issue 2, pp. 837-849.

[3] Catherine, S. Hong; Charles, D. Shackelford; and Michael, A. Malusis. (2012). "Consolidation and Hydraulic Conductivity of Zeolite-Amended Soil-Bentonite Backfills". Journal of Geotechnical and Geoenvironmental Engineering, ASCE Vol 138, Issue 1, pp. 15-25.

[4] Edward J. Barben; Jeffrey C. Evans; and Michael A. Malusis. (2009). "Hydraulic Conductivity and Compressibility of Soil-Bentonite Backfill Amended with Activated Carbon". Journal of Geotechnical and Geoenvironmental Engineering, ASCE Vol 135, Issue 5, pp. 664-672.

[5] Ahmad, N. S; Chew, S. H; and Lee, S. L; and Karunaratne, G. P.(2012). "Bentonite-Kaolinite Mix for Barrier Systems". Environmental Geotechnics, Proceedings.

[6] Joseph Scalia; and Michael, A. Malusis. (2007). "Hydraulic Conductivity of an Activated Carbon-Amended Geosynthetic Clay Liner". *Geoenvironmental Engineering*, ASCE proceedings.

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MODELLING AND ANALYSIS OF TAPERED STONE COLUMNS USING ABAQUS SOFTWARE

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Abstract - Urbanization and industrial developments laid the foundation for utilization of ground for construction activities. Scarcity of land along with very weak sub soil conditions of the existing ground forced the geotechnical engineers to work round the clock to find suitable solutions. As far as both economy and efficiency in ground modifications are concerned, stone columns have proved to be a good soil improvement technique to increase the bearing capacity of the soil.

In addition to increase in bearing capacity of soil and settlement reduction, they have got the added advantage of increasing the rate of consolidation, mitigating the potential for liquefaction etc.

Studies carried out on cylindrical stone columns, show that the failure occurs by buckling of the stone columns. Usually it occurs at a depth of 2D, where D is the diameter of the stone column. Here increasing the top area of the stone column could reduce buckling. This variation in size could be brought about by adding a small degree of tapering to the stone column. Also, introducing stone columns in groups, would also reduce the buckling and hence the failure of stone column.

In this investigation, the load v/s settlement analysis of stone columns were done by introducing different degree of tapering. By using ABAQUS 6.14-2 software, a parametric study was conducted to determine the most effective size of the stone column. Keeping both economy and efficiency into consideration, a group analysis of tapered stone column were done and the buckling behavior of stone columns in group were studied.

The paper clearly describes the analysis of tapered stone column using ABAQUS Software. It was found that the bearing capacity and reduction in settlement have improved and array of column groups added the efficiency.

Keywords— **Tapered Stone column, Ground improvement, Bearing capacity, Numerical Analysis**

I. INTRODUCTION

India has a wide coastline in the southern region. In view of the developments on coastal areas in the recent past, large number of ports and industries are being built. In addition, the availability of land for the development of commercial, housing, industrial and transportation , infrastructure etc. are scarce in urban areas. This necessitates the use of land which has weak strata , wherein the geotechnical engineers are challenged by the presence of different problematic soils with varied engineering characteristics. Many of these area are covered with thick soft marine clay deposit with very low shear strength and high compressibility.

In simple words ground improvement can be defined as “the process of enhancing the geotechnical quality of soil”(Rudrabir Ghanti and Abhijeet Kashliwal,2008).

Of the various ground improvement techniques available, the final choice among the methods depends on the overall economy in total foundation cost. In most of the cases, ground treated with any of these methods results in less foundation cost compared to the cost of pile foundation.

Stone columns are one of the extensively used methods to improve the bearing capacity of poor ground and reduce the settlement of structures beneath it. It offers a much economical and sustainable alternative to

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piling and deep foundation solutions. Load carrying capacity of a stone column is attributed to frictional properties of the stone mass, cohesion and frictional properties of the soil surrounding the column. The stone column derives its axial capacity from the passive earth pressure developed due to bulging effect of the column. They also act as vertical drains and speed up the process of consolidation. By introducing the stone columns, soft soil in the field is replaced with a stronger material and initial compaction during the process of installation increases the unit weight of soil. They also mitigate the potential for liquefaction and damage, preventing built up of high pore pressure by providing drainage path. In all recent studies , tests were conducted on stone columns having cylindrical shape. Little studies were carried out by varying the shape of stone columns. In this situation, the introduction of tapered stone column refers something new.

This research focuses on the stabilization of sea-sand by introducing tapered stone columns of different dimensions. The results of the numerical analysis done using Abaqus 6.14-2 software on single and group of tapered stone columns are presented here. Effects of various parameters of tapered stone columns are also studied.

A. *Objectives of the study*

The main objectives of the study include:

1. To generate 3-Dimensional models of tapered stone columns and ordinary circular stone columns and conduct numerical analysis using ABAQUS Software.
2. To compare the circular stone columns and tapered stone columns numerical results and conduct further parametric study.
3. To study the effect of groups of tapered stone columns.

II. METHODOLOGY

A. Model details

Soil reinforced with Tapered stone column

Part: 3 D Deformable

Properties: density, modulus of elasticity, Poisson's ratio, cohesion and friction angle

Section: solid homogeneous

Assembly: soil, tapered stone column and loading plate

Step: geostatic for a time period 1

Interaction and constraints: The steel plate was tied to the soil and the stone column was embedded in the soil.

Load: Pressure load was applied on the surface of the steel plate.

Boundary condition: Bottom encastred and in sides only vertical movement is allowed

Mesh: finer mesh at loading surface (0.0025) and coarser mesh at far ends (0.05)

Element type: 8 noded linear brick, reduced integration (C3D8R)

Element shape: Hexahedral

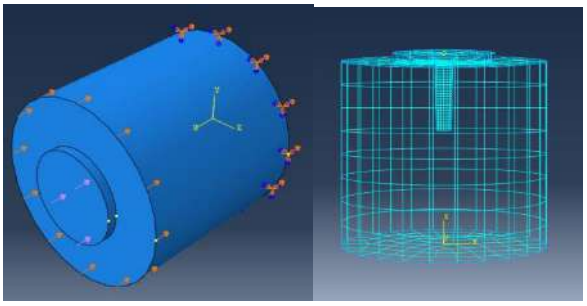

Figure 1.a.Assembled model with Boundary condition; b.Meshed model

B.Material properties used

The properties of the material used are presented in the following table.

Table 1: Soil properties used in FEM

Properties	**Values**
Density($k\,N/m^3$)	16
Modulus of Elasticity(kPa)	25000
Poissons ratio	0.35
Angle of internal friction(º)	38

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Table 2: Stone column properties used in FEM

Properties	Values
Density($k\,N/m^3$)	17.5
Modulus of Elasticity(kPa)	48000
Poissons ratio	0.3
Angle of internal friction(°)	47
Dilation angle(°)	8

Table 3: Loading plate properties

Properties	Values
Density($k\,N/m^3$)	7.86
Modulus of Elasticity(kPa)	$2.1x10^8$
Poissons ratio	0.303

III. RESULTS AND DISCUSSION

A. Validation of ABAQUS 6.14-2

The package was validated by analyzing the stress-settlement behavior of group of stone columns by J.T.Shahu and Y.R.Reddy(2011).The test tank used in the experiment was 300mm diameter and height of clay bed is 300mm. A group of 9 stone columns of diameter 13mm and height 150mm was made in square grid pattern and loaded with a plate of 100mm diameter. A 3D analysis was carried out using Mohr-coulomb criterion for clay and stone columns. The finite element discretization shown in Figure. 2 compares the results obtained from the model test and based on ABAQUS6.14-2 analysis, which matches well.

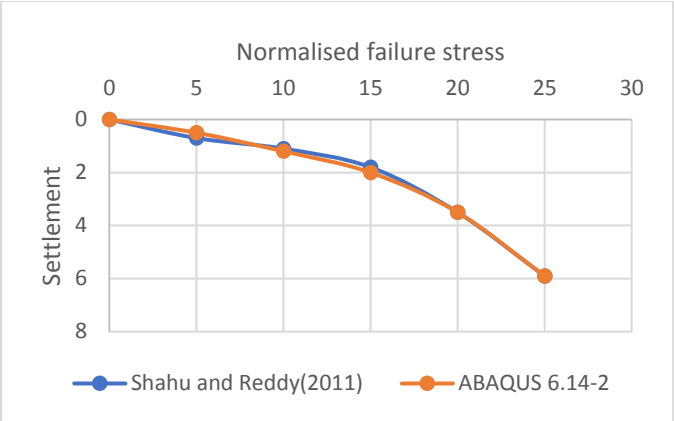

Figure 2: Validation of ABAQUS 6.14-2 with J.T.Shahu and Y.R.Reddy(2011)

B. Comparison of TSC and OSC for same length

A comparison is made between TSC and OSC by keeping the length as same. Bearing stress versus settlement plot is shown in Figure 3 and Figure 4. A comparison of stress settlement behavior of 20-16mm tapered stone column by varying length with corresponding conventional stone column.

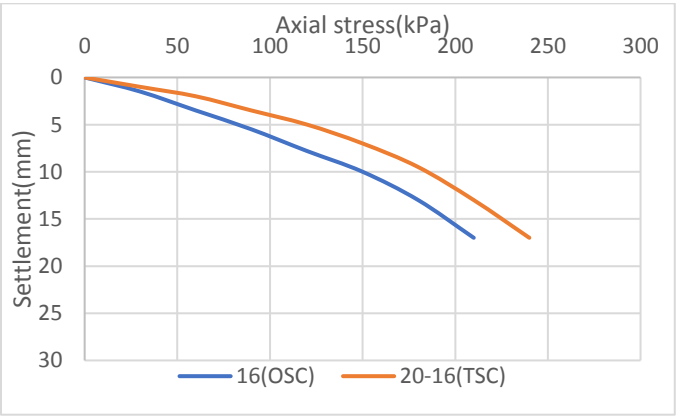

Figure 3: Stress settlement behavior of TSC and OSC , by keeping 150mm length

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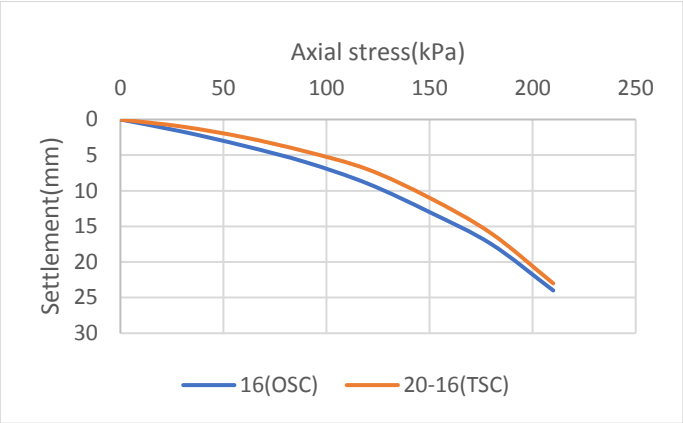

Figure 4: Stress settlement behavior of TSC and OSC , by keeping 200mm length

C. Effect of top diameter and length of TSC

Stress-settlement response of 40-32 mm TSCs with different lengths was plotted in Figure 5.It is seen that as the length of the column increases from 150 to 200 and to 250 mm , bearing capacity was slightly reduced. Figure 6 represents the stress settlement plots of 40-32, 30-24, 20-16mm TSC of 150mm length. It is seen that as the cross sectional area of the column increases, the bearing capacity increases. From the two graphs it is clear that bearing capacity increases with increase in angle of tapering of stone column.

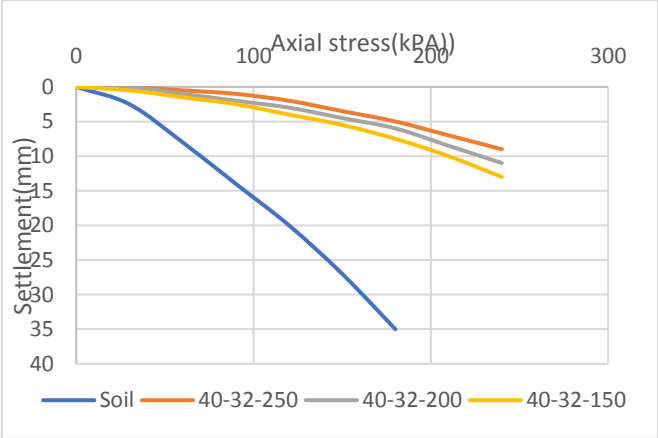

Figure 5: Stress settlement curve of 40-32mm TSC with different lengths

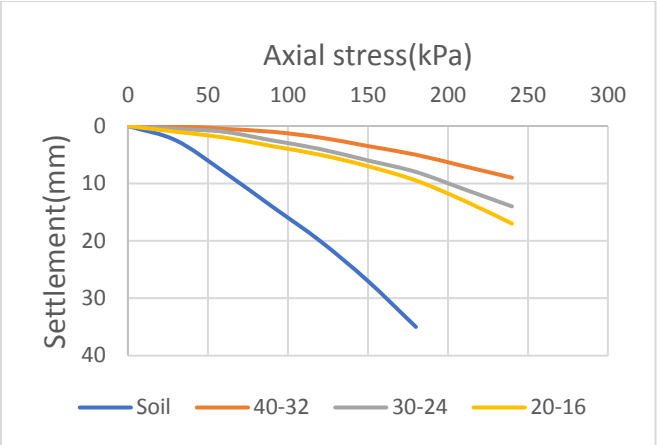

Figure 6: Stress settlement curve of TSC with 150mm length

D. Group analysis of TSC

Group analysis was done to find the optimum spacing for insertion of stone columns. The TSCs were arranged in triangular pattern with varying centre to centre spacing. TSC having top diameter 30mm and bottom diameter 24mm and height of 150mm is used. Three different spacing of 2.5d(7.5cm), 3.0d(9.0cm) and 3.5d(10.5cm), where d=top diameter of the stone column. The arrangement of stone column is as shown in Figure 7. Stress-settlement curve is as shown in Figure 8.It is seen that the bearing capacity increases with increase in spacing and attain a maximum value and then is reduced. The spacing of 3d is taken as the optimum spacing for the stone columns.

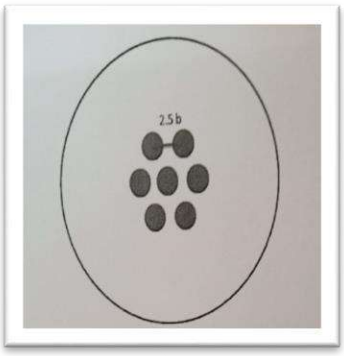

Figure 7: Arrangement of group of stone columns

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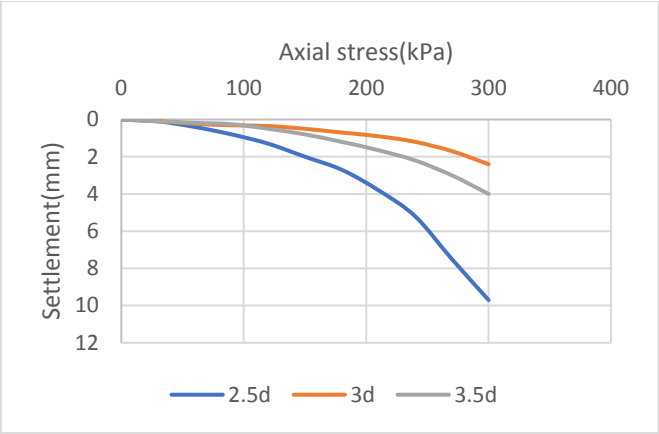

Figure 8: Stress settlement curve of group of stone column with 150mm length

IV. CONCLUSION

Based on the numerical work done using ABAQUS 6.14-2 finite element software, the following conclusions were arrived at:

- When compared with ordinary circular stone columns, tapered stone columns showed 41% increase in bearing capacity .
- Tapered stone columns showed a 28% reduction in settlement than OSC.
- The bearing pressure increases with increase in angle of tapering of tapered stone columns.
- The optimum spacing between tapered stone columns groups was found to be 3d(d= top diameter)
- From the numerical studies conducted by reinforcing soil with tapered stone columns, it can be suggested as an effective method of soil reinforcement.

REFERENCES

[1] Ali,K., Shahu, J.T. and Sharma ,K.G.(2014).”Model tests on single and groups of stone columns with different geosynthetic reinforcement arrangement.” Geosynthetics International ,21,pp.103-118.

[2] Hamed Niroumand Kassim, K.A., and Yah, C.S.(2011).”Soil improvement by reinforced stone columns based on experimental work.”Elec.J.Geo.Engg.,16,pp.1477-1499.

[3] Mani, K., and Nigee, K.(2013).” A study on ground improvement using stone column technique.”Int,J, Innovative R, Sci,2-11,pp.6451-6456.

[4] Narasimha Rao,S.,Madhiyan,M., and Prasad, Y.V.S.N.1992.”Influence of bearing area on behavior of stone columns.” Indian Geotechnical conference , Calcutta, India,pp.235-237.

[5] Pulko,B., and Majes,B.(2006).”Analytical method for the Analysis of Stone Columns According to the Rowe Dilatancy Theory .” Acta Geotechnica Slovenica ,pp.37-45.

[6] Shahu, J.T., and Reddy, Y.R.(2011).”Clayey soil reinforced with stone column group: model tests and analysis.” J.Geotech.Geoenviron.Eng., ASCE,137,pp.1265-1274.

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GIS Based Morphometric Analysis and Flood Hazard Vulnerability of Two River Basins Under Different Climatic Milieu

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***Abstract*— Morphometry is the branch of science that deals with quantitative measurement of the shape or form of any natural features. The study areas are Vamanapuram river basin, Kerala and Tamarabarani river basin,Tamil Nadu, both coming under different climatic settings. The GIS based morphometric analysis of these basins revealed that the former is a 5th order basin and the latter, a 6th order one. The present study mainly deals with the determination of parameters like Stream order (Nu), Bifurcation Ratio(Rb), Stream Frequency (Fs), Drainage density (Dd), Drainage texture (T) etc.. Total number of streams in Vamanapuram basin is around 288 and that at Tamarabarani basin is 1679. After the determination of each of these parameters, El-Shamy method is done so as to estimate the flood hazard degree of each sub-basins. Hazard analysis of both basins are administrated and the hazardous factors are detected.**

Keywords*— Morphometry; GIS; Hazard Analysis; El-Shamy Method

I. INTRODUCTION

Remote sensing and GIS techniques are the proven efficient tools in the delineation (both basin and sub-basin delineation), updating and morphometric analysis of river basin. This type of analysis is important in any hydrological investigation like watershed modeling, ground water potentiality, ground water management and hazard detection so on. The morphometric analysis provides hydrological and geological understanding with complete quantitative description of the watershed analyzed. This study can be precisely done using the Digital Elevation Model (DEM) and satellite imageries of the area and thus extraction of the drainage basin and its various parameters like area, basin length, frequency, drainage density etc.. can easily be carried out.

For the future development and effective administration of any watershed, estimating hazard degree is an important foot-step. Flooding, soil erosion and land slide are some of the hazards affecting a watershed. There are different methods for determining the hazardous sub-watersheds of a river basin like multi-criteria decision analysis and so on. One such method is the El-Shamy flood vulnerability analysis. El Shamy (1992) established two relation graphs to classify the basin's risk assessment based on the relations between particular morphometric parameters of the basin. This method is easy to use since it requires only three morphometric parameters for its computation. Using this method, all the sub-basins can be properly classified under different hazard risk. Further, preparedness measures can be proposed in a timely manner in order to minimize destructive flood effects. The present study aims to determine the morphometric parameters of two river basins coming under different climatic conditions; ie, one on the western side and other on the eastern side of Western Ghats. And using these parameters, hazard degree estimation is also carried out.

II. STUDY AREA

A. Vamanapuram River Basin

Vamanapuram river, which flows through the Trivandrum district of Kerala, lies between 8.58°N to 8.83°N 76.66°E to 77.25°E. This river originates from Chemunjimotta hills (altitude 1800m) on the south-western side of Western Ghats. It ends in Anchuthengu lake near Attingal. The major tributaries of this river are the Upper Chittar and Manjaprayar streams. Vamanapuram river is around 88 km in length. The south-west monsoon, from June to September is the principal rainy season.The area also gets thunderstorm rains in the pre-monsson months of April and May.

B. Tamarabarani River Basin

Tamarabarani river, which flows through Tuticorn and Thirunelveli districts of Tamil Nadu, lies between 8.60°N to 8.64°N and 77.26°E to 78.13°E. This river originates from Pothigai hills (altitude 1750m) on the eastern slopes of Western Ghats. From the source to sea, the river is about 128 km long and one of the perennial rivers in Tamil Nadu. This river flows

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to north direction initially. However, it changes to east direction later. The major rainy season is from October to middle of January. It is fed by both the monsoons – South western and North eastern.

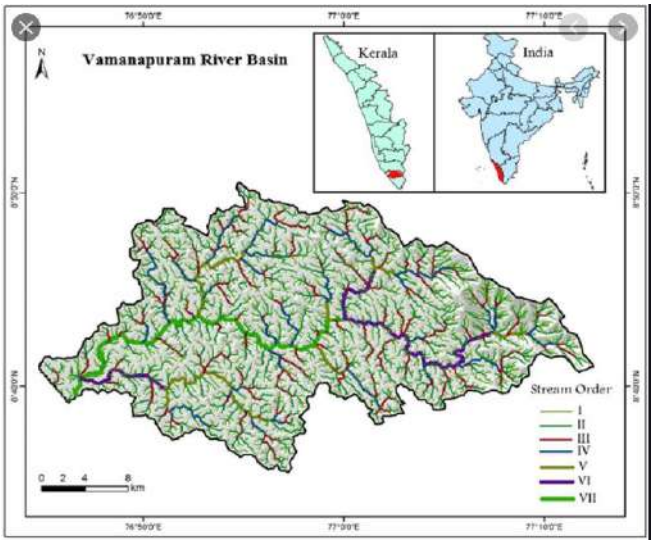

Fig 1: Vamanapuram River Basin

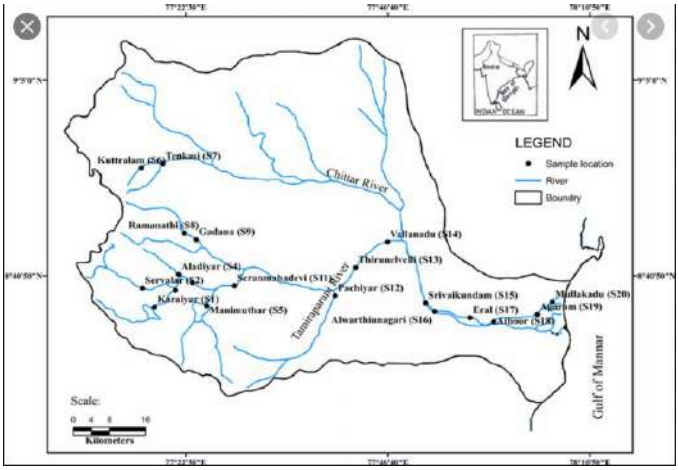

Fig 2: Tamarabarani River Basin

III. METHODOLOGY

The morphometric analysis of basins are carried out based on the delineation of drainage network and geomorphological features obtained from topographic map (1:50,000 scale), Landsat Images (Landsat 8) and JAXA DEM (30m resolution).

JAXA DEM is used for the delineation of watershed and its sub-basins, whereas Arc-GIS Software is used for the assessment of drainage network, basin relief characteristics, drainage texture and basin geometry. The map layers of drainage pattern along with stream order, watershed and sub-watershed boundaries in the study area have been prepared in this environment. The basic morphometric parameters are grouped into linear, areal and relief aspects.

The ArcSWAT extension in ArcGIS is used for the basin and sub-basin delineation. The watershed delineation administrates advanced GIS function to aid the user in segmenting watersheds into several "hydrologically" connected sub-watersheds for use in watershed modeling with SWAT.

Flood hazard estimation using El-Shamy method is also done. The degree of hazard for each sub-basin is determined using the hazard degree diagram based on El-Shamy's model (El-Shamy 1992).

IV. RESULTS AND DISCUSSIONS

A. Morphometric Analysis

(1) Linear Morphometric Parameters:

(Vincy et al 2012)

- Stream Order(u)

  The determination of stream order is the very first step in drainage basin analysis. It is based on hierarchic ranking of streams proposed by Strahler (1964).As the stream order increases, frequency of stream decreases. Vamanapuram basin is obtained as a 5^{th} order basin and the Tamarabarani as 6^{th} order one. (Table 1)

- Stream Length (L)

  The stream length is computed based on the law proposed by Horton.It is indicative of contributing area of the basin of a given order. Vamanapuram is of 88 km in lenth and Tamarabarani, 128km.

- Bifurcation Ratio (Rb)

  This term was introduced by Horton (1932) to express the ratio of number of streams of any given order to the number of streams in the next lower order. According to Strahler (1964), it is the ratio of number of streams of any given order (N_u) to the number of streams of next higher order (N_{u+1}). The variation in Rb values is a reflection of the differences in the shape of stream networks. For normal basins, Rb ranges from 2 to 5. This value also shows the proneness to flooding. ie., higher the Rb value, shorter will be the time taken for the discharge to reach the outlet and higher will be the peak discharge – leading to greater possibility of flood. Here, Tamarabarani basin is having higher Rb value (4.26) than the Vamanapuram basin (2.95) and both come under normal range. Values are given in Table 1.

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TABLE 1: LINEAR PARAMETERS

Linear Aspects	Vamanapuram River Basin	Tamarabarani River Basin
Stream Number (N)	288	1679
Stream Order (u)	5	6
Stream Length (L)	88 km	128 km
Bifurcation Ratio (R_b)	2.95	4.26

(2) Areal Morphometric Parameters:

(Vincy et al 2012)

- Drainage Density (Dd)

  It is a measure of how well or how poorly a watershed is drained by a stream channel. It can affect the shape of a river's hydrograph Higher Dd represents a flashy hydrograph, ie., greater flood risk. Even though Dd is affected by various factors like topography, lithology, climate, pedology and vegetation, relative dominance of each factors vary from place to place. High Dd values represent impermeable sub-surface material, sparse vegetation and high relief. The measurement of Dd provides a numerical measurement of land-scape dissection and runoff potential. Dd value for Vamanapuram (0.21) is more than that of Tamarabarani (0.09), which shows that flooding chances are more for Vamanapuram. (Table 2)

- Stream Frequency (Sf)

It is having a positive correlation with Drainage density. It shows the index of landscape evolution. As the stream frequency increases, the drainage density as well as the relief increases. Values obtained for the basins are more or less similar. (0.41 and 0.42)

- Drainage Texture (T)

Also known as Texture Ratio. It is an expression of the relative channel spacing in a fluvial dissected terrain.

According to Smith (1950), the value of range of D_d :

$D_d < 2$ = Very Coarse

2 to 4 = Coarse

4 to 6 = Moderate

6 to 8 = Fine

$D_d > 8$= Very Fine drainage texture

The values obtained for Vamanapuram (0.09) and for Tamarabarani (0.04) shows that they both are having coarse-grained texture.

- Length of Overland Flow (Lg)

It is defined as the length of water over the ground before it gets concentrated into definite stream channel. This factor is inversely related to the average slope of the channel. Tamarabarani is having higher value (5.82) than Vamanapuram (2.33). (Table 2)

- Constant of Channel Maintenance

This factor depends upon rock type, permeability, climatic regime, vegetation cover and relief as well as duration of erosion. It can also be said as a quantitative expression of the minimum limiting area required for the establishment of a stream. Value for Vamanapuram (4.66) is less than that obtained at Tamarabarani (11.64) (A/L = 1/D)

- Elongation Ratio (Re)

It is the ratio of diameter of a circle having the same area as that of the basin to the maximum basin length. A circular basin is said to be more efficient in the discharge or runoff than an elongated basin. The values generally vary from 0.6 to 1 for a wide range of climatic and other conditions. Values close to 1 represent regions of very low relief, whereas values ranging from 0.6 to 0.8 are usually associated with higher relief. Values can be grouped as: Circular (>0.9), Oval (0.9-0.8), Less elongated (<0.7) (Hamdan 2018). For both basins, the values obtained are less than 0.7, showing that they are elongated basins.

- Form Factor (Ff) and Shape Factor (Fs)

Form factor is having direct relation with peak discharge and is the reciprocal of Shape factor. The watershed with high form factors have high peak flows of duration, whereas elongated watershed with low form factor ranges from 0.54 indicating them to be having a flow of longer duration.

- Circularity Ratio (Rc)

It is the ratio of area of the basin to the area of a circle having circumference as the perimeter of the basin. Value 1 indicates circular basin. Values obtained are more or less similar, showing that the basins are elongated basins. (Table 2).

- Compactness Coefficient (Cc)

It is the ratio of perimeter of a basin to the circumference of a circle having the same area as that of the basin. It is used to express the hydrologic relationship of a basin to a circular basin having the same characteristics of a hydrologic basin. Values obtained are 2.64 and 2.52 respectively for Vamanapuram and Tamarabarani basins.

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TABLE 2 : AREAL PARAMETERS

Areal Aspects	Vamanapuram River Basin	Tamarabarani River Basin
Drainage Density (D_d)	0.21 km/km2	0.09 km/km2
Stream Frequency (F_s)	0.42 /km2	0.41 /km2
Drainage Texture (T)	0.09 /km	0.04 /km
Length of overland flow	2.33 km	5.82 km
Constant of channel maintenance (C)	4.66 km	11.64km
Elongation Ratio (R_e)	0.33	0.57
Form Factor (F_f)	0.09	0.25
Shape Factor (F_s)	11.11	3.99
Circularity Ratio (R_c)	0.14	0.16
Compactness Coefficient	2.64	2.52

(3) Relief Morphometric Parameters:
(Vincy et al 2012)

- Relative Relief (H)

  It is the difference between highest and lowest elevation of the basin. It controls the stream gradient and therefore influences flood pattern of a This factor plays an important role in drainage development, surface and sub-surface water flow, permeability and erosion properties of a basin. (Table 3)

- Relief Ratio (Rh)

  Channel gradient and relief are directly related to each other, as in the case of hydrological characteristics and the relief ratio of a drainage basin. It normally decreases with increasing drainage area.

- Ruggedness Number (Rn)

  It indicates the structural complexity of a terrain. Basins having high Rn values are highly susceptible to erosion. Values obtained are 0.37 and 0.16 respectively for Vamanapuram and Tamarabarani basins.

TABLE 3 : RELIEF PARAMETERS

Relief Aspects	Vamanapuram River Basin	Tamarabarani River Basin
Relative Relief (H)	1714 km	1837 km
Relief Ratio (R_h)	19.48	14.35
Ruggedness Number (R_n)	0.37	0.16

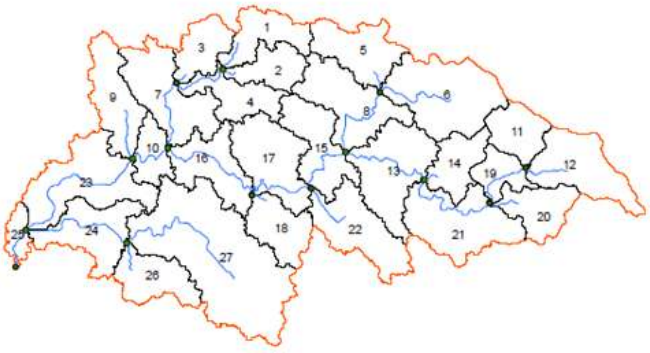

Fig 3 : Vamanapuram Sub-basins

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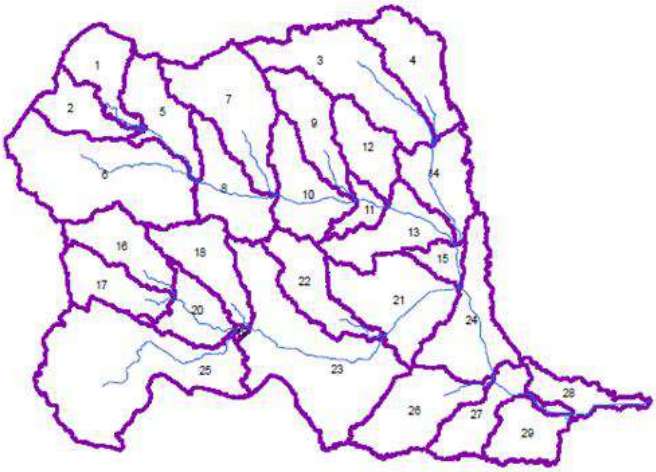

Fig 4: Tamarabarani Sub-basins

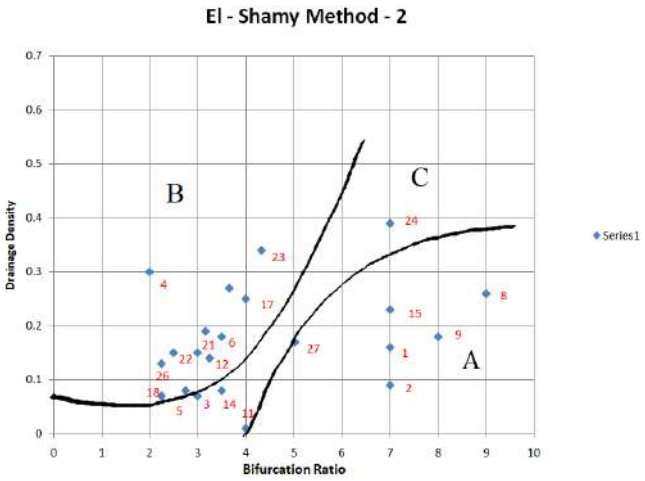

Fig 6: El-Shamy 2 for Vamanapuram Basin

B. El-Shamy Analysis

The degree of hazard for each sub-basins is determined by using the hazard degree diagram based on El-Shamy's model (El Shamy 1992). Two different models are there for this determination. The first one employs the relation between Rb and Dd of the basins, while the second is based on the relation between other two morphometric parameters which having a direct effect on flooding, i.e., Rb and Stream Frequency.

This model is divided into 3 zones :A, B and C. A represents sub-basins with low potentiality to floods, B with very high potentiality and C represents moderate potentiality floods.

Table 4 gives the list of sub-watersheds of Vamanapuram basin prone to low, medium and high floods and Table 5 of Tamarabarani basin.

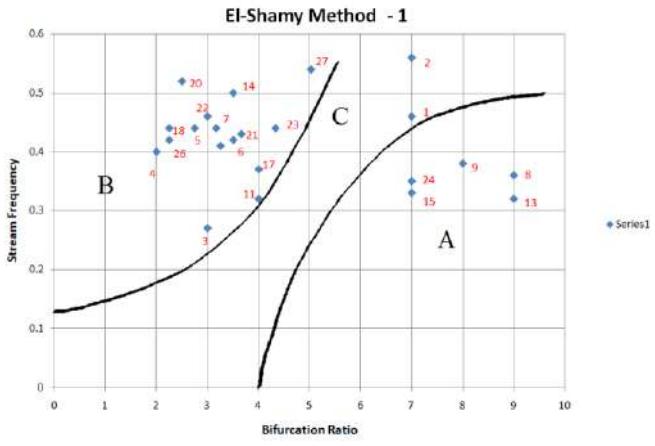

Fig 5: El-Shamy 1 for Vamanapuram Basin

Figures 5 and 6 shows the El-Shamy hazard degree estimation of Vamanapuram basin. Figures 7 and 8 shows the hazard estimation of Tamarabarani river basin. Most of the basins of Vamanapuram is having a high degree of flood hazard as per El-Shamy method. Whereas most of the sub-basins of Tamarabarani basin is showing less proneness to flooding.

TABLE 4: SUB-BASINS PRONE TO FLOOD HAZARD : VAMANAPURAM

High Flood prone sub-basins	Medium Flood prone sub-basins	Low Flood prone sub-basins
4	3	1
7	6	2
10	8	5
17	9	11
18	13	12
22	15	14
23	16	19
25	21	20
26	24	
27		

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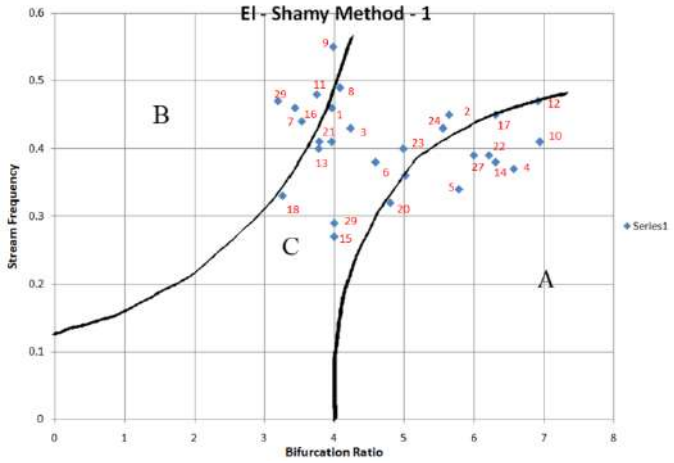

Fig 7: El-Shamy 1 for Tamarabarani Basin

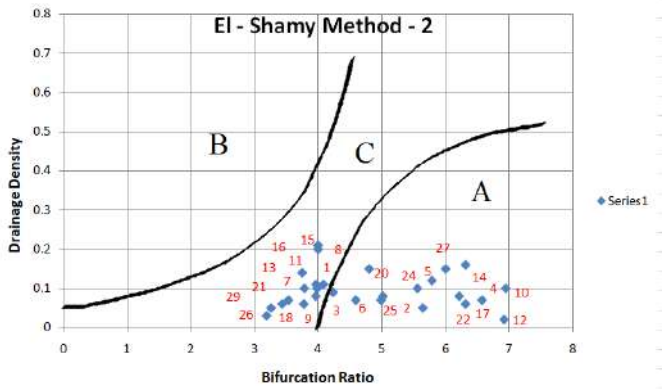

Fig 8: El-Shamy 2 for Tamarabarani Basin

TABLE 5: SUB-BASINS PRONE TO FLOOD HAZARD: TAMARABARANI

High Flood prone sub-basins	Medium Flood prone sub-basins	Low Flood prone sub-basins
28	1	4
29	2	5
	3	6
	7	10
	8	12
	9	14
	11	17
	13	19
	15	20
	16	22
	18	23
	21	25
	24	26
		27

C. CONCLUSION

In this study, the morphometrical characteristics of two river basins are studied. The Vamanapuram and Tamarabarani river basins are identified as 5th and 6th order respectively. The former consists of 27 sub-basins and the latter, 29. The basins generally follows the Laws of Drainage with respect to stream number and total stream length. From the hazard degrees obtained, it is seen that the chances of flooding is more for Vamanapuram basin than that of Tamarabarani basin. In Vamanapuram, there are around 11 sub-basins prone to high chances of flooding (48% of the total basin area), whereas in Tamarabarani, only 2 sub-basins are prone to high flooding chances (6.9% of total basin area).

REFERENCES

[1] R. E. Horton, " Drainage-basin Characteristics".,Advanced Earth and Space Science,10:1029 (1932)

[2] A. N. Strahler, "Quantitative Geomorphology of Drainage basins and Channel networks"., Handbook of Applied Hydrology,McGraw-Hill, New York,439-477 (1964)

[3] El-Shamy, "Recent Recharge and Flash Flooding Oppurtunities in the Eatern Desert,Egypt"., Annals of Geological Survey of Egypt,323-334(1992)

[4] M.V. Vincy, B Rajan, A.P. Pradeepkumar, "Geographic Information System – based morphometric characterization of sub-watersheds of Meenachil river basin, Kottayam district, Kerala,India"., Geocarto International, 1-24(2012)

[5] A. Hamdan,H. Khoziyem, " Morphometric,statistical, and hazard analyses using ASTER data and GIS technique of WADI El-Mathula watershed,Qena,Egypt"., Arabian Journal of Geosciences,11:772 (2018)

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Behaviour of Circular Footing Subjected to Moments

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Abstract*— Foundations of certain structures are subjected to large moments and relatively small vertical and horizontal forces. This paper investigates the influence of moment acting on the structure, on the settlement and angular distortion of the footing by carrying out a series of laboratory scale load tests on model circular footing. The parameters varied are magnitude of moment, magnitude of vertical load, depth of foundation, etc. It is observed that tilt increases with increase in moment initially and thereafter decreases. It is also observed that tilt decreases with increase in depth of footing. The rotation is found to be minimum for D/B=1.0; where D is the depth of footing and B is the diameter of footing. Moment acting on the structure influences the load-settlement behaviour. For a constant moment, depth of footing influences the load settlement behaviour.

Keywords*— Angular movements, Circular footing, Moment, Load settlement behaviour

INTRODUCTION

Foundations for overhead catenary systems carrying electrical power in railway networks, transmission towers, and for large road and railway hoardings and other elevated commercial signs have to be designed mainly to resist large moments and relatively small vertical and horizontal forces. Moments on the foundation base are mainly caused by horizontal forces acting on the structure. Horizontal forces are the resultant of earth pressure, wind pressure, seismic force, and hydrostatic pressure etc. The non-uniformity of the soil pressure tends to tilt the footing. This tilt increases with the increase of load eccentricity, and consequently the bearing capacity is reduced. Short bored pile or pier foundations are widely used in situations where moment-carrying capacity is the dominant design requirement. But such foundations are very costly and cannot be adopted for small projects. Published literature on the moment-deformation behaviour of shallow foundation is very scarce.

Much research has been carried out in different foundations Laman M et al. (1999), K. Sawadan and J.Takemura (2014), Taiebat H.A et al. (2000; 2002) and Bransby M.F and Randolph M.F (1998). Saleh et al. (2008; 2009) carried out laboratory investigation and numerical analyses to study the behaviour of one sided skirted strip footing subjected to eccentric load. Sharma and Kumar (2018) studied the behaviour of ring footing resting on loose sand and/or compacted randomly distributed fiber reinforced sand when subjected to eccentric, inclined and eccentric-inclined loadings by using finite element (FE) software PLAXIS 3D.

This paper investigates the influence of moment acting on the structure, on the settlement and angular distortion of the footing by carrying out a series of laboratory scale load tests on model circular footing resting on clayey soil.

EXPERIMENTAL STUDIES

Methodology and materials

The load tests are conducted in a combined test bed and loading frame assembly. The test beds are prepared in a tank of internal dimension 1000 mm length x 750 mm width x 750 mm depth. The test tank is constructed with 230 mm thick brick masonry walls on the three sides. The front side of tank is formed using a frame work of steel channels and angles. The model circular footing has a diameter of 100 mm, thickness 20 mm and is fabricated with mild steel. The clayey soil is filled in the test tank to the required level with compaction done in layers of 50 mm thickness. The water content of the clayey soil is maintained at 18%. To achieve the

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desired density of the soil, the layered filling technique is used. The pre-determined density of clay is used to calculate the desired weight of soil required to fill the tank in layers of 50 mm height. A uniform density of 15.6 kN/m^3 for clay was maintained in all the tests. The clay was compacted by ramming. The compactive effort required to achieve the required density was determined by trial and error. The loading tests are carried out in a loading frame fabricated with ISMB 300. The vertical load is applied using a hand operated-mechanical jack of capacity 50 kN. The applied vertical load is measured using a proving ring of capacity 100 kN. Moment is applied by eccentric loading on the footing in addition to the vertical load. The eccentricity in all the tests is 245mm. Eccentric load is measured using an additional proving ring of capacity 50 kN. The tilt of the model footing is measured using two dial gauges of 0.01 mm sensitivity kept diametrically opposite to each other 350 mm apart. The photograph of loading frame and test tank is shown in Figure 1. Locally available clay is used as foundation soil. The properties of clay are listed in Table 1.

Table 1. Properties of clayey soil

Sl No	Properties	Values
1	Specific gravity	2.68
2	Optimum Moisture Content (%)	18
3	Maximum Dry Density (kN/m^3)	15.61
4	Liquid Limit (%)	58
5	Plastic Limit (%)	22
6	Shrinkage limit (%)	16.2
7	Plasticity Index (%)	36
8	IS Classification	CH
9	Unconfined Compressive Strength, UCC (kN/m^2)	140.08
10	Permeability, k (m/s)	3.03 x 10^{-6}
11	Cohesion , c (kN/m^2)	25

Fig. 1 Test tank and loading frame

Parameters used in the study

The diameter and depth of circular footing are 'B' and 'D' respectively. Diameter of the footing is 100 mm. Distance between two dial gauges is fixed as 350 mm. Eccentric load (P2) is increased at regular intervals. The eccentric distance of eccentric load P2 is fixed as e = 245 mm. The experimental setup is shown in the Figure 2 and parameters varied in Table 2.

Table 2. Parameters Varied

Parameter	Vertical Load P1 (N)	D/B	Moment M (N-m)
Value	0, 90, 130, 170	0, 0.5, 1	0, 0.56, 1.13, 1.69

Fig. 2a

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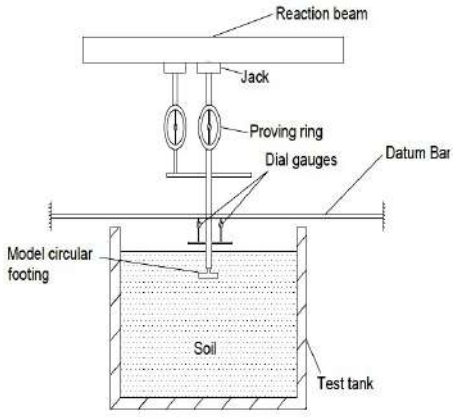

Fig. 2b

Fig. 2a & 2b Experimental setup

RESULTS AND DISCUSSION

Moment rotation behaviour of circular footing is investigated by carrying out a series of laboratory scale load tests. Influences of depth of foundation and vertical loading on tilt of footing are investigated and the results are presented below.

Moment versus rotation curve for constant vertical load P1=130 N and different depths is presented in Figure 3.

Fig 3. Moment v/s Rotation curves for P1= 130 N and different depths of footing

It is observed that depth of embedment influences the tilt of footing. For a constant vertical load, as the depth of embedment increases the tilt of footing reduces. The rotation is found to be minimum for D/B =1.0. Maximum rotation is observed when the footing is at the surface. When moment is applied, one side of footing moves down and other side moves up. The downward movement is restricted by the bearing capacity. The upward movement of footing is restricted by the weight of soil above the footing. As depth increases, the bearing capacity increases and the weight of soil increases. This increases the moment resisting capacity of footing.

Moment versus rotation curve for constant depth D/B=0 and varying vertical loads is given in Figure 4.

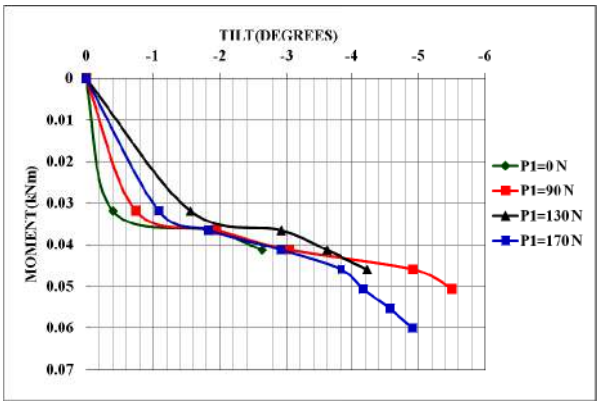

Fig. 4 Moment v/s Rotation curves for D/B=0 and varying vertical loads

Vertical load influences the tilt of footing. For constant depth, when vertical load increases, the tilt increases upto P1=130 N and further increase in vertical load tilt reduces. Maximum tilt is found at vertical load of 130 N.

The load-settlement curve of circular footing resting on surface (D/B=0) for varying the moments is given in Figure 5.

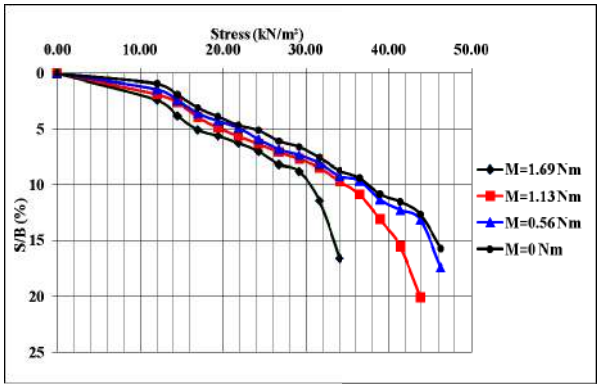

Fig. 5 Load-settlement curves for D/B=0 and varying the moments

It is seen that the load-settlement behaviour is influenced by the moments acting on the structure. For a constant depth, when the moment increases, the settlement increases. As the moment increases, the load carrying capacity reduces.

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The load-settlement curve of circular footing resting on different depth for constant moment M= 0.56 N-m is given in Figure 6.

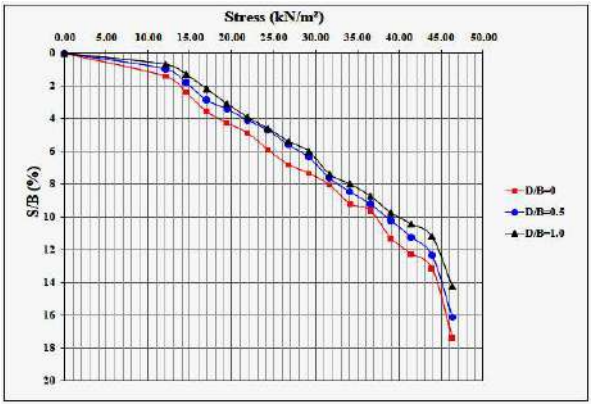

Fig. 6 Load-settlement curves for constant moment M=0.56 N-m and different depth of footing

It is observed that depth of embedment influences the settlement of footing. For a constant moment, as the depth of embedment increases the settlement of footing reduces. The settlement is found to be minimum for D/B =1.0. Maximum settlement is observed when the footing is at the surface.

CONCLUSIONS

Based on the results of this investigation, the following conclusions can be made:

[1] Depth of embedment reduces the tilt of footing and settlement of footing.

[2] Moment acting on the structure influences the load-settlement behaviour.

[3] Vertical load acting on the footing significantly influences the tilt.

[4] The rotation is found to be minimum for D/B =1.0.

[5] Maximum rotation is observed when footing is at surface.

REFERENCES

Bransby, M. F., and Randolph M. F. (1998). "Combined loading of skirted foundations." *Geotechnique*, 48, No. 5, pp no. 637-655.

Laman, M., King, G. J. W., and Dickin, E. A. (1999). "Three-dimensional finite element studies of the moment-carrying capacity of short pier foundations in cohesionless soil." *Comput Geotech*., 25, 141–155.

Saleh, N. M., Elsaied, A. E., and Elleboudy, A. M. (2008). "Performance of Skirted Strip Footing Subjected to Eccentric Inclined Load." *Electronic Journal of Geotechnical Engineering*, 13, 1-13.

Saleh, N. M., Elleboudy, A. M., and Elsaied, A. E. (2009). "Behaviour of skirted strip footing under eccentric load." *Proceedings of the 17th International Conference on Soil Mechanics and Geotechnical Engineering*, 586-589.

Sawadan, K., and Takemura, J. (2014). "Centrifuge model tests on piled raft foundation in sand subjected to lateral and moment loads." *Soils and Foundations*, 54(2), 126–140.

Sharma, V., and Kumar, A. (2018). "Behavior of ring footing resting on reinforced sand subjected to eccentric-inclined loading." *Journal of Rock Mechanics and Geotechnical Engineering*, 10, 347-357.

Taiebat, H. A. and Carter, J. P. (2000). "Numerical studies of bearing capacity of shallow foundations on cohesive soil subjected to combined loading." *Geotechnique,* 50(4), 409-418.

Taiebat, H. A., and Carter, J. P. (2002). "Bearing capacity of strip and circular foundations on undrained clay subjected to eccentric loads." *Geotechnique,* 50(1), pp no. 61–64.

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PAPER ID 67

Ozonation as a technique for domestic wastewater treatment

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***Abstract*—Ozone is coming across as an emerging technique for the treatment of wastewater. This paper outlines the effect of varying doses of ozone of screened raw sewage sample on parameters like dissolved oxygen, turbidity, hardness and chemical oxygen demand (COD). The percentage reduction in turbidity, hardness and COD are in the range of 15-18%, 20-40% and 75-80% respectively.**

Keywords—ozonation, ozone, wastewater treatment

I. INTRODUCTION

Water that is used for any work in the household forms a part of wastewater that gains an entry to the municipal wastewater treatment plant (WTPs). After treatment, the sludge generated may be either used as landfill or disposed by dilution i.e. discharged into water body. A large number of WTPs allow the treated effluents to enter into various water bodies such as rivers or lakes which are situated close to the plants. [1]

A typical wastewater treatment system has a primary and secondary treatment method which is then followed by the disposal of solids and water thus generated. The presence of suspended / floating matter decides the necessity of a preliminary treatment.

The main aim of treatment provided to the wastewater could be listed as follows:

1) Floating/suspended particles elimination
2) Decrease or complete removal BOD
3) Elimination of pathogens

Since 1990, increased scientific knowledge and understanding of long term effects on environment due to wastewater has led to an awareness of health issues resulting from the release of various toxic and potentially toxic chemicals in the environment. [2]

In the older days, WTPs used chlorine for the treatment of the wastewater as chlorine was effective and had low cost. Chlorine is known to be effective in destroying a variety of bacteria, viruses and protozoa, including Salmonella, Shigella and Vibrio cholera [3], but studies showed that chlorine reactions with organic matter results in the formation of disinfection by-products like tri-halomethanes and haloacetic acids. [4]

These by-products, being carcinogenic, adversely affect both public and aquatic life. Fish kills were also experienced in water bodies receiving municipal wastewater disinfected with chlorine. Chlorine and chlorine-ammonia compounds have been reported to be toxic to various species of freshwater fish. [5]

Due to the drawbacks of such chlorinated effluents, alternate methods of disinfection were tried. Ozone and ozone-based advanced oxidation processes, which promote ozone decomposition to hydroxyl radicals, are quite effective at transforming antibiotics in real systems. Hence, ozone-based processes offer an effective solution to this emerging threat. [6] Ozone and Ultra-Violet treatment were most obvious choice for treatment of wastewater methods as these were being used for drinking water treatment.

Traditional methods are not efficient in terms of the energy used and also lead to pollution of air and water in the vicinity. As energy and water are critical elements, the scenario is now changing with more focus on saving both of them [7,8]. This leads to the search for newer methods for the treatment of wastewater [9]

This paper uses ozone as a stand-alone method of treatment of municipal wastewater. The economics of treatment is beyond the scope of this paper and may be considered as future work.

II. MATERIAL AND METHOD

A. Sample collection

The wastewater to be treated was collected from the sewage treatment plant (STP) at NMIMS University building, Vile Parle, Mumbai. Grab samples of screened wastewater were collected in one-litre bottles at various times of the day to account for the variation in the influent characteristics. The three times chosen for collection of sample were 10 am, 12 noon and 2 pm. These effluent samples were collected over a period of four months from August to November, 2019. The samples were tested within a time of 20 minutes from the collection of the sample. The characteristics of the raw sewage sample for the testing period are shown in table 1.

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B. *Ozone Generation and Addition of Ozone*

The generation of ozone was done by using an oxygen concentrator (Ventox oxycon-1) and ozone generator. Ozone was passed through 500 ml sample of wastewater for time periods varying from 2 to 25 minutes at the rate of 3 lit/min.

C. *Testing of samples*

The testing for different parameters were done using test kit of Aquasol brand manufactured by Rakiro Biotech Systems. The following parameters were tested: pH, Dissolved Oxygen(DO), Chemical Oxygen Demand(COD), Turbidity and Hardness.

III. RESULT AND DISCUSSION

Table 1: Characteristics of the raw screened sewage

Parameter	Value range
DO in ppm	0.5-1.5
COD in ppm	380-420
Turbidity in NTU	28-38
Hardness in ppm	600-850

The pH of the raw screened sewage was found to lie between 7.2-7.9. The variation in pH due to the addition of ozone was not significant enough to warrant the use of this method as a means to reduce the pH of the effluent (results not shown here).

A. *Effect of ozonation on Dissolved Oxygen*

Increase in DO is seen till it reaches a saturation value of about 23 ppm at the end of 17 to 20 min. The maximum amount of ozone which can be dissolved in water at a room temperature of 25^{0}C is about 8.2 ppm (ref: standard methods of examination of water and wastewater). Here, it is important to remember that such a high concentration of oxygen is instantaneous and unstable; it will degenerate on its own as ozone is unstable. Table 2 shows the increase in the DO values in ppm (parts per million) for the samples collected at various testing times namely, 10 am, 12 noon and 2 pm (referred to as 10hrs, 12 hrs and 14 hrs in the paper). The variation is depicted graphically in fig.1. The nature of the graph is seen to be same for all the three times of sample collection.

Table 2: Increase in DO for various ozonation duration

Increase in DO in ppm	Time of ozonation in minutes								
	2	4	5	10	12	15	17	20	25
At 10 hrs	5.5	12.5	14.5	16	21	21	23	23	23
At 12 hrs	8	13	15	14	18	20	21	23	23
At 14 hrs	6.5	12.5	14.5	13.5	18.5	20	20.5	23.5	23

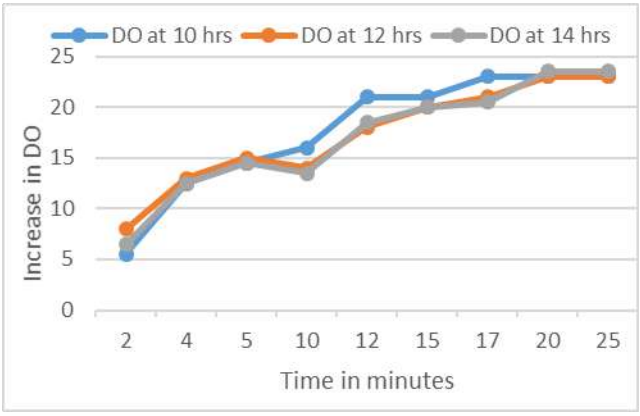

Fig 1: Increase in DO due to ozonation

B. *Effect of ozonation on COD*

The reduction in COD varies from 40-340 ppm for different time periods. The percentage reduction is seen to be around 5% for 2 min of ozonation to 80% for 25 min of ozonation. Table 3 shows the percentage reduction in the values of COD for various durations of ozonation while fig.2 shows the graphical variation. The nature of the graph is same for all the three times of sample collection and shows similar variation.

Table 3: Percentage decrease in COD for various ozonation duration

% decrease in COD	Time of ozonation in minutes								
	2	4	5	10	12	15	17	20	25
At 10 hrs	5	10	14	20	35	50	60	75	75
At 12 hrs	0	5	NA	14	33	43	67	81	81
At 14 hrs	11	16	16	25	30	40	55	75	75

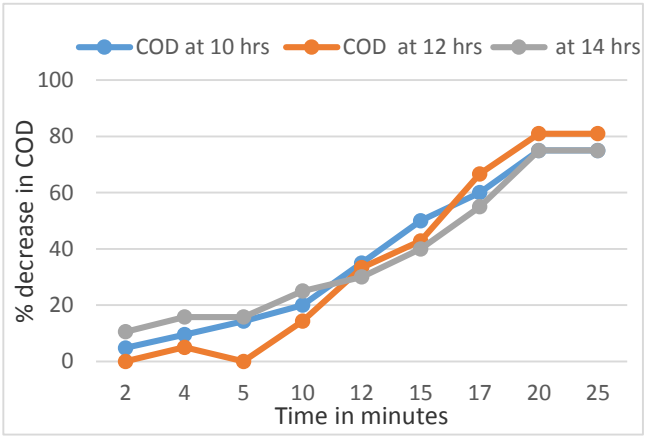

Fig 2: Percentage reduction in COD due to ozonation

C. *Effect of ozonation on turbidity*

The percentage reduction in turbidity varies from 2 to 18% in a time span of 25 min. as seen in table 4. This decrease does

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not seem to be large enough to warrant this method as a means of reduction in turbidity as the economics of providing ozonation for such long duration would lead to higher cost whereas this cost does not give sufficient reduction in turbidity.

Table 4: Percentage decrease in turbidity for various ozonation duration

% decrease in turbidity	Time of ozonation in minutes								
	2	4	5	10	12	15	17	20	25
At 12 hrs	0	0	0	1	3	10	13	16	18
At 14 hrs	2	6	8	11	12	13	13	16	16

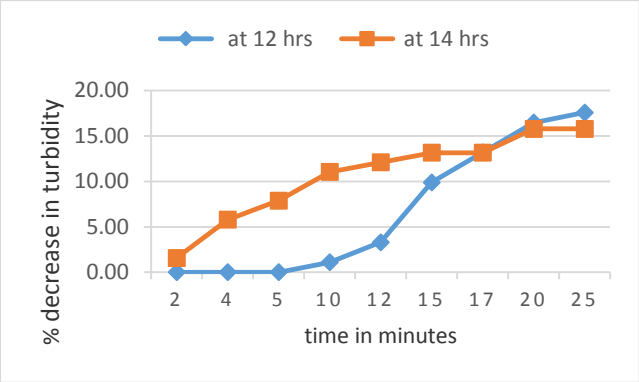

Fig. 3: Percentage reduction in turbidity due to ozonation

D. Effect of ozonation on hardness

The percentage reduction in hardness varies from 5-40% in a time span of 2 to 25 min. as seen in table 5 and fig.4. The reduction in hardness could be due to oxidation of dissolved salts present in the wastewater.

Table 5: Percentage decrease in hardness for various ozonation duration

% decrease in hardness	Time of ozonation in minutes								
	2	4	5	10	12	15	17	20	25
At 10 hrs	0	6	13	16	19	22	25	25	25
At 12 hrs	5	9	12	21	24	29	35	35	NA
At 14 hrs	6	9	14	29	34	34	37	37	40

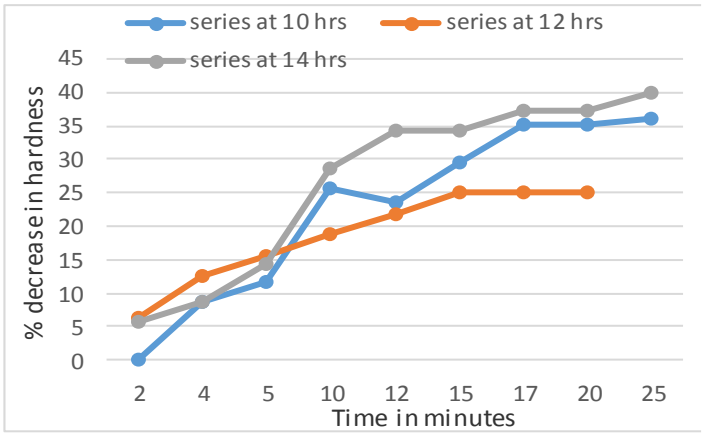

Fig.4 : Percentage decrease in hardness due to ozonation

IV. Conclusion

Ozonation is a method used currently for treating drinking water or as a tertiary method of treating domestic wastewater. Using ozone for wastewater treatment is expected to replace aeration and settling tanks resulting in savings in terms of space which is of prime importance in metropolitan cities. As the cities are expanding, space requirement for treating wastewater is also increasing; where ozonation may turn out to be helpful.

The decrease in the values of COD are very encouraging. Within a time span of 20-25 min, a residual COD of about 80-100 ppm is obtained showing a reduction of approximately 80%. This suggests that ozonation may be used for secondary treatment rather than using it only as a method of tertiary treatment.

Unlike chlorine, residual by-products are not formed during ozonation as ozone is unstable and decomposes on its own. Ozone results in greater ease of installation, operation and maintenance. Hence, ozone may turn out to be a greener option. But, in order to substantiate this, more experiments and further studies will have to be carried out. As mentioned earlier, the economics of the treatment are also not included within the scope of this paper.

Acknowledgment

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References

[1] P.Rajasulochana, V.Preethy (2016). Comparison on effiiciency of various techniques in treatment of waste and sewage water- A comprehensive review. *Resource Efficient Technologies* ,vol. 2, pp 175-184.

[2] I. Bakkaloglu, , T.J. Butter, L.M. Evison, I.C. Holland,. (1998). Screening of various types biomass for removal and recovery of heavy metals (Zn, Cu, Ni) by biosorption, sedimentation and desorption . *Water Science Technology* vol.38, pp 268–277.

ISBN 978-93-89105-41-4

[3] Stover, E.L., Haas, C.N., Rakness, K.L. and Scheible, O.K. (1986). Design Manual: Municipal Wastewater Disinfection. Cincinnati, OH, US Environmental Protection Agency.

[4] Singh, Saileshkumar, "Ozone Treatment of Municipal Wastewater Effluent for Oxidation of Emerging Contaminants and Disinfection" (2012). University of Windsor, Electronic Theses and Dissertations. 95.

[5] Donald R. Grothe & John W. Eaton; (2011), " Chlorine-Induced Mortality in Fish", Journal of *Transactions of the American Fisheries Society*, Vol.104, Issue 4, pp 800-802.

[6] Blaney, L. (2014). Ozone treatment of Antibiotics in water, Water Reclamation And Sustainability, 265-316 DOI: 10.1016/B978-0-12-411645-0.00012-2

[7] Scott C.A., Pierce SA, Pasqualetti MJ, Jones AL, Montz BE,Hoover JH (2011). Policy and institutional dimensions of the water–energy nexus. Energy Policy, vol. 39, pp 6622-6630.

[8] Panepinto D, Fiore S, Zappone M, Genon G, Meucci L. (2016). Evaluation of the energy efficiency of a large wastewater treatment plant in Italy. *Applied Energy*, vol. 161, pp 404-411.

[9] S.Rao Chitikela, K.Witt, S.Chandran, "Air Permitting of Municipal Water and wastewater Treatment options-An Overview" World Water and Environmental Resources Congress-2004, pp. 529-551

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Stabilization of Pavement Subgrade with Quarry Dust and Lime

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Abstract—**Marine clay deposits, which are typically of low strength, low stiffness, weak inter-particle bonding and very difficult to compact, are widely distributed in the coastal area and impose great challenges in the construction of highways along the coastal line, thereby such soils may need to be improved to make them suitable for Road construction activities. Accumulation and safe disposal of various waste materials is now becoming a major concern to the environmentalist. India has a large network of industries which are producing million metric tons of industrials waste. Quarry dust is one such by-product obtained during the production of aggregates through the crushing process of rocks in rubble crusher units. A range of tests that include standard Proctor tests (SPT), California Bearing Ratio (CBR) tests and micro-structural analyses by using X-ray Fluoresence (XRF) were conducted to investigate the properties of marine clay stabilized with stabilizers (Quarry Dust and Lime) in varying proportions. From the present study, it is observed that CBR value of the stabilized marine clay has been increased by 345% on addition of 25% Quarry dust and it has been improved by 460% for stabilized soil-Quarry dust-Lime (69:25:6) mixture.**

Keywords— ***Marine clay, Quarry dust, Lime, Compaction test, California Bearing Ratio, X-ray Fluoresence***

I. INTRODUCTION

The disposal of waste materials coming out of industry now a days is posing a great environmental and ecological problem. These waste materials can be effectively used in the pavement construction as they have got good potential in improving the strength of subgrade soil of pavement whereby there can be reduction in thickness of the pavement. Such construction may prove to be economical. In view of development of coastal areas in recent past, large number of ports and industries are being built. The viability of land for the development of commercial, housing, industrial and transportation, infrastructure etc in urban areas is a moot question. This necessitates the use of land, which has weak strata where geotechnical engineers are challenged by varying engineering characteristics of various problematic soils.

Continuous efforts have been made all over the world to different ways to solve the problems of marine clay. Some of the tried and tested remedial measures are placement of adequate surcharge load, chemical stabilization and use of various reinforcement techniques to avoid problem posed by marine clay. Expansive soils cause more damage to structures, particularly light buildings and pavements than any other natural hazard, including earthquakes and floods [1].

Quarry dust is a waste obtained in the quarrying process. Quarry dust/crusher dust is obtained as a soil solid waste during crushing of stones to obtain aggregates. The use of quarry dust is to ensure economic stabilization of soil and also used under flexible pavements to increase the load carrying capacity of the pavement by distributing the load through a finite thickness pavement[2]. The amount of quarry dust generated is about 25% of total output of each crushing unit. The annual production of quarry dust in India is about 200 million tons. [3] Problems associated with the construction of highways over clayey subgrade can be reduced significantly by mixing with quarry dust[4,5]

The aim of present study is to use the quarry dust as a stabilizing agent in addition with lime for soil subgrade material. The most important reason of using quarry dust with subgrade soil is economy and waste utilization.

II. BACKGROUND

Extensive literature is available on soil improvement by the application of additives, notably cement and lime. Lately, many researchers have reported on additives that could substitute lime as a soil modifier. Such materials include fly ash [6-9] , rice husk[10,11], marble dust [12,13]and quarry dust [14,15]

Sridharan and Soosan[16] conducted experimental studies on the shear strength of soil-quarry dust mixtures. The results revealed that the quarry dust proved to be a promising substitute for sand and can be used to improve the engineering properties of soils. Roohbakshan and Kalantri[17] investigated the effect of lime and waste stone powder on clayey soil. They reported that the plasticity index decreased with increase in a waste stone powder and lime content. Deepiya.[18]reported that the

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liquid limit of clayey soil has been decreased by 9.61% on addition of 38% quarry dust and 2% lime. They also concluded that the compressibility nature of soil reduces some extent with mixing of quarry dust andlime.

Sabat[14] analyzed, Compaction characteristics (Modified Proctor) and Shear Strength parameters using lime with expansive soil stabilized with Optimum percentage of quarry dust (40%). Addition of lime along with Quarry dust, decreased Plasticity Index, Maximum Dry Density whereas Plastic Limit, Shrinkage Limit, Cohesion and Angle of internal friction, Optimum Moisture Content of the soil –quarry dust mixes increased. Curing had positive effects on shear strength parameters and maximum values were reported at 5% addition of lime and 28 days of curing. Satyanarayana [19] had reported that the strength characteristics of compacted crushed stone mixes through a series of CBR tests by varying the crushed dust.

The aim of present study is to use the quarry dust as a stabilizing agent (in addition with lime) for soil subgrade material. A range of tests that include standard Proctor tests (SPT), and micro-structural analyses by using X-ray fluorescence (XRF) ,California bearing ratio (CBR),were conducted to investigate the properties of marine clay stabilized with stabilizers in varying proportions.

III. MATERIALS AND EXPERIMENTAL PROGRAM

A. Materials

The following materials are used in this study

Soil: Marine clay

It is collected from the JNPT (Jawaharlal Nehru Port Trust), Maharashtra State, India by approximately 50m-60m form the banks of the Uran River at a depth of 3m-3.5m. The location of the site in Google map is shown Fig.1. The index properties of soil are given in Table.1.

Fig. 1. Site location

TABLE 1. PHYSICAL PROPERTIES OF SOIL SAMPLE

Sr.No.	Parameters	Value
1	Specific gravity	2.5
2	Liquid limit (%)	80
3	Plastic limit (%)	35
4	Plasticity Index (%)	45
5	Shrinkage limit(%)	22.35
6	Sand (%)	3.9
7	Silt + Clay (%)	96.1 (47.1+49)
8	Unified Soil Classification	CH
9	Soil specification as per AASHTO	A-7-5
10	Optimum moisture content (%)	31
11	Maximum dry unit weight (kN/m3)	13.73
12	Unsoaked CBR(%)	4.54
13	Soaked CBR (%)	1.85

Quarry Dust

Quarry dust/Stone dust is obtained as soil solid wastes during crushing of stones to obtain aggregates. It has very recently gained good attention to be used as an effective Stabilizer. The Quarry Dust which is used for this investigation was collected from nearby crusher unit located in Navi Mumbai, Maharashtra. The Quarry Dust which is passing through 4.75mm sieve was collected and mixed with Marine clay from 0% to 30% at an increment of 5%.

The geotechnical properties of the Quarry Dust are given in Table .2.

TABLE 2. PHYSICAL PROPERTIES OF QUARRY DUST

Sr.No.	Parameters	Result
1	Specific Gravity	2.65
2	Sand Sized particles(%)	92
3	Silt and Clay Sized particles(%)	8
4	Maximum Dry Unit Weight (kN/m3)	18.8
5	Optimum Moisture Content(%)	12.85
6	Unsoaked CBR(%)	19
7	Soaked CBR(%)	10.5

Lime

Lime is a general term that includes three different types, such as quick lime (CaO), hydrated Lime [Ca(OH)2] and carbonate of lime (CaCO3). Quick lime and hydrated lime are commonly used in soil stabilization. Lime tests were performed. The following Table 3 lists the different admixtures used for this study was locally available quick lime mainly consisting of 61.05% CaO and 7.9% Silica.

The main contribution of lime to strength of soil is forming its ability decrease the apparent amount of fines in a soil causing flocculation and agglomeration of clay particles. Lime also create cementation between soil particles, higher the surface area of soil the more effective the process of lime cementation. Lime is easily available and thus it was used in our study.

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B. Testing Procedure

To find optimum percentage of quarry dust, for stabilization of marine clay, marble dust was varied from 5 percent to 30 percent by dry weight of soil in increments of 5 percent.

Standard Proctor Compaction tests, CBR tests were conducted on these samples/mixes according to the relevant Indian Standard codes. Further the lime was added from 0 to 10% at an increment of 2% to study the effect of lime on marine clay stabilized with optimum percentage of quarry dust. Different percentages of admixtures and their respective contents listed in Table 3. To establish the mineralogical composition of Marine clay, and quarry dust X-ray fluorescence (XRF) and their respective contents used in the present study.

TABLE 3.DIFFERENT PERCENTAGES OF ADMIXTURES AND THEIR RESPECTIVE CONTENTS

S.No	Type of Soil	Admixtures	Different Percentages of Stabilizing alternatives (% by weight of the dry Soil)
1	Marine Clay	Quarry dust	5,10,15,20,25,30
2	Marine Clay	Quarry dust+Lime	25+2,25+4,25+6,25+8,25+10

E. X-ray fluorescence (XRF)

The results of the chemical analysis carried out using X-ray fluorescence spectrometry (XRF) of the raw materials is summarized in Table 4. The values of the combined percentages of silica, alumina, and iron oxide in the quarry dust are more than 70% indicating their usefulness as natural pozzolana as per ASTM C618 (ASTM 1999).

TABLE 4.CHEMICAL COMPOSITION OF RAW MATERIALS

Sample	MC	QD
SiO2 (%)	39.10	54.40
Al2O3	13.30	15.00
Fe2O3	10.80	11.60
CaO	9.62	9.32
MgO	3.39	4.18
MnO	0.13	0.15
TiO2	1.51	1.10
Na2O	8.60	2.54
K2O	1.53	1.04
P2O5	0.47	0.16
SO3	5.90	0.10
Cl	4.63	0.03
SiO2 +Al2O3 +Fe2O	63.2	81

IV. ANALYSIS OF TESTRESULTS

The results of the Standard Proctor Test and CBR Test values of Marine Clay- Quarry Dust-Lime specimens are presented in Table 5.

TABLE 5 STANDARD PROCTOR AND CBR TEST RESULT

Marine Clay + Quarry Dust + Lime	Optimum moisture content %	Maximum dry unit weight (kN/m3)	CBR(%)(Un Soaked)	CBR(%)(Soaked)
(100+0)%	31	13.729	4.54	1.85
(95+5+0)%	28.26	14.27	7.08	3.43
(90+10+0)%	27.49	14.74	10.43	4.78
(85+15+0)%	26.88	15.18	12.35	5.05
(80+20+0)%	25.79	15.59	13.7	6.85
(75+25+0)%	24.39	15.79	15.35	8.25
(70+30+0)%	25.03	15.61	14.98	5.95
(73+25+2)%	24.06	15.89	15.84	8.76
(71+25+4)%	23.85	16.05	18.7	9.43
(69+25+6)%	23.07	16.56	20.73	10.37
(67+25+8)%	22.45	16.35	17.65	8.75
(65+25+10)%	23.68	16.2	14.7	7.16

Figure 2 shows the variation of maximum dry unit weight (MDU) of marine clay with addition of different percentage of Quarry dust and lime. MDU goes on increasing irrespective of the increase in percentage of addition of quarry dust and lime. MDU of soil increase from 13.72kN/m3to 16.2kN/m3 for stabilized soil with 25% quarry dust and 6%lime.Further, the addition of lime increases the OMC and decreases the maximum dry unit weight. The increase in MDU is an indicator of the improved properties of stabilizedsoil.

The OMC goes on decreasing irrespective of percentage addition of quarry dust and Lime as shown in Figure 3. The OMC decreases to a value of 23.85% from 31%, when 25% quarry dust and 6% lime were added to marine clay.

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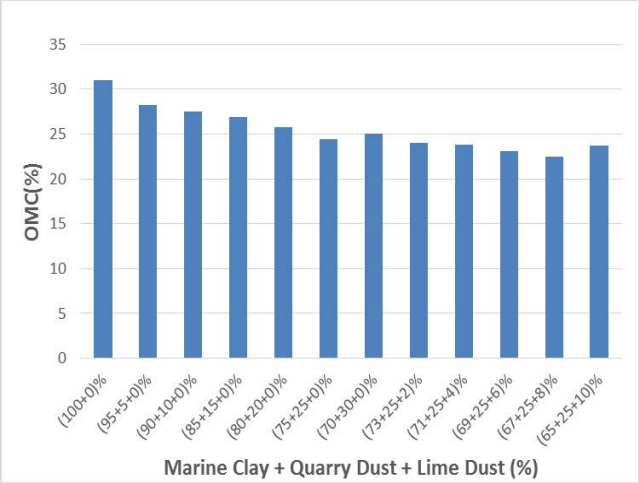

Fig.2. Variation of OMC with % of Quarry dust and Lime

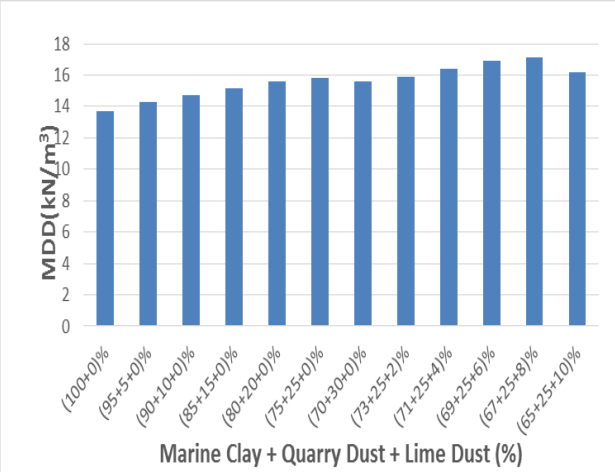

Fig.3. Variation of MDD with % of Quarry dust and Lime

California bearing ratio was conducted to find the suitability of soils for road pavements Fig.4.shows that the addition of Quarry dust increase the CBR value upto 25% since all the finer particles of soil and the Quarry Dust are used up to this value and addition of more becomes counter-productive, thereafter.

CBR values are varied from 8.25% to 10.37% when 6% lime added with 25% optimum quarry dust, and it decreases afterwards. Lime causes the soil particles to coagulate or flocculate. Thus soil becomes more easily workable and its strength and stiffness increases up to a certain value. [20]

CBR of soil increase from 1.85% to 10.37% for stabilized soil with 25% quarry dust and 6%lime which makes it suitable for subgrade soil for road pavements

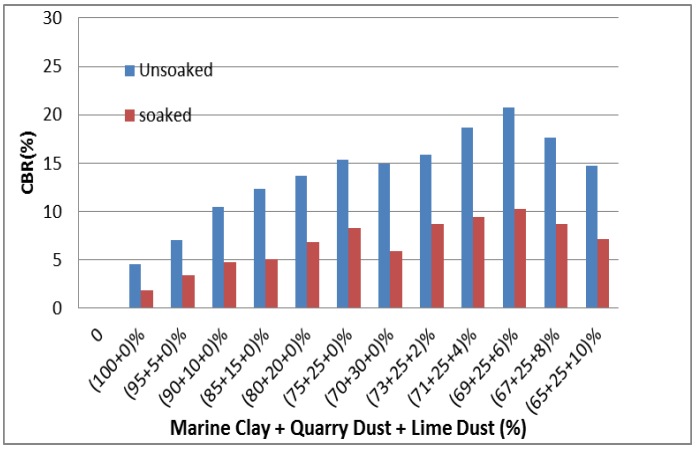

Fig.4. Variation of CBR with % of Quarry dust and Lime

V. CONCLUSION

A series of laboratory tests were conducted to study the effect of lime and Quarry Dust on Compaction Characteristics (MDD, OMC) and California bearing capacity (CBR) on marine clay.

Some of the broad conclusions deduced from the present experimental work are given below

- The O.M.C of the marine clay is found to be decreased by 21.32% on addition of 25% Quarry dust and further decreased by 23.06% on addition of 6% of lime.
- The M.D.U of the marine clay is found to be improved by 15% on addition of 25% Quarry dust and improved by 20.62% when 6% lime is added.
- X-Ray fluorescence of samples shows the The values of the combined percentages of silica, alumina, and iron oxide in the Marine clay and quarrydust.
- The California Bearing Ratio (CBR) Soaked value of the marine clay is found to be increased by 345.6% on addition of 25% Quarry dust and further, improved by 460% when 6% lime is added.
- For the best stabilization effect, the optimum proportion of Quarry Dust-Lime is found to be 69:25:6.
- The industrial waste like Quarry dust has a potential to modify the characteristics of Marine clay to be suitable in many geotechnical applications.
- Quarry dust itself satisfying required Subgrade bearing capacity, still an attempt has been made to analyse the effect of Lime along with Quarry dust.
- Based on the CBR value for the optimum proportion of Quarry Dust-Lime is satisfying the requirements of MoRTH. [21]

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VI. REFERENCES

1. D.E.Jones,, and W.G.Holtz, "Expansive Soils - the hidden disaster, Civil Engineering, ASCE 43(8), pp. 49-51, 1973.
2. O.J.Eze-Uzoamaka. and D.Agbo, "Suitability of Quarry Dust as Improvement to Cement Stabilized Laterite for Road Bases" EJGE. 15(K): 1053-1066, 2010.
3. R.K.Aditya Chansoria, M.E.Yadav ," Effect of Quarry Dust on Engineering Properties of Black Cotton Soil ," IJIRST, Volume 2, Issue 11 | April,2016.
4. T.G.Soosan, B.T.Jose, and B.M.Abraham, "Use of quarry dust in embankment and highway construction", Proceedings of Indian Geo-Technical Conference, Indore, pp. 274–277, December2001.
5. T.G.Soosan, B.T.Jose, and B.M.Abraham, "Improvement of ground and highway sub-bases using quarry waste," Proceedings of International seminar on civil engineering, ICCE, IISc. Bangalore, pp.730–737- July 2001.
6. E.Çokça,," Use of Class C Fly Ashes for the Stabilization of an Expansive Soil", Journal of Geotechnical and Geoenvironmental Engineering, Vol. 127, No.7, pp. 568-573,2001..
7. B.R.Phanikumar, R.S. Sharma, .: Effect of fly ash on Engg properties of expansive soil. J. Geotech. Geoenviron. Eng. 130(7), 764–767 (2004).
8. B.R.Phanikumar, R.S. Sharma Volume change behavior of fly ash-stabilized clays. J. Mater. Civ. Eng. (ASCE) 19(1) , 0899-1561(2007).
9. B.R.Phanikumar,: Effect of lime and fly ash on swell, consolidation and shear strength characteristics of expansive clays: a comparative study. Geomech. Geoeng. Int. J. 4(2), 175– 181 (2009).
10. A.S.Muntohar, "Behaviour of engineering properties of the clay blended with LRHA (lime rice husk ash)". Research Rep. from Grant, Muhammadiyah Univ. of Yogya-Karta, Yogya-Karta, Indonesia,1999.
11. A.S.Muntohar. and Hantoro"Influence of rice husk ash and lime on engineering properties of clayey subgrade" Electronical J. of Geotechical Engineering,2000.
12. C.O.Okagbue, and Onyeobi, "Potentials of marble dust to stabilize red tropical soils for road construction, Engineering Geology", 53, pp. 371-380, 1999.
13. A.K.Sabat, and R.P.Nanda, "Effect of marble dust on strength and durability of rice husk ash stabilised expansive soil", International J. of Civil and Structural Engineering, Vol.1 (4), pp 939- 948.,2012.
14. G. Purushotham. Sarvade and N. Sitaram , "Studies on the utilization of quarry dust to improve the geotechnical properties of lithomargic clay" International J. of Advanced Structures and Geotechnical Engineering ISSN 2319-5347, Vol. 03, No. 01, January 2014.
15. K. V. S. Raja Praveen, K.Vijay Teja, R. Dayakar Babu and K. V. N. S. Raviteja," strength behaviour of marine clay stabilized with Lime – quarry rock dust and waste plastics", https://www.researchgate.net/publication/262264361.
16. A.Sridharan, T.G.Soosan,: Utilization of quarry dust to improve the geotechnical properties of soils in highway construction" Can. Geotech. J. 28(4), 391–400 (2005).
17. Roohbakshan Armin and Kalantri Behzad "Stabilization of Clayey Soil with Lime and Waste Stone Powder", International J. of Scientific Research in Knowledge (IJSRK),1 (12),pp.547-556, (2013).
18. R.Deepiya, N.Durga, J.Steffi and S.Ayappan , "Stabilization of Clay Soil Using Quarry dust and Lime", International J. of Advanced Information Science and Technology, Vol.32, No.32,pp.111-114,2014.
19. P.V.V.Satya Narayana, P.Raghu, R.AshokKumar and N.Pradeep "Performance of Crusher Dust in High Plastic Gravel Soils as Road Construction Material", IOSR J. of Mechanical and Civil Engineering (IOSR-JMCE) Vol. 10, No. 3, pp. 1-5, 2013.
20. Ankur Mudgal, Raju Sarkar and A.K. Sahu effect of lime and stone dust in the geotechnical properties of black cotton soil" Int. J. of GEOMATE, Vol. 7, No. 2 (Sl. No. 14), pp. 1033-1039, Dec., 2014.
21. MORTH-2013: Specifications for Roads and Bridge Works, Ministry of Road Transportation and Highways, Govt. of India

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Prediction of unconfined compressive strength of stabilized soil using regression analysis

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***Abstract*— The necessity for providing the sufficient transportation facility for growing population is putting a lot of pressure on natural resources. Highway engineers are facing a problem for providing suitable material for highway construction. Several highway pavements are deteriorating due to lack of use of soil with adequate engineering strength. Most of the naturally available soil do not have adequate strength to support the wheel load. So the need for improvement of the engineering properties of soil has been a paramount concern to the transportation engineers. Engineering properties of soil can be enhanced by stabilization of soil using fly ash and cement. Unconfined compressive strength (UCS) is important geotechnical property which is widely used in design of the highway construction projects. It helps in measuring the strength and load bearing capacity of the soil. But Laboratory investigation using UCS test is tedious, expensive and time consuming process. Present study aims at developing the equations based on multiple regression analysis for evaluation of unconfined compressive strength of fly ash and cement stabilized soil. The accuracy of the model so developed is tested by assessing the coefficient of determination. Performance indices showed the better prediction capacity, indicated by coefficient of determination ranging from 0.84 to 0.97.**

Keywords*— Stabilized soil, Unconfined compressive strength, multiple regression analysis.

I. INTRODUCTION

Highway engineers are facing a challenge for providing suitable material to be used in highway construction to cater to increasing needs of growing population. On other hand several existing highway pavements are failing due to lack of use of soil with adequate engineering strength. It has become a key issue to transportation engineers to find soil that fulfils the basic criteria for proposed geotechnical design.

Laterite soil is formed in wet and hot tropical areas due to prolonged and rigorous chemical and mechanical weathering of the parent rock. It has poor engineering properties such as high plasticity, poor workability, low strength, high permeability. Thus the soil needs to be stabilized before construction to improve its properties. The ability to blend the naturally available lateritic soil with cement, fly ash and some chemical reagents to impart strength has been of vital importance to transportation engineers.

Fly Ash is combustion by product of coal industry and is Pozzolanic in nature. Stabilization using industrial waste and cementitious material is common technique to improve strength of weak soils. The strength developed by this stabilization technique depends on percentage of additives, soil properties and curing period. In order to reduce the time consuming process of laboratory investigation and for effective utilization of industrial waste, mathematical model should be developed.

II. REVIEW OF LITERATURE

Review of available literature shows that various laboratory investigations have been carried out on utilization of fly ash in conjunction with variety of soils. Douglas O. A. Osula [1] reported that the laterite soil when stabilized with lime and cement give more strength with the increase in time. Kalantri *et al.* [2] concluded that UCS and CBR of the cement stabilized soil, compacted at their respective OMC, increase by several folds. Purbi Sen *et al.* [3] studied the effect of fly ash, lime and cement for the strength improvement of soil. He concluded that strength of specimen increases with addition of fly ash. Joshi *et al.* [4] stated that, the addition fly ash to the highly plastic clay increased its strength and durability and decreases its plasticity characteristics. Lekha *et al.* [5] presented the engineering properties of chemically stabilized lateritic soil for pavements. The study reveals that there is an improvement in CBR, UCS values with the addition of chemical in the stabilized lateritic soil. Anagnostopoulos *et al.* [6] reported new statistical model describing compressive strength of cement stabilized soils based on the comprehensive laboratory work carried out for different silt clay soil mixes stabilized with various quantities of cement. The laboratory results were used for the development of a non-linear regression equation that best relates the compressive strength of a stabilized soil to the afore-mentioned parameters

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considered as the descriptor variables. Das *et al.* [7] compared two techniques, namely- artificial neural network and support vector machine technique for development of model for prediction of maximum dry density and unconfined compressive strength of soil stabilized with cement. Sharma *et al.* [8] developed the equations which are reliable and capable of predicting unconfined compressive strength of artificially structured soil. Das *et al.* [9] used previously available database to develop the prediction model to predict maximum dry density and unconfined compressive strength of cement stabilized soil using artificial intelligence techniques like Functional Networks (FN) and multivariate adaptive regression splines (MARS).

III. Problem Statement

Keeping in view some of the gaps in the available literature , an experimental study was undertaken to bring out the strength parameters of lateritic soil stabilized with different percentages of Fly ash and cement for different curing periods in respect of soaked and un-soaked conditions. Unconfined compressive strength is used as an input parameter to evaluate the strength of construction material in various geotechnical applications. But laboratory investigation using UCS is tedious, expensive and time consuming process. Prediction of soil behavior with additives can reduce the effort of doing experiments. The present study aims at developing regression equations using multiple linear regression technique based on the statistical approach. Intention of the present study is to compare the unconfined compressive strength observed experimentally with values predicted using the model so developed.

IV. Material Used

The lateritic soil used for the project was brought from Devgad (Ratnagiri District) of Maharashtra. The index properties of soil are mentioned in Table I

TABLE I. INDEX PROPERTIES OF SOIL

Sr.No.	Property	Value
1	Liquid Limit	21.79%
2	Plastic Limit	19.43%
3	Specific Gravity	3.1
4	Optimum Moisture Content	13.45
5	Maximum Dry Density	1.932

TABLE II. PROPERTIES AND COMPOSITION OF FLY ASH

Chemical Composition			
Property	**Value**	**Property**	**Value**
Silica (SiO_2)	58.04	Titanium Oxide (TiO_2)	1.3
Alumina(Al_2O_3)	25.71	Magnesium Oxide (Mgo)	1.589
Ferric Oxide (Fe_2O_3)	5.31	Sodium Oxide (Na_2O)	0.601
Sulphur Tri Oxide (SO_3)	0.677	Potassium Oxide (K_2O)	0.6
Calcium Oxide (C_2O)	5.59		
Physical Properties			
Specific Gravity		2.13	
Liquid Limit		20	
Plastic Limit		30	
Moisture		0.21	

The fresh fly ash to be used in the experimental investigation was provided by Dirk India Limited, Nasik, who in turn had obtained it from Nasik Thermal Power Station. The chemical composition and physical properties of the fly ash as supplied by the suppliers are mentioned in Table II

V. Experimental Method and Data Collection

The investigation is aimed at evaluating the effect of the various parameters in the context of the different combinations of mixes on the unconfined compressive strength test (UCS). The materials used include Lateritic soil, Fly Ash and Ordinary Portland Cement. In the investigation, the lateritic soil was proposed to be replaced by 10%, 20%, 30% and 40% fly ash and 1%, 2% and 3% Cement. Samples were tested for both soaked and un-soaked conditions. The soaking period was proposed to be kept as 8 Hours. The values of unconfined compressive strength of different mixes with respect to 7 and 28 days curing period were evaluated from laboratory experiment.

VI. Regression Analysis and Performance Indices

Proposed work encompasses the multiple regression analysis technique to develop the equation and predict the strength of various mixes. Development of predictive model or equations is based on accuracy of data. Data so obtained from extensive laboratory tests is used to derive the equations using multiple regression technique. Dataset is divided into two groups, as independent variables and dependent variable. Based on data collected from laboratory experiments, equations are developed which correlates the unconfined compressive strength of mix corresponding to 7 and 28 days curing period, with one dependent variable being unconfined compressive strength. The formula derived from the multiple regression analysis in respect of various mixes comprises of different combinations of the ingredients and having been cured for different curing periods.

Robustness of the equation or predictive model was evaluated from the statistical indices. Coefficient of determination measures the proportion of variance in dependent variable that is predictable from independent variable. It is sum of square of coefficient of correlation and it ranges from 0 to 1. An R^2 of 0 indicates that dependent variable cannot be predicted from independent variable while its value equal to 1 supports the claim that value of dependent variable can be evaluated without any error.

VII. Result and Discussion

The variation in unconfined compressive strength of fly ash stabilized soil in un-soaked condition is shown in Fig.1 whereas Fig. 2 shows the variation in unconfined compressive strength of soil stabilized with fly ash and cement.

It is found that strength of lateritic soil increases with increase in percentage of fly ash. Further, addition of slight amount of cement to a mix increases compressive strength. Experimental study indicates that soaking reduces the compressive strength of stabilized soil- fly ash-cement mixture. Further, strength of stabilized soil increases with increase in curing time.

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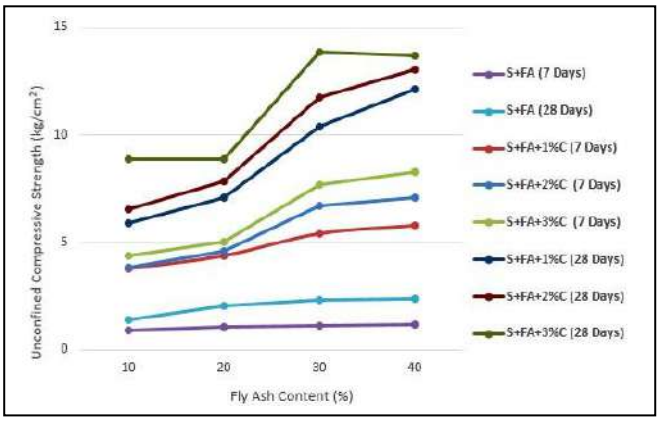

Fig. 1. Variation in unconfined compressive strength (Unsoaked Condition) with variation in Cement and fly ash content

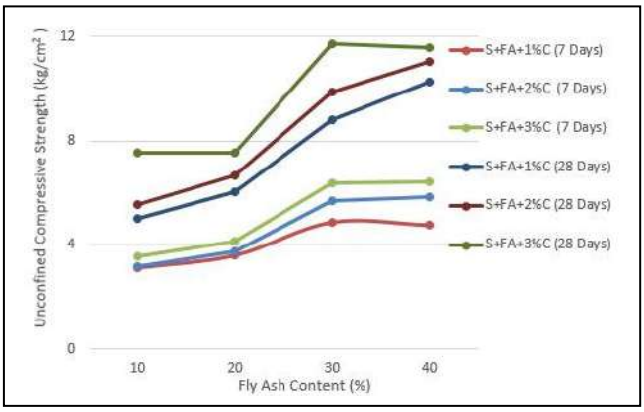

Fig. 2. Variation in unconfined compressive strength (Soaked Condition) with variation in cement and fly ash content

Intention of the current study is to develop the equations to evaluate unconfined compressive strength based on dependent parameters such as fly ash content and cement content. Data so obtained from extensive laboratory investigation is used to derive the equations using linear regression technique. Dataset is divided into two groups as independent variables and dependent variable. First set of parameters includes fly ash content and cement content which are grouped as independent variable where fly ash content varies from 10-40% and cement content varies from 0-3% by its weight. Unconfined compressive strength is considered as dependent variable.

TABLE III. EQUATION FOR PREDICTING UNCONFINED COMPRESSIVE STRENGTH

Mix	Details of Mix for experimental programme		
	Curing period	*Equation*	R^2
I	Soil + Fly Ash mix (Unsoaked Condition)		
A	7 Days	UCS = 0.850 + (0.009*FA)	0.973
B	28 Days	UCS = 1.210 + (0.033*FA)	0.838
II	Soil + Fly Ash + Cement (Unsoaked Condition)		
A	7 Days	UCS= 1.292 + (0.111* FA) + (0.746*C)	0.893
B	28 Days	UCS =2.171 +(0.216 *FA) + (1.211* C)	0.913
III	Soil + Fly Ash + Cement (Soaked Condition)		
A	7 Days	UCS= 1.342+(0.090*FA) +(0.505*C)	0.863
B	28 Days	UCS= 1.861+(0.182*FA) +(1.029*C)	0.914

Equations obtained from regression analysis to evaluate the unconfined compressive strength for curing period of 7 and 28 day are mentioned in Table III along with coefficient of determination (R^2). Coefficient of determination is evaluated to determine the accuracy of the equation so developed.

Values of unconfined compressive strength of the fly ash stabilized soil were predicted by applying the formulae obtained from multiple regression analysis. Fig.3 and fig.4 shows the comparison between the values of unconfined compressive strength predicted from the equation and value obtained from experimental work for curing period of 7 and 28 days respectively.

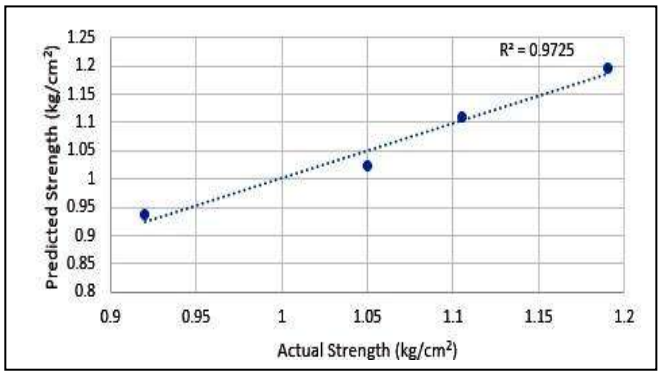

Fig. 3. Comparison of actual and predicted value of UCS (7 Day Curing) of Soil and fly ash Mix

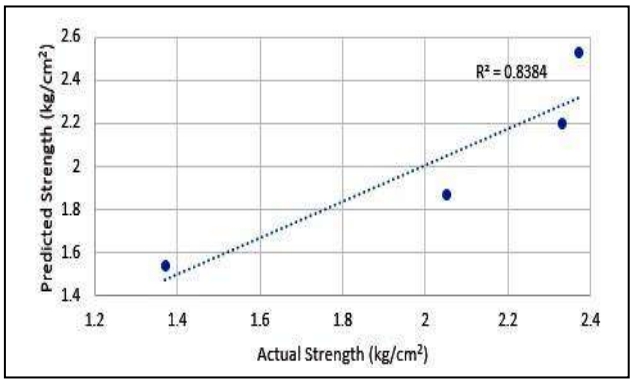

Fig. 4. Comparison of actual and predicted value of UCS (28 Day Curing) of Soil and fly ash Mix

Values of unconfined compressive strength of soil stabilized with Fly ash and cement for different soaking conditions were predicted by applying the formulae's obtained by multiple regression analysis. Fig.5 and fig.6 depicts the comparison between the values of unconfined compressive strength predicted from the equation and value obtained from experimental work for curing period of 7 and 28 days respectively.

From the regression analysis, it is found out that coefficient of determination for the various equations so formed to estimate or predict the unconfined compressive strength of the mix ranges from 0.838 to 0.973. This supports the claim that values can be predicted using the equations with more accuracy.

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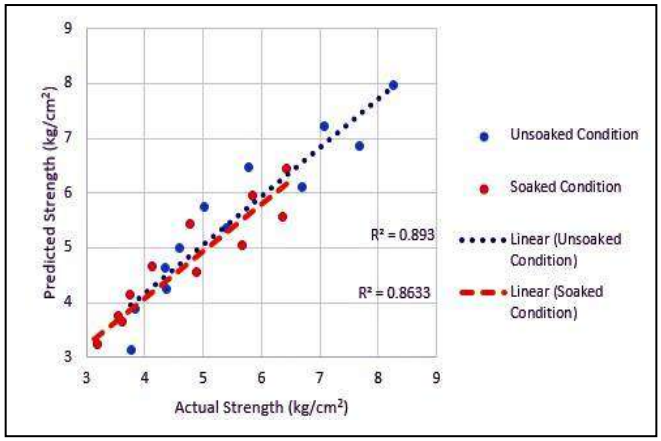

Fig. 5. Comparison of actual and predicted value of UCS (7 Day Curing) of Soil and fly ash and cement Mix

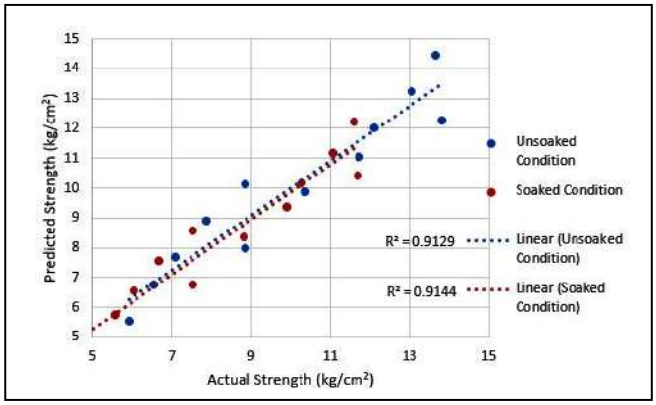

Fig. 6. Comparison of actual and predicted value of UCS (28 Day Curing) of Soil and fly ash and cement Mix

VIII. SUMMARY AND CONCLUSION

From the experimental studies conducted on the lateritic soil samples stabilized by fly ash and little amount of cement, it can be concluded that Pozzolanic activity of the fly ash and cementitious reactions of the cement increases the strength of the lateritic soil. Further, it can be said that the waste material such as fly can be used in conjunction with little amount of cement for stabilization of the lateritic soil and hence, the mix can be used as a sustainable civil engineering material. This will help highway engineers in improving the engineering properties of the weak soil and make it suitable for proposed geotechnical design.

Equations so developed from multiple regression analysis gave satisfactory results. Coefficient of determination indicates there exists a better agreement between predicted value and as actual value of unconfined compressive strength.

REFERENCES

[1] D.O.A. Osula," Evaluation of admixture stabilization for problem Lateritic", Journal of Transportation Engineering, vol. 115 (6), pp. 674-687, November 1989

[2] B. Kalantari, A. Prasad, B.B. Huat, “Use of cement, polypropylene fibers and optimum moisture content values to strengthen peat.” International journal of physical sciences,16;7(8), pp. 1276-85, February 2012

[3] P. Sen, M.D. Mukesh, M. Dixit, “Evaluation of Strength Characteristics of Clayey Soil by Adding Soil Stabilizing Additives.” International Journal of Earth Sciences and Engineering.;4(06), pp. 1060-1063, 2011

[4] R.C. Joshi, D.M. Duncan and H.M. McMaster, "New and conventional engineering uses of fly ash", Journal of Transportation Engineering, Proceedings ASCE, 101, pp. 791-806,Novemeber 1975

[5] B.M. Lekha, A.U. Ravi Shankar, G. Sarang, “Fatigue and Engineering properties of chemically stabilized soil for Pavements”, Journal of Geotechnical Engineering, 43(1), pp. 96-104, March 2013

[6] C.A. Anagnostopoulos, M. Chatziangelou, ”Compressive strength of cement stabilized soils. A new statistical model.”, Electronic Journal of Geotechnical Engineering, 13, pp.1-10, 2008.

[7] S. Suman, M. Mahamaya, and S.K. Das, “Prediction of maximum dry density and unconfined compressive strength of cement stabilized soil using artificial intelligence techniques.” International Journal of Geosynthetics and Ground Engineering, 2(2), p.11. June 2016

[8] L.K. Sharma, T.N. Singh,”Regression-based models for the prediction of unconfined compressive strength of artificially structured soil.” Engineering with Computers, 34(1), pp.175-186, January 2018

[9] S.K. Das, P. Samui, and A.K. Sabat,”Application of artificial intelligence to maximum dry density and unconfined compressive strength of cement stabilized soil.” Geotechnical and Geological Engineering, 29(3), pp.329-342, May 2011

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Modelling of post-tensioned beams with parabolic cable profile

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***Abstract*— In the last few decades, precast prestressed concrete construction has emerged as an effective solution for the accelerated infrastructure development of countries like India. Among these, post-tensioned bridge superstructure with cable profile curved in elevation and plan, which are easily cast at site, are increasingly adopted. Prototype development becomes very costly to determine the exact behaviour of such structures. Therefore, modelling of post-tensioned structures to study the behaviour is necessary. A post-tensioned beam with parabolic cable profile is modelled by using equivalent load technique and also under preload condition. The deflection as obtained from the models is compared with the theoretical results. It is seen that the behaviour of post-tensioned beams was accurately predicted by the model based on preload technique while that using the equivalent load technique exhibited slight variation.**

Keywords*— post-tensioned beam; concrete damage plasticity; finite element model; preload; equivalent load

I. INTRODUCTION

Practical applications of prestressed concrete structures have been gathering increasing attention. The scope of the pre-tensioning method is more or less restricted to prefabricated elements while the post-tensioning can be extended to cast in situ elements like slabs and beams and its applications include office, apartment buildings, parking structures, slabs-on-ground, bridges, sports stadiums, rock and soil anchors, water-tanks etc. In post-tensioned members, the ducts can be placed in a shape corresponding to the bending moment curve and this allows the prestressing to more effectively counteract the moment caused by external loading. Since the post-tensioned concrete can be cast in place, there is almost no limit to the shapes that can be formed using the technique.

Post-tensioned bridge superstructures with cable profile curved in elevation and plan, easily cast at site, are increasingly adopted these days. Modelling of these structures is highly appreciable. Arab et al. [1] used the Concrete Damaged Plasticity (CDP) model for the analysis of prestressed concrete beam. Pre-stressing strand is modelled in two methods such as extrusion technique and embedment technique. The results from the embedded models are found to be equivalent when compared to the corresponding extruded simulations.

A comprehensive overview of the modelling techniques that are used for the analysis of post-tensioned structures was presented by Aalami [2]. The prestressing tendon may be modelled as an applied loading to the member or as a load resisting component in the structure.

Robert [3] has already presented a method for the analysis of post-tensioned reinforced concrete structures in which a uniformly distributed or concentrated load was used to express the effect of tensile force in the cable. This provides a quite simpler method of analysis of the post-tensioned structures by making use of the familiar analysis methods used by designers and can help visualize the concept and function of prestressing easily. This simpler technique of analysis of the post-tensioned structures is adopted in this work to model the post tensioned beam. A combination of upward distributed load and axial compression on a beam simply can be used to express the effect of a parabolic cable provided within the beam. This is the basis of equivalent load technique used in the present modelling study. The full value of the applied tension will be taken by the direct compression given at the ends and the vertical component of cable tension will be taken as the vertical reaction developing at the beam ends. The presence of sheath housing the cable is expected to create a variation in moment of inertia of the structure which has been neglected in this method. The equivalent load method would be a simpler way of analysis of post-tensioned members.

Yapar et al. [4] also presented a nonlinear finite element model for pre-tensioned prestressed concrete beam allowing for plasticity and damage behaviour of concrete and slip-bond failure behaviour for strands.

Literatures available related to the finite element analysis of post-tensioned structures are limited and various modelling studies carried out for post-tensioned beams are with straight tendons only. The present numerical study was performed using the finite element analysis software ABAQUS 6.14 and used the CDP model to analyse the post-tensioned concrete beam. The study will be beneficial in the field of accelerated construction of bridges. Scope of this work is limited to study

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on behaviour of simply supported post-tensioned beams with a parabolic cable profile. Two different techniques of modelling were adopted; the load balancing technique or the method of equivalent loads and the preload condition to induce the prestressing of the strands in the post-tensioned beam. The load-deflection values obtained from the models are compared to the theoretical values.

II. FINITE ELEMENT MODELLING

A. Details of Specimen

A prestressed beam with dimensions 300 x 350 x 3700 mm and an effective span of 3500 mm was considered for the analysis. It was designed according to IS:1343-2012. The beam was reinforced with two 12 mm diameter bars at the bottom and two 10 mm diameter bars at the top. 8 mm diameter stirrups were provided at 200mm spacing. To counteract the bursting tensile force, the end zone was provided with bars of 8 mm diameter in the form of links. Two such links were provided at each end of the beam. The cross section of the beam is shown in Fig. 1. The prestressing force at the middle of cross section was calculated as 257.5 kN and 206 kN at transfer and service stages respectively. The stresses at the top and bottom of the beam were checked and were within the permissible limits as per IS 1343-2012. A parabolic cable profile with an eccentricity of 100 mm at the centre of span and zero eccentricity at the ends was adopted.

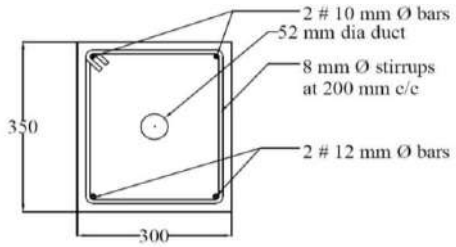

Fig. 1. Cross section of beam

B. Material Properties and Constitutive Models

1) Concrete

M60 grade concrete properties were adopted. The behaviour of concrete was represented by using the CDP model. The material properties were applied to the corresponding elements with reference to [4]. Concrete shows highly nonlinear behaviour under tension as well as in compression, due to its cracking and plasticity nature. A combination of two numerical material models was used in the study to represent the complete stress-strain response of concrete in tension and compression with the inclusion of damage properties. A constitutive model modified by Thorenfeldt et al. was used to describe the compressive behaviour of concrete [5]. The stress strain curve for the high strength concrete in compression based on this model is shown in Fig. 2.

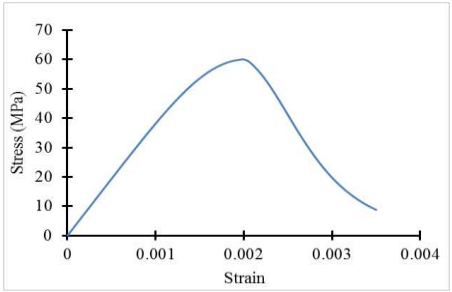

Fig. 2. Thorenfeldt model

. Belarbi & Hsu model as in Fig. 3 was used to depict the stress-strain behaviour of concrete in tension [6]. Three dimensional solid brick element C3D8R was used to simulate the concrete property.

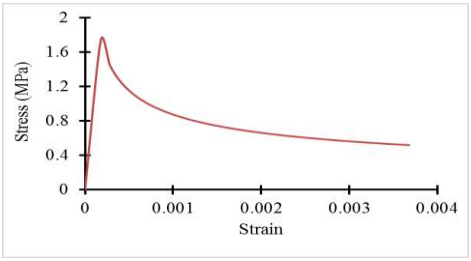

Fig. 3. Belarbi and Hsu model

The plasticity behaviour of concrete depends upon four parameters such as Dilation angle (φ), eccentricity (ε), ratio of biaxial and uniaxial compressive strength (f_{bo}/f_{co}), ratio of deviatory stress in uniaxial tension to uniaxial compression (K_c). Viscosity parameter (μ) is considered to encounter convergence error [7]. Constants used in this study are listed in Table 1.

Table 1 CDP model parameters

Dilation angle (φ)	**Eccentricity (ε)**	**f_{bo}/f_{co}**	**Kc**	**Viscosity parameter (μ)**
31^o	0.1	1.16	0.667	0.0001

2) Steel and prestressing strand

The strand in the preload condition technique and the steel reinforcement were modelled as elastic-plastic material. The stress- strain behaviour of 1862 MPa low relaxation prestressing strand was taken from Devalapura et al. [8]. The stress-strain behaviour of non prestressing steel and prestressing steel are shown in Fig. 4. Properties of low relaxation strands used in the model are shown in Table 2. A single strand of equivalent diameter 15.86 mm was provided in the beam instead of two strands for the ease of modelling. To model this strands behaviour in simulation, plasticity parameter was considered since its behaviour is ductile in nature. Wire element (T3D2) is used to simulate strand property and plasticity model is selected for strands.

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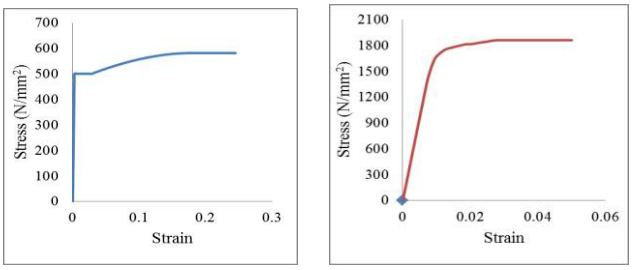

Fig. 4 Stress strain behaviour of steel and prestressing strand

Table 2 Properties of strand

Avg. Tensile strength (MPa)	1862
Area of cross section (mm^2)	98.40
Modulus of elasticity (MPa)	195000
Poisson's ratio (γ)	0.30
Nominal mass (kg)	0.775
Braking load (kN)	185.6
Size	7 ply 12.7 mm

C. Finite Element Model

The required contact between the steel reinforcements and concrete to make the steel set fully into the concrete mass was ensured by the embedded region constraint. In the preload condition, the prestressing strand was also embedded into the concrete using the same constraint. The reinforcement assembly inclusive of the prestressing steel in the preload condition is shown in the Fig. 5. Mesh convergence studies were performed using the measurements of deflections to select a finer mesh to obtain a more reliable result. The beam was discretized with an approximate element size of 20 mm. The finite element model is shown in Fig. 6.

Fig. 5 Reinforcement assembly in finite element model

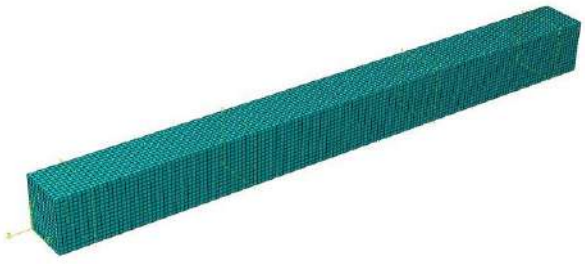

Fig. 6 Finite element model

The parabolic strand was removed in the load balancing technique. Instead an axial load of 190.12kN and upward equivalent load of 12.416 kN/m were applied on the beam to simulate the effects of prestressing force on the concrete beam at the transfer stage after the reduction of immediate losses. At the loading stage, the applied loads were 170kN and upward distributed load of 11.279 kN/m considering the total losses in prestress. The loading setup is shown in Fig. 7. The model was analysed during the transfer stage to check the upward deflection induced due to application of prestress and also during the loading stage to study the deflection characteristics and behaviour under loading.

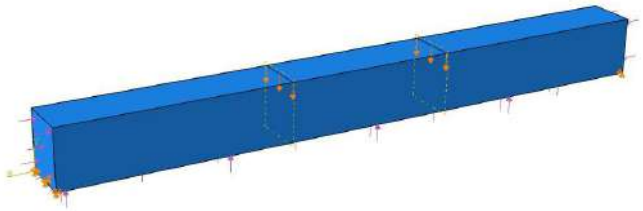

Fig. 7 Loading in method of equivalent loads technique

Prestress was directly applied to the strand using the predefined field manager in the preload technique. The effect of prestress was modelled as an effective initial prestress applied on the prestress wire truss element uniformly. The applied stress on the strand was 963.122 N/mm^2 at transfer stage and 874.982 N/mm^2 at loading stage. This was after deductions for all immediate losses at the transfer stage and deducting the total losses at the loading stage. Fig. 8 shows the tensioned strand. The boundary conditions remained the same in both the methods.

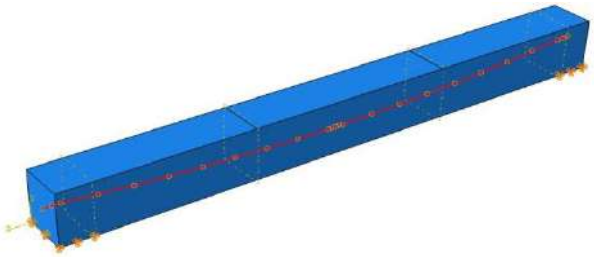

Fig. 8 Loaded strand in preload condition

III. RESULTS AND DISCUSSION

A. Deflection Due to Application of Prestress

The application or transfer of prestressing force resulted in an upward deflection in the beams. The upward deflection calculated theoretically for the prestressed beam with a parabolic cable was 0.648 mm. The profile of the beam and corresponding deflection as obtained from both the finite element models are shown in Fig. 9.

Table 3 shows the upward deflections as obtained in the two models. The calculated deflection nearly matched to the values obtained from the numerical models.

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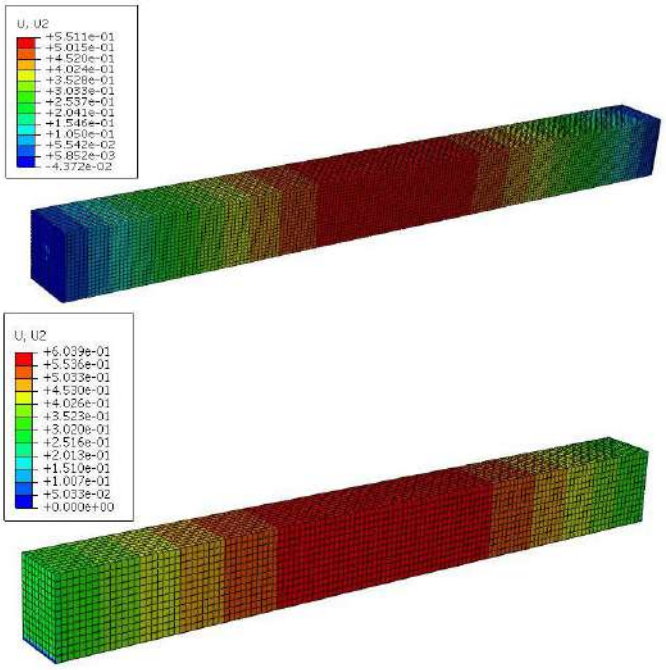

Fig. 9 Deflection due to prestress under preload and equivalent load

Table 3 Comparison of deflection at transfer stage

	Preload Condition	Equivalent Load Technique
Upward deflection (mm)	0.5511	0.6039

The load-deflection behaviour at the centre of the beam from the two models is shown in Fig. 10. The load-deflection plot showed a linear behaviour upto the cracking load beyond which it attains a non-linear behaviour. Displacement controlled loading procedure was used in the finite element analysis. It was noticed that the modelling under preload condition gave agreeable results while the results showed slight variation in case of equivalent load system from calculations based on flexural strength of concrete.

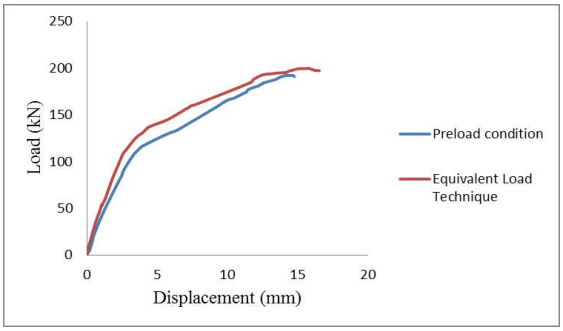

Fig. 10 Load –Deflection Characteristics

Equivalent load technique offers reduced computation time and is a simpler method to introduce the effect of prestressing. Thus for complex sections, equivalent load technique may be used to predict the behaviour in an approximate manner, whereas preload technique actually simulates the effect of prestressing and provide good results.

Crack initiation was identified by the change in slope of load- deformation plot as obtained from the finite element model. The damage pattern at the failure stage predicted by the model using preload technique is shown in Fig. 11. A similar pattern was obtained from the equivalent load technique also.

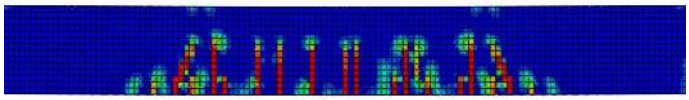

Fig. 11 Damage pattern from finite element model

The cracking and ultimate loads corresponding to the model based on the two techniques are shown Table 4. Cracking load was calculated theoretically based on the flexural tensile strength of concrete and obtained as 108 kN.

Table 4 Cracking and Ultimate Loads

	Preload condition	Equivalent load technique
Cracking Load (kN)	111	114
Ultimate Load (kN)	192	200
Deflection at ultimate Load (mm)	14.51	15.75

IV. CONCLUSION

The study aimed at developing a finite element model to study the behaviour of post-tensioned beam in an easier and simpler way. In the absence of adequate and detailed test results, the numerical models developed in various finite element packages would be an asset in assessing the behaviour of post-tensioned members.

The displacement and crack patterns obtained from finite element models almost matched with each other. The models were showing good correlation with the theoretical studies also, while in the case of equivalent load technique, the model results showed a slight variation. The stiffness as observed in the numerical model was higher for the equivalent load technique when compared to preload condition.

The modelling under preload condition can be used to predict the behaviour of post tensioned beams accurately. The equivalent load technique concept may also be incorporated in finite element modelling which predicts the beam behaviour in an approximate manner.

The study was limited to simply supported post-tensioned beams with parabolic cable profile. The study may

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be extended to beams of other support conditions also. Further experimental studies are also recommended.The cable profile may also be varied and the effect can be studied.

REFERENCES

[1] **Amir A. Arab, Sameh S. Badie and Majid T. Manzari (2011). A methodological approach for finite element modeling of pretensioned concrete members at the release of pretensioning, Engineering Structures, 33,1918–1929.**

[2] **Bijan O. Aalami (2000). Structural modeling of post tensioned members,Journal of Structural Engineering, ASCE, 126(2), 157-162.**

[3] **Robert B. B. Moorman (1952). Equivalent Load Method For Analyzing Prestressed Concrete Structures, Journal Of The American Concrete Institute, Title No. 48-28.**

[4] **Yapar O, Basu P.K and Nordendale N. (2015). Accurate finite element modeling of pretensioned prestressed concrete beams, Engineering Structures, 101, 163-178.**

[5] **Thorenfeldt, E. Tomaszewicz, A. and Jensen, J.J. (1987). Mechanical Properties of High-strength Concrete and Application in Design, Proceedings of the Symposium-Utilization of High-Strength Concrete, Tapir, Trondheim, 149–159.**

[6] **Belarbi, A., & Hsu, T. T. C (1994) Constitutive laws of concrete in tension and reinforcing bars stiffened by concrete,ACI Structural Journal, 91(4), 465–474.**

[7] **Lakavath, C., Joshi, S. S., &Prakash, S. S. (2019). Investigation of the effect of steel fibers on the shear crack-opening and crack-slip behavior of prestressed concrete beams using digital image correlation. Engineering Structures, 193, 28-42.**

[8] **Devalapura R K and Maher K. T (1992). Stress-Strain Modeling of 270 ksi Low-Relaxation Prestressing Strands, PCI Journal, 37(2), 100-106.**

[9] **Ho Park, SeungminJeong, Seong-Cheol Lee and Jae-Yeol Cho (2016). Flexural behavior of post-tensioned prestressed concrete girders with high-strength strands, Engineering Structures, 112, 90-99.**

[10] **IS 1343-2012: Indian Standard Code Of Practice For Prestressed Concrete**

[11] **IS 456-2000: Indian Standard Plain and Reinforced Concrete - Code Of Practice**

[12] **IS 6006 (1983): Uncoated stress relieved strand for prestressed concrete**

[13] **IS 14268 (1995): Uncoated stress relieved low relaxation seven-ply strand for prestressed concrete**

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Effect of Nickel on the Adsorption characteristics of Landfill Liner using Marine soil

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Abstract— Landfill liners are containment systems for the careful handling and disposal of waste materials which may otherwise causes severe environmental and health related consequences. Leachates generated from a landfill contain a higher aggregate of heavy metal ions that are the roots of unhygienic environment.In order to maintain a balanced ecosystem an engineered landfill liner that could adsorb a higher quantity of heavy metals are required. This study discusses about the suitability of soil bentonite mixture as a liner material emphasizing its adsorption characteristics by focusing batch adsorption and batch studies. Adsorption studies are carried out by varying different dependent parameters. Various adsorption isotherm models are plotted with different initial conditions out of which a perfectly fit model is determined. Adsorption study revealed that Freundlich model better fits the experimental data when compared with other isotherms models.

Keywords- Liner, Heavy metal, Batch adsorption, Isotherm

I. INTRODUCTION

One of the major threats faced by the society nowadays is the disposal of waste materials without emphasizing its safety and hazardous conditions. Conventional practice of disposing waste is into a landfill that lack engineering design and criteria. Due to the increase in the industrialization most of the municipal solid waste landfills are dumped with industrial wastes which contain a number of heavy metals. These heavy metals can cause serious health related consequences as well as harmful environmental impacts. Nickel, Cadmium, Copper, Mercury, Nickel, Chromium, Iron, Zinc and Selenium are the major heavy metals commonly found in the landfill leachate. It is necessary to construct an engineered landfill that could adsorb these heavy metals on to their surface and there by prevent the migration of these ions to the surrounding groundwater.

Landfills accept a variety of wastes that could contain a mixture of organic and inorganic hazardous constituents. Therefore poorly designed landfills and migration of leachate from the landfills pose a serious environmental threat. A landfill liner is an impermeable membrane laid under engineered landfills to retard the migration of leachate and also to isolate the waste materials from surroundings. Low permeability soils are most commonly used soil for the construction of landfill liners. If locally available soil doesn't meets liner criteria then bentonite is added to the soil to form an amended clay liner. The hydraulic conductivity of such soil based structures may get affected by the formation of desiccation cracking, which can result in the loss of effectiveness of the containment system as an impermeable barrier. Leachate migrates through the cracks at a much greater rate. Various efforts are put forward to address these problems out of which using admixtures with soil were one of the economically feasible practices.

Landfill requires a layer of compacted clay with an optimum thickness of 2 feet to minimize crack and to allow leachate migration (US EPA 1997). It should have a hydraulic conductivity in the range of 10^{-7} cm/sec. According to the waste materials the liner design and material varies. In addition to other organic and inorganic materials heavy metals are the major constituents present in the landfill leachate. Even in traces these heavy metals are harmful to the organisms and the environment. The chief sources of these metals are from fertilizers, paints, textiles, electronic industries, batteries, iron and steel industries, chemical factories etc. The major health issues are respiratory problems, skeletal damages, damages to the

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nervous system, pulmonary system, visual disorders etc. Nickel compounds are skin irritants, which can cause allergies and thereby causing respiratory problems [1]. They are even carcinogenic in nature, thus good absorption characteristics to restrict the mobility of heavy metals for a barrier material are desirable.

Transfer of materials from a fluid phase to a solid phase is termed as adsorption. It can be either physical or chemical in nature. The transport process involved in adsorption is analyzed by using batch adsorption, one-dimensional equilibrium adsorption on a column, and one-dimensional non-equilibrium adsorption.

An adsorption isotherm is a plot between equilibrium concentration of the adsorptive and the quantity of adsorbate on the surface at constant temperature which is used to represent adsorption. There are many empirical adsorption models, out of which Langmuir adsorption isotherm model is the commonly used model. This model assumes that there is a specific amount of site that is available for adsorption and adsorbent molecules will adhere to that specific site. Several other models dealing with two, three, and multi parameters are involved in the adsorption study [4]. The best fit of the experimental data with these models can give a suitable method for computing the adsorbed quantity and several other adsorption parameters. This study were to evaluate the optimum percentage of bentonite used for the preparation of amended clay liner and also investigate the adsorption behavior of amended clay liner using marine soil bentonite.

II. MATERIALS AND METHODS

A. Materials

1) Bentonite

Bentonite is a clay with extra ordinary properties such as very high expansion capability by absorbing water (swelling capacity), high ion exchange capacity and very low water permeability. Two types of commercially available bentonites like calcium bentonite and sodium bentonite are commonly used. Calcium bentonite is less sensitive to leachate compared to sodium bentonite. Calcium bentonite used in the study was procured from a quarry near Coimbatore in Tamilnadu. The index and engineering properties of calcium bentonite is found out in laboratory as per Bureau of Indian standards, are presented in Table 1.

2) Marine Soil

The Marine soil was collected from Cochin Coastal area at a depth of 2m below the ground level. The collected sample was first air dried and pulverized into fine powder. The prepared samples were used to determine the geotechnical characteristics, the properties were shown in Table 1.

TABLE 1 PHYSICAL PROPERTIES OF THE MATERIALS.

Property	Marine Soil	Bentonite
Liquid limit (%)	48	265
Plastic Limit (%)	26	54
Shrinkage limit (%)	35	6
Specific Gravity	2.20	2.6
Percentage clay	26	34
Percentage silt	44	74.33
dry density (g/cc)	1.74	1.33
OMC(%)	19.50	13.62

B. Synthetic Leachates

Leachate sample for the study is collected from the Njeliyanparamba landfill, Kozhikode district. It is a municipal solid waste landfill that handles around 100 tons of waste per day. Leachate samples are collected from its leachate plant. The properties of the leachate sample are listed in the Table2. The sample was tested inorder to identify the major heavy metals that are present in the leachate.

TABLE 2 COMPOSITION OF ACTUAL LEACHATE COLLECTED

Parameter	Value
pH	8.06
Chloride	4199mg/L
Conductivity	28.25 mS/ppt
Turbidity	126.7NTU
Total dissolved solids	7.9 mg/L

TABLE 3 CHEMICAL COMPOSITION OF ACTUAL LEACHATE COLLECTED

Leachate constituents	Mean value(mg/L)	Standard value
Fe	30	-
Cu	0.35	3
Zn	1.6	5
Cd	0.1	2
Ni	1.12	3
Pb	0.23	0.1

Synthetic leachate was prepared by using Nickel chloride hexahydrate. A stock solution was prepared to get 1PPM

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(1000mg/L) of solution for which 1.6g of Nickel chloride hexahydrate is mixed with a litre of distilled water. Further it is diluted to 10 gm/L, 20gm/L, 30gm/L, 40gm/L and 50 gm/L.

B. *Methodology*

In order to find the optimum bentonite percentage for a liner material, the hydraulic conductivity which is the important property of a liner material was studied by varying the bentonite content from 0 to 7%. The standard proctor test was done according to IS 2720(part 7) to obtain the maximum dry density and optimum moisture content. Adsorption characteristics of the liner material were studied by conducting Batch adsorption test. The adsorption data was analyzed using various numerical models.

1)Standard Proctor Compaction test

Compaction is the process of reduction in volume of soil by the reduction of air void in it under sudden impact loading. The test is performed as per IS 2720-part 7-1980.

2) Batch adsorption test

Batch adsorption test was conducted as per ASTM D4646-16 standards for finding out the adsorption characteristics of the liner material. In a conical flask soil leachate mixture was taken and agitated in a mechanical shaker and then decanted. A small retention time was provided after which it is filtered through a Whatman filter paper. The filtrate is analysed using an atomic adsorption spectrophotometer for finding out the equilibrium concentration of the liner material. Figure 1 shows the test set up of a batch adsorption test. Studies were conducted by varying the concentration of the leachate solution. Equation (1) and (2) shows the relation between equilibrium concentration and percentage adsorbed where is the quantity adsorbed (mg/g), V is the volume of solution (ml), M is the mass of soil (g), is the initial concentration (mg/L) and is the equilibrium concentration (mg/L).

$$qe = (Ci - C0)/M \quad (1)$$

$$\text{Percentage adsorbed} = ((Ci - Ce)/Ci) * 100 \quad (2)$$

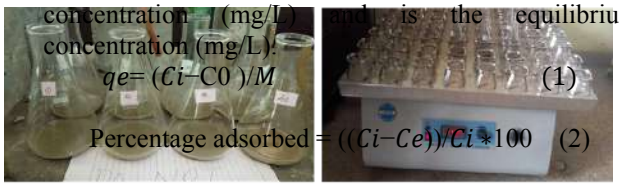

Fig 1.Batch adsorption test equipments

3. Langmiur adsorption model.

Langmiur assumed that chemical adsorption does not occur beyond a single layer and hence layer adsorbed will only be one molecule thick. It is a theoretical model where the adsorption surface is plane without any corrugations and the molecules adsorbed don't interact with the adjacent sites. Equation (3) & (4)shows the general and linear form of the langmiur adsorption isotherm model, where represents the concentration of adsorbate at equilibrium is, is the amount adsorbed at equilibrium, is the maximum amount adsorbed and b is the coefficient related to affinity. One of the peculiarities of Langmiur adsorption isotherm is that it takes into account a special factor termed as separation factor (R_L) which defines the favorability of the adsorption. It is given by the equation (5) and if $0<R_L<1$ then Favourable adsorption occurs, $R_L > 1$ Unfavourable adsorption, $R_L = 1$ Linear adsorption and if $R_L = 0$ Irreversible adsorption.

$$Ce/qe = 1/(bqm) + Ce/qm \quad (3)$$

$$qe/qm = bCe/(1+bCe) \quad (4)$$

$$RL = 1/(1+(bCo) \quad (5)$$

4. Freundlich adsorption model

It is an empirical model that assumes adsorption occurs on to a rough heterogenous surface. It is extended to multilayer adsorption where non uniform heat of adsorption and adsorbate affinity is considered. This model lacks a strong thermodynamic mechanism. Equation (6), (7) represents the general and linear form of freudlich adsorption isotherm model respectively, where is the concentration of adsorbate at equilibrium, is the amount adsorbed at equilibrium,K_f , the intercept and 1/n is the slope of the isotherm plotted.

$$q_e = K_f Ce^{1/n} \quad (6)$$

$$\ln q_e = \ln K_f + \ln C_e \quad (7)$$

5. Temkin adsorption model

One of the peculiarity of the Temkin adsorption isotherm is that it explicitly take into account a factor that represent adsorbent adsorbate interaction. It assumes a logarithmic relationship and its derivation are put forward with an assumption of uniform distribution of binding energy. Equation (8) & (9) represents the general and linear form of Temkin adsorption isotherm where is the Temkin isotherm equilibrium binding constant (L/g), b is the Temkin isotherm constant, R is the Universal gas constant (8.314 J/mol/K), T is the standard temparature (298K) and is the constant related to heat of sorption.

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$$q_e = \frac{RT}{b}\ln(A_T C_e) \quad (8)$$

$$q_e = \frac{RT}{b} lnA_T + \left(\frac{RT}{b}\right) lnC_e \quad (9)$$

6. Dubinin Rudushkevich isotherm model

Adsorption mechanism is expressed as Guassian energy distribution over a heterogeneous surface. One of the main features of this model is that it is temperature dependent. The equations (10) & (11) represent the general and linear form of D-R model, where *q* is theoretical isotherm saturation constant (mg/g), K_{ad} is the D-R isotherm constant (mol^2/ kJ^2), Є is the D- R isotherm constant and is given by the equation (12).

$q_e = q_s \exp(-K_{ad} Є^2)$ (10)

$lnq_e = lnq_s - K_{ad} Є^2$ (11)

$Є = RT \ln(1 + 1/Ce)$ (12)

C. *Results and Discussion*

1. Determination Of Optimum Bentonite Content

It is observed that with increase in the bentonite percentage from 0 to 7% there is a decrease in the maximum dry density and an increase in the optimum moisture content. This result may be attributed to the high activity of the bentonite which allows more water molecules to get adhere onto the clay surface and thereby reducing the maximum dry density. Compaction characteristics of the soil at different bentonite percentage are shown in the Fig.2

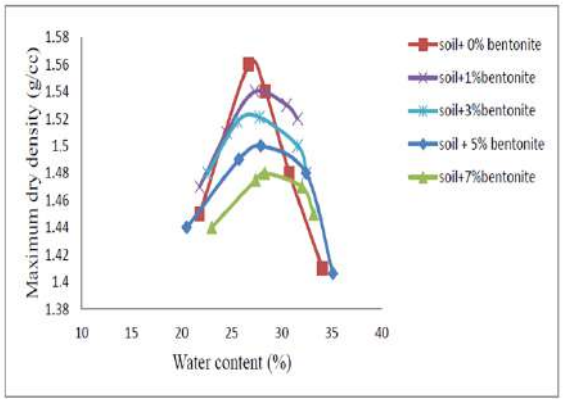

Fig 2.Compaction curve for various bentonite percentage

2.Isotherm Parameters

a. *Langmiur adsorption isotherm*

When the experimental data was plotted according to Langmiur adsorption isotherm equation, it is observed that isotherm has got a distribution coefficient value (R^2) of 0.97. The maximum quantity that can be adsorbed (q_m) is obtained as 0.36mg/g. The Fig.3 shows the adsorption isotherm plotted and Table 4 shows the values of the adsorption parameters obtained from the graph plotted. One of the other features of this Langmiur isotherm is a factor termed as separation factor (R_L). It is seen from table 5 that R_L value for all the cases is below 1 showing that the adsorption is favorable.

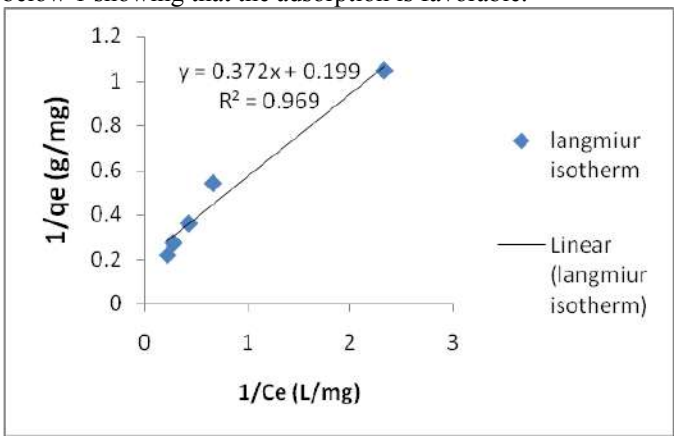

Fig 3. Langmiur adsorption isotherm

TABLE 4. ADSORPTION PARAMETERS

Parameters	Value
Slope	0.372
Intercept	0.199
q_m (mg/g)	5.025
b	0.074

TABLE 5 SEPERATION FACTOR FOR DIFFERENT INITIAL CONCENTRATION

Initial Concentration (C_o) (gm/L)	R_L (Separation Factor)
10	0.57462
20	0.403135
30	0.310478
40	0.252454
50	0.212703

b. *Freudlich adsorption isotherm*

The Freudlich adsorption isotherm plotted is shown in the Fig.4, from which it is clear that the R2 value for this case is 0.99. Value of an adsorption parameter Kf is 1.57 mg/g which gives an approximation of the maximum adsorbed quantity. It's shown in Table 6.

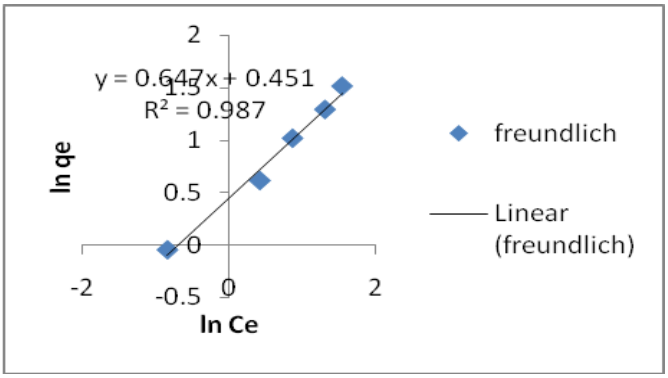

Fig 4. Freundlich adsorption isotherm

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Parameters	Values
Slope	0.451
Intercept	0.647
Kf	1.569881282

TABLE 6. ADSORPTION PARAMETERS

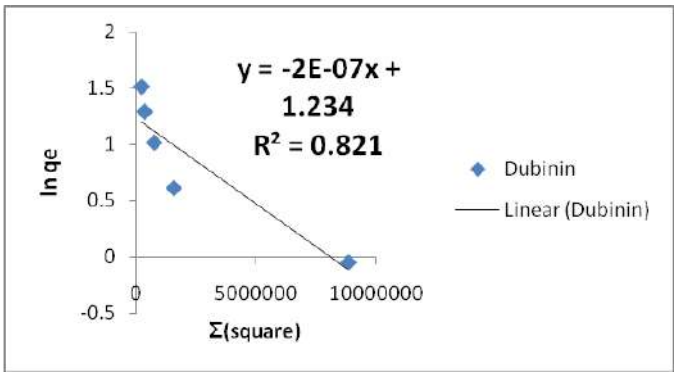

Fig 6. Langmiur adsorption isotherm

C. *Temkin adsorption isotherm*

The R^2 value obtained is 0.9 which is clear from the graph shown in the Fig.5Table 7 contains the values obtained as adsorption parameters

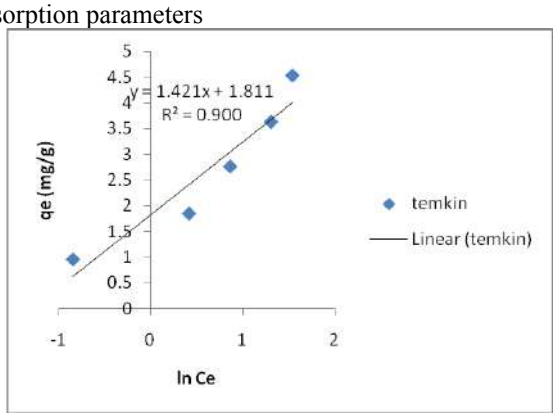

Fig 5. Temkin adsorption isotherm

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TABLE 7. ADSORPTION PARAMETERS

Parameters	Values
Slope	1.811
Intercept	1.421
RT/b	1.421
b	1368.06847
A_T	1

d. Dubinin Rudushkevich adsorption isotherm

The R^2 value that is obtained is 0.821 showing a less fit. The adsorption parameters obtained is shown in the Table 8 and Fig.6represents the D-R adsorption isotherm. The maximum quantity that can be adsorbed is obtained as 0.23mg/g.

TABLE 8 . ADSORPTION PARAMETERS

Parameters	Values
Slope	1.234
Intercept	-0.0000002
qs	3.434941861
Kad	-0.0000002

D.*Conclusion*

The main purpose of the study was to focused on understanding the effectiveness of landfill liner material in adsorbing nickel heavy metal content. It gave emphasis to adsorption studies like batch adsorption test for understanding various adsorption parameters, later isotherm models was plotted from which a best fit model was identified and there by the adsorption capacity of the liner material is found out.
Numerical model studies revealed that out of the four considered models Freudlich model better fits the experimental data that any other model with an R2 value is 0.99.

E.*Acknowledgement*

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REFERENCES

[1]Amadi. A.A., and Osinubi. K.J. (2017) “Transport parameters of lead(Pb) ions migrating through saturated lateritic soil bentonite column” *International journal of Geotechnical engineering,* pp 1-7
[2] Chalermyanont. T., Arrykul. S., and Charoenthaisong. N(2008) “Transport of heavy metals and chemical compactibility of hydraulic conductivity of a compacted sand bentonite mixture” *Songklanakarin Journal of Science and Technology* pp269-276

ISBN 978-93-89105-41-4

[3] Desta. M. H (2013)"Batch sorption experiments: Lagmiur and Freudlich isotherm studies for the adsorption of textile metal ions onto teff straw" *Journal of thermodynamics* pp 1-5
[4] Foo. K. Y and Hameed. B. H (2010) "Insight into the modeling of adsorption isotherm systems" *Elsevier pp* 2-10
[5] Lu. H.J.,Laun.M.T and Zhang. J.L. (2011) "Study on transport of Cr (VI) through the landfill liner composed of two layer soils" *Elsevier* 266 pp 87-92
[6] Lu. H., Luan. M. T. and Zhang. J. L (2010) "Transport of Cr(VI) through clay liners containing activated carbon or acid-activated bentonite" *Applied Clay Science* pp99-105
[7] Nethaji. S., Sivasamy. A. and Mandal. A. B. (2013) " Adsorption isotherms, kinetics and mechanism for the adsorption of cationic and anionic dyes onto carbonaceous particles prepared from Junglans regia shell biomass" *International journal of Environmental Science and Technology* pp 231-242

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Study on Integrated Treatment system for Medium Strength Domestic Wastewater

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***Abstract*— Domestic wastewater treatment in decentralized manner incorporated with natural systems of treatment is cost effective. 45 kLD integrated and decentralized treatment system was installed in Walchand College of Engineering, Sangli (Maharashtra, India) for the treatment of wastewater generated from residences, hostels and food courts. The system consists of Anaerobic Baffled Reactor (ABR), Baffled and Floating Hybrid Constructed Wetland (BFHCW) and Vertical Flow Constructed Wetland (VFCW). Floating constructed wetland (FCW) which is a part of BFHCW was developed by using the cost-effective floating mat (plastic tray and waste thermocol sheets) vegetated with multispecies wetland plants. Floating rack also has wetland plants vegetated in charcoal bed. *Canna Indica* and *Typha Angustata* were used as vegetation in construction wetland due to their abundance and easy availability. The final stage of treatment system consisted of vertical flow constructed wetland filled with mix media of aggregate and coal and vegetated with C*anna Indica and Typha Angustata*. This integrated system was assessed for its potential to remove COD during July to October, 2018. Anaerobic Baffled Reactor and Floating constructed wetland contributed 35% and 20% for COD removal respectively. Vertical Flow Constructed Wetland contributed 30% for COD removal. The overall COD removal was found to be 70% to 75%.**

Keywords—Decentralized Treatment ; Domestic Wastewater ; ABR ; FCW ;VFCW.

I INTRODUCTION

Domestic wastewater is generally contributed by many sources in both rural and urban areas. The wastewater generated from the sources such as public building, educational institutes, and commercial establishment is significant apart from residential sources. Wastewater treatment for such establishments is important else it will lead to isolated pollution. The development of an appropriate and cost effective system is essential. Constructed wetland (CW) technologies are natural treatment system with coal and aggregate as substrate material and planted vegetation [1]. CW technology can be applied to treat different types of wastewaters. Initially they were used to treat phenol, dairy and livestock wastewaters as well as domestic effluents. The mechanisms of treatment in constructed wetland are complex process which can happen simultaneously or sequentially involving microbial degradation, plant uptake, sedimentation, filtration. The wastewater load (volume and strength) can be reduced to some extent if the sources other than residential sources are segregated and provided with a separate treatment.

The concept of constructed wetlands applied for the purification of various wastewaters has received growing interest and is gaining popularity as a cost-effective wastewater management option in both developed and developing countries [2]. CW systems are easy to operate with low maintenance, and are cost effective. Macrophytes are the main biological components of CW. However, it is important in determining the appropriate macrophytes species that can survive in the wastewater environment, because only suitable macrophytes can treat a high concentration of pollutant in the wastewater.

In this context, the concept of Decentralized Wastewater Treatment System (DWTS) can be implemented for treating wastewater from such isolated sources. The provision of DWTS will increase the potential for reuse and recycling at source of generation. The benefits derived are lesser load on municipal water supply as portion of non-potable water demand is met from reuse/recycled water. The possible non-potable purposes for which the reuse/recycled water can be used include gardening, flushing, cleaning, and washing. The groundwater recharge is also a potential option for disposing treated water from DWTS [3].

CWs have not gained much popularity in India majorly due to large area requirement and possibility of clogging of wetland beds due to high suspended solids in the wastewater, microbial biomass sedimentation through various processes, filtration and growth of microorganisms blocking pore volume [4]. The modified versions of CW such as vertical flow CW (VFCW) and floating CW (FCW) can also be applied as a part of DWTS. VFCW for wastewater treatment are preferred due to their high oxygen transfer rate and effectiveness in reducing organic carbon and nitrogen. The area requirement in VFCW is less. FCW are made up of an extremely simple structure of synthetic buoyant mat supporting vegetation with their roots hanging into the free water [5]. Pollutants removal is carried by nutrient uptake through macrophytes and microorganisms, which grow on submerged portion of the plant and floating mat. Combination of Baffled Subsurface Flow Wetland (BSFW) along with FCW, termed as, Baffled and Floating Hybrid Constructed Wetland (BFHCW) can be the better alternative for conventional CW.

In the present study, an Integrated Decentralized Wastewater Treatment System (IDWTS) incorporated with anaerobic baffled reactor, BFHCW and VFCW was developed in the campus of Walchand College of Engg., Sangli (WCE), and operated to assess its performance to remove organic carbon in terms of COD over a period of four months.

II MATERIAL AND METHOD

A. Source of Wastewater

Wastewater generated from residences, hostels, and food courts was collected and treated in IDWTS. The flows reaching treatment system were greywater, and septic tank effluent. Oil and grease traps were provided at the source for the removal of floating mater. The maximum flow observed for the system was 6000 L/h.

B. IDWTS

In the present study, IDWTS was studied for its potential to treat 45 kLD wastewater. The total system was divided into three parts where primary and two stage secondary treatment. The preliminary system consisted of bar screens (Coarse and fine), and primary in the form of ABR. And the two stages of secondary treatment were BFHCW and VFCW. Fig. 1 shows photographic view of field scale IDWTS.

Figure 1: Photographic view of IDWTS at WCE, Sangli.

ABR has six baffled compartments connected by down take pipes inducing upflow and down flow movement of wastewater. BFHCW is a brick masonry structure made up of twenty compartments comprising of an inlet chamber, alternate compartments having brickbat vegetated with *Canna Indica* and *Typha Angustifolia* and FCW. Thermocol sheets and perforated baskets were used to support vegetation in FCW. Fig. 2 shows photographic view of vegetation in FCW.

ABR treated effluent undergoes further treatment in FCW and collected in a sump. Then it is pumped to VFCW for second stage secondary treatment. The pump operation was sensor based and feeding VFCW is auto-regulated. VFCW has bed made up of brickbat at the bottom and mixed media of coarse aggregates and charcoal. It was vegetated with *Canna Indica*. HBBCW effluent was applied uniformly on the surface of VFCW through the feeding system.

C. Operation and monitoring of IDWTS

CBCW was monitored from July to October, 2018. Initially, flow measurement was carried out to determine the fluctuations in the flow rate. Flow was measured by time-volume technique and was found to range between 532 L/h and 6000 L/h. The wastewater samples were collected at different times (morning and afternoon) and days (Monday to Saturday) from different locations at IDWTS. The sampling locations used for assessment of wastewater characteristics include, screened wastewater, ABR treated wastewater, HBBCW effluent and final effluent from VFCW. The sampling was done in 2 L plastic cans which were thoroughly washed and disinfected. Grab sampling method was used. pH, COD, BOD, EC, and TKN were measured by referring to [1].

III Results and Discussion

A. Influent wastewater characteristics

The influent wastewater characteristics are given in Table 1. No specific variation was observed in pH and EC. It can be seen that biological treatment is effective as BOD_3/COD ratio is more than 0.30. The influent to IDWTS is categorized to be medium strength wastewater as COD is between 500 to 1000 mg/L.

Table 1: Influent wastewater characteristics

	pH	EC (mS/cm)	COD (mg/L)	BOD_3 at 27^0C (mg/L)	TKN (mg/L)
Influent	7.5±0.25	2.41±0.08	500±50	258±10	54±8

Figure 2: Photographic view of vegetation in BFHCW

B. Performance of IDWTS for COD removal

Figs. 3 and 4 show COD variation and its removal at various stages of treatment system at different times (morning and afternoon) in a day. COD values decrease at each stage of treatment system. ABR contributes to an extent of 40% for the removal of COD. Anaerobic condition is more effective for the treatment of medium strength wastewater and hence ABR has significant contribution. BFHCW is supposed to be aerobic partially, however the system was in developing phase with vegetation growth in its initial stage and hence COD removal is relatively lower (15 to 20%). VFCW contributed to COD removal by 20 to 25%. The overall removal for COD is to an extent of 70% to 75% by IDWTS. The vegetation growth in VFCW is better than in BFHCW and support bed is better aerated. Thus VFCW is more efficient as compared BFHCW due to better aerobic conditions.

Figs. 5 and 6 show the variation of COD with time in the morning and afternoon period during 4 months of study. It was observed that there was no signifiant variation in the system performance at different times in a day. The results also showed that effluent COD was not consistently same and it varied with time. The treatment systems based on natural mechanisms of purification have such limitations umlike mechanized treatment systems. However, effluent COD is less than 100 mg/L during major portion of the study period.

The observed efficiencies in BFHCW and VFCW were relatively lesser considering the fact that IDWTS was subjected to high hydraulic (>1m^3/m^2.d) and organic loading (2.5 kg COD/m^2.d) rates.

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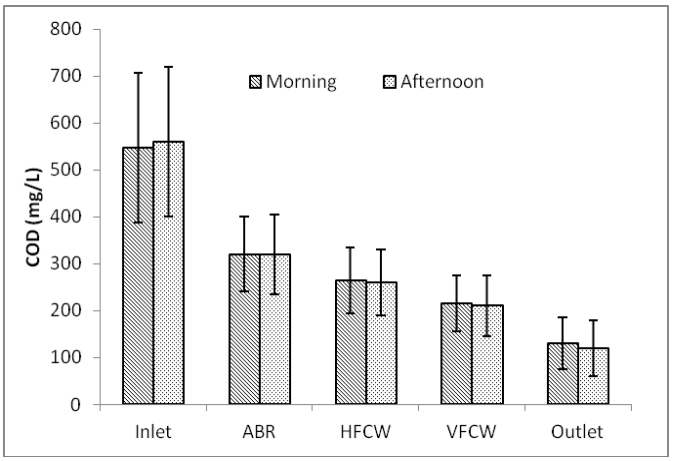

Figure 3 : COD variation in IDWTS at various stages and times of treatment (Average value of 4 months)

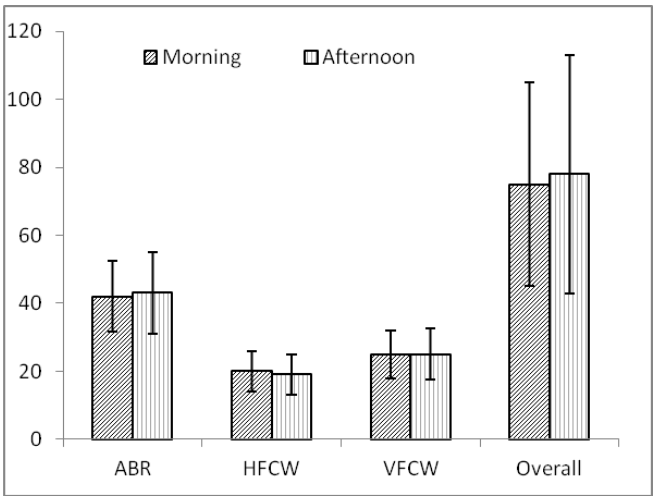

Figure 4 : COD removal in IDWTS at various stages and times of treatment (Average value of 4 months)

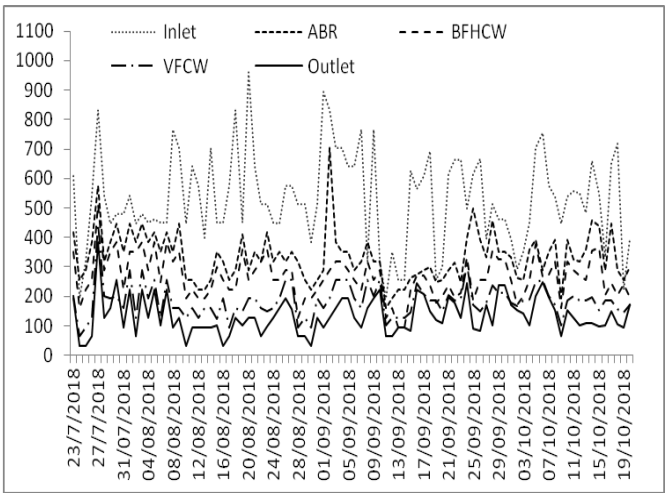

Figure 5: COD variation throughout the study period in morning

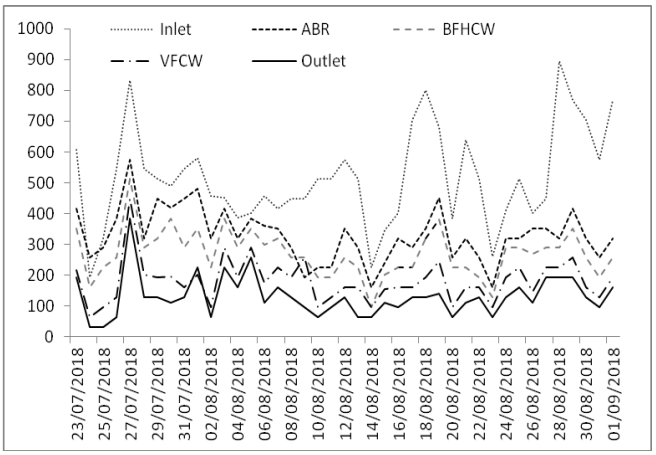

Figure 6 : COD variation throughout the study period in afternoon

Table 2: Effluent wastewater characteristics

	pH	EC (mS/cm)	COD (mg/L)	BOD_3 at 27^0 C (mg/L)	TKN (mg/L)
Effluent	7.5±0.25	2.00±0.08	100±50	50±10	38±8

Table 2 shows summary of effluent characteristics observed for study period of 4 months.

IV Conclusions

IDWTS at WCE was monitored for a period of four months and performance for COD removal was assessed. ABR contributed significantly to COD removal in comparison with other units. The performance of BFHCW and VFCW is satisfactory owing to high hydraulic and organic loading rates. VFCW is more effective than BFHCW systems. IDWTS is found to be an alternative option for decentralized treatment of domestic wastewater with overall COD removal of 70% to 75%.

ACKNOWLEDGMENT

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REFERENCES

[1] APHA (2012) Standard Methods for the Examination of Water and Wastewater, American Water Works Association, Water Environment Federation.

[2]Manual on constructed wetland as an alternative technology to sewage management in India, Central Pollution Control Board, Ministry of Environment, Forest & Climate Change, India, March 2019.

[3]S. Abou-Elela, G. Golinelli, A. El-Tabl and M. Hellal, „Treatment of municipal wastewater using horizontal flow constructed wetlands in Egypt", Water Sci & Tech, Vol. 69(1), 38-47, 2014.

[4]S. Sathe and G. Munavalli, „Domestic wastewater treatment by modified bio-rack wetland system", Journal of Water Process Engg, 28, 240-249, 2019.

[5]P., Cooper, 1999, "A review of the design and performance of vertical flow and hybrid reed bed treatment systems." Water Science Technology, 40 (3), 1–9, 1999.

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Water Audit for Engineering College Campus

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***Abstract*— In order to be water sustainable, it becomes obligatory to optimize the usage of water. A water audit is a process of tracing the path of water within a system from its source to its end users. It involves finding out quantities of water by all consumers with the help of various manual techniques and relevant technologies. It provides a reliable and scientific approach that enables us to understand the pattern of consumption, losses and scope for the conservation of water. Incognizance of water consumption and its pattern gives rise to excessive generation of wastewater. Hence with the use of water audit, a rational approach can be implemented to achieve water sustainability and to deal with wastewater. The area selected for water audit is the campus of Walchand College of Engineering, Sangli (WCE). The study involves the division of the entire campus area into various units to find its consumption. Thus, at the end of the project, the water consumption of the various units in the campus was found and also the major areas of water consumption were identified. The total non-potable water consumption was found to be 96.4% and potable water consumption was 3.6% of the overall consumption. These values were later compared with the standards and the results obtained were comparable. The water loss quantity through leakage was also determined. It was found that the water losses were 1% of the total consumption which is much less than 15% which is the specified limit in the standards. The maximum water consumption was found in the hostels accounting for 81% of the non-potable water usage and 56% of potable water use. The maximum tap leakages were also found in the hostel units. The total water consumption was compared with the total inflow water and the reasons for the differences in the inflow and outflow were also identified, thus completing the water balance.**

Keywords*— Water audit; Water balance; Water losses; Engineering campus.

I. INTRODUCTION

Water is a precious natural resource which is available in limited quantity. With the continuously growing population and rising standards of people, per capita availability of utilizable water is decreasing [1].Hence, it becomes important to optimize the water usage. Thus, proper water management is required. Water audit is the most effective tool for water management. Hence with the use of water audit, a rational approach can be implemented to achieve water sustainability.

The water audit is a quantitative analysis of water consumption to identify means of reducing, recycling and reusing it [1]. It is a periodic exercise to determine the water supplied, consumed and lost in the water distribution system. The water audit works as a tool to overcome drought-related problems, leakages and losses.Elements of water audit include the record of the amount of water supplied by the sources, the amount of water consumed, water losses and measures to address water losses [1].

A. Importance of water audit:

Today, most of the part of the world is facing problems of water scarcity. With rising standards of living of people, per capita water demand is increasing. If this demand continues to increase, the available natural water resources may not be able to fulfill it. Hence, to prevent the water crises in near future, it's necessary to take preventive measures. Reducing the water losses, reusing the available water and recycling of water supplied are some of the measures that can be taken to prevent drought-related problems. Proper water management can help in coping up with the imbalanced water demand-supply cycle. For this, we need to know the amount of water available for distribution, the amount of water consumed and the amount of water lost. Hence, the water audit is carried out to get all the data required.

B. The necessity of water audit in WCE campus:

The amount of water required for various activities in the campus is huge, so is the electricity bill paid by the college authority. As the number of activities requiring water is more, the chances of water loss are also more. The college authority has to pay for the amount of water lost along with the actual amount of water used. Determination of these water losses can help in reducing them thereby optimizing the cost of water. Also, by performing a water audit, appropriate steps can be undertaken to recycle and reuse the water supplied to optimize the usage of water. Previously, no water audit has been carried out in the campus. Hence, to determine the amount of water supplied, the actual amount of water consumed and the amount of water lost, water audit was needed to be carried out.

C. Objectives of project work:

The objectives of the present project work are i) to conduct a water audit in the WCE campus to quantify the consumptive use of water for potable and non-potable purposes; ii)to identify the source location with leakages and quantify leakage; iii)to compare observed consumptive use with actual water supplied; iv)to suggest an action plan for proper water utilization using water audit data.

II. MATERIAL AND METHODS

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A. Site for Water Audit:

The water audit was conducted for Walchand College of Engineering, Sangli (WCE). The description of the site is given in 1.1.

1) Sources of water supply:

There are four wells situated in the campus and one outside the campus. The water from these wells is used for non-potable purposes. For potable water use, there is a separate metered municipal water connection.

The potable water is stored in an underground water tank of 20,000 l capacity near the Ganpati temple. For distribution purposes, two separate overhead water tanks of capacity 10,000 l are provided over the electrical and mechanical department. The water stored in these tanks passes through the filter and disinfection unit and thereupon it gets distributed to the whole campus.

The non-potable water is stored in an underground water tank of 70,000 l. There is an elevated storage reservoir (ESR) of capacity 1,50,000 l provided for non-potable water distribution purposes. The water is pumped from the underground water tank to ESR and thereupon it gets distributed in the campus. The average pumping is six to eight hours per day.

The various units in the campus are as mentioned in the Table 1.

B. Methodology:

1) Procedure for water audit:

a. The entire campus was divided into units.
b. The sources of water supply and the purpose of use was identified in these units. The purposes included potable and non-potable uses.
c. The water used for the cooking and drinking purpose was considered as a part of potable water. The water used for flushing, gardening, washroom cleaning, floor cleaning, utensils washing, laundry and hand washing was considered as a part of non-potable water use.
d. The quantity of water consumption was calculated by identifying the frequency of use and the water use pattern of people through interview method and measurement method.
e. The inflow of water and the water consumption was compared.

2) Methods for data collection:

The data collection method to be used in the water audit needs to be precise in order to yield accurate distribution of water in different units and also to determine the losses accurately so as to implement the most effective and efficient method to optimize the water usage. The methods that are used to find the water usage in this project are explained in 2.2.1 and 2.2.2.

3) Methods to find consumer data:

a) Method to find per capita use:

The interview method was adopted to find out the quantity of water for the purposes where water consumption data could be found using various units such as buckets (e.g. bathing), bottles (e.g. drinking) or vessels (e.g. cooking). This method was used to get the information regarding water usage pattern. A series of questions [2] were asked to the concerned users and the responses were noted down. The average consumption was calculated from the data obtained.

b) Method to find number of users:

In the CCTV method, the exact count of users was found out by observing CCTV footages for working days and non-working days. The count was multiplied with the per person water use to find the total consumption.

The registers were used to find the count of people in places like hostels, Exam cell and study room, where the cameras were not accessible. The in-time and the out-time was used to find the total number of users for these units.

4) Measurement Technique

Time volume method was used to obtain water quantities for the purposes like flushing, gardening and cleaning and also to determine the leakages in the taps. In this method, the average discharge of water through pipes and taps was found by conducting a number of iterations. In each iteration, selected group of individuals were asked to open the tap and the time required to fill the bucket was noted. The overall result of all individual's readings minimizes the possibility of variation due to partial and complete opening of the tap. The average of measurements helped in arriving at the most probable discharge and the duration of use.

III. Results and Discussion

A. Water consumption of residential blocks:

There are four blocks of residential housing (faculty quarters) in the campus and two individual housing. Quarters A and B had a common washroom for all houses and the rest of the houses had attached washroom. It was found that these two quarters had lesser water consumption as compared to other quarters. Table 1 gives the details of the potable and non-potable water use for the residential blocks.

TABLE 1. FACULTY QUARTERS WATER USE RATE

Unit	Potable water use (l/d)	Non-Potable water use (l/d)	Potable water use (%)	Non-Potable water use (%)
Block A	100	696	10.78	17.47
Block B	75	488	8.08	12.25
Block C	518	1033	55.82	25.92
Block D	225	1658	24.25	41.61
Faculty house	10	110	1.08	2.76
Total	**928**	**3985**		

B. Water consumption rate:

Table 2 gives the water consumption of various units in the campus. The maximum water consumption was found in the

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hostels accounting for 81% of the non-potable water usage and 56% of potable water use. The non-potable and potable water consumption for all the units is given in Fig.1 and Fig.2. The total water consumption was found to be 144100 l. It was found that the potable water use was 3.6% and non-potable water use was 96.4% of the total use. As per standards, [3] the breakdown for 135 l/d consists of potable water requirement as 7.4% and non-potable water requirement as 92.6% for domestic use. In engineering college water requirement of labs is important; it is shown separately in Table 3. The water consumption by labs is around 0.37% of the total non-potable water consumption.

TABLE 2. WATER CONSUMPTION RATE

Sr no	Building units in campus	Non-potable water use (l/d)				[b]Potable water use (l/d)
		Flush-ing (a)	Gard e-ning (b)	[a]Other purpos e (c)	Total use of non-potabl e water (a+b+c)	
1	Rector Office	50	-	65	115	28
2	Exam Cell	220	114	50	384	27
3	[c]TPO	80	-	100	180	-
4	Library	770	34	60	864	70
5	Academic complex	900	343	460	1703	37
6	[d]Admin Building	1013	1222	1455	3690	180
7	Civil Department	570	771	219	1560	86
8	Mechanical Department	395	96	206	697	44
9	Physics Department	-	441	45	486	25
10	Electrical Department	-	-	60	60	58
11	Cafeteria 1	-	-	155	155	30
12	Cafeteria 2	-	643	190	833	20
13	Canteen	125	129	170	424	113
14	Boys' Hostel	23000	206	20400	43606	1401
15	Girls' Hostel	19860	257	49880	69997	1512
16	Boys' Mess	200	-	2750	2950	210
17	Girls' Mess	400	-	3600	4000	365
18	[e]Faculty Quarters	1410	1000	1545	3955	928
19	Leakages	-	-	-	3090	20
Total					**138749**	**5155**

[a]Other purpose includes various cleaning purposes such as washroom cleaning, floor cleaning, Utensils washing, laundry and Hand washing
[b]Potable water use includes water used for cooking and drinking
[c]TPO: training and placement office
[d]Admin Building includes administration wing, the director's cabin and departments (Electronics, Computer engineering, Information technology, Chemistry and part of Mechanical and Electrical department)
[e]Faculty quarters includes the four blocks of residential quarters in the college

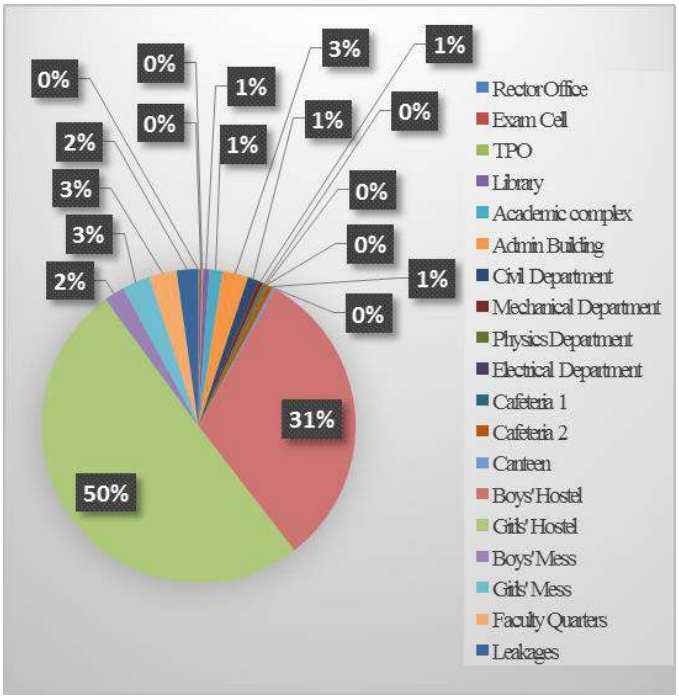

FIG. 1. NON-POTABLE WATER USE DISTRIBUTION FOR THE CAMPUS

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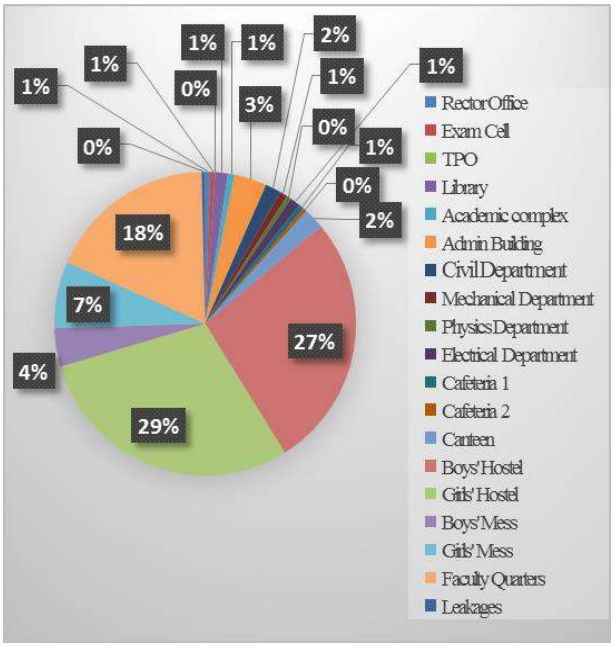

Fig. 2. Potable water use distribution for the campus

Table 3. Lab wise Water Consumption

Department	Name of lab	Consumption per day (l/d)
Civil	Environmental engineering lab	60
	Soil mechanics lab	30
	Fluid mechanics lab	60
	Transportation lab	30
Mechanical	IC engine lab	30
Chemistry	Chemistry lab	300
Total		510

C. Leakages identification in campus units

The plumbing system of all the units in the campus was checked for leakages. Time volume method was used to find the leakage quantity. It was found that maximum leakages were found in the hostels. The main reason for leakages was the broken taps and leaky taps. In most of the hostels the leaky taps were the major contributors for leakage. In hostel D1 the maximum quantity of leakage was found due to the presence of broken tap. Table 3 gives the details about the leakages in various building units in the campus. The leakages in these fixtures contribute merely 2% of the total water consumption which is much less than the limit of 15% as stated in the standards [4].

TABLE 4. UNIT WISE INDOOR LEAKAGES IN PLUMBING SYSTEMS

Building Units	**Leakage Quantity (l)**	**Leakage (%)**
Hostel D1	988	31.76
Hostel D5	289	9.28
Hostel D6	303	9.74
Hostel D7	459	14.76
Hostel D8	401	12.88
Hot Bath facility	448	14.41
Mess	203	6.53
Canteen	20	0.64
Total	**3110**	

D. Water Balance:

1) Inflow:

The inflow consists of municipal water supply which is mainly used for potable purposes and water from wells situated in the campus and outside the campus which is used for non-potable purposes.

a) Potable Water:

Potable water for inflow calculation includes water from the municipal supply. To calculate the inflow, water meter readings were used. The readings were taken at an interval of one month for three months and based on that per day usage was calculated by taking an average of those readings.

Table 5 Water supply as per metering records

Date	Water Meter Reading(kl)	Total Water used in a month(kl)	Total Water used in Day (kl)
1st Sept. 2019	56007	-	-
1stNov. 2019	56837	830	27.8
1stDec. 2019	57582	745	24.83
Average			26.3 kl

Computed Potable Water Demand- 26,300 l/day.

b) Non-Potable Water:

To compute Non-potable use the power rating of the pumps was used. There are three pumps (2 pumps of 5 HP) in the campus for lifting water to ESR which is at an elevation of 10m. The data related to discharge of pumps was collected from water supply authority who gave a value of 296 l/min. This discharge was also compared with the records obtained from the maintenance department.

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Pumping duration: Average 6- 8 hours daily. Thus, the pumps are used alternatively on an average for 7 hours daily.
Quantity of Water lifted: 296* 60* 7 = 1, 24,320 l/d
Hence, Computed Water Demand =1,24,320+26300
=1,50,620 l/d.

2) Outflow:

Outflow is the total amount of water consumed by the users in the WCE campus.From the results of water audit, it has been observed that,
Potable Water Requirement: 5155 l/d
Non-Potable Water Requirement: 138749 l/d
In the campus, it was found that a part of the water from the municipal water supply (potable water) was used for non-potable purpose because of which the negative value was observed in the water balance.

TABLE 6. WATER BALANCE ANALYSIS

	Inflow (l/d)	Outflow (l/d)	Difference between inflow and outflow (l/d)
Potable water	26300	5155	21145
Non-Potable water	124320	138749	-14429
Total	150620	143904	6716

E. Reasons for the difference between inflow and outflow:

The water demand was majorly calculated based on the count of people. The count was computed based on continuous trend obtained for a week in a year. This count is not fixed and may vary every day. The results obtained through interview method are prone to variations. Sometimes, pumping hours also vary with the daily use. The efficiency of the pumps reduces with time. Seasonal variations may also affect the results. Also, the overflow of water from the ESR and potable water tanks contributes to the unaccounted-for water outflow. This generates a difference of 6700 l/d between inflow and outflow.

IV. CONCLUSION

The water consumption in all the units of the campus was found through the water audit. It was found that the total potable water use was 3.6% and total non-potable water use was 96.4% of the overall consumption. As per standards, the breakdown for 135 l/d consists of potable water requirement as 7.4% and non-potable water requirement as 92.6% for domestic use. This indicates that the results obtained through the audit are comparable with the standards. Among all the units, the hostels turned out to be the major source of water consumption requiring around 81% of total non-potable water and 56% of total potable water**.** It has been observed that there were no major losses due to damage to the water distribution system as no wet patches were found along the distribution line in the campus. The losses observed were mainly due to the use of inefficient water fixtures. The leakages in these fixtures contribute merely 2% of the total water consumption which is much less than the limit of 15% as stated in the standards. There is a difference of around 6700 l/d between inflow and outflow. The reduction in pumping efficiency and variation in the data obtained through interview method are some of the reasons for this difference as stated already in detail. The consumption data will be used as a baseline for future studies such as for determining waste water generation rate and its treatment.

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REFERENCES

[1] Pranav Kubade, Nitish Deshmukh, SnehalGadekar, “Industrial Water Audit”, 4th International Conference on Multidisciplinary Research & Practice (4ICMRP-2017).
[2] Manual on “Jal Shakti Campus and Jal Shakti Gram”, Mahatma Gandhi National Council of Rural Education,Ministry of Human Resource Development,GOI,2019.
[3] P. N. Modi, “Water Supply Engineering”, Volume-1,Rajsons Publication, Third Edition, 2010.
[4] Manual on “Water Supply and Treatment”, Third Edition, CentralPublic Health and Environmental Engineering Organization, Ministry of Urban Development New Delhi, GOI, May 1999.

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Assessment of soil surface roughness statistics using a simple photogrammetric acquisition system

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***Abstract*—Surface roughness is identified as one of the dominant factors governing runoff and erosion. It also influences processes such as infiltration, depression storage, and deposition. Contact and Non-Contact methods are used for determining surface roughness. This study presents photo acquisition technique, a non-contact method. A hand held camera Canon EOS 1300D and a metal frame with installed spikes at known heights to act as Ground Control Points was used for study. Metal frame was placed over surfaces and overlapping photographs were taken. Digital elevation models (DEMs) were generated using the Agisoft photo scan software and accuracy assessment was done using ground control points. Different roughness indices such as height standard deviation, Variogram parameters and Tortuosity index were determined for roughness characterization. From the roughness indices ploughed field shows higher height standard deviation and tortuosity index. In variogram analysis also ploughed field shows higher sill and slope factor under study area.**

Keywords—Surface roughness, Digital Elevation Model, Photo acquisition, Roughness indices

I. INTRODUCTION

Surface roughness is commonly identified as one of the dominant factors governing runoff and rill erosion. Surface roughness is known to influence many processes occurring on the soil surface, including infiltration, depression storage, runoff, flow meandering, flow velocity, soil loss, and deposition. Therefore, considerable effort has been made to characterize soil surface roughness and to implement it into soil erosion models. Most often, this is done by means of an index. Micro-scale soil surface roughness is a critical parameter in a wide range of environmental applications [6]. However, the availability of micro scale soil surface roughness information is still not satisfactorily solved, introducing numerous soil erosion estimation errors particularly at large-scale modeling applications. Soil moisture retrieval from space or air borne microwave sensors and uncertainty of the received signal is still an unsolved problem due to the characteristic dependency of the signal on both geometric and dielectric properties. Soil surface roughness may appear in different orders of magnitude, and it is especially caused by the usage of tillage implements or by surface processes such as runoff concentration. Regarding a natural soil surface in the environment, soil surface roughness is a superimposition of different roughness scales. Different methods such as Roller chain, pin board, stereo photos, Terrestrial Laser Scanner and the Xtion Pro are generally used to find the soil surface roughness [7]. Geo-spatial studies are increasingly using photogrammetry technology because the cost of the equipment is becoming cheaper, the techniques are accessible to not experts and can generate better quality topographic data than traditional approaches. This study investigates the application of remote sensing techniques such as a simple photo acquisition technique for the determination of roughness indices for different types of land surfaces.

A. Scope of study

Soil roughness is an important parameter to find surface storage, infiltration, runoff, sediment detachment and erosion. It is an important parameter in the soil erosion models. Here a new method is used to find the surface roughness without disturbing the soil profile.

B. Objective of the study

- To generate the Digital Elevation Models (DEMs) for different land Surfaces.
- To assess the accuracy of DEMs
- To find the Surface roughness indices of different Surfaces and to compare them.

II. SOIL SURFACE ROUGHNESS

Soil surface roughness is well-defined as the anomalies of the soil surface, caused by factors such as soil texture, aggregate size, rock fragments, plant life cover and land management. [1] Soil roughness influence surface storage,

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infiltration, overland flow, and ultimately sediment detachment and erosion.

A. Roughness indices

In order to describe surface conditions numerically for different applications, different roughness indices are developed. Some of such roughness indices are explained below.

1) Height Standard Deviation (HSD)

Height Standard Deviation (HSD) is characterized by the standard deviation of the height values compared to a reference plane [4]. It gives an idea of the vertical height variation of the area. Different surfaces with different surface properties may have same Height Standard Deviation. So it can only give information about the Vertical variation and not about the horizontal variation of the surface. Height Standard Deviation is defined as

$$\mathbf{HSD} = \sqrt{\frac{\sum_{i=1}^{n}(Z_i - \bar{Z})^2}{n-1}} \quad (1)$$

Where

Z = height values of surface

$\bar{Z}$ = reference height

n = no of height reading

2) Tortuosity Index

Tortuosity index is the ratio of the real surface area within the DEM unit to its flat horizontal projection area [8]. It is determined using equation 2

$$\text{Tortuosity index} = \frac{\text{Real surface area}}{\text{Projected Area}} \quad (2)$$

3) Variogram Analysis

A Variogram takes the spatial correlation of topographic data into account. It is mainly represented by the following equation [5].

$$\bar{\gamma}(h) = \frac{1}{2n}\sum_{i=1}^{n}[Z(x_i) - Z(x_i + h)]^2 \quad (3)$$

Where γ (h) is the theoretical variogram, *Z* (*xi* + *h*) and *Z* (*xi*) are the observations and *h* is the lag distance between observations *Z* (*xi* + *h*) and *Z* (*xi*), and *n* (*h*) is the number of pairs separated by the lag distance *h*. Sill, nugget and range are mainly used as surface roughness index. Slope factor is another term to represent Surface Roughness. The slope factor is defined as

$$\text{Slope factor} = \frac{(\text{sill} - \text{nugget})}{\text{range}} \quad (4)$$

4) Auto correlation length

The autocorrelation length describes the horizontal component of the roughness spectra [3]. While, it is usually determined along 1d-profiles, the derivation of auto correlation length using three-dimensional roughness measurements is more complex. For an efficient estimation of auto correlation length, a variogram analysis was used and inverted the autocorrelation function (ACF) from a calculated theoretical omnidirectional variogram (γ), where it is defined as the distance (h) at which the ACF drops under e^{-1}. This implies an exponential fit of the theoretical variogram and therefore of the ACF. Usually best fit was always achieved with an exponential model. The theoretical variogram (γ) with an exponential shape is fitted to the experimental variogram (γ^) , which is defined as equation 3

From the theoretical variogram (γ) the ACF (ρ) can be derived as

Follows:

$$\bar{\rho}(h) = 1 - \frac{\bar{\gamma}(h)}{\bar{\gamma}(\infty)} \quad (5)$$

Where γ (h) is the semi variance at distance h between two points and γ (∞) is the semi variance at distance where the sill of the variogram is reached. For the assumed exponential model, where the sill is asymptotically approached, γ (∞) corresponds to the distance where 95% of the sill is reached.

Fig 1 shows the definition sketch of variogram and the important terms related to it [3]

Sill: The semi variance value at which the variogram levels off. As sill value increases the surface roughness increases.

Range: The lag distance at which the semi variogram reaches the sill value is called as Range. Autocorrelation is essentially zero beyond the range.

Nugget: When there is significant difference from zero for lags, then this semi variogram value is referred to as the nugget. The nugget represents variability at distances smaller than the typical sample spacing, including measurement error.

Slope factor: (sill-nugget)/range. As slope factor increases the roughness of the surface increases

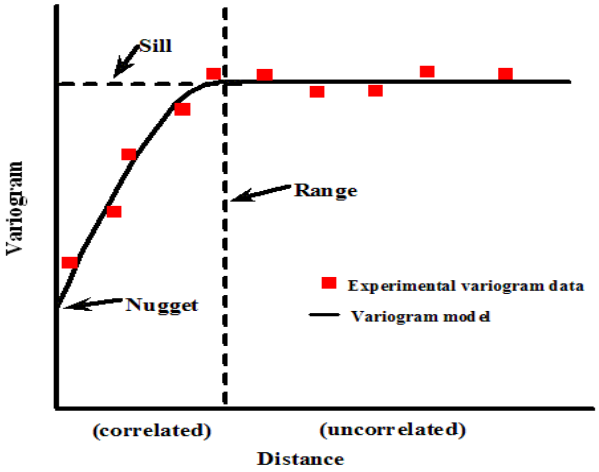

Fig 1.Variogram

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III. METHODOLOGY

Photo acquisition is a simple and efficient method to measure surface roughness in an environment. The methodology of this study involves acquisition of stereo images, Determination of camera coefficients, Derivation of Digital Elevation Models (DEM) and computation of Roughness indices. Different types of land surfaces are considered in this study. Fig 2 explains the methodology followed. Agisoft photo Scan and surfer 13 are the software used in the study. Agisoft photoscan is a 3D scanning software package developed by the Agisoft Company, Russia. It mainly uses the latest 3D reconstruction technology from multiple view s which can process any picture taken by a non-metric camera. It can process images and create Digital Ortho photo Map (DOM) and Digital Elevation Model (DEM). From that a 3D model can be created. For processing, Photos can be taken at any position and at any angle with only one pre-condition, that there exist corresponding points between two adjacent pictures of the target. In digital image processing, three-dimensional models are reconstructed on the basis of spatial geometric information of the object which is found from one or several images taken by a non-metric camera achieved.

Stereo image Acquisition was done by using the Canon EOS 1300D camera. Five different land surfaces area considered in this study and images are taken from all the surfaces. Ploughed, barren land, Sand surface, Concrete surface and Road surface are the five different surfaces considered in this study.

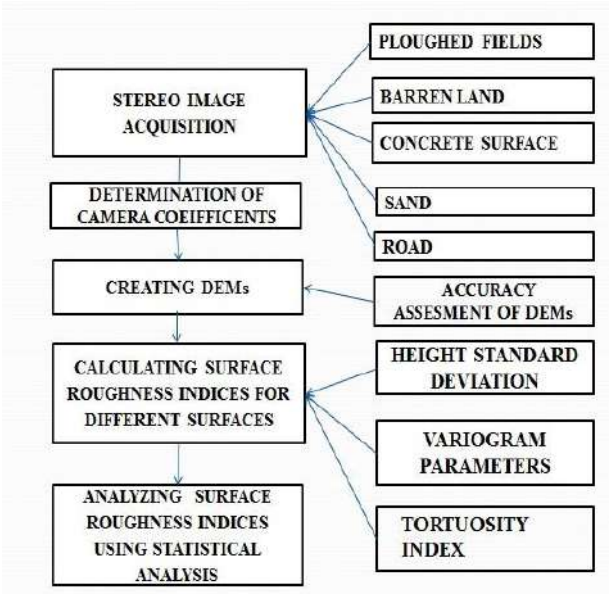
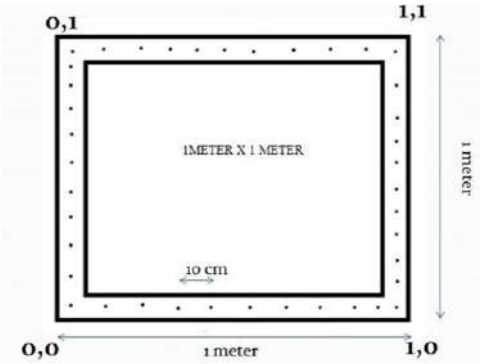


Fig 2 Methodology

A customized Canon EOS 1300D digital camera and reference frame marked with spikes of known elevations. The derivation of the DEM is done with Agisoft photo scan package. Since Agisoft photo scan needs ground control points (GCPs) with known coordinates for the creation of DEM, a reference frame was designed providing 40 horizontally and vertically distributed spikes of known elevations which acts as GCPs. Fig 3 (a) shows the metal frame with known GCPs and 4(b) shows the schematic representation of metal frame. The horizontal size of the frame is set to 1 x1m^2 to keep the reference frame handy. Co-ordinates of the GCPs in the reference frame were measured by a caliper ruler with an accuracy of 0.10 mm in x, y, z direction. Each GCPs were placed at distance of 10cm center to center distance. Images are acquired with a forward overlapping and side lap of at least 70% and 30% respectively to cover the entire area in the frame.

(a)



(b)

Fig 3 Metal frame 1x1m size GCPs (nails) spaced 10cm each other

After taking the photograph we have to find the camera calibration parameters. Agisoft Photo Scan estimates intrinsic camera parameters during the camera alignment and optimization steps based on the Initial values derived from photos. Calibration is the process of Modeling of the inner geometry (interior orientation) of the camera. Tool used for interior orientation in the Agisoft photoscan was Agisoft Lens. It is checked by using a set of checkerboard images which was already in the software.

The following are the camera parameters to be determined.

- ✓ fx, fy - Focal length in x- and y-dimensions measured in pixels.
- ✓ cx, cy- Principal point coordinates
- ✓ k1, k2, k3,k4 -Radial distortion coefficients.
- ✓ p1, p2,p3,p4- Tangential distortion coefficients.

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We have to load the images to Agisoft Photo Scan, the software automatically aligns photos with the camera. Fig 4 represents the workflow of the DEM generation. It will search for the corresponding points and match the photographs. They identify the location of the camera.A .csv file is then created from already measured Control points from the metal frame and is imported to Agisoft. Then Tie point generation determines common feature points on image pairs. Agisoft Photo Scan can build an irregular triangle network (TIN) with a dense point cloud. Texture mapping is carried out according to the TIN. Digital Elevation Model (DEM) is generated from the Mesh. After that Ortho image is then produced. Export formats are usually GeoTIFF (*tif) and JPG formats. Combining the above DEM and DOM, a 3D model is reconstructed for the study. Accuracy assessments were done by using the control points and RMSE errors were calculated. From the DEM the Roughness indices Height standard deviation, Tortuosity indices and variogram parameters are found out.

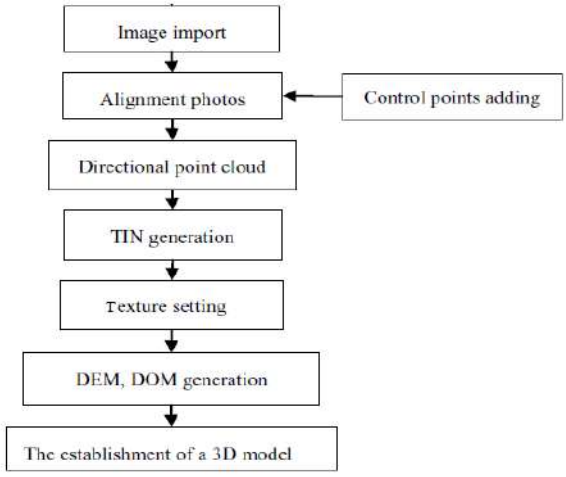


Fig 4 Work flow of DEM generation and 3D Model in Agisoft photoscan

IV. Results and Discussions

In photo acquisition the photographs were taken for five different surfaces. All images were taken with at least a forward overlapping of 70% and a side lap of 30%.Photo acquisition details are given in table 1.

Table 1 Photo acquisition details

Surface	Date of Acquisition	Time of Acquisition	No of images
Road	15th March 2019	4.30 pm	25
Barren land	21th March 2019	5.20 pm	24
Concrete	25th March 2019	4.45 pm	33
Sand	2nd May 2019	5.00pm	33
Ploughed field	2nd May 2019	5.30 pm	47

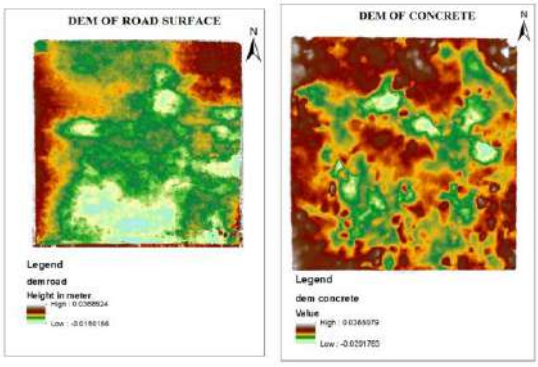
The camera parameters were determined using the acquired images in Agisoft Photo scan software. In this study twenty four images taken from the barren land surface were used. After loading all images, Camera calibration is selected in the workflow menu. First a pre calibration of camera was done by that. After adding the Ground control points camera parameters were optimized from the work flow menu. Table 2 shows the results of the camera calibration done on Agisoft photo scan software

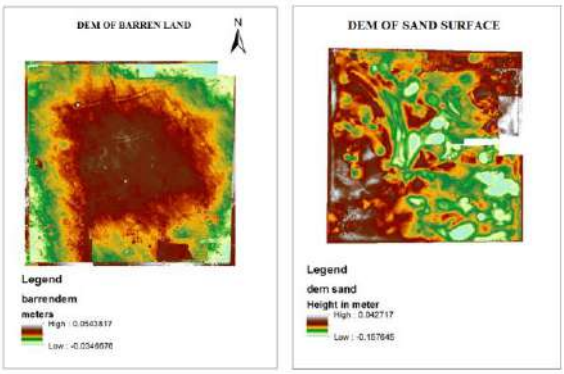
Table 2. Camera calibration parameters

Fx	7986.49		Cx	2766.73
Fy	7986.49		Cy	1982.81
k1	-0.045		p1	0.0084
k2	0.28		p2	0.0071
k3	-0.66		p3	0
k4	0		p4	0

A. *Generated DEMs*

For DEM generation the images were added and aligned in the Agisoft photo scan work flow menu. 20 control points were added as markers and placed. A Local coordinate system was created with known Ground Control Points. Fig 5 shows the different DEMs generated for Concrete, ploughed field, barren land, road surface and Sand surface.





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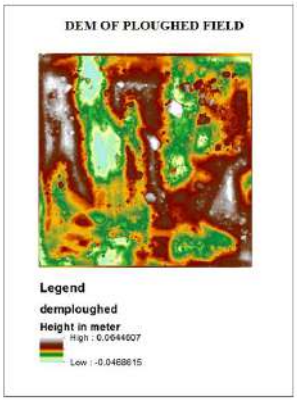

Fig 5 Generated DEMs

B.*Accuracy assessment of dems*

Accuracy assessments of all the DEMs were done by 20 control points and RMSE were found. RMS error for z error is more for barren land and least for the ploughed field. In the case of DEM the z value is more sensitive compared to x and y.Table3 shows the results of accuracy assessment.

Table3. RMSE error in X, Y, and Z Direction

Surface	No of Control points	X error (mm)	Y error (mm)	Z error (mm)
CONCRETE	20	2.02	2.20	3.67
ROAD	20	2.93	2.28	3.76
BARREN	20	1.7	2.1	3.92
SAND	20	3.1	3.5	3.5
PLOUGHED	20	1.7	2.8	3.4

C. Roughness indices

Roughness indices are indices used to express roughness of surface. Mainly three indices are considered in this study which is Height Standard deviation, Tortuosity index and Variogram parameters. Roughness indices are found and compared. For Height standard deviation and tortuosity index the equations (1) and (2) are used. Surfer 13 software was used for variogram analysis. An excel file was created with the x, y, z coordinates of the point cloud from the generated DEMs and imported to the surfer 13 software. Exponential fit was the best fit for the variogram. Variogram were created using the excel file and exported. Same procedure was repeated for creating the autocorrelation plot also. Only difference was to invert the variogram. Variogram analysis were done using the plots and Sill, range, Nugget, Slope factor as well as auto correlation length were found.

Height standard deviation is the vertical variation of height value reference to a plane and is computed from the equation (1). The bottom surface of the metal frame was taken as the reference plane. From there the HSD for different surfaces were found. Height Standard Deviation for different surfaces obtained in this study is graphically shown in Fig 6. From the Table 8.1 and Fig 8.1, it can be seen that height standard deviation is more for the ploughed field which is about 14 mm. Road surface showed the minimum height standard deviation of 4.4 mm.

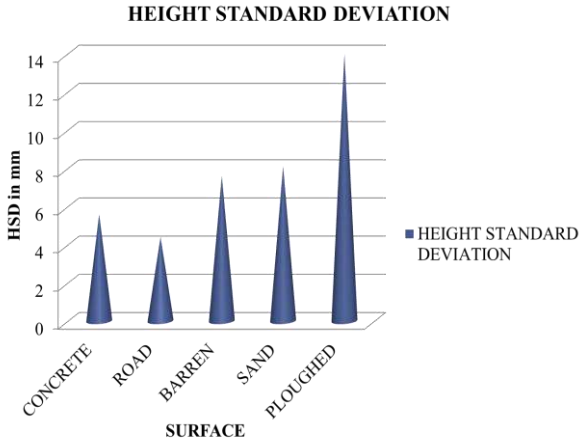

Fig 6. Height standard deviation of the different surfaces

The tortuosity index mainly gives the overall roughness of an area. The three dimensional surface area can be calculated from 3D model and the plane area is 1 m2. Tortuosity Indices for different surfaces obtained in this study is graphically shown in Fig 7.From that it was observed that ploughed surface shows the higher tortuosity index of 1.4 and road surface shows the minimum of 1.09.

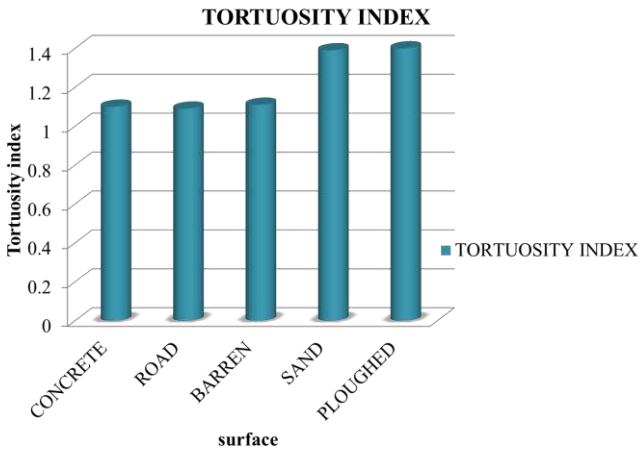

Fig 7. Tortuosity index of different surfaces.

A Variogram takes the spatial correlation of topographic data into account. The X axis is the lag distance and the y axis the variance. The variogram was drawn using Surfer 13 software. An Excel file was created from the DEM with X, Y, Z coordinate values. The variogram as well as the auto correlation plot was created. For all the surfaces considered exponential model was the best fit. From this the sill, nugget,

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range and slope factor are obtained as well as the auto correlation plot for each surfaces.

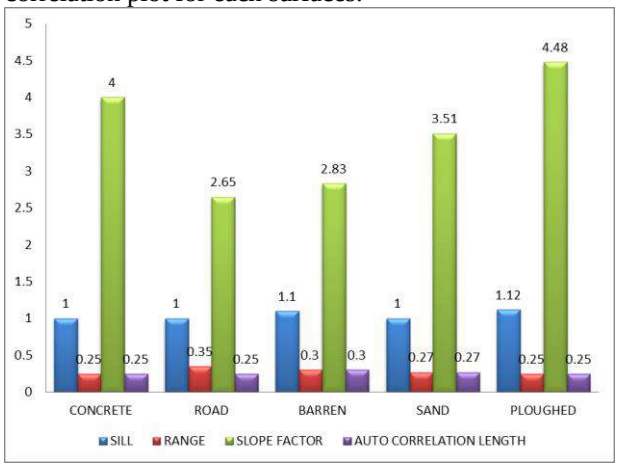

Fig 8. Representation of variogram parameters

From all the Variogram the sill, nugget, range, and auto correlation length were measured. Concrete surfaces and ploughed field shows clear sill, range and zero nugget for variogram and the auto correlation plot. A Clear wave like pattern was observed for the Concrete as well as ploughed surface. This may due to the higher roughness in these surfaces. Road, barren land and sand surface don't show clear sill or range. This was due to the fine soil aggregates in the surface. In the case of concrete and ploughed surface the size of the aggregates were more. As the nugget value increase there is an increase in the error in the semi variogram. Fig 8 shows that ploughed field has high sill value of 1.14 so more Roughness comparing to other surfaces in the study. Slope factor was more for ploughed field of about 4.48 and less for road surface. Auto correlation length of barren land is more but due to the higher nugget we can't consider higher roughness for barren land.

D. Discussion

Height standard deviation gives the vertical roughness spectra. Height standard deviation can be same for different surfaces with different properties. Height standard deviation value cannot have a limit because it always represents the vertical variation of the surface undulations. For higher rougher surfaces higher Height standard deviation. In the present study, ploughed field have higher Height standard deviation value as 14 mm and road surface have the minimum of 4.4 mm. Tortuosity index gives the overall area roughness of the plot. Ploughed field have higher tortuosity index of 1.40 and road surface have the minimum of 1.09. Out of all the surfaces, ploughed and sand surface have almost higher values for tortuosity index. The sand surface imaged had undulations due to the foot prints. This may be a reason for the increase in 3D area and thus the tortuosity index. Road surface had the minimum tortuosity index because the study area considered for the road was well leveled. Variogram parameters give the horizontal roughness spectra of the area. Concrete surface and ploughed field shows clear sill, range and zero nuggets for variogram and the auto correlation plot. Road, barren land and sand surface don't show clear sill or range. A Clear wave like pattern was observed for the Concrete as well as ploughed surface with a clear sill. This is due to the higher roughness in these surfaces. Barren land had the highest nugget value. Out of all surfaces barren land surface was the only natural surface. All other surfaces were man made. As the nugget value increase there is an increase in the error in the semi variogram. Variogram analysis for ploughed field showed high sill value of 1.14 so more Roughness. Slope factor was more for ploughed field of about 4.48 and less for road surface. Auto correlation length of barren land is more compared to other surfaces, but due to the higher nugget.

V. CONCLUSIONS

The images of the different surfaces were taken using Canon EOS 1300D digital camera. Using the stereo images, the DEMs of these surfaces were created and different Roughness indices such as Height Standard Deviation, Tortuosity index and Variogram Parameters are found. The Roughness indices can be found using the simple photo acquisition techniques. The accuracy of the results was in millimeters. This is a new method which is a non-contact method which does not disturb the soil profile. This study can be used were we cannot use heavy machines and only with minimum field work.

A main limitation of the study was the one year time limit so only 1 meter square area was considered for each surface which cannot give overall property of the surface. Images are taken from level ground to avoid the slope error in the study. Only one set of surface area was considered for the whole study to compare the Roughness of different surfaces. A generalization of roughness indices for different surfaces can be made only after taking more samples from each type of surface.

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REFERENCES

[1] Allmaras, R.R., Burwell, R.E., Larson, W.E., Holt, R.F., 1966. Total Porosity andRandom Roughness of the Interrow Zone as Influenced by Tillage. USDA Conservation Research Report 7. USDA.

[2] Davidson, M.W.J., Toan, T.L., Mattia, F., Satalino, C., Manninen, T., Borgeaud, M., 2000. "On the characterization of agricultural soil roughness for radar remote sensing studies". IEEE Transactions on Geoscience and Remote Sensing 38 (2), PP 630–640.

[3] Davidson, M.W.J., Mattia, F., Satalino, G., Verhoest, N.E.C., Le Toan, T., Borgeaud, M., Louis, J.M.B., Attema, E., 2003. "Joint statistical properties of rms height and correlation length derived from multisite 1-m roughness measurements" IEEE Transactions on Geoscience and Remote Sensing 41 (7), PP 1651–1658.

[4] Taconet, O., Ciarletti, V., 2007. Estimating soil roughness indices on a ridge-andfurrow surface using stereo photogrammetry. Soil and Tillage Research 93 (1), 64–76.

ISBN 978-93-89105-41-4

[5] Philip Marzahn, Dirk Rieke-Zapp , Ralf Ludwig (2012). "Assessment of soil surface roughness statistics for microwave remote sensing applications using a simple photogrammetric acquisition system" Journal of Photogrammetry and Remote Sensing vol 72 pp 80-89.

[6] J. Vermang, L. D. Norton, J. M. Baetens, C. Huang, W. M. Cornelis, D. Gabriels (2013) "Quantification of soil surface roughness Evolution under simulated rainfall". Transactions of the ASABE (American Society of Agricultural and Biological Engineers Vol. 56(2):PP 505-514.

[7] L. M. Thomsen, J. E. M. Baartman, R. J. Barneveld, T. Starkloff, and J. Stolte (2015) Soil surface roughness: comparing old and new measuring methods and application in a soil erosion model, Soil vol 1, pp 399-410.

[8] Xiu quan Li, Zhu an Chen,Li ting Zhang,Dan Jia (2016). "Construction and Accuracy Test of a 3D Model of Non-Metric Camera Images Using Agisoft PhotoScan" Procedia Environmental Sciences 36 (2016) 184 – 190.

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Impact of Natural Disasters on Traffic and Transportation - The 2019 Kerala floods

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Abstract-**The period from 5th to 11th of August 2019 witnessed heavy discharges in almost all the rivers especially in Northern districts of the state of Kerala, India due to heavy rainfall. Huge amount of precipitation resulted in flash floods and subsequent landslides leading to evacuation of thousands of people from their homes to safer places and relief camps. During 20th to 27th August 2019, officials from NATPAC visited the major locations across the state, where traffic was reported to be disrupted as a result of flash floods, landslides on the roads and pavement damages due to large discharges. The regions in the districts of Idukki, Palakkkad, Malappuram, Kozhikode Wayanad and Kannur which were majorly affected by the 2019 flood were covered. It was observed that the flood had severely affected the transportation system especially in the Ghat regions and the areas near the adjacent valleys. A number of settlements got isolated during the flood period and were denied access to their daily needs. Bridges and culverts got washed away and severe damages were observed for the pavements. The local people had to incur too much expenditure on transport for meeting their daily needs. This paper summarizes the impacts of the floods with special focus of transportation.**

Keywords—transportation; flooding; bridges; roads; pavements; landslide

I. INTRODUCTION

The average annual precipitation of Kerala is 3000 mm. About 90% of the rainfall occurs during the six monsoon months in which the South-west and North-east monsoons prevails. The high intensity storms prevailing during the monsoon months result in heavy discharges in almost all the rivers, especially in Northern Kerala. The continuous and heavy precipitation that occurs in the steep and undulating terrain finds its way into the main rivers through the innumerable streams and water courses. During the period from 5th to 11th of August 2019, there was heavy rainfall in the state. As a security measure to the prevailing situation of heavy rains, Government of Kerala issued Red alert in the nine districts in Northern and Central Kerala, orange alert in the three districts in Central Kerala, and yellow alert in the remaining two districts of southern Kerala. Thousands of people were evacuated to safer places and relief camps. During the disaster that followed in the form of landslides and floods, a total of 121 people lost their lives since 14th August 2019. Floods, landslides and consequent disasters affected 13 districts of Kerala and 1038 villages were declared as flood or landslide affected.

II. LITERATURE REVIEW

Feifei et al. [1] quantified the impact of rainfall on traffic operation of urban road network. The macroscopic analysis method of the network i.e. the Macroscopic Fundamental Diagram (MFD), was used to describe and estimate the level-of-service of road network and evaluate the network-wide traffic state. The results of the empirical analysis indicated that rainfall had an obviously diminishing effect on traffic variables of the network's MFD. Coles et al. [2] described the development of a method to couple flood modelling with network analysis to evaluate the accessibility of city districts by emergency responders during flood events. The modelled surface water flooding was found to have a larger spatial footprint than fluvial flood events resulting in impact on accessibility of emergency services. The six highly damaging natural disasters that occurred in the Czech Republic between 1997 and 2010 in the form of floods and landslides induced by extreme rainfall or by rapid snowmelt were investigated by [3] to arrive at probable mitigative measures. Similarly, [4] developed a relationship between depth of standing water and vehicular speed which could incorporate the developed function into existing transport models to produce better estimates of flood induced delays. The most vulnerable points to flooding along a highway located in the Mexican state of Tabasco where extreme precipitation events and floods were frequent was presented in an integrated framework by [5]. They showed that this framework was useful for the generation of a flood management strategy to the analyzed highway, which includes an optimum location of adaptive measures to an anticipated more intense future climate. The watershed characteristics such as the physical catchment descriptors describing topography, road characteristics, soil type and land use was used for predicting flood-prone road/rail-stream intersections [6, 7]. This communication tool facilitated the prioritization of maintenance and design of adaptive management strategies targeting road-stream intersections that are predicted to be at high risk. The flood risk assessment of the safety of pedestrians, traffic and emergency provision provided crucial spatial understanding of high-risk areas and enabled emergency responders to prioritize evacuation and other actions [7].

III. DISASTER EVENT

As per Indian Meteorological Department (IMD) data, Kerala received an excess rainfall of 196% that occurred till 26th August 2019 there by getting a rainfall of 823 mm instead of 419.5 mm. During the 24 hours ending on 8.30 am of 5th August 2019, a rainfall of 23.7mm happened in Kerala giving an indication of intensifying rainfall again during the monsoon of the year as in the previous year of 2018. The monsoon got intensified and a rainfall of 36 mm was received on the 24 hours ending on 6th August 2019 with Chalakkudi recording the highest with 150.4 mm followed by Kochi airport with 120.7 mm and Thrissur with 110.6mm. The rainfall increased to 71.6mm on 7th August recording greater than 100 mm with highest at Vythiri and Vadakara. A rainfall similar to that occurred in last flood time in 2018 had occurred on 24 hrs ending on 9th August with an intensity of 156.3 mm. On 10th

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August 2019, the precipitation mostly concentrated in the Northern districts. The rainfall receded except at some places in North Kerala by 11th August. Landslides occurred in Idukki, Wayanad, Palakkad and Malappuram districts causing damages to life and property; blockage to roads and rivers etc. in many regions.

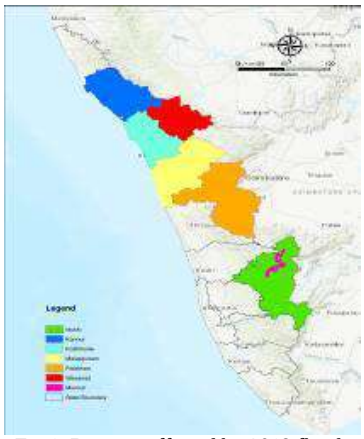

Fig 1. Districts affected by 2019 floods

IV. METHODOLOGY

In order to assess the impact of 2019 floods on traffic and transportation, the major locations in the districts of Idukki, Palakkkad, Malappuram, Kozhikode, Wayanad and Kannur across the state, where traffic was reported to be disrupted due to the rain havoc and subsequent floods were visited during 20th to 27th August 2019. Based on the field visits and subsequent analysis, an assessment of the impacts on transportation and possible interventions were suggested..

V. DISASTER EFFECTS AND IMPACTS ON TRANSPORTATION

The devastating floods and landslides caused extensive damage to houses, roads, bridges, power supplies, communications networks, and other infrastructure; washed away crops and livestock and affected the lives and livelihoods of millions of people in the state especially in Northern Kerala. As of 14th August 2019, 121 people lost their lives due to the 2019 floods across the state of Kerala. Over 2 lakh people were reported to be directly affected by the flood, and were shifted to 1318 relief camps in different parts of the state. Airport authorities suspended operations of the flood-affected Cochin International Airport till 15:00 (IST) on 11th August 2019. The data from the Kerala State Disaster Management Authority (KSDMA) states that, as many as 1789 houses had been damaged fully in between 8th and 19th August, while the number of partially damaged houses was 14,542. Districts that have been severely affected include Wayanad, Malappuram, Kozhikode, Kannur, Palakkad, Thrissur, Idukki and Ernakulam. The north-eastern part of Malappuram district, particularly Nilambur and neighboring regions, were submerged since 7th August night following incessant rain during the previous three days. The entire Nilambur town got inundated with hundreds of houses, shops and business establishments being submerged. Water rose to -3-metres in some places. A red alert was sounded for Malappuram district. The flood had vastly affected many roads and bridges, which were depended on by many peoples, thereby reducing the moblilty and accessibility to their needed destinies. Reports were being aired that traffic and transportation has been severely hit by the floods. Several regions were reported to be isolated as their only access was either washed off or cut off.

VI. DISTRICT WISE DESCRIPTION OF EXTENT OF MAJOR DAMAGE AND GENERAL RECOMMENDATIONS FOR RECTIFICATION

We summaries and tabulate the disasters, affected transportation element and possible interventions in a district wise manner in the subsequent sections.

A. Idukki

For Idukki district, Munnar region was the most affected. The Munnar town was flooded and landslips were observed in many road stretches. The Periyavurai Bridge was washed away isolating Marayoor from Munnar. A large pit also developed near the view point. A massive landslide (Fig 2) hit along the shoulder slide for a stretch of 60 m and hence only one lane length was available for transportation which resulted in traffic congestion. The major disasters in different road stretches in Idukki district are summarized in Table 1.

Table 1: Flood -2019 affected roads in Idukki District

Sl. No	Name of road affected	Flood/ Landslide
1	Marayoor - Munnar Road	Landslide
2	Munnar-Top Station Road	Landslide
3	Adimaly – Munnar – Poopara Road	Flood and landslide
4	Gap Road - Bison Valley Road	Flood and landslide
5	Thottappura – Ambazhachal Road	Landslide
6	Vellathooval- Selliampara Road	Landslide
7	Kakattukada - Anjuruli Road	Flood and landslide
8	Adimali- Rajakkad Road	Landslide
9	a. Panniyarkutty - Ponmudi Road	Landslide
10	b. Vellathooval - Kallarkutty Road (Adimaly - Chithrapuram Road)	Landslide
11	Kallarkutty - Cheruthoni - Kattappana Road	Landslide

Recommended interventions in Idukki district - General Recommendations for rectification include construction of permanent bridge (Periyavurai Bridge) which is capable of passing the design flood under the bridge after conducting proper hydrologic design and retaining walls to protect embankments. Proper drainage facilities

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should be provided along the road and size of culverts should be according to the total runoff accumulated at the drainage outlet. Proper slope protection needs to be provided after carrying out detailed soil investigation.

B. Palakkad

As far as Palakkad district is concerned, Attappadi region was the most affected in the 2019 floods. Floods were also reported in Palakkad town and Pattambi regions but did not cause much destruction. Attappadi had to suffer massive destructions in the form of washing out of bridges, approaches, landslips, embankment failure etc. Approach road to the Moochikadavu bridge and the adjoining piece of land on Sholayoor - Chittoor road along with 200 m length of main road got washed off completely and in case of Vannanthara Bridge (Fig 3) five spans of the bridge got washed off while remaining two spans got dislocated. Table 2 summarises the major disasters seen in Attappadi region of Palakkad district.

Table 2: Flood affected roads in Attppadi Block in Palakkad District

Sl. No	Name of road affected with flood/ landslide	Flood/ Landslide
1	Mannarkkad- Attappadi Road	Flood and landslide
2	Goolikadavu–Chittoor – Sholayoor Road	Landslide
3	Moochikadavu Bridge	Flood
4	Vannanthara Bridge-Dhoodh Valley Road	Flood

Fig 3 Collapsed Vannanthara Bridge

Recommended interventions in Palakkad district - Reconstruction of the bridges and approaches is necessary to facilitate the accessibility of the people. It is recommended to clean the watercourse for debris, silt and logs and suitable slope stabilization techniques may be adopted.

C. Malappuram

Nimabur region in Malappuram district was the most affected area in the 2019 floods. Chaliyar river which flows through the region had massive run offs and this resulted in flooding and landslides at several locations. The Kaippini Bridge (Fig 4) collapsed completely during the flooding. Also, Seethi Haji Bridge was damaged severely at the expansion joints where the span had dislocated for 15 to 20cm. The spans of Karulayi Bridge were found to be moved off eccentrically from the piers in the flow direction. The deck slabs as well as the approach roads were destroyed in the gush of floodwaters. The top layer of the bund road connecting the bridge and Mampad region was washed off. The approach road which is the only means of connectivity for the local community was completely damaged with settlement. The foot over bridge connecting Mampad and Pullipadam was collapsed after water level rose above the bridge and several regions were inundated for three to four days for a height of 1.5m. Table 3 summarizes the major issues in Malappuram district.

Fig 4 Collapsed Kaippini Bridge

Table 3: Flood affected roads in Malappuram District

Sl. No.	Name of road affected	Flood/ Landslide
1	Nilambur – Vazhikadavu - Nadukani Road	Flood and landslide
2	Edavanna – Manjeri Road	Flood
3	Manjeri – MalappuramRoad	Flood
4	Perinthalmanna – Malappuram	Flood
5	Malappuram – Kottakkal Road	Flood
6	Malappuram – Vengara- Kooriyadu Road	Flood
7	Kaippini Bridge	Flood
8	Pookottumanna Bridge	Flood
9	Panankayam- Bhoodanam - Kavalapara Road	Landslide
10	Panankayam Bridge	Flood
11	Karulayi Bridge	Flood
12	Muttiyel – Erumamunda Road	Flood
13	Akampadam– Adyanpara Road	Flood
14	Nilambur-Edavanna road	Flood
15	Edavanna – Areekode road	Flood
16	Perinthalmanna - Pattambi Road	Flood and landslide
17	Kakkad-Chemmad-Parappanangadi Road	Flood
18	Tippu Sultan Road	Flood

Recommended interventions in Malappuram district -Immediate measures must be taken to rectify the collapsed bridges and partly damaged bridge structures to account for safe and efficient transport of vehicles. Suitable earth retaining structures need to be designed to withstand the forces exerted by the retained ground and other external loads after proper soil investigation studies. Sufficient drainage should be provided along with a layer of gravel or geotextiles behind the structure to prevent clogging of weep hole. Proper surface and cross drainages may be added while redesigning the road sections. It should be ensured that GSB layer is given for the full formation width of pavement, i.e., from drain to drain, so as to facilitate easy draining of subsurface water.

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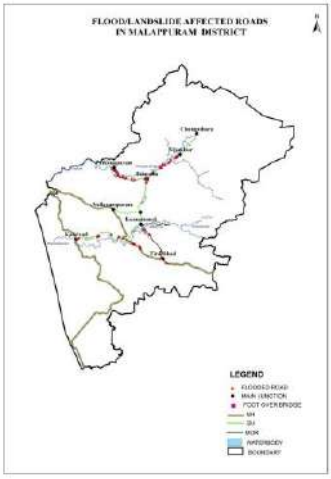

Fig 5 GIS Mapping of the major disaster affected areas in Malappuram

D. Kozhikode

Thusharagiri -Adivaram regions in the foothills of Wayanad Ghats had severe disasters in the 2019 floods. It was observed that at some places the road has been completely damaged due to the rock fall. Chempukadavu Bridge had undergone large damages along with large settlement of sediments, debris and uprooted trees near and around the bridge. The Pothundi Bridge (Fig 6) collapsed completely and the pavement surface at the center of the bridge and the concrete handrails were washed off making the bridge unsafe for traffic. The bituminous layer was completely washed off at several road stretches. The shoulders also got damaged and several boulders were found to have come and settled on the road. Table 4 summarizes the major issues in Kozhikkode district.

Fig 6 Collapsed Pothundi Bridge

Recommended interventions in Kozhikode district - Structural damages to the bridges should be rectified by conducting proper load-settlement tests before permitting heavy vehicles. The boulders and debris obstructing the waterway is to be removed and the banks of the river are to be protected to avoid further erosion. Suitable road maintenance works including shoulder construction and designed side drains are to be done to improve the transportation through the road. Embankment structures should be constructed.

Table 4: Flood affected roads in Kozhikode Districts

Sl. No.	Name of road affected	Flood/Landslide
1	Kandappanchaal Bridge	Flood
2	Chembukadavu Bridge	Flood
3	Kappad – Thusharagiri – Adivaram Road	Flood and landslide
4	Nooramthode-Adivaram Road	Flood
5	Thalayad – Cheedikkuzhi Road	Flood
6	Kakkayam–Kakkayam Dam Road	Landslide
7	Thottilpalam – Mananthavady – Pakramthalam Road	Landslide
8	Pantheeramkavu-Ramanattukara Road Stretch in NH 66	Flood

E. Wayanad

In Wayanad, a massive landslide occurred in Pothumala, Meppady killing 23 people. Traffic and transportation system were disrupted at various places in the region due to flooding, landslips and wash out of cross drainage structures along with damages to pavement. The approach road to a culvert was completely washed off at Kuppadithara. Pavement stretches in the Mananthavady – Periya Road was completely damaged at one section as shown in Fig 7. Plantation crops on either side of highway as well as the roadways were submerged during the high intensity flow. Some of the locations on this stretch were submerged under water for two to three days. The retaining wall collapsed and the debris fell on the house underneath. Table 5 summarises the major issues in Wayanad district.

Fig 7 Damaged pavement in Mananthavady– Periya Road

Recommended interventions in Wayanad district -Immediate measures must be taken on the roads which were submerged. They need to be evaluated for the structural and functional performance. The areas where pot holes are found need to be reconstructed. The flood affected culverts need to be cleaned and checked for any structural damage and are to be rectified, for repairs if any. Suitable earth retaining structures need to be designed to withstand the forces exerted by the retained ground and other external loads after proper soil investigation studies. Construction of retaining walls should be considered on either side of the road constructed through cut and fill sections. The design of the retaining wall should incorporate provision for proper drainage. Other sustainable slope protecting measures like terrace farming, coir textile reinforcing, rock bolting etc. can also be considered.

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Table 5: Flood affected roads in Wayanad District

Sl. No.	Name of road affected	Flood/ Landslides
1	Mananthavadi – Padinjarathara Road	Flood and landslide
2	Mananthavady – Kozhikode Road	Flood and landslide
3	Tharuvana - Padinjarathara Road	Flood
4	Puthusserykadavu – Bankkunnu Road	Flood
5	Kalpetta – Padinjarathara Road	Flood
6	Vythiri – Padinjarathara Road	Landslide
7	Meppadi - Chooralmala Road	Landslide
8	Panamaram - Nadavayal Road	Flood
9	Mananthavady – Periya Road	Flood
10	Periya- Nedumpoyil Road	Landslide
11	Mananthavady – Koilery – Panamaram Road	Flood
12	Manaanthavady – Panamaram – Kalpetta Road via Kaithakal	Flood
13	Beenachi – Panamaram Road	Flood
14	Thazheyangadi – Kenichira	Flood
15	Noolpuzha – Bathery Road	Flood
16	NH 766: Muthangga – Gundulpet Section	Flood

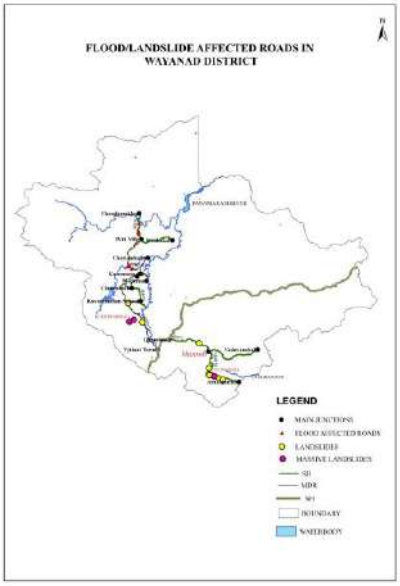

Fig 8 GIS Mapping of the major disaster affected areas in Wayanad

F. Kannur

The Valappatanam river in Kannur overflowed at many locations causing flooding in areas like Sreekandapuram, Peravoor, Iritty etc. One pier of Kandakassery Janakeeya bridge had settled and damaged during the flood. Kacherikadavu bridge (Fig 9) which is an old bridge and was abandoned got toppled in this flood, the broken parts of the bridge obstructing the water course. It was observed that the drains next to shoulders of inner side at many locations were occupied with boulders. Retaining wall of 50 m length had completely collapsed and had fallen into the valley on the outer side. Table 6 summarises the major issues observed in Kannur district.

Table 6: Flood affected roads in Kannur District

Sl. No.	Name of road affected	Flood/ Landslide
1	Kottiyoor - Irrity Road (From Boys Town to Vilakode)	Flood and landslide
2	Link Roads	Flood
3	Iritty – Koottupuzha Road	Landslide
4	Vallithode - Ulikal – Payyavoor	Landslide
5	Kandakassery – Kaniyarvayal Road	Flood
6	Podikalam –Madambam - Parakadavu Road	Flood
7	Payyavoor - Sreekandapuram Road	Flood
8	Sreekandapuram - Chengalayi Road	Flood
9	Chengalayi - Perinkonnu Road	Flood
10	Valakai - Koyyam Road	Flood
11	Nedumpoyil – Iritty Road	Flood
12	Iritty - Taliparamba Road	Flood
13	Parassinikadavu region	Flood

Fig 9 Collapsed Kacherikadavu old bridge

Recommended interventions in Kannur district-New bridge needs to be constructed or the old bridge (Kandakassery Janakeeya bridge) renovated for the free flow of traffic through this region. The old bridge at Kacherikadavu should be dismantled as soon as possible. Maintenance and repair works should be carried out where damages have occurred. Trees should be planted on slopes to prevent mud slip and soil erosion. Surface water should be diverted towards the natural gallery enabling water to quickly drain away from the slope. Culverts and side drains are to be provided for proper drainage. Boulders and silt accumulated in the river which is causing obstruction has to be dredged out for smooth flow of river.

II SUMMARY

Consequent to the incessant rains that befell in Kerala during the period from August 7th to 11th 2019, several disasters happened affecting the traffic and transportation system of the state. The impacts of flood included wash out of bridges and culverts, damages to approaches, flooding on roads that lasted from a few hours to weeks, damages to road pavements including sinking and caving, landslips and landslides ranging from minor to major, etc. Some of the impacts are yet to be resolved and may require proper planning and design.

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Immediate measures are required for restoration of transportation facilities so that people get better access to their daily needs. It is to be ensured that, suitable design practices may be followed before implementation so as to warrant long term sustainability. In the meantime, short term measures like temporary bridges, clearing of debris and sediments from roads, temporary slope stabilization methods, etc., may be thought of. It is to be ensured that proper maintenance of waterway including culverts and bridges are made. Routine maintenance including cleaning and removal of silt and debris deposited in the drainage facilities may be carried out, so that water flow is not obstructed and thus do not affect the infrastructure and public mobility cum accessibility.

REFERENCES

[1] Feifei XU, Zhaocheng HE, Zhiren SHA, Lijian ZHUANG and Wenbo SUN, "Assessing the Impact of Rainfall on Traffic Operation of Urban Road Network," Procedia - Social and Behavioral Sciences 96 (2013) 82 – 89

[2] Daniel Coles, Dapeng Yu, Robert L. Wilby, Daniel Green, Zara Herring, "Beyond 'flood hotspots': Modelling emergency service accessibility during flooding in York, UK," Journal of Hydrology 546 (2017) pp 419–436

[3] Michal Bíl, Rostislav Vodák, Jan Kubecˇek, Martina Bílová, Jirí Sedoník, "Evaluating road network damage caused by natural disastersin the Czech Republic between 1997 and 2010," Transportation Research Part A 80 (2015) 90–103

[4] Maria Pregnolato, Alistair Ford, Sean M. Wilkinson, Richard J. Dawson, "The impact of flooding on road transport: A depth-disruption function," Transportation Research Part D 55 (2017) 67–81

[5] A. Pedrozo-Acuña, G. Moreno, P. Mejía-Estrada, P. Paredes-Victoria, J.A. Breña-Naranjo, C. Meza, "Integrated approach to determine highway flooding and criticalpoints of drainage," Transportation Research Part D 50 (2017) 182–191

[6] Astrid Michielsen, Zahra Kalantari, Steve W. Lyon, Eva Liljegren, "Predicting and communicating flood risk of transport infrastructure based on watershed characteristics," Journal of Environmental Management 182 (2016) 505-518

[7] C. Arrighi, M. Pregnolato, R.J. Dawson, F. Castelli, "Preparedness against mobility disruption by floods," Science of the Total Environment 654 (2019) 1010–1022

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Maintenance and Management of Parvathy Puthanar Canal in Thiruvananthapuram

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***Abstract*—Parvathy Puthanar is a man made canal which runs in Thiruvananthapuram District. The canal was clean and clear during its initial period. The Government of Kerala has taken initiative to reinstitute the water transport in the state from Kovalam to Kasaragod of about 560km. Hence various measures were taken for cleaning and preventing pollution of Parvathy Puthanar. Cleaning was done to remove the floating solids in the canal and cutting of branches of trees which would obstruct the canal vessel movement. Various phsyico-chemical and biological parameters of surface water of Parvathy Puthanar were measured before and after cleaning of the canal. A total of seven sampling stations were selected for monitoring. The measured water quality parameters include pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Dissolved Oxygen (DO), Alkalinity, Biochemical Oxygen Demand (BOD), Total Hardness (TH), Chlorides and E-coli. These parameters were compared with the standards set by WHO and Central Water Commission for designated use of water. Various measures to prevent further pollution of the canal such as installation of septic tanks, aerobic compost centers, fencing etc are also discussed.**

Keywords—*Physico-chemical parameters; Parvathy Puthanar; Recreation; Management.*

INTRODUCTION

Water is a precious gift of nature to human being. Water is of prime importance for the survival of human beings, animals, plants and all other living things [1]. Water quality is a function of both natural and human influences. Urbanization is immensely polluting the surface water and endangering the aquatic life. It creates public health concern. If the present rate of pollution continues, survival of life on earth will be exposed. Wide variety of inorganic, organic and biological pollutant afflicts the water quality. The major sources affecting the surface water in most countries are the untreated sewage and effluent from industries. Variation in temperature depends on geographic location, seasons, sampling time and temperature of effluent entering the stream [2].

Parvathy Puthanar located in Thiruvananthapuram district of Kerala is a man made canal. The width of canal varies from 10-160m and depth ranges between 0.1m to 3m. The canal has altitude mean sea level. It originates from Kadinamkulam Lake in north and flows south east parallel to Trivandrum coast. It finally empties into the Arabian sea by forming a small delta at Poonthura. It was built to connect backwater of Travancore coast and thereby establishing inland waterway to promote the trade and industry of Travancore. Parvathy Puthanar is linked to Karamana River, Kadinamkulam Kayal and also to the Veli-Akkulam Kayal [3]. At first it was clear and fresher than any other river or manmade canal in India. The Parvathy Puthanar (T. S. Canal) and contiguous water bodies passing through the central parts of the city of Thiruvananthapuram has become highly polluted over the years, causing detrimental impacts on the health, sanitation, water and tourism sectors. These regions are developed and thickly populated and requires special protection in interest of environment. Drains at several localities discharges into this canal. Thus the water is black, polluted and most portions are not navigable.

Inland Water Transport (IWT) is one of the oldest, economic and sustainable modes of transportation. Kerala has 1687km long waterways with 590km of West Coast Canal (WCC). The Government of Kerala has given top priority for the development of Kovalam - Kasaragod stretch of WCC. As part of this, development of a portion of Parvathy Puthanar between Kovalam and Akkulam, which connects two major tourist locations of the area, is in progress. The first step towards this was cleaning of Parvathy Puthanar. The task has been divided into two phases namely, cleaning and desilting. As a part of the program, the first stage is to clean the aquatic weeds and other waste which has been dumped into the canal. An Aquatic weed shredder was used to remove the aquatic weeds while an amphibious Truxor was used to remove the

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waste. In the second stage of cleaning, silt pusher equipment is to be used to clean the silt accumulated in the canal and to provide a water depth of 1.5m at every section, so as to make the canal navigable.

MATERIALS AND METHOD

A. Study Area

The study was conducted at the Kovalam Akkulam stretch of Parvathy Puthanar Canal. The waterway passes through Panathura, Edayar Island, Poonthura, Vallakadavu, Trivandrum airport and ends at Akkulam Lake. The study stretch extends for 16.5km. This stretch of the canal consists of many drains which discharges the waste into the canal. Effluent from the sewage treatment plant is also discharged into the canal. An estuary is present in this section at Poonthura. The temperature of water varies from 28^{o}C to 32^{o}C. The study area map is shown in Figure 1.

B. Cleaning of Canal

The canal is polluted with solid and liquid waste. In many places drains are joining the canal. Bushes and branches of trees which obstruct the waterway have been cleared. The water weeds were cleaned and plastic waste were removed. The cleaning works was implemented by KWIL and supervision during the cleaning of the canal was done by NATPAC. One of the equipments used for cleaning was Truxor equipment which is an amphibious machine capable of operating in slushy conditions with low or nil water depth. It can cut through submerged vegetation and rake out and cut floating vegetation. Aquatic weed shredder was also used to shred the weeds and a Pontoon crane was used to remove the shredded weeds from the canal. The cleaned material after drying was transported to selected disposal sites by means of truck and buried under soil cover. The canal is to be dredged to maintain the flow of water and to achieve the minimum required depth of water for boat movement.

Shallow section is proposed to be dredged by maintaining the existing width. Cutting of a new canal is required at Panathura where a road crosses the canal near Panathura Temple. A lifting bridge is proposed in this area. Figure 2 shows the canal before and after cleaning. There are 28 cross structures in this canal, in which three are to be reconstructed.

C. Sampling Locations and Sampling Collection

Seven sampling locations were selected based on introduction of waste and accessibility for testing the physico-chemical parameters. The critical location selected for sampling is given in Table 1. Before cleaning the samples were collected during the month of May. Cleaning was started on June. After cleaning, sampling was done on October. For the analysis, surface water was collected in clean 1L Pearl PET bottles using clean buckets. Preservation and transportation of samples were as per APHA standard methods. The sampling locations are shown in Figure 3

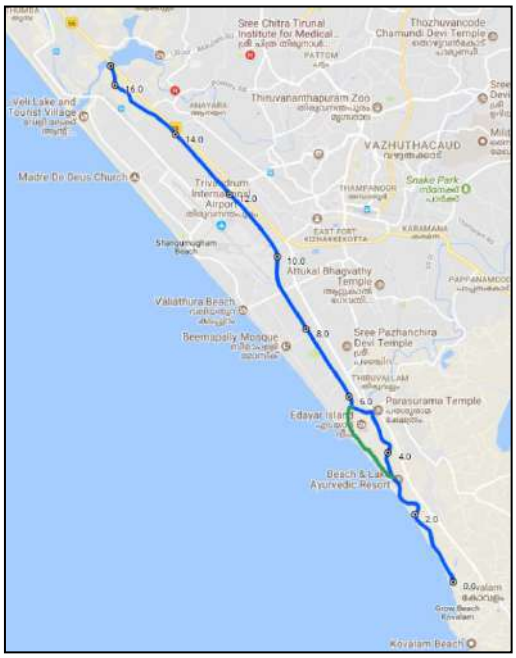

Fig1: Study Area Map

Fig 2: Canal before and after cleaning

Table 1: Sampling Location

Sample No.	**Sampling Location**
S1	Near Moonnattumukku Steel Bridge
S2	Near SM Lock
S3	Outlet of Sewage Treatment Plant
S4	Near MVD Testing Ground
S5	Footbridge Enchakkal
S6	Near Footbridge Karikkakom
S7	Samethi Bridge

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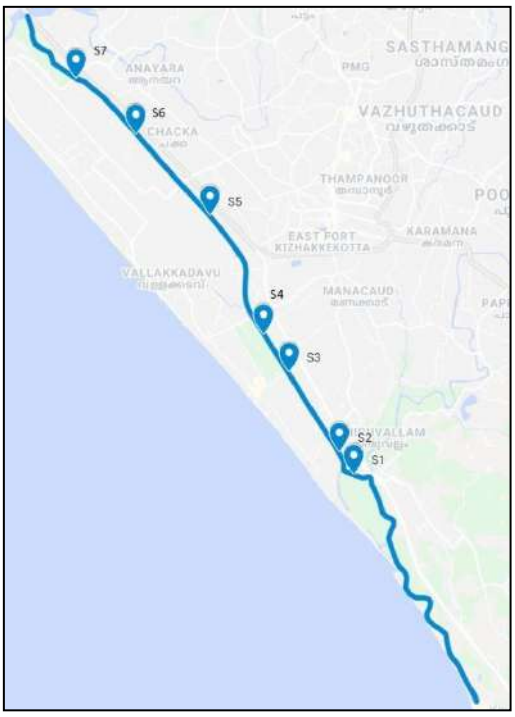

Fig 3: Sampling Location for Analysis

D. Estimation of Physico- Chemical Contaminants

The physico-chemical parameters which alter the quality of water are identified. Chemical analysis of water was done for pH, Electrical Conductivity, Total Dissolved Solids (TDS), Total Hardness (TH), Chlorides, Alkalinity, Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD).

E. Estimation of Biological Contaminants

Microbiological analysis of water was done for E-coli. The sampling locations for E-coli are as shown in Table 2.

Table 2: Sampling Location for E.coli

Sample No	Sampling Stations
E1	Akkulam boat club (200m towards Akkulam bridge)
E2	Nearby Chakka road bridge
E3	Muttathara pipeline bridge 1
E4	Muttathara pipeline bridge 2
E5	SM lock road bridge
E6	Beach & Lake tourist resort
E7	Nearby Temple (100m towards Thiruvallom)
E8	Nearby Temple (100m towards Kovalam)
E9	Nearby Quarry Site(Kovalam)

RESULTS AND DISCUSSION

The results of physico-chemical analysis from seven sampling locations within the Parvathy Puthanar Canal before and after cleaning are summarised in Table 3 and 4 respectively. Each of these parameters is discussed in detail in the subsequent sections. Apart from this the bacteriological analysis for E-coli was also conducted and the results of the same are also discussed in this chapter.

Table 3: Physico-Chemical Parameter before Cleaning

Parameter	S1	S2	S3	S4	S5	S6	S7
pH	7.2	7	6.9	6.9	7.2	7.2	7.2
Electrical Conductivity (µS/cm)	587	470	339	481	708	659	811
TDS (mg/L)	435	350	427	357	523	485	608
DO (mg/L)	4.45	4.13	4.92	4.02	4.1	5.28	5.1
Alkalinity (mg/L as $CaCO_3$)	88	52	142	72	112	92	108
Total Hardness (mg/L as $CaCO_3$)	128	120	100	108	192	176	200
Chlorides (mg/L)	99.8	76.0	57.6	61.8	95.0	95.0	138
BOD (mg/L)	4.64	4.04	4.9	3.19	4.06	5.8	5.75

Table 4: Physico-Chemical Parameter after Cleaning

Parameter	S1	S2	S3	S4	S5	S6	S7
pH	6.89	6.85	6.88	7.33	7.42	7.3	7.26
Electrical Conductivity (µS/cm)	423	342	335	458	461	468	618
TDS (mg/L)	531	428	431	575	579	591	686
DO (mg/L)	5.51	4.64	5.34	4.48	4.52	6.38	6.33
Alkalinity (mg/L as $CaCO_3$)	149	131	150	146	199	166	155
Total Hardness (mg/L as $CaCO_3$)	104	96	85	116	124	110	126
Chlorides (mg/L)	87.3	59.6	56	60.5	67.5	73.4	89.3
BOD (mg/L)	2.89	3.36	4.52	2.79	1.18	2.68	2.92

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A. pH

pH scale ranges from 0 to 14. pH of 7 indicates neutral solution; pH below 7 is acidic and above 7 is alkaline. The component governing the pH in water is carbonate, bicarbonate and carbon dioxide. Natural water system requires a pH of 6-8.5 to support the diverse aquatic system. Very low and very high pH can cause skin and eye irritation hence pH is an important factor for recreational water quality. The variations of pH at sampling location before and after cleaning are shown in Figure 4.

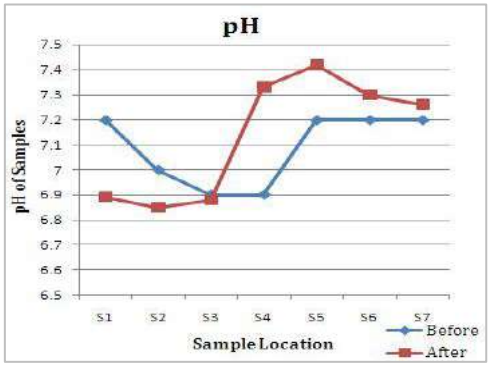

Fig 4: pH Variation before and after cleaning

pH before cleaning varied from 6.9 to 7.2 with a maximum pH of 7.2 at four sampling locations. pH after cleaning varied from 6.8-7.4. The pH measured during either the times were within the safe limit of 6-8.5 for class E use of inland water as per IS2296-1982.

B. Electrical Conductivity

Conductivity is the measure of ability of water to conduct electric current. It measures the concentration of ions in water. Conductance is affected by various factors such as bedrock, presence of inorganic dissolved solids, soil etc. As the sewage contains chlorides, phosphates and nitrates, introduction of sewage would increase the conductivity. Variations of pH before and after cleaning are shown in Figure 5.

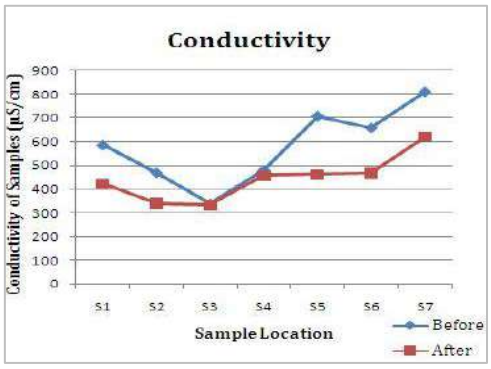

Fig 5: Conductance variation before and after cleaning

The average conductivity before cleaning was observed to be 580µS/cm and after cleaning average conductance was 445µS/cm. The reduction in conductance is due to removal of ions during cleaning and monsoon showers. The conductance before cleaning and after cleaning was within the permissible limits of 2250µS/cm (IS 2296-1982).

C. Total Dissolved Solids

The dissolved solids in water include all inorganic salts, silica and soluble organic matter. Water with too much of dissolved solids is not suitable for common uses. Variations of TDS before and after cleaning are as shown in Figure 6.

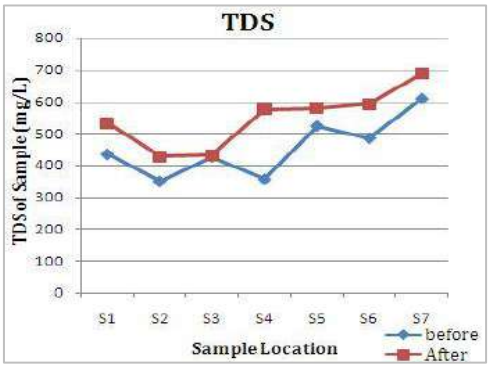

Fig 6: TDS variation before and after cleaning

Average TDS before cleaning was observed to be 455 mg/l and that after cleaning was 545mg/l. An increase in TDS was observed, this could be due to the fact that test after cleaning was done during monsoon. Both the TDS values before and after cleaning were within the limits of 2100mg/l (IS2296-1982).

D. Dissolved Oxygen

Dissolved Oxygen is the amount of gaseous oxygen in dissolved form. It is one of the most critical parameters of concern with any kind of aquatic habitat. Deficiency of DO causes problems to the ecosystem through bioaccumulation and biomagnification. DO values shows seasonal and spatial changes depending on the industrial, human and thermal activity in this area. DO doesn't have direct impact on the users but would influence the microbial activity and chemical oxidation through which undesirable gases like Hydrogen Sulphide would be formed which would affect the aesthetics of the canal water. Variation of DO in the canal stretch before and after cleaning is as shown in Figure 7.

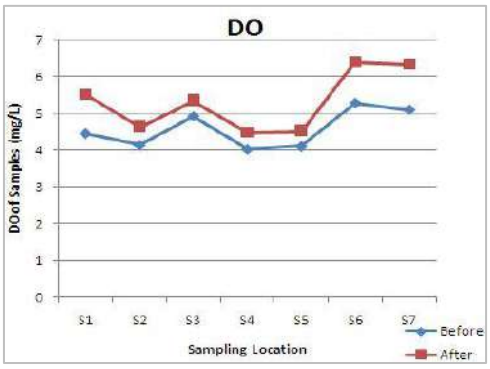

Fig7: DO variation before and after cleaning

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DO level increased after cleaning of canal. Cleaning process would create reaeration which would initiate DO recovery. Further with rain, aeration of river increases so that DO will increase. The general DO level standard for surface water is 4mg/l. Low DO concentrations in water can result in disruption of aquatic ecosystems characterized by fish death, odor and aesthetic disorders.

E. Alkalinity

Alkalinity is the capacity of water to neutralise the acids. Alkalinity changes with rocks, soils, plant activities and industrial wastewater discharge. Without the acid neutralizing capacity any acid added to the water body would change the pH. Variations of alkalinity before and after cleaning are as shown in Figure 8.

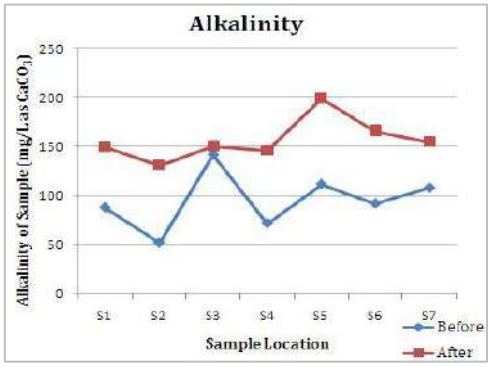

Figure 8: Alkalinity variation before and after cleaning

The alkalinity increased in every sampling location after cleaning of canal. The increase in alkalinity may be due to change in chemical condition of water in canal after cleaning. The average alkalinity after cleaning was observed to be 162mg/l.

F. Total Hardness

Hardness is caused due to the presence of multivalent metallic ions which come from minerals dissolved in water. These minerals comes from sedimentary rocks, seepage and run off from soils. Primary ions in fresh water causing hardness are calcium and magnesium, however iron and manganese also contributes to hardness. Hard to very hard water is suitable for industrial activities and non contact recreation. Variations of hardness before and after cleaning are as shown in Figure 9.

The average hardness before and after cleaning was observed to be 145mg/l and 110mg/l respectively. The hardness after cleaning seems to decrease. A major reason for this decrease would be dilution with rain water after cleaning process.

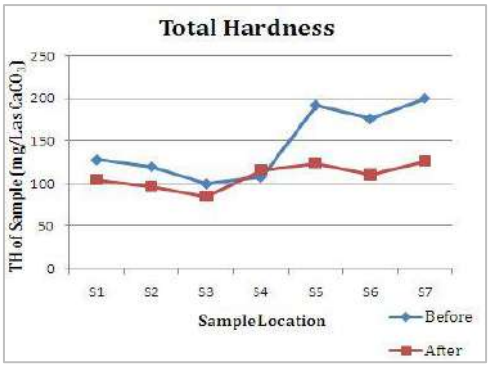

Figure 9: Total Hardness variation before and after cleaning

G. Chlorides

Chloride is an indication of salinity in water. From an environmental aspect chloride is a conservative parameter which acts as an index of pollution occurring in natural freshwater from primary sources such as municipal and industrial outlets. Chloride increases the electrical conductivity and increases corrosivity. The variations of chloride content in canal before and after cleaning are shown in Figure 10.

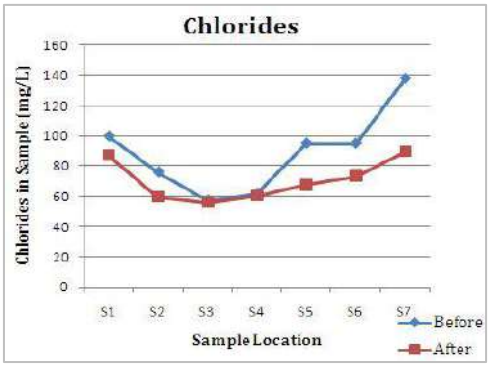

Figure 10: Chloride content variation before and after cleaning

The chloride concentration tends to reduce after cleaning. The average chloride concentration before cleaning and after cleaning was 89mg/l and 73mg/l respectively. The chloride content is within the limit as per IS 2296-1982.

H. BOD

BOD is designed to quantify the potential of oxygen consumption by bacteria to break down organic carbon in the water. The amount of DO in the river and streams is directly affected by BOD. Greater the BOD more rapidly would be the depletion of oxygen. Hence less oxygen is available for the aquatic life. Domestic wastes, agricultural wastes, and livestock wastes are sources of organic pollutants. Variation is shown in Figure11.

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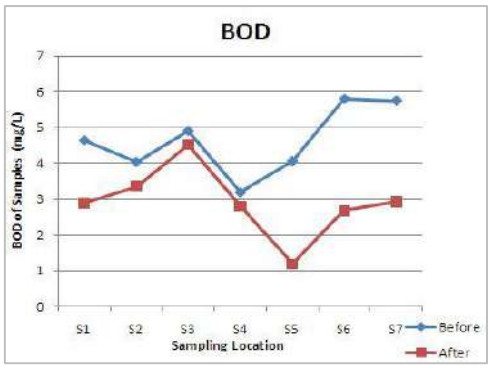

Figure 11: BOD variation before and after cleaning

BOD decreased after cleaning of canal. As cleaning was done during rainy period, an increase in discharge was observed which resulted in a decrease in BOD. The decrease is due to dilution as a result of increase in volume of water in the canal.

I. Bacteriological Analysis

The presence of the indicator bacteria in the water indicates fecal contamination. Fecal contamination is often linked to the presence of pathogens and thus health hazards. The results are shown in Table 5

Table 5: Results of E-coli test

Sample No:	E-coli (CFU/ml)
E1	260
E2	26500
E3	29000
E4	42000
E5	14000
E6	1420
E7	90
E8	360
E9	30

Based on the test results the E-coli count is the highest at Muttathara region. The portions from Chacka to Moonattumukku have households who have kept the outlets of their toilets and latrines directly to the canal. The households in the banks of canal is occupied by those having small plot (1 cent) who are forced to discharge both solid and liquid waste to the canal.

EXISTING WASTE MANAGEMENT SYSTEM

The major obstacle leading to the pollution of the canal is disposal of solid and liquid waste into the canal. Proper waste management system is not present in this study stretch. Households in this study stretch either dump their waste into the canal or burn or bury it in their plot. Previously Thiruvananthapuram Municipal Corporation (TMC) followed a centralised waste management system, whereas now TMC follows decentralised system. According to this system segregation should be done at source itself. Aerobic Compost Bins, Kitchen Bin, Pipe Composts, Biogas plants etc are the various services provided for segregation of solid waste. Along with the aerobic compost center, material recovery facility is also provided which would collect the non biodegradable wastes as per the calendar set by the TMC. For the management of liquid waste, a Sewage Treatment Plant (STP) has been functioning at Muttathara. Sewer lines convey the liquid waste to the STP. The plant can handle 107-million litres a day (MLD), currently handles only 55-60 MLD of sewage as the sewerage network in the city is yet to be completed. The municipal corporation also started a facility where the residents could prebook for septage water collection. The corporation vehicle collects the septage water from these houses and conveys it to the STP.

MANAGEMENT MEASURES

The high E-coli count in the canal is due to direct disposal of toilet and latrine waste into the canal. The short term solution to this existing problem is by constructing septic tanks to those houses without a septic tank. There are 680 houses requiring immediate constructing of septic tank in Chacka to Moonnattumukku stretch. It was found that houses are located very close to each other and therefore adequate land is not available adjacent to each houses for constructing individual septic tanks. After detailed scrutiny it was found that space was available for only for 510 houses. In Ponnara region 61 families are residing at 25 houses. Hence 15 user type septic tank is proposed to be provided for each house. Therefore, in the case of the remaining 145 buildings, it is possible to provide only combined septic tanks of larger capacity to cater to two or more houses at available vacant spaces. Since most of the septic tanks are to be carried manually or through boats, it is advised to use light weight septic tanks made of polyethylene. Nine community toilets are proposed to be constructed. A permanent solution to this is by laying sewer network connecting the outlet of latrines to the sewage treatment plant for treating this waste before disposal. The sewerage networks in the Municipality have to be improved.

Fig 12: Location of Aerobic Compost Centers

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Currently there are 15 Aerobic Compost Center in the study area wards. These 15 centers come under Chacka, Poonthura, Thiruvallam and Fort Health Inspector Zones. Under the Chacka HI zone there are 14 aerobin under the 3 aerobin centers. The average quantity of biodegradable waste collected in the aerobin under Chacka HI zone is 122kg per day. Similarly there are 22 bins under the Fort HI zone which collects around 135kg of biodegradable waste per day. Poonthura HI zone have 25 bins which collects 265kg of biodegradable waste per day. Thiruvallam HI zone have 6 bins which collects 70kg per day of biodegradables. The locations of these units are shown in Figure12. But the availability of the aerobic compost center near to the canal is to be improved. Sufficient centers must be made available along the canal stretch from Moonnattumukku to Vempalavattom so that people could use this facility for disposing the solid waste. The houses in this stretch doesn't have place to dump or bury the biodegradable waste. The provision of Material Recovery Facility along with Aerobic Compost Center would help in preventing the dumping of plastic, glass and other non-biodegradable waste into the canal.

Dumping of poultry waste into the canal is also observed at few stretches. Fencing of canal stretch is an option to prevent further dumping of waste into the canal. Chain linked fencing with GI pipes at 2.5 m interval and 2.5 m height on both sides of canal from Moonnattumukku to Vempalavattom and fencing one side from Moonnattumukku to Thiruvallam bridge is advised.

Installation of surveillance camera is to be promoted so that those dumping the waste could be caught. Strict enforcement of law should be implemented against those who violate the rules.

Beautification of Canal with provision of walkway, cycle track, hand rails, concrete benches and other amenities can also prevent the people from dumping the waste into the canal. All these measures would turn out to be effective only with proper cooperation of the society. Awareness among the people should be created for proper management and maintenance of the canal. A committee can be formed for each stretch to monitor the condition of the canal. Any violation leading to the deterioration of the canal shall be reported to the concerned authority through this committee.

CONCLUSION

Parvathy Puthanar is a man made canal in Thiruvananthapuram. Parvathy Puthanar has become polluted due to the developmental activities and dense population associated with it. The Government of Kerala has accorded top priority for the development of Kovalam - Kasaragod stretch of West Coast Canal. Hence cleaning of the canal has become mandatory. The weeds and other floating wastes were removed. Monitoring of water in the canal was done before and after cleaning. The parameters tested were pH, electrical conductivity, total dissolved solids, dissolved oxygen, alkalinity, total hardness, chlorides, biochemical oxygen demand and E-coli. It was clear from the test results that disposal of solid and liquid waste into the canal must be controlled. Various mitigation measures to control the waste disposal into the canal such as construction of septic tanks, aerobins, fencing of canal etc are discussed.

Waste disposal into Parvathy Puthanar is of great concern, as it is polluting the water and is a source of infectious diseases. Regular monitoring and strict regulations is required for controlling the pollution. Illegal encroachments need to be removed and offenders must be punished.

REFERENCES

[1] I. Razo, L. Carrizales, J. Castro, B. F. Diaz, and M Moroy, "Arsenic and Heavy Metal Pollution of Soil, Water and Sediments in a semi-arid Climate Mining area in Mexico" Water, air, Soil Poll., 152 (1-4): 129-152 2004.

[2] M. V. Ahipathy, E.T. Puttaiah. "Ecological Characteristics of Vrishabhavathy River in Bangalore (India)" Environ Geol 49: 1217–1222 2006.

[3] B. R. Rohini, Akhila. Jayan, B. R. Praveen. Kumar, "Analysis of Heavy Metal Pollution on Parvathy Puthanar an Artificial river Canal in South Kerala" IJRAR 2349-5138 2018.

[4] Susilowati, Joko. Sutrisno, Muhammad. Masykuri, Maridi, "Dynamics and Factors that Affects DO-BOD Concentrations of Madiun River" AIP Conference Proceedings 2049 020052-1–020052-6 2018.

[5] P. C. Sujitha, Mitra. Dev, P. K. Sowmya, Mini. Priya, "Physico-Chemical Parameters of Karamana River Water in Trivandrum District, Kerala, India" International Journal of Environmental Sciences Volume 2 No 3 2012.

[6] O. P. Verma, Bushra. Khanna, Shruthi. Shukla, "Determination of Physical-Chemical Characteristics of Four Canals of Allahabad region and its suitability for Irrigation" Pelagia Research Library 3 (3):1531-1537 2012.

[7] Abdul. Razzaq. Ghumman, "Assessment of Water Quality of Rawal Lake by Long Term Monitoring" Environ Monit Assess180:115-126 2011.

[8] Tolerance and Classification of water use-Central Water Commission 2010 IS 2296-1982

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Study on depth and characteristics of sludge in field-scale Anaerobic Baffled Reactor

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***Abstract*— Anaerobic Baffled Reactor is used as a primary treatment in most of the decentralized wastewater treatment systems. The series of baffles are provided for up flow and down flow of wastewater in the reactor. This particular motion increases the contact time of wastewater with the microbial ecology present in the settled sludge at the bottom of the rector. The operational efficiency of the ABR depends on the active biomass present in the system in the form of a suspension and in the settled sludge. So for the ABR, it is essential to find sludge depth and characterization of the sludge present in the compartments to relate it with the microbial population. The sludge sampling and sludge depth measurement are easy for the laboratory scale models of ABR but for the field scale system, it is difficult to do sludge sampling and to measure the actual sludge depth. In the present study, the new method used for sludge sampling for field-scale ABR is discussed. Also, the results of the sludge characterization of different compartments of ABR, on the basis of moisture content, pH, fixed solids and volatile solids are reported. The fixed solid percentage in the sludge for all compartments was varying from 50% to 60%. No significant variation in moisture content and pH were observed for all four compartments.**

Keywords*— Anaerobic Baffled Reactor; Active Biomass; Sludge Sampling; Sludge Depth; Sludge Characterization;

I. INTRODUCTION

Nowadays with the rapid growth in urbanization and industrialization wastewater generation is increasing. The treatment and reuse of wastewater are becoming more and more attractive. The problems associated with conventional centralized wastewater treatments such as higher footprint, high installation cost, difficult operation and maintenance processes, sludge disposal and effluent reuse are minimized in the decentralized wastewater treatment systems (DWTS). The use of DWTS has advantages such as there is a reduction in the sewer lengths and sewer diameters in the collection system, lower footprint, better controls in the operations and maintenance, and better reuse options as a source of generation is in the nearby area of the treatment plant. The appropriate treatment in the DWTS includes anaerobic treatment as primary treatment followed by secondary and tertiary aerobic treatments. The treatment systems for DWTS include anaerobic baffled reactor (ABR), anaerobic filter (AF), constructed wetland (CW), and polishing pond. Also, the conventional treatments used for centralized treatment plants can be used for DWTS depending upon the wastewater characteristics and field conditions. The combined treatment considering anaerobic and aerobic treatment is suitable and beneficial for the tropical climate regions. The performance of such operational DWTS plants in India where anaerobic treatment followed by aerobic treatment was reported [1]. Among the anaerobic treatments, the advantages of ABR have been reviewed [2]. The advantages include the phase separation, less biomass washout, operation under gravity flow, and cost-effectiveness for field-scale use. The ABR is a modified septic tank having 4-8 compartments and baffles are provided for up flow and down flow motion of wastewater. This flow pattern increases the contact time with the active biomass present in the sludge at the bottom of the compartments of ABR.

The operational efficiency of ABR depends upon the microbial ecology present in the suspended form and in the settled sludge. The literature on the granulation of sludge in ABR shows the increase in settling properties and less prone to sludge washout [3]. Although the granulation of sludge is not necessary for the working of ABR, the granulated form of sludge tends to immobilization of active biomass present in the sludge. This is because of the granulated form of sludge gives shelter for the microorganisms. So the sludge present in the compartment of ABR is an important factor considering the operation of ABR. The importance of sludge accumulation in ABR measured on the basis of sludge depth has been reported [4]. Based on the sludge depth measurement and sludge characterization of the ABR the author had related it to the anaerobic microbial activity [4].

For the field scale ABR, it is quite difficult to do sludge measurement and sludge sampling as the openings of the compartments are smaller in size and depth of sludge can not be seen as ABR is a closed system. From the literature, the method using hollow plexiglass and metal rod can be used to measure the sludge depth and for sludge sampling [4]. But the method suggested by the author is quite difficult due to the complex arrangement and the leakage problem. The other method of sludge depth measurement by Velcro tape is also suggested in the literature [5]. The problem associated with this method is the attachment of floating sludge and the suspended particle to the Velcro tape which can mislead the measurement of actual sludge depth.

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Although the methods of sludge depth measurement are present but they are difficult to implement on field-scale systems due to problems associated with them. Therefore there is a need for a new method of sludge sampling and sludge depth measurement. Also, very few studies have been reported in the literature which focuses on the sludge depth measurement and sludge characterization in various compartments of ABR [4]. In the present study, the new method is suggested for sludge sampling and sludge depth measurement. The objectives of the present study are to asses the variability of sludge depth in various compartments and to asses the change in characteristics of sludge present in the various compartments of field scale ABR.

II. MATERIALS AND METHODS

A. Source of influent wastewater and its characteristics

The primary source of raw wastewater to Integrated decentralized wastewater treatment system (IDWTS) Walchand College of Engineering (WCE), Sangli, Maharashtra is generated from the college campus, hostels, and the mess. The wastewater contains septic tank effluent and greywater from the bathroom, toilets, kitchen and washing places of the hostels and the mess. Table-1 summarizes the influent wastewater characteristic to ABR (average of 53 samples)

Table 1 Influent wastewater characteristics

Parameters	Value
Total COD (mg/L)	478±180
pH	7.11±0.24
TSS (mg/L)	223±70

B. Field-scale ABR

IDWTS consisting of bar screen, ABR, horizontal flow baffled constructed wetland (HFBCW), and vertical flow constructed wetland (VFCW) is operational in WCE, Sangli, Maharashtra. The ABR is working as a primary treatment in the system having 8 compartments. The flow of wastewater through each compartment of ABR is vertical and between the compartments is by horizontal gravity flow. The split feed provision is given from the C2 compartment to the C5 compartment as shown in Fig. 1. For the present study, stage-1 of split feed ABR with the first four-compartments is taken into consideration. The effective volume of the stage-1 of ABR is 26 m3. The first two compartments of the ABR have an effective volume of 2.85 m3 each and the third and fourth compartments have an effective volume of 10.40 m3 each. The effective depth of wastewater was 2.5 m in the compartments of ABR.

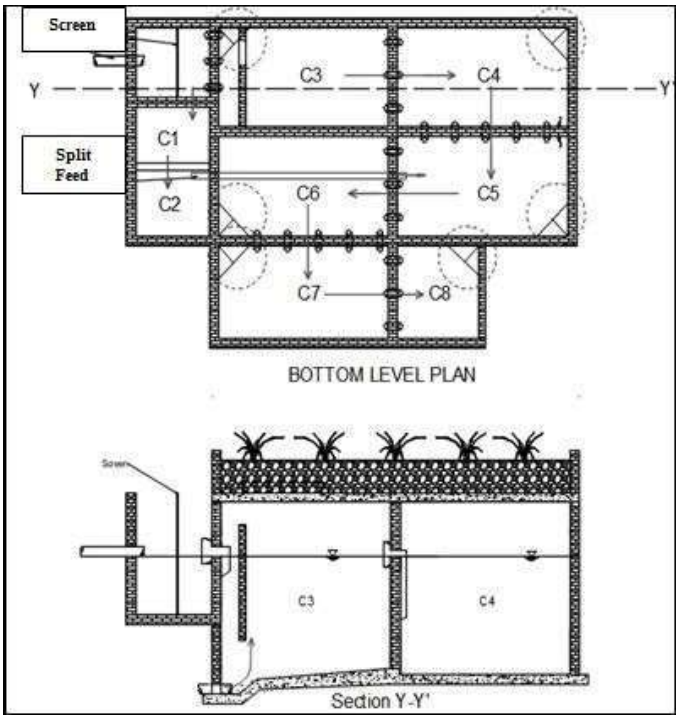

Figure 1 Schematic sketch of plan and section of ABR as a part of IDWTS at WCE, Sangli

C. System Operation

The ABR was operated under the uncontrolled conditions for the study period from November 2019 to January 2020. The observations showed that flow rate was varied as peak flow rate (~5000 L/h) which was between 8:00 a.m. to 10:00 a.m, at intermediate flow rate (~2800 L/h) which was observed between 12:00 p.m. to 2:00 p.m. and at least flow rate (~ 1200 L/h) which was between 4:00 p.m. to 6:30 p.m.

D. Sludge Sampler

1) Components of Sludge Sampler

The sludge was collected using the sludge sampler from the opening of ABR compartments. The components of the sludge sampler are shown in Fig. 2 which are a transparent acrylic pipe and a foot valve. The transparent acrylic pipe used for sludge sampler was with an outer diameter of 30 mm and an inner diameter of 26 mm with a length of 2 m. The foot valve without a spring was attached to the bottom of the transparent pipe for smooth entry of wastewater in the pipe without applying the external sucking pressure. The reason for providing the foot valve was to restrict the down flow of the wastewater from the pipe. The self-weight of wastewater in the pipe was applying pressure to the footplate which was responsible for restricting the down flow of wastewater from sludge sampler. The leakage problem at the bottom was eliminated as sludge settlement at the bottom of the pipe and it was restricting the leakage. The reason for using a transparent acrylic pipe was for detecting the actual sludge depth in the pipe which was related to the sludge depth in the compartment of ABR

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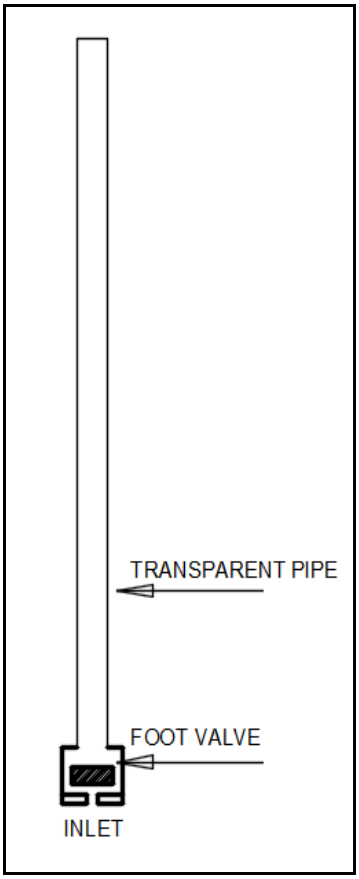

Figure 2 Schematic sketch of sludge sampler

2) Use of Sludge Sampler

The proper use of sludge sampler was important as sludge depths were varying according to the way of handling of sludge sampler. Before immersing the sludge sampler in the wastewater the care was taken that thorough mixing of the wastewater with the sludge should take place. Thoroughly mixing the sludge with wastewater was important because the thickened sludge could not enter the sludge sampler. The immersion of sludge sampler in the wastewater was done in a slow manner so that mixed sludge and wastewater could enter the sludge sampler. After this, the sludge sampler was taken out from the compartment for the settling of sludge solids. Settling was done for 15 minutes and sludge depth was measured as the pipe was transparent. For collecting the sludge sample footplate of the foot valve was pressed on the upward side which opened up the foot valve. Fig. 3 shows a photographic view of the sludge sampler.

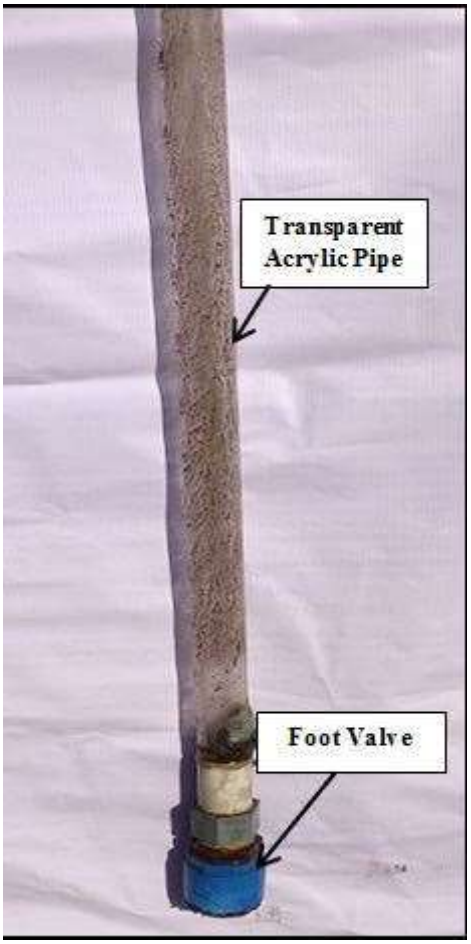

Figure 3 Photographic view of sludge sampler

E. Sampling Method

The sludge samples were collected from the openings of compartments of ABR. These opening locations are marked by dotted circles in Fig. 1. The sludge depth measurement was done once in each month in the study period from November 2019 to January 2020. For each sampling, five-time samples were taken and the average of the data is represented in the results.

F. Analytical methods

Analytical laboratory tests on sludge samples included Chemical Oxygen Demand (COD) by Closed reflux method and Titrimetric method (APHA 5220), pH by Potentiometric method (APHA 4500-H^+), Moisture Content (MC), Volatile

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Solids (VS) and Fixed Solids (FS) by Gravimetric method (APHA 2540) all according to Standard Methods [6].

III. Results and Discussions

A. Sludge depth measurement

The measured sludge depths in the month of November 2019, December 2019 and January 2020 in compartments of ABR are shown in Fig. 4. The literature shows that the sludge depth is more for the first two compartments of ABR, [4], but for this case, the scenario was different as sludge depth was more in the third and fourth compartments. The reason behind this was among all four compartments of stage-1, the C3 and C4 compartments of the ABR were operational from March 2017 and C1 and C2 compartments were added to IDWTS from September 2019. So the sludge depths in C3 and C4 compartments were more than C1 and C2 compartments. As the C1 and C2 compartments were operational from September 2019 the gradual increase in sludge depth from November 2019 to January 2020 can be seen in Fig. 4. This shows the accumulation of biomass along with the settable particles in the first two compartments of ABR. The variation in the depth of sludge for the C3 and C4 compartments for three months was very less for ABR. The reason for this was the more volume of C3 and C4 compartments than of C1 and C2 compartments so the increment in depth was lesser for these compartments. The overall depth of sludge of the C3 compartment is seen to be more than other compartments of the ABR because the C3 compartment of ABR was the first compartment when it was operational in the year 2017 so the amount of accumulated sludge in the C3 compartment was more

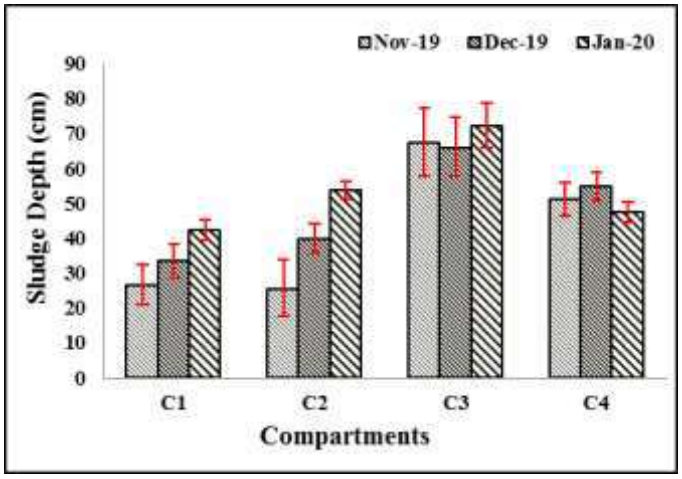

Figure 4 Sludge depths in the compartments ABR

B. Sludge characterization

The sludge characterization study was done for the sludge of all the compartments of ABR. The sludge characterization of compartments of ABR is shown in Table-2. The moisture content of the sludge from all four compartments of ABR ranges between 80-90%, no significant variation was seen in the moisture content of the sludge. The variation in the pH and COD of all four compartments of ABR was also negligible.

The sludge from the C1 and C2 compartments was brownish-black in color due to the presence of undegraded settled biomass. For C3 and C4 compartments, the color of sludge was more black than sludge from the C1 and C2 compartments. Also, the settling of the sludge was more for the sludge from C3 and C4 compartments than sludge from C1 and C2 compartments.

The literature shows that the amount of volatile solids is more in the first two compartments of ABR [4] but the amount of fixed solids in sludge was more for all compartments of ABR. The variation in the volatile solids was ranging between 40% to 50% for all compartments. The fixed solid percentage in the sludge was varying from 50% to 60%. After the testing of sludge for fixed solids, the grit particles and clay were seen in the dried sludge. IDWTS is not provided with the primary settling tank so the incoming grit particles get trapped in the compartments of ABR, as a result, the fixed solid percentage was more in the sludge. As the C3 and C4 compartments were also the first compartments of ABR when it was operational in the year 2017-2019 the amount of fixed solids present in these compartments was also in the same range that of C1 and C2 compartments for ABR.

Table 2 Sludge characterization of ABR

Compartment	Moisture content %	Total Solids		pH	COD (mg/L)
		FS %	VS %		
C1	82	50	50	7.40	26240
C2	84	60	40	7.27	24320
C3	82	53	47	7.08	23040
C4	86	60	40	7.48	24960

IV. Conclusions

In this study, the four compartments of field-scale ABR as a part IDWTS WCE, Sangli was studied for sludge depth measurement and sludge characterization. The new method of sludge sampling was used for taking the sludge samples and for sludge depth measurement. The sludge sampler used for sludge sampling can be the better option for sludge sampling than methods suggested in the literature. The sludge depth measurement and sludge sampling were easy by using this sampler.

The sludge depth measurement shows the variation of sludge depths in compartments. Also, the gradual increase in the sludge depths was seen for the individual compartment for the study period of three months. The accumulation of sludge in C1 and C2 compartments were more in ABR than other compartments as these compartments were initial compartments of ABR.

The sludge characterization study of ABR did not show any significant difference between all compartments. The percentage of volatile solids was less in all the compartments

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of ABR. As the study was done on the field scale ABR without primary settling tank the amount of fixed solids in the sludge was higher than volatile solids in all compartments of ABR. The clay particles and grit particles were seen in the dried form of sludge which was responsible for higher fixed solid content in the sludge. No significant variation in pH, COD and moisture content was seen between all the compartments of ABR.

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REFERENCES

[1] Sakthivel R., Seshadri A., Rahman Md A. and Chariar M. (2012), Standardisation of Design and Maintenance of DEWATS Plants in India." Paper presented in IWA Conference, Nagpur.

[2] Barber W.P and Stuckey D.C. (1999), "The use of anaerobic baffled reactor (ABR) for wastewater treatment: a review" Water Research, 33,1559-1578

[3] Uyanik S., Sallis P.J, and Anderson G.K, (2002b). "The effect of polymer addition on granulation in an anaerobic baffled reactor (ABR)", Part I: process performance. Water Research, volume 36(4), pp. 933-943

[4] Reynaud, N. S., (2015) "Operation of Decentralized Wastewater Treatment Systems (DEWATS) under tropical field conditions" Ph.D. Thesis, Department of Environmental Sciences, Technical University, Dresden.

[5] "Do-It-Yourself Septic System Inspection Field Guide (GravitySystem)" Web Resource. https://www.doh.wa.gov/Portals/1/Documents/Pubs/337-122.pdf

[6] APHA (2012) "Standard Methods for the Examination of Water and Waste Water". 22nd Edition, American Public Health Association, American Water Works Association, Water Environment Federation.

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Estimation of Oxygen Transfer Parameter in Feeding System of Vertical Flow Constructed Wetland

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Abstract— **Constructed wetland is a part of a decentralized wastewater treatment system and appropriate to treat domestic wastewater. Vertical Flow Constructed Wetland (VFCW) is generally a secondary treatment and as part of field-scale Integrated Domestic Wastewater Systems (IDWTS) at Walchand College of Engineering (WCE), Sangli (Maharashtra) planted with *Canna indica* and *Arundo donax* L. (Giant reed). In this study, oxygen transfer parameter of feeding cum aeration system was evaluated on a field scale VFCW for the first time. Oxygen transfer parameter values obtained are 6.26 h^{-1}, 25.82 h^{-1}, 16.15 h^{-1} for the 1st stage, 2nd stage and overall feeding system respectively.**

Keywords— Decentralized Treatment, Dissolved Oxygen, Oxygen transfer parameter, Domestic Wastewater, Vertical Flow Constructed Wetland.

I. INTRODUCTION

Domestic wastewater, industrial effluent and agriculture run-off are the three main sources of water pollution in India. The increase in population and varied activities of people have increased domestic wastewater generation rate. The most significant environmental problem and a threat to public health is the generation of wastewater and its treatment. The treatment of domestic wastewater is a challenge in recent times. The collection, treatment and disposal of domestic wastewater can be done through centralized or decentralized systems. There are many centralized treatment plants available to treat the wastewater, but it requires large scale infrastructure, high amount of input energy, expensive and require complex operations along with maintenance. These limitations of a centralized wastewater treatment system can be overcome by adopting a Decentralized Wastewater Treatment System (DWTS) wherever feasible. DWTS is composed of primary, secondary and tertiary treatment for wastewater. Typically constructed wetlands (CW) are part of DWTS. Vertical Flow Constructed Wetland (VFCW) is normally used as secondary/tertiary treatment. The advantages associated with VFCW are good efficiency, smaller foot-print, enhanced oxygen transfer and simpler hydraulics**.** The main advantage of VFCW systems is the ability to transfer high amounts of oxygen inside the bed [1]. The feeding system and aeration within the bed in VFCW plays a significant role in system performance. Aeration during feeding to VFCW improves the performance for COD removal [2]. A feeding with aeration system is provided in field-scale Integrated Domestic Wastewater Treatment System (IDWTS) operational at Walchand College of Engineering (WCE), Sangli. The performance of such systems is evaluated through the oxygen transfer efficiency. The estimated value of the oxygen transfer parameter is indicative of the efficacy of the system to transfer oxygen. However, there are no studies reported on an estimation of oxygen transfer parameter in the feeding system of VFCW. In the present study, an attempt is made to estimate the oxygen transfer parameter at different stages of feeding system and for the system as a whole.

II. MATERIAL AND METHODS

A. Feed wastewater to VFCW

The domestic wastewater generated in WCE campus is treated in field-scale IDWTS. Feed wastewater to VFCW is pretreated through primary and secondary treatment. The effluent from CW based secondary treatment is applied through feeding cum aeration system of VFCW.

B. Description of Feeding System

Fig. 1(a) shows the feeding cum aeration system which consists of a tank, PVC pipes and trays. A circular tank was provided at the centre of VFCW. The bottom of the tank is at 0.6m from VFCW bed. A grid of cross-connected discarded plastic bottles is placed within the tank in four layers with 5 cm vertical distance (Fig.1 (b)). The eight outlet ports were provided at the bottom of the tank which was connected to 25 mm diameter sloping PVC pipes having a length of 1.5 m. These eight outlet pipes are connected to perforated trays. The perforated tray system (4 levels) of 1 m total depth with 5 mm perforation at each level and filled with charcoal. 1st stage of feeding cum aeration system is defined for the portion from inlet to the end of outlet pipes. 2nd stage is defined for the outlet

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of pipes to the end of multilevel perforated tray (Fig.1 (a)). Feed wastewater falls on this grid from a height of 1 m and collected at the bottom of the tank. The collected wastewater was fed uniformly through these PVC pipes at eight different locations. Further wastewater passes from perforated tray system. Due to grid surface, water droplets get ejected and later fall within the tank which provides more contact time between influent wastewater and atmospheric air. The perforated tray filled with charcoal to enhance maximum turbulence and thereby aiding aeration. Finally, wastewater passes through the bed of VFCW.

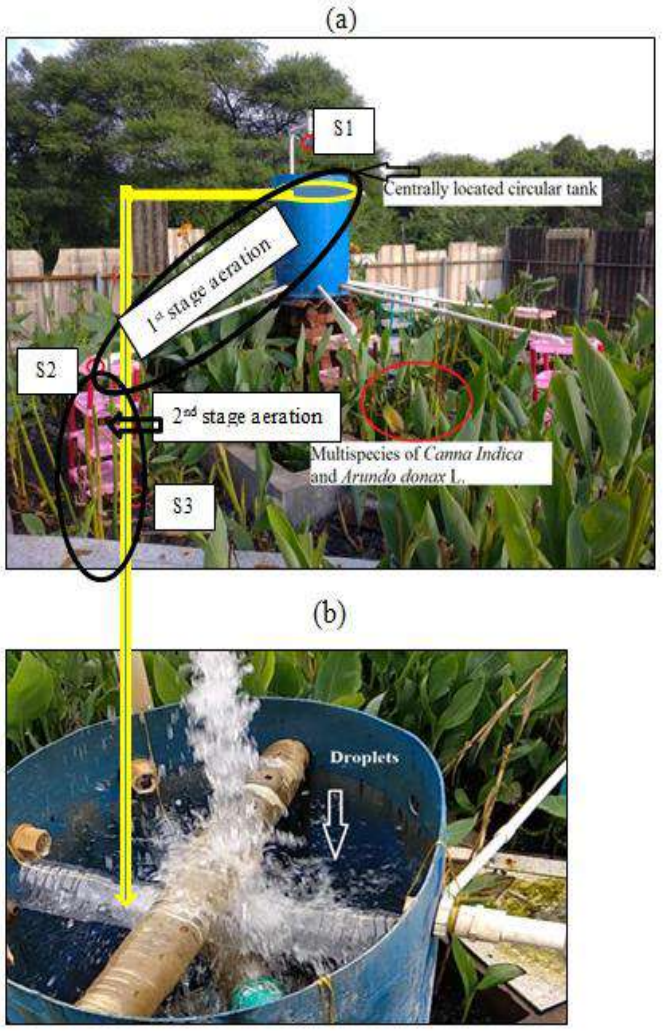

Figure 1 Photographic view of (a) Feeding cum aeration system of VFCW (b) Grid surface.

C. Oxygen transfer parameter (k) and its determination

The process in which oxygen is transferred from the gaseous to the liquid phase means oxygen transfer. Oxygen transfer rate is indicative of mass absorbance of oxygen in a certain period into wastewater. There are various factors which affect the oxygen transfer parameter, such as temperature, quality of water, partial pressure and turbulence. According to two-film theory, the interface is composed of two distinct films i.e. gas and liquid, that serves the barrier between the bulk phase. Oxygen transfer is governed by the liquid film because oxygen is slightly soluble gas. Resistance occurred when it comes from air to interface and then interface to liquid film. Hence to transfer a large amount of oxygen, there is a need to form several droplets or to reduce the thickness of wastewater and make more turbulence to the wastewater.

Oxygen transfer at any time‘t’ is given by equation (1).

$$Ct = Cs - (Cs-Co)\, e^{-kt} \quad (1)$$

Where, C_t = DO concentration at time‘t’ (mg/L)

C_s = saturated DO concentration (mg/L)

C_o = initial DO concentration (mg/L)

k = oxygen transfer parameter

t = time (h^{-1})

Equation (1) is rearranged and expressed as,

$$K = \ln [(Cs-Co) / (Cs-Ct)] / t \quad (2)$$

For calculation of oxygen transfer parameter, it is necessary to know initial DO concentration(C_o), DO concentration at time ‘t’(C_t) and saturation DO concentration (C_s). For two month study, 44 number of samples were taken at each sampling locations. The temperature of wastewater was measured. By knowing temperature and chloride content, Cs value was determined [4]. Flow-through time was measured by using a tracer study.

III. RESULTS AND DISCUSSION

A. Characteristics of Influent wastewater

Table 1 Characteristics of feed wastewater

pH	COD (mg/L)	BOD_3 at 27ºC (mg/L)
7.2 – 7.8	100 - 250	30-80

In Table 1. Characteristics of feed wastewater in terms of pH, COD, BOD_3 based on 44 samples analyzed during the study. There is no much variation in pH and it is in a neutral range which is helpful for the bacterial actions. The influent to VFCW is categorized as low strength as COD ranges between 100-250 mg/L.

B. DO measurement

Table 2 DO concentration at the 1st stage and 2nd stage

Inlet of 1st stage aeration (mg/L)	Outlet of 1st stage aeration (mg/L)	Outlet of 2nd stage aeration (mg/L)
0.24 ± 0.16	0.43 ± 0.19	1.04 ± 0.08

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Different DO concentration was found at inlet and outlet of 1st stage aeration, outlet of 2nd stage aeration as 0.24 mg/L, 0.43 mg/L and 1.04 mg/L respectively. DO concentration was increased at the outlet of 1st stage aeration due to the number of water droplets formation at a grid of discarded cross-connected plastic bottles. Also DO was enhanced at the outlet of 2nd stage aeration due to cascade aeration at perforated multilevel trays.

C. *Oxygen transfer parameter values*

Table 3 Oxygen transfer parameter values at 1st stage, 2nd stage and overall feeding system

1st stage aeration (h^{-1})	2nd stage aeration (h^{-1})	Overall feeding system (h^{-1})
6.26	25.82	16.15

The temperature of wastewater was obtained as 24ºc. According to chloride content and temperature Cs value was obtained as 8.075mg/L. For the 1st stage, 2nd stage and overall (feeding system) time was measured 12 sec., 8 sec. and 20 sec. respectively. Figure 2 shows different oxygen transfer parameter values at a different stage of the feeding system as 6.26 h^{-1}, 25.82 h^{-1} and 16.15 h^{-1} respectively. Oxygen transfer parameter value was increased at stage 2 due to more turbulence and layer formation occurred this stage.

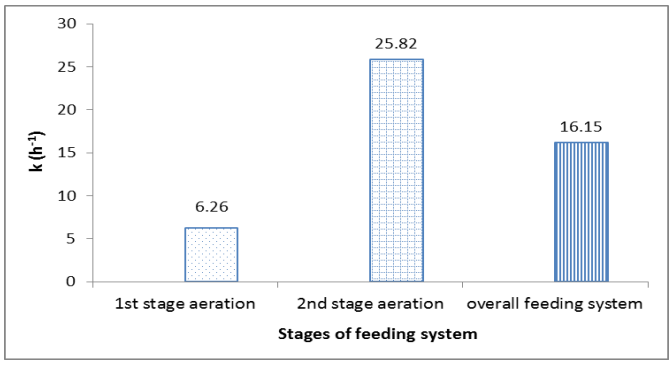

Figure 2 Variation of 'k' at different stages of feeding system

D. *Effect of initial DO on oxygen transfer parameter*

Table 4 Oxygen transfer parameter values at various DO concentration

Initial DO(mg/L)	0	0.1	0.24	0.43	0.68
k (h^{-1})	6	9.17	13.7	14.05	17.54

Figure 3 shows the variation in oxygen transfer parameter at different DO concentration. When initial DO concentration was zero, 0.1mg/L, 0.24 mg/L ,0.43 mg/L and 0.68 mg/L, oxygen transfer parameter values were obtained 6 h^{-1}, 9.17 h^{-1} 13.07 h^{-1}, 14.05 h^{-1} and 17.54 h^{-1} respectively. It shows that, with the increase in initial DO concentration, oxygen transfer parameter also increases.

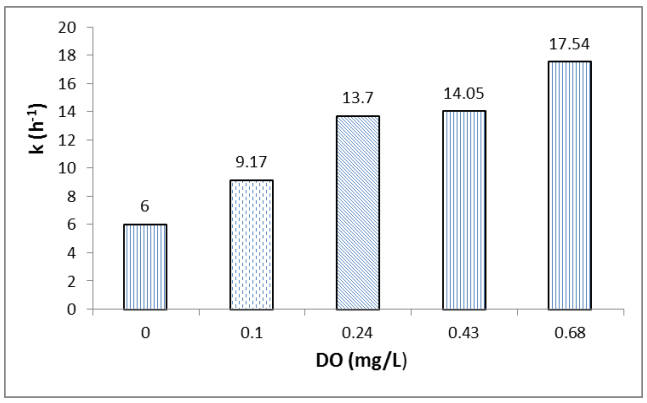

Figure 3 Variation in 'k' at different DO concentration

E. *Characteristics of Effluent wastewater*

Table 5 Characteristics of effluent wastewater

pH	COD (mg/L)	BOD_3 at 27ºC (mg/L)	DO(mg/L)
7.59 – 7.83	68 - 83	23-38	0.5-0.82

There is no much variation in pH. Feeding cum aeration system significantly contributes to the removal of COD and BOD_3 at 27ºC. Also, effluent wastewater shows DO up to 0.82 mg/L, it is because of plants root penetrate oxygen into the bed of VFCW.

This is a natural system so that DO was enhanced up to a certain extent. It is required to measure DO on site.

IV. CONCLUSIONS

The feeding cum aeration system for field-scale VFCW was assessed for its performance of oxygen transfer parameter. The evaluated oxygen transfer parameter was found to be 6.26 h^{-1}, 25.82 h^{-1} and 16.15 h^{-1} for stage 1, stage 2 and overall feeding system respectively and it increases with increase in initial DO concentration. The result indicated that the newly developed feeding cum aeration system provides better quality of feed wastewater to VFCW.

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REFERENCES

[1] Zou J., Guo X., Han Y., Liu J. and Liang H., "Study of a novel vertical flow constructed wetland system with drop aeration for rural wastewater treatment." *Water Air Soil Pollution*, 223, 889–900., 2011.

[2] Jadhav P. and Munavalli G. "Effect of Feeding with Aeration System on COD removal in Vertical Flow Constructed Wetland". International Conference on Engineering, Mathematical and Computational Intelligence (ICEMCI 2019), Jabalpur Engineering College, Jabalpur., 2019.

[3] APHA (2012) "Standard Methods for the Examination of Water and Waste Water". 22nd Edition, *American Public Health Association, American Water Works Association, Water Environment Federation*

[4] Metcalf, Eddy, "Wastewater Engineering: Treatment and Reuse", In Tchobanoglous, G., Burton, F.L., Stensel, H.D. (Eds.). McGraw-Hill., 2003.

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Package Treatment System for Domestic Wastewater

A Review

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***Abstract*— Water supply and sanitation are the two basic needs that affect people's standard of living. When sewage is exposed to an open environment without any treatment, there are chances of health hazards. Conveying the sewage to the central treatment facility and its safe disposal is the major concern of wastewater management authorities. Cost and resources are the major constraints to maintain this huge infrastructure. To tackle this, a decentralized wastewater treatment system (DWTS) is evolved. DWTS consists of a combination of the septic tank, Anaerobic Baffled Reactor (ABR), Constructed Wetland (CW), activated sludge process (ASP), moving-bed biofilm reactor (MBBR), etc. Wastewater treatment plants can never be a revenue-generating model as the product is treated water and a small fraction of sludge. To make it economically feasible, recycling and reusing wastewater at the point of generation can solve water issues to a great extent. When one or more unit operations incorporated into a single system for wastewater treatment is known as the package wastewater treatment system. The commercially available package systems in the market are energy-intensive and have high capital costs. Hence there is a need for a package treatment system incorporated with less energy-intensive and natural treatment. The present study is focused on the development of a highly efficient, compact, user-friendly and economical system incorporated with natural treatment in order to serve the needs of developing countries.**

Keywords*— Package treatment plant; Domestic wastewater; Scale effect; Constructed wetland;

I. INTRODUCTION

To protect society from waterborne diseases, the central sewer system was evolved by the human in early civilization. To collect and transport the sewage generated within the reach of society, the sewer system was adopted. The main objective in front of the current urban wastewater management process is to transport wastewater from its point of generation to the central municipal treatment plant (which is far away) through sewers and finally ends at the disposal point[1]. In India, from 35 major cities, 15644 Million liters per day (MLD) wastewater is generated. The shocking fact is only 8040 MLD can be treated with the help of available infrastructure and the remaining sewage exposed to an open environment resulting in the danger of aquatic life in terms of undesirable matter in freshwater sources [2].

Simultaneously, the flushing toilet was invented and has been praised ever since as a most important civilization gain disregarding the fact that high quality (and often scarce) drinking water is required for flushing and transport of wastes to the treatment plant. In industrialized countries, a huge amount of money has been spent over the past decades to build up and operate such sewer systems, with drinking water as a transport medium. Gradually, the cities, villages and rural areas in Europe and elsewhere have been provided with sewers. In Germany, for instance, more than 95 percent of the population is currently connected to sewer systems [1].

The domestic wastewater treatment process consists of four stages which are pre-treatment, primary treatment, secondary treatment, and tertiary treatment. The first two stages of treatment are common in all the different treatment technologies. The traditional wastewater management concept i.e. centralized system includes sewage collection and its treatment at the central treatment plant. To adopt this type of system in developing countries is not desirable in terms of the cost as a parameter. The problem is that the costs for implementing a centralized system in mega-cities, in particular, the investment costs for the sewer system are exorbitant. To overcome this limitation of the centralized system, decentralized wastewater management systems were evolved, with the wastewater treated close to where it is generated.

Wastewater treatment plants (WWTP) can never be a revenue-generating model as the product is treated water and a small fraction of sludge. To make it economically feasible, recycling and reusing wastewater can solve water issues to a great extent. Therefore, there is a need for innovations in the field of wastewater treatment on decentralized treatment plants so that efficient and low-cost technologies can be developed [2].

However, with the increasing awareness of the potential of wastewater, the government of India has implemented various schemes and policies which encourage recycling and reuse of water [2].To fulfill the demand of each household in developing countries, a new generation of highly efficient,

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compact, user-friendly and low-priced treatment systems incorporated with natural treatment is to be developed urgently.

The current paper focuses on the importance of DWTS. The significance of small scale WWTP as a decentralized unit is also discussed. The opportunity for the sustainability concept of domestic wastewater treatment is stated. The sustainability of package treatment systems is evaluated. On that basis, the potential of the package treatment system for domestic wastewater and future scope for the adoption of natural treatment in the package system is discussed.

II. DECENTRALIZED WASTEWATER TREATMENT

Centralized and decentralized systems have coexisted over the past years, but water authorities of industrialized countries were hardly fond of the decentralized alternative. The reason for that is obvious when taking into account the low purification level achieved by most of the treatment facilities that are on the market (septic tanks, ponds, wetlands, etc.), and the poor and mostly non-professional attention on-site facilities receive during operation[1].

There are three main advantages of decentralized sanitation systems provide [1].

i. Transport sewers including lifting stations and storage facilities to handle combined sewage flow are not needed; that results in significant cost savings.
ii. A large number of opportunities are granted for on-site water reuse and groundwater recharge.
iii. Failures of single units do not affect the whole system.

For the successful implementation of the decentralized system over the centralized, the following conditions should be met [1].

i. Decentralized applications must provide advanced wastewater treatment; they must be highly effective, robust, and easy to operate, and low in costs.
ii. Operation and control of the treatment systems must be accomplished by people who are specially trained for the job to be accomplished.
iii. Water is a valuable material, especially in water shortage areas.
iv. It should be realized that wastewater that is generated in households, enterprises and in industrial plants consists of various fractions each specific with respect to flow, composition and concentration, patterns of flow and patterns of mass fluxes. There are fractions that require sophisticated action, and others that can be treated with a minimum of effort.

Decentralization of municipal sanitation can be considered as an economically and ecologically interesting alternative to the traditional concept provided the individual treatment systems produce a high-quality effluent reliably and for a reasonable price.

Decentralized on-site individual wastewater treatment systems (i.e. with a population equivalent (p.e.) smaller than 10) can, for local authorities, represent a financially attractive alternative to a sewer connection in remote locations. Usually, it is expected that the owners of the houses and persons in charge of small enterprises and industries should supervise and maintain the plants. Due to the lack of any in-depth knowledge of the processes and motivation to take care, the successful operation of the treatment system depends. Hence it is necessary to adopt a new approach in designing, fabricating, and operating for decentralized package plants. Mass production using modern industrial methods provides the best chances to serve the public with reliable, effective, robust and reasonably priced treatment plants.

III. SMALL SCALE WASTEWATER TREATMENT

To fulfill the potential needs of wastewater treatment, there are several techniques to be used singly or in combination. Separation techniques (e.g. grit separation, sedimentation, air flotation, filtration micro- and ultrafiltration, oil-water separation) are mainly used in combination with other operations as a first or final treatment step. Physio-chemical treatment techniques (e.g. coagulation/ precipitation/ sedimentation/ filtration, crystallization, chemical and wet air oxidation, supercritical water oxidation, chemical reduction, hydrolysis, nano-filtration, reverse osmosis, adsorption, ion exchange, extraction, distillation/ rectification, evaporation, stripping and incineration) are primarily used for non-biodegradable wastewaters, inorganic or hardly biodegradable organic contaminants, and biological treatment techniques (e.g. anaerobic/aerobic processes, nitrification/denitrification, and central or decentralized biological treatments) are considered for biodegradable wastewaters[3].

The design of small treatment is critical as compared to the design of works of larger capacities. The cost is the main concern. The capital cost of small treatment plants being higher per capita than larger plants is because of the scale effect.

There are various costs that need to be considered while designing WWTPs i.e. the cost of land acquisition, access, electricity supply, and site development, buildings, etc. These high-cost influences can only be countered by attention to simple and economic construction and equipment design. To tackle this economic situation, we need to adopt simple, economic design and construction of the system [4].

There has been a general acceptance by stakeholders and professionals of small and medium-sized wastewater treatment (SMTs) applications because they help the improvement of public and environmental health by minimizing the impact of wastewaters [3]. There are various factors that should be considered while selection of SMTs, like population density, location, technology, and its efficiency, investment, operation of maintenance, protection of environmental quality, conservation of resources (including the energy use), water reuse, nutrient recycling, protection of public health, convenience security, government policy, and the human settlement planning. To establish small-scale WWTPs, it should possess the following characteristics:

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i. Small WWTPs are suitable for remote or less-dense population or in the case where only a small amount of space is available for the installation
ii. Small WWTPs are generally compact, with highly flexible operating conditions and reduced aesthetic impact

The output of SMT can be the reuse of water for flushing and the gardening and also decrease in the impact on the environment than a centralized system. To achieve greater efficiency by saving energy can also possible by source stream separation of black and greywater. The proper locations for the successful implementation of SMTs can be remote locations where access to the main drainage is difficult. As the SMTs are compact in nature, which provides a small footprint, aesthetics and no other environmental impacts as compared to the centralized system. They provide greater flexibility for adoption, operation, and easy maintenance; also no need for extensive pumping.

Hence to achieve more and more reuse and recycling of water at various levels of technology, it is necessary to adopt the best available technologies, which are economical and having less footprint.

IV. Domestic wastewater treatment

As the wastewater flowing out of the household is small, which resulting in less assurance of high efficiency of operation. Hence, the effluent of the household treatment plant is of poor quality. In rural areas especially in areas where a conventional system is not adopted, the domestic wastewater treatment plant becomes a major component of sanitary infrastructure. There are various conventional methods of sewage treatment systems adopted in rural areas i.e. with infiltration drainage, sand filters, CW treatment plants and technological systems using conventional methods of sewage treatment – biological deposits, activated sludge and treatment plants with the hybrid reactor.

Septic tank systems are a compartmentalized tank followed by a drainage field for subsurface irrigation and disposal of wastewater. The tank designed in such a way that anaerobic condition is maintained in the system which allows settlement, storage, and bio-degradation of solids [5]. It is one of the cost-effective forms of on-site treatment that assures effluent quality does not hamper the environment.

Conventional ASP is one of the common and widely adopted wastewater treatment technologies around the globe over the decade. Generally, all the conventional centralized sewage treatment plant works on this principle. ASP can be operated at a range of organic and hydraulic loading is the basic advantage of this system. The requirement of a constant supply of power, highly skilled operators, expert design and construction are the disadvantages [2].

Sequencing the biological and physical unit operations within a single reactor are achieved in Sequencing Batch Reactors (SBRs). SBR offers the unit operation in the treatment cycle but in a single reactor. The flexibility to adjust the treatment cycle of hydraulic retention time (HRT) is achieved as it is not dependent on the influent flow rate in SBR. Subsequently, HRTs are independent of the influent flow rate, which gives the operator the flexibility to adjust each treatment cycle. This allows several processes to be performed within the same reactor i.e. carbonaceous, oxidation, nitrification, denitrification and phosphate removal. An equalization tank is required to control the HRT of each cycle because the processes are independent of the incoming flow. In order to control the HRT of the processes independent of the incoming flow, an initial holding tank for flow balancing is required.

In the attached growth phenomenon, suspended microorganisms grow as a biofilm attached to an inert solid support. Substrate and oxygen in solution are transported to the microorganisms within the biofilm. The different attached growth processes are characterized on the basis of relative motion between the substrate, liquid, and configuration of support media i.e. rotating biological contactors (RBCs), submerged aerated filters (SAFs), moving bed biofilm reactors (MBBRs) and sequencing batch biofilm reactors (SBBRs).

Rotating Biological Contactors (RBCs) use a rotating disc media which provides a surface area to develop a biofilm. It adopted a different approach for aeration and relative motion occurred so that contact between substrate and biofilm takes place. Wastewater is transported to rotating media, where rotating media to bring the biofilm in alternate contact between substrate and oxygen. The biofilm grows on media that are mounted rotating horizontal shaft. Rotating media is partially submerged in applied wastewater so that proper contact between substrate and biofilm within wastewater and contact between oxygen and biofilm takes place within the air.

Submerged Aerated Filter (SAF) technology is the innovative technology of the attached growth process, where the filter bed is fully submerged. To achieve aerobic conditions within the system, diffused aerators are provided at the bottom of the system. The mixing within the bioreactor is also achieved by providing extra aeration which controls the growth of biofilm.

To achieve the phenomenon of both attached and suspended growth within the bioreactor, the concept of MBBR is evolved. The surface area of carrier media is exposed within the bioreactor so that biofilm can be grown on fully suspended carrier media. Generally, the carrier element having a diameter in the range of 20-30 mm with a specific surface area up to 500 m^2/m^3. For the proper working of the system, a 30-70 % filling ratio is adopted. To achieve free movement of carrier element and aerobic condition within the bioreactor, diffused aerators are provided at the bottom.

Sequencing Batch Biofilm Reactors (SBBRs) is the combined form of submerged aerated filter technology with sequencing batch operation. The fixed or moving filter bed is used as support media for the biofilm in SBBRs. The reactor is operated in discrete cycles (fill, react and draw). SBBRs required less time for final clarification resulting in as compared to other treatments as biomass attached to the media bed, less time is required for final clarification [5].

When the conventional ASP is combined with filtration technology, the new system is evolved known as Membrane

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Bioreactors (MBRs). As the filtration technology is introduced, it replaces all settling units required for treatment and also removes pathogens which are advantageous over conventional treatment systems. It also removes organic concentration from wastewater. A high MLVSS level is achieved in MBRs which results in less HRT and sludge production. Current MBR systems employ flat or hollow fiber membrane filtration modules, which have relatively high energy consumption and require significant operator attention and alkali supplements during operation [6].

V. PACKAGE WASTEWATER TREATMENT SYSTEM

When one or more unit operations incorporated into a single system (which is a prefabricated tank) for the enhancement wastewater treatment is known as the package wastewater treatment plant. Most package plants include biological unit operations as secondary treatment to remove soluble pollutants i.e. ASP, SBR, RBC, MBBR, SBBR, MBR and also wet composting and vermicomposting tanks; anaerobic treatments; sand, soil, and peat filters; CW; and grey, black and urine water separation systems, following an initial primary treatment stage. Electric power is required as a power source, as aerators are used to develop the aerobic condition within the system [5]. The effluent from the package treatment system can be reused for flushing and gardening as the treatment takes place at a higher standard than conventional methods.

The package system should be designed by considering the future demand so that it can sustain for future flow condition. Running at a lower capacity than it is designed is the main cause of inefficiency. In such cases, effluent also does not meet the standards of the pollution control board [2].

While designing any system, it is necessary to consider resource constraints i.e. land availability, power requirement. In the urban area where land is scarce, it is required to adopt technologies that require less area. While industries and commercial sectors go with those package systems which require less area for installation. In a rural area, users can go with an affordable system that may require more area for installation. From literature, it is seen that DWTS for individual households proves to be uneconomical as for lesser design capacity also, high power consumption takes place.

To be successful in the market, the package system should possess the following characteristics:

i. To produce a good quality effluent for reuse
ii. To tackle with high flow and load variations
iii. Simple and easy operation
iv. Low maintenance
v. Minimal aesthetic impact
vi. Low overall cost - i.e. capital, installation, and operating cost
vii. The small footprint of the treatment plant
viii. Long life

VI. COMMERCIALLY AVAILABLE PACKAGE TREATMENT SYSTEM

A. Bio-Rock Septic System

Primary tank: Clarifies the wastewater coming from the residence by retaining oils, fats, greases, and organic solids. The water passes through an effluent filter before discharging into the Biorock reactor.

Bioreactor: The Biorock media in the bioreactor treats the wastewater naturally with the aerobic digestion process (secondary treatment) and a filtration process (tertiary treatment).

Biorock media: The wastewater percolates through the filtering media. The Biorock media is a very effective carrier material for bacteria. The Biorock media is highly resistant to degradation and remains extremely stable over the long term. The Biorock media is 100% recyclable.

Up to 96 % COD removal and 99%, BOD removal is observed.

Unique advantages:

i. non-electric
ii. Extreme low running costs
iii. totally silent
iv. Odorless
v. Ultra-compact and discrete

B. Grey Water Treatment Using A Submerged Membrane Bioreactor

For the production of high-quality recyclable water, it is necessary to adopt proper greywater treatment. The use of a complicated and relatively costly system for greywater treatment ensures high-quality recyclable water. As compared to other systems, Submerged Membrane Bioreactor (SMBR) proved effective technology for the greywater treatment as the recycled water can be used for outdoor uses such as irrigation but also for indoor uses such as toilet flushing. Treated greywater is almost free of pathogenic content. Up to 96% of COD removal is recorded by the system. The feasibility of the SMBR system for greywater treatment in single houses depends on freshwater and sewage disposal costs.

C. Submerged Aerated Filter for Single Household

Submerged aerated filter technology (SAF) is a compact package system that is a combination of both ASP and filter technology. The installed jet aeration system provides sufficient oxygen transfer at minimal water depth. Average BOD, COD and SS removal is observed as 94.2%, 85.9%, and 87.6 % respectively. While considering other alternative treatment processes like RBC and Trickling Filters either make insufficient use of the overall tank volume. E.g. Extended Aeration, in order to minimize excavation cost, resulted in a cost-effective treatment solution.

D. Bio-Max Aerobic Treatment Units (ATU)

BioMax Aerobic treatment is the product of Durrant and Waite Pvt. Ltd is a Western Australian company. The company is known for the design, manufacture, installation, operation, and maintenance of wastewater treatment systems.

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The capacity bioMAX systems can be applied for 10 persons (domestic residence) to community package treatment units (500- 2,000 persons). The input of the system is the wastewater that is converted into the stabilized end product. The effluent of the system can be safely disposed of without any adverse effect on the environment. The bioMAX ATU adopts conventional aerobic and anaerobic biological process uses no new processes than which are already available to large scale WWTPs. 99.4 % BOD removal and 95.3% TSS removal are achieved by the system. The system's processes are divided into five principal chambers:

i. Anaerobic - primary settlement and anaerobic treatment
ii. Aeration - aerobic treatment
iii. Clarification- sludge settlement and removal
iv. Disinfection - contact time with chlorine
v. Pump out - discharge to the irrigation area

VII. Incorporation of Natural Treatment in Package Wastewater Treatment System for Household Wastewater

For sustainable life, to solve problems associated with human diseases and environmental pollution, it is necessary to adopt reliable and inexpensive methods of wastewater treatment. Today developing countries are facing the problems associated with ineffective and costly sewage disposal methods [7]. The efficiency of the entire on-site treatment system of domestic wastewater depends on the performance of each and every treatment step. The commercially available package systems in the market are energy-intensive and have high capital costs. They are useful for a relatively larger flow. To make it ecologically as well as economically self-sustainable system, natural treatment technology should be adopted. Hence there is a need for a package treatment system incorporated with less energy-intensive and natural treatment.

In the secondary or tertiary treatment of wastewater, researchers are working on improvement in the effectiveness and design of CW from the past twenty years. After this research, it is seen that CWs provide an efficient and economical way for domestic wastewater treatment.

CWs are already adopted for municipal wastewater treatment on a large scale all around the world. Initially, secondary treatment is given by CW in most of the cases for industrial applications such as dairy, oil refinery, leachate treatment. In some cases, polishing (tertiary) treatment is also given by CW. For single-family households and local treatment facilities (for less than 2000 pe), CW proved as sustainable technology in many western countries [11].

The most effective bio-degradation and undisturbed settling of solids are done in the septic tank as a primary treatment [8]. To treat the wastewater naturally by wetland vegetation is done in the controlled environment known as CWs with the help of natural processes such as sedimentation, filtration, adsorption, biological degradation, phytoremediation, etc [9].

As the mechanism of CW is to treat the wastewater naturally without any expensive infrastructure to build and operate, the performance is found to be satisfactory as compared to equivalent tertiary or advanced treatment present. Up to 64-92%, BOD and 44-77% TKN removal were achieved in the secondary treatment by CW[12]. The desired effluent quality should satisfy the standards given for gardening and flushing purposes. Although the efficiencies of commercially available package wastewater treatment system are higher than CW, desired effluent quality can be achieved by CW. The effluent characteristics of CW are within the limits given by authorities. As the commercially available package treatment plants produce effluent having standards of secondary treatment are expensive to adopt and operate which needs technical expertise and skilled operator [10].

The main objective of the package treatment plant for the household is to treat the wastewater at the point of generation itself. Primary treatment takes place in a septic tank where anaerobic biodegradation of pollutants takes place naturally which will undergo further treatment. CWs provide an opportunity to treat domestic wastewater at the point of generation itself without any excessive sludge generation during the secondary treatment. This natural treatment process can be proved as cost-effective and self-sustainable in rural and remote areas as there is very little energy requirement.

VIII. Summary

It is seen that DWTS is advantageous over the centralized system. SMTs, the part of the decentralized system are affected by scale effect which results in a poor response from the market. To make the SMT more sustainable, the effluent from the system should have high-quality standards that have the potential of in-door and outdoor reuse. The commercially available package treatment system having high capital costs with energy-intensive operations are less sustainable in remote as well as rural areas. Although the efficiencies of commercially available package wastewater treatment system are higher than CW, desired effluent quality can be achieved by CW. The effluent characteristics of CW are within the limits given by authorities. To make it ecologically as well as economically self-sustainable, natural treatment technology should be incorporated into the package treatment system.

Acknowledgment

The present study is a part of a research project sanctioned by the Department of Science and Technology (DST) under the Water Treatment Initiative (WTI) program. The authors sincerely acknowledge and thank DST for providing financial support to undertake this study. During this research study, Technical Quality Improvement Programme- III (TEQIP- III) has supported financially for traveling and other expenses, we would also like to express our gratitude towards them.

References

[1] Wilderer P., and Schreff D., "Decentralized and centralized wastewater management: a challenge for technology developers", Water Science and Technology, Vol. 41, No 1, pp. 1–8, 2000.
[2] Hazarika S., and Pandit D., "Feasibility Analysis of Decentralized Wastewater Treatment Systems", Innovations in Infrastructure,

Proceedings of ICIIF 2018, pp. 207-219, 2018.

[3] Libralato G., "The Small-Scale Approach in Wastewater Treatment", Wastewater Reuse and Management, pp. 195- 224, 2013.

[4] Staples K., Kawksley W., "Design of Small Sewage-Treatment Works", Proceedings of Design and Operation of Small Sewage Works, 1981.

[5] Daude D., "Design And Evaluation of A Small Package Sewage Treatment System", Thesis Submitted to School of Water Sciences School of Industrial And Manufacturing Science Cranfield University, 2003.

[6] Ren X., H.K. Shon H., Jang N., Lee Y., Bae M., Lee J., Cho K., and Kim I., "Novel membrane bioreactor (MBR) coupled with a nonwoven fabric filter for household wastewater treatment", water research, 44, pp. 751–760, 2010.

[7] Nelson M., Odum H., Brown M., and Alling A., "Living Off The Land": Resource Efficiency Of Wetland Wastewater Treatment", Advanced Space Research, Vol. 27, No. 9, pp. 1547-1556, 2001.

[8] Paruch A., Maehlum T., Haarstad K., Blankenberg A., and Hensel G., "Performance of Constructed Wetlands Treating Domestic Wastewater in Norway over a Quarter of a Century – Options for Nutrient Removal and Recycling", *Natural and Constructed Wetlands*, pp. 41-55, 2016.

[9] Poyyamoli G., Edwin G., and Muthu N., "Constructed Wetlands for the Treatment of Domestic Grey Water: An Instrument of the Green Economy to Realize the Millennium Development Goals", *The Economy of Green Cities: A World Compendium on the Green Urban Economy*, Local Sustainability 3, pp. 313-320, 2012.

[10] Kadlec R., and Wallace S., "Treatment Wetlands", by Taylor & Francis Group, LLC, 2009.

[11] Cawley A., and Healy M., "Evaluation of The Waste Treatment Performance of Constructed Wetlands with Special Reference to Williamstown Co. Galway Wetland System", National hydrology Seminar, pp. 42-50, 2000.

[12] Obarska-Pempkowiak H., Gajewska M., Wojciechowska E., and Kołecka K., "Sewage Gardens – Constructed Wetlands for Single Family Households", Environment Protection Engineering, Vol. 41, No. 4, pp. 71-82, 2015.

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Study on alternate modes of plantation in bio-rack constructed wetland

A Review

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***Abstract*—Constructed wetland (CW) is generally used at secondary or tertiary level in decentralized wastewater treatment system. Bio-rack CW system is an easy solution to avoid the clogging problem. The growth of vegetation and its grip with the bioracks pipe is key in the success of the bio-racks CW system. The conventional method of plantation in bio-rack CW is to make a bundle of vegetation and insert it into the bio-rack pipe. However, such methods of plantation of vegetation in bio-rack CW do not result in good vegetation growth in a few cases. Hence alternative modes of plantation in bio-rack CW are introduced in the present study. Vegetation is grown initially in perforated plastic bottles, acclimatized for one to two weeks and then placed in bio-rack CW. This gives better growth of vegetation and better root development of vegetation.**

Keywords— Bio-rack constructed wetland; Vegetation; Wetland; Mode of vegetation;

I. INTRODUCTION

Presently, wastewater management is the major concern. It is one of the main environmental issues which have been creating multiple miscellaneous impacts on the environment. This issue is more sensitive in India because of improper drainage facilities and due to the absence of proper sewerage system in urban as well as rural areas. Sewage treatment plants (STP) cannot be provided at every corner of the city. However, waste generation is present and the waste is directly disposed into the sewers and rivers. To stop this, decentralize wastewater treatment system (DWTS) is introduced. DWTS can be provided at every colony, apartment, and college and can reuse the treated wastewater so that load of STP and river is reduced.

Constructed wetland (CW) is a vegetated bed where wastewater moves in the horizontal or vertical mode. CW has gained much popularity in this decade as one of the solutions of the DWTS. CW is emerging in India. It is an artificial wetland to treat municipal or industrial wastewater. CW consists of vegetation, soil or brickbat as media and micro-organism to treat wastewater. Bio-rack is the perforated vertical pipe which prevents the clogging problem in CW and perforations provide more surface area to micro-organisms. Recent modification in bio-rack is carried out in references ([1], [2]) in which used plastic water bottles are used as bio-rack. Brickbat is used as supporting media along with the bio-rack. Brickbat is a low cost alternative which helps in holding the bio-rack pipe as well as provides maximum surface area for the bacteria to remove organic matter [3]. Dual species of vegetation showed better results for treatment of wastewater. Planting multispecies vegetation in bio rack made up of discarded non perforated plastic water bottles gives good root matrix distribution [1]. The vegetation growth is an important factor for removal efficiency. Growth of vegetation is generally observed by measuring height and the root development of the vegetation.

In the present study, alternative modes of plantation of vegetation in bio-rack CW and assessment of the effective vegetation in terms of root/vegetation growth are studied.

II. MATERIALS AND METHODS

A. Study site

Walchand College of Engineering, (WCE) Sangli has two integrated domestic wastewater treatment systems, IDWTS 1 and IDWTS 2 to treat the wastewater generated from the college premises. IDWTS 2 is taken as the study site. IDWTS is divided into three parts where primary treatment is given by a screen chamber, then a primary settling tank followed by an anaerobic baffled reactor (ABR). The site of this study is secondary treatment given by baffled hybrid bio-rack constructed wetland.

B. Source of Water

The water from Municipal Corporation and the water from an open well present in the college are used for portable and non-portable use respectively. The wastewater is generated from Hostel, Mess, Canteen and residential facilities. The wastewater treated in the wetland is present in college premises. The effluent of the ABR from the wetland is used for the present study

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C. Source of Vegetation

The selection of vegetation is such that they are locally available. *Typha angustafolia* and *Canna indica* are effective for the treatment. The vegetation is collected from Sangli, Miraj and Dhamni Road from Nallas and marshy land.

D. Bio-rack System

The bio-rack wetland system is based on attached growth system. It increases surface area which helps to enhance treatment efficiency with low cost. Bio-racks are made from perforated and corrugated plastic pipes. It has immense potential to overcome the clogging problem in the constructed wetland.

E. Mode of Plantation

In this study, possible ways of plantation for proper growth of vegetation in bio-rack CW are described. First mode of plantation of vegetation is basic mode. In this mode, vegetation is directly placed in bio-rack without acclimatization. In the second mode of plantation, plastic balls are placed in bio-rack pipe as supporting media which helps to float the vegetation. Then vegetation is planted after proper acclimatization. In the third mode, vegetation is placed in perforated discarded plastic bottles. These bottles are filled with small brickbat. The bottles along with the vegetation is left to acclimatize for one to two weeks and then placed in the bio-rack CW.

F. Methodology

Acclimatization of vegetation was initially carried out by watering the vegetation with fresh water and then slowly increasing the strength of wastewater. Initially, feed wastewater concentration was 25% for 2-3 days. It was then gradually increased to 50% and then to 75% for 4-5 days for each concentration. After 1-2 weeks, the growth of the shoots was observed. Then, the plastic bottles with vegetation were placed in the perforated bio-rack. The growth of the vegetation was monitored in terms of number of shoots, height of vegetation and root depth of the vegetation.

III. Results and Discussion

Fig.1 Photographic view of Bio-rack pipe without vegetation

Fig.2 Photographic view of plantation mode 1 for a) initial growth and b) final growth

Fig.1 and 2 show the first mode of plantation of vegetation in bio-rack CW. In this mode, vegetation is placed in bio-rack CW without external support for gripping the vegetation. Fig.1 shows the bio-rack CW without plantation of vegetation. Fig.2a shows the initial growth of vegetation in the basic mode of plantation. In this mode, vegetation was placed in bio-rack CW without any external support on 31st August 2019. Fig.2b shows final growth of vegetation. By the end of September, the vegetation did not sustain in the bio-rack and were wilting because of improper grip of their roots and fluctuation of water level in bio-rack CW.

Fig.3 Second mode of plantation

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Fig.4 Photographic view of plantation mode 2 for a) initial growth and b) final growth.

Fig.3 and 4 show the second mode of plantation of vegetation in bio-rack CW. In this mode, 3-4 plastic balls were placed in the bio-rack for proper gripping of vegetation and to prevent the effects of fluctuation of water level in the bio-rack CW on the vegetation. Fig.3 shows the bio-rack pipe filled with 3-4 plastic balls on 9th October. Fig.4a shows initial growth of vegetation in the second mode. The vegetation was placed in bio-rack pipe over the plastic balls. Fig.4b shows that the plastic balls failed to hold the vegetation as they did not give proper gripping to the root. This resulted in their decomposition due to fluctuation of water level in bio-rack pipe in the beginning of December.

Fig.5 Third mode of plantation

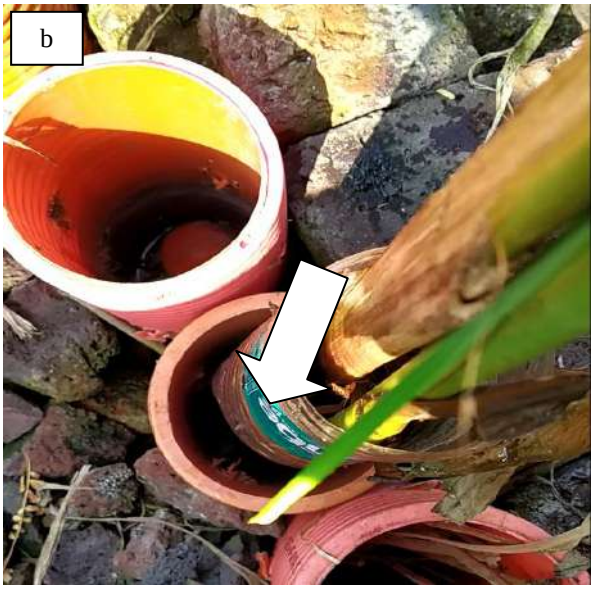

Fig.6 a) Photographic view of plantation mode 3, b) initial growth, c) development of growth

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Fig.7 Photographic view of development of vegetation in third mode of plantation

Fig.5, 6 and 7 show the third mode of plantation of vegetation in bio-rack CW. In this mode vegetation was placed in used perforated plastic bottles and after 1-2 weeks of acclimatization period, the plastic bottles were placed in the bio-rack pipes. Fig.5 shows the vegetation placed in the perforated plastic bottle in the beginning of December (3-9 December). Fig.6a shows the development of shoots and roots of the vegetation after 1-2 week of acclimatization period in the end of December. In fig.6b the acclimatized vegetation which were in plastic bottles were placed in the bio-rack pipes over the balls in the beginning of January. Fig.6c shows the good condition of vegetation in bio-rack CW after using the third mode in mid-January. Fig.7 shows the effective growth of the vegetation after a span of 20-25 days (25th January 2020).

Table1. Growth of vegetation in 3rd mode of plantation

Sr. No.	Plant name	No. of shoots	Height of vegetation
1.	*Canna indica*	2-3	45-60 cm
2.	*Typha angustafolia*	3-4	110-120 cm

Table 1 shows the vegetation growth in the 3rd mode of plantation. It shows the number of shoots that appeared at the end of the acclimatization period and the height of the vegetation.

Conclusions

The vegetation development in bio-rack CW was assessed using different modes of plantation. First mode of plantation was the basic mode of plantation. In this, the vegetation was directly placed in bio-rack pipes. In the second mode of plantation, the plastic balls were placed in bio-rack pipes for proper grip. In the third mode, vegetation was placed in perforated plastic bottles which were subsequently placed in bio-rack CW. The first and second mode of plantation did not give good results. In the first mode, due to improper grip the vegetation wilted. In the second mode, plastic balls were placed in the bio-rack pipes to hold the vegetation but they could not do so because of the fluctuation of water level in bio-rack CW. In the third mode, the growth of vegetation was better than the other modes. Furthermore, the root development was significantly better and the shoots were growing well. Thus, plantation of vegetation in bio-rack CW using the third mode of plantation was most effective.

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REFERENCES

[1] S. Sathe and G. Munavalli, 'Domestic wastewater treatment by modified bio-rack wetland system', Journal of Water Process Engg, 28, 240-249, 2019.

[2] A. Valipour, V. Raman and V. Ghole, 'A new approach in wetland systems for domestic wastewater treatment using Phragmites sp.', Ecol Engg, 35, 1797–1803, 2009.

[3] A. Valipour, V. Raman and V. Ghole, 'A new approach in wetland systems for domestic wastewater treatment using Phragmites sp.', Ecol Engg, 35, 1797–1803, 2009.

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Urban Heat Island Effects: a Review

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***Abstract*— As urbanization progress, reflective surfaces like vegetation, water bodies, etc will be converted to built up area which can absorb more light and emitted back as heat. There might be changes in the surface temperature which in turn causes Urban Heat Island (UHI).UHI effect is one of the important issues in crowded cities, which is simply the urban area becoming warmer than its surrounding rural areas. Land use changes are playing a major role in the formation of heat islands. UHI can be studied by analyzing the changes in Land Surface Temperature (LST) as it is the major factor in UHI formation, which in turn depends upon land use changes. This paper presents the review of research works conducted on UHI. The studies on these aspects are very rare in India though urbanization is taking place at a faster rate. More studies are needed in urbanized areas for planning to reduce UHIs.**

Keywords—***Urban heat island; land surface temperature; land use changes.***

I. INTRODUCTION

Although urbanization and industrial expansions improve our lives and luxury, they also lead to increasing environmental problems like climate change, industrial pollution, vehicular air pollution, water pollution, etc. The climate is the most important influencing physical factors that control the life behaviours, economic activities and the indoor and outdoor comfort of an individual. The residents of major cities often experience a regional climate phenomenon known as the Urban Heat Island (UHI), where in the urban area becomes significantly warmer than its surrounding rural areas. The higher be the urbanization, larger be the difference in temperature between urban and rural areas and is most noticeable during summer and winter. The UHI causes reduced night time cooling, daytime temperature, and higher air pollution levels which affect human health adversely. UHI is caused by many factors including both natural and anthropogenic such as geographic location, climate, urban morphology, heat release from anthropogenic heat sources, atmospheric pollution, etc. Due to urbanization, the reflective surfaces like water bodies, vegetation, etc are replaced by the surface which can absorb more light. When a surface absorbs light, it will be converted to thermal energy and emit it back as heat. This causes changes in the surface temperature of the city. Also year after year, more rural areas are converted to urban areas leading to more variations in the temperature. UHI can be studied by evaluating Land Surface Temperature LST, which is measured close to the earth's surface plays a major role in energy budget and ambient air temperature in an area. LST variation is mainly due to the effect of reflective surface, presence or absence of vegetation, bare soil, etc. Since land use change is one of the main factors affecting LST, Normalized Difference Built-up Index (NDBI) and Normalized Difference Vegetation Index (NDVI) should be evaluated. This paper presents a review on the research works addressing these aspects.

II. INFLUENCE OF IMPERVIOUS SURFACE ON UHI

Xiaomo et al. (2017) studied the relationship between UHI response with urban expansion and the temporal and spatial variations using MODIS images and concluded that due to the urban expansion, heating effect occurred and it varied spatially and UHI effect was more in day time and also in summer season. Lin et al. (2016) conducted a long term mobile survey of temperature and humidity for the evaluation of the changes in the intensity of UHI and concluded that due to the human activity, the average UHI intensity reached the lower value during the midnight and higher during the noon. Youpie et al. (2016) conducted a study on urban heat island effect by developing an experiment to test mitigation possibilities of UHI by optimizing Sky View Factor (SVF) and concluded that as the density of an urban area increases, it lowers the SVF and causes higher UHI intensity. Vardoulakis et al. (2013) investigated the UHI in the Mediterranean city of Greece with higher temperature and cooling effects. For the evaluation of existence and intensity of UHI, measurement station was installed and data loggers were also used between UHI intensity and airflow was studied and it revealed that high intensities were related with low wind speed. The study concluded that UHI effect was more significant during night and summer seasons. Study based on urban heat island effect in the continental USA using remote sensing satellite imageries conducted by Marc et al. (2010) revealed that transformation of forest to urban area caused relatively high summer time UHI when compared to winter time UHI and therefore energy consumption of residential area during summer was higher. Liqin et al. (2008) investigated the impact of impervious surface on UHI in Wuhan, China by quantitative and qualitative analysis and conclude that impervious surface was the main reason for the variation in LST

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which in turn causing UHI and also during summer season, mean LST was lower in the suburban area than the urban area.

III. INFLUENCE OF LAND COVER ON UHI

Fonseka et al. (2019) conducted a study on urbanization and its impacts on land surface temperature. Urban land cover changes were obtained from satellite imageries and urban density from both the gravity model and multi ring method. The study concluded that loss of vegetation due to urbanization causes increase in LST and both models were appropriate to evaluate the effect of land cover changes on the LST in the study period. Weimin et al. (2019) studied urban heat island using remote sensing satellite imageries. In this study, linear spectral mixture model was used for the extraction of information about land coverage and the effect of urban land cover on the LST was analyzed. The study concluded that UHI during summer season, difference in LST among different land covers, variances in the latent heat fluxes in the study area were significant. So it has great importance in formation and elimination of UHI. Suman et al. (2018) studied the impacts of urbanization on land use /cover changes and its effects on groundwater level and local climate in West Bengal. Land Use Land Cover (LULC) changes and NDBI were computed from Landsat imageries using remote sensing and GIS techniques and concluded that urban area has expanded, which led in the reduction of other types of land use types and also due to growth of built-up area, precipitation and temperature pattern changed, which in turn adversely affected the ground water level. El-Hattab et al. (2017) studied UHI intensity to find out whether there was any relationship between LULC changes, LST and UHI using Landsat images. LULC changes were assessed using neural network and from the study, it was clear that it is superior to all other methods. The study concluded that heat island formation had strong correlation with urban expansion. Neil et al. (2015) studied the UHI effect by using PRISM climate model for its evaluation. LULC data were obtained from the department and it sometimes enhances the UHI intensity. The study also concluded that the spatial contiguity of urban development is the critical influencing factor of UHI effect. Yupeng et al. (2015) compared different urban forms with vegetation, three locations like detached house area, middle-rise area, and high-rise area were selected and land use and building height in each area were evaluated. The effect of cool surfaces on UHI was evaluated using ENVI- met software. The study concluded that the effect of cool pavement in high –rise area is lower than that in detached house area. Juri et al. (2014) studied UHI using half hourly temperature data and mobile measurements and concluded that decrease in green cover related with urbanization had increased UHI. As Guwahati is high humid region, discomfort is caused to inhabitants during summer. Chuan-Yao et al. (2008) conducted Weather Research and Forecasting (WRF) model coupled with the Noah land surface model and Urban Canopy model (UCM) to study UHI. Sensitivity tests were also used and results showed that anthropogenic heat had great importance in formation of boundary layer and in turn UHI intensity. Also the model is able to predict UHI effect during night time and early morning. Nyuk et al. (2005) studied the relationship between green area and UHI by mobile survey for measuring temperature and relative surface radiation and temperature was higher at the centre than at the edge. NDVI and surface radiation temperature maps were produced in North South and East West direction and it showed contrary trend. Results also show that industrial and commercial areas had higher heat island strength than other areas and also concluded that the study area was severely affected by UHI and temperature mapping showed that clear variation of the same from urban area to rural area.

IV. INFLUENCE OF WATER BODIES ON UHI

Li et al. (2016) investigated UHI by establishing the CFD model where urban area was divided into main road, commercial zone, public architecture, forest and river system with boundaries. The study concluded that rivers and lakes balance urban temperature and separated urban thermal fields and can eliminate UHI effect. Another study was done (Hathway et al. 2012) to know the relationship of rivers in reducing the UHI effect. Temperature and humidity data were measured adjacent to the river and urban weather station was installed. Different types of urban forms were selected like enclosed, open square, open street and closed street for finding out the cooling effect of river. Results showed that during day time, significant cooling on the river bank was observed and also highly vegetated area showed lower temperature.

V. INFLUENCE OF NDBI AND NDVI ON LST

Ahmed (2018) conducted an assessment of UHIs and impact of climate change of Suez Governorate, Egypt for a period of 27 years (1988 to 2014).The investigation was conducted using Landsat imageries, Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) data and socioeconomic data for the retrieval of UHI and LULC changes using remote sensing and Geographic Information System (GIS) techniques. Vulnerable areas for UHI had been assessed. Black body temperature was derived from the satellite images. It was then converted to LST by using emissivity and from the LST, UHI was calculated. By taking into consideration of socioeconomic parameter, Urban Thermal Field Variance Index (UTFVI) was calculated. From the study, hot spots of UTFVI identified were mainly in the densely populated and heavily industrial areas. This is the study which included the socioeconomic factors for studying Urban Heat Island effect. Wei et al. (2016) investigated urbanization and UHI in Beijing based on remote sensing from 1992 to 2012 using Landsat ETM, Defense Meteorological Satellite Program's Operational Line-scan System (DMSP-OLS) and Official Statistics. From Landsat ETM, NDVI and LST were extracted. UHI effect was surveyed using the Landsat TM/ETM data in 1995 and 2009. Then it was processed to get the NDVI and LST in the study area. From the study, it was concluded that there was marked urbanization in Beijing during the study period and also correlation between LST and NDVI showed close relationship

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between vegetation, temperature distribution and urbanization level of that region. Yang et al. (2012) conducted a study on UHI effect based on NDVI of Wuhan City in China using satellite imageries. NDVI and surface radiation temperature maps were produced in North South and East West direction and had contrary trend.. Results also show that industrial and commercial areas had higher heat island strength than other areas. NDVI is higher in urban edge than the centre and surface radiation temperature is higher at centre than at edge. From the study, it was concluded that surface radiation temperature and NDVI had inverse correlation. Zhang et al. (2010) conducted a study on relationship between vegetation and urban heat island effect of Beijing City, China using Landsat 5 TM image and NDVI and brightness temperature (Tb) were calculated. Profiles of Tb and NDVI were plotted in the directions of North East –South West and North West-South East using the Remote Sensing and GIS techniques. Correlation between Tb and NDVI with distance were established. From the study, it was concluded that vegetation is low in centre and high in edge but it has opposite trend for temperature. From the correlation analysis, there was positive correlation for NDVI with distance and negative for brightness temperature with distance. Correlation value is decreasing from centre to the edge. Tran et al. (2006) studied the UHI Effects in Asian mega cities based on satellite data. The moderate Resolution Imaging Spectroradiometers (MODIS) imageries from 2001 to 2003 were used to produce LST maps. Spatial patterns and temporal variations of UHI were studied. During 2001 summer, all the selected temperate climate regions experienced notable surface UHIs. Qihao et al. (2004) studied the relationship between vegetation and LST with UHI using remote sensing satellite imageries. The vegetation fraction was derived from spectral mixture model and concluded that LST has strong positive correlation with UHI and has strong negative correlation with vegetation

CONCLUSIONS

Study of Urban Heat Island effect has become highly significant in addressing climate change based problems. As the collection of meteorological data required for studying UHI is quite difficult, most of the studies in this area were conducted using various satellite imageries like MODIS, DMSP-OLS, Landsat, etc. The studies reveal significant effect of UHI effect during summer and winter season and UHI effect is higher during summer. From the earlier studies, it is found that LST is more dependent upon NDVI than NDBI. The studies on these aspects are very rare in India though urbanization is taking place at a faster rate. More researches are needed, especially in urbanized areas for restricting the occurrence of UHIs.

REFERENCES

[1] Ahmed S (2018) "Assessment of urban heat islands and impact of climate change on socioeconomic over Suez Governorate using remote sensing and GIS techniques" *The Egyptian Journal of Remote Sensing and Space Sciences*, 21,15-25.

[2] Chuan-Yao Lin, Fei Chen, J.C. Huang, W.-C. Chen, Y.-A. Liou, W.-N. Chen, Shaw-C. Liu (2008) "Urban heat island effect and its impact on boundary layer development and land– sea circulation over northern Taiwan" Atmospheric Environment,42, 5635-5649.

[3] El-Hattab M , Amany S.M. , Lamia G.E (2017) "Monitoring and assessment of urban heat islands over the Southern region of Cairo Governorate, Egypt" *The Egyptian Journal of Remote Sensing and Space Sciences.*

[4] Fonseka H P U, Hongsheng Zhang, Ying Sun, Hua Su, Hui Lin, Yinyi Lin (2019) "Urbanization and Its Impacts on Land Surface Temperature in Colombo Metropolitan Area, Sri Lanka, from 1988 to 2016" *Remote sensing*

[5] Hathway E A, Sharples S (2012) "The interaction of rivers and urban form in mitigating the Urban Heat Island effect: A UK case study" *Building and Environment*,58, 14-22.

[6] JuriBorbora, Apurba Kumar Das (2014) "Summertime Urban Heat Island Study for Guwahati City, India" Sustainable Cities and Society, 11, 61-66.

[7] Lin Liu, Jing Liua, Yaoyu Lin (2016) "Spatial-Temporal Analysis of the Urban Heat Island of a Subtropical City by Using Mobile Measurement" *Procedia Engineering*,169, 55-63.

[8] Liqin Cao, Pingxiang Li, Liangpei (2008)"Impact of Impervious Surface On urban heat island in Wuhan, China".

[9] Li Yang, Feng Qian, De-Xuan Song, Ke-Jia Zheng (2016) "Research on Urban Heat Island Effect" *Procedia Engineering*, 169,11-18.

[10] Neil Debbage, J. Marshall Shepherd (2015)" The urban heat island effect and city contiguity" *Computers, Environment and Urban Systems*,54, 181-194.

[11] Nyuk Hien Wong, Chen Yu (2005) "Study of green areas and urban heat island in a tropical city" Habitat International, 29, 547-558.

[12] Marc L Imhoff, Ping Zhang, Robert E Wolfe, Lahouari Bounoua (2010) "Remote sensing of the urban heat island effect across biomes in the continental USA" *Remote sensing of environment*, 114(3),504-513.

[13] Suman Patraa, Satiprasad Sahoob, Pulak Mishraa, Subhash Chandra Mahapatrac (2018) "Impacts of urbanization on land use /cover changes and its probable implications on local climate and groundwater level" *Journal of Urban Environment*, 7, 70-84.

[14] Qihao Wenga,, Dengsheng Lub, Jacquelyn Schubring (2004)" Estimation of land surface temperature–vegetation abundance relationship for urban heat island studies" Remote Sensing of Environment,89, 467-483.

[15] Tran Hung, Daisuke Uchihama, Shiro Ochi, Yoshifumi Yasuoka (2006) "Assessment with satellite data of the urban heat island effects in Asian mega cities" *International Journal of Applied Earth Observation and Geoinformatics*,8,34-38.

[16] Steve Kardinal Jusuf, N.H. Wong, Emlyn Hagen, Roni Anggoro, Yan Hong (2007) "The influence of land use on the urban heat island in Singapore" *Habitat International*, 31, 232-242.

[17] Vardoulakis E , Karamanis D, Fotiadi A, Mihalakakou G (2013) "The urban heat island effect in a small Mediterranean city of high summer temperatures and cooling energy demands" *Solar Energy*,94,128-144.

[18] Wei Chen, Yao Zhang, Weijun Gao, Dian Zhou (2016) "The Investigation of Urbanization and Urban Heat Island in Beijing Based on Remote Sensing" *Procedia Social and Behavioral Sciences*, 216, 141-150.

[19] Weimin Wang, Kai Liu, Rong Tang, Shudong Wang (2019) "Remote sensing image-based analysis of the urban heat island effect in Shenzhen, China" *Physics and Chemistry of the Earth*, 110,168-175.

[20] Xiaoma Li , Yuyu Zhou , Ghassem R. Asrar , Marc Imhoff c, Xuecao Li (2017) "The surface urban heat island response to urban expansion: A panel analysis for the conterminous United States" Science of Total Environment, 605-606,420-435.

[21] Yang Zhang, Chen Yiyun, Ding Qing, Ping Jiang (2012)" Study on Urban Heat Island Effect based on Normalized Difference Vegetated Index: A Case Study of Wuhan City" *Procedia Environmental Sciences*, 13,574-581.

[22] Youpei Hu, Marcus White, Wowo Ding (2016)"An Urban Form Experiment on Urban Heat Island Effect in High Density Area" *Procedia Engineering*, 169,166-174.

[23] Yupeng Wanga, Umberto Berardi, Hashem Akbari (2015) "The Urban Heat Island effect in the city of Toronto" *Procedia Engineering*, 118, 137-144.

[24] Zhang X X, P F Wu, Chen B (2010) "Relationship between vegetation greenness and urban heat island effect in Beijing City of China" Procedia Environmental Sciences, 2, 1438-1450.

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INFLUENCE OF FLOOD ON THE BEHAVIOUR OF FOOTING

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Abstract— ***Many states of our nation experienced unprecedented floods in the past few years, causing widespread damage to structures and embankments. This paper investigates the impact of floods on the settlement behaviour of shallow foundation. The results of a series of laboratory scale load tests to determine the influence of sudden submergence and drawdown on the settlement of footings are presented. The effects of three types of submergence are studied; due to sudden rise of ground water, drawdown and due to sudden inflow of surface water. Laboratory scale load tests on model circular footings are carried out in a masonry tank, which has arrangements for pumping in water and drawdown. The influence of rate of submergence on settlement is studied by varying the discharge of inflow of water. It is observed that the settlement of footing considerably increases due to sudden submergence of footing.***

Keywords— ***Shallow foundation, sudden inflow, Settlement***

INTRODUCTION

Urban flooding is a phenomenon that occurs where there has been a man-made development within the existing floodplains or drainage areas (e.g., new residential communities, retail establishments, commercial buildings, parking lots, etc). Damages to the building during inundations can be the result of not only the direct activity of the flood wave and surface water, but also changes in groundwater flow conditions, including the increase of their piezometric level . In the past few decades many researches have been carried out to investigate the analysis of settlement in foundation due to rise of ground water. It has been proved that there is an increase in settlement resulting in decrease in bearing capacity during inundation.

Rise of ground water level is believed to increase the settlement significantly and had been a topic of research for many years. Some of the studies which have been conducted in this field are the effect of Submergence on Settlement and Bearing Capacity by Monir Kazi et.al (2015). They conducted simple laboratory experiments and have shown that the sand bed settles significantly when it is submerged under water for lower values of relative density. Terzaghi (1943) postulated that the submergence of the sand reduces the soil stiffness by half, which in turn doubles the settlement. Stress and pore water pressure changes in partially saturated soils under strip footings had been studied by Mohammed Yousif Fattah et.al(2014) They reported that there are two phenomena governing the behavior of footing represented by settlement (negative vertical displacement) and heave (positive vertical displacement). An increase of load on the foundation will increase the settlement and the failure surface will gradually extend outward from the foundation in heave behavior. Adel asakereh et.al (2015) evaluated the effect of water table rise on settlement of footing in coarse grain soil, also the effect of soil elasto-plastic parameters include the effect of changes in modulus of elasticity, cohesion, internal friction angle and dilation angle of soil on the bearing capacity and settlement efficiency was calculated. Amy B. Cerato et.al (2007) were investigated the scale effects of shallow foundation bearing capacity on granular materials to further evaluate the trend of decreasing bearing capacity factor, $N\gamma$, with increasing footing width, B. Ernesto Ausilioet.et.al (2017) They derived the analytical expression, allowing the bearing capacity of strip footings

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resting on a soil where the water table is at some depth below the footing base to be calculated.

There is a scope for further investigations to identify the effect of other important factors (e.g. depth of embedment, footing width, soil gradation and different intensities of discharge in settlement behaviour of shallow footings with changing groundwater level. Many researchers have carried out numerical and experimental work to study the settlement and bearing capacity of soil in the past decade.

This paper investigates the impact of floods on the settlement behaviour of shallow foundation by carrying out a series of laboratory scale load tests. The influences of sudden submergence and drawdown on the settlement of footings are investigated. The effects of three types of submergence are studied; due to sudden rise of ground water, sudden inflow of surface water and draw down of water.

LABORATORY SCALE LOAD TESTS

The experimental investigation was carried out at the Geotechnical Engineering Research Laboratory of LBS Institute of Technology for Women, Thiruvananthapuram. The details of materials used, experimental setup and methodology are presented below.

Material Used

The sand used for granular bed was well graded sand (SW). Properties of the sand are presented in Table 1.

Table 1. Properties of Sand

Property	**Sand**
Dry Unit Weight (kN/m^3)	17
Specific Gravity	2.3
Cohesion (kPa)	2
Angle of Shearing Resistance (°)	30

Experimental set up

Laboratory scale load tests are conducted in a test bed and loading frame assembly.

The test beds are prepared in a tank which is designed keeping in mind the size of the model footing to be tested and the zone of influence. The dimensions of the test tank are 1000mm length x 750mm width x 750mm depth. Model circular footing having diameter 100mm is fabricated with mild steel. The loading tests are carried out in the loading frame fabricated with ISMB 300. The load is applied using a hand operated mechanical jack of capacity 50 kN. The applied load is measured using a proving ring of capacity 10 kN. Plumbing arrangements were given as, two inlet pipe at the bottom of the tank for raising the ground water level at various discharges at longitudinal and lateral direction, Another inlet at top of the tank for giving submergence due to surface flow, an outlet pipe for measuring the drawdown. The settlement of model circular footing is measured using two dial gauges kept diametrically opposite to each other. The model circular footing is placed exactly beneath the center of loading jack to avoid eccentric loading.

Figure 1: Loading frame

Preparation of test bed and flooding condition

The initial test is conducted with sand alone in the test tank. Sand is filled in layers of 5 cm thickness and is compacted using a plate vibrator. Piezometers are placed between these layers on opposite side of footing for measuring the head of water. After the preparation of sand bed, the circular footing is placed at the centre of the tank. Two dial gauges are fixed diametrically opposite to each other to measure the deformation. The given load measured by means of a proving ring, simultaneously the settlement measured by means of two dial gauges placed diametrically opposite to each other.

Figure 2: Plumbing arrangement

The two inlet pipe at the bottom of the tank is opened for the full discharge (given in table 2), when the water level reaches the significant depth, the measurement of settlement commences. Tests are carried out at different

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discharges. The inlet pipe at the top of the tank is opened and fills the tank just above the level of footing there by creating the surface flooding. The settlement values are then measured from the dial gauges corresponding to the time intervals. The corresponding head can be measured by means of the level of water in the piezometers. Then the outlet valve is opened for simulating the drawdown condition.

Table 2.Discharge parameters

Variation of discharge	Full	3/4	1/2	1/4
Longitudinal discharge ($x10^{-6}m^3/s$)	1.63	1.48	1.36	1.16
Lateral discharge ($x10^{-6}m^3/s$)	1.63	1.40	1.28	1.11

Figure 3. Test setup for Laboratory Scale Load Test

RESULTS

Rise of ground water

The rise of ground water corresponding to the longitudinal and lateral discharges of water is shown in figure 4.

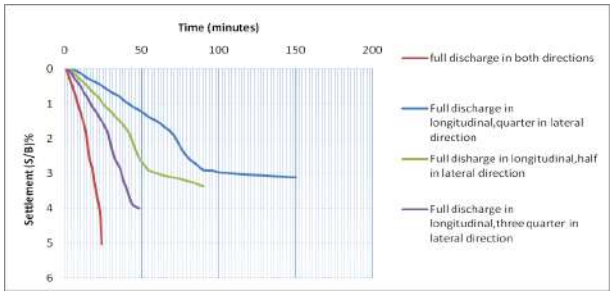

Figure 4. Rise of Ground water table

The rise of ground water corresponding to the head and time graph is shown in figure 5.

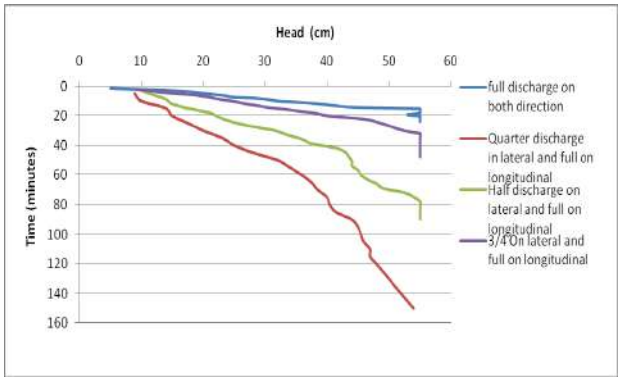

Figure 5 .Time Vs Head graph

Drawdown condition

The drawdown of water corresponding to the longitudinal and lateral discharges is shown in figure 6.

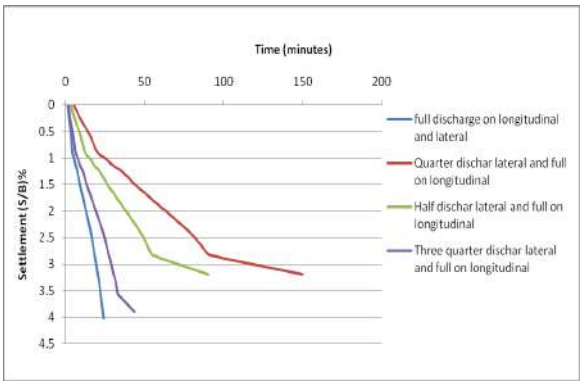

Figure 6.Drawdown condition

Submergence due to surface flow

Time Vs Normalised settlement of submergence due to surface flow is shown in figure 7.

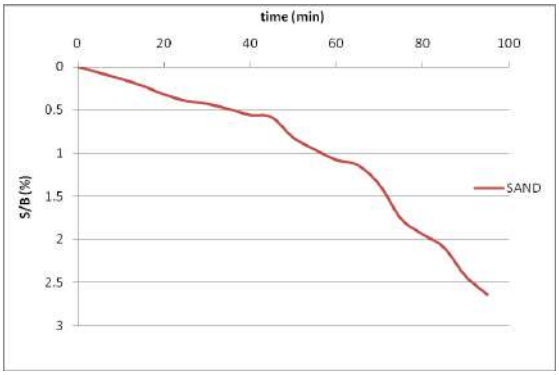

Figure 7.Surface flow

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DISCUSSIONS

From figure (4) it is observed that within a short span of 30minutes, settlement rate is more than 5%, when there is full discharge on the lateral and longitudinal direction. Then the discharge on the longitudinal direction kept constant at full rate and varying the discharge at three quarter opening of valve in lateral direction gives a settlement of 4% in 50 minutes, correspondingly, half discharge in lateral direction shows a settlement of more than 3% in 90minutes.The settlement rate is comparatively less for the quarter discharge, i.e. 3% in 150minutes. In case of ground water rise, the discharge on the longitudinal direction is kept constant and varying the rates of discharge on the lateral direction, it is observed that rate of settlement increases with increase in discharge.

Figure (5) shows that in full discharge condition on two direction reach the saturation of footing in 20minutes.The apparent cohesion is destroyed when the sand becomes saturated. The higher discharges compress the soil, where the effective stress in the soil increases, causes the settlement of footing. Settlement rate increases with respect to time and head of water. The increase in settlement is due to hydrostatic pressure that develops with increase in head.

The drawdown condition in figure (6) shows the settlement increases with time. The value (4% in 30minutes) goes on increasing at a rapid rate for the full discharge condition. It is observed that the draw down settlement rate is less when compared to the rise of ground water.

Submergence due to surface flow (Figure 7) shows a settlement of 2.6% in a time period of 90minutes.This result indicate that the rate of settlement for the surface flow is less compared to the drawdown and rise of ground water.

CONCLUSION

- In case of ground water rise, the rate of settlement increases with increase in discharge. Higher settlement values are obtained in this condition.
- In drawdown condition, settlement increases with time. The time taken to reach the settlement values is almost same for the ground water rise condition.
- The settlement increases at a rapid rate for the full discharge condition in rise of ground water and draw down condition
- The increase in settlement is due to hydrostatic pressure that develops with increase in head.
- The higher discharges compress the soil, where the effective stress in the soil increases, causes the settlement of footing.
- In case of submergence due to surface flow the rate of settlement is comparatively less than that of the other two condition.

REFERENCES

Adel asakereh, Alireza akbari (2015). “Effect of groundwater and various parameters on bearing capacity of shallow Foundations using finite element method.” *International Research Journal of Engineering and Technology (IRJET)*, Volume 02, Issue 05.

Amy B. Cerato, Alan J. Lutenegger (2007). “Scale Effects of Shallow Foundation Bearing Capacity on Granular Material.” *Journal Of Geotechnical And Geoenvironmental Engineering / ASCE*, volume 133, Issue 10.

Ernesto Ausilio, Enrico Conte (2017). “Influence of groundwater on the bearing capacity of shallow foundations.” *Canadian Geotechnical Journal*, 42(2):663-672.

Mohammed Yousif Fattah (2014). “Stress and pore water pressure changes in partially saturated soils under strip footings.” *International conference for Engineering sciences*, University of Mustansiriya, Bagdhad.

Monir Kazi Sanjay Kumar Shukla, Daryoush Habibi (2015). “Effect of Submergence on Settlement and Bearing Capacity of Surface Strip Footing on Geotextile Reinforced Sand Bed.” *Int. Journal of Geosynth and Ground Eng.*, 1:4.

Shariful Islam.M (2019). “Soil improvement technique by sand piling.” *International Journal of Research in Engineering & Science*, volume 3, Issue 2

Terzaghi K, Theoretical Soil Mechanics. John Wiley and Sons. New York, NY, USA, 1943

Dr.K.R.Arora, Soil Mechanics and Foundation Engineering (Geotechnical Engineering.

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Green Roofs for Urban Stormwater Management: A Review

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***Abstract*— Urban areas are dominated by hard, impervious surfaces that contribute to heavy runoff, which can overburden existing storm-water management facilities. It causes combined sewage overflow into lakes and rivers and results in an increased frequency of flooding and erosion. Impervious surfaces also act as a first flush mechanism for pollutants to accumulate which ultimately impact the aquatic ecology of the receiving waterways. Green roof implementation proved to be a sustainable approach to mitigate the impact of urbanization in developed areas. It helps to reduce the volume of runoff, delays and reduces peak stormwater runoff flow rates and can reduce pollutants carried to water bodies through the runoff. In addition to the storm water control benefits, green roofs also provide many ecological, social, and economic benefits such as mitigation of the urban heat island effect, energy conservation, extending the service life of the roof, creation of wildlife habitats, as well as creation of a more aesthetically pleasing environment to work and live. This article provides an overview of green roof's benefits toward the sustainable environments. Green roofs are likely to become an important component of urban sustainability in the future, provided that favorable public policy measures encourage and enable their construction.**

Keywords*— Green roof, sustainable environment, stormwater management

I. INTRODUCTION

As cities grow and man advanced technologically, industrialization and urbanization tend to affect the natural environments adversely and the world started facing some environmental complications such as urban heat island, increase in noise and air pollution, storm water run-off, ultra violet radiation etc., which causes discomfort to man and other living organisms in the world. Therefore the need for sustainable environment arose and green roof tend to be the one of the key solutions which will help to reduce these side effects to a great extend.

Urban areas are dominated by hard, impermeable surfaces that contribute to heavy runoff, which can overburden existing storm-water management facilities and cause combined sewage overflow into lakes and rivers. These impervious surface cover increase stormwater volume and flow rate, which result in an increased frequency of flooding [1] causing changes in stream channel geomorphology. The channel cross section will expand through erosion to compensate for more stormwater runoff. This destroys riparian buffer zones and decreases stream depth during dry periods [2]. The erosion will increase sediment loads in the water and alter stream bed composition, ultimately impacting the aquatic ecology that depends on the stream ecosystem. Urban stormwater contains higher levels of suspended solids, bacteria, heavy metals, oil and grease [1]. If the effects of urbanization are not appropriately managed, channel geomorphology and aquatic ecology will degrade, stream base flow will decrease, water quality will diminish, and flooding frequency will increase [3].

In the developed urban areas, roof surface areas account for 40–50% of all total impervious surface areas [4,5]. Rooftops are generally vacant areas that are not required for any essential building operations, yet remain impervious and contribute to stormwater runoff. Green roof is suggested as one of the environmental friendly innovation under category of sustainable site planning and management. The implementation of a stormwater control as a retrofit on vacant roofs could significantly reduce the impervious surface cover and help to eliminate stormwater generation at the source. Green roofs are designed to capture, temporarily retain and infiltrate storm water, promote evapotranspiration and harvest water at the source, encouraging in general evaporation, evapotranspiration and the re-use of storm water.

II. CONSTRUCTION

The general design of a green roof consists of five distinct layers: water proofing membrane, an impermeable roof membrane, a drainage layer, lightweight growth media, and adapted vegetation, as shown in Fig.1.

Water Proofing Membrane: The first layer directly above the conventional surface for waterproofing.

Roof Membrane: Before a green roof can be installed, the roof must be covered with an impermeable membrane that will not let roots penetrate.

Drainage Layer: The drainage layer is an open, highly drainable material that quickly channels gravitational water to the down-slope edge of the roof. It is usually a synthetic mat or

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a layer of porous media that permits conveyance of excess precipitation to outlets and roof drains.

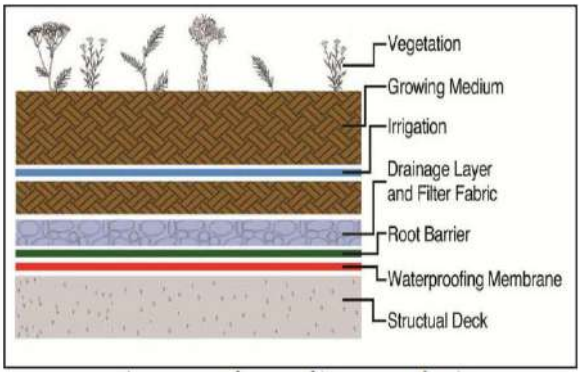

Fig.1. Layers of green roof (www.greenroofs.org)

Growing Media: This is an engineered substrate generally consisting of sand, gravel, crushed rock and some organics. The substrate's main purpose is to store excess rainfall and support plant life. The substrate used in the construction of green roofs should not add pollutants to the runoff. The substrate's maximum storage capacity (or field capacity) is governed by its particle size and void size distributions [6]. Using the proper growing media is in fact crucial for the success of any green roof system. The medium should be of low density to allow retrofit installation on existing buildings, and also reduces the need for extra structural support in new buildings.

Vegetation Layer: Green roof plants are exposed to the hottest and driest conditions as well as the wettest and coldest conditions. The plants provide shade to the surface below the foliage, intercept rainfall, and slow the movement of runoff from sloped roofs.

Green roofs can be categorized as ''intensive'' or ''extensive'' systems depending on the plant material and the planned usage for the roof area.

A. Intensive Green Roof

Intensive green roofs are so named because of their ''intense'' maintenance needs. They are designed to be similar to landscaping found at natural ground level. They typically use a wide variety of plant species that may include trees and shrubs and thus require deeper substrate layers (usually >15.2 cm). This type of green roof has a heavy weight and required high maintenance [7]. Intensive green roof can weigh from 171 – 391kg/m^2 [8]. They are often park -like areas accessible to the public and are generally limited to flat roofs.

B. Extensive Green Roof

The extensive green roof is simpler compare to intensive green roof because it is lightweight and requires low-maintenance. Vegetation on extensive green roofs usually consists of hardy, low growing, drought resistant, and fire resistant plants that provide dense cover and are able to withstand heat, cold, and high winds. The more successful plants have been succulents, especially the many varieties of sedums. It has thickness of less than 15 cm. According to a study [8] extensive green roof can weigh from 73kg/m^2 to 122 kg/m^2. They are typically not accessible to the public. They can be built upon a sloped surface with slope less than 10^0 [9,10].

Generally, extensive green roofs are cheaper, require less maintenance and are lighter than intensive systems. Therefore, extensive systems are implemented more frequently than intensive systems, most especially on existing building stock where rooftop weight limitations come into play.

C. Green Roof Maintenance

Generally green roofs do not need much maintenance. They require some support during establishment and then yearly maintenance thereafter. With drought resistant vegetation, irrigation of an extensive green roof is rarely necessary after the two year establishment period. Extensive green roofs should normally only require biannual or annual visits to remove litter, check drains and, in some cases, remove unwanted invasive plants. Intensive green roofs are likely to require regular inspection and maintenance.

III. Benefits Of Green Roof

A. Stormwater Management

The stormwater benefits offered by green roofs include delaying the runoff peak [5, 11, 12] and decreasing the peak rate of runoff [5,11,12,13]. A comparison of rainfall runoff responses of green roof with conventional roof is given in Fig.2. Green roofs intercept stormwater before it runs off a roof, which addresses the stormwater issue at the source rather than after the runoff has been collected.

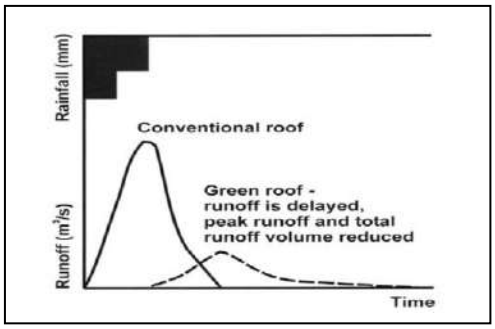

Figure 2. Rainfall runoff response of the green roof and conventional roof [15]

Green roofs reduce total runoff by retaining part of the rainfall and spreading the residual runoff over a long time period through a relatively slow release of the excess water that is stored in the substrate layer [14]. This all helps to stabilize the groundwater level, reduces the peak load on the sewage system and reduces the risk of flooding. Green roofs are able to retain rainfall volumes with retention efficiencies ranging from 40 to 80% [16-20]. The depth of substrate, the slope of the roof, the type of plant community, and rainfall patterns affect the rate of runoff [21-23]. These studies show that green roof retention increases with: thicker growing substrate depths [24,25], lower roof slopes [25,26], and higher evapotranspiration rates [27]. They can also be integrated with

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rainwater harvesting to provide a source of water for landscape irrigation or other non-potable use.

B. Improved Runoff Water Quality

Through a variety of physical, biological and chemical treatment processes, within the soil and root uptake zone, which filter airborne pollutants and pollutants entrained within rainwater, green roofs can help to reduce the amount of pollution delivered to the local drainage system and, ultimately, to receiving waters. Green roofs act as a sink for nitrogen, lead and zinc [28]. Green roofs can provide further benefits in terms of moderating the temperature of the runoff. It has been found that green roofs can neutralize the acidity of rainfall [29,30]. Additionally, runoff from an extensive green roof can reduce lead by 99%, Zinc by 96%, Cadmium by 92%, and copper by 97% [31]. This reduction in heavy metals is largely a result of total pollutant load reduction due to retention rather than an effective filtration process. Green roofs can also reduce the effects of acid rain by raising the pH value from 5 to 6 in rain water to over 7 to 8 in runoff water. The water quality of the outflow produced by the green roof was generally good and achieved high Water Quality Index [32].Reducing the fertilization of green roof vegetation improves the runoff water quality but may reduce plant growth.

C. Reduced Energy Consumption

The greater insulation offered by green roofs can reduce the amount of energy needed to moderate the temperature of a building, as roofs are the site of the greatest heat loss in the winter and the hottest temperatures in the summer. In warm climates, the green roof will cool the building by shading the roof, preventing direct solar radiation and adding extra insulation. During the winter, it can reduce heat loss by 25% or more. Green roof vegetation uses about 60% the incoming solar radiation for photosynthesis and the green roof has an albedo (the reflection of incoming radiation away from a surface) of 0.7-0.8 resulting in less available energy to heat the media [33].

Green roofs lower heating and cooling costs because the trapped air in the under drain layer and in the root layer help to insulate the roof of the building. Air temperatures above the building have been shown to be 30 ^{0}C lower when vegetated compared with a conventional roof [34], resulting in up to 15% annual energy consumption savings.

Incorporating solar panels with green roofs enables photovoltaic cells to operate at peak efficiency. Panels mounted on a green roof will produce significantly more energy than those mounted on a non-living roof. Additionally, green roof vegetation removes pollutants and dust from the air that might otherwise interfere with a cell's ability to produce electricity [35].

D. Improved Air Quality

The plants in a green roof filter particulate matter from the air and convert CO_2 into oxygen. The plants also act as a bio-filter in reducing the pollutant content of the rainfall. In addition, a study conducted in Chicago [36] demonstrated that green roofs reduced the air pollution through the uptake of ozone by plants. The type of vegetation found on the rooftop largely determines the amount of air-quality improvement.

E. Decreased Urban Heat Island Effect

According to the USEPA (2003), urban air temperatures can be up to 5.6^{0}C warmer than the surrounding countryside. In an urban heat island effect situation, even night air temperatures are warmer because built surfaces absorb heat and radiate it back during the evening hours. This effect can be reduced by increasing albedo or by increasing vegetation cover with sufficient soil moisture for evapotranspiration. Conventional roof surfaces have much lower albedos, ranging from 0.05 to 0.25 (USEPA, 2005). They use heat energy during evapotranspiration, a natural process that cools the air as water evaporates from plant leaves.

F. Protection from UV Radiation

The plants can absorb large quantities of solar energy through biological functions. Of the total solar radiation absorbed by the planted roofs, 27% is reflected, 60% is absorbed by the plants and the soil, and 13% is transmitted into soils [37]. Even without considering the increased thickness of soil due to additional layers of soil and drainage, the plants layer can shield off as much as 87% of solar radiation while a bare roof receives 100% direct exposure.

G. Maintain Hydrologic Cycle

Green roof is very helpful for retrieving the natural hydrologic cycle. They are unique in that they have the ability to capture and retain a volume (depth) of rain from each rainstorm. This captured water is then evapotranspired back to the atmosphere through the green roof vegetation.

H. Noise Reduction

Hard surfaces in urban areas are more likely to reflect sound, whereas green roofs absorb sound waves (especially low frequency sounds) because of the nature of the substrate and vegetation. An extensive green roof can reduce sound from outside by 40 decibels, while an intensive green roof can reduce sound by 46-50 decibels [38]. The layer of soil and plants can reflect and absorb up to 30% of noise pollution. The media depth directly relates to noise reduction; as the depth is increased, improved noise reduction is experienced [39].

I. Enriched Biodiversity

Green roofs can help to conserve valuable habitat and biodiversity and provide an oasis of life in an otherwise sterile urban environment. Even in densely populated areas, birds, bees, butterflies and other insects and invertebrates can be attracted to green roofs and gardens at great heights, which provide them with nesting and foraging habitats [40]. Green roofs, like other constructed ecosystems (e.g., sewage treatment wetlands, bioswales for storm-water management, or living walls), mimic natural ecosystems to provide ecosystem services. A green roof designed for minimal maintenance means that habitats are less likely to be disturbed and, with appropriate design, they can provide habitat for a wide range of vulnerable plants and ground-nesting birds. Well-designed green roofs can provide habitat compensation for rare and

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endangered species affected by land-use changes. Green roofs are commonly inhabited by various insects, including beetles, ants, bugs, flies, bees, spiders, and leafhoppers [41].

J. Improved Aesthetic Value

Green roofs can improve the roofscape with the variety of planting and habitats creating a more colourful, aesthetically pleasing and natural environment, particularly in dense urban areas. Living roofs also provide psychological benefits for people in urban areas. Green rooftops offer a rooftop retreat and a place to plant gardens or relax. When humans view green plants and nature, it has beneficial health effects, such as reducing stress, lowering blood pressure, releasing muscle tension, and increasing positive feelings [42]. These benefits can be translated into improved health. Many people choose a green roof for its visual impact. This can even have a positive impact on property value.

K. Increased Service Life of Roof

A green roof protects the roofing material from external influences such as the sun, rain, wind and temperature fluctuations and doubles or triples the life span of the roof to up to 60 years or even longer. The high-temperature levels often reached by unused roof surfaces create high levels of stress on the roofing system and materials. Vegetation cover of green roof moderates the temperature extremes of the roof surface and prevents the roof from being exposed to ultraviolet (UV) radiation. Also they prevent accelerated aging of roof due to UV degradation. The result is an extended life span of a roofing system. A longer service life of roofing systems would mean fewer roof replacements during the life of the building, thereby reducing future maintenance and replacement costs. Engineered green roofs in Europe have been shown to function for over twice the life span of conventional roofing systems [43].

Waterproofing membranes on conventional dark roofs deteriorate rapidly in ultraviolet (UV) light, which causes the membranes to become brittle. Such membranes are consequently more easily damaged by the expansion and contraction caused by widely fluctuating roof temperatures. Green roofs extend the life span of the roof's waterproofing membrane and improve building energy conservation. Temperature stabilization of the waterproofing membranes by green-roof coverage may extend their useful life by more than 20 years (USEPA 2000). A green roof also creates a natural fire-resistant layer on the building.

IV. Limitations

The most frequent concerns expressed about using green roofs is the cost and the possible need to provide additional reinforcement to the structure. Green roofs require moderate structural support which can be easily accommodated during design for new construction. For existing roofs, additional structural supports can be added during reroofing or renovation. It has been found that if a building is designed and built to present-day codes, an extensive green roof can typically be placed on the roof without any additional reinforcement. Green roofs cost more than the normal traditional roof, but it has its own advantages and benefits on the long run which will counter the initial cost of installation[21].

Another common concern about green roofs is the potential for leaks. The performance of green roofs has improved dramatically since the 1970s, when many leak problems were associated with the first generation of green roofs. Current waterproofing materials, root barriers, and rigorous design and construction standards have largely eliminated these problems.

V. Cost Analysis

The benefits of green roofs can easily outweigh the increased first costs for most installations [44]. The costs of constructing green roofs depended on the components, including the growing medium, type of roofing membrane, quantity of plants and drainage system. Usage of local materials and careful selection of media can greatly reduce this amount. A study conducted in Michigan [45] demonstrated a return on investment of 11 years on a single green roof when low green roof installation costs and high environmental benefits were considered.

VI. Conclusions

Green roof implementation proved to be a sustainable approach to mitigating the impact of urbanization in developed countries. Although Green roofs are not a popular phenomenon in India but it can be considered as an excellent approach towards saving the environment. They appear to be a suitable technology for urban areas, as there is limited space to implement traditional stormwater controls. Land values are too high to devote much surface area to stormwater control devices. Green roofs do not consume valuable urban land, as there may be with other sustainable stormwater systems such as bioretention areas. Green roofs involve growing plants on rooftops, thus replacing the vegetated footprint that was destroyed when the building was constructed. Additionally, green roofs are independent of watershed soil type. Green roofs can be implemented in densely developed urban centers where other practices are impossible or cost-prohibitive.

Studies show that in addition to the storm water control benefits, green roofs also provide many ecological, social, and economic benefits such as mitigation of the urban heat island effect, energy conservation, reduction in noise and air pollution, protection from ultra violet radiation emitted by the sun, extending the service life of the roof, creation of wildlife habitats, as well as creation of a more aesthetically pleasing environment to work and live. Green roofs are able to retain rainfall volumes with retention efficiencies ranging from 40 to 80%. It can reduce heavy metals by more than 90%. It helps to reduce annual energy consumption up to 15% when compared with a conventional roof.

Green roofs are likely to become an important component of urban sustainability in the future, provided that favorable public policy measures encourage and enable their construction. The government can play the leading role for implementation of green roof systems by providing incentives, including tax breaks, to the owners. Roofs can be used as a

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viable option for urban agriculture on the account of decreasing agricultural land, especially in Indian cities. Changing one roof to a green roof in a city may have limited impact, however if green roofs became an accepted part of building practice the impact on air quality in cities could be huge.

REFERENCES

[1] Dhalla, S. and C. Zimmer (2010). Low Impact Development Stormwater Management Planning and Design Guide, CVC & TRCA: 300.

[2] P'ng, J., D. Henry, et al. (2003). Stormwater Management Planning and Design Manual. M. o. t. Environment: 379.

[3] Voyde, E. A. (2011). Quantifying the Complete Hydrologic Budget for an Extensive Living Roof. Doctor of Philosophy, The University of Auckland.

[4] Mentens, J.; Raes, D.; Hermy, M. Green roofs as a tool for solving the rainwater runoff problem in the urbanized 21st century? Landsc. Urban Plan. (2006), 77, 217–226. [CrossRef]

[5] Stovin, V.; Vesuviano, G.; Kasmin, H. The hydrological performance of a green roof test bed under UK climatic conditions. J. Hydrol. (2012), 414, 148–161. [CrossRef]

[6] Beattie, D., Berghage, R., 2004. Green roof media characteristics: the basics. In:Greening Rooftops for Sustainable Communities, 2–4 June, Portland.

[7] Magill, J. D., Midden, K., Groninger, J., and Therrell, M. (2011). A History and Definition of Green Roof Technology with Recommendations for Future Research. Retrieved on 12th December 2015 http://opensiuc.lib.siu.edu/gs_rp/91

[8] Breuning, J. (2015) Green Roof Types Retrieved 12th December 2015 from http://www.greenrooftechnology.com/green-roof-types

[9] Kolb, W., Schwarz, T., (1999). Dachbegrunung, intensiv und extensiv. ¨ Ulmer, Stuttgart.

[10] Krupka, B., (1992). Dachbegrunung. Pflanzen- und Vegetationsanwen- ¨ dung an Bauwerken. Ulmer, Stuttgart

[11] Shafique, M.; Kim, R.; Lee, D. The Potential of Green-Blue Roof to Manage Storm Water in Urban Areas.Nat. Environ. Pollut. Technol.(2016), 15, 715–719

[12] Spolek, G. Performance monitoring of three eco roofs in Portland, Oregon. Urban Ecosyst. (2008), 11, 349–359.

[13] Palla, A.; Gnecco, I.; Lanza, L.G. Hydrologic restoration in the urban environment using green roofs. Water (2010), 2, 140–154

[14] Mentens J, Raes D, Hermy M (2006) Green Roof as a Tool For Solving the Rainwater Runoff Problem in The Urbanized 21st Century? J. of Landscape and Urban Planning 77 217-226

[15] L Bonzanigo and G Sinnona. “Present Challenges for Future Water Sustainable Cities: a case study from Italy”. Drink Water Engineering and Science7 (2014): 35–40.

[16] Villarreal E L and Bengtsson L (2005) Response of a sedum green-roof to individual rain events Ecological Engineering 25 1-7

[17] Morgan, S.; Celik, S.; Retzlaff, W. Green roof storm-water runoff quantity and quality. J. Environ. Eng. (2012),139, 471–478

[18] Getter, K.L.; Rowe, D.B.; Andresen, J.A. Quantifying the effect of slope on extensive green roof stormwater retention. Ecol. Eng. (2007), 31, 225–231

[19] Carpenter, D.D.; Kaluvakolanu, P. Effect of roof surface type on storm-water runoff from full-scale roofs in a temperate climate. J. Irrig. Drain. Eng. (2011), 137, 161–169

[20] Tillinger, D.; Ostroff, G.; Beattie, D.; Berghage, R.; Mankiewicz, P.; Montalto, F. Hydrologic functions of green roofs in New York City. In Green Roofs in the New York metropolitan region: Research Report. Columbia University Center for Climate System Research and NASA Goddard Institute for Space Study; Columbia University Center for Climate Systems Research: New York, NY, USA, (2006); pp. 27–36. Available online: https://pubs.giss.nasa.gov/docs/2006/2006_Rosenzweig_ro05800e.pdf (accessed on 10 October 2017).

[21] Dunnett NP, Kingsbury N. (2004). Planting Green Roofs and Living Walls. Portland (OR): Timber Press

[22] Mentens J, Raes D, Hermy M. (2005). Green roofs as a tool for solving therainwater runoff problem in the urbanized 21st century? Landscape and Urban Planning 77: 21–226

[23] VanWoert ND, Rowe DB, Andresen JA, Rugh CL, Xiao L. (2005)b.Green roof stormwater retention: Effects of roof surface, slope, and media depth. Journal of Environmental Quality 34: 1036–1044

[24] De Cuyper K, Dinne K and Van DeVel L (2004) Rainwater discharge from green roofs 30th Int. Symp. on Water Supply and Drainage for Buildings (Rotterdam: The International Council for Innovation and Research in Building and Construction (CIB)) (online: www.irbnet.de/daten/iconda/CIB10549.pdf

[25] VanWoert N D, Rowe D B, Andresen J A, Rugh C L, Fernandez R T and Xiao L (2005) Green roof stormwater retention: effects of roof surface, slope, and media depth J. Environ. Qual. 34 1036–44

[26] Getter K L, Rowe D B and Andresen J A (2007) Quantifying the effect of slope on extensive green roof stormwater retention Ecol. Eng. 31 225–31

[27] DiGiovanni K, Gaffin S and Montalto F (2010) Green roof hydrology:results from a small-scale lysimeter setup (Bronx, NY) Low Impact Development 2010: Redefining Water in the City (San Francisco, CA: ASCE) pp 1328–41

[28] Gregoire, B.G., Clausen, J.C., (2011). Effect of a modular extensive green roof on stormwater runoff and water quality. Ecol. Eng. 37, 963–969

[29] Teemusk, A. and U. Mander (2007). "Rainwater runoff quantity and quality performance from a greenroof: The effects of short-term events." Ecological Engineering 30(3): 271-277.

[30] Berndtsson, J. C. (2010). "Green roof performance towards management of runoff water quantity and quality: A review." Ecological Engineering 36(4): 351-360

[31] Steusloff, S. (1998). "Input and output of airborn aggressive substances on green roofs." Urban Ecology

[32] Evaluation of green roof as green technology for urban stormwater quantity and quality controls K H Kok1, L M Sidek1, M R Z Abidin2, H Basri1 , Z C Muda1 and S Beddu1, 4th International Conference on Energy and Environment (2013) ICEE 2013

[33] Weng, Q., Lu, D., & Schubring, J. (2004). Estimation of land surface temperature–vegetation abundance relationship for urban heat island studies. Remote Sensing of Environment, 89, 467–483

[34] Wong, N.H., Tay, S., Wong, R., Ong, C.L., Sia, A., (2003). Life cycle cost analysis of rooftop gardens in Singapore. Building and Environment 38, 499–509

[35] http://www.greenrooftechnology.com/Solar_PV_Greenroofs, accessed on 12 January 2020

[36] Yang, J., Qian, Y., Peng, G., 2008. Quantifying air pollution removal by green roofs in Chicago. Atmos. Environ. 42, 7266–7273

[37] Ekaterini E, Dimitris A. The contribution of a planted roof to the thermal protection of buildings in Greece. Energy and Buildings (1998);27(3):29–36

[38] Peck, S.W., C. Callaghan, M.E. Kuhn, and B. Bass. (1999). Greenbacks from green roofs: Forging a new industry in Canada. Canada Mortgage and Housing Corporation. Ottawa, Canada

[39] Yang HS, Kang J, Choi MS., (2012), Acoustic effects of green roof systems on a lowprofiled structure at street level. Build Environ, 50, PP 44–55

[40] Johnston and Newton, (2004), Building Green A guide to using plants on roofs, walls and pavements

[41] Coffman RR, Davis G. (2005). Insect and avian fauna presence on the Ford assembly plant ecoroof. Paper presented at the Third Annual Greening Rooftops for Sustainable Communities Conference, Awards and Trade Show; 4–6 May 2005,Washington, DC

[42] Ulrich, R.S., and R. Simons. (1986). Recovery from stress during exposure to everyday outdoor environments. In J. Wineman, R. Barnes,

ISBN 978-93-89105-41-4

and C. Zimring (eds.). The costs of not knowing. Proceedings of the 17th Annual Conference of the Environmental Research Association. Environmental Research Association, Washington, D.C. The Role of Extensive Green Roofs in Sustainable Development Kristin L. Getter1 and D. Bradley Rowe2,3, HORTSCIENCE 41(5):1276–1285. 2006

[43] Kohler, M., Schmidt, M., Grimme, F., Laar, M., Gusmao, F., (2001).Urban water retention by greened roofs in temperate and tropical climate. In: Proceedings of the 38th IFLA World Congress, Singapore

[44] Scholz-Barth K. Green roofs: stormwater management from the top down. Environmental Design & Construction Home, Retreived 25 November 2001 from http://www.edcmag.com /CDA/ArticleInformation, January/February,(2000)

[45] Clark, C., Adrians, P., Talbot, B., (2006). Probabilistic economic analysis of green roof benefits for policy design. In: Proceedings of the Fourth North American Green Roof Conference: Greening Rooftops for Sustainable Communities, Boston, MA, The Cardinal Group, Toronto, 11–12 May

[46] Muhammad Shafique, Reeho Kim and Kwon Kyung-Ho, Sustainability Green Roof for Stormwater Management in a Highly Urbanized Area: The Case of Seoul, Korea (2018), 10, 584; doi:10.3390/su10030584

[47] K H Kok, L M Sidek, M R Z Abidin, H Basri , Z C Muda and S Beddu, Evaluation of green roof as green technology for urban stormwater quantity and quality controls, 4th International Conference on Energy and Environment 2013 (ICEE 2013)

[48] Rufai Mohammed Ahmed and Asst. Prof. Dr. Halil Z Alibaba, An Evaluation of Green roofing in Building , International Journal of Scientific and Research Publications, Volume 6, Issue 1, January 2016

[49] CIRIA SuDS Manual 2015

[50] Environmental Protection Agency (EPA) in the United States, Green roofs for Stormwater Runoff Control (2012)

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Developing Cool Concrete Pavements Using Phase Change Materials: A Review

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Abstract—**High pavement temperature leads to urban heat island and thermal distresses in pavements. Also, the extreme low temperature in pavements causes freeze and thaw damage and low temperature cracking. Incorporation of phase change materials (PCMs) in pavements to restrict the temperature extremities is an emerging field of research importance. Incorporation of PCM can restrict both the higher and lower temperature extremities in pavements. PCMs can store energy in the form of latent heat without any rise in temperature and with minimum change in volume. Encapsulated PCMs are used in pavements to minimize the PCM leakage. This paper provides a general outlook on different types of PCMs along with their encapsulation techniques suitable for concrete pavement applications. The paper is more focused towards understanding the effect of incorporating PCMs in concrete pavements. Being the first literature review in this area, the current paper act as a firm foundation for future developments in this field.**

Keywords—cool pavements; phase change materials; PCM encapsulation; urban heat island

I. INTRODUCTION

Urban surface temperature has a strong correlation with the air temperature. The pavement temperature has been found to be up to 10 ˚C higher than the natural vegetation during summer [1]. This elevated urban temperature leads to urban heat island effect (UHI), causing air pollution [2] disturbance in local wind patterns [3] and an increase in energy consumption [2]. In the United States, urban heat island effect has increased the air conditioning demand in the city areas and approximately 8% of the total electricity produced is consumed to meet this demand [4]. Cooler pavements restrict the surface temperature and flow of sensible heat towards the atmosphere significantly. Hence, it can be considered as an effort towards UHI mitigation. Also, the repeated temperature curling in concrete pavements results in transverse, longitudinal and corner cracks [5]. Higher temperature differential has also been found to be the major reason for cracking [6] and therefore, reduced pavement temperature may restrict the thermal stresses induced in concrete pavements. Cooler concrete pavements can be achieved by an increase in the albedo of the pavements (reflective pavements) or by utilizing the latent heat of water evaporation for pavement cooling (water retention pavements) [7].

There are different technologies and materials developed to restrict/reduce the pavement temperature and in such cases, the pavements are termed as cool pavements. Although the conventional cool pavement technologies such as reflective pavements effectively reduce the pavement temperature, it increases the glare related issues, thermal load on pedestrian traffic and temperature of the nearby buildings [8]. The lower thermal inertia and solar reflectance of evaporative pavements results in higher pavement temperature in the absence of water [9]. Hence, there is a need for developing cool pavement technologies with minimum impact on the surrounding environment. Introducing PCM into the pavements may be a solution this regard. Generally, organic PCMs are used in pavements because they do not require supercooling during phase change and have good resistance against corrosion [10], [11]. Moreover, they have high cyclic chemical and thermal stability for a longer period of time. Among the organic PCMs, paraffin compounds are mostly used as PCM in pavements due to their wide range of melting temperature and higher latent heat of fusion [12]. The problems and solutions related to the incorporation of PCM in concrete specimens is discussed in detail in the following sections.

II. PHASE CHANGE MATERIALS IN PAVEMENTS

Researches indicate that the incorporation of solid-liquid PCMs in pavements can decrease the pavement temperature [13]. As the pavement temperature reaches above the phase change temperature of PCM, it undergoes phase change by absorbing heat energy from the pavement and contribute towards the reduction in pavement temperature [14]. Also, freeze and thaw deterioration is one of the major pavement distresses in cold regions [15]. During winter, there is a necessity of removing ice and snow from pavement surface to provide a better riding surface. Usually deicing chemicals and salts, snowplowing or often both may be used for this purpose

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[16]. Such methods are uneconomical, adversely affect the pavement strength, and may cause environmental issues [17]. Incorporation of liquid-solid PCM is an effective way of low temperature thermoregulation [10]. The heat released during the solid-liquid phase change of PCMs can be utilized to increase the pavement temperature and to melt snow from the pavement surface [18]. A schematic representation of the role of PCMs in the thermoregulation of pavements is shown in Fig. 1.

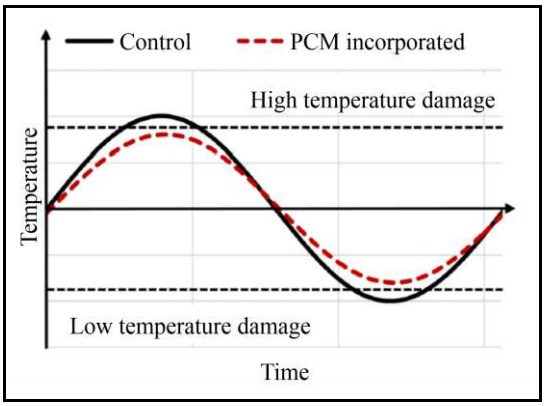

Fig. 1. Thermal performance of PCM incorporated pavement [14]

Hence, the incorporation of PCMs in pavements is one of the prospective ways of achieving both higher and lower temperature regulation in pavements [15]. Even though the heat energy can be stored in a material by an increase in the temperature of the material (sensible heat storage), by a change in the phase of the material (latent heat storage), by a change in intermolecular bond (thermochemical energy storage), or by a combination of these [11], the latent heat storage materials can store comparatively higher energy per unit mass without much variation in temperature [13]. Therefore, the different possibilities of incorporating PCMs in pavements has been widely investigated.

III. PCM ENCAPSULATION

PCM encapsulation is the process of covering the PCM with a proper shell or coating. The encapsulation medium acts as a support for PCM and prevents the leakage of PCM during phase change. In concrete pavements, PCM leakage may hinder the contact between cement particles and water and cause retardation in cement hydration [19]. Encapsulated PCM can be broadly classified into core-shell encapsulated PCM and shape-stabilized PCM [20] as illustrated in Fig. 2. Core-shell encapsulated PCM consists of PCM (core) covered with some other material of higher melting point (shell). Porous carrier material absorbs the PCM in molten state by capillary action to form shape-stabilized PCM. The methods such as vacuum impregnation techniques, as explained by Kastiukas *et al.* [21], can be utilized to impregnate PCM into the porous material effectively. Both core-shell encapsulated and shape-stabilized PCMs can be used for pavement application. The benefits of PCM encapsulation as listed by [22] are as follows.

- Hold the PCM during phase change
- Maintain the purity of PCM by isolating it from surrounding materials
- Provide flexibility during frequent state change
- Increase thermal and mechanical stability
- Compatibility for certain uses such as food storage

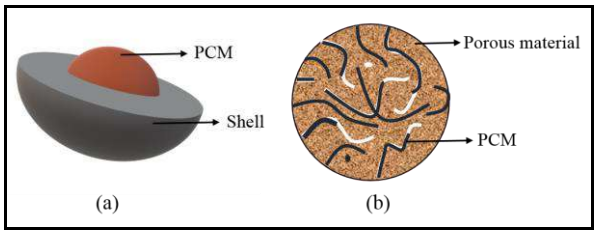

Fig. 2. (a) Core-shell encapsulated PCM; (b) Shape-stabilized PCM

IV. EFFECT OF PCM ON MECHANICAL STRENGTH OF CONCRETE

Recent studies indicate that the incorporation of PCM adversely affects the mechanical strength of concrete. The inherent softness of PCM microcapsules is one of the reasons behind the reduction in mechanical strength. Falzone *et al.* [23] evaluated the effect of soft microcapsule inclusions on the mechanical strength of cement concrete, and suggested critical volume ratio of stiff to soft inclusions. The mechanical strength and elastic modulus was found to be decreasing with increase in PCM dosage.

Further, Pilehvar *et al.* [24] studied the effect of PCM, in both solid and liquid state, on the mechanical strength of concrete. The results indicate the state of PCM in concrete does not influence the mechanical strength significantly. The weaker connections and air voids between the PCM and cement paste, as identified from the microstructure analysis, is the reason behind the reduced the mechanical strength of concrete.

Researches show that the hydration reactions are delayed in concrete with PCM leakage with respect to that with no leakage [25]. The PCM leakage in concrete may hinder the contact between cement particles and water [26]. Studies of Eddhahak-Ouni [27] indicate that the retardation in cement hydration and higher porosity of PCM incorporated concrete contributes towards a decrease in mechanical strength. Recently developed PCM encapsulation techniques like emulsion polymerization can be adopted to develop more leakage resistant PCMs [28]. Also, the type of shell material of PCM microencapsulation has a significant effect on the mechanical strength of concrete [29]. The key reasons behind the strength reduction of PCM incorporated concrete, as summarized by Marani and Nehdi [30], are illustrated in Fig. 3. Further, the PCM incorporation tends to decrease the density of concrete due to the lower density of PCM microcapsules [30].

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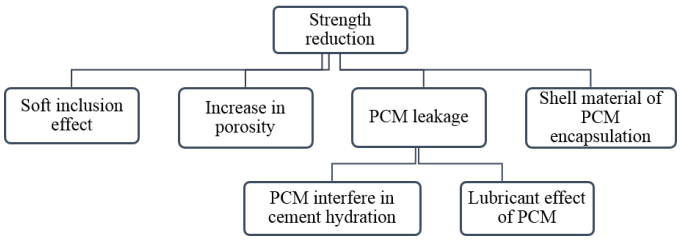

Fig. 3. Reasons for strength reduction in PCM incorporated concrete pavements [30]

V. APPLICATION OF PCM IN CONCRETE PAVEMENTS

Dehdezi et al. [31]analyzed the thermal, mechanical and microstructural properties of PCM incorporated concrete pavements. Micro-encapsulated paraffin wax (melting temperature = 26 ˚C; Latent heat = 160 J /g) of particle size 20 to 80 µm was used as PCM. Although there was no evidence of PCM damage in microstructure analysis during mixing and curing, the particles fail by bursting under loading. The PCM bursting increase the porosity of concrete beyond the limits which adversely affect the mechanical strength of concrete. A peak temperature reduction upto 4 ˚C in the laboratory and 3.5 ˚C in the field was achieved by the PCM incorporation. Even though the thermal performance of this PCM incorporated concrete was acceptable, the poor mechanical strength is a disadvantage for pavement application.

Later, Arora et al. [32] presented a numerical model to predict the early and later age thermal behavior of concrete pavements. The model simulated the exposure of PCM incorporated concrete pavements to actual environmental conditions in Phoenix, Arizona or San Francisco, CA. The model analyzed the effect of replacement of fine aggregate or cement paste with PCM of melting point 24˚C and 35˚C. A significant reduction in the early age hydration heat was observed in both replacement conditions. The model provides an outlook to predict the PCM type and dosage based on the climatic conditions to restrict the critical stresses at early and late age. The results of the transient one-dimensional thermal model developed by Young et al. [33] implies that the incorporation of 10% microencapsulated PCM by volume reduce the pavement temperature by 5˚C in the first 24 hours. Moreover, the incorporation of PCM reduced the local temperature gradients developed within the pavement section so long as the effective thermal conductivity of the pavement was not reduced. Later, She et al. [34] studied the effect of incorporating PCM on the early age heating and cooling rate of concrete pavements and the related improvement in thermal cracking. Moreover, the study developed a one dimensional thermal model with the thermophysical properties of PCM-mortar composite to predict the temperature changes related to heat of hydration. A good correlation was observed between the experimental and numerically simulated values. Further, the study suggests the use of PCMs with melting temperature above the placement temperature of concrete for effective cooling.

VI. PCMS FOR LOW TEMPARATURE THERMOREGULATION IN CONCRETE PAVEMENTS

Ma et al. [35] developed PCM for low temperature thermoregulation. Tetradecane (C14H30) of phase change temperature similar to the temperature of low temperature pavement distresses is used as PCM. Ethyl cellulose was used as a membrane material and activated carbon and silica was used as carrier materials. As the theoretical enthalpy of PCM with silica was higher, silica is a better choice than activated carbon as PCM carrier. A lab made dispersion agent was used to disperse the carrier material which also improves the heat storage capacity and restrict the cluster formation of PCM particles. The optimum proportion of tetradecane, silica, EC and dispersant was found to be 1:1:0.1:0.1.

Farnam et al. [10] suggested the use of light weight aggregates (LWA) and embedded tubes to incorporate PCM in concrete pavements. Plastic pipes of 10 mm diameter was used as embedded tubes. Paraffin oil (petroleum based) and methyl laurate (vegetable based) was used as PCM. When incorporated in LWA, Paraffin oil released a heat of 11,000 kJ/m^3 of mortar at ~3.0°C during freezing. Methyl laurate exhibited no heat release due to the chemical reaction occurred between the methyl laurate and cementitious material. A heat release of 7500 kJ/m^3 of mortar at ~3.0°C and 12000 kJ/m^3 of mortar at ~1.2°C was observed for Paraffin oil and methyl laurate incorporated mortar respectively. Furthermore, the incorporation of PCM in embedded pipes did not exhibit any chemical reaction. Later, Farnam et al. [36] replaced plastic pipes with metal pipes (22.4 mm inner diameter) of carbon steel with 0.5% carbon content and a thermal conductivity of 45 W/m.K. As the maximum size of aggregate used was 19 mm, a spacing of 25 mm was provided between the pipes. This PCM incorporated concrete slab melted 136.9 mm of snow during the first 24 hours.

Yeon and Kim [15]studied PCM microencapsulated with melamine-formaldehyde resin by emulsification method to control the freeze and thaw deteriorations in concrete pavements. As the process of getting microencapsulated PCM in powder form increases the unit cost by 5 times, PCM was incorporated in the slurry form. The liquid phase of this PCM slurry will act as free water available and the water content for each mix proportions should be modified accordingly. The results indicate that the addition of PCM significantly improves the resistance against freeze and thaw damage in concrete pavements. It was also noticed that the influence of PCM almost disappeared when the ambient temperature was lower than the phase change temperature of PCM for a long time. This is because the PCM is fully solidified and the temperature is in equilibrium with the ambient. A PCM with lower phase change temperature is suggested in such case. Later, Nayak *et al.* [37] developed a numerical simulation model to predict the behavior of PCM incorporated pavements under low temperature conditions. The study considered 20 % replacement of sand with PCM. The simulation indicate that

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the incorporation of PCM in concrete pavements significantly reduce the freeze and thaw damages.

Urgessa *et al.* [38] studied the effect of PCM incorporation in concrete pavements under realistic environment condition for a period of 14 months. Inorder to avoid the effect of PCM on cement hydration, PCM was encapsulated with melamine formaldehyde resin. The results indicate that the PCM addition decrease the freeze and thaw cycles and thus improves the pavement life by 5.2 %%–35.9 %.

VII. SUMMARY AND DISCUSSION

PCMs can be used in concrete pavements to restrict the low temperature and high-temperature thermal distresses. Suitable phase change temperature and latent heat of fusion are the key parameters while selecting the PCM for pavement application. PCMs of melting point slightly above 0˚C are usually used in pavements to regulate low-temperature thermal distresses, whereas the phase change temperature of PCMs for high-temperature thermoregulation varies over a wide range as it depends on the atmospheric temperature and climatic condition.

Paraffin compounds are utilized in most of the previous studies due to its suitable melting temperature and low cost. The thermal performance of PCM incorporated pavements depends on the properties of PCM used, especially the melting temperature and latent heat of fusion. It is better to keep the latent heat of fusion as high as possible while the melting temperature of the PCM should be selected wisely as per climatic condition. As most of the previous studies focus on the development of numerical models to predict the thermal characteristics of PCM incorporated pavements, more detailed studies are necessary on the selection of PCM for a particular climatic condition in site. Further studies in this area should focus on this aspect. Pavement sections consisting of different PCMs can be cast and exposed to various climatic conditions to establish a relationship between climatic condition and PCM melting temperature to be selected for that climate.

Method of incorporating PCM in pavements is as important as selecting the right PCM. The purpose of encapsulation is more significant in the case of low-temperature thermo regulation as liquid-solid PCMs are used. Shape-stabilized PCM and encapsulated PCM are used to avoid the PCM leakage. In shape-stabilized PCM, porous materials absorb PCM and prevents leakage by capillary and surface tension forces. The quantity of PCM that can be incorporated in pavements by shape stabilization technique is very low. To solve this issue, porosity of the medium may be increased or PCM may be provided in encapsulated form. For low-temperature thermoregulation, PCM is provided in LWA, in metallic containers or in metal pipes. PCM is usually provided in some carrier material such as LWA, silicon powder, expanded graphite, polypropylene and ceramisite for high-temperature thermoregulation. The thermal performance of pavements will be better if the PCM is provided in some carrier material as it is evenly distributed. In case of metallic containers and metal pipes, PCMs will be concentrated in a small area and will affect the thermal performance. As the tests were conducted under different climatic conditions, it is not possible to draw a general conclusion from these. Hence, a comparative study is suggested under same environmental conditions to select the best method of encapsulation among these.

VIII. CONCLUSIONS

PCMs are proven to regulate the temperature extremes in concrete pavements. Incorporation of PCM in pavements reduce the heating and cooling rate, restrict the temperature peaks and delay the occurrence of extreme temperatures. This review paper focused on the effect of incorporating PCM on the thermal performance of concrete pavements. It provides an outline of the current state of art in this particular field, mainly focusing on the type of PCMs and mode of application fit for pavement application. Shape stabilized and encapsulated PCMs are suitable for pavement application. The selection of suitable PCM depends on the environmental conditions while the method of encapsulation is purely engineer's choice. Further studies are needed to increase the quantity of PCM that can be incorporated without affecting the mechanical strength of these pavements significantly.

REFERENCES

[1] T. P. Lin, Y. F. Ho, and Y. S. Huang, "Seasonal effect of pavement on outdoor thermal environments in subtropical Taiwan," *Build. Environ.*, vol. 42, no. 12, pp. 4124–4131, 2007.

[2] J. Yang, Z. Wang, K. E. Kaloush, and H. Dylla, "Effect of pavement thermal properties on mitigating urban heat islands : A multi-scale modeling case study in Phoenix," vol. 108, pp. 110–121, 2016.

[3] P. A. Mirzaei and F. Haghighat, "Approaches to study Urban Heat Island e Abilities and limitations," *Build. Environ.*, vol. 45, no. 10, pp. 2192–2201, 2010.

[4] A. H. Rosenfeld, H. Akbari, J. J. Romm, and M. Pomerantz, "Cool communities: strategies for heat island mitigation and smog reduction," *Energy Build.*, vol. 28, no. 1, pp. 51–62, 1998.

[5] I. Lines, J. E. Hiller, M. Asce, J. R. Roesler, and M. Asce, "Determination of Critical Concrete Pavement Fatigue Damage Locations Using Influence Lines," vol. 8, no. August 2005, 2015.

[6] B. Choubane and T. Mang, "Nonlinear Temperature Gradient Effect on Maximum Warping Stress in Rigid Pavements," *Transp. Res. Rec. 1370*, pp. 11–19, 1982.

[7] M. Santamouris, "Using cool pavements as a mitigation strategy to fight urban heat island - A review of the actual developments," *Renew. Sustain. Energy Rev.*, vol. 26, pp. 224–240, 2013.

[8] M. Pomerantz, H. Akbari, P. Berdahl, S. J. Konopacki, and H. Taha, "Reflective surfaces for cooler buildings and cities," vol. 2812, no. June, 2016.

[9] Y. Qin, "A review on the development of cool pavements to mitigate urban heat island effect," *Renew. Sustain. Energy Rev.*, vol. 52, no. December, pp. 445–459, 2017.

[10] Y. Farnam *et al.*, "Evaluating the Use of Phase Change Materials in Concrete Pavement to Melt Ice and Snow," *J. Mater. Civ. Eng.*, vol. 28, no. 4, p. 04015161, 2015.

[11] A. Sharma, V. V. Tyagi, C. R. Chen, and D. Buddhi, "Review on thermal energy storage with phase change

ISBN 978-93-89105-41-4

materials and applications," *Renew. Sustain. Energy Rev.*, vol. 13, no. 2, pp. 318–345, 2009.

[12] A. Kumar and S. K. Shukla, "A Review on Thermal Energy Storage Unit for Solar Thermal Power Plant Application," *Energy Procedia*, vol. 74, pp. 462–469, 2015.

[13] B. Ma, W. Si, J. Ren, H. N. Wang, F. W. Liu, and J. Li, "Exploration of road temperature-adjustment material in asphalt mixture," *Road Mater. Pavement Des.*, vol. 15, no. 3, pp. 659–673, 2014.

[14] B. J. Manning, P. R. Bender, S. A. Cote, R. A. Lewis, A. R. Sakulich, and R. B. Mallick, "Assessing the feasibility of incorporating phase change material in hot mix asphalt," *Sustain. Cities Soc.*, vol. 19, pp. 11–16, 2015.

[15] J. H. Yeon and K. K. Kim, "Potential applications of phase change materials to mitigate freeze-thaw deteriorations in concrete pavement," *Constr. Build. Mater.*, vol. 177, pp. 202–209, 2018.

[16] Y. Farnam, D. Bentz, A. Hampton, and W. J. Weiss, "Acoustic Emission and Low-Temperature Calorimetry Study of Freeze and Thaw Behavior in Cementitious Materials Exposed to Sodium Chloride Salt," *Transp. Res. Rec.*, vol. 2441, no. 1, pp. 81–90, 2014.

[17] X. Shi, L. Fay, M. M. Peterson, and Z. Yang, "Freeze--thaw damage and chemical change of a portland cement concrete in the presence of diluted deicers," *Mater. Struct.*, vol. 43, no. 7, pp. 933–946, Aug. 2010.

[18] M. R. Kakar, Z. Refaa, J. Worlitschek, A. Stamatiou, M. N. Partl, and M. Bueno, "Effects of aging on asphalt binders modified with microencapsulated phase change material," *Compos. Part B Eng.*, vol. 173, no. May, 2019.

[19] L. Haurie, S. Serrano, M. Bosch, A. I. Fernandez, and L. F. Cabeza, "Single layer mortars with microencapsulated PCM: Study of physical and thermal properties, and fire behaviour," *Energy Build.*, vol. 111, pp. 393–400, 2016.

[20] Y. E. Milián, A. Gutiérrez, M. Grágeda, and S. Ushak, "A review on encapsulation techniques for inorganic phase change materials and the influence on their thermophysical properties," *Renew. Sustain. Energy Rev.*, vol. 73, no. December 2016, pp. 983–999, 2017.

[21] G. Kastiukas, X. Zhou, and J. Castro-Gomes, "Development and optimisation of phase change material-impregnated lightweight aggregates for geopolymer composites made from aluminosilicate rich mud and milled glass powder," *Constr. Build. Mater.*, vol. 110, no. 2016, pp. 201–210, 2016.

[22] P. B. Salunkhe and P. S. Shembekar, "A review on effect of phase change material encapsulation on the thermal performance of a system," *Renew. Sustain. Energy Rev.*, vol. 16, no. 8, pp. 5603–5616, 2012.

[23] G. Falzone *et al.*, "The influences of soft and stiff inclusions on the mechanical properties of cementitious composites," *Cem. Concr. Compos.*, vol. 71, pp. 153–165, 2016.

[24] S. Pilehvar *et al.*, "Mechanical properties and microscale changes of geopolymer concrete and Portland cement concrete containing micro-encapsulated phase change materials," *Cem. Concr. Res.*, vol. 100, pp. 341–349, 2017.

[25] A. Eddhahak, S. Drissi, J. Colin, S. Caré, and J. Neji, "Effect of phase change materials on the hydration reaction and kinetic of PCM-mortars," *J. Therm. Anal. Calorim.*, vol. 117, no. 2, pp. 537–545, Aug. 2014.

[26] V. D. Cao *et al.*, "Microencapsulated phase change materials for enhancing the thermal performance of Portland cement concrete and geopolymer concrete for passive building applications," *Energy Convers. Manag.*, vol. 133, pp. 56–66, 2017.

[27] A. Eddhahak-Ouni, S. Drissi, J. Colin, J. Neji, and S. Care, "Experimental and multi-scale analysis of the thermal properties of Portland cement concretes embedded with microencapsulated Phase Change Materials (PCMs)," *Appl. Therm. Eng.*, vol. 64, no. 1–2, pp. 32–39, 2014.

[28] U. Stritih, V. V Tyagi, R. Stropnik, H. Paksoy, F. Haghighat, and M. M. Joybari, "Integration of passive PCM technologies for net-zero energy buildings," *Sustain. Cities Soc.*, vol. 41, pp. 286–295, 2018.

[29] F. Liu, J. Wang, and X. Qian, "Integrating phase change materials into concrete through microencapsulation using cenospheres," *Cem. Concr. Compos.*, vol. 80, pp. 317–325, 2017.

[30] A. Marani and M. L. Nehdi, "Integrating phase change materials in construction materials: Critical review," *Constr. Build. Mater.*, vol. 217, pp. 36–49, 2019.

[31] P. K. Dehdezi, M. R. Hall, A. R. Dawson, and S. P. Casey, "Thermal, mechanical and microstructural analysis of concrete containing microencapsulated phase change materials," *Int. J. Pavement Eng.*, vol. 14, no. 5, pp. 449–462, 2013.

[32] A. Arora, G. Sant, and N. Neithalath, "Numerical simulations to quantify the influence of phase change materials (PCMs) on the early- and later-age thermal response of concrete pavements," *Cem. Concr. Compos.*, vol. 81, pp. 11–24, 2017.

[33] B. A. Young *et al.*, "Early-age temperature evolutions in concrete pavements containing microencapsulated phase change materials," *Constr. Build. Mater.*, vol. 147, pp. 466–477, 2017.

[34] Z. She *et al.*, "Examining the effects of microencapsulated phase change materials on early-age temperature evolutions in realistic pavement geometries," *Cem. Concr. Compos.*, vol. 103, no. July 2018, pp. 149–159, 2019.

[35] B. Ma, S. Adhikari, Y. Chang, J. Ren, J. Liu, and Z. You, "Preparation of composite shape-stabilized phase change materials for highway pavements," *Constr. Build. Mater.*, vol. 42, pp. 114–121, 2013.

[36] Y. Farnam, H. S. Esmaeeli, P. D. Zavattieri, J. Haddock, and J. Weiss, "Incorporating phase change materials in concrete pavement to melt snow and ice," *Cem. Concr. Compos.*, vol. 84, pp. 134–145, 2017.

[37] S. Nayak, N. M. A. Krishnan, and S. Das, "Microstructure-guided numerical simulation to evaluate the influence of phase change materials (PCMs) on the freeze-thaw response of concrete pavements," *Constr. Build. Mater.*, vol. 201, pp. 246–256, 2019.

[38] G. Urgessa, K. K. Yun, J. Yeon, and J. H. Yeon, "Thermal responses of concrete slabs containing microencapsulated low-transition temperature phase change materials exposed to realistic climate conditions," *Cem. Concr. Compos.*, vol. 104, no. March, p. 103391, 2019.

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Behaviour of Circular Footing Subjected to Horizontal Loads

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Abstract*— The bearing capacity of foundations has always been one of the subjects of major interest in soil mechanics and foundation engineering. Evaluations of bearing capacity of vertically loaded shallow foundations on various soils have been studied by many researchers. There are structures where horizontal loading has greater influence and much research has not been carried out to evaluate the horizontal load bearing capacity of shallow foundations. This paper investigates the load-settlement behaviour of footings subjected to horizontal loads by carrying out a series of laboratory scale load tests. The parameters varied are Depth of footing, Soil type, Ratio of vertical load to horizontal load etc. It is observed that depth of foundation and vertical load influences the lateral load bearing capacity of footings. It is observed that the lateral deformation decreases with the increase in depth of foundation and vertical load. The tilt of the footing is also found to decrease with depth when the footing is subjected to combined lateral and vertical loading. The influence of micropiles on the improvement in lateral load-deformation behaviour is also studied.

Keywords*— Lateral load-deformation behaviour, Micro piles, Shallow foundation

INTRODUCTION

The bearing capacity of foundations has always been one of the subjects of major interest in geotechnical engineering. Most of the bearing capacity theories have been developed for footings carrying vertical and symmetrical loads. In actual practice footings will also carry horizontal loads due to various climatic and boundary conditions. In foundations of certain structures like retaining walls, the major force is horizontal. But a satisfactory theory to evaluate the horizontal load bearing capacity of foundations is not yet comprehensively developed. Evaluations of bearing capacity of vertically loaded shallow foundations on various soils have been addressed by previous researchers. Taiebat H.A et al. (2000) did numerical studies on shallow foundations on cohesive soil subjected to combined loading. They did 3D Finite element analysis of circular foundations on cohesive soil under combined loading and proposed new equation for failure locus in terms of all three components. Patra et al. (2012) studied ultimate bearing capacity of strip footings under eccentric and inclined loadings and suggested empirical reduction factors based on lab tests. Gang Zheng et al. (2019) studied the effect of inclined loading on bearing capacity of strip footing on sand layer and they did parametric study to determine the factors influencing the failure mechanism. Abbasali et al.(2019) studied influence of using composite soils under shallow foundations. 3D Finite element analysis was done and studied bearing capacity improvement and shows that Sand clay mixture shows better performance than gravel clay mixture. Horizontal load bearing capacity of deep foundation had been investigated by Reese and Matlock

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(1956), Mayerhof (1983) etc. It is uneconomical to provide pile foundations for all structures carrying horizontal loads due to its cost and difficulty in construction. Hence it is important to investigate horizontal load bearing capacity of shallow foundations.

EXPERIMENTAL STUDIES

Methodology and materials

The load tests are conducted in a combined test bed and loading frame assembly. The test beds are prepared in a tank of internal dimension 1000mm length x 750 mm width x 750 mm depth. The test tank is constructed with 23 cm thick brick masonry walls on the three sides. The front side of tank is formed using a frame work of steel channels and angles. The model circular footing has a diameter of 100 mm, thickness 20mm and is fabricated with mild steel. Micropiles have a length of 200mm and diameter 3mm and are also made of mild steel. The clayey soil is filled in the test tank to the required level with compaction done in layers of 50 mm thickness. The water content of the clayey soil is maintained at 18%. To achieve the desired density of the soil, the layered filling technique is used. The pre-determined density of clay is used to calculate the desired weight of soil required to fill the tank in layers of 50mm height. A uniform density of 15.6kN/m3 for clay was maintained in all the tests. The clay was compacted by ramming. The compactive effort required to achieve the required density was determined by trial and error. The loading tests are carried out in a loading frame fabricated with ISMB 300. The vertical load is applied using a hand operated- mechanical jack of capacity 50kN. The applied vertical load is measured using a proving ring of capacity 100kN. Lateral load is applied by lateral loading apparatus which is welded in the loading frame. Lateral load is measured using a proving ring of capacity 50kN.The lateral displacement of the model footing is measured using two dial gauges of 0.01mm sensitivity kept diametrically opposite to each other. The tilt due to combined vertical and horizontal loading is also measured using two dial gauges of 0.01mm sensitivity kept diametrically opposite to each other. The model footing is placed exactly beneath the centre of loading jack to avoid eccentric loading. The photograph and schematic diagram of test setup is shown in Figure 1&2. The arrangement for Lateral loading is shown in Figure 3. Locally available clay is used as foundation soil. The properties of clay are listed in Table 1.

Table 1. Properties of clayey soil

Sl No	Properties	Values
1	Specific gravity	2.68
2	Optimum Moisture Content (%)	18
3	Maximum Dry Density (kN/m^3)	15.61
4	Liquid Limit (%)	58
5	Plastic Limit (%)	22
6	Shrinkage limit (%)	16.2
7	Plasticity Index (%)	36
8	IS Classification	CH
9	Unconfined Compressive Strength, UCC (kN/m^2)	140.08
10	Permeability, k (m/s)	3.03×10^{-6}
11	Cohesion , c (kN/m^2)	25

Fig. 1 Test tank and loading frame

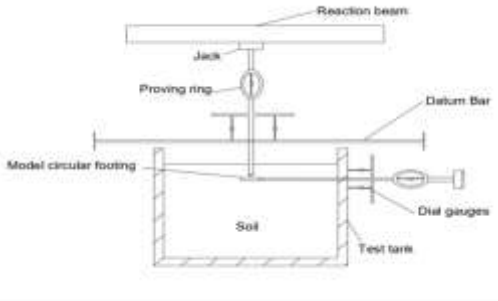

Fig. 2 Schematic diagram of test setup

Fig. 3 Arrangement for Lateral loading

Parameters used in the study

The parameters varied are presented in Table-2

Table 2. Parameters Varied

Parameter	Diameter of Footing (B)	Vertical Load (N)	Depth of footing (d/B)
Value	100 mm	0, 90, 130, 170	0, 0.5, 1

RESULTS AND DISCUSSION

Load settlement behaviour of circular footing subjected to combined vertical and horizontal loading is investigated by carrying out a series of laboratory scale load tests. Influence of depth of foundation and vertical loading on lateral displacement and rotation of footing are presented below.

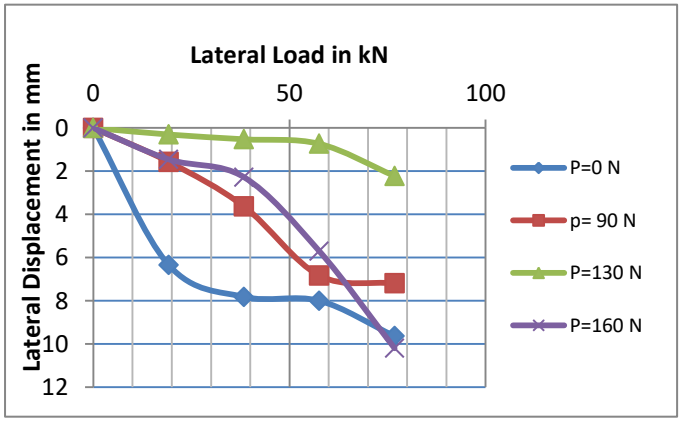

Fig 4. Influence of vertical load on the lateral load-deformation behaviour when d/b=0

From the curves it is observed that as lateral loading increases, lateral displacement increases. At all depths as vertical loading (P) increases, lateral displacement decreases. This is because as vertical load increases, normal stress beneath the footing increases and thereby increasing the force of friction. Hence lateral displacement decreases.

Minimum lateral displacement is found at vertical load of 130 N. Increase in displacement at higher load may be due to decrease in soil resistance since some part of soil surrounding the footing get separate due to tilting of footing.

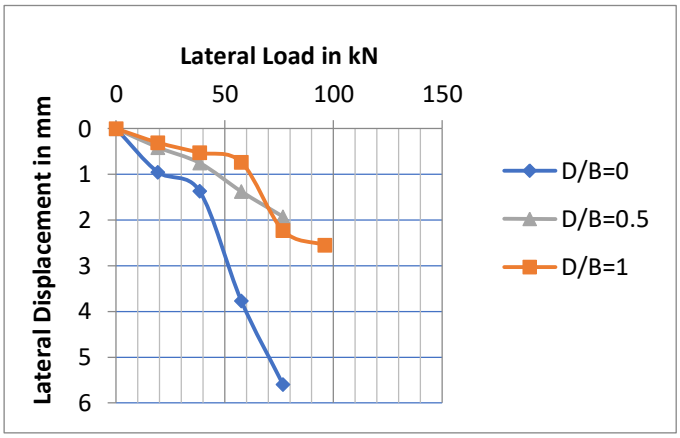

Fig. 5 Influence of depth of footing on the lateral load-deformation behaviour when vertical load = 130 N

As depth increases lateral displacement decreases .This is because increase in depth causes footing to get confined with more soil and thereby decreasing lateral displacement.

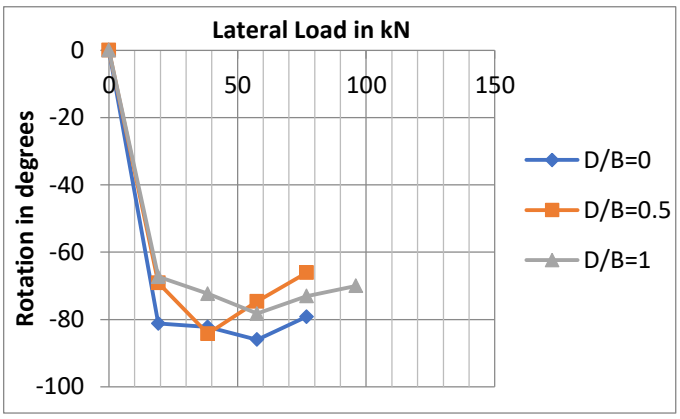

Fig. 6 Lateral load v/s rotation curve for P = 0 N

Figure 6 shows relation of lateral load and rotation with increase in depth. From the curve 6 it is observed that as lateral loading increases, rotation increases. Also it found that

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as depth increases tilt decreases. Rotation is found minimum for D/B = 1. Maximum rotation is found at surface. Decrease in tilt is due to increase in confinement of soil with depth.

Influence of micropiles

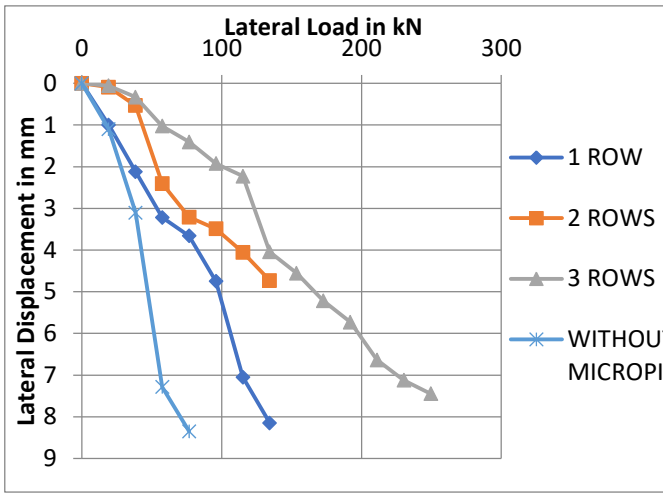

Fig. 7 Lateral load v/s displacement curve for P=130 N and d/B=1

Use of micropiles shows improvement in lateral displacement. Maximum decrease in lateral displacement is found when three layers of micropiles were used.

CONCLUSION

Based on the results of this investigation, the following conclusions can be made:

- ✓ Depth of foundation and vertical loading influences the behaviour of footings subjected to lateral loads
- ✓ Rotation decreases with depth & found minimum for d/b =1
- ✓ As depth increases rotation of footing decreases due to increase in confinement
- ✓ Lateral displacement decreases with increase in vertical loading due to increase in normal stress.
- ✓ As number of micropiles increases, lateral displacement decreases. Thus the behaviour of clayey soil against lateral loading can be improved.

REFERENCES

[1] Abbasali., Taghavi Ghalesari., Mohammadreza Khaleghnejad. (2019). “Behaviour of eccentrically loaded shallow foundations resting on composite soils.” J. Build.Eng.,102(18), 303-315.

[2] Gang Zhenga., Jiapeng Zhaoa. (2019). “Ultimate bearing capacity of strip footings on sand overlying clay under inclined loading.” Computers and Geotechnics.,106 (5), 266–273.

[3] Hudson Matlock., Reese. (1956). “Generalized Solutions for Laterally Loaded Piles” Transactions of the American Society of Civil Engineers, 1962, Vol. 127, Issue 1, Pg. 1220-1247.

[4] Mayerhof.,Mathur. (1983). “ Lateral resistance and deflection of rigid walls and piles in layerd soil” Canadian Geotechnical Journal 18(2), 159 - 170

[5] Patra, C.R., Behera, R., Sivakugan, N., and Das, B.M. (2012). “Ultimate bearing capacity of shallow strip foundations under eccentrically inclined load.” International Journal of Geotechnical Engineering.,6(4), 507-514.

[6] Taiebat, H. A., and Carter, J. P. (2000). “Numerical studies of the bearing capacity of shallow foundations on cohesive soil subjected to combined loading.” J. Geotech. Eng., 122(4), 409-418.

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Urban design strategies for retention of wetlands in urban areas

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***Abstract*—*The Wetlands are defined as areas having transitional water level below six meters. The aim of this study is to develop urban design strategies for retention of wetlands in urban areas. Wetland parks have been the ultimate solution for retention of wetlands in urban areas. Mangalavanam in Kochi city is a best example for Wetland Park in urban area. The urbanisation in Kochi city revamped wetland areas with housing stock. The Kochi city development plan delineates wetland land use in its existing and proposed maps. The Pokkali rice cultivation that happens in wetland areas of Kochi city is shrinking in area. Modern wetland parks have several features from agriculture to waste water treatment. Qunli storm water park, Houtan Park, Zhongshan Park, Sarovarom bio park, Adyar Poonga Park and Mangalavanam park are the six case studies considered. The six case studies were studied and analyzed. Urban design strategies for retention of wetlands in urban areas were derived.*

Keywords—wetland park; neighbourhood; wetland islands; Kochi city

I. INTRODUCTION

Wetlands are defined as "areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters"[1].

Wetland types on the basis of hydrology

1) *Tidal*
2) *Non tidal*

Wetland types according to location

1) *Reveries – along a stream*
2) *Lacustrine – Present in a lake*
3) *Palustrine – Isolated*

All over the world wetlands are known by different names such as fens, marshes, bogs, mires, peat lands, swamps and other local names present in different parts of the world. Wetlands are found in every continent except the Antarctica. Wetlands are used as man managed rice cultivation fields in various parts of the Asia. The paddy wetlands of the state are a potential source for the food security of the state. The area of the wetlands is shrinking at an alarming rate due to the shift from rice to cash crops and non-agricultural use. Wetlands were part of the early settlements in civilisations[1][2]. The first rules for protection of wetlands in India came in 2008. "Wetlands (management and conservation) rules 2008". Then came the other rules such as

1) *"The Kerala Conservation of Paddy Land And Wetland Act 2008"*
2) *"Wetlands (Conservation and Management) Rules 2010"*
3) *"Wetlands (Conservation and Management) Rules 2017"*
4) *"The Kerala Conservation of Paddy Land And Wetland Act 2018"*

According to "The Kerala conservation of paddy land and wetland act 2008" there is prohibition on reclamation of wetlands and sand mining from wetlands. Removal of slurry and mud to maintain the wetland is accepted. Restrictions on the kind of construction activities allowed on wetlands are also specified under these rules[2]. Wetlands behave like sponges that absorb excess water during high tide and floods. The loss of wetlands leads to destruction of biodiversity and floods.

II. RELEVANCE OF THE STUDY

In Kerala only the present CRZ (coastal regulation zone) and KLU (Kerala land utilization order) practically prohibits people from reclaiming wetlands. The CRZ norms clearly state the setback that is to be given under its zones. Also large scale development projects require sanction for environmental clearance for reclaiming wetlands or construction activities in wetlands. Sanction from pollution board is required for all projects. Wetlands have very high bio diversity value. Therefore environmental protection groups are active in spreading awareness about the contribution of wetlands to the ecosystem. Wetlands are calculated as one fifth of the land area

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of Kerala state. The Ernakulam district has the highest share of wetlands. The proposed land use map of Kochi prepared by the town planning department of Kerala published in the city development plan 2006 clearly demarcates land as wetland land use and paddy land use. Kochi is an estuarine city. The high tide time sea water rises 3 feet above mean sea level. The wetlands of the Kochi city contain the water during the five hours that it takes for the sea to subside back to low tide. Thus wetlands and paddy fields are natural water harvesting systems.

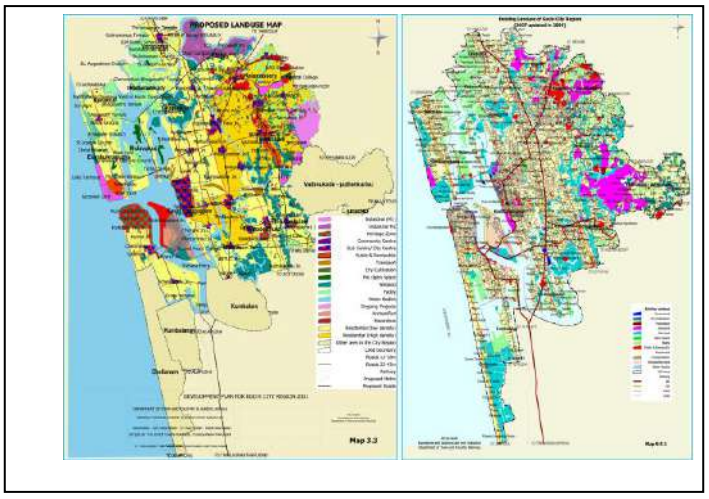

Fig. 1. Existing and proposed Kochi city development plan 2006 with wetland land use.

The paddy fields and wetlands were land filled to create residential areas such as The Panampilly Nagar, The Giri Nagar, The Jawahar Nagar, The Gandhi Nagar and The Shastri Nagar. The Pokkali fields were acquired for the infrastructure projects. The infrastructure projects brought development in the estuarine islands. Wetlands are being land filled. If pokkali fields disappear from the landscape of the estuarine islands then the soil in these places shall turn saline and acidic. The result will be complete destruction of vegetation and biodiversity. At present to secure the food security of our state we need to save the Pokkali fields. Pokkali cultivation practice has a strong cultural genius loci associated with Kochi. It was the livelihood of many over generations. Pokkali tourism is promoted in places such as Kumbalangi and Pizhala. Veerepu is another rice variety that is also grown in the wetlands.

Wetlands are protected in the country under various national parks and sanctuaries as wilderness. The only trouble with retention of wetlands as wilderness is dumping of waste and mosquitoes. Mosquitoes breed in stagnant waters of the wetlands. Only man managed wetlands can help reduce mosquito menace, pollution and protect biodiversity. Also wetland parks have several features that make it productive and profitable. Therefore wetland parks have become the ultimate solution for wetland retention in urban areas.

III. METHODOLOGY

Methodology of study is as follows.

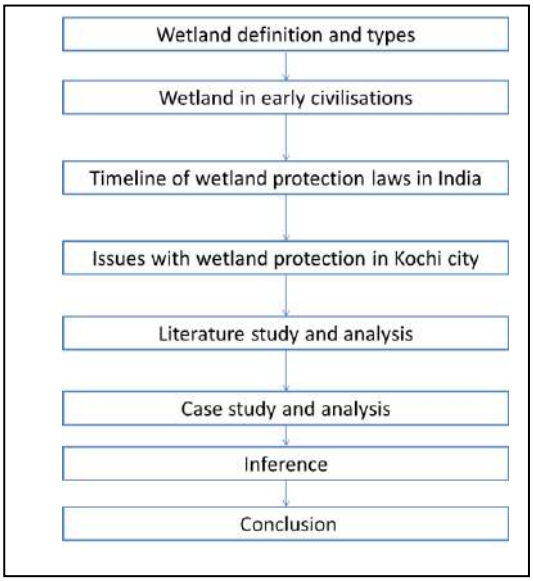

Fig. 2. Methodology of study.

The scope of study shall be extended to all relevant examples of wetland parks and wetland areas in Kochi city. Following are the 6 case studies included in this study.

1) *Qunli storm water park*
2) *Zhongshan shipyard park*
3) *Houtan park*
4) *Sarovarom bio park*
5) *Adyar Poonga park*
6) *Mangalavanam park*

IV. LITERATURE STUDY

Beyond the ecological value of the wetland park, the park neighbourhood also has equal importance.

Today wetland parks occupy neighbourhoods before or after urbanization. Wetland park neighbourhood is similar to sustainable neighbourhoods in several ways. Douglas Farr explains this phenomenon with case studies under sustainable urbanism as built infill, built greenfield, unbuilt infill and unbuilt greenfield. [2].

Also wetland parks may be called as a patch or corridor that functions with an urban matrix according to Richard T T Forman [3].

Such wetland park neighbourhoods together can contribute to an Ecopolis according to Paul F Downton [4].

Modern wetland parks consist of several features that range from agriculture to waste water treatment. From the literature analysis the major features of wetland parks are [5].

1) Performative wetland landscape infrastructure : Wetland is a natural system that needs to be reviewed regularly for understanding the performance of the system. Wetland is measured to find water quality, chemical nature of water, levels of pollution and biodiversity count.

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2) Dynamic wetland landscape : People prefer assorted planting in wetland parks. Wetland landscape is not a static landscape. Wetland landscape is dynamic landscape.

3) Water Retention Landscape : Water retention landscape refers to a type of hydrological design of water landscape such as ponds, lakes, reservoirs and wetlands by arranging the order of flow based on the volume of water calculations from the catchment basin of the channel to its water retention bowls at lower level.

4) Sustainable Drainage System (Suds): Sustainable drainage system refers to drainage system that is designed to control the velocity of flow and quantity of flow by ecological methods such as bio swales, retention ponds and wetland.

5) Conveyance Spreader Channel (Csc): The conveyance spreader channels refer to area of land that is used to convert channel flow into sheet flow. This reduces the velocity of water flow considerably. The wetland shrubs and plants are used to reduce the flow further by planting them in the path of the water flow. Also small bunds and rock buffers are added to reduce the speed of flow of water.

6) Constructed Wetland (Cw): A constructed wetland is an artificial wetland built to grow wetland plants. It is usually a concrete basin with bunds to retain the water. Wetland plants are grown in these bunds. Agriculture can be practised using this method. Also grey water can be treated if it is passed through the constructed wetland. The one end of the constructed wetland shall be at a higher elevation and the other end shall be at a lower elevation. This helps in the cascade flow of water from higher elevation to lower elevation. There are three types of constructed wetlands they are sub surface flow constructed wetland, surface flow constructed wetland and floating treatment constructed wetland.

7) Reservoir Wetland: The purpose of the reservoir wetlands is to improve local livelihoods by enhancing fisheries through the construction of small wetlands just below the full supply level (FSL) of a reservoir. Balloon barrage reservoir and check dams are two types of reservoir wetlands.

8) Wetland Park: The Wetland parks are ecological restoration sites for conservation, education and tourism facility with an ecological mitigation area (EMA) for the wetlands lost due to city development. Wetland parks may be constructed in brown field sites or green field sites. Wetlands parks may be located within urban development or as wilderness outside urban development.

9) Water-Sensitive Urban Design (Wsud): The Water sensitive urban design refers to a practice of water management used in the Middle East to conserve water by recycling grey water in a sustainable way. Urban design components such as artificial lakes are constructed within neighbourhoods. The artificial lakes are fed with recycled storm water and grey water from nearby residential areas. Also Green houses are built to grow food using the grey water. The artificial lakes create an urban oasis that can reduce the urban heat island effects considerably.

10) Constructed Wetlands In Anaerobic Digester Plant: The latest research in waste management technology proves that wetland plants have the capability in filtering grey water after post treatment in anaerobic digestion facility. The slurry from anaerobic digestion tank shall become manure for plants and the residual water from watering these crops shall sediment in wetland ponds. Only the solid waste is reduced in the anaerobic digester. The sedimentation of the coagulated water takes place in wetland ponds. This concept has been used to create waste treatment plants.

V. CASE STUDIES

Wetland park case studies that were considered for this study are [6][7][8].

1) Qunli storm water park : The Qunli storm water park is a storm water park that was constructed in a green field site in Qunli. The wetland plants are grown inside the storm water park. The storm water park has a catchment area of 111 acres. The park is located in the centre of the Qunli neighbourhood. The rain water that gets collected in the catchment area of the park gets collected in the wetland park. Agriculture is practised in the wetland park. Park size is 23.1 hectares.

2) Mangalavanam park : Mangalavanam bird park is located in Kochi city. It is a small park under the forest department of government. The wetland park lies in CRZ II zone with a setback of 10 metre. The buildings immediate to the wetland park are tall towers. Mangalavanam is essentially a wilderness with lots of birds and trees. The park has one tree house and a small walkway. The park is only 2.74 hectares in size. Earlier it used to be the timber depot.

3) Adyar Poonga park : Adyar Poonga park is located in the Adyar estuary. The Adyar estuary was heavily polluted. All the plastic waste was buried deep in the ground and wetland plants were sown over it. This created a green forest in the neighbourhood. Adyar Poonga park is a small region in the estuary. Adyar Poonga park is landscaped to include bridges, gazebo, seating, stage and walkways through the park. Park size is 10 hectares.

4) Houtan park: Houtan Park was built in a brown field site that earlier had a blight. The slum and the industries were removed to create a wetland park. The wetland park purifies city grey water that reaches the park through a channel. The park has exclusive zone for agriculture and deck for boating. Besides which the park has gathering space and historic remains of the industrial site. The park is very large and occupies the edge of the neighbourhood in the shape of a strip. Park size is 26.6 hectares.

5) Zhongshan park: Zhongshan park is built in the site of a historic shipyard along the banks of a river. Zhongshan park is surrounded by buildings. People come to the park to take photos and enjoy the lighting features in the park at night. Park size is 9.5 hectares.

6) Sarovarom bio park: Sarovarom bio park is a small area near the Kootoli wetlands and lies adjacent to the Cannolly canal. Sarovarom bio park has boating facility. Sarovarom bio park has amphitheatre, stage, park play equipment and parking space for cars. Park size is 9.6 hectares.

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VI. ANALYSIS AND INFERENCE

Six wetland park case studies were cross examined for their different attributes [2][3][4].

A. Analysis of wetland parks

1) Morphological evolution: The morphological evolution study revealed that Qunli storm water park was built in a green field site. Houtan park was built in a brown field site by clearing of industries and slums. Zhonghan park was built in an abandoned shipyard site. Sarovarom bio park is built in a green field site. Mangalavanam park is built in an abandoned timber depot site. Adyar Poonga park was built in a polluted estuary site. All these developments shows that wetland parks can be built in brown field site, green field site and historic abandoned sites.

2) Shape of water body: Qunli storm water park is built with a water body in the center of the neighbourhood and drainage canals flow parallel to the park. Houtan park is attached to a navigable river. Zhongshan park is attached to a navigable river. Sarovarom bio park is attached to Kootoli wetlands and Cannolly canal. Mangalavanam is attached to a canal that is not navigable. Adyar Poonga park stands detached from the estuary. All wetland parks are eventually connected with a water body.

3) Section: Section of all the wetland parks was considered. Qunli storm water park stood below the drainage channel level. Houtan park stood above the river water level. Zhonghan park stood above the river water level. Sarovarom bio park stood below the canal water level. Adyar poonga park stood above the water level of the city drainage canal. Mangalavanam stood below the water level of the adjacent canal. The change in the elevation of the park with respect to the water level in the river directed the water flow.

4) Edge: All the wetland parks had an edge not far from the park. This was usually along the water channel or canal or river. The rupture of settlements happened along the water edge. Using planting and circulation the water edge was sealed to prevent rupture of settlements.

5) Road networks in neighbourhood: All the wetland parks are located in dense urban neighbourhoods having roads for connectivity. Wetland parks are not navigable. Hence road connectivity is very important.

6) Boundary: All the wetland parks had a boundary that had buildings oriented for a good view of the park. Except Mangalavanam all other wetland parks had walkways adjacent to the park.

7) Amount of bleeding of communities: Qunli storm water park, Adyar Poonga park and Mangalavanam park had minimum amount of bleeding of communities due to lesser number of road networks within the immediate context of the park. This was because all these three wetland parks where interior wetland parks. Houtan park, Zhongshan park and Sarovarom bio park had maximum amount of bleeding of communities due to more number of road networks within the immediate context of the park. This was because all these three parks where located in the edge of a river or canal.

8) Ped shed analysis: All the wetland parks are located in walkable neighbourhoods. Within the 300 meters from the park there is a road. Also within the 2000 meters from the park there is a metro station or bus station or transit stop.

9) View shed analysis: All the wetland parks had buildings along the perimeter of the park having views into the park.

10) Water mosaic and land mosaic analysis: All the wetland parks had a proportional amount of water mosaic compared to land mosaic.

11) Contextual analysis: All the wetland parks had a river or lake in the context of the park.

12) Amount of attached cells: Qunli storm water park, Adyar Poonga park and Mangalavanam park had maximum amount of attached cells around the park. This was because all these three wetland parks where interior wetland parks. Houtan park, Zhongshan park and Sarovarom bio park had minimum attached cells around the park. This was because all these three parks where located in the edge of a river or canal.

13) Land locked or not: Qunli storm water park, Adyar Poonga park and Mangalavanam park where land locked. Houtan park, Zhongshan park and Sarovarom bio park where not land locked.

14) Block size: Houtan park was the biggest park it fitted in a 2000 meter by 2000 meter grid. Qunli storm water park, Adyar Poonga park and Zhongshan park fitted in a 800 meter by 800 meter grid. Mangalavanam park fitted in a 300 meter by 300 meter grid.

15) Park size: Houtan park was the biggest park. Second biggest park is Qunli storm water park. Third biggest park is Adyar Poonga park. Fourth biggest park is Sarovarom bio park. The fifth biggest park is Zhongshan park and the sixth biggest park is Mangalavanam park.

16) Compressed circulation: All the wetland parks had compressed circulation because water is the main component of the wetland park area. There are only minimum possible circulation routes within the wetland park. Rest of the spaces is occupied by plants and water.

17) Evasive identity: All wetland parks had an evasive identity. Wetland parks do not behave like a Maidan or playground. Wetland parks are usually hidden in vegetation and water.

18) Flight corridors for birds to descent: All wetland parks had flight corridors for migratory birds to descent to their nesting on trees in wetland park. Birds cannot descent down into trees like helicopter or drone. Birds need flight corridor space in wetland park neighbourhood. The attached river or canal offers a flight corridor for birds to reach wetland park trees. All the wetland park case studies had such associated water channels leading to the wetland park.

B. Analysis of two islands in Kochi city with wetland land use

1) Vallanthakad: Vallanthakad has a micro community. Only 40 houses are present on the island. There are green buffer vegetation and mud bunds to prevent flooding of the island during high tide. These buffers are also the walkways to the group of houses. These buffers protect the prawn farming fields and rice fields present in the island. These buffers also offer protection from rising waves of water. Recently the

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island got sanction for construction of a bridge to reach the mainland. The wetlands in the island stand in juxtaposition to the micro communities. Vallanthakad had low density micro communities with lesser population.

2) South Chittoor: South Chittoor island in the beginning had a micro community and a temple. The reconstruction activities of the temple brought the first iron bridge to this island. The bridge brought about connectivity to this island. More residences came in the center of the island. Later the urbanization spread to different parts of the island. The wetland area in the island has fragmented and diminished in size. There is a heterogeneous landscape created by the left over wetland patches and urban land mosaic. South Chittoor had high density edge communities with high population.

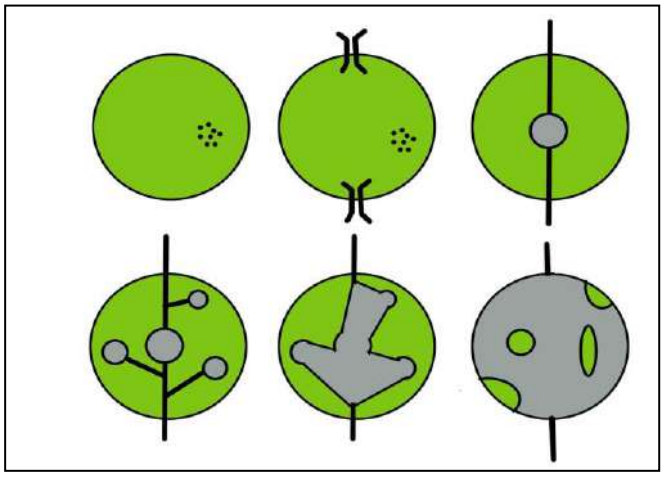

Fig. 3. Diagram showing the wetland patch undergoing fragmentation and diminishing in size to form interior wetland patch and edge wetland patch over the years.

C. Inferences

1) Qunli storm water park, Mangalavanam park and Adyar Poonga park are of the interior wetland patch type and Houtan park, Zhongshan park and Sarovarom bio park are edge wetland patch type.

2) From the analysis of Vallanthakad and South Chittoor it was evident that the wetland patch in these islands was fragmenting and diminishing in size to form interior wetland patch and edge wetland patch over the years.

3) Both interior wetland patch and edge wetland patch had different attributes which is evident from the wetland park case studies.

4) Qunli storm water park, Adyar Poonga park and Mangalavanam park are interior wetland patch. Interior wetland parks had a coarse urban fabric around the park. The park size was smaller than adjacent plot area/block area/water body area. There were more attached cells. There was minimum amount of bleeding of communities. The interior wetland patch was land locked and detached from navigable river. The wetland patch created a heterogeneous landscape by stitching various fragmented wetland patches.

5) Houtan park, Zhongshan park and Sarovarom bio park are edge wetland patch. Edge wetland parks had a fine grain urban fabric around the park. The park size is larger than adjacent plot area. There were less attached cells. There was maximum amount of bleeding of communities. The edge wetland park was found in the edge of the land attached with a navigable river. Edge wetland park always stands in juxtaposition to the rest of the urban land mosaic.

VII. CONCLUSION

From the study of the six wetland park case studies their neighbourhood conditions and their characteristics were identified. Following are the urban design strategies for retention of wetlands in urban areas. In the case of an interior wetland park the park neighbourhood must be integrated with walkable size city blocks that is pedestrian centric in design. In the case of an edge wetland park the park neighbourhood must be integrated with super block size city blocks that is auto centric in design. Ceiling of rupture of settlements along the water front associated with a wetland park can be done by constructing a drive way, bicycle path, walkway, berm wall, planting green buffers or landscaped trail. Bridging of communities must be done in the wetland park neighbourhood by adding bridges, Foot over bridges, elevated landscaped walkways, tunnels, subways and underpass that connects settlements across wetland park or water body. The bridges can even be water bridges or green bridges. Wetland parks must be planted with assorted planting scheme. Wetland parks are the green lungs in an urban matrix. Hence wetland parks must be designed like an urban oasis with buildings surrounding the park with openings for ventilation and views to the park. Wetland parks can be installed with under water tunnel marina, bunkers and underground rooms. Wetland parks must be substituted with additional Elevated Park for people to gather above the wetlands. Wetland parks must be connected with green corridors within the city blocks for the easy movement of birds. Wetland Park must be in filled with amphibious modules of infrastructure such as floating markets, floating housing, floating hospital etc…Wetland parks must be integrated with infrastructure on stilts. Wetland parks can be left open or covered using perforated roof structure for optimum sun light.

REFERENCES

[1] City of Saskatoon (2014)'Wetland Design Guidelines'CH2MHILL

[2] Douglas Farr (2008) 'Sustainable Urbanism: Urban Design with Nature'.

[3] Richard T. T. Forman (1995) 'Land Mosaics: The Ecology of Landscapes and Regions'Cambridge university press.

[4] Paul F Downton (2009)'Ecopolis architecture and cities for a changing climate' Springer.

[5] C. Max Finlayson, Mark Everard, Kenneth Irvine, Robert J. McInnes, Beth A. Middleton, Anne A. van Dam, Nick C. Davidson (2018)' The Wetland Book I: Structure and Function, Management and Methods Springer.

[6] Turrenscape 'Landscape projects' .Available at: https://www.turenscape.com/en

[7] WWT Consulting 'Good Practices Handbook for integrating urban development and wetland conservation', page 1-50

[8] Pa Azeez, S Bhupathy 'The Mangalavanam Bird Sanctuary / Mangrove Area, Ernakulam, Kerala a brief report'.

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Reconsidering the concept of Residual spaces:

"Flyovers" as a potential opportunity for the city fabric

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Abstract*— "Within the dense press of the built fabric, the greatest luxury of all is, empty space"- Spiro Kostof. Public space is the common ground intended to transcend all socio-political barriers and provide a platform that is accessible to all people and form the essence of an urban life. Public spaces need to instigate the users, have a "lingering effect" and interact with the daily life of its users for a successful impact. Versatility in the use of public spaces and its ability to adapt with changing context ensure longevity in the use of that space. Re-purposing of the existing neglected spaces of the city is relevant to the present-day urban context. Urban designers have constantly been using such opportunity of designing residual spaces for creating public spaces, but the: NAM VAN SQUARE gives a perfect example where the design of transportation corridor incorporates the character identity and functional entity from the initial panning process itself. This research aims to evaluate the criteria for the design of such structured void spaces along with the initial urban planning process itself.

Keywords—Residual spaces, Flyovers, Interstitial spaces, Revived leftover spaces, Functional entity, Character identity.

I. INTRODUCTION

Cities are composed of varied spaces, including that which exists between the built environments, wedges of the spaces defined by the infrastructure components such as transportation and communication industry [2]. This includes what Jacobs refers to as the '*Border vacuums'*, what Trancik calls '*urban anti-space*' or '*Lost space'*. This is the odd shape left over where highways cross, where a once active waterfront goes unused, where a stretch of land borders a campus or large complex, where railroad tracks have been abandoned, where a building has burned and the lot has gone into weeds [2].

They often are simply neglected, inaccessible and eventually rupture the sense of community. The uniqueness of flyovers lies in its character of an overhead shelter with its generous underneath space that is longitudinal and barrier free. It is sheltered from the rain and from the heat of the sun. It is also free of much of the politics, land tenure disputes and real estate speculation that plague much of the developing cities today [2].

Fig.1. Existing condition of spaces left underneath Flyover (Source: Google)

But as they are spaces programmed to be used in a certain way, at specific times, by certain types of people, for a limited set of purposes ,they accordingly offer opportunities to withdraw from the formal and informal control of public space to a less controlled territory.

II. RESEARCH HYPOTHESIS AND METHODOLOGY:

As the cityscape is carved up and structurally developed for improvement in modes for transportation as primary requirement, are these border zones and anti-spaces inevitable? Or is there any different way of design process? Hence how to organize during the planning process itself for an outcome of producing sense of place?

Through a **qualitative research analysis the characterization of these left over residual spaces have been evaluated** and found that they are universally unthought-of in the initial design process and are somehow pulled in by the planners as opportunities to enhance the urbanscape later by stitching it all together and hoping it to workout. **But isn't it all like creating a problem and then finding a solution to it?** [1]. Highline park project & The Cheonggyecheon River park in Seoul and Superkilen in Denmark gives a perfect example for such urban revivals. As a flyover itself is designed as a necessary civic infrastructure, why this idea cannot be extended to define specific function to the bottom spaces as a quality open public place which can be explored by citizens rather than leaving that as just a base for structural supports? **Thus the research analyzes varied scope for designing transportation corridors in a way to reduce imperfections which will not pose challenges after execution.**

III. RESIDUAL SPACES

A. Defining residual spaces

When we think of urban public space, it is more often parks, plazas, malls, and squares that come to mind. There as spaces of obsolescence and dysfunctional unproductive urban areas those no longer meet any aesthetical and economic expectations, which can be called as Residual spaces [2]. The construction of transportation corridors such as highways in urban areas leads to a lot of such empty spaces along and under elevated highways which produce obstructed views, and act as physically / psychologically dividing the urban fabric making the pedestrian experience unpleasant (Trancik, 1986). This unclear territoriality of the spaces sometimes leads to misuse of land as dumping debris, abandoning of cars, or illegal activities

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that can lead to social problems in addition to being unsightly and lowering the value of adjacent properties through economic decline as well (Halprin, 1966).

B. ***PRIMARY STUDY**: Flyovers- Structured residual spaces:*

Generally, the flyovers shape the ground level where they are constructed. Sense of intimacy could be felt at which distance between the ground and the roof level that are close where else openness and freedom could be felt when the distance are far apart.

The uniqueness of flyovers lies in its character of an overhead shelter with its generous underneath space that is longitudinal and barrier free. It is sheltered from the rain and from the heat of the sun. These diverse volumes stimulate activities to happen mostly due to limitation in height clearance and varied ground covering finishes such as interlocking block pavement, paved road, earth and natural landscape beneath. Under the flyovers, lies an existence of a space that might differ from the rush of the above, a loose space with endless possibilities [1].

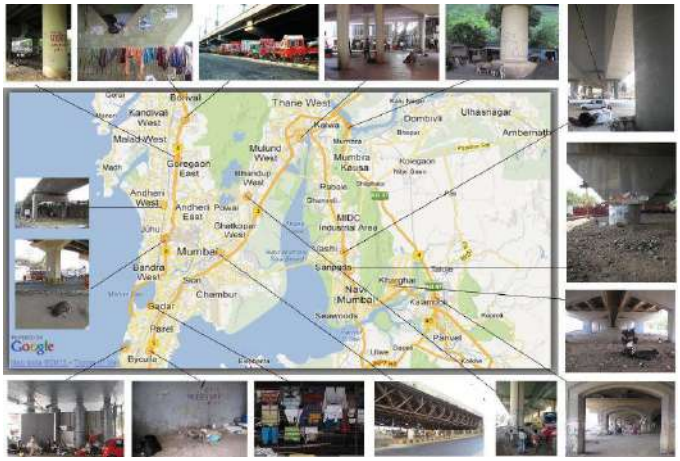

Fig.2. Primary study: Mumbai city, India – defines the condition of MSRDC 35 odd flyovers from JJ hospital junction to Vashi junction in the Mumbai city **before urban regeneration proposals** (Source: [1])

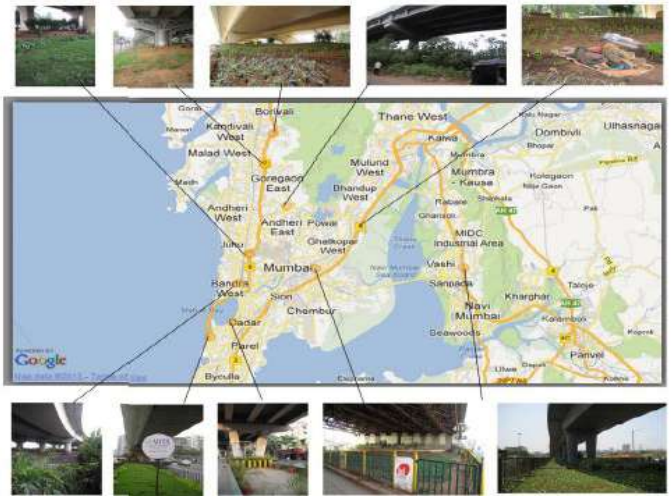

Fig.3. Primary study: Mumbai city, India – defines the underutilized condition of MSRDC 9 odd flyovers in the Mumbai city **after urban regeneration landscape proposals because of inaccessibility and character** (Source: [1])

C. *Negative effects caused by FLYOVERS:*

Typically, the flyovers have also been responsible for cutting off cities from waterfronts and recreational spaces. The residual spaces under the flyovers and the buffer spaces around them, instead of acknowledging and exploiting these characteristic kinds of space we make them into parking lots or feeble patches of grass-no-man's lands between the scale of the region and the locality. The process of planning and implementation of a flyover system results in unexpected negative consequences in entire urban areas. Some of which includes: **divisions of well-established communities, disconnection of neighborhoods, isolation of residential areas, relocations of entire families, excessive noise, and unwanted views, shadowing, and overpowering effect produced by the magnitude of the structure, which drastically change the urban landscape**[1].

There are some general effects produced by the introduction of a flyover into urban areas. The different types of impacts that might be produced by the development of a flyover can be classified as:

- **Physical**: includes wall or barrier effects produced by highways, increase in noise or vibrations, and shadowing effect.
- **Social and psychological conditions/ safety factor**: includes changes in redistribution/loss/increase in population, changes in the interactions of persons or groups, isolation or separation of certain people, changes in social values, and perceived impact on the quality of life that leads to change in the positive or negative changes in crime levels, accidents and emergency response in the area where the highway is located.
- **Visual and Environment**: includes changes in the aesthetic character of communities and the context.
- **Land Use and density:** includes the creation or loss of land as the result of the development of a highway.
- **Economic Conditions and displacements**: includes the introduction of a highway in an urban area may encourage new businesses to establish in the area or cause the relocation of existing ones or changes could be the increase or reduction of visibility to the commercial area, and thus changes in property value and thus changes in neighborhood's character due to displacements.

Fig.4. Illustrative example of how a designed square was been underutilized visually and functionally because of the inaccessibility caused by structural barrier due to the improper designed flyovers and intersections (Source: [1])

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IV. THEORETICAL FRAMEWORK

A. *How can these leftover spaces be potential elements?*

1. "THE EMPTINESS OF PLACE IS IN THE EYE OF THE BEHOLDER" (Bauman 2001, p.26 f) What Bauman refers to as empty spaces covers two categories that each has its own logic. First is the left-over space that is related to the forms and functions of built structure, and the second to complex & dynamic socio-cultural processes of the urban environment.
2. **Rob Kier defines urban space as 'comprising all types of space between buildings in towns and their localities.'** Thus, urban space is a resource which is much more all-inclusive than traditional view that it simply comprises of a limited typology of distinct sites such as parks, sports grounds and city squares. Urban space is understood here to include all the non-built up land within and around urban areas, forming a matrix of space which connects inner urban areas with the surrounding landscape. **But one of the problems with planning and architecture today is that the spaces between urban solids are rarely designed.** This is especially true in case of this century's modern movement - Stanford Anderson, On Streets [1]. Anti-space, Border zones are usually chaotic, since they are comprised of the remnants of other uses. **But these could be used to knit together the fabric of a city at a crucial border zone**.
3. **Kevin Lynch's theory of "5 elements of imageability" Edge, Landmark, Path, Node and District,** that defines the importance of functional and aesthetical characters that should be defined through design. These elements can be considered as secondary objectives in planning process itself while designing such elevated transportation corridors.

Thus from an urban theoretical analysis, it is been understood **that these interstitial spaces can act as potential opportunity for urban restructuring.** They can act as public spaces which today occupy crucial components of the city, both in terms of the physical as well as social function they serve. **Edges, while generally separating and isolating areas, could conversely be seen uniting space between two areas. The space could be designed to give a sense of ownership of it to the community; it could be designed to reunify areas of the city that have been severed by urban renewal.** Any flyover must not present a significant visual obstruction that effectively cuts the community, and similarly, must eliminate undesirable residual spaces. Identified objectives from theories:

- Improve linkages across the bridge under-spaces by redesigning road intersections under the bridge.
- Node: Instead of parking, propose spaces for play, for shelter, for community building, for worship and for celebration and Improve pedestrian connectivity
- Functional District: cohesive landscaped public spaces such as pocket parks shaded seating areas, food courts, plazas etc.
- Landmark: Provide kiosks, markets and vending zones to attract the public in dense neighbourhoods
- Path: Facilitate use of these spaces by lighting, signage and waste collection, strategic parking, restrooms etc.

V. CASE STUDIES: REVIVED THROUGH RE-DESIGN

The residual spaces that had redesigned with thriving public realm either as a FUNCTIONAL ENTITY or with a CHARACTER IDENTITY according to the spatial configuration which could be elements of imageability in city. There are numerous examples that celebrate design and engineering, creating contemporary urban sculptures that add positively to sense of place, rather than detract from it [1].

Fig.5. Illustrations of different functional typology of users through spatial interactions (Source: Google)

A. *CASE.1- A8erna; Zaanstad, Netherlands:*

Koog aan de Zaan is a town in the Amsterdam metropolitan area, located 10 km northwest of the city. In the 1970s, a new freeway was built, brutally dividing the town's urban fabric. For many years, the area had been neglected and was mostly used for surface parking. The project aimed to restore the connection between the two sided of town and to activate the space underneath the elevated freeway [4].

Fig.6. Images showing the activity happening before and after redesign of residual space with addition of water as a landscape element (Source [4])

Fig.7. Illustrations of re-established connections and addition of different functional typology such as container office/recreational spaces, sports hall, art decorated open play zone (Source: [4])

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B. CASE.2- Folly for a flyover by assemble, Hackney Wick England:

Fig.8 Installation beneath a disused motorway underpass; the Folly hosted an extensive program of cinema, performance and play (Source: [7])

C. CASE.3- Toronto Underpass park :

An innovative use of dead space as a park is "transforming a derelict space into a neighborhood amenity." Vast skateboarding ground, futuristic playground toys and even functional public art [7].

Fig.9 Images showing before & after the re-design of underpass (Source: [7])

VI. CASE STUDIES: INDIAN CITIES- REVIVAL OF RESIDUAL

Urban landscapes in India are today emerging as a set of disparate conditions such as transportation facilities like the railways, road networks, flyovers and highways form the basis of contemporary Indian urbanism spreading across the country irrespective of the city boundaries. They mark the nature of city's progress and observe the need of the public. But there have also been a few initiatives in some cities in India too, to revive the derelict pockets within the city and turn the urban "negatives" into "positives" after being a structural jungle [1].

A. **CASE.1- Ahmedabad- IM Flyover Development:**

AMC (Ahmedabad Municipal Corporation) had floated a competition and later proposed a flyover at the IIM junction due to the prolonged traffic congestion at this intersection and HCP was the awarded the project for design and project management which includes city wide traffic pattern and traffic count surveys of the intersection, which lead to the finalization of the alignment of the flyover [1]. This project goes beyond the conventional flyover project includes development of 920m length that includes the flyover (504 m), the 1340 Sqm built up are spaces under the flyover and the complete right-of-way width [1].

Fig.10. Conceptual illustrations of competition proposals such as defined parking areas and functional entities such as sitable spaces (Source: [3])

Fig.11. Proposed Library space under AMC flyover at IIM junction

B. **CASE.2- Mumbai- Mantunga to Tulpule Flyovers:**

"The MMRDA had recently called for expression of interest from people, to beautify the space below flyovers across Mumbai. Residents of Matunga took it upon themselves and chalked out a plan that speaks for itself, clearly shows exactly where local residents want to set up a small museum displaying old photos of the city, an amphitheater, a skating path, a joggers' track, seating arrangements along & around pillars for people, small flower garden and a basketball court [1].

Fig.12. Illustrations showing proposals underneath flyovers (Source: [1])

VII. DESIGN INTERVENTION

However, there are vast amount of urban spaces appear in various scales, intense forms which are abandoned due to such kind of structural urbanism**.** And still the question remains as to why create a problem in order to solve it? What is the use of Evaluating, Designing, Imagining, Inventing and then again Re-evaluating, Re- designing, Re-imagining, Re-inventing, Re-inhabiting and Re-adapting the "once left over"? [1]. **These can be resolved through giving Character identity and defined functional entity to residual spaces of flyover design in the planning /design stages itself to attain IMAGEABILITY or sense of place/ community.**

A. With respect to giving a Character identity to such spaces- as Small interventions gives greater impact in usage:

LQC approach (Gulati,n.d.), tactile urbanism, D.I.Y pop-up projects etc which is a community based placemaking process that enhance identity of urban context by reviving the structural barrier of flyover as an aesthetical edge , identifiable landmark or functional/ sportive space opens to a healthy society.

Fig.13. Illustrative examples- Image 1: Under art in Hammersmith Junction London , *Image-2: Integrating live community space (Source: Google)*

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Fig.14. Illustrative examples- Image-1 A glowing golden forest of trees called Aspire by artist Warren Langley, illuminates a site beneath the Western Distributor at Ultimo, Sydney , Image 2: Ballroom Luminoso Installation by JB Public Art, San Antonio


Fig.15.Folly for a Flyover by Assemble, England (Source: [7])

B. With respect to a Functional entity- A structured planning: with designed elements: NAM VAN SQUARE (2001)-.

A new development plan for the central shore of the historic city – the Nam Van Lakes plan designed by Manuel Vicente throughout the late 1980s and 19990s, serves a perfect example. It interpreted and extended the curve of the historic bay out into the river and featured a culmination point in the form of a formal/functional roundabout at the meeting point of the two lakes – stood out as the irrefutable place for the new civic project.

From the core of the roundabout's inner square, the formal hard-surfaced floor that represents the real foundation of the public space, one can walk through the series of familiar typologies that irradiate from it – esplanades, terraces, gardens, walkways and embankments – to the lake's shore, along a path shaded by the traffic flyovers that form an important part of the design of the new civic square.

An urban park was commissioned two years after the square, as a simple landscaping of the access areas for the new (third) bridge to the outlying islands, in an adjoining stretch of causeway. This project organizes two different park areas along the two waterfronts, each finding a design pattern to divorce itself from its proximity to the roads. On the lakeside, a sloping scenic garden with pools on different levels overlooks the city and transforms the over-imposing macro-presence of the bridge as a framer of views. And on the riverside, a children's playground stretches along the water.



Fig.16. Illustrative site views of Nam Van Square along the Flyover passing through, OAT, a park leading to water bay, embankments etc (Source: [5])

VIII. CONCLUSION

The qualitative research study thus emphasizes on identification of the functional gaps and overall movement pattern of development opportunities, which should be done before choosing the site allocation for flyovers or any transportation corridors with accessible and imageable architecture or landscape elements that define a good public open space. The emphasis should be on the groups and sequences of outdoor spaces of the district, rather than on the individual space as an isolated entity. Special attention should be given to the users and character of residual spaces between the structured transportation flyovers and the wasteland at their edges. A major requirement therefore is to design environments in which individual buildings or spaces around are integrated with this dictatorial circulation system. The designed qualities such as activity interfaces, comfort and imaging, accessibility and linkage, social values must be applied to enhance the functional entity & visual character identity, in order to avoid the void character that might develop as a result of such neglected structured imageability.

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We extent our heartfelt gratitude to all those have offered their help to accomplish the research. We would like to thank all our colleagues and friends who have continuously helped us with their guidance and brainstorming ideas.

REFERENCES

[1] Dipti Shukla, 2012, Reconsidering Residual Spaces 'A boon or Bane for the city', (Unpublished research work) https://www.researchgate.net/publication/333966258

[2] Dipti Shukla, 2014, Flyovers-Infrastructural barrier or a potential opportunity for knitting the city fabric (Unpublished research work) https://www.researchgate.net/publication/333966210

[3] 8241101_Vision_of_Ahmedabad_Monograph- Our cities ourselves.

[4] https://globaldesigningcities.org/publication/streetdesign-guide/elevated-structure-improvement/case-study-a8erna-zaanstad-the-netherlands/.

[5] http://lbamacau.net/portfolio/nam-van-square/

[6] https://www.architonic.com/en/project/nl-architects-a8erna/5100103

[7] https://weburbanist.com/underpass-art-parks-15-fun-projects-reclaiming-disused-urban-space/2/

[8] Adaptive reuse of public spaces- https://issuu.com/keshavrathi/docs/front_cover_dissertation

IMMM2020_21

Architecture and Interactions

The Role of Physical interface in facilitating user interactions at World Expos

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Abstract— Combining a wide variety of visual and sensual experiences, expos are an ephemeral microcosm that offers memorable experiences to participants and visitors alike. Expos have a transformative power in shaping perceptions of nations and cultures, increasing awareness of the host country and international participants by helping to shape and enhance a nation's image and reputation. As a part of urban development, expos act as a catalyst which accelerate this transformation of urban scenario and there by citizens life. Hence this research analyzes the influence of such tangible and intangible elements in the expo cities, through which the social interaction happens and offers unprecedented experience to the users, visitors and urban community alike.

Keywords- Expo cities, Social interaction, Urban phenomenology, Architecting interactions, Temporal instability.

I. INTRODUCTION

The innovative architecture of the expo site, the interactive exhibits within international pavilions, the ground-breaking technology and the packed cultural program all make expos a convivial and engaging experience for visitors. Expos advance and encourage the meeting of new cultures, fostering the public's understanding of interconnections and there by extending ways for the socio-cultural interaction within a unique platform. The public realm in and around the structures, the amenities provided within its built environment along with their location have a huge impact on the user interactions that take place in the physical interface of these expo sites.

II. RESEARCH METHODOLOGY AND SCOPE:

The paper aims at understanding the role of physical space in promoting user interactions in the context of world expo which are the common grounds for global interactions. The research presented here starts with understanding the theories related to human interactions followed by qualitative analysis of Expo cities as case studies.

III. INTERACTIVITY, INTERACTION AND SPACE:

It is first important to understand the difference between Interaction and interactivity. Interaction is a combination of two words 'inter' and 'action' which means action happening between two entities whereas interactivity is affiliated with technology and digital world. We live in a physical world with predominantly physical interactions. Thus, space acts as a physical interface for the interactions. These interactions can be broadly categorized in three different categories [1]:

a. Interaction between users and space
b. User interactions within the space
c. User interactions through the space

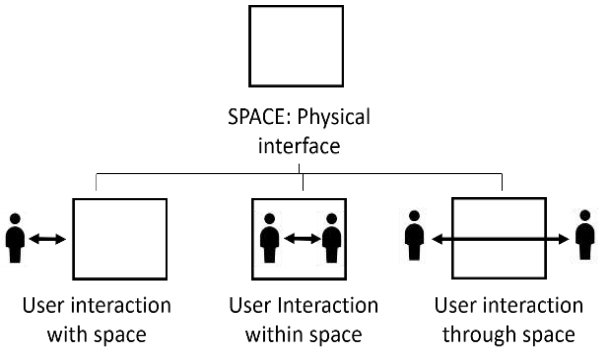

Fig. 1. *Different types of interactions in a space (Source: Author generated illustration)*

Now whatever the interactions are, or whichever user is involved in it, **the space thus becomes the context for interaction, thus giving meaning to it.**

IV. PROMOTING INTERACTIONS THROUGH DESIGN:

A. PRINCIPLES FOR INTERACTION:

i. *Proximity:* Theodore Newcomb first documented this effect in his study of the acquaintance process, which demonstrated how people who interact and live close to each other are more likely to develop a relationship.
ii. *Diversity:* Diversity in the user group brings in an array of ideas and ideologies, thus, in turn sparking interest for interactions
iii. *Interaction points:* The design should have common nodes or interaction points which are accessible by all the users and act as common hubs for interaction.
iv. *Build functionalities:* Creating spaces having one or more function develop as nodes, a common platform.

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B. MENTAL IMAGES :

They are nothing more than representations of what is occurring in our minds; a projection of the human mind that tries to understand the outer world. "A mental image is not an accurate representation of the world, but a map from which the subject receives information, which is not yet recognized and analyzed. It is the inner side of spatial prediction" (Neisser, 1978).

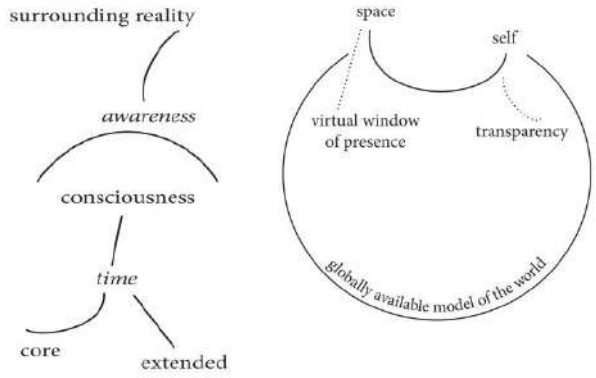

Fig. 2. *Image.1: constitutes a larger and more complex schema of mental mapping in interactive spaces (Neisser, 1978), Image.2: a reflexive circulation' (Kosslyn, 2005). & Image.3:The consciousness (Damasio, 2010)*

V. THEORETICAL BACKGROUND:

A. HUMAN INTERACTION THEORY:

According to Dewey (2005), in general there are two levels of human interaction. The first one is symbolic interaction, which is uniquely human and second, non-symbolic interaction, which is shared with infrahuman. The basic reason for human interaction according to Dewey (2005), which is associated with moral conduct, was the active connectedness of human beings with one another, which is characterized by their "mutual intertwined activities" such as desire, beliefs, judgment, satisfaction and dissatisfaction. Human interaction then is influenced by individual need towards the environment and how the perceived benefits might influence negatively or positively are based on the self-judgment. Thus, it is vital to know about the society and the people needs and preferences. Maslow (1954) provides a good example for identification of the basic needs and creates a foundation.

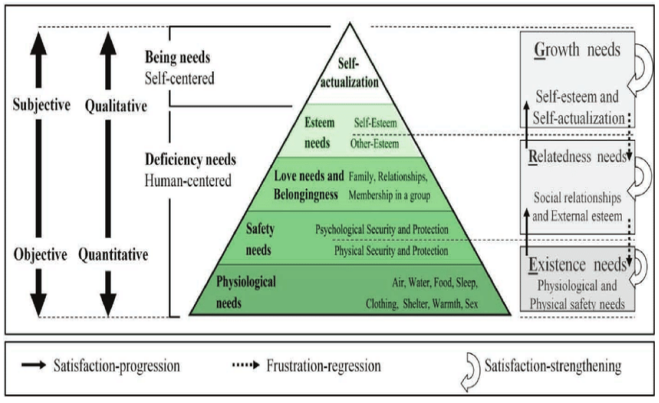

Fig. 3. *Maslow Hierarchy of Human Interaction Needs (Maslow, 1943)*

B. THEORY OF PHENOMENOLOGY:

Phenomenology demonstrated in architecture is the manipulation of space, material, and light and shadow to create a memorable encounter through an impact on the human senses. **This theory promotes the integration of sensory perception as a function of a built form**. This creates an experience that is beyond tangible, but rather abstract, observed and perceived. An analysis of this aesthetic through interpretation of its qualitative elements and the exploration of case studies by phenomenological theorists, Alberto Pérez-Gómez, Peter Zumthor and Steven Holl, as supportive evidence will highlight its fundamental characteristics as a theory, in contrast to a more rationalist design approach.

Architecture influences the community through incorporating human activity with adapted site context, organized programmatic and interstitial space, and exploration of material. As defined by theorist Vernon Bourke, **rationalism is a theory "in which the criterion of the truth is not sensory but intellectual and deductive"** (Bourke p.263). Rationalism produces a layered system of scientific reduction, whereas phenomenology delivers layers of sensory details such as emotion informed by design features of light and shadow, material and spatial perception. **A new interpretation of functionality within design exists in the phenomenological construct**.

Architecture is designed to serve the needs of human activity; therefore, creates a relationship between human senses and the building to transform emotion and perception. Christian Norberg- Schulz stresses that "the environment influences human beings, and this implies that the purpose of architecture transcends the definition given by early functionalism" (Norberg-Schulz 5).

Phenomenology is the function of quality. In phenomenology, space is determined by the development of fluid, flexible space and the utilization of interstitial space. Steven Holl elaborates on an "architectural synthesis" in the book, "Questions of Perception", suggesting, "foreground, middle ground, and distant view, together with all the subjective qualities of material and light, form the basis of 'complete perception'" (Holl, Pallasmaa, and Perez-Gomez 44). **This establishes the necessity for place making through sensory observance**. **Material is the tactile form of phenomenology that facilitates memory**. Light and shadow create a playful interaction of color, texture and related emotion associated to the space. The contrast between these can be sharp or blurry depending on the desired effect. This strategy can create depth and display texture and is one of the strongest design features in phenomenology.

Thus Phenomenology becomes an evident way to establish the urban Semiology of orientation as even less a psyche-sociological way of understanding "how a space is experienced and lived by its inhabitants" [3]. Hence the imagination of users that generated through spatial communication is basically the experience of movement which is delivered through careful designing.

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C. ARCHITECTING INTERACTIONS- Process of creating Interactions:

Architecting interactions explores **designing for interactions through space in which pace act as a physical interface to stimulate human, analogue and digital interactions**. All are actions nothing but one or the other form of interactions. The process of creating spaces that promote interaction is generally considered as a four staged process. The first three stages of this process happen before the project is delivered whereas the fourth stage comes after the delivery of the project, says Stephanie Akkaoui Hughes in her talk titled "Human interactions: Physical and Virtual". The process is as follows:

Stage 1: involves understanding the design brief, identifying the problem. This is done through consultation from the different stakeholders of the project and taking inputs from them.

Stage 2: involves developing a 'shared vision' with the client.

Stage 3: involves bringing the vision into reality and the execution of the project.

Stage 4: comes after the delivery of the project. One of the important things to do in this step is observing- it is important to see how people are using the space and reacting to it. This helps in creating a renewed understanding of the project, thus making the process a continuous circular nature.

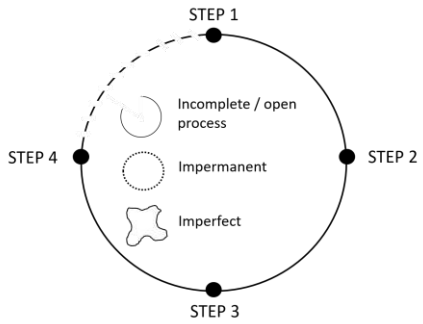

Fig. 4. *Process of creating Interactions: At any point in time this process is changing, adapting and developing, thus making it impermanent in nature (Source: Author generated sketch).*

VI. EXPO - BREEDING GROUNDS FOR GLOBAL INTERACTIONS:

The exhibitions in Expos were surrounded by public entertainments such as concerts, live music, conferences and debates and even sporting activities. A vast public means commercial facility, restaurants, places to stay and to rest (covered, shady, airy or warm depending on the climatic conditions of the city). Besides such considerations, the people themselves represented an important component of such events [2]. Greenhalgh describes a "vast cultural noise, an unending sequence of frenzied movement and colour, as the ocean of voracious exhibitors vied for the attentions of the millions of visitors (Greenhalgh 1993 p.29). Thus expos can be categorized as-

i. A platform for international dialogie in favour of progress and co-operation: **Intellectual & Cultural**
ii. An immersive and engaging journey into a key theme: **Visual & Sensual memorable experiences**
iii. A unique platform for public diplomacy & **nation branding**: Enhance nation's image & reputation and increasing public awareness& **participation**
iv. **A catalyst for change**: Accelerate transformations of cities and having long term impacts in **tangible and intangible ways**
v. A window of and to the world: **create a fleeting miniature world,** a microcosm of global progress and dialogue.

Thus, through the pavilions or dedicated spaces each country projects itself with large, captive and diverse audience, creating global village -physical and visual model; that offers an unprecedented experience to visitors and participants alike.

A. THROUGH THE HISTORY OF EXPOS

The world fairs have left a mixed legacy for their host cities. London's Great Exhibition of 1851 opened the door to a procession of spectacular festivals of self-representation and image-making. Many got an iconic building for their trouble:

Fig. 5. *Images of Eiffel tower, Atomium, Space needle (Source: Google)*

These Expos uniquely positioned to create lasting legacies due to the **landmarks they create as they possess dramatic structure**s. Expos frequently feature attractions that live on past the event, or structures that can be converted. Both legacy applications provide **long-term tourist destinations and can also build the city brand**. Continuing attractions include aquariums (Lisbon), theme parks (Montreal, Daejeon), and performance venues (San Francisco, Barcelona); that provides the semblance of a certain cultural identity of the host city.

B. FROM THE ENCLAVES TO MAGNETS-APPRECIATE THE INCOMPLETE:

Temporary uses also distinguish themselves spatially from the sub-cultures mentioned above in the sense that these tended to form enclaves of a collective shaped by political leanings, whereas contemporary informal urban users operate almost diametrically.

Fig. 6. *Biosphere, formerly the US pavilion at expo 1967 Montreal, Tower of Sun Osaka expo 1970, South bank Brisbane expo 1988(Source: [5])*

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Vibrant cities do not originate in test tubes but develop over time. The focus is not on urban design, but urban use. The incomplete, the dissimilar, the transitory, the temporary become part of the cityscape. The expos should have made such conceptual realities rather than illustrative iconic forms.

VII. CASE STUDIES

A. SHANGHAI EXPO 2010:

Staged an unprecedented number of pavilions, built by nation states and corporate exhibitors, which deployed cutting edge architecture and state of the art exhibit techniques to comment on the theme rendered in English as 'Better City, Better Life' though the Chinese version was closer to 'City: Let's make life better'. More than 70 million visitors streamed onto a site the size of Baltimore. Spatial functional aesthetical improvements such as utopian interior experience the "Eco house " and the new exterior urban space the "Boat ride" through china pavilion that featured reproduction rocks from Lake Tai literally translates as an innocence that in the context referred to contemporary devastation of the world's ecological system..

Fig. 7. *Image-1:Korean pavilion which had their indigenous character and figures depicted over façade, which was conveyed to other nationalities in visual interpretation alone, Image-2: Hountan Park that maintained the momentum with a positive view of the city to the public (Source: Google)*

And few foreign language guides were available to explain these references, thus leaving most non-Chinese visitors to appreciate the spectacles as a largely impressionistic visual experience only rather interacting with the physical essence

B. MILAN EXPO 2015

Focus was to promote its sinking economy and re-establish the made in Italy concept with sustainability in mind given more importance to visual connectivity with eye level design elements ,build facades angled to ensure effect of daylight & sciography that enhanced human comfort and user interactions along the entrance of pavilions , common areas etc as well.

Fig. 8. Image 1-Tree of life depicted the most interactive node, Image2-UAE Pavilion *and Image3- Italy pavillion(Source: [4]and Google)*

C. UPCOMING DUABI EXPO 2020

It is a scale of autocratic ambition only likely to be matched by the next World's first indoor city Expo 2020, to be hosted in the global capital of architectural hubris, Dubai. Through its theme, "Connecting Minds, Creating the Future", and its three subthemes – Opportunity, Mobility and Sustainability – Expo 2020 Dubai aims to unlock the potential of each visitor while encouraging collaboration and presenting opportunities for all to make a difference towards the future development of humanity and our planet. These include the "Al Wasl dome", the centerpiece of the Expo site, Terra – "The Sustainability Pavilion" – which is "pushing the boundaries of sustainable design" with 9,300m2 of solar panels and 'e-trees' , Parks and the "drinking water fountain for the future" which will be the main interactive nodes etc.

Fig. 9. *Conceptual Images of interactive nodes in the pavilions and exteriors spaces in Dubai Expo 2020 (Source: [6])*

The Visitors will be surprised by the level of automation and digitization across expo site that includes Smart site technology such as digital maps, triangulation solutions and smart phone apps for crowd analysis to enhance the user interaction experience.

VIII. DESIGN INTERVENTION:

From qualitative analysis of case studies it is evident that phenomenological strategies in an architectural design intend to develop a unique experience of the space or form, material, light and sciography; through certain designs deliverables/ objectives that enhance the spatial quality of Expo spaces.

A. FACTORS THAT PROMOTE INTERACTION in expos:

i. *Connecting people:* The designs have spaces which allow people to approach one another. Apart from physical connectivity, visual connectivity also plays a key role in this.

ii. *Accessibility and inclusivity:* Spaces which are easily accessible and connects different functional areas and user group acts as interaction nodes within the space.

iii. *Technology:* build initial bridges among people.

iv. *Building facades:* This factor revolves around openness & connections, by creating transparent and seamless structures which aid to building visual connections that help user not just to interact with the spaces within the structure but with its surroundings as well.

v. *Creating multipurpose and multifunctional spaces:* By creating spaces which have more than one function helps in attracting a greater number of users to it and hence acts as common nodes for interactions.

vi. *Facilitate the unexpected:* Creating elements of surprise in the design gives the user common topics to interact.

vii. *Social context:* creating a comfortable environment.

viii. *Eye- level design:* This deals with the scale of spaces and the connections/ flow of spaces from one function area to another. Creating eye level designs help create engaging user experiences.

ix. *Daylight:* Reflecting, illuminating, inviting atmosphere helps promote interactions.

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x. *Informal spaces:* Designed spaces which are informal in nature helps users to be comfortable and relaxed.

xi. *Comfort:* This includes both physical and psychological comfort of the users along with light, colors, materials, textures, and furniture and building amenities.

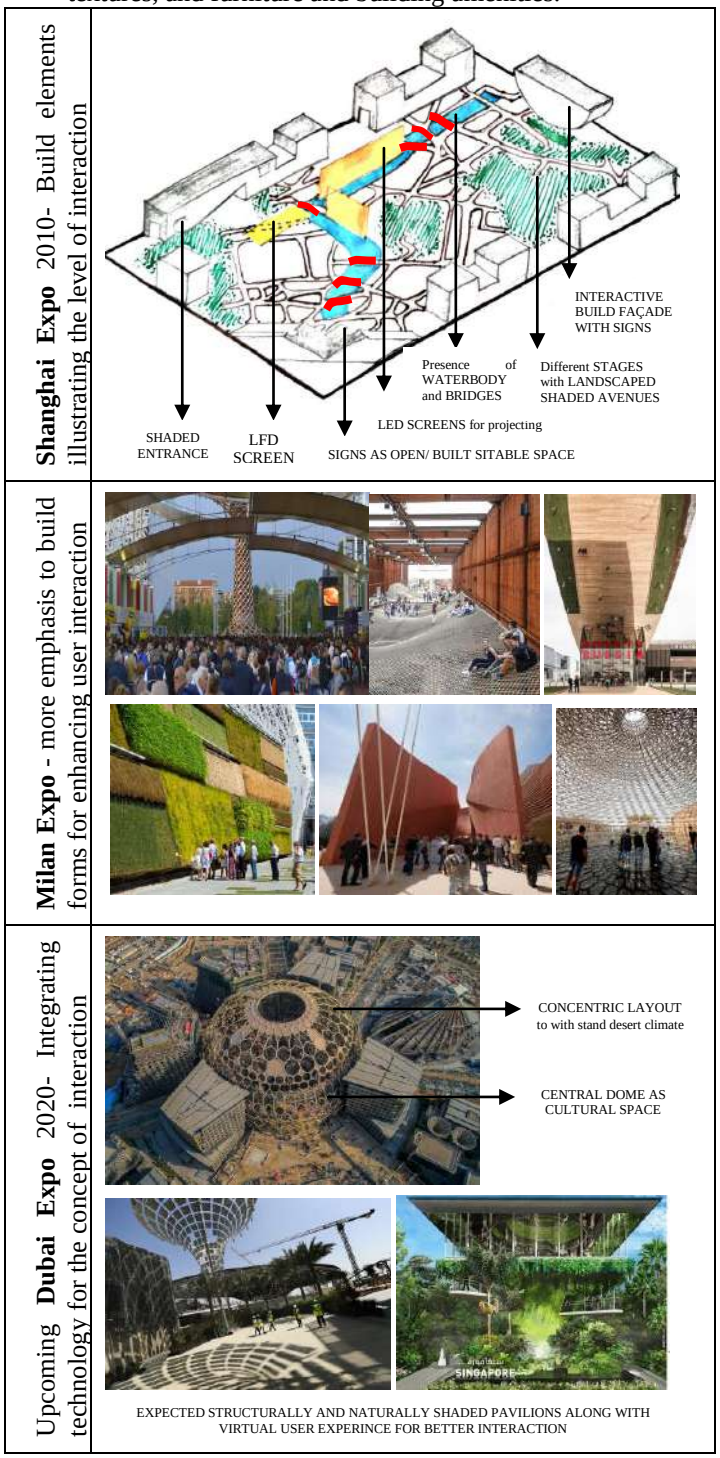

Fig. 10. *Analysis of applied design objectives of phenomenology in expo cities spatial planning for user experience (Source: Author generated illustrations [6] and Google)*

IX. DISCUSSION:

Instead of creating self-contained areas, expos create public places as magnets that, if they are successful, function as urban hot spots. The basic principle is not exclusion, but creating attractions, even if these places target a diverse user group. In terms of politics and culture, today's temporary uses are marked by a great deal of permissivity, if not promiscuity. The importance of such spaces and platforms that are developed is majorly attributable to their public character, which plays a considerable role with respect to life in the respective city and thus its context, identity and image.

In conclusion these places act as breeding grounds for innovations, and even as heralds for the mainstream. Hence it is inevitable for a universal image that confers splendor and opulence with features that will make visitors memorable for all their lives, to should have flexible elements which could change upon time to fit the **user interpretation as semblance**. Most of the expo sites have undergone adaptive re-use and were converted as museums, public parks and created lasting legacies in the form of important landmarks. From the London's Great exhibition of 1851, the Expos had left an indelible cultural impression on the world while propelling their users to the forefront for global conversations. Over the course of time the building functionalities of these Expo sites had **temporal instability,** such as The Eiffel tower of Universal exposition Paris 1889 is now the world's most photographed landmarks, (according to a Sony mobile analysis of Instagram posts) and an entire genre of music ragtime was created at the world's Columbian exposition in Chicago 1893, which also inspired L.Frank Baum's Novel The wonderful wizard of Oz.

Although the expos serve their initial purpose of providing a strong platform to magnify the communications among the users and change the host city's global image, it is important to have flexible elements in the design which can be put to adaptive reuse. It will be interesting to see how Expo 2020 site will respond in this context and what impression will Dubai leaves on the global front.

ACKNOWLEDGMENT

We extent our heartfelt gratitude to all those who have offered their help to accomplish this research. We would like to thank all our chairperson, colleagues and friends who have continuously helped us with their guidance and brainstorming the ideas.

REFERENCES

[1] Stephanie Akkaoui Hughes "Human Interactions: Physical and Virtual" -Interaction14, https://vimeo.com/87226293

[2] Lucka Azman Momirski, Dec 2018, Architecture and human experience.

[3] Georges Mounin, William O. Beeman, Aug1980, Journal article, The Semiology of Orientation in Urban Space

[4] Philipp Oswalt, Klaus Overmeyer, Philipp Misselwitz, Urban catalyst, The Power of Temporary Use

[5] https://www.bie-paris.org/site/en/focus/entry/expos-temporary-events-with-lasting-impact

[6] About expo 2020 Dubai, the foundation of a sustainable expo, index report.

Readjusting Urban Land Through Town Planning Schemes in Kerala

A Critical Analysis

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***Abstract*— Town Planning Schemes (TPS) were introduced in Bombay, India through the Bombay Town Planning Act of 1915, to improve the public health through improvement of the urban environment. Since then, it was used to guide urban development in Maharashtra and Gujarat. With the SMART Cities Mission under AMRUT, there is a renewed thrust to follow the Gujarat model TPS in other states as well. Specifically, the pilot project under AMRUT suggests Town Planning Schemes for the development of the new fringe areas. 25 Cities were selected under this pilot program, with Trivandrum being selected from Kerala.**

This paper aims to analyze the effectiveness of Town Planning Schemes as an urban land management tool in the context of Kerala. Critical factors and indicators are derived through literature review to analyze the effectiveness of TPS as an urban land management tool, which are at the policy, financial and management levels. TPS in Gujarat was studied along with a similar plot reconstitution technique adapted in Kerala. The urbanization patterns and spatial planning systems present in Kerala were also considered while determining the overall effectiveness of TPS in the state. The findings show that a mere replication of Gujarat model TPS would not suffice in the context of Kerala. The weak links within the mechanism were also identified during critical analysis.

Keywords—Urban land management, Town Planning Schemes, Land Pooling, Land readjustment, Plot reconstitution

I. INTRODUCTION

Land is a non-renewable resource, i.e., its quantity is fixed. Therefore, it becomes imperative to manage available land, especially in urban areas where its supply is limited. Effective land management is essential for promoting sustainable growth of cities.

In India, few techniques were developed to counter urban land supply issues, with Town Planning Schemes (TPS) being one among them. TPS was introduced in India through the Bombay Town Planning Act of 1915, to improve the public health through improvement of the urban environment. Since then, it has been modified several times and rampantly used in the states of Gujarat and Maharashtra to support urban development in fringe areas. TPS in Gujarat has been touted as a success and this model is proposed to be implemented in 25 cities across India, including Trivandrum in Kerala, as per the pilot program under Smart City Mission of the Ministry of Housing and Urban Affairs (MoHUA). This paper seeks to critically analyze the effectiveness of Gujarat model TPS as an urban land management tool in Kerala.

II. TOWN PLANNING SCHEMES

As per Urban and Regional Development Plans Formulation and Implementation (URDPFI) Guidelines, TPS is defined as a "land assembly technique, wherein the land is pooled and its development is financed with the involvement of land-owners without compulsorily acquiring land". Therefore, Town Planning Scheme (TPS) is used synonymously with terms like Plot Reconstitution and Land Pooling. (URDPFI Guidelines, 2015)

As an urban land management tool, it is essentially a process where the two major contributors are the land owners and the development authority. Land from the land owners is collected and pooled into a single plot. The development authority then replots this large plot into smaller plots, after deducting land for public purposes such as roads, amenities etc., to return it to the land owners. In terms of financial transaction, the net of betterment charges to the development authority and the compensation to the land owners is computed based on development costs and land characteristics. This is known as 'value capture financing'.

The land owners benefit from a serviced plot of land with enhanced value. Expropriation is also avoided. The development authority is benefitted by the creation of 'reserve land'. This land can be used for generating income to fund the scheme, through the sale of the whole or a part of it. It can also be used for providing affordable housing, among many other uses. Therefore, both parties are benefitted by this process, and this, in turn, creates opportunities for further development.

A. Origin of Land Readjustment

Land readjustment as a practice emerged after the industrial revolution to convert agricultural land parcels for industry expansion. In some cases, it has also been used as a rehabilitation tool after a calamity like fires or floods.The first recorded law was the Lex Adickes Law adopted in Germany in 1903. It was named after Franz Adickes, the Lord Mayor of Frankfurt, who prioritized land supply for urban development. This law provided for 'reorganizing' properties to make them

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available as sites for expansion and also to regulate property prices. (Yomralioglu, 1993)

B. Origin of Town Planning Scheme

The town planning scheme was introduced in Bombay, India under the colonial rule, through the Bombay Town Planning Act of 1915. It was in response to deteriorating public health and unsafe living condition. Earlier, Improvement Trusts were set up to undertake the upgradation of the urban environment. They were to carry out these operations through acquisition of land and its neighboring property. The benefits of development remained with the Trust rather than the land owner. This practice deprived the land owners of their land and hence was unfavorable among the masses.

Under the Bombay Town Planning Act, the interests of the land owners were promoted and they were to benefit from the development project rather than being excluded from it. It was formulated by Mirams and was based on Lex Adickes and parts of the English Housing and Town Planning Act 1909. The land owners were now stakeholders in the development process and hence this mechanism was supported over conventional methods of land acquisition. Benefit sharing, value increment of land were a few perks of this scheme for the land owners. TPS continued even after Bombay split into two states – Maharashtra and Gujarat, under their respective Town Planning Acts. While TPS was slowly discontinued in Maharashtra, it was booming in Gujarat. Almost 90% of Ahmedabad is now developed through TPS. (Deuskar, 2011)

C. Uses and Merits of TPS

The TP Scheme mechanism can be used in different circumstances:

1. Redeveloping older areas of the city
2. Building city wide infrastructure
3. Regulating unauthorized construction

The following are a few advantages of TPS:

1. Land owners retain the ownership of the land, or a part of it after deducting land for infrastructure and other services. Expropriation is avoided, thereby preventing displacement of original land owners.
2. Land owners become stakeholders in the development process. This improves people's participation in the development projects and results in better outcome and delivery. The development agency's role is that of a facilitator.
3. The land owner also benefits from the development through the increase in land value and it also reduces the financial burden on the development agency to acquire land which is not viable due to large compensation to be provided to the land owners. There exists a trade-off between the compensation and final land value.

III. CRITICAL FACTORS

The following literature was assessed to derive the critical factors that determine the effectiveness of TPS.

TABLE I. IDENTIFICATION OF FACTORS THAT DETERMINE THE EFFECTIVENESS OF TPS

Title	***Aspects Considered***
(Patel & Macwan, 2014)	Effectiveness, Accountability, Efficiency, Transparency, Competitiveness, Profitability, Land legislation, Land tenure, Land information, Land speculation and Land Registration.
(Vaidya, 1984)	Process, time requirement, management, use, investment, cost recovery and setting
(Yau & Cheng, 2010)	Existence of Legal Support, Cost Recovery, Support from and Participation of the Majority of Property Owners, Equitable Distribution of Project Benefits and Costs, Land Registration and Cadastral System, Personnel and Management, Strong Leadership
(Yilmaz, Cagdas, & Demir, 2015)	Policy level - Land policy aspects, Legal Aspects, Financial Aspects, Management and Operational Level - Social Aspects, Project Management, Technical Principles External factors – Capacity building, R&D, Technology, Data Quality, Other

Source: Compiled by Author

These factors were classified based on their focus points and critical factors were deduced based on their repetitions in each of these cases. Indicators have also been derived to support these critical factors. The effectiveness of the TPS mechanism would be dependent on three major critical factors, which are:

1. Policy level factors – dealing with land policy and legal aspects of the mechanism
2. Financial factors – based on compensation and cost recovery
3. Management factors – that determines the role of urban local bodies (ULB), development authorities (DA) and participation of land owners

The following table shows the indicators under each sub factors.

TABLE II. CRITICAL FACTORS AND INDICATORS

Critical Factors	***Sub factors***	***Indicators***
Policy level factors	Land Policy	Government policy for TPS
		Availability of master plans
		Provision for fair valuation of land
	Legal aspects	Existence of a legal basis
		Provision for reducing plot speculation
		Conformity with other laws
Financial factors	Compensation	Compensation based on contribution ratio – (area/value)
		Process of valuation - transparent and fair
	Cost recovery	Method of cost recovery for local bodies and land owners
		Provision to create reserve lands
Management factors	Role of urban local bodies (ULB),	Defined roles for DA's and ULB?
		Provision to constitute an implementation agency/body

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Critical Factors	*Sub factors*	*Indicators*
	development authorities (DA)	
	Land owners participation	Provision for public participation
		Incentives to land owners – TDR, increase in F.A. R

Source: Compiled by Author

IV. TOWN PLANNING SCHEMES IN GUJARAT

Town Planning Schemes emerged as a significant tool for urban land management in Gujarat, especially from 1990 – 2010. The legal basis for TPS is the Gujarat Town Planning and Urban Development Act, 1976 which has been consecutively amended to make way for changes to facilitate the implementation of TPS mechanism. One particular change in the 1999 amendment was to delink the physical and financial aspects, to improve implementation progress and allow raising capital as the project progresses. (Ballaney, The Town Planning Mechanism in Gujarat, India, 2008)

For instance, TPS for Vinzol 2 was envisioned in the Development Plan of 1999 by the Ahmedabad Urban Development Authority. The area was expected to take in the urban expansion due to the potential growth generators, such as Mehmedabad Highway, Sardar Patel Ring Road and neighboring industries. Availability of vacant land in the area was also a boon while preparing TPS. An area of 82 ha was considered, with nearly 80 plots. The scheme was prepared in three stages – the draft, preliminary and final schemes with adequate revisions in each stage. The draft scheme was prepared by demarcating original plots (OPs), establishing road network and earmarking areas for public land use and reserve lands. It was then open for public inspection and scrutiny, following which it was sanctioned by the government after making necessary modifications. (Ballaney, The Town Planning Mechanism in Gujarat, India, 2008)

Determination of final plots and computation of compensation and betterment charges were undertaken while preparing the preliminary scheme. The compensation is calculated as the difference between the product of value and area before and after replotting. The betterment charges are calculated based on the increment of land value of each plot, which is the product of the value and area of the final plot. The total cost of development is divided by the total land area of the final plots to determine the cost of development per unit area of land. This charge is deducted from the final compensation, if compensation is greater or yielded as betterment charge, if cost of development is greater. The final scheme was prepared after modifications and changes made to the preliminary scheme. Nearly 35-40% of the delineated area was used to provide for public amenities including creation of reserve land. 12-15% of this area was used for roads.

Town Planning Officer was appointed while preparing the draft scheme to oversee the proceedings of the scheme. The development authority initiated the implementation of the scheme. Land owners were also involved in revisions and modifications of the scheme. Therefore, this mechanism allowed public participation in development.

While, the mechanism looks flawless in theory, in practice it is an entirely different scenario. Land is valued based on the predetermined set of betterment charges. The government usually calculates the development cost first, then it determines the portion of cost it can bear and then yields the rest from the land owners through betterment charges. This results in unfair valuation practices and thereby increasing corruption. (Sanyal & Deuskar, 2011) Also, participation of land owners is limited. Farmers in the fringe areas, who were thought to be benefitting from this scheme were not necessarily the ultimate benefactors. There is a lack of transparency and control mechanism to monitor the implementation. Land owner led scheme initiations must be promoted along with a robust control and coordination mechanism.

V. URBANIZATION IN KERALA

Kerala has a total geographical area of 38,863 km². The total population is 3.34 crores. It has one of the largest proportions of urban population – 47.72 % as compared to other states in India. The total population density is 860 persons per sq. km. and in urban area is 2097 persons per km2 as per census 2011. The availability of natural resources, specifically water, in most of the areas is one reason for such high densities. Homestead development is also another notable factor that contributes to high densities

Kerala's unique geographic patterns also facilitate scattered settlement along the low lying, mid land and high land. Another notable feature of development in Kerala is that nature of development is along a continuum, the areas cannot distinctly be classified into urban or rural. It is a rurban continuum. Population density is greater in costal and midland regions. These regions also have 40% - 50% of its population living in urban areas. District wise urban content justifies the density patterns as well, with more urban areas having greater densities. (Department of Town and Country Planning Kerala, 2012)

Master Plans in Kerala

Area based plans, such as Town Planning Schemes, are dependent on the master plan for initiation and direction. Fig.1. shows the relationship between master plans and Town Planning Schemes.

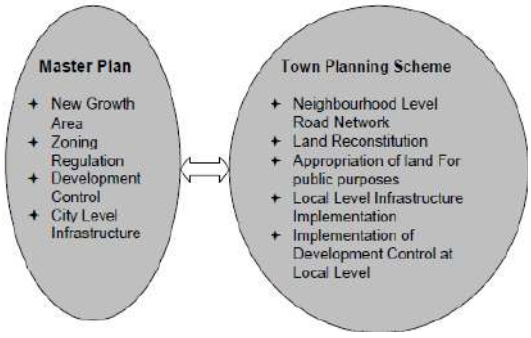

Fig. 1. Relationship between master plan and TPS

Source: Centre for Good Governance, 2010

Therefore, the effectiveness of TPS is ultimately based on the effectiveness of the master plan under which it was conceived. In 1995, Kerala had 15 master plans approved by the government, 6 draft master plans prepared and 21 of these plans under preparation amounting to a total of 42 plans. (Gurumukhi, 2003) This shows that while planning activity has been undertaken it has not been able to keep up with the growing development demands. Planned development is challenged due to the inflexible nature of master plans to cater to the needs of the community. Most of these plans take on an average 10 – 15 years from planning to implementation. The time gap also shows disconnect between need and supply.

VI. PLOT RECONSTITUTION IN KERALA

The Plot Reconstitution (PR) scheme under the Kannankulangara Detailed Town Planning (DTP) scheme in Trichur is the first and only one of its kind to be implemented in Kerala. It was conceived and implemented in a time bound manner. Cost recovery was made without imposing it on the development authority or the land owners. It led to the creation of reserve lands for the development authority that can be used for public purposes.

TABLE III. OVERVIEW OF SCHEME

Overview of the Scheme	
Location	Kannankulangara, Trichur
Area	6.2 ha
Time Period	1984-1987
Number of land owners	9
Authorities involved	State Town Planning Department, Trichur Urban Development Authority (TUDA)

Source: S Aswathy, 2016

The DTP scheme for the area was prepared, considering the development of radial roads originating from central Thrissur, passing through Koorkenchery. The DTP scheme for Kannankulangara was prepared considering this development and making provisions for acquisition. However, this type of acquisition was not supported by the land owners. They were willing to give up a portion of their land provided that they would not be completely expropriated from it and also receive benefits in the form of value increment from the development. The extent of benefits for in return for the land was evaluated based on land characteristics. Location, area, road frontage, nature of land were a few characteristics considered.

Low lying paddy fields were reclaimed for reconstituting the plots. All plots post reconstitution had access to road, with the width varying 12-15m.Through this process TUDA was able to consolidate 2.21 ha, roughly 35% of the total area, as a reserve land free of cost. Therefore, the reconstitution of plots allowed in creating reserve land for the development authority and also provided for road access and other connected services. It can be inferred that the creation of reserve land can improve the revenue of the development authority and can also be used for providing affordable housing.

The analysis reveals that TPS provided for a mechanism whereby both the land owners and TUDA benefitted from the development proposal. Lengthy acquisition procedures were also avoided. Participation of land owners in the reconstitution process also ensured that they are partners with the development authority in urban development. Monitoring and control by TUDA alongside cooperation form land owners ensured quality of service delivery.

One of the major takeaways from this endeavor was that a reduction in overall cost of project was possible, as no compensation or betterment levy was yielded. Engaging participation and dialogue with the stakeholders promoted inclusive development. Value appreciation of land parcels was also ensured in line with development of road.

Evaluation of Plot Reconstitution under Kannankulangara DTP Scheme

The Plot Reconstitution under Kannankulangara DTP scheme has been analyzed based on the deduced critical factors.

a) Policy level

- *Land policy/control* – Based on DTP scheme for Kannankulangara
- *Legal aspects* - in accordance with Travancore Town Planning Act 1108 (ME)

b) Financial aspects

- *Compensation* - no compensation was given to landowners; land value increased up to 7.7 times average.
- *Cost recovery* – TUDA recovered development cost, from the sale of a part its reserve land, through which it also generated profit. A part of this land was also used to construct an office building.

c) Management

- *Role of ULB/ DA*-
- Infrastructure and services were to be provided by TUDA, bearing all the expenses, within 3 years
- Registration and other administrative charges were also to be borne by TUDA
- *Land owners participation* – land owners were entrusted with land development and construction work within 3 years from the date of provision of services by TUDA

The following are a few limitations identified for undertaking this mechanism –

1. It requires high level technical and administrative skills from land survey to negotiation with stakeholders
2. It may be challenging if the entire land is not of uniform quality (benefit distribution might be unfair)
3. Valuation of land may be projected higher than actual in order to justify the viability of the scheme

VII. FINDINGS

The analysis is based on the critical factors deduced, to determine the overall effectiveness of Town Planning Schemes for urban land management in Kerala. The following are the findings obtained from the analysis:

1) Policy level

a) Land policy/control –

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i. Kerala Town & Country Planning Act 2016 has broad provisions for alternate land management practices under:

- Master plans [Chapter 5. (34)] - may contain proposals for Transferable Development Rights, Accommodation Reservation, Land Pooling Schemes or any other similar technique for promoting planned development;
- Detailed Town Planning Schemes [Chapter 7] - Provision for land assembly methods
- Control of Use and Development of Land [Chapter 10]– (72) Contents of land pooling scheme (73) Reconstitution of original plots into final plots.

There is a need for a more detailed framework to facilitate proper planning and implementation of TPS.

ii. The process of preparing master plans is lengthy and time consuming. It is also burdened with various administrative challenges. The preparation and implementation of master plans are therefore, not able to keep up with the demands of urbanization. They are often dated at the time of implementation. On the global front, the process of master planning has been questioned and the credibility of a long-term land use plan is doubted, that are unable to keep up with rapid changes due to its inflexible nature. However, in India, the solution to the existing drawbacks of the master plan is a 'better' master plan, as per the national conference on alternatives to master plans held organized by the Ministry of Urban Development. (United Nations Human Settlement Programme, 2009) TPS mechanism is dependent on these master plans for their initiation. This can therefore, undermine the effectiveness of TPS, if it is solely dependent on master plans.

Therefore, there is a need for initiating TPS within the scope of other development projects to enhance urban land management.

b) Legal aspects –

i. The Kerala Conservation of Paddy Land and Wetlands Act of 2008 restricts conversion of agricultural lands into other land uses. While there is no doubt on the significance of this Act, it has undermined the land value of wetlands and schemes such as the one carried out in Kannankulangara, would be difficult to execute today.

ii. Land market is largely speculative in Kerala. Market value of land may not be actually indicative of the original value of land. It is difficult to define. The State uses another valuation method - using fair value for stamp and registration and also to collect tax. It is based on type of road access, nature of the land among other land characteristics. This value is only indicative, and is generally, a quarter of the market value. This may be a problem while preparing TPS, as the compensation and betterment charges are dependent on land values. Lower valuation of land compared to its market value would dissuade land owners from readjusting their property.

There is a need for new legislation that allows the sustainable development of land especially for residential development and also to control speculation of land value.

2) Financial aspects

a) Compensation

In TPS mechanism, compensation to the land owners is based on the land value and its contribution to the scheme. In Germany, it is calculated on the basis of either area or value of land. This is dependent on the type of land, its location whether it is in urban or rural areas. In rural area, this is calculated based on area. In urban areas, it is calculated by means of land value. In Japan, it is done by street evaluation method, wherein the value of the plot is calculated based on the value of the street it abuts. This is the 'street value'. Location from street, land use are other determinants. In Gujarat, the final value is the product of the value of final plot and its area. Contribution ratio is kept uniform for all plots, while it is different in other cases.

Therefore, it should be noted that while implementing TPS in Kerala, it should be flexible to incorporate valuation based on both area and value of land based on its location. There is a need for fair and transparent valuation of compensation.

b) Cost recovery

One of the major ways to raise capital for TPS and also to create revenue for the developing agency is through creation of 'reserve land'. Reserve lands help the agency involved to recover cost besides making land available for public use. This is particularly useful in Kerala where the majority of land holdings are privately owned. Other value capture financing tools such as betterment levies are used to recover costs in Gujarat. However, the Kannankulangara example has shown that betterment charges can be omitted entirely without financial burden to the agency or land owners.

TPS mechanism in Kerala must have provisions for creating land banks and also provide for tools that facilitate cost recovery.

3) Management

a) Role of Urban Local Body (ULB)/ Development Authority (DA)-

After the 73rd and 74th constitutional amendments, the local governments have increased control over planning and land regulation. The town planning departments and other agencies perform the role of advisory bodies and also provide technical assistance if called upon by the local body. The local bodies don't prepare long term plans but a mere compilation of development projects. They lack the high technical and administrative skills required to carry out mechanisms like TPS, which now falls under their purview.

TPS mechanism must therefore, allow the collaboration of local bodies and planning agencies to enhance the delivery of such schemes.

b) Land owners participation

Land owners consent is required to proceed with TPS in all cases except where compulsory readjustment is carried out. In Gujarat, the TPS is revised multiple times based on objections and feedbacks. In Kannankulangara, the land

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owners were actively involved in the reconstitution process from their initiation stages.

Therefore, the TPS mechanism must pave way for people's participation in planning and development.

VIII. Other Challenges

Contextual challenges must be addressed in the long term while introducing TPS and other such land management schemes in Kerala. The challenges are as follows:

1. Limited availability of habitable vacant land - Kerala has three notable land forms – the high hilly region, the plain midland and low-lying coastal area all within an average width of 35-120 km and average length of 580 km. This itself imposes many geographical constraints for urban expansion and development. Hazard vulnerability is also another cause for concern, with nearly 14.5 % prone to flooding alone (Government of Kerala; Kerala State Disaster Management Authority; United Nations; European Commission; Asian Development Bank, 2018). The unscientific reclamation of wet land has also added to the increase in vulnerability. It is practiced rampantly despite being legally prohibited.
2. High density homestead development - As per state urbanization report, dispersed settlement pattern is a result of historical trends, comparatively developed infrastructure in urban and rural areas, geographical reasons, availability of sub-soil water etc. Further densification would cause decay of urban core – Analysis of fringe areas near urban cores shows an increase in density in fringe areas as compared to the core area.
3. Urban Sprawl – It is evident by high value of urban population growth rate with practically nil increase in population density of the urban areas in the state. It shows that state is experiencing urban sprawl rather than concentration.
4. Aging infrastructure and connectivity challenge - Urban growth and spread puts immense pressure on the infrastructure services and poses new challenges to connectivity. It has to keep up with new urban demands, which would result in greater financial burden to local bodies due to sprawl like conditions. Most of the total income of the local body is spent on construction and extension of roads.
5. Outdated survey and land records - Poor maintenance of land records and lack of updation of survey records pose further challenges while undertaking land development schemes.
6. High F.A.R and Coverage - As per Kerala Municipality Building Rules (KMBR) 1999, the maximum permissible Floor Area Ratio (FAR) for most building occupancies varied between 3-4, except for assembly buildings. This combined with greater coverage varying on average from 40% - 60% increased the total area of development for a particular land. This poses challenges for alternate land management practices that require incentivizing FAR/FSI. With the revision of KMBR in 2019, the rule now regulates the Floor Space Index (FSI) – which in turn controls total buildable area. This move could improve incentivizing development controls for land pooling schemes.

IX. Conclusion

Judicious use of land is imperative to ensure sustainable development of urban areas. All of the solutions in land management are aimed at improving the urban environment, thereby improving the quality of living of the people that reside in these areas.

Alternate land management practices have to be adopted in the long term to meet the demands posed by rapid urbanization and population expansion. In case of Kerala, TPS and other land management practices are the need of the hour, especially in the context of rehabilitation due to the mega floods of 2018-19. However, through the course of this study it can be noted that TPS can only be effective in Kerala if it is made adaptable to the unique urbanization characteristics of the state. Duplicating Gujarat model TPS would not yield the desired results due to the inherent differences between the states based on geography, land characteristics, urbanization patterns etc. The mechanism is not faultless and needs thorough revisions

TPS is not the single step solution to all land management issues. It is but merely a tool that can be strengthened with other mechanisms to promote holistic development of urban areas. Thus, they have to be carefully planned and implemented while considering their impact and the long-standing effects of urbanization.

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References

[1] Ballaney, Shirley and Bimal Patel. Using the 'Development Plan—Town Planning Scheme' Mechanism to Appropriate Land and Build Urban Infrastructure. New Delhi: Oxford University Press,, 2009.

[2] Ballaney, Shirley. "The Town Planning Mechanism in Gujarat, India." 2008.

[3] Centre for Good Governance. "Managing Urban Growth using the Town Planning Schemes in Andhra Pradesh." 2010.

[4] De Souza, Felipe Francisco, Takeo Ochi and Akio Hosono. "Land Readjustment: Solving Urban Problems Through Innovative Approach." 2018.

[5] DEPARTMENT OF TOWN AND COUNTRY PLANNING - GOVERNMENT OF KERALA. *STATE URBANISATION REPORT KERALA*. Thiruvananthapuram: DEPARTMENT OF TOWN AND COUNTRY PLANNING - GOVERNMENT OF KERALA, 2012.

[6] Deuskar, Chandan. "A BETTER WAY TO GROW? Land Readjustment through Town Planning Schemes in Ahmedabad." 2011.

[7] Government of Kerala; Kerala State Disaster Management Authority; United Nations; European Commission; Asian Development Bank. "Kerala - Post Disaster Needs Assessment Floods and Landslides - August 2018." 2018.

[8] Gurumukhi, K.T. "Land Pooling Technique : A tool for plan implementation- An Indian experience." *Map India 2003*. 2003.

[9] Jain, A. K. "URBAN LAND POLICY AND MANAGEMENT REFORMS." *ITPI JOURNAL* 3 (2008): 60-68.

[10] John, Anna " Analysing The Effectiveness Of Town Planning Schemes For Urban Land Management In Kerala", unpublished

[11] Lozano-Gracia, Nancy, et al. "Leveraging land to enable urban transformation : lessons from global experience." 2013.

[12] Mahadevia, Darshini, Madhav Pai and Anjali Mahendra. *Ahmedabad: Town Planning Schemes for Equitable Development—Glass Half Full or Half Empty*. Washington D.C: World Resources Institute, 2018.

[13] MERZ, SINCLAIR KNIGHT. *India: Kerala Sustainable Urban Development*. Australia: Asian Development Bank, 2005.

[14] Ministry of Housing & Urban Affairs. "Pilot on Formulation of Local Area Plan (LAP) and Town Planning Schemes (TPS) for selected cities." 2018.

[15] Ministry of Urban Development, Government of India. "URBAN AND REGIONAL DEVELOPMENT PLANS FORMULATION AND IMPLEMENTATION (URDPFI) GUIDELINES." 2015.

[16] Pastagia, Digant A., Jignesh K Patel and Joel E. M. Macwan . "SMART Model for Urban Land Management." *ITPI Journal* 16.1 (2019): 1-7.

[17] Patel, Jignesh K. and Dr. J.E.M. Macwan. "Sustainability Assessment of Urban Land Management Polices of India and new Proposal." *2nd International Conference on Emerging Trends in Engineering and Technology*. London, 2014.

[18] Sanyal, Bishwapriya and Chandan Deuskar. "A Better Way to Grow?: Town Planning Schemes as a Hybrid Land Readjustment Process in Ahmedabad, India." *Value Capture and Land Policies*. Lincoln Institute of Land Policy, 2011. 149-183.

[19] Satashia, Avinash. "Study of Urban Land Management Techniques in India ." *INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN TECHNOLOGY* (2015): 274 - 277 .

[20] Sorensen, AndreÂ. "Land readjustment and metropolitan growth: an examination of suburban land development and urban sprawl in the Tokyo metropolitan area." *Progress in Planning* (2000): 217-330.

[21] Supriatra, Andri. The feasibility study of Land Readjustment for Kampung upgrading in Jakarta. Enschede: University of Twente, 2011.

[22] United Nations Human Settlement Programme. Planning Sustainable Cities: Policy Directions Global Report on Human Settlements 2009. London: Earthscan, 2009.

[23] Vaidya, Chetan. "Town Planning Scheme as a Technique for Urban Land Management in India." *Nagarlok* (1984): 79-100.

[24] YAU, Yung and Ching Yin CHENG. "Applicability of Land Readjustment in Urban Regeneration in Hong Kong." *Journal of Urban Regeneration and Renewal* (2010).

[25] Yilmaz, Ahmet, Volkan Cagdas and Hülya Demir. "An evaluation framework for land readjustment practices." *Land Use Policy* (2015): 153–168.

[26] YOMRALIOGLU, Tahsin. "A NOMINAL ASSET VALUE-BASED APPROACH FOR LAND READJUSTMENT AND ITS IMPLEMENTATION USING GEOGRAPHICAL INFORMATION SYSTEMS." 1993.

[27] Zabihi, Hossein and Sohaila Hamidzadeh Khiavy. "Analysis of land readjustment (LR) methods used in Joibareh, Iran." *Indian Journal of Science and Technology* (2012)

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Framework For Assessment Of Suitability Of Multi-Storeyed Residential Buildings Under Slum Upgradation Programmes

A case of Chennai Corporation

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***Abstract*—** *The paradox of rising living expenses of Chennai Corporation and convenient accessibility to workplaces from certain locations have increased the number of slum settlements within the city limit throughout the years. In Tamil Nadu alone, vacant housing units account for 6% of the 11 million vacant households in India, despite this, the State faces a huge shortage of 1.5 million homes. Several schemes and programmes have been applied across Tamil Nadu to increase the quality of living of the urban poor. It is noticeable that most of the dwelling units are Multi-storeyed residential buildings and not all them provided under these Slum Upgradation Programmes are effectively used - some of them are illegally rented. It is important to derive an assessment framework for these dwelling units, particularly in the Chennai context. This study is explained through the evolution of Slum Upgradation Programmes in Chennai to understand the reason for the discontinuity of the past Housing projects. Literature case studies on Post Occupancy Evaluation and Housing Quality Assessment have facilitated the derivation of an assessment framework to assess upcoming projects under Slum Upgradation in Chennai Corporation. The derived assessment framework consists of 4 dimensions – socio-economic, dwelling unit, building and neighborhood. It is applied to a primary study, in Nochikuppam Chennai, concluding with recommendations to the framework.*
Keywords—assessment; framework; suitability; multi-storey building; residential; slum; slum upgradation programme

Aim— Aim of the study is to derive a Framework for assessment of suitability of multi-storeyed residential buildings under Slum Upgradation Programmes (SUP) for Chennai Corporation. The assessment framework derived is limited to the characteristics, culture and lifestyle of Chennai Corporation. Only one mathematical model is used for analyzing the primary study. Further research must be conducted to understand a broader user perception of housing projects under various SUP in Chennai.

I. INTRODUCTION

The Chennai Corporation encompasses 426sq.km. with a population of 71,53,000. The density of the Corporation area is 16,791 twice that of Chennai Metropolitan Area (CMA). The slum population is 28% of the total population and the growth of slums is gradually increasing *(Census, 2011)***.** 79 percentage of the slum population is located in untenable areas, mostly along the water bodies, coastal areas, roads and rail networks *(Darashaw & Co. Pvt.Ltd; Tamilnadu Slum Clearance Board; mhupa.gov.in, 2014). Figure 1* indicates slums in Chennai Corporation. Although the housing demand is seen reducing in recent years, demand and supply go parallel. This raises the question of "Why is Housing still not catering to the needs of the people?" It is seen that the maximum of the demand is from EWS and LIG population.

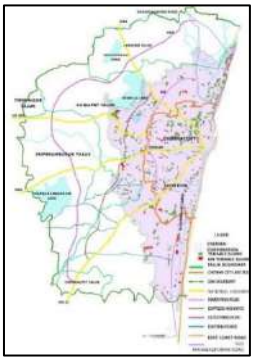

Figure 1 CMA map indicating slums in Chennai Corporation (Darashaw & Co. Pvt.Ltd; Tamilnadu Slum Clearance Board; mhupa.gov.in, 2014)

A. Structure of the paper

In Section II of the paper, the evolution of SUP's in Chennai is discussed reviewing major thrust areas and reasons for discontinuity of these projects. In Section III, the focus is on the formulation of the assessment framework from six literature case studies. Section IV, details the application of the framework in a Primary study, assesses a SUP in Nochikuppam, Chennai under Emergency Tsunami Reconstruction Project (ETRP). A survey was conducted in September 2019 with a sample size of 50 and a survey team of 4 members. The sample chosen is based on random sampling. In addition to case-specific qualitative and quantitative analysis, a review of the literature—covering both academic and "grey" literature on Nochikuppam housing project by Tamil Nadu Slum Clearance Board (TNSCB). Major issues are addressed with simple recommendations. Section V highlights the recommendations

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that can be applied to the assessment framework. The study is concluded with a discussion of the need for assessment of the suitability of multi-storeyed residential projects under SUPs.

II. Evolution Of Slum Upgradation Programmes

Understanding the evolution of SUP is important to know why past programmes failed or succeeded. These factors may be used in future for assessments. *Figure 2* shows the timeline of Slum Upgradation Programmes for Housing in Chennai.

Figure 2 Timeline of Slum Upgradation Programmes in Chennai (Darashaw & Co. Pvt.Ltd; Tamilnadu Slum Clearance Board; mhupa.gov.in, 2014) (Jothilakhmy N., 2010)

Programmes with similar objectives are color coded to identify the changes made over the years. The summary of thrust areas and reasons for discontinuity of Slum Upgradation Programmes are listed below to include them as factors of the assessment framework.

TABLE 1 Broader Level - Objectives & Reasons for Discontinuity of Slum Upgradation Programmes

THRUST AREAS	DISCONTINUITY
Developed Plots	
Rehabilitate in Multi – storeyed tenements (In situ)	No temporary availability of Transit Camp
Resettlement of untenable slums	Displacement caused hardship
Reconstruction, Repair & Renewal of Dilapidated Houses	
Improved Living Environment	Poor Quality Infrastructure - plot sizes provided, dwell unit, sanitary core, sewerage disposal, waste managem non accessibility of public transport
Provision of Basic Amenities & Infrastructure facilities	Beneficiary not involved in repayment
Beneficiary Responsive	Ineffectiveness in cost recovery – low maintenance
Affordable Housing, low cost techniques	No tenure rights
Retain Livelihood	No space for livelihood activities
Tackle Urban Land Shortage	Land scarcity

Factors that were majorly identified as a reason for discontinuity of SUPs included from the time of temporary displacement to the infrastructure provided and the maintenance issues. Minimal beneficiary involvement along with land scarcity was also addressed as a planning issue that led to discontinuity od SUPs in Chennai city.

III. Deriving Framework For Assessment of Suitability Of Multi-storeyed residential Buildings

Several works of literature were perused to unearth apt methods of assessment for residential projects. Housing Quality Assessment and Post Occupancy Evaluation (POE) was majorly used as assessing framework. Housing Quality Index is the physical condition and quality of the social environment of an individual's home. *(Healthypeople.gov, 2019).* From literature studies, it is understood that housing quality was assessed through user satisfaction. POE is the process of systematically evaluating buildings rigorously after being built and occupied for some time. (Baird, 2001). Literature case studies were considered to understand the methodology to conduct the assessment and to understand the dimensions in which it was evaluated. *Table 2* lists the case studies chosen which are comparable with the condition of Housing in Chennai. Housing for the lower-income group was taken priority while shortlisting case studies.

TABLE 2 Literature Case Studies

POE	User satisfaction: "old" and "new" public housing schemes in **Bangkok**	1. Comparison of 2 schemes 2. Affordable Housing 3. 5-storey building (no elevators)
	Social Housing in **Liberia**	1. Low Income Housing
	An investigation of neighbourhood satisfaction – **Dublin, Ireland**	1. Migration trend to the central city 2. Apartments
HQA	5 districts in **Kerala** for MIG Housing Quality Assessment	Indian Context
	Indicators to Measure Social Housing Quality in **Vietnam**	Low Income Groups
	Literature: Assessment Criteria (Apartment unit)	Dwelling Unit Assessment Criteria

(Howley, Scott, & Redmond, 2009) (Jacob Arku Ziama, Bo Li, 2018) (Tanaphoom Wongbumru; Bart Dewancker, 2015) (Tanaphoom Wongbumru; Bart Dewancker, 2015) (Lea, Taa, & Danga, 2016) (Brkanić I. , 2017)

A. Methodology for conducting assessment

To conduct any assessment, the need or scope is established as the first step. In this study, the need is the assessment of the suitability of multi-storeyed residential dwelling units under Slum Upgradation Programmes in Chennai Corporation. Steps involved in conducting assessment are given in Figure 3.

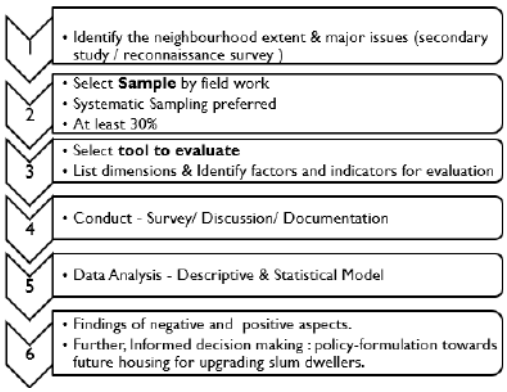

Figure 3 Steps derived in conducting assessment

A secondary study or a reconnaissance study is done to help us understand the major issues the study area faces. A tool is developed to gather information about the study area from several sources. Evaluation tool includes questionnaire survey – closed & open-ended; focus group discussion; key informant interviews & observation. The data collection is done on several dimensions. A satisfaction study is also conducted to understand the needs of the end-users and to evaluate the efficiency of the existing conditions. The satisfaction study is

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conducted based on a 5-point Likert scale. 1. Very Unsatisfied; 2. Unsatisfied;3. Moderate; 4. Satisfied & 5. Very Satisfied.

B. Dimensions, Factors and Indicators for assessment

There are four major dimensions identified for assessment.

1. Socio-Economic Dimension *(Table 3)* helps assess the social and economic status of the beneficiary. They are evaluated based on 16 factors.

2. Dwelling Unit Dimension (*Table 4*) helps assess the resident's satisfaction on the condition of the dwelling unit. They are evaluated at two levels (Physical condition and Ambience) based on 7 factors (General, Construction, Room sizes, Materials, Indoor comfort, Light, Others).

3.Building and Community Dimension (*Table 5*): The assessment includes building's physical condition, common spaces, circulation, infrastructural facilities, environmental and social factors include for the understanding of building and community level condition.

TABLE 3 DERIVED FACTORS AND INDICATORS FOR EVALUATION OF SOCIO-ECONOMIC DIMENSION

FACTORS		INDICATORS	FACTORS		INDICATORS
1	AGE	0-5 | 6-17 | 18-58 | >58	9	RATION CARD	Green | White
2	GENDER	M | F | T	10	TENURE STATUS	Owned | Rent | Lease | Others
3	RELIGION	Hindu | Christian | Muslim | Others	11	VEHICLE OWNERSHIP	No., What?
4	CASTE	BC | MBC | SC | ST | OC	12	No. of OCCUPANTS	No.
5	MARITAL STATUS	Single | Married | Divorced | Others	13	DIFFERENTLY ABLED	No. ,What?
6	EDUCATION	Up to Primary School (5th std) Higher Secondary(12th std), Graduate, PG	14	NATIVITY	Local(within corporation) | Within District| Other district| Other State
7	OCCUPATION	Main worker| Marginal worker| Self Employed| No work | Retired with pension | Retired without pension|	15	DURATION of OCCUPANCY	>20 years | 15-20 | 10-15 | <10years
8	INCOME per month	<12K | 12-18K | 18- 37K | 37-62K | >62K	16	RENOVATION	No | Yes, what?

TABLE 4 DERIVED FACTORS AND INDICATORS FOR EVALUATION OF DWELLING UNIT DIMENSION

	General	Room Sizes	Materials		Indoor Comfort	Others
PHYSICAL ASSESSMENT	House No.	**Area/ Height/No.**	Floor	AMBIENCE	Natural Ventilation	Comfort
	Block No.	Dwelling Unit	Wall		**Indoor Air Quality**	View
	Floor position	Living Room	Ceiling		Fresh/ stale	Less Repair
	Layout	Dining Area	Door Operation		Humid/ Dry	Privacy
	Construction	Kitchen	Window Operation		Outdoor Air quality	Safety
	Flexibility	Bathroom	Kitchen Fixtures		Noisy Surrounding	Withstand Break-in
	Sustainability	Toilet	Sanitary fittings in Toilet		Indoor Temperature	Prevent Insects
	Eco-friendly	Balcony	Plumbing Works		**Light**	
		Pooja Room	Electrical Works		Natural Light	
		Sunshade	Traditional Touch		Size & Location of windows	
		Storage	Interior Aesthetic			
		Capacity :Occupants	Acoustics		Window sill level	

TABLE 5 DERIVED FACTORS AND INDICATORS FOR EVALUATION OF BUILDING AND COMMUNITY DIMENSION

Building level	Common spaces	Circulation	Infrastructure	Environment
Design/ Layout	Parking Facility – occupants & guest	Fire Exit	Waste segregation	Provision of Green space
Street Lighting	Communal spaces	Corridor	Waste Disposal	Littering
Facilities	Lobby	Staircase (no.)	Water Supply	Air Pollution
Exterior Finishes	Space between units	Lift (no.)	Electricity	**Social**
Disaster resilient		Pedestrian connectivity	Drainage System	Neighbours
Structural span		Vehicular connectivity	Run off Water collection	Resident Association
Orientation		Barrier Free Environment (what?)	Neighbouring Building (5m away)	Maintenance
Space Between Blocks			Cooking Fuel	Beneficiary involvement
Compound Wall			Common Toilet	Security
				Doctors on call
Qualitative				Child Care
Severity of Floods				Livelihood activities

4. Neighborhood Dimension: It is majorly assessed by the proximity of amenities to the residential building. The 15 factors include employment, school – kindergarten, primary, secondary, hospital, market/ shopping mall, bank, nearest public transport, place of worship, public park, sports or playground facility, social & leisure, post office, city center, future potential, daily commuting time, theatre.

C. Questionnaire Preparation

A questionnaire is prepared based on the factors and indicators identified. Open-ended questions are added from the reconnaissance study conducted. It is to note that the questions may vary based on the context of the study area.

D. Data Analysis Technique

The data obtained from satisfaction study and general observation are analyzed through descriptive analysis and statistical analysis. The descriptive analysis includes calculation of Frequencies and percentages. The technique opted for statistical analysis is Pearson's Correlation by IBM SPSS statistical analysis software. It finds out the correlation factor (R) and its level of significance (p). It also finds out the relationship between three dimensions – Dwelling Unit, Building/ Community and Neighborhood.

A tool is prepared with the help of Excel sheet for easy generation of following results. Cross tabulating dimension with the comparison of Performance Score (%) of three dimensions (Dwelling Unit, Building/ Community and Neighborhood) to identify the most satisfying dimension. Mean Satisfaction Obtained Score and Mean Satisfaction Expected Score of each dimension helps in calculating Performance score. Comparative result of satisfaction percentage at three dimensions for every household (HH) is also identified.

IV. PRIMARY STUDY- NOCHIKUPPAM SLUM UPGRADATION PROGRAMME

Nochikuppam Slum upgradation project under ETRP and was identified for study because it is a recently completed programme in the heart of the city. It is in zone 9, untenable location which was hit by the tsunami. *Figure 4* shows a glance of Nochikuppam Housing project. *Figure 5* shows a timeline of the evolution Nochikuppam project.

Figure 4 Nochikuppam Housing by TNSCB (Primary study, September 2019)

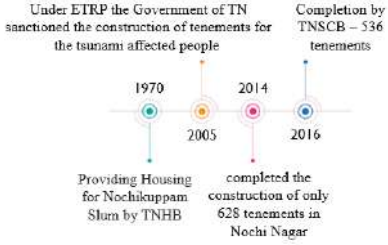

Figure 5 Timeline of Nochikuppam Slum Upgradation Project (Primary study, September 2019)

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A. Location

The Nochikuppam slum upgradation project lies close to Marina Beach. It is located at a distance of 100m from the sea. It is well connected through road transport. The nearest bus stop and local railway station is the Light House located 250m from the project site. This project occupies a prime location in the Foreshore Estate, majorly focusing on the fisherman community.

B. Demography

The total population of the project is 2308 with an average household size of 4. From the 10% sample, it is seen the female ratio is much higher. 68 percentage of Dus (Dwelling units) are owned by users. The major occupation of the community is Fishing and maximum belonging to Hindu religion with highest MBC and SC population. The Dus are renovated over the years. Duration of occupancy for most of the occupants are two years. Each unit was allotted to families on a Hire Purchase system, with minimum pay of Rs.250 per month for 20 years. The people who have rented the flats pay an average rent of Rs.5000 per month to the owners.

C. Layout – Housing project complex, block & dwelling unit

The Housing project consists of 24 blocks in a site area of 20283 sqm., housing 536 Dwelling Units. *Figure 6* shows the layout of the project. The layout has three types of blocks – A, B & C. Type The height of the apartment is stilt with four floors. There is sufficient planed open space along with children's play area and Primary Health centre within the complex. These amenities are not effectively used. The typical plan of Type – A layout is shown in *Figure 7*

Figure 6 Layout of Nochikuppam Project (Primary study, September 2019)

Figure 6.A Type - A Plan (Primary study, September 2019)

D. Dwelling unit assessment

All the dwelling units have a typical plan consisting of a living room, a bedroom, a kitchen, a bathroom and a toilet. The floor area of a Du is 28sqm, with a ceiling height of 2.8m. Original Flooring is cement and the wall is brick plastered.

Figure 7 Original & Renovated Dus (Primary study, September 2019)

In the comparison of Du sizes with standards followed by TNSCB:

The area, width and height of certain spaces have complied with the standards. *Table 6* tabulates the standards with the sizes observed in Nochikuppam Dus. Dus has been upgraded by most of the households with better materials. *Figure 7* shows the renovation made by a Du from the original state. *Table 7,8* indicates Physical Assessment of Du based-on satisfaction study. The ambience is indicated by indoor comfort and lighting. Humidity is seen high in this area.

TABLE 6 COMPARISONS OF SIZES OF DU IN NOCHIKUPPAM WITH STANDARDS *(Affordable Housing standards, TNSCB) (Primary study, September 2019)*

	Mi. Area (sqm)	Min.Area (sqm)	Min.Width (m)	Min.Width (m)	Height (m)	Height (m)
DU	15	28			2.6	2.8
Living, Dining	9	13	2.5	3.16		
Bedroom	6.5	7	2.1	2.47		
Kitchen	3.3	4.6	1.2	1.61		
Combined bathroom & water closet	1.8	(1.5+1.5)	1	(0.95+0.95)		
Balcony			0.9	No balcony		
Ventilation	3.5	5.1				
Water Closet	0.9	0.9	0.9	0.9		
Staircase width			0.9	0.9		
			Standards	Nochikuppam		

TABLE 7,8 PHYSICAL ASSESSMENT OF DU – AREA & MATERIALS

Area	Satisfaction Level
Dwelling Unit	60% are neutral
Living Room	62% are satisfied
Kitchen	40% are not satisfied
Bathroom	40% are satisfied
Toilet	48% are satisfied
Sunshade	66% are neutral
Storage	88% are very unsatisfied
Capacity :Occupants	70% are neutral
Height of DU	56% are satisfied

Materials	
Floor	76% are satisfied
Wall	58% are satisfied
Ceiling	58% are not satisfied
Door Operation	56% are neutral
Window Operation	70% are satisfied
Kitchen Fixtures	50% are neutral
Sanitary fittings in Toilet	50% are neutral
Plumbing Works	54% are not satisfied
Electrical Works	56% are neutral
Traditional Touch	72% are not satisfied
Interior Aesthetic	76% are neutral
Acoustics	60% are neutral

(Primary study, September 2019)

E. Building and Community assessment

Building level satisfaction assessment is carried out through Physical assessment of buildings, common spaces, circulation, infrastructure, environmental and social factors. Water supply is through the Chennai metro water supply network, where the tanks are filled once in 15 days. The hand pumps are installed on the ground affront each block, from which water can be filled in vessels and taken upstairs manually.

Table 9, 10, 11, 12 lists the satisfaction study conducted.

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TABLE 9 PHYSICAL ASSESSMENT OF BUILDING
TABLE 10 INFRASTRUCTURE ASSESSMENT FOR BUILDING

Physical Assessment	
Design/ Layout	58% are neutral
Street Lighting	70% are satisfied
Exterior Finishes	67% are very unsatisfied
Disaster resilient	45% are neutral
Structural span	20% are neutral
Orientation	61% are satisfied
Space Between Blocks	52% are very satisfied
Compound Wall	40% are not satisfied

Infrastructure	
Waste segregation	75% are not satisfied
Waste Disposal	78% are not satisfied
Drinking water Supply	57% are neutral
Electricity*	69% are satisfied
Drainage System	51% are neutral
Run off Water collection	67% are not satisfied
Distance from neighbouring building	64% are satisfied
Common Toilet	86% are not satisfied

TABLE 11 COMMON SPACES AND CIRCULATION WITHIN BUILDING TABLE 12 ENVIRONMENTAL AND SOCIAL FACTORS OF COMMUNITY SPACE

Common spaces	
Parking Facility – occupants & guest	67% are neutral
Communal spaces	53% are not satisfied
Lobby	47% are satisfied
Space between units	45% are satisfied
Circulation	
Fire Exit	42% are neutral
Corridor	56% are satisfied
Staircase (no.)	79% are satisfied
Lift (no.)	80% are not satisfied
Pedestrian connectivity	62% are satisfied
Vehicular connectivity	76% are very satisfied
Barrier Free Environment (what?)	77% are very unsatisfied

Environment	
Provision of Green space	62% are not satisfied
Littering	76% are very unsatisfied
Air Pollution	81% are satisfied
Social	
Neighbours	70% are satisfied
Resident Association	45% are not satisfied
Maintenance	63% are not satisfied
Beneficiary involvement	41% are not satisfied
Security	43% are satisfied
Doctors on call	74% are not satisfied
Child Care	48% are satisfied
Livelihood activity space	72% are not satisfied

(Primary study, September 2019)

F. Neighborhood Assessment

The nearest school is Santhome School, which is a private concern. The nearest hospital is Krishnampet Health Post, 1.5 km away. The local market is quite far away and everyday grocery needs are met by mobile vendors. From neighborhood assessment it is seen that all factors are satisfying in terms of proximity, making Nochikuppam an ideal place of living.

G. Cross Tabulating Dimensions

An excel tool generated helps the cross-tabulation of results by entering the satisfaction data for all dimensions from the survey conducted. From the comparison of performance score in *Figure 8,* it is seen that the Neighborhood dimension holds the highest satisfaction level. 75% of the Households are 66-70% satisfied. Overall the HHs are satisfied within 51-75% range.

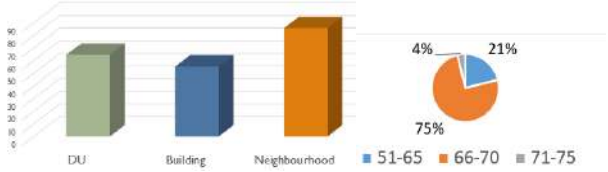


Figure 8 Performance Score (%);

Figure 9 Percentage of Satisfaction at HH level (Excel generated tool)

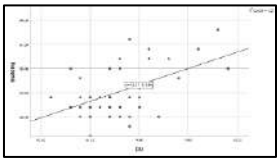
H. Pearson's Correlation

This method was used to test the correlation between each of the dimensions individually.

a. DU and Building *(Figure 10):* A positive correlation exists i.e., the physical condition of the Dus has a significant correlation with infrastructure, services and community aspects.

b. Building and Neighborhood (*Figure 11*): A negative correlation exists. As the building variable increases the neighborhood variable decreases.

c. Neighborhood and DU (*Figure 12):* The graph shows a negative correlation. As the DU variable increases, the neighborhood variable decreases. The relationship between the variables is weak.



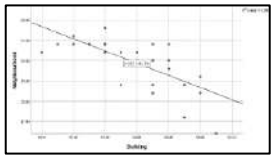


Figure 10 Simple scatter of dwelling unit by building (IBM: SPSS)
Figure 11 Simple scatter of building by neighbourhood (IBM: SPSS)

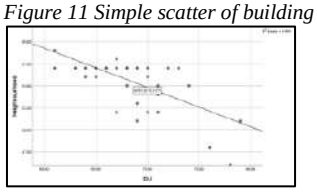


Figure 12 Simple scatter of Neighborhood by Dwelling unit (IBM: SPSS)

I. Issues Identified

Though the project has helped to achieve affordability, the quality of living and maintenance aspects have been highly compromised. Based on the satisfaction study and other analysis, issues identified are listed below.

a. Dwelling Unit: Lack of Storage space within DU for HH provisions. There is no space for cold storage of fishes. Although it is only 2 years since occupancy, wear and tear of plastered walls occur. Being near the sea, the place faces a high degree of humidity.

b. Building and Community: The community being fishermen are highly dependent on the wholesale and retail sale of fish from the sea. Due to the lack of retail spaces, hawking on the roads and the beach directly opposite the building have taken place. This has led to mosquito breeding and other unhealthy living conditions. The stilt parking facility is not optimally utilized. The stilts have been very effective in removing the threat and danger of having houses on the ground floor, during the floods and have provided efficient parking spaces. However, the households which have commercial vehicles choose to park them on the streets. The vacant stilt spaces have become places for retail sales and other activities The Open spaces along the road becomes a garbage disposal area, and spoils the surrounding, hence unable to be used as a playground. No doctors on call, skin, eye, infection and parasitic diseases affected about 14.7% of the Chennai population. (Gopalakrishnan, Ganeshkumar, & Katta, 2015). 22.5% of the surveyed population of Nochikuppam had an Eye infection; Skin infection was also hugely addressed. This proportion is greater than that seen in Chennai city. This needs to be addressed immediately. Waste segregation and disposal is a huge concern for the environment. Inactive resident's association for social activity or any community decisions.

c. Multi-storeyed Buildings: These buildings provide a great view, fresh air- ventilation, natural light and fewer insects. They are a new concept to urban poor and it is difficult to adjust. The livelihood activities of residents may be hindered. Elderly and differently-abled find it difficult to climb all along without lifts. Drinking water should be carried to floors by the residents in pots. There is no gathering space/outdoor space at higher levels and no place for Drying Clothes. Upper floors face thermal heat during summers

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J. Recommendations

- Proper implementation of projects should be ensured.
- Spaces should suit the needs of the beneficiary
- Design to include a barrier-free environment
- Sense of ownership for beneficiaries.
- Active Residents association to keep community activity going and self-sustaining.
- Waste Management to reduce harm to the environment

Multi-storeyed residential buildings are solutions to land scarcity in the high dense city. (urban compaction)

- Elevators can be provided to ease the vertical circulation.
- Effective planning by providing green spaces at all levels as gathering space would enhance the design.
- Water supply to be brought in all levels all the time with no compromise.

V. Recommendations For Assessment Framework

From Pearson's correlation test in Nochikuppam, there is a strong relationship in Dwelling unit and Building & Community dimension. Eg, the amount of storage space depends on the social factor of livelihood activities of the beneficiaries. Kitchen space is affected by the overall design of the layout of the building. A well planned and implemented building layout may help dwelling units from facing any issue. Improper exterior finishes maybe the reason for leakage in the ceiling. Inadequate provision of communal spaces and green spaces maybe due to sufficient parks available within the neighbourhood, thus proving a strong negative relationship between building & community and neighbourhood dimension. The need for the provision of special amenities for the building can be avoided if the neighbourhood is in an accessible and self-sufficient location. dwelling unit dimension and neighbourhood has no relationship proving that the context was not considered during the design process of the dwelling unit.

If multi-storeyed residential buildings are to be successful in the long term, then there needs to be a well-planned built environment that can offer residents a high quality of life.

- The eventual approach and output should be humane and habitable, serving the needs of the occupants of a specific lifestyle. Planners and architects should ensure social design.
- Establish the system, standardize and upgrade the system step by step. Distinct characteristics of the study area should be considered before application of the assessment framework.
- Assessment framework established should be updated periodically to suit policy's changes, neo construction technology or lifestyle, etc.
- Reassessing would revitalize the quality of housing.

VI. Conclusion

In conclusion, this research is an attempt to derive and formulate a Framework for assessment of Dus under Slum Upgradation Programmes in Chennai. Assessment of spatial factors was made possible from available data for Nochikuppam housing project. Further extensive research must be conducted to ascertain a broader user perception of housing projects under different SUP in Chennai. Effective study of assessment of the dwelling units under all existing Slum Upgradation Programme in Chennai can help in formulating strategies for built environment of multi-storeyed residential buildings under current Slum Upgradation Programmes in Chennai city.

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References

[1] *Le, L. Huong, D. Ta Anh, and H. Q. Dang, "Building up a system of indicators to measure social housing quality in Vietnam," Procedia Engineering, pp. 123, 2016.*

[2] *I. Brkanić, "Housing Quality Assessment Criteria," Znanstveni rad, 2017.*

[3] "Census of India," retreived from censusindia.gov.in, 2011.

[4] "Tamil Nadu Slum Clearance Board," retrieved from TNSCB report, 2017.

[5] Darashaw & Co. Pvt.Ltd, Tamilnadu Slum Clearance Board, "Rajiv Awas Yojana (Ray) Slum Free City Plan Of Action –Chennai City Corporation," retreived from mhupa.gov.in, 2014.

[6] S. Gopalakrishnan, P. Ganeshkumar, and A. Katta, "Study of morbidity profile of rural population in Tamil Nadu," retreived from www.ncbi.nlm.nih.gov/pmc/articles/PMC4378752, February, 2015.

[7] Healthypeople.gov, retrieved from Healthypeople.gov, 2019.

[8] P. Howley, M. Scott, & D. Redmond, "Sustainability versus liveability: an investigation of neighbourhood," Journal of Environmental Planning and Management, 2009.

[9] Jacob Arku Ziama, Bo Li, "Residents Post-Occupancy Evaluation of Social Housing in Liberia," Journal of Building Construction and Planning Research, 2018.

[10] N. Jothilakhmy, A. M, "Inclusive planning processed and institutional mechanism for urban poor: Innovations and Lessons Learnt from Different Schemes in Chennai City," ITPI, pp 50-62, 2010.

[11] Tanaphoom Wongbumru; Bart Dewancker, "Post-occupancy evaluation of user satisfaction: a case study of "old" and "new" public housing schemes in Bangkok," Architectural Engineering and Design Management, 2015.

[12] R. Simon Agnes, "Framework for assessment of suitability of multi-storeyed residential building under Slum Upgradation Programmes: A case of Chennai Corporation," Unpublished report, 2020

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Formulation of methodology to assess the effectiveness of responsible tourism in Kerala

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Abstract *— Responsible tourism is a new concept of tourism which gained wide range of acceptance from 2002 cape town declaration of responsible tourism at destination levels concept which introduces a new approach of tourism through active community participation and involvement of various stakeholders directly and indirectly in tourism developmental activities. There are very few studies to assess the effectiveness of responsible tourism at these destinations with proper methodology. Unlike other forms of tourism which involves only tourism development authorities as the apex body determining the success or failure of tourism in an area, responsible tourism needs to be analyzed by considering benefits and demerits on both local community and tourism department contributing to overall tourism development.*

This study is focused on understanding the trends and concepts of responsible tourism initiative in Kerala and to formulate a methodology to study the effectiveness or impacts of responsible tourism at destination levels in Kerala. Literature study on various programs and policies of responsible tourism in Kerala at all destinations and their impacts in terms of various aspects is studied. A methodological framework is formed which includes, the various steps involved in the effectiveness study for responsible tourism, identification of various parameters and indicators used in the effectiveness study, the type and method of study, various sampling techniques, selection of sample population of community based tourism at different destinations through case studies and literature studies. Finally derivation of appropriate methodology for the study is done and formulation of a proper framework for evaluation of responsible tourism which can be used for effectiveness study of responsible tourism in Kerala.

Keywords— Responsible tourism, initiatives, effectiveness, tourism development, community benefits, monitoring methodology

I. INTRODUCTION

Responsible tourism was a concept from 1980's which was prevailing as 'Alternative tourism' and was re termed as Responsible tourism from Cape Town declaration in 2002. The Cape Town declaration held in South Africa with Harlod as the head introduced the concept of responsible tourism at destination level with the planning of certain principles that have to be followed by these destinations. Meetings were held at different locations during different years which started off in 2002 in Cape Town, 2008 In Kerala till 2016 in Jyvaskyla, Finland. Responsible Tourism is taking responsibility for, and action to, address the issues of sustainability such as social, economic and environmental that arise in destinations. Tourists and local communities interact in the local, natural and socio-cultural environment in the destinations and needs to be managed in order to minimize negative impacts and to maximize positive ones. Responsible tourism concept in Kerala was initiated due to certain problems that existed in tourism destinations of Kerala like Kumarakom. The responsible tourism initiative started in Kerala in 2007 as an effective form of community participatory tourism at different destinations namely Kumarakom, Kovalam, Wayanad (Vythiri) and Thekkady where tourism activities created both positive and negative impacts on the community in terms of social, economic and environmental aspects. Responsible tourism mission was formed in 2007. The different problems identified at Kumarakom were Waste management, Loss of jobs, Pollution of water bodies, Fish cultivation issues, and unused cultivation fields. This problems lead to the stagnation of tourism. Three days meeting were held at Kanakakkunnu palace, Trivandrum in the year 2007 with concerned government officials, tourism department, NGO's, LSG's etc. Various methods and principles were formed in order to resolve this issue with Responsible tourism as main concept. The considerations were focused on the economic aspects of the place at the beginning. Local self-governments at panchayat level was introduced to take part in tourism planning, decision making and encourage community benefits. State level responsible tourism committee was formed.

The study had three objectives in which the first objective was to study the concepts of Responsible tourism and its Programmes. The second one was to identify and derive parameters and indicators for monitoring of Responsible tourism activities and the third one was to derive a methodology to use the identified indicators to measure the effectiveness of responsible tourism at destination level in Kerala. All the above objectives was dealt with literature studies and Key informant interviews at various destinations of responsible tourism in Kerala.

II. METHODOLOGY

The methodology for the study is as followed which includes various steps from identification of topic and need for the study, formulation of aim, objective, scope & limitation, data

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collection which includes both primary data collection and secondary data collection. The secondary data included study the concept of responsible tourism & programs under responsible tourism and to identify various methodologies used in case studies, identify the method through which the sample selection is done and identify various indicators used to assess the effectiveness of community based tourism, study of various tools used for the analysis of data collection and study the various programs at destinations in Kerala. The primary study included understanding the current practices & problems of responsible tourism in Kerala through Key informant interviews. Data analysis includes comparing the methods, tools and identify appropriate tools to assess the effectiveness of RT, derive parameters, indicators by comparison of case studies & literature data and formulate a monitoring methodology to assess the effectiveness of RT in Kerala and to come to a final conclusion on what methodology should be adopted for the assessment of responsible tourism in Kerala.

III. LITERATURE REVIEW

A. Responsible tourism in Kerala

It began at state level in coordination with Dept. of tourism, Govt. of Kerala and International centre for Responsible tourism. Discussions were held in sub groups i.e. with Local self-governments and civil society organizations, Tourism industry, State Government and Other departments and organizations. Three stages of preparation of Responsible tourism in Kerala was introduced at the conference held in Kerala. Stage 1 - Preparation stage, Stage 2 – Tourism resource mapping, Stage 3 - Sensitization Programmes: Programmes for Local community and industry to accept and practice RT in the larger interest of the society, tourists and tourism business [9].

The responsible tourism was planned and implemented at three phases. Phase 1: Planned and implemented the concept of responsible tourism in 2007. Implemented at four different places in Kerala depending the topography of the places depending on the geography of the place. The four places are Kumarakom, Kovalam, Thekkady and Vythiri (Wayanad). Responsible tourism became a milestone in tourism planning by the end of first phase. Focused on developing the economic status of local community by involvement of local self-governments, hence contributing to the growth of tourism sector development. Phase 2: The phase two was from 2011 to 2017. Responsible tourism cells were started and three more destinations were selected for responsible tourism implementation which are Bekal, Ambalavayal and Kumbalangi. Phase 3: Responsible tourism mission started in 2017 and the initiative was spread to all regions of Kerala. The mission aimed at providing women empowerment, development of village & local community, Poverty alleviation and better livelihood.

The mission aims to provide an additional income and a better livelihood to farmers, traditional artisans, and marginalized people along with creating a social and environmental equilibrium [9].It includes every forms of tourism and aims to reduce economic impact, social impact and environmental impact of tourism in Kerala. Provides more opportunities to local community and creates more opportunities for generation of local economic income. This initiative grew rapidly from 2008 since it involved local community and activities that ensures benefits to both local community and tourism development.

The below figure shows the various aspects of responsible tourism practices in Kerala. The three different aspects of Responsible tourism are economic, environmental and social.

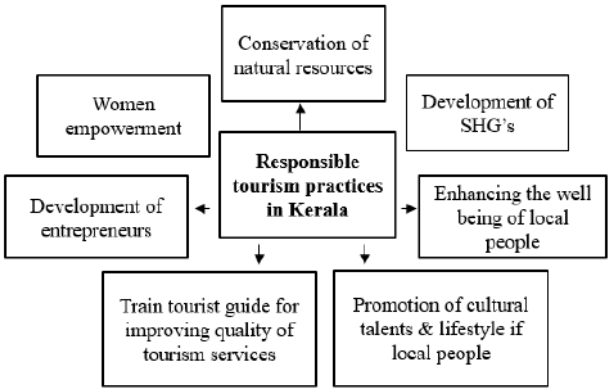

Figure 1Responsible tourism practices in Kerala

Source: Author generated

Map not to scale

Figure 2 Destinations of RT in first and second phase

Source: Author generated

B. Benefits from responsible tourism

The three types of benefits from responsible tourism mission are economic benefits, social benefits, and environmental benefits. Experiential tourism was promoted in responsible tourism mission after the year 2017.

1. Economic benefits

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The different programs introduced to promote local community participation of responsible tourism are local production groups, supply groups, microenterprises, and farmer groups for supply of products to different tourism industries which are hotels, resorts and other types of enterprises. All this were led by Local self-governments. Excess produced materials are distributed to the local market by various outlets [9].

2. Social benefits

Skill development Programmes for marketing local products, souvenir making. Art and cultural promotions by introduction of cultural groups among local community to perform dance performances and other local cultural form of arts at hotels/ resorts etc. with women and children's cultural group for traditional artistic performances. Samrudhi food restaurants group identified traditional and authentic food products and sold it out to the visitors which could generate a good local income to the community people [9].

3. Environmental benefits

Environmental problems at tourist destinations in Kerala such as pollution, land use change, waste management etc. was resolved by environmental programs such as Waste Management programs, Protection of Mangroves and Local Trees, Reconversion of Fallow Land to Cultivable Land [9].

IV. Inferences from Literature Studies

The responsible tourism development can be measured by considering the quality of life and standard of living in terms of economic, environmental, social and cultural factors and its efficiency in long term run at every RT implemented destinations.The successful and effective running of responsible tourism can not only be identified through indicators and parameters related to activities of responsible tourism but also by the role of government and non-government organizations at local level, destination level, and national level. The revenue generating programs of responsible tourism are village life experience programs, souvenir units, production units, supply units, micro enterprises, art and cultural groups. The benefits from RT can be measured by considering two types of benefits.

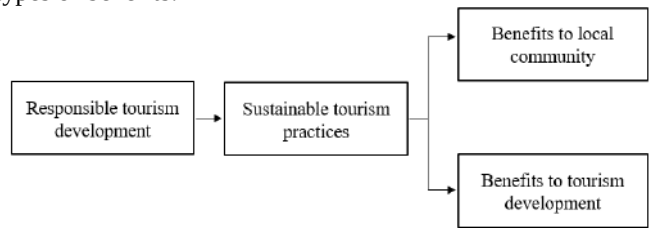

Figure 3 Two types of benefits and development from responsible tourism

Source: Author generated

V. Case Studies and Key Informant Interviews

A. Indicators identified from Case studies

A comparative analysis of five different case studies were done to identify the methods, techniques, indicators and tools used for the effectiveness study of community based tourism. From first three cases studies which includes Critical Success Factors for Community Based Tourism (CBT) initiatives, Impact of responsible tourism initiative in Kerala-A case study of Kumarakom panchayat, A study on the community development through responsible tourism practices in Wayanad district, An Assessment of Local Community Involvement in Community Based Ecotourism Planning and Development: Cameroon [1][2][5], the most used method of study for the community participation studies are both quantitative and qualitative and includes various methods of collection of data which are semi structured interviews, Questionnaire survey and observation. Analysis tools are statistical analysis by percentage method, Likert scale method and establishment of relationship between different factors.

Two more case studies was done which involves both quantitative and qualitative and includes data collection methods like Questionnaire survey, semi structured interviews, Focus group discussions, filed observations. Data description, classification and linkage between different categories i.e. interactive circular qualitative data analysis, Likert scale method, SPSS software for deriving the relationship between various factors etc. were used as analysis tools.

All the studies had common indicators which can measure the involvement of local community in tourism and how they contribute to the growth of tourism development. The below table shows the identified indicators for analyzing the effectiveness of responsible tourism in Kerala.

Table 1 Indicators identified for measuring the effectiveness of responsible tourism

Employment opportunities
Income generation
Standard of living
Role of local people in decision making of tourism development plan
Impact on livelihoods
Women participation
Economic generation
Relationship between various stakeholders
Poverty alleviation
Infrastructure development
Revenue generation
Growth of tourism service providers
Microenterprise growth
Expenditure and Income of tourist
Growth of heritage and culture

Source: Author generated

B. Indicators identified from key informant interviews

From literature case studies, different sections of people were identified and key informant interview was conducted among the members or stakeholders involved in responsible tourism activities of Kumarakom, Vythiri, Kovalam, and Thekkady.

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The figure given below shows the methodology adopted to do the key informant interview of people and authorities from the four different destinations of Kerala.

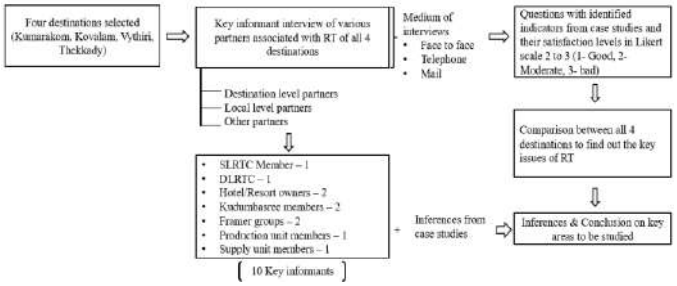

Figure 4 Methodology for selection of sample informants for the key informant interview

Source: Author generated

The stakeholders pointed out few areas of key areas and issues of the community from responsible tourism activities.
The identified areas of issues from the key informant interviews are as shown below

Table 2 Key areas of issues identified from literature studies of responsible tourism

AREAS	KEY ISSUES
COMMUNITY BASED TOURISM PERFORMANCE	• Involvement of local community in decision making • Profit from tourism • Investment of local community in tourism improvement • Tourism satisfaction from community based tourism activities • Marketing of community based tourism • Tourism training among local people
STAKEHOLDER INVOLVEMENT	• Coordination of local self government bodies at the destination • Local people's willingness to involve in RT initiatives • Tourist willingness to involve in RT initiatives/activities
ENVIRONMENTAL	• Management of waste generation and disposal • Quality of services • Environmental awareness among local people • Protection of natural areas and forests • Availability of land areas for developmental activities
ECONOMIC	• More local employment opportunities • Generation of more income • More employment opportunities for women • Generation of new jobs sectors • Working of new production and supply units
SOCIAL & CULTURAL	• Change in traditions and culture • Development & management of heritage areas • Improvement in health & education • Involvement of marginalized sectors • Community perceptions on tourism & its development

Source: Author generated

VI. Derived Methodology for Assessing the Effectiveness of RT

A. *Development of parameters and indicators from literature and case studies*

From the above studies the areas that have to be focused in order to understand the success and failure of responsible tourism was identified. Considering the benefits to both sections namely local community and tourism sector indicators are divided taking social, cultural, economic and environmental factors.

1. Areas of benefit to local community

The local community are the people who are active participants of the responsible tourism initiative who have maximum benefit in terms of employment, income, standard of living, better opportunities to involve in tourism development plan etc.
From the above identified indicators and tools of responsible tourism from literature studies, the following are the areas which have to be studied and analysed in order to understand the benefits and demerits of this practices in tourism at these destinations of Kerala which are local employment generation, employment opportunities for women, generation of more income, more profit from tourism, marketing of responsible tourism, opportunities to invest more in tourism development, generation of new job sectors, new production and supply units, percentage of products and services consumed by tourist which are produced locally.

2. Areas of benefit to tourism development

Along with the benefit to local community through responsible tourism activities, there is a benefit to the tourism through development with the running of certain areas like increase of market demand, development of local infrastructure, revenue generation from activities, shops, resorts etc. From the above studies certain indicators or areas are found where the research or study can be conducted so that the contribution of responsible tourism to tourism development can be analyzed for better improvement of the area in the future. The areas are market demand, growth of infrastructure, growth of culture and heritage of a place, revenue generated from tourism activities and improvement in transportation facilities.

B. *Tools developed for effectiveness of tourism measurement*

Various indicators developed for the study from the case studies and literature case studies are categorised under 4 categories which are social indicators, economic indicators, and socio-cultural indicators. Tools for analysing each of the component identified. The various tools identified are yes or no questions, range values, count or numbers, Likert scale.

1. Socio cultural and Economic indicators for local community

The socio cultural factors identified from the study included the topics like community involvement, resident's satisfaction, handicrafts and performing arts, gender equity and social inclusion.

The economic dimensions identified from the study included the topics like Income generated from tourist, Economic generation from tourism production and supply units, Micro-enterprise.

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Table 3 Social, Cultural &Economic indicators to measure local community benefits

Income generated from tourist	• Wage rates on an average among local people • Number of employed local community gender wise • Percentage of people who works in accommodation facilities • Number of community run tourism businesses
Economic generation from tourism production and supply units	• Number of employed local community gender wise • Revenue generation from tourism activities • Percentage of people who works in accommodation facilities • Number of community run tourism businesses
Micro-enterprises	• Total number of Small and Medium Enterprises operating in the community
Community involvement	• Degree of community participation in tourism development • Percentage of potential local establishments • Benefits and problems from RT to local people
Residents satisfaction	• Local satisfaction with tourism • Percentage of residents who would prefer less tourists • Percentage of residents who believe tourism has helped improve services & infrastructure • Percentage of residents who are satisfied with their level of involvement in tourism planning discussions
Handicrafts & performing arts	• Number of souvenir units & number of training performing arts groups • Tourist satisfaction with quality of souvenirs • Income from souvenir trade & Income generated by performances at designated hotels • Expenditure of tourist for this products
Gender equity and social inclusion	• Percentage of tourism employees that are female • Percentage of owner-operator tourism businesses run by women/me

Source: Author generated

2. Social, cultural and economic indicators for tourism development

The activities of the local community members indirectly helps in the development of standard of living of people as well as the development of services and infrastructure facilities of the area which can contribute to tourism development indirectly.

Table 4 Social, cultural and economic indicators to measure tourism development benefits

National tourism earnings	• Percentage of employment provided by tourism • Average growth in total tourism expenditure per visitor • Total expenditure per tourist per day • Change in number of visitor arrivals • Average tourist length of stay
Tourism development	• Existence of land use or development planning processes • Percentage of new tourism developments • Number of programs which get back income to both tourism sector & local people • Number of tourism developments not in compliance with tourism plan
Facilities & services	• Tourist satisfaction with sites facilities and services • Percentage of growth of infrastructure facilities • Percentage of visitors making return trips • Number of hotels undertaking guest satisfaction questionnaires
Visitor flows	• Percentage of visitors to the destination per year • Participation of tourists in local activity packages • Amount of profit from using of public transportation
Tourist satisfaction	• Tourist satisfaction with the tourism of destination • Tourist satisfaction by local people behaviour and coordination • Tourist satisfaction with facilities at sites
Business performance	• Businesses offering tourism services as percentage of all businesses • Cost/price ratios of accommodation, attractions, tours and packages compared to industry/competitors • Value of new foreign/resident applications for hotel development per year
Stakeholder role	• Degree of stakeholder involvement in preparation of tourism plans • Percentage of industry stakeholders • Percentage of landowners leasing land to tourism investors • Number of stakeholder communities satisfied with their role in tourism development

Source: Author generated

4. *Environmental indicators which affects both local community and tourism development*

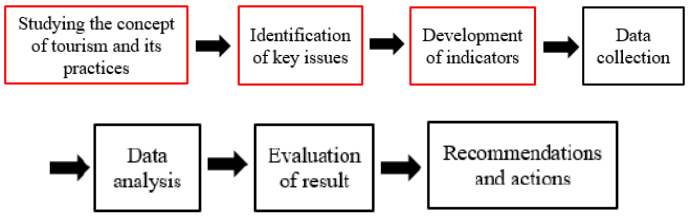
The environmental factors identified from the study to measure the effectiveness of RT towards tourism development and local community benefits are solid waste, environmental initiatives and land management.

Table 5 Environmental indicators for measuring both local community and tourism sector benefits

Solid waste	• Amount of waste produced per year, per tourist by type • Number hotels separating composting/recycling 25% or more of their waste
Environmental initiatives	• Plastic control programs • Efficiency of this programs • Percentage of people using the waste disposal facility
Land distribution	• Percentage of land developed with tourism activities • Percentage of land damaged by tourism activities

Source: Author generated

B. Steps formulated for the assessing the effectiveness study



The table below shows the processes involved under each of these steps for assessing the effectiveness of responsible tourism in a destination.

Table 6 Steps and processess involved in RT study

STEPS	PROCESS
Study of concept	• What is responsible tourism • Programs under responsible tourism • Destinations of implementation
Identification of Key issues	• Identification by participants of study from communities • Order of priority • Suggestions from authorities on the method and techniques of study
Indicator development	• Indicators according to key issues identified • On the basis of sectors of tourism based on different aspects
Data collection	• Identification of data collection methods • Preparation of questionnaire & interview survey
Data analysis	• Identification of a data analysis method • Preparation of a database
Evaluation of results	• Understanding of the problems • Sorting of problems according to the priority • Discussion with a group of people from community & authorities involved
Recommendations & actions	• Listing of possible causes for poor management of identified indicators • Preparation of action plan for the issues • Discussion of the formulated strategies or plan of action with authorities • Finding of ways to implement it for better responsible tourism at destination level

Source: Author generated

VII. METHODOLOGY TO ASSESS THE EFFECTIVENESS OF RT IN KERALA

From the above study a total methodology is adopted for the effectiveness study of responsible tourism at destination levels. The detailed methodology steps are as shown below

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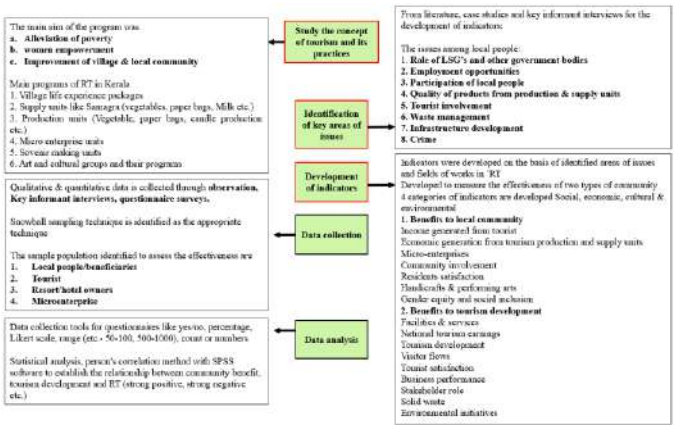

Figure 5 Detailed methodological steps for the study of RT

Source: Author generated

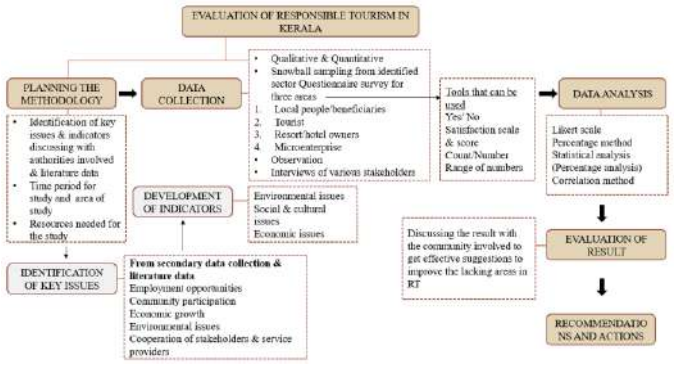

Figure 6 Methodology to assess the effectiveness of RT

VIII. Conclusions

The identified method of study is both quantitative and qualitative which includes key informant interviews, Questionnaire survey and observations. The sampling technique that can be used is snowball sampling technique which can help to choose people from different fields of the responsible tourism practices like tourism industry, microenterprise, local community, supply and production units, village life experience package areas, heritage and cultural shops, activities etc. Social, cultural and economic indicators in two categories which includes local community and tourism development. Tools are identified to measure each indicators of responsible tourism activities which can show the benefits and negative impacts of tourism at destination levels in Kerala and measures can be taken to improve the practices of RT at these areas. A proper methodological framework is formulated at the end of this study which acts as a guideline on how to conduct a study to on the effectiveness of responsible tourism initiative at destination level in Kerala. The methodological framework is as shown below.

IX. Avenues for Future Research

The formulated methodology from the study can be applied at a destination in Kerala with proper use of available resources for a research that can ensure a proper result of the effectiveness of responsible tourism in Kerala and can help to identify areas of issues that have to focused on for better growth and benefit to local community and tourism development with the participation and opinions of local community in responsible tourism.

Acknowledgement

I sincerely thank my guide Associate professor Lakshmi S.R for guiding me throughout the project, all other faculties of the Department of architecture, CET Trivandrum and A. Kasturi Rangan for his guidance. Special thanks to all authorities who gave valuable information regarding the topic and participants of key informant interview and god almighty for the good blessings.

References

[1] B.Sudheer. (2015). Economic economic and cultural impact of responsible tourism initiative in kerala-a case study of kumarakom panchayat. New Delhi: University Grants Commission.

[2] Arnab gantait*1, G. A. (June (2019)). Sustainable Destination Development through Responsible Community Based Tourism Initiatives.

[3] G*, N. (2015). Local Community Involvement in Tourism: A Content Analysis of Websites of Wildlife Resorts . Atna, J Tour Stud,10,, 13-21.

[4] AAlshboul, K. (2016). Assessing Local Community Involvement in Tourism Development around a Proposed World Heritage Site in Jerash, Jordan . Waterloo, Ontario, Canada,.

[5] Ekwale, A. E. (2014). An Assessment of Local Community Involvement in Community Based Ecotourism Planning and Development: The Case of Takamanda National Park. South West Region, Cameroon . Gazimağusa north Cyprus: Eastern Mediterranean University .

[6] Emerging Trends in Kerala's Responsible Tourism, IOSR Journal of Business and Management

[7] Aref, F. (2011). Sense of Community and Participation for Tourism Development. Life Science Journal, Volume 8, Issue 1, 20-25.

[8] https://www.keralatourism.org/responsibletourism/destination/keralaupdate.php

[9] https://www.responsibletravel.com/holidays/kerala/travel guide/responsible-tourism-in-kerala

[10] http://asiapacific.unwto.org/content/responsible-tourism-initiative-kerala

[11] department, T. (2018). Kerala tourism. Retrieved from www.Keralatourism.org

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Assessment of the Quality of Urban Parks in Kerala context

A case of Ernakulam city

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***Abstract*—** *Urban parks and green spaces can provide multiple benefits to the people and the surroundings, from tangible socio-economic values to intangible quality of life. Growing urbanization in the city has resulted in pollution, congestion and lack of efficient utilization of spaces. Thus, open spaces can give a structure and life to the city, where urban parks are breathing spaces. These breathing spaces are multi-functional and are a social necessity in an urban context as it contributes to a healthier life both mentally and physically. Hence the planning strategies should reflect a wider vision by including consultation and involvement of multiple stakeholders. This study aims to formulate a tool for assessing the quality of urban parks in the Kerala context by analyzing various literature and case studies that define the concept of quality for an urban park. As a result, the quality criteria is defined based on four factors: Natural factors, Social factors, Design considerations, Maintenance and services. The formulated tool is applied on to a primary case study, Subhash Park in Ernakulam within the KCR (Kochi City Region), since it is the most urbanized metro city in Kerala context and faces rapid growth with lack of planned open spaces. The determined quality was assessed at Subhash Park using three categories of the tool: Questionnaire survey, Key informant interview and Observation to understand the activity pattern. It was concluded that this tool gives scope to understand the need to maintain public urban parks, to identify deficiencies, to secure new provision, and to improve its quality while planning for a location, purpose and need of a park. The result of this study is being used to guide future research regarding the development of a framework in planning to define aspects of the quality of urban parks in the Kerala context.*

Keywords—*Urban parks; Green space; Open space; Quality; Assess; Activity pattern; Subhash park; KCR*

I. INTRODUCTION

Public green space plays a vital role in sustaining the public realm. A public realm is created by including parks and open spaces that blend with the context, as both built and open spaces mutually benefit to each other by its degree of usefulness to the people around. The major objective of urban parks is to create a point of attraction or reference which can be entered for a social communication in a natural environment which is built artificially or developed naturally. This space can be a primary solution to the negative impact of urbanization, pollution and congestion. Therefore it is necessary to maintain and develop urban parks, especially in cities by valuing its quality. There are various tools which include empirical and theory based principles for measuring the quality of any green spaces, open spaces and public spaces. Therefore in Kerala, where such effective planning of urban parks are lacking, this research would help in the formation of quality green spaces through extensive study on literature, along with related case studies and primary survey.

The aim of the research is to formulate a tool for assessing the quality of urban parks in Kerala context. The key objectives are:

(i) To conduct a background study and understand the importance and issues of urban parks in different context.
(ii) To identify various tools to assess the quality of parks.
(iii) To formulate an appropriate tool with necessary parameters for assessment.
(iv) To test the applicability of the tool derived from the literature study in an existing park in urban Kerala context.
(v) To develop a framework of tool from secondary and primary study to define aspects of quality in parks.

The methodology of the study includes empirical and theory based consolidation of the literature studies, along with the implications of fact and practically collected data for the formulation of a tool to assess the quality of urban parks in Kerala context.

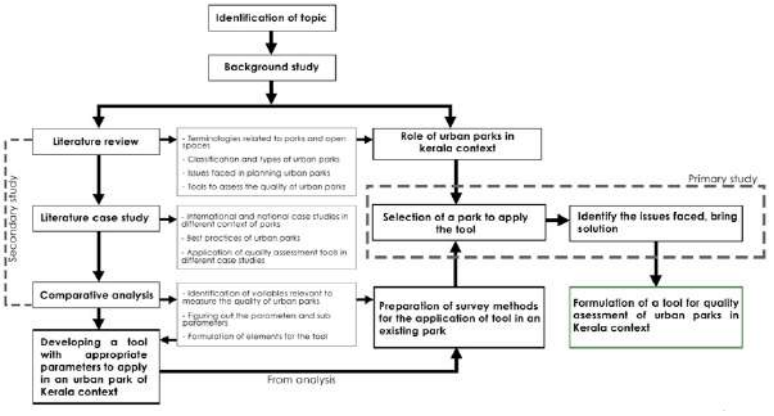

Figure 1: Methodology

The study is an exploratory research with more qualitative content. Perspective of multiple users are considered through sample surveys. Both objective and subjective type of questionnaires will be involved to include the user's vision into final conclusions.

Urban parks are multi-functional and is a social necessity in an urban context as it contributes to a healthier life both mentally and physically. The study gives the scope to understand the need to maintain public urban parks, to identify deficiencies, to secure new provision, and to improve its quality. This research outcome is evolved from the critical analysis of the literature, secondary and primary case studies, through which the term quality for urban parks will be defined. The conclusion of this study will act as a tool for future development and alteration of urban parks to define its quality for Kerala context.

II. LITERATURE REVIEW

A. *Open space and its hierarchy*

An open space cater towards the development of an area by bringing in quality use of that particular space depending on the need of the society. It is the breathing space of a city and is multifunctional. Urban open space is a broad notion which includes parks, green spaces and other open areas. It can be natural or artificial, however, these spaces become unusable, when it is not planned depending on the need and demand of the locality. Thus, considering the need of open spaces in a city, URDFI guidelines have put forward various categorization and the area to be served for different population.

The hierarchy of green space in plain area is as shown in the figure:

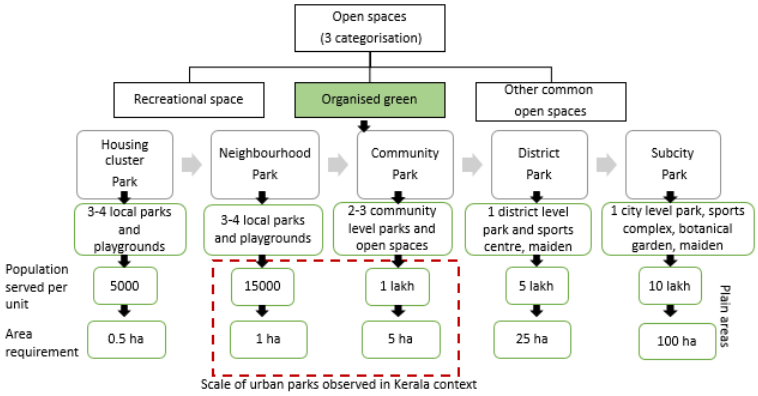

Figure 2: Hierarchy of parks (Source: URDPFI guidelines)

B. *Urban parks*

"Frederick Law Olmstead, the "father" of urban parks, argued that parks should be built as places where city residents could experience the beauty of nature, breathe fresh air, and have a place for "receptive" recreation (music and art appreciation) as well as "exertive" activities. Parks are also places where people can socialize with friends and neighbours." An urban park is important towards the city sustainability. Therefore the assessment the quality of urban parks should begin from the need of a sustainable city. Urban parks have a strategic importance for quality of life in our urbanizing society and play a significant role in increasing the liveability of cities (Biddulph, 1999). Urban parks, open spaces and green places are effective in permitting urban residents to get closer to nature and in developing positive behaviours such as adapting to and embracing the environment in which they live by increasing their socio-cultural awareness (Gold, 1980). A park is created according to the public need. The needs, possibilities and demands of people in cities grow with time, as a result the urban parks should also develop simultaneously; otherwise they become unusable spaces (dead space) that do not cater with the needs of the urban population. Therefore, the planning and management of urban parks should include the wider view from general public, along with the professionals.

The benefits of urban parks depends on the purpose for which it is created and will have multiple function to the society and towards the development of the city with a healthier life. Urban parks fulfil several functions, including providing opportunities for air circulation in and around the city, moderating temperature, absorbing or disseminating noise, providing landscape and sources of nature, providing a refuge where urban residents can escape from the crowd, noise and stress of the city; urban parks also provide psychological support in terms of refreshing people and adding value to their daily lives as they increase the quality of society in terms of education, health, psychological, aesthetic and cultural aspects (Yıldızcı, 1978; Richter, 1981; Ulrich, 1988)

The quality of urban parks includes different parameters that is derived from empirical theoretical studies. Quality was defined as the 'gestalt' attitude towards a service which was acquired over a period of time after multiple experiences with it (Parasuraman, Zeithaml and Berry, 1985). It is the degree to which opportunities satisfy the motivations for which they were designed. Hence, the challenge of providing high quality recreational services would become less difficult when agencies are aware of what their patrons desire from their services (Mackay and Crompton, 1990). Quality is not solely about techniques and procedures but includes people who actually use the techniques.

Quality criteria in this study will be determined from the parameters developed from each criteria used by authors for quality assessment of urban parks, as shown below:

Table 1: Quality assessment criteria of urban parks (Source: Smith et al, 1997; Marcus and Francis, 1990)

Sl.No	Year	Author	About	Quality assessment criteria
1.	1997	Smith et al.	list of **quality and needs principles for urban communities**. They focused on **six key factors** for reaching success/quality in designing urban places	1. Livability 2. Character 3. Connection 4. Mobility 5. Personal freedom 6. Diversity
2.	1990	Marcus and Francis	**outdoor places can be assessed as eligible/qualified** if they are	1. easy to access and view; 2. have aesthetic attraction; 3. provide the activities to meet the expectations of users; 4. provide safe and natural environments; 5. arranged 6. according to climatic changes; 7. regularly maintained.

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III. LITERATURE CASE STUDY

A. Comparative study of the identified literature case studies

Table 2: Comparative study of literature case studies (Source: Author generated from Ter U, 2011; Malek N, 2010; Siregar J, 2014)

	Case 1	Case 2	Case 3
Name	**The case of Alaaddin Hill**	**Assessing the Quality of Green Open Spaces**	**Assessment Of Public Space Quality**
Location	**Konya-Turkey**	**Malaysia**	**Indonesia**
Year	2011	2010	2014
Author	Ummugulsum Ter	Nurhayati, Manohar, Mustafa, Azlizam	Johannes Parlindungan Siregar
Department	Department of City and Regional Planning Selcuk University	Dept. Landscape Architecture and Dept. Park and Recreation Management	Urban and Regional Planning University of Brawijaya; Indonesia
Objectives	• To propose quality criteria for assessing the role of urban parks in increasing quality of life for people living in cities. • To determine design principles for creating a qualified living environment.	• **Development of tools** to evaluate the aspects of **quality in a Malaysian neighbourhood park.** • Explaining the causal relationship between **use patterns**, **needs**, and **preferences** towards achieving a Quality Neighbourhood Park.	• To explore characteristics of public space in the adjacent local roads and inner part of residential block. • Assessing quality of public space and evaluating the quality in relation to existing physical feature.
Area	26 acres (10.5 ha)	15 locations	3 streets
Methodology	Method 1: Visitor's Questionnaire 3 sections. Method 2: one-to-one interview, observations, photographs; visual materials such as drawings and schemes.	**theory-based consolidation**	**Good Public Space Index (GPSI) concept**. Data for this analysis came from observations on day time. Then, the measured GPSI was analysed using multiple linear regression in relation to build environment components and gain result that of local traffic condition as the main predictor of public space quality.
Parameters /attributes/ tools	User, Activity/Variety, Comfort and Image, Sociability **Assessment of study:** sensorial effects on users, physical and visual quality of activity places, accessibility	**Structural equation modelling (SEM) Technique** **Theory of reasoned action (TRA)**	**Good Public Space Index (GPSI)** 1. Diversity of use 2. Variety of use- activities 3. Diversity of users 4. Intensity of social use 5. Peoples duration of stay 6. Intensity of users
Analysis	Quality assessment likert scale. Percentage on type of users, duration of use, time of use, frequency of visits, period of visits, mode of transport to visit the area, preferable area to visit. Mean and standard deviation is taken for each attributes	Theory of Reasoned Action diagram. To improve services and facilities, best variables for a quality neighbourhood park in an urban context, design attributes, neighbourhood satisfaction level, gender, socio-economic status and the cultural background.	Parameters standardized in determining GPSI on a scale of 0 to 10.
Result	The general assessment of the park is "bad", visual quality of the park was categorized as "good"		GPSI is useful in measuring **quality of public space.** **Motorized vehicle** activity has negatively dominant influence in maintaining conducive environment for outdoor activity. Support **pedestrian activities** to avoid negative influence.
Inference	This study is important since it proposes **design principles for urban parks**, improves current situation and informs the design of new urban park areas. Urban parks is necessary in locations where the **relationship between humans and the environment** is damaged.	**Neighbourhood park** was chosen as the subject of assessment for this tool because it has **social, economic and cultural values** on our everyday lives. It defines the concept of quality for a neighbourhood park. The result from this study is can used to guide future research regarding the development of a **framework to define aspects of quality** in Malaysian local parks.	In GPSI, certain parameters will be identified to analyse the quality of the parks. Using those **parameters** different cases are analysed and the range of its value can be calculated.

Along with the international literatures case studies as shown in Table 2, national case studies have also been compared for the identification of theories and parameters for the development of tool for assessing the quality of urban parks.

B. Theories and tools for the assessment of the quality urban parks from the literature case studies

Grounded theories are important to state any aspect of both tangible and intangible factors. Hence, while proving the quality of urban parks factors and parameters from such theories will be useful for its practicality. Some of the identified theories and tools to assess the quality of public urban parks are: Good public space Index, Structural equation modelling (SEM), Theory of reasoned action.

IV. ANALYSIS AND INFERENCE

A. Comparative analysis of literature case studies

Comparative analysis of literature case studies listing the variables relevant to measure quality of urban parks has been categorized based on four factors. The location, context, site categorization, sample size and research type have also been considered important. The scale of the park is primarily compared with the identified factors to assess the quality factor of an urban park.

Table 3: Comparative analysis of literature case studies (Source: Author generated from the analysis of secondary studies)

Sl.No	Year and source	Country	Site categorisation	Sample size	Research type	Variables relevant to measure quality of urban parks
1.	2011 Ter U	Turkey	Urban parks 26 acres	350	Empirical	Natural factors: visual quality, green space, air quality Social factors: interactive space, younger users (16-24), activities Design considerations: easily accessible, city furniture. Maintenance and services: Safe and management.
2.	2010 Malek et al	Malaysia	Neighbourhood park	_	Theory	Social factors: User satisfaction and use pattern Design considerations: Preference based.
3.	2014 Siregar J	Indonesia	Public space (residential area)	_	Theory & Empirical	Natural factors: atmosphere and ambience Social factors: User satisfaction Design considerations: Seating space, all age groups usable. Maintenance and services: Safe
4.	2010 Jim and Chen	Hong Kong	Neighbourhood parks	18 pvt apartments	Empirical/ case study	Natural factors: Natural element, aesthetic quality of plants, environmental functions. Social factors: community pride, humanized, familiar, social interaction. Design considerations: Urban aesthetics, conveniently located, easily accessible. Maintenance and services: neat and managed, safe and economic value.
5.	2009 Chen et al	China	Urban green space	280	Empirical	Natural factors: Scenic beauty, peace with nature, plants identity, smell/scent. Social factors: Opportunity of social contact, cultural features. Design considerations: proximity to residence, visual quality.
6.	2009 Sugiyama et al	UK	Neighbourhood open space	1818	Empirical	Natural factors: Pleasantness. Social factors: Social interaction and sense of community. Design considerations: Quality of path and facilities, actual use. Maintenance and services: Safe
7.	2006 Sanesi and Chairello	Italy	Urban green space	351	Empirical	Natural factors: More green spaces, relax air quality. Social factors: Usage, space for socialising and leisure, younger user, accompany by friends, family and pets. Design considerations: quality and quantity of green spaces, more facilities, children play equipment, sport facilities, walking areas, cycle tracks. Maintenance and services: improvement of management, funding, safety and security.
8.	2006 Hillsdon et al	UK	Urban green space	4732	Empirical	Natural factors: atmosphere. Social factors: usage. Design considerations: accessibility and connection, recreational facilities, signage and lighting. Maintenance and services: good maintenance and services, amenity provision.
9.	1997 Smith et al	Canada	Urban community	_	Theory	Social factors: Walkable community. Design considerations: outdoor amenities, lots of seating, accessibility and connection, character and distinctiveness. Maintenance and services: Barrier free

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B. Inference from the secondary studies

Based on the analysis of the literature review and literature case study, the following parameters: (i)Natural factors, (ii)Social factors, (iii)Design considerations and (iv)Maintenance & services, have been considered to convert it into a tool.

Parameters and sub parameters for formulating the tool to assess the quality.

1) Macro level factors

Table 4: Macro level parameters (Source: Author generated)

Parameters	Sub parameters		Elements for the tool
(i)Natural factors	Visual quality	Aesthetics	Design of the park
	Air quality	Context, waste management	Proper waste disposal
	Ambience	User specific	Music, noise Free
	Green space	Landscape	Planned design
(ii)Social factors	User satisfaction	Easy flow of circulation	Most used space
	Interactive space		Most unused space
	User activities/pattern		Time of use
	Walkable community		Mode of transport

2) Micro level factors

Table 5: Micro level parameters (Source: Author generated)

Parameters	Sub parameters		Elements for the tool
(iii)Design considerations	Accessibility	Vehicular, pedestrian, wheel chair	Segregated flow of circulation
	Seating space		Position and type of seating
	Character		Identity of the park
	Play equipment		Maintained objects
(iv)Maintenance and services	Safety		Safe design for children
	Security		24 hrs security
	Barrier free		wheel chair access
	Funding	Source of funding in maintenance and upgradation	Periodical maintenance

V. PRIMARY CASE STUDY

The secondary studies, it proves that parks are essential in any context. When compared to the number and area of parks in international and national scenario, Kerala has least in both number and area.

Even though some open spaces are converted into parks, due to lack of planning it most are left unused. In a developing urban context, parks can act as a relaxing space for all the age groups, when it is multifunctional (Usable by all the age groups). There are three urban parks in Kerala context which has the scope to apply the tool formulated from the secondary study, due to its location, context, function and area (between 1ha to 5 ha). Namely:

1) Subhash park, Ernakulam- 11.5 acres (4.65 ha)

2) Napier Museum Park area, Trivandrum- 9.2 acres (3.73 ha)

3) Mananchira park, Kozhikode- 3.5 acres (1.4 ha)

A. Primary study area

Urban parks in locations where the human-nature linkage is under serious damage, increasing building density and proliferated traffic congestion, provides a wider spectrum of attractions such as an opportunity for the community to relax and re-discover the contact with the nature around. It is necessary to regain the deteriorating environmental quality of the urban parks.

Urban parks is a major dependent factor for quality of life in our urbanizing city and play a significant role in increasing the livability of Ernakulam. A metropolitan city like Ernakulam is facing intense densification due to urban sprawl. In this busy life schedule, in order to maintain the quality of life, planning of open space for public use is vital. The stretch adjacent to the Arabian Sea has its location significance and planning importance to retain it open without heavy built use. Thus, Subhash park can be an apt primary study to apply the formulated tool to assess the quality of urban parks, because of its: significance of location, area, purpose, activity and function.

B. Application of the formulated tool in Subhash Park

3 steps in the formulated tool to apply in an Subhash Park:

1) Observation

2) Questionnaire survey

3) Key informant interview

Step 1: Observation

a) Map based on the usage and design elements of the park: Prepared to identify the activity, peak time and other major functions of the space as shown in figure 4(a).

b) Map based on the Purpose of the park: The planning and design of every park depends on the purpose or need, varies with location and scale/extent. It is situated along the starting point of 1.5 km marine drive stretch, maintaining the network of leisure, a contribution towards tourism. One side is adjacent to lake, act as a catchment area and the other side adjacent to the busy district road connecting to the highways and the densest land of Ernakulam city, a relaxing space from the busy street and daily life of the context population including 3 major colleges established near the park, an active recreation space for the large number of youth around. The map was prepared considering high built density, low built density, district road, green space, built space and pathway within the park, other nearby green spaces and waterbody as shown in figure 4(b).

c) Map based on the function inside the park: The map highlights the formal and informal seating, children's play area, unused maintained and unmaintained area, amenity space, exercise space and walking area as shown in figure 4(c).

d) Map based on the user group of the park: The map delineates the area showing children zone, youth zone, middle aged group zone, all age group zone and wheel chair access as shown in figure 4(d).

e) Map based on the population density distribution during peak time: Demarcate the area with population density from 0 to 200 during the peak time as shown in figure 4(e).

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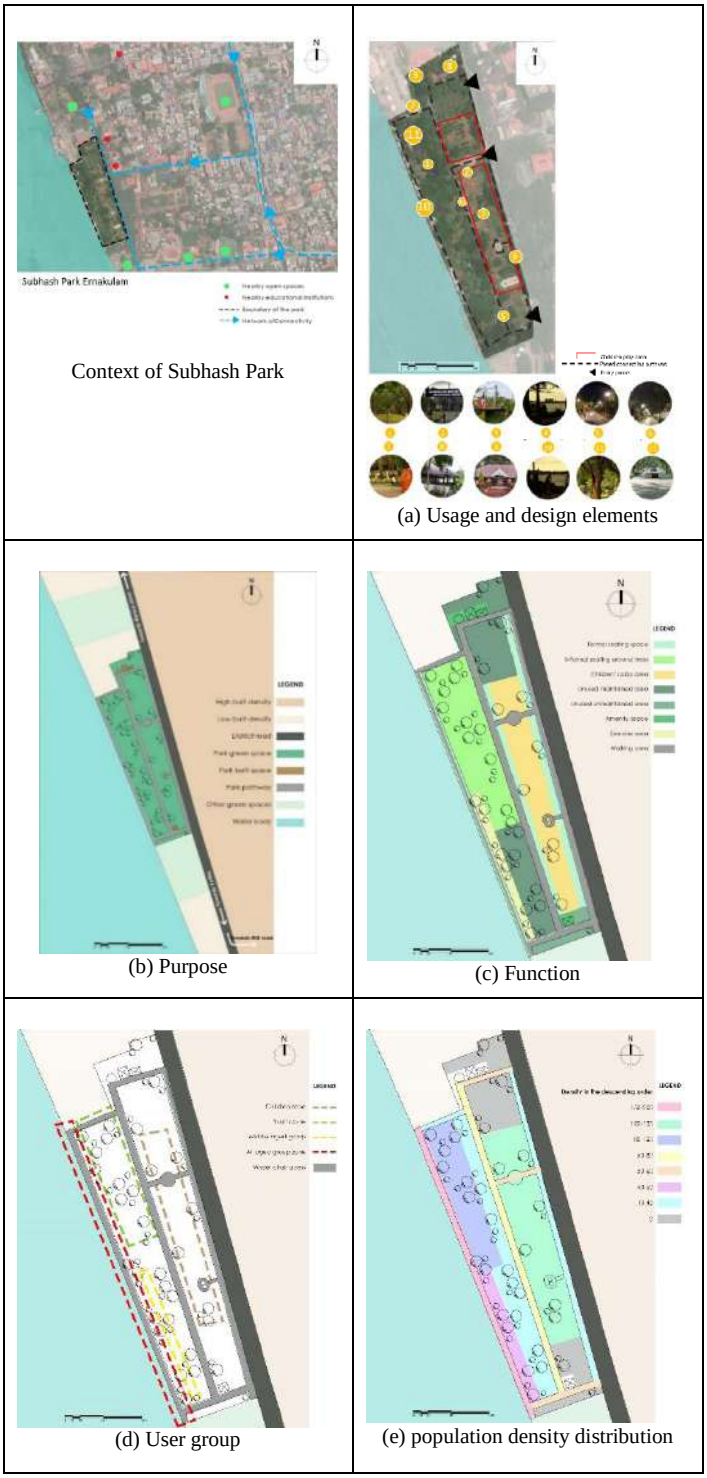

Figure 3: Mapping based on observation (Source: Primary study, 2019)

Step 2: Questionnaire survey

Using the questionnaire derived from the studies, a primary survey was conducted in the park on 30 randomly chosen sample. The questionnaire had two categories:

Category 1: Respondent details

70% of the user group is youth of 16-35 age group. 70% of the user group is under employed category and use the space for relaxing after busy schedule. 75% has a private vehicle and 54% uses it regularly. i.e. 21% are interested in using public transport, though having private vehicle.

Category 2: Usage of the park

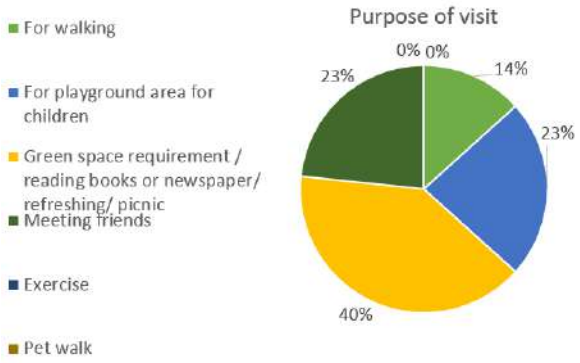

Figure 4: Purpose of the visit (Source: Primary survey, 2019)

40% of the user group uses the park for its green space, reading books, refreshing and relaxing. Only 14% uses it for walking and hardly for exercise, since the planning does not provide a separate uninterrupted track for the purpose.

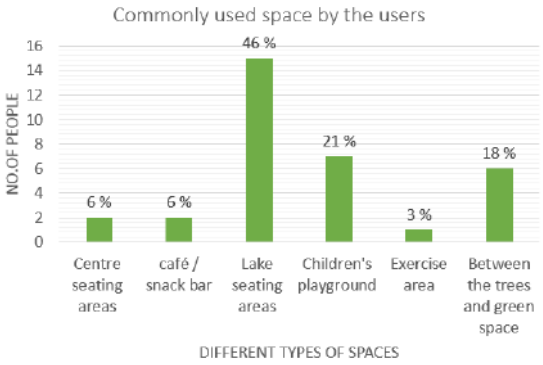

Figure 5: Commonly used space (Source: Primary survey, 2019)

46% of the user group prefer to use the lake seating areas. Exercise area is least used (3%), since the setting has no segregation from other activities.

83% of the user group prefer to use the park at evening. The frequency of the visit is very low.

59% of the visitors prefer to use the park with family. 47% of the user group prefer to reach the park by private vehicle and 23% by city bus, 17% on foot and 3% by metro, i.e. 43% uses eco-friendly means of transport to reach the park.

46% of the user group prefer to return the park by before nightfall and 33% return whenever they prefer to.

Safety within the premises: 79% are satisfied with the safety within the park premises.

Maintenance of the premises: 83% are satisfied with the maintenance of the park.

Step 3: Key informant interview

Following questions have been interviewed to the park office employees under municipal corporation, during the primary study: History of the park, Purpose of the park,

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Ownership, Funding agency, Average number of visitors every day, Timing of the park, Number of workers and securities, Monthly expense of the park, Maintenance period, Restrictions, Future vision.

The data obtained from all the three steps have been used to conclude with the findings and recommendations for Subhash Park.

VI. FINDINGS AND RECOMMENDATIONS

A. Quality assessment on Subhash Park

The assessment of the quality have been done to the identified primary case study using the formulated tool, and has come up with its findings, analysis and recommendations based on the derived four factors:

Table 6: Quality assessment on Subhash park (Source: Author generated from Primary study 2019)

Findings	Analysis	Inference/Recommendations
(i)NATURAL FACTORS (macro level)		
Location of the park: The park is located with its one side adjacent to Arabian sea, with a beautiful lake view, in the urban centre of Kochi, around mixed use.	The whole stretch adjacent to the lake is used as open space leading to the marine drive walkway. A good solution if the water level rises	Location of a park should arise based on the need of the locality and blend with the natural setting without any major destruction.
Use of nature: Trees of ages, efficient utilisation of lake view.	Well used and is commendable.	Nature is beautiful when used properly without exhausting. Natural elements in that specific context should be shaped to the identity of the park.
(ii)SOCIAL FACTORS (macro level)		
Connectivity: Connectivity to all means of transport and other open spaces	Nearest metro station is away compared bus and auto service. Hence metro commutation is least seen from the primary survey.	Connectivity is the second factor which makes a park active. Maintained footpath should be encouraged till the nearest radius, so that on foot commutation is also promoted.
Users: Park facilitates all age group users and is barrier free.	Age above 60 is lesser. More used by 16-35 age users, because of the context setting.	Purpose of the park is derived from the context. Thus more focus on the user group identified.
Functions/Activity: Functions are zoned in defined areas like playing equipment in children play area, exercise equipment near the wider lake walkway area	Major activities aimed in planning has been achieved, like the play zone for children, seating their for accompanying user, lake relaxation and walkway. But the pavilion is left unused.	A park should facilitate the activities of all the users- relax, play, refresh, read, walk, exercise, etc. Thus planning should cater all user groups.
(iii)DESIGN CONSIDERATIONS (micro level)		
Park furniture: Lack of lighting in all premises. Seating to be maintained from damage. Ample playing equipment for children.	Lack of lighting makes some area unused. Anthropometrically difficult play equipment left unused.	Seating can be of any form which is comfortable and usable, with ample lighting, focusing the view. Easier play equipment for children.
Circulation: Within the park the circulation is easier with wide visibility.	The pavement of the pathway is often damaged. Lack of lighting. Apart from the major paved pathway, undefined paths between green space gives an exploring experience	Uninterrupted visible circulation can make the user feel more safe.
Facilities: A snack bar within the premises, street vendors outside the premise. Toilet facility. Few off street parking. Music facility is an entertainment.	Snack bar is not functioning properly, which makes it difficult for the users to have basic water facility. Entry area awful with not maintained toilet.	Facilities supporting the use of park can increase the number of visitors. Payed parking, payed use of toilet and more catery options.
(iv)MAINTENANCE AND SERVICES (micro level)		
Safety: Survey says that there are some issues related to safety for women and children.	Lack of lighting in all premises a factor of safety.	A user should feel despite of their age, gender, caste or colour. Proper provision for security, installation of camera.
Maintenance: Currently the park is well maintained compared to its old situation.	Plastic waste dumped in an open area in the entrance of the park	Proper waste management, regular cleaning, Fixing of damaged park furniture, is necessary for its continuous development.

B. Framework of tool from secondary and primary study to define aspects of quality in urban parks

It has been concluded that in the assessment of the quality of urban parks in Kerala context, location and purpose is the determining element for its planning. Therefore the basic procedure for developing a tool to assess the quality of urban park, should include the preliminary framework of the tool as shown below:

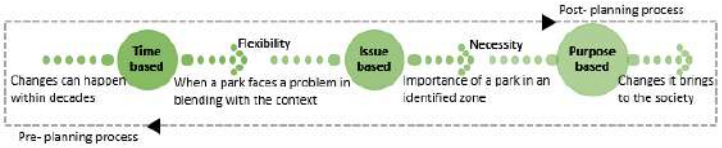

Figure 6: Preliminary framework of the tool to assess the quality of urban park (Source: Author generated)

In Post planning process, the purpose is redefined after understanding the time based changes and the impact of any issues within the location. Whereas in the pre-planning process, the purpose is figured out initially and predict with the timely changes and issues it can create. Therefore, both the process are mutually dependent. Using this preliminary framework, it can be applied on to the formulated major framework.

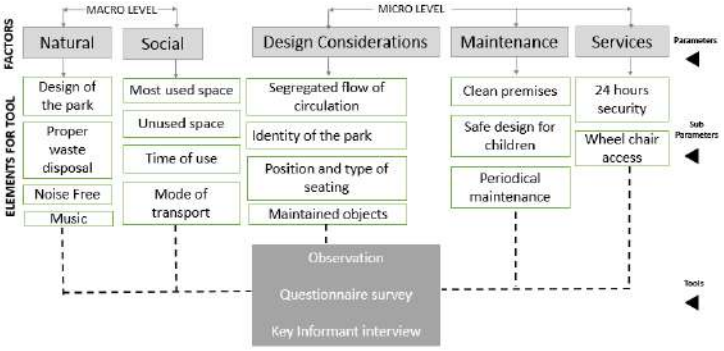

Figure 7: Major framework of tool to assess the quality of urban parks (Source: Author generated)

This framework of the tool can be applied on to any newly developing or existing urban park in Kerala context to assess its quality so that a social communication and healthier life can be promoted in the urban city.

VII. CONCLUSION

The framework formulated from this study can be used to guide future research regarding the assessment of quality of parks in Kerala context. Therefore, it can be used as a tool to analyze how to develop an open space into a useful green space, defined with specific context based activities. The application of the tool experimented in one park of Ernakulam city, can be continued by identifying all the dead open spaces and analyzing the feasibility of its development into a green network. This process can emerge any city into a green city.

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REFERENCES

[1] Eriawan T, S. L. (2017). Improving the quality of urban public space through the identification of space utilization index at Imam Bonjol Park, Padang city.

[2] Mehta, V. (2007). A Toolkit for Performance Measures of Public Space. Performance Measures of Public Space.

[3] Nurhayati Abdul Malek, M. M. (2010). Assessing the Quality of Green Open Spaces: A review. Malaysia.

[4] Siregar, J. P. (2014). Assessment Of Public Space Quality Using Good Public Index(Case study of Merjosari Sub District, Municipality of. Science direct. Indonesia.

[5] Wong KK (2009). Urban park visiting habits and leisure activities of residents in Hong Kong, China. Manag. Leis., 14: 125-140.

[6] Chiesura, A. (2004). The role of urban parks for the sustainable city. Landscape and Urban Planning (68), 129-138.

[7] Ter, U. (2011). Quality criteria of urban parks: The case of Alaaddın Hill (Konya-Turkey). African Journal of Agricultural Research.

[8] Low S, Taplin D, Scheld S (2005). Rethinking Urban Parks: Public Space and Cultural Diversity, Austin, TX, University of Texas Press.

[9] Marcus CC, Francis C (1990). People Places, Design Guidelines for Urban Open Space, Edited by; Clare Cooper Marcus and Francis, Van Nostrand Reinhold, New York.

[10] Smith, T., Nelischer, M., & Perkins, N. (1997). Quality of an urban community: a framework for understanding the relationship between quality and physical form. Landscape and Urban Planning (39), 229-241.

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Sensitive ecological issues leading to development induced landslides in urban highlands

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Abstract—**Many people are living under the vulnerable bio physical and socio cultural conditions of high lands. Developing sustainable design framework for urbanizing highlands is a major concern of present time in the context of increasing climatic issues and natural disasters. Mountain areas are always prone to natural disasters like landslides, flash floods, temperature rise etc. Landslides are one of the major issues faced by the people of urban highlands. There are many methods to control landslides and its vulnerability. We have different policies and guidelines for developing our land but these are not considering the geographical features of the areas to be developed. This is creating many issues during land development and leading to more problems. There are landslides occurring due to natural reasons and because of human activities also. This research focuses mainly on development induced landslides and the measures to control it. We have studies such as Gadgil report, Kasthuri Rangan report etc describing the issues of Western Ghats and the need for sustainable development. There are many other studies which list out different factors triggering development induced landslides in urban highlands. But all these factors can be listed under some major parameters. Finding out good methods to overcome these parameters can be the best design solutions to control landslides. It is important to have mountain specific policies and frameworks for the development of hill areas. High altitude urbanism is an important thing to be seriously considered and sustainably executed for a better future.**

Keywords—***Development induced landslides, slope instability, urban highlands***

I. INTRODUCTION

Mountains with different altitudes and variety of features are found on all parts of the world. Mountain areas are always special and difficult to handle due to their extensive array of topography, flora, fauna and its indigenous population belonging a unique cultural context. Sustainable mountain development has been an issue for many years. Almost 46.7% of all the areas of continents are above 500 meters from the sea level.This highlights the need for a sustainable design framework for urbanizing highlands as the need of the hour in the context of increasing climatic issues and natural disasters. Mountain areas are always prone to natural disasters like landslides, flash floods, temperature rise etc. All the unfortunate events have become more frequent now due to different development activities which are completely unscientific. Landslides are often considered as a local issue, but their effects cross local boundaries and may become provincial and national issue.

There are many methods to control landslides and its vulnerability. The first step includes controlling of urbanization spread on unstable slopes and sustainable management of steep areas. This study is an attempt to understand sensitive ecological issues leading to landslides on urban highlands. The causes behind it and the measures of mitigation to be taken to control it. Formulating design strategies for urban highlands will be the end result of this research.

II. NEED FOR THE STUDY

The world is now going through the horrifying threat of climate change and natural calamities. Due to population explosion sensitive hill areas are also becoming part of human interventions, creating more issues due to its fragile features. Landslides are one of the major problems we are facing in our hill towns. There are many unscientific approaches followed by human beings leading to this problem. Unauthorized constructions, improper land use, cutting trees, destroying green cover, hindering natural processes are some of the reasons. In the Past two years, the people of Kerala went through the painful situation of flood and landslides. We have witnessed the death of hundreds of people in natural disasters during last monsoon. The rhythm of climate has changed a lot. Kerala was not a place like this before two to three generations. And we don't know if our children and grandchildren can coexist if the same activities continue. Since we have lot of hill towns in Kerala, sustainable development of urban highlands is a major concern today. Even though we have many studies on our fragile ecology as Gadgil report, Kasthoori Rangan report etc, we are trapped in a terrible climate crisis. This is the time to have serious studies and researches on climate change and redefine our attitude towards development. This is one of the important topics to be studied as far as the climatic change and the condition of the environment are considered.

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III. METHODOLOGY

This study is based on secondary data. As part of background study, urban highlands and its ecology is studied. Madhav Gadgil report and Kasthoori Rangan report is referred for listing out the ecological issues of highland areas. The study focuses only on development induced landslides and the physical aspects of the hill towns. Study is not dealing with the social and administrative aspects. Causes and mitigation measures of development induced landslides are found from available studies and the parameters leading to it is listed out. It is then proved with the help of literature case studies. Literature case studies selected are Almora- Uttarakhand-India,Laipuitlang-Aizawlcity-India,Dashtegan–Rudbar landslide. After doing analysis design strategies for urban highlands for controlling development induced landslides is formulated.

IV. LITERATURE REVIEW

A. *Defining the term - Urban highland*

Mountain areas are the world's most vulnerable ecosystems. This is because of their high relief, slope and other climatic conditions. Climatic change is holding its grip on the unique eco system in the mountain areas. The physical vulnerability directly affects the social conditions of the mountain people. The mountain people have vast knowledge about the land management techniques and construction procedures that they were following traditionally [1]. But now due to modern development activities everything has changed a lot.

"Most of the times our mountain areas are becoming disaster prone area due to the inefficient policies which are made for those areas. Most of the times we don't have special policies for mountain areas. While creating policies, the challenges such as vulnerability of highlands, poor connectivity from other areas, decreasing biodiversity and marginalization in political sector etc are not considered. Effective mountain-specific policies need to be designed at the local level country level and beyond, as all these challenges are universal in nature [1].

The term "Urban highlands" can be defined as any areas around the world where urbanization happened and which have a minimum height of 300m from the mean sea level and having a slope and elevation changes from the surrounding areas.

B. *The landslide hazard*

The term "landslide" is used to describe a wide variety of processes that result in the perceptible downward and outward movement of soil, rock, and vegetation under gravitational influence [2]. The materials may move by: falling, toppling, sliding, spreading, or flowing. Although landslides are primarily associated with steep slopes, they also can occur in areas of generally low relief. In these areas landslides occur as cut-and-fill failures (highway and building excavations), river bluff failures, lateral spreading landslides, the collapse of mine-waste piles (especially coal), and a wide variety of slope failures associated with quarries and open-pit mines. Underwater landslides on the floors of lakes or reservoirs, or in offshore marine settings, also usually involve areas of low relief and small slope gradients [2].

C. *Contributing factors to landslides*

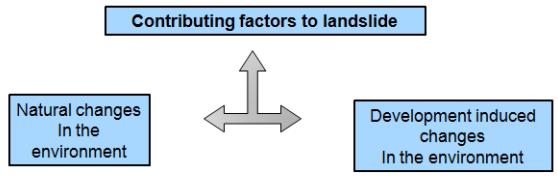

Fig. 1. *[2] Contributing factors to landslides*

D. *Basic causes of slope instability*

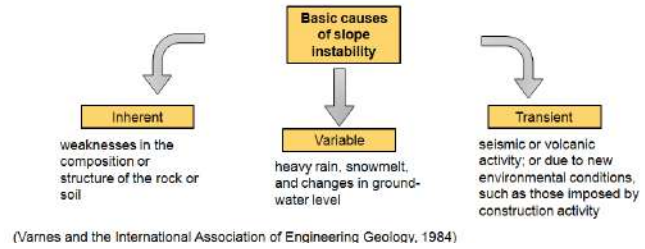

Fig. 2. *[2] Basic causes of slope instability*

E. *Mitigation measures for landslides*

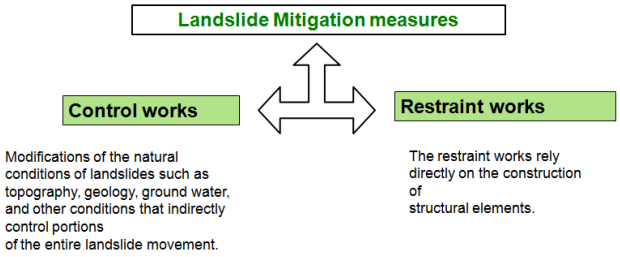

Fig. 3. *[3] Mitigation measures*

F. *Terzaghi's parameters causing development induced landslides*

The seven modes of action of agents describe the fundamental physical or chemical processes destabilizing the slope [4].

- *Slope re-profiling*

  Fill slopes, Embankments,Cut slopes, Excavation work, Construction work, Tailing hills.

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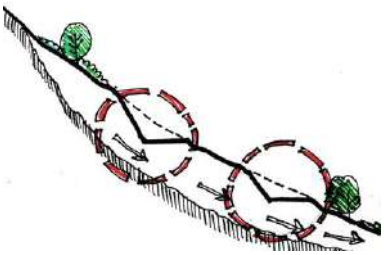

Fig. 4. *Cutting and filling of slopes (Source-Author)*

- *Ground water flow perturbation and fast pore water pressure changes*

  Pipe bursting, Dam reservoirs, Pipe leakes, Leaks in old canalization networks

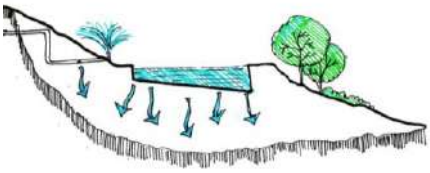

Fig. 5. *Ground water flow perturbation due to artificial water bodies (Source-Author)*

- *Surface water overland flow modifications*

  Diverting river , Deficient drainage system

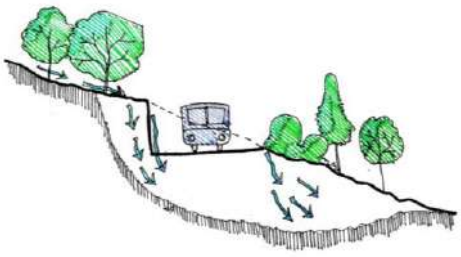

Fig. 6. *Water flow modifications due to slope disturbances (Source-Author)*

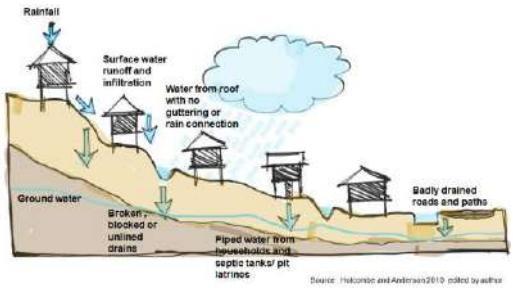

Fig. 7. *Surface water flow modifications due to unauthorized constructions over hill area (Source-Author)*

- *Land use changes and land degradation*

  Forest fire, Deforestation, Urbanizations

- *Inappropriate artificial structures*

  Infrastructure breaks, Inappropriate retaining wall

- *Vibration and explosive*

  Heavy traffic, Blasting

- *Ageing and degradation of infrastructure*

  Torrential check dams filling , weakening of terraced wall

G. Parameters of Holcombe and Anderson

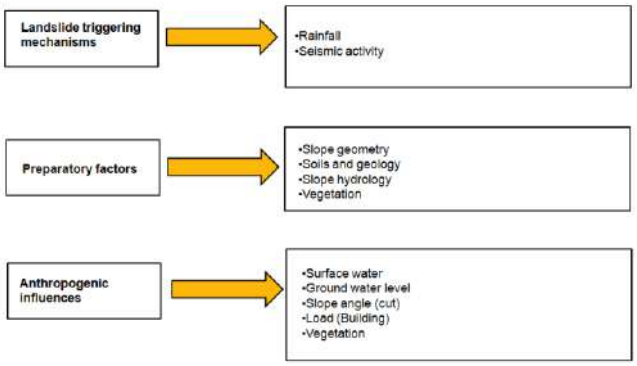

Fig. 8. *[5] Parameters*

H. Main issues on Western Ghats from the Gadgil and Kasthoori Rangan reports

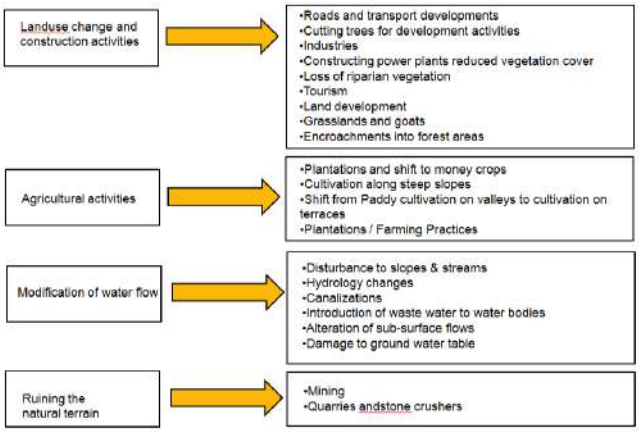

Fig. 9. *[12], [13] Issues from Gadgil and Kasthoori Rangan reports*

I. Parameters leading to development induced landslides

From the literatures referred, five parameters are found to be the major cause of development induced landslides. Those parameters are listed below in the table.

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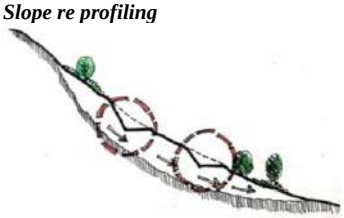
TABLE I. [4], [5] AND AUTHOR PARAMETERS LEADING TO DEVELOPMENT INDUCED LANDSLIDES

No.	Parameter
1	***Slope re profiling***  Construction of roads, Infrastructures, Mines quarry and buildings, Embankments, Fill slopes and cut slopes, Excavation work,Tailing hills.
2	***Water flow modifications (Ground/Surface water)***  Surface water or collector diversion , Water leakages, Permeability decrease or pore pressure increase by loading, Soil sealing induced by surface changes, Simple small modifications of the topography, Lake or river levels and routes variations, Irrigation,
3	***Changes in land use and land degradation***  Urbanization along slopes, Terraced slopes, Forest fires, Deforestation, Agricultural activities, Grasslands
4	***Inappropriate artificial structures and structural degradation***  Poorly designed reinforced structures, Torrential check dams filling, Inappropriate infrastructure dimensioning, Terraced wall weakening, Pipe leaking
5	***Vibration and explosive***  Blasting operations for engineering works, Heavy traffic

V. LITERATURE CASE STUDIES

A. Almora, Uttarakhand

Almora district is situated in central Uttarakhand State in India. It stands over a mountain ridge and is situated at 1440-1560 meters above from the mean sea level. On September 2010 right after a heavy rain fall which lasted for three to four

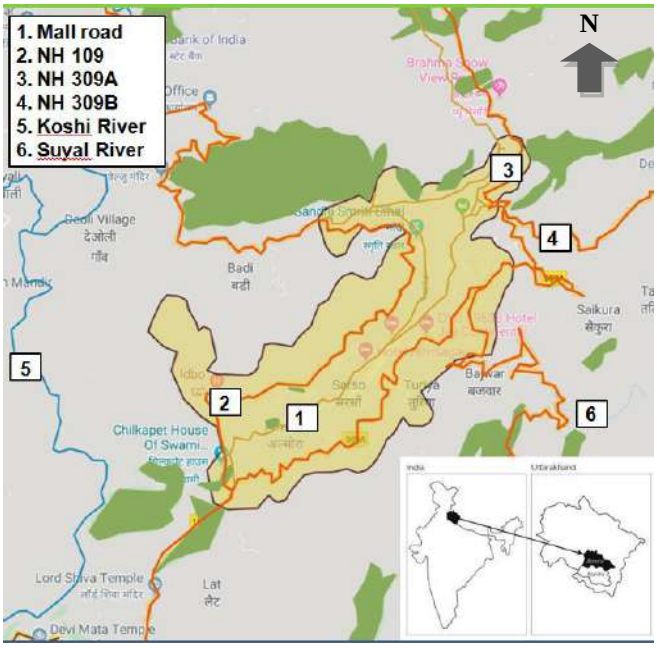


Fig. 10. *Almora Location map (Source-Google map edited by author)*

days, the landslide occurred. About 4835 km of roads were damaged and many communities were disconnected from road communication. When road criss crosses to upslope, the

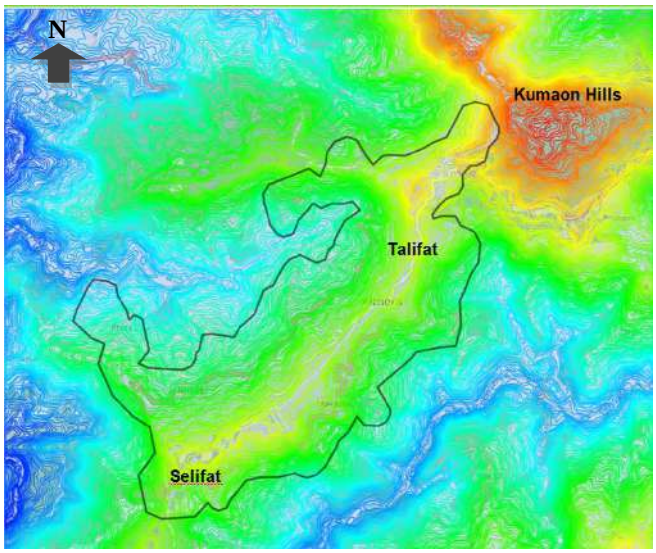


Fig. 11. *Almora relief map (Source-Contour generator edited by author)*

lower part is impacted negatively by the upper parts [6]. The green cover along the roads was diminished over the years due to development activities over the years. The terraced agricultural activities over the hill area was disturbing the nearby aquifer. SSJ campus of Almora, situated along the lower mall road purchased some part of the land for development. The yearly maintenance of the terraced land was also disturbed. All these activities triggered landslide

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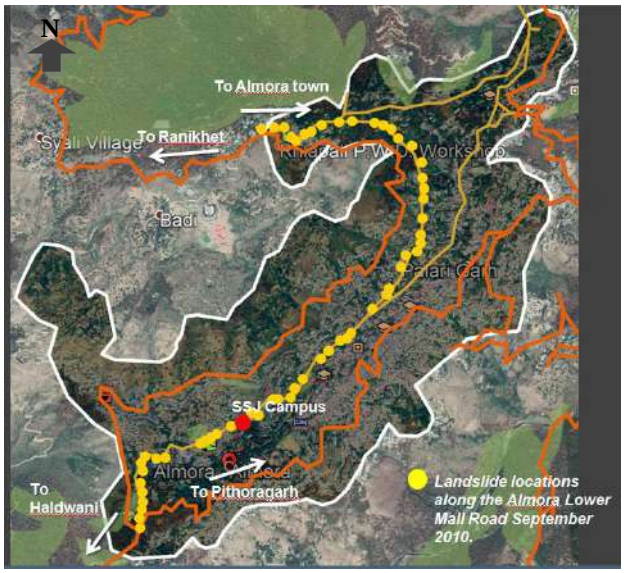

Fig. 12. *Almora landslide location map (Source- Generated and edited by author , Martin Haigh and J.S. Rawat 2016 Landslide disasters: Seeking causes:A casestudy from Uttarakhand, India)*

disaster. In olden times people chose relatively flat and safe areas for constructing buildings.

But nowadays since adequate land is not available, people are forced to construct over steep slopes which disturb the natural terrain a lot. Most of the buildings ruined during landslide were found to be new buildings than their traditional constructions.

So the parameters identified are slope re-profiling due to road and building constructions ,water flow modifications due to terraced farming and other construction activities, land use changes, artificial structures without considering the natural terrain and vibrations due to heavy traffic.

Laipuitlang, Aizawl city, Northeast India

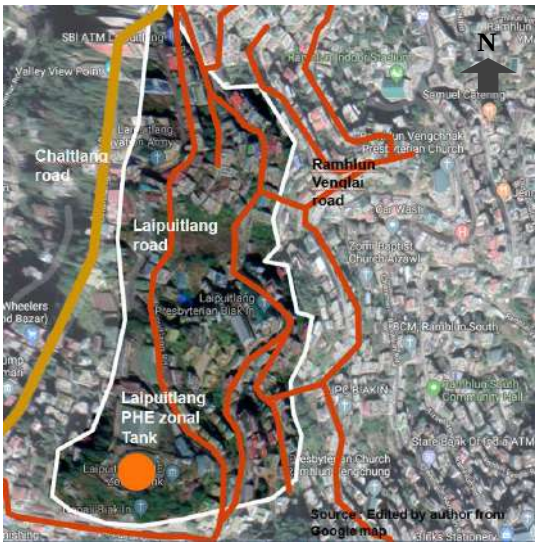

Fig. 13. *Laipuitlang location map (Source-Google map edited by author)*

It is situated on the hill called Laipuitlang, in the northern part of the city at an altitude of 1,132 m from mean sea level. The Laipuitlang area is one of the most populated localities in the Aizawl town. Here the main reasons to the landslide were the geological characteristics of the area and the unscientific development activities by the authorities [7]. The Laipuitlang PHE zonal tank was situated at the top of the hill and it had poorly maintained water supply pipes which triggered the disaster.

The area was a sandstone quarry. Quarrying activities destabilized the soil and led to rock slides on 1957 and 1968.The base of majority of the buildings were placed over the shale-sandstone interface. The massive sandstone bed above the shale was the prominent lithology of the area [7].

Improper drainage and sewerage system has led to large amount of water penetration in the foundation of the PWD building which was located in the crown region. The shale sandstone joints and the improper drainage systems worsen the situation. High rainfall has led to the minimization of the cohesive strength in the basal part consisting of incompetent shale and the landslide occurred.

A summary of the main causative factors [7]:

- The shale foundation and the load of the P.W.D. building.
- Accumulation of erosion generated soil debris, along the bedding plane on the right flank.
- Loose soil on the southern edge of the bedding plane.
- Presence of sub vertical joints to impart weakness to the slope.
- Heavy rainfall before slide.
- Leakage of PHE pipe lines causing active damage to the shaly foundation.
- Large scale penetration of seepage into the weaker shale foundation.

The improper construction activities and land use change, Water flow modifications due to improper drainage facilities of the buildings. Inappropriate infrastructure facilities provided etc led to landslide in this case.

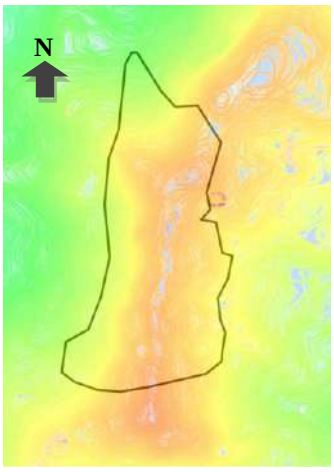

Fig. 14. *Laipuitlang relief map (Source-Contour generator edited by author)*

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B. Dashtegan-Rudbar landslide

The area is part of the heights of Western Alborz in north of Iran and one of the mountainous regions along the Rasht-Qazvin freeway [8].

After constructing trenches, as part of development activities landslide occurred in the area under the influence of different factors and due to seismic activity and various geological conditions.

The landslide occurred in the eastern part of the old landslide of Dashtegan, along the Rasht-Qazvin freeway. Dashtegan landslide is a mixture of soil and rock. Its rock material is made of tuff, green and gray agglomerate, ignimbrite and red and brown ignimbrite tuffs.

The route was completely stable before trench excavation. Excavation was performed at the level of the slope and in fact, by removing anchor of fine- grained section of mass. Some cracks were formed in the upper part of landslide near the area of high voltage tower. Over time and under the effects of some factors such as excavation at the toe level of the slope, the great Dashtegan landslide occurred in June 2005.

Due to the landslide, about 1.5 million soil and rock moved downward in only a few minutes, accompanied by loud noises. As an unstable mass, it blocked the freeway in this area, displaced agriculture lands, and olive gardens, disturbance of agriculture task, and collapse of high voltage towers in the region. As a great challenge, the landslide hindered construction procedure of the Rasht-Qazvin freeway [8].

Causes of Dashtegan-Rudbar Landslide:
These factors are as follows.

•Unique structural and tectonic impacts, 45 degree slope of land topography, known faults (Herzevil fault, Rudbar fault, and Sefidrood fault)
•The effect of mass weight, material and components of its mass volume
•Over 30 m height Trenches with side slope of 8 vertical and 1 horizontal
•Temperate to slightly arid climate of the region
•Surface waters of the Sefidrood river, was disturbed
•Trenches construction, explosion and change in slopes

TABLE II. [9], [10], [11] AND AUTHOR, SOME IMPORTANT CASE STUDIES OF HUMAN INDUCED LANDSLIDES IN EUROPE AND OTHER PARTS OF THE WORLD

Case study	Material type	Main cause
Fourviere Lyon,France	Marly sand & Backfill layers	Lack of **maintenance of the old water canalization network,** which led to **increased pore water pressure** in the superficial layers.
Fully Switzerland	Karsts, scree deposits and moraines	**Breaking of water canalization** that created several debris flows.
Lautenberg Switzerland	Moraine, sandstone and marls	Permanent **water saturation caused instability** due to broken pipe.
Quebec Quebec city, Canada	Sedimentary rocks (Utica slate formation)	Unfavorable geometry of discontinuities + **slope cutting + water infiltration** due to leak in drainage pipe.
Aberfan Wales, United Kingdom	Coal mining debris	**Slope destabilized** by modification of the geometry.
Arvel Switzerland	Rock	Geometry of slopes and discontinuity sets were favorable for toppling. The g**eneral stability of the slope was disturbed and worsened by the quarry**.
Elm Switzerland	Slate	**Unfavourable geometry of discontinuities + critical slope cutting.**
Frank South West Alberta, Canada	Rock	**Unfavourable geometry of discontinuities** + **mining** activities.
Alesund More and Romsdal, Norway	Rock	Bad slope design and **inadequate slope stabilization.**
Eterpas Switzerland	Shaly sandstones	**Road cut.**
Namsos Trondelag, Norway	Quick clay	**Blasting** during **road construction.**
Rissa Trøndelag, Norway	Quick clay	**Building works** (head charge with excavation material) leading to retrogressive sliding.
Menton Menton, France	Superficial soils	Heavy rainfall event on a territory where **land use has changed. Bad management of water flows.**
Norway Europe	Clay soil	Construction work typically **road construction** **Agricultural landscaping** **River regulation** **Deforestation** **Concentration of water runoff**
Alpine slopes Switzerland	Leptosols and regosols are the main soil types found in the alpine belt	Slope overloading Agricultural activities **Land use changes** Existing embankments and retaining walls **Hydraulic regime modification on catchments** **Pipeline breach and uncontrolled water discharge** **Water deviation** Touristic developments **Construction of infrastructure and buildings on potentially unstable slope**

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VI. CONCLUSION AND DESIGN STRATEGIES

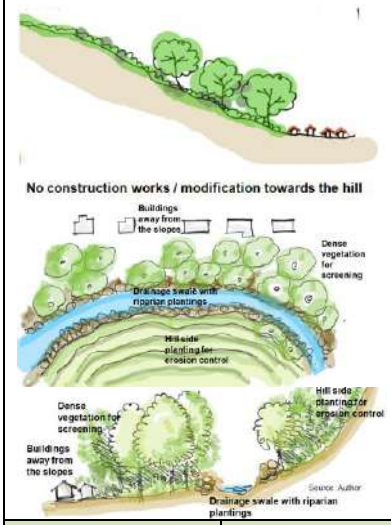
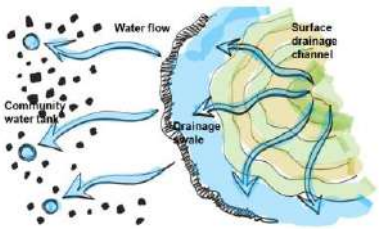
Urban high lands are any areas around the world where urbanization happened and which have a minimum height of 300m from the mean sea level and having a slope and elevation changes from the surrounding areas. Landslides can be divided as nature induced and development induced. All the development activities without considering our environment are decreasing slope stability and gradually leading to landslides. There are five major parameters that trigger landslide occurrence in urban highlands.

Those parameters are,

- Slope re profiling
- Water flow modifications (Ground and surface water)
- Change in land use and land degradation
- Inappropriate artificial structures and structural degradation
- Vibration and explosive

Cutting and filling of natural slopes for construction activities will change surface and ground water flow and these modifications will be negatively affecting the slope stability. Construction of buildings and roads, mining activity, construction of artificial water body, pipe leaking etc will be creating issues. Change in land use and land degradation is another factor. Terraced farming, forest fires, urbanization on slopes etc will also be leading to slope instability. Inappropriate artificial structures and structural degradation is another factor creating landslides. Poorly designed reinforced structures, inappropriate infrastructure dimensioning, weakening of terraced walls and vibration and explosives such as blasting operations for engineering works, heavy traffic etc will be other triggering factors. Even though we cannot apply same policies and frame works to the whole landslide prone areas, we can provide general deign frameworks to the land to be developed. Those are listed in the table.

TABLE III. [5], [14] AND AUTHOR, STRATEGIES FOR THE PARAMETERS LEADING TO DEVELOPMENT INDUCED LANDSLIDES

Parameter-1	***Slope re profiling***
Strategies • Construction work , Embankments, , Cut slopes, Excavation work , Fill slopes etc to be controlled strictly on the slopes and it should be done only after strict environmental impact assessment(EIA) for the region • Mines and quarrying to be prohibited / controlled as per the environmental sensitivity of the region • Altering natural slopes for tourism and other development activities to be controlled as per the terrain of the area and to be done only if necessary under the super vision of the authorities	**Demonstration** 
Parameter-2	***Water flow modifications (Ground/Surface water)***
Strategies • Rivers need to be preserved • Drainage blocking, Water pipes leakage etc to be avoided and regularly checked • Construction of artificial water body on hilly terrain such as, swimming pools , water fountain etc to be prohibited • Activities which change or influence surface or ground water flow on slopes to be strictly avoided • Water run of from roof after rain to be efficiently collected and circulated without disturbing the slope • Water flow in the rivers to be managed by proper scientific riparian management programs involving community participation • Construction of dams and artificial water bodies to be done only after proper scientific studies • Assure proper waste water management and rainwater flow management for weaker areas.	**Demonstration** 
Strategies ***The surface drainage control work to be done efficiently*** • Drainage channel work and drainage collection works to be done • The drainage collection works should collect surface flows and connect directly with the drainage channel. • The drainage channels works are designed to remove the collected water out of the landslide zone as quickly as possible • The collected water can be stored in a tank for community water needs • During the disaster , the swale will act as a screen which slow down the landslide	**Strategies** 

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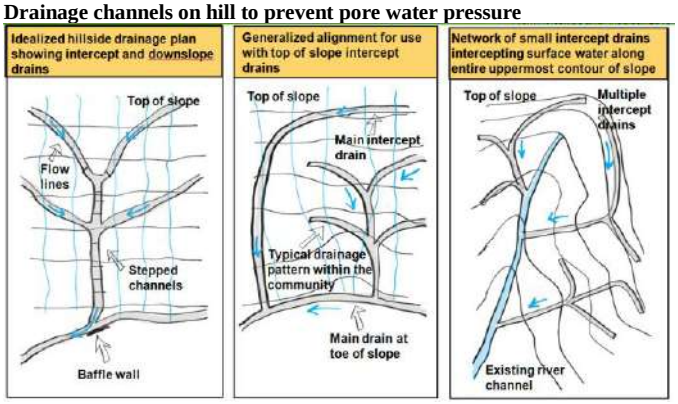
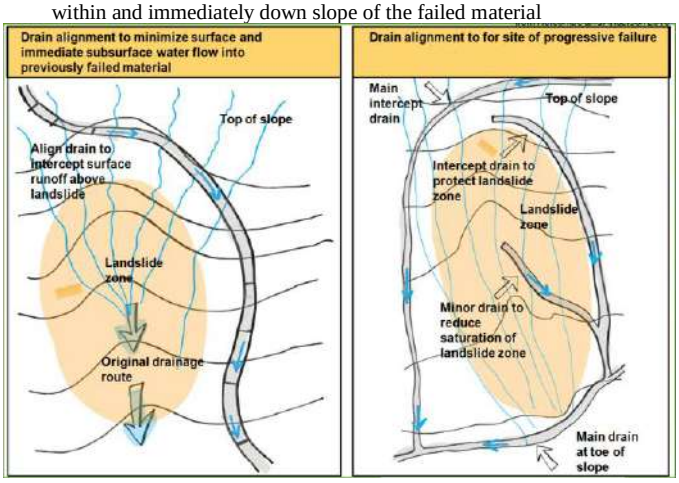
Drainage channels on hill to prevent pore water pressure



- Lines orthogonal to contours indicate likely surface an sub surface water flow paths and emphasize the importance of drains in preventing increased pore water pressures within the landslide.
- A comparatively high density drain network can help prevent down slope water ingress to a failed site. Consider aligning drains above, within and immediately down slope of the failed material



Parameter-3	***Changes in land use and land degradation***

Strategies

Urbanisation

- Unplanned urbanization towards the slopes to be strictly restricted
- Environmental impact assement to be done before each construction on slopes
- Each and every structure on slopes to be well designed so that the disturbances caused to the environment can be minimized maximum
- Built density on slopes to be limited
- Tourism and leisure activities to be controlled based on environmental sensitivity
- Prevent slopes from waste dumping

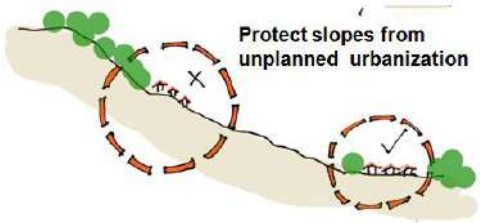
Deforestation and forest fire

- Deforestation for agricultural activities, construction activities, grass lands etc to be controlled as per the environmental sensitivity
- Vegetated slopes to be protected considering the slope angles, types of trees and environmental significance

Restoration of the hill eco system

- Proper aforestation programmes which consider the soil characteristics and the plants suitable for the area
- Reintroducing local flora and fauna to the hill will help to regain the lost biodiversity balance of the ecosystem

Demonstration



Strategies

Restoration of the hill eco system

- Maintain as much vegetation as possible on the slope to help retain the soil.
- Take immediate actions to control development induced forest fire that eventually leads to slope instability

Other measures to be taken

- Change in land use from agricultural to non agricultural, forest to non forest etc to be restricted
- Modified crops should not be allowed for slopes more than 20 degrees.
- Discourage cultivation of annual crops and encourage perinial crops to these areas.
- Provide incentives for private land holders for
  - Protecting natural vegetation
  - Protecting bio diversity
  - Maintaining natural terrain etc

Strategies

Parameter-4	***Inappropriate artificial structures and structural degradation***

Strategies

- Inappropriate artificial structures or poor reinforced structures to be removed from the slopes
- Well designed structures to be constructed for slope protection for problem areas
- Areas of infrastructure break such as missing of retaining walls, finished roads etc to be found and solved to avoid before leading to slope failure
- Strictly check the condition of infrastructure like water supply pipes , road etc. and do repair works if necessary based on the slope stability

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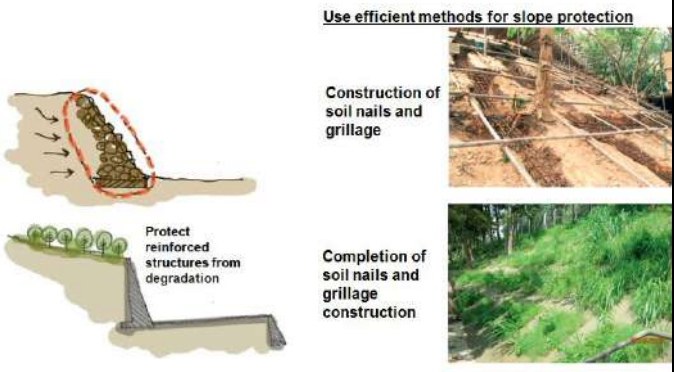
Demonstration



Strategies

- Follow different measures for natural terrain mitigation like Flexible barrier, Soil nail etc
- Roads and other infrastructural expansions to be done only after proper EIA by the authorities before excavation of the projects
- Do not build near steep slopes, close to mountain edges, near drainage ways, or natural erosion valleys.

Demonstration

Flexible barrier at the toe of a natural hill side

Screening planting in front of a flexible barrier

Parameter-5	***Vibration and explosive***

Strategies

- Find alternate building materials to replace the natural materials for construction so that we can stop quarries and mining activities on hills upto a limit
- Blasting operations for engineering works on the hills to be strictly restricted
- Encourage adaptive reuse other than new construction on hilly areas
- Control new road and railway construction on hills maximum and use alternate routes if ava

ACKNOWLEDGMENT

Expressing deep gratitude to Dr. Bejene S Kothari, Associate Professor, Department Of Architecture,College of Engineering Trivandrum for her guidance and timely criticism in the successful completion of this work.

REFERENCES

[1] M.Macchi, ICIMOD team, "*Mountains of the World –Ecosystem Services in a Time of Global and Climate Change ; Seizing Opportunities – Meeting Challenges"* ,Frame work paper prepared for the Mountain Initiative of the Government of Nepal by ICIMOD and the Government of Nepal, Ministry of Environment, 2010.

[2] R.Wold, L.Candace, Jochim, *"Landslide Loss Reduction:A Guide for State and Local Government Planning"*, Department of geology and mineral industries,Portland,Oregon, 1995.

[3] L.Highland, P.Bobrowsky, "*The Landslide Handbook—A Guide to Understanding Landslides"*, United States Geological Survey and Geological Survey of Canada, 2008.

[4] M.Jaboyedoff,C.Michoud,M.Derron,J.Voumard,G.Leibundgut,S.Rieux, *"Human-induced landslides: toward the analysis of anthropogenic changes of the slope environment",2009.*

[5] M.G.Anderson,E.Holcombe,"*Community-Based Landslide Risk Reduction: Managing Disasters in Small Steps",* International bank for reconstruction and development/ The world bank,1818 H street NW, Washington DC 20433, ISBN 978-0-8213-9491-5, 2013.

[6] J.S.Rawat, "*GIS of Almora Disaster 2010",* Almora, Kumaun University Centre for Natural Resources Data Management System, 2010.

[7] R.Verma, *"*Landslide Hazard in Mizoram: Case Study of Laipuitlang Landslide, Aizawl" , *Article in International Journal of Science and Research (IJSR), 2012.*

[8] M.Chamchal,M.Rezaei,S.Hakimi,"*Engineering geological characteristics of the North Freeway between Rostam Abad - roudbar landslide Dashtgan" ,* Twenty-fifth Symposium of Geosciences, Iran, Tehran, 2006.

[9] B.Kalsnes,F.Nadim,R.Hermanns,H.Hygen,G.Petkovic,H.Berg,D.Hogvol d , "Landslide risk management in Norway", 2016.

[10] F.Nadim, O.Hoydal, Haugland, H.Haugland, A.McLean,"*Living with landslide risk in Europe: Assessment,effects of global change*, and risk management strategies", 2018.

[11] M.Beniston,"*Switzerland Climatic change in mountain regions: a review of possible impacts",* Department of Geosciences ,University of Fribourg, Switzerland, 2003.

[12] **V.**S.Vijayan, "*Comparative study of Gadgil Kasthoori Rangan reports"* ,SAF Publication, Salim Ali Foundation, 2013.

[13] *"Report of the Western Ghats ecology expert panel ,The ministry of environment and forest" ,* Government of India, 2011.

[14] T.Rahman,*"Landslide risk reduction of the informal foothill settlements of Chittagong city through strategic design measure",* Postgraduate Programs in Disaster Management (PPDM)BRAC University,Dhaka,Bangladesh, 2012.

Community based disaster preparedness

A case of Western Ghats Kerala region

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***Abstract*— No one challenge remains alone, and no one organization or government is exclusively responsible for a disaster. Support on each level, from individual to regional, and from people in public, private and non-profit sectors, is basic to effectively construct a resilient future for all.**

The foundation of the research is based on the critical study of the Western Ghats Ecology Panel Reports and the failure in implementing the proposed guidelines. This paper aims to identify the importance of community based disaster resilience in the context of Western Ghats Kerala region. Applied is a literature review on the Western Ghats conservation and community based disaster preparedness methods, which evaluates their impact along the primary study within a delineated area in the region.

The outcome shows that with regulative policies towards community based preparedness planning and implementing the identified tools in local level a sustainable development in Western Ghats can be initiated. Required is a substitution in the current legislations and organization in community level so as to keep up social integration, ecological assurance and disaster resilience.

Keywords—Preparedness, Resilience, Disaster management, Hazards, Spatial planning, Risk reduction, Community participation

I. INTRODUCTION

With regards to hill towns in the Western Ghats experiencing tremendous developmental activity having densely built multi storied structures caused extreme concerns with suitability in the region.

A. Why community based?

To achieve the vision of disaster resilient communities by empowering them with self-developed and culturally acceptable ways of coping.

B. Why Western Ghats?

To investigate the community based development strategies on the basis of Western Ghats Ecology Panel reports of Prof. Madhav Gadgil and Dr. Kasturirangan.

II. METHODOLOGY

Ensuring long-term sustainability of Western Ghats requires the identification of localised community driven disaster resilient methods. The study is limited to Western Ghats Kerala sub region and focuses only on the Preparedness stage in disaster resilience.

This paper begins with discussion on the importance of disaster risk reduction in ensuring sustainable development of Western Ghats followed by description on the relation between community based approaches in disaster preparedness. The next section describes the inference of the literature review on the importance of community participation in disaster preparedness. It then addresses primary study conducted to consider the ground realities of the study. The recommendations to integrate community based disaster preparedness based on the primary and literature review analyses how the concepts can be implemented in the Western Ghats Kerala region. The final section provides summary and conclusions.

III. GLOBAL SCENARIO

"Transforming our world The 2030 Agenda for Sustainable Development recognizes and reaffirms the urgent need to reduce the risk of disasters." [1] The emphasis in the execution of reduction methods gives a chance to empower expanded political duty and financial investment to reduce risks and make development action that considers disaster resilience as basic to poverty decrease and a key empowering influence of sustainable development.

IV. WESTERN GHATS OVERVIEW

"The Western Ghats also known as Sahyadari Mountains is one among 35 global hotspots of biodiversity, forms a continuous mountainous chain. The mean rise of the mountains is higher than 600 m and surpasses 2000 m at certain spots, Anamudi peak being highest. The annual rainfall received by this area is between 2000 mm and 8000 mm." [2] The Western Ghats is a unique Eco region, which covers 6% of the total land area of India.

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Western Ghats Regional Development Program was one of the important Programs began by the planning commission under Hill Area Development Programme. The basic targets were to achieve balance among communities and the infrastructure development thinking about the vital substance of ecological and community resilience.

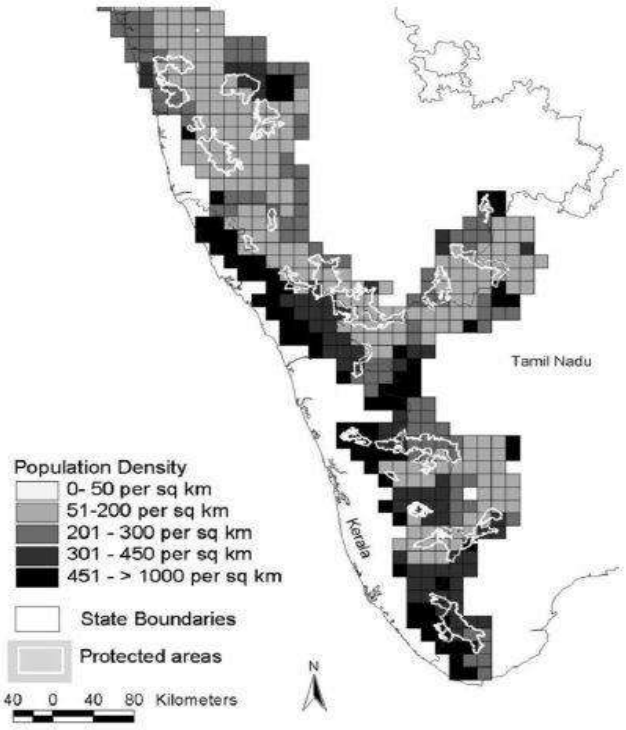

Fig. 1. Population density and protected areas of Western Ghats Kerala region [3]

A. Western Ghats Panel reports

Two expert panel commissions were appointed for the ecological and development consideration for Western Ghats region by the central government. The comparison of the major three sections of the reports are given in Table I.

- Madhav Gadgil report

An environmental research commission is named after its chairman Madhav Gadgil. The commission is officially known as the Western Ghats Ecology Expert Panel (WGEEP). The WGEEP selected the whole hill extend as an Ecologically Sensitive Area (ESA). The report suggested that "no new dams dependent on enormous scale be allowed in Ecologically Sensitive Zone 1.

The report shows that the current administration of environment ought to be changed and referenced a bottom-up approach from Gram sabhas. It additionally referenced decentralization and more powers to neighborhood actors." [4]

- Kasturirangan report

The Kasturirangan panel was comprised to inspect the WGEEP report. The board of trustees is called as High Level working gathering (HLWG) headed by Dr. Kasturirangan

. As opposed to the total region, only 37% of the land be brought under ESA. Kasturirangan report on the Western Ghats has made two or three pro-farmer suggestions, including the exclusion of possessed land from the ESAs.

TABLE I. COMPARISON OF WESTERN GHATS PANEL REPORTS

	Gadgil report	Kasturirangan report
The extend of the area of ESZ	Entire Western Ghats Created three categories of protection regimes and listed activities. 137,000 hectares awarded the status of ESZ.	Removed cash crops, agricultural lands and settlements from ESZ Cultural and natural landscapes. 60,000 hectares should as ESZ.
Activities permissible	Ban pesticide use and genetically modified crops. Decommissioning of Hydro Power Projects. The gradual shift from agricultural land to natural forests.	Restrictions on highly interventionist and environmentally damaging activities. All mining and red-category industry And buildings over 20,000 square metres completely banned. Hydropower projects, the panel set tough conditions.
Concerns on governance	Recommended a national-level authority, with counterparts at the state and district levels.	Argued for strengthening the existing framework of environmental clearances and setting up of a state monitoring agency.

[a] [Author generated]

Protests against the reports frequently are not because of a sense of assurance towards the environment, yet regularly on fear of removal or loss of livelihood.

V. COMMUNITY BASED DISASTER PREPAREDNESS (CBDP)

The adoption of area-based data sharing technologies and the rise of volunteered geographic data has seen changes to public participation. Governments will respond more to political persuade than to contemplated contentions in changing their policies, applied by the people. CBDP is likewise essential in expanding participation, obtaining resources, and changing policies and regulations.

Actions can be made to reduce or deal with the hazards or their outcomes. The disaster preparedness must include individuals that may unintentionally be adding to the hazard

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and will more likely than not be influenced by it. This management plan given in Fig. 2 should likewise include incorporation of policies with external organizations and governments.

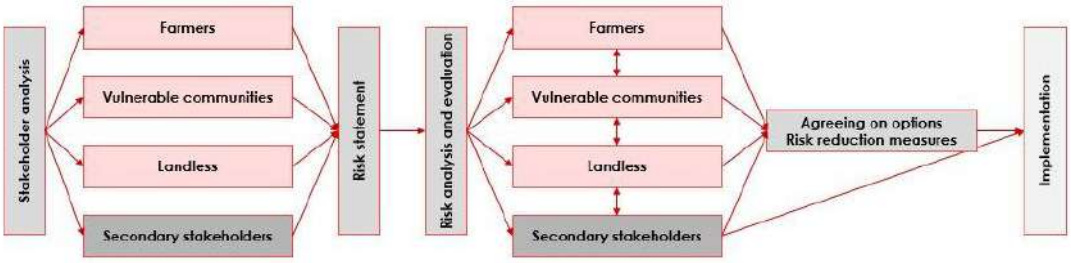

Fig. 2. Recommended CBDP Action plan [Author generated]

A. CBDP Methods

The community based spatial methods for disaster preparedness can be adopted from examples from different global and national scenarios. The major and most effective forms of methodologies are listed below:

- *Hazard Mapping*: used to help the community to depict the qualities and risks criteria as indicated by the effects of the significant hazards that are recognized.
- *Social Mapping*: to demonstrate the area of social infrastructure and distinguish specifically risk zones and found vulnerable groups.
- *Problem tree*: discovers solutions by mapping out the life structures of circumstances and logical results along similar way to a Mind map.
- *Transect walk*: used to record the topography of terrains, to comprehend the interrelationships with the environment.
- *Seasonal Calendar*: Seasonal changes and related hazards, diseases and other information related to specific months.

A lot of limits expected to produce and scatter timely and significant warning data to empower people, communities and associations undermined by a hazard to prepare and to act suitably and in adequate time to diminish the chances of loss.

VI. Existing Legislations and Programmes

The existing legislations and development programmes related to conservation of Western Ghats and the disaster management acts in national and state level were studied to identify the gaps in implementing each of these legislations.

- *Western Ghats development programme*: Creation of care among people on the suggestions of ecological degradation and confirming active speculation for eco-development plans.
- *Disaster management act 2005*: Community based disaster management, including last mile incorporation of the approach, plans and execution. Criticised for cultivating order and control, 'top down', approach that gives the central, state authorities significant roles.
- *Village Disaster Management Plan 2012*: It traces the procedure by which the village ought to deal with the disasters through public participation.
- *Kerala State Disaster Management Plan 2016*: Fortify community-based risk reduction activities at LSG level. Absence of Community-based spatial planning in hazard reduction.
- *Working groups in Local government level* (constituted after Kerala floods 2018): Group of elected members, administrative staff and community volunteers from each Local self-government (LSG) for disaster mitigation.

VII. CBDP Actions to Reduce Hazard Impacts

CBDP assists with distinguishing the basic vulnerabilities, hazard priorities, and existing capacities in the local level and investigates the raw data gathered. It additionally gives the vital data to planning community based action plans as given in Fig. 3.

Actions	Flood	Land slide	Drought
Public awareness and preparedness	■	■	■
Identifying location of structures in ESA		■	
Hazard monitoring	■	■	
Implementing ecology panel reports to limit construction	■	■	
Including local knowledge about the region	■	■	■
Warning signage for risk areas		■	
Forest restoration	■	■	■
Resilient crops for cultivation		■	■
Bio engineering	■	■	■
Identifying irrigation canals that requires maintenance			■

Fig. 3. Community actions for each hazard [Author generated]

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VIII. INFERENCE

A. Western Ghats

Unplanned developmental activities, Consequence of short-sighted policymaking and Politics over resilience of the community.

B. Community based disaster resilience

Disaster preparedness on locally acceptable methods is needed for planned spatial development. Citizen science should be developed in the form of Citizen Knowledge + Subject experts + Local administration.

C. Legislations and development programmes

Lack of community based techniques and tools in disaster management action plans.

D. Parameters Identified for CBDP Actions

From the three major sections of the study which are Community, Preparedness and Western Ghats conservation, set of variables were identified based on the analysis and inference of the literature reviews. Further, these are sorted into 6 other set of variables belonging common to these sections. Finally, four parameters were derived as:

a) *Contingency planning* (emergency planning actions)

b) *Capacity building* (training and awareness)

c) *Monitoring* (evaluating and analyzing existing situations of the region)

d) *Communication* (communication within all the levels of decision makers)

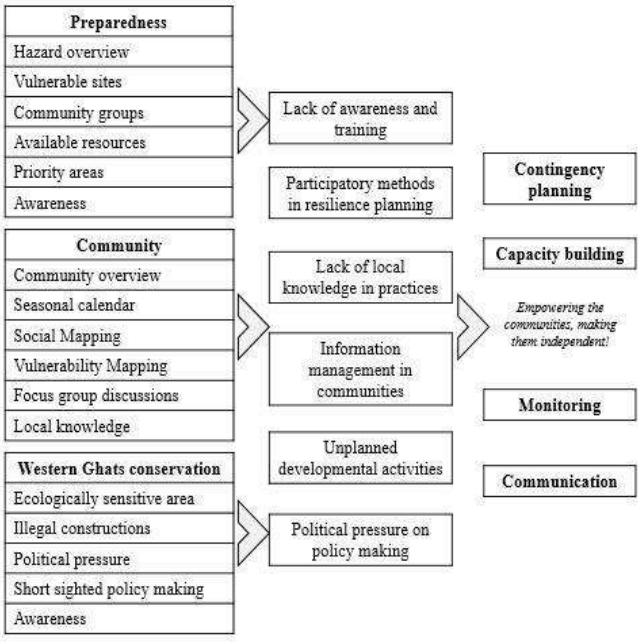

Fig. 4. Parameters identified for CBDP actions [Author generated]

These four parameters will be used as the base for the recommendation stage in Grama panchayat level.

IX. PRIMARY STUDY

A methodology was developed for assessing the analysis and inferences from literature studies through cross evaluating with the primary site study. The primary study methods follows the site delineation methodology, and key informant interviews from the delineated regions of Western Ghats.

A. Selection of Study area

First the district for study area was selected on the basis of criteria given below in the figure 5. The districts with comparatively large portion of ecologically sensitive zones which is found to be Idukki and Wayanad districts were sorted out at the earlier stage itself.

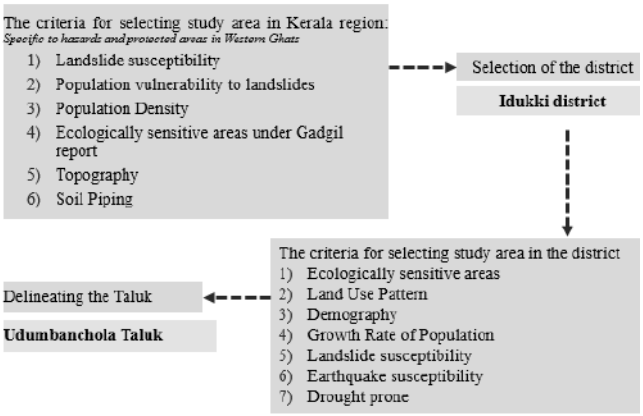

Fig. 5. Methodology for Site selection [Author generated]

Based on these criteria, Idukki district was selected for further study. The Local self-governments for conducting the key informant surveys was chosen from the district using these same set of criteria mentioned in the methodology.

Analysing the land use pattern of the district shows that the residential zones overlaps with ecologically sensitive zones of Western Ghats. From these, Udumbanchola Taluk was selected for further primary study using Key informant interview.

Three Grama Panchayats which have high percentage of growth rate and high risk proximity were identified and selected for the sampling of Key Informant interview. Panchayat Secretary, one Ward member and 2 community members each from the selected Rajakumary Grama Panchayat (GP), Rajakad GP and Chinnakanal GP were called for a key Informant interview through a survey schedule.

The survey schedule was prepared to cover the hazard vulnerability and community actions in the Panchayat and identifying the issues faced by them during the process. The analysis and inferences given in Table II of which, became the recommendations for this study.

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TABLE II. SURVEY RESULTS

Yes No Neutral

GP	CBDP by GP			Previous CBDR activities by community	NGO/community organisations	Opinion about WG conservation
	Working group	In grama sabhas	Post disaster activities			
Rajakumary GP						Fear of losing their land rather than WG conservation
Chinnakanal GP						Gadgil report recommendations are still not accepted in most regions
Rajakad GP						Fear of losing their land. Lack of awareness among Tribal people

b. [Author generated]

B. Survey Observations and Results

"Community refers to all people at local level in any disaster stricken Area that in immediate response phase to disaster and later in recovery phase have the main role." Community-based organizations (CBO) members are combinations of residents, subject experts and local government authorities. The major findings from the primary survey are:

- Lack of awareness about Western Ghats conservation and hazard vulnerability in communities. Citizen science can be adopted.
- No regular meetings and monitoring of CBDP methods in Local administration.
- An action plan with CBDP methods for spatial planning of hazard assessment is needed in ward level of Local self-governments.

X. RECOMMENDATIONS

The recommended actions of Community Based Organisations (CBO) for disaster preparedness in local government level are given in the Table III.

A. Contents of CBDP tools

The different CBDP methods and tools can be adopted in the preparedness stage as part of spatial mapping of hazards and vulnerability.

- *Seasonal Calendar:* To distinguish the environmental impacts on the seasonal exercises and thus improving the resilience of the region. I.e., Seasonal Shift, Impacts, and Responses.
- *Risk Matrix:* To recognize the most notable features and patterns of hazards to lessen vulnerability of the communities. I.e., Hazard and Community Impact.
- *Community Mapping:* To outline and distinguish the priority areas, assets, and actors action planning. I.e., Mapping, Vulnerability Analysis and Priority Areas.
- *Community Overview*: To give a review of the community "at a glance" initially. I.e., Demographics, Natural Resources, Infrastructure and Hazard Risks.

The contents of each of the tools were prepared based on the literature reviews and case examples done in earlier stages.

TABLE III. RECOMMENDED CBO ACTIONS

CBO actions	CBDP Tool		Objective
Hazard history and Timeline of events	Seasonal Calendar Trend Line		Identification of hazard seasonality, frequency, and severity in order to integrate projections into action plans
Hazard ranking according to the severity	Risk Matrix		Overview of the major hazards in the community, salient features, and prioritization in action plans
Identification of Social Infrastructure	Social Mapping	Community Mapping	A consolidated map with all the relevant details between the community's assets, and underlying vulnerabilities and capacities, with the ultimate purpose of identifying the important areas for action
Identification of Vulnerable sites	Vulnerability Mapping		
Identification of Resources	Resource Mapping		
Socio economic particulars of the Community	Community Overview		Identification of the goals of CBDP, key priority areas, and quick overview of community particulars
Design or individual practices	Bio engineering, drains, debris traps, nature based solutions		To ensure that all relevant safeguards are addressed, especially regarding drain alignment, with both landowners and community residents

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B. *Preparedness Planning*

Sound Preparedness should lead to an improved state of readiness that ultimately leads to safeguarding lives and livelihoods.

- *Contingency Planning:* Includes an in-depth analysis of hazard risk, vulnerability, and capacities ought to be created and regularly updated.
- *Capacity Building:* Causes the communities to procure and upgrade important information, and abilities to perform their undertakings and obligations for self-resilience and are well prepared for effective disaster preparedness.
- *Monitoring:* A framework that applies scientific data and hazard information set up and ready to impart alerts to prepare activity in all in Communities by the communities itself.
- *Communication:* Encourages the two-path trade of technical data among primary and secondary stakeholders will be created.
- *Decision Making Structure*

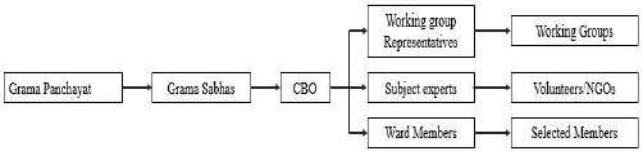

Fig. 6. Recommended Organisational structure for CBDP at Grama Panchayat level [Author generated]

"Multi sectoral, integrated, multi hazard work" A comprehensive approach in implementation. Involving multiple stakeholders at multiple levels, is a key factor for success.

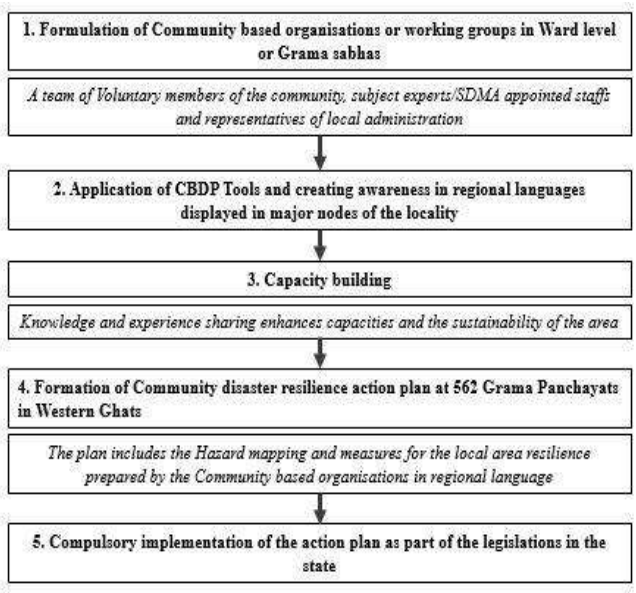

Fig. 7. Recommended framework for CBDP in Grama Panchayat level [Author generated]

XI. Conclusion

Neighborhood information is regularly consumed by prevailing groups, is formed by some inconsistent social relationships, particularly caste and religion and also the need for responsibility towards youth. Hazard perception of the community was a significant powerful factor on account of Western Ghats conservation programs. Therefore making legitimate mindfulness among individuals itself acquires a significant change actualizing the resilience of the neigbourhood.

Diminishing disaster risk in communities remembers understanding the risks for the primary stage. At that point further the choice of communities and members dependent on the vulnerability assessment is done and the following stage in the process will be the community based mapping of the hazard. The plan and practice for slope drainage should be possible as an individual instrument for decreasing vulnerability of the hilly regions. At last, the implementation stage includes a coordinated methodology which is multi stakeholder participation for an efficient disaster management.

The communication and capacity building phase is an extra stage however an unavoidable stage in the preparedness as it outlines the procedure by which communities receive adopt new risk reduction behavior. It creates communication and capacity-building techniques to empower social change regarding hazard management in vulnerable communities.

A mix of community and government cooperation, scientific strategies, and the conveyance of hazard reduction measures on the ground to lessen chance must be created as part of a CBDP action plan. Introducing low-cost drains and practices in Western Ghats that use suitable local materials can draw in the individuals in growing great slope management and provide hands on training for supervisors, contractors, and laborers.

Sustainable community based techniques and preparedness planning is in this way firmly connected to balancing development and environmental preservation of Western Ghats region. Further extent of this study can incorporate a community and ecosystem based disaster preparedness model which can be adjusted in any region of the Western Ghats.

Acknowledgment

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REFERENCES

[1] UNISDR, "Disaster risk reduction and resilience in the 2030 agenda for sustainable development," UN Office for Disaster Risk Reduction, October 2015.

[2] UNESCAP, "Community-based disaster risk management for local authorities" Asian Disaster Preparedness Centre, September 2006.

[3] The World Bank, "Community-Based Landslide Risk Reduction", International Bank for Reconstruction and Development, 2013

[4] A. A. Selmi & V. Murray, "Disaster risk reduction; a cross-cutting necessity in the SDGs", UN Sustainable development, London, 2015.

[5] S. Gupta, S. Gupta, B. H. Aithal and T. V. Ramachandra, "Land use dynamics in central and southern Western Ghats", Conference on conservation and Sustainable Management of Wetland Ecosystems in Western Ghats, November 2014, pp. 200-201.

[6] A. Das, J. Krishnaswamy, K. S. Bawa, M. C. Kiran, V. Srinivas, N. S. Kumar and K. U. Karanth "Prioritisation of conservation areas in the Western Ghats, India," Biological conservation, 2006, pp. 26.

[7] The Ministry of Environment and Forests, "Report of the Western Ghats ecology expert panel", Government of India, 2011.

[8] A. Walia and S. Guleria, "Village Disaster Management Plan", NIDM New Delhi, 2012.

[9] Kerala State Disaster Management Authority, "Kerala State Disaster Management Plan", September 2016.

[10] DTCPO, "Idukki District Urbanisation report", 2011.

[11] Census of India, "Idukki district census handbook" 2011.

[12] A. Bose, "Toolkit for Urban Planning In Disaster Management", NIDM New Delhi, 2012.

[13] SEED, "Participatory Vulnerability Mapping", University of Manchester, 2017.

[14] Y Wulandari and S. A, "The Role of Community-Based Organization in Disaster Response", IOP Conference Series- Earth and Environmental Science, 2018.

[15] S M Labib, "Participatory Vulnerability Mapping: A case study on community based disaster management in (ward 13) Dhaka city, Bangladesh", 2017.

[16] National Dalit Watch, "The extent of inclusion of Dalit and Adhivasi communities in the post disaster response in Kerala 2018", 2018.

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Need of Urban Consciousness in Designing Responsive Public Spaces

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***Abstract*— Streets are public spaces that are living corridors of the city where people gather, interact and celebrate. The growing urbanization has led to the formation and creation of urban spaces that are found to be unresponsive and chaotic in nature. The responsiveness of the space depends on the degree of available alternative choices put forward to its users which can be attained only through urban consciousness. This research shows that cognition plays a very important role in enhancing our responsiveness towards an urban environment giving rise to perceptions of sense of place. Cognitive science play an important role in creating better responsive urban spaces. Memory is formed based on the degree of context awareness which determines of how one interprets, assesses and responds. The study investigates the concept of urban consciousness and explores various attributes of spatial cognition that aids to understand responsiveness of an environment. Based on the review of literature and theories on urban consciousness and responsive environment, various attributes were identified. Analysis of the attributes demonstrates that there is a strong correlation between spatial attributes and cognition. The findings also highlight the need for considering of urban consciousness to enhance the sensory experiences of the built environment and to address its problems adequately.**

Keywords - Urban Consciousness, Responsiveness, Spatial Cognition.

I. INTRODUCTION

Urbanization not only brings demographic changes but also profound spatial, social, cultural, and economic changes in cities. The growing urbanization has led to the formation and creation of urban spaces that are found to be unresponsive and chaotic in nature. A conscious city is a large built environment that is aware of the needs and activities of its inhabitants and responds to them. According to Itai Palti (2015), a conscious city applies new technology, data analysis, artificial intelligence and the application of cognitive sciences into improving the urban experience through the mental and physiological effects that it has on its users [1]. Urban consciousness can be defined as the city's awareness of the motives, personalities and moods of its inhabitants [2]. Amos Rapoport argues that 'a place not only has physical features, but also meanings perceived and decoded by people on the basis of their own expectations, roles, experiences and motivations'. It is also believed that urban consciousness influence stress, anxiety and boredom by being sensitive to the pervading moods and personalities of people in different parts of the city [2]. All the five senses of a person workhand in hand to understand perceive and navigate through the world around us. Analyzing people's behavior and their surroundings is an important factor for enriching our knowledge about people's perceptions, experiences and decisions. Further exploring the surroundings in terms of the characteristics of the built environment and its diversity will help us bring in the human factor as the core of urban design strategies.

Urbanization has led to a situation where people are found to be competing to find their own space in places where they live, work and move about. The urban spaces in historic cities were largely influenced by social, cultural, political and ecological aspects hence gave unique spatial experiences. Whereas, currently cities are rapidly transforming, catering to global needs and are converting urban spaces into moving corridors rather than being experiential spaces. This is a serious issue for the public environment as human needs and values are not linked to the places formed leading to unresponsive and ill-used urban spaces. Toady's cities are spaces of congestion, chaos, and mere means of connectivity creating fragmentation in the social functioning and structure of the society. Studies find factors like overcrowding and pollution are increasing the level of mental stress causing violence in the urban environment, which suggests, stressful living leads to neurotic and psychiatric disorders in people.

The fast-paced life styles, cultural transformation, complexities of living, breakdown of support systems due to family disintegration & alienation, challenges of economic instability, socio-economic stress, etc. are found to be increasing the level of mental illness among people living in urban areas. Creating responsive urban environments is hence found to be necessary to transform the rapidly changing urban spaces into communal spaces and enhance its value and importance in the public realm. It is thus vital to redesign urban spaces into a more responsive environment by improving the vitality, vibrancy, integrity, productivity etc. and ultimately achieve better quality of life and human satisfaction for healthy urban living. This research hence deals with the study of how to increase the responsiveness of urban spaces, by applying the concept of urban consciousness, taking into concern the various aspects of human mind, body and soul linked to quality of life. The issues faced are explored and recommendations are made to create responsive spaces within cities.

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II. METHODOLOGY

The study uses the theory of responsive environment by Bently et al., and theories of Jan Ghel as theoretical framework for understanding the human aspects involved in experiencing urban spaces. The literature review focuses on three main components: the concept of urban consciousness, responsive urban spaces and the factors affecting responsiveness that influence user satisfaction. A framework is then developed to analyze and evaluate the responsiveness of urban spaces using various attributes like: location, access, permeability, variety, edge condition, sense, personalization and sensory experience. The three literature case studies chosen: New Road in Brighton, Ostra Storgatan in Kristianstad, Sweden, and Las Ramblas in Barcelona were analyzed in detail based on these aspects. In all the three cases a basic understanding of street characteristics and its context is done before various attributes were analyzed in detail. Further a cross comparative study was conducted on the physical attributes, social activities, economic activities, and environmental aspects using photographic observation and description technique. Key findings based on the analysis and comparison are highlighted to get a better understanding of the various parameters and aspects that need to be looked into while designing responsive urban spaces.

III. LITRERATURE REVIEW

A. Definition of Conscious Cities

The term conscious city was first explained by Itai Palti in The Guardian (2015) as the city's awareness where cutting-edge data, technology and planning techniques are used to address the patterns of behavior [2]. In this rapidly transforming world we often forget the constant: the human factor. With the idea of conscious city this constant gets analyzed and starts developing spaces in accordance. Just like the technological developments which brings in newer generations of ideas annually the conscious city can happen in a smart city, which is responsive as they are all part and parcel of the same lineage, but with certain upliftments. 'Conscious Cities' is also a movement intended in creating urban environments through data analysis, artificial intelligence and the application of cognitive sciences in design [1]. Thus a large built environment that is aware of the needs and activity of its inhabitants and responds to them is what is described as a conscious city [4].

B. Definition of Responsiveness

Bentley's definition of responsive places emphasizes that a built environment should provide its users with opportunities by the degree of choice available to them [3]. The oxford dictionary defines being responsive as reacting positively or in response [5]. Therefore it is responsiveness that helps to identify the quality of relationship between man and built environment in terms of how we perceive and respond. Seven components: permeability, variety, legibility, robustness, visual proportions, richness and personality, are identified as attributes of responsiveness [3]. The quality of a built environment and its use over time also determine the degree of responsiveness in a built environment.

C. Urban Consciousness

Abraham Maslow postulated the Hierarchy of Needs Theory that defines a five-tier model which was later modified to an eight-tier model where he states the order of the needs are achieved through urban consciousness [6]. Urban consciousness brings awareness to the mind, body and soul which in turn helps us to think, feel and act accordingly to the context [7]. Context awareness is the ability of the user to understand the whereabouts, activities and situations occurring in a place. Urban consciousness can thus be described as planning and designing of cities and spaces by looking into physiological and functional aspects it provides to achieve our motives, the different perception of spaces which may be either negative or positive, depending on our experiences that defines the personality of the space, and lastly the mood that it induces in us according to how we absorb, perceive and react within a built environment. Gopal & Bhaduri (2017) proposed three approaches in analyzing urban consciousness through (i) spatial analysis for assessment of awareness of user motives, (ii) perception-oriented survey of inhabitants for assessment of user personalities, (iii) study of the cognition/sensory load of urban spaces for assessment of the moods of its inhabitants [8], [19].

D. Cognitive Science and Memory

Cognitive science is the study of the mind and its mental organization of thought and learning. Cognition is the mental action or process of acquiring knowledge and understanding through thought, experience and senses [9]. So cognitive science in developing urban consciousness deal with how the nervous system perceives, processes and transforms information to the brain using sensory implications in terms of auditory, visual, tactile and smell and how the brain responds back to the information. We experience a space through our sensory motors which work in unison, for us to feel and experience a place. The various sensory aspects according to Gibson are the visual, auditory, hepatic, taste-smell, and basic orientation systems [10]. The qualities and quantity of sensory stimulation defines our level of perception and cognition of the urban environment.

Our memory plays a very important role in understanding learning and preserving our surroundings using the sensory memory, working memory and long term memory. Cognitive load refers to the total amount of mental activity imposed on working memory at an instance in time. The load should be within the cognitive or mental resource range for us to learn and understand of what we perceive [9]. Long term memory is the infinite body of knowledge that we have learned over the period of time used by the working memory through query for information needed [9].

E. Responsive Urban Space

A responsive urban space is where, human values are linked to activities and places in order to create an image of that environment. A place that provides us a sense of place, variety of choices and possibilities as well as an image of understanding using sensory motors, is a responsive urban space. Permeability is the extent to which an environment

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allows people choice of access through it from place to place through the degree of physical and visual barrier free environment [3]. Variety and robustness brings in diversity and makes a space lively that caters to different users, for different uses and purposes [3]. Legibility creates the mental image of a space defining it and engraving scenes in minds through understanding of the degree of choices offered by the place. Visual Appropriateness, Richness and Personalization depends on the human dimension that directly activates all our sensory apparatus. Various authors define characteristics of such spaces using various spatial attributes. For Marshall it is 1. Form (Physical characteristics) 2. Use (Activity on Street) 3. Relation (Relative position of a Street) 4. Designation [11]. For Department of the Environment, Transport and the Regions, DERT and Commission for Architecture and the Built Environment, CABE it is 1. Hard landscaping; 2. Planting on the street; 3. Street furniture; 4. Structures; 5. Signs and banners; 6. Lighting elements; 7. Public art; 8. Shopfronts; 9. Advertisements; 10. Special treatments and provision; 11. Safety and security; 12. Traffic and highway installations; 13. Uses of public realm [12], [14]. Hiller & Hanson states that for a place to be alive it must be interconnected and integrated. [13]. Tables 1 lists various attributes described by different authors that constitute a good responsive urban space.

TABLE I. [15] MATRIX OF VARIOUS THEORIES COMPARED

No.	**Kevin Lynch 1982**	**Jane Jacobs 1961**	**Bently et.al 1985**	**Tibalds 1968**	**HRH The Prince of Wales 1989**	**Holyoak 1985**	**Urban Design Group 1987**	**Wales 1988**	**Buchanan 1988**
1	Vitality (include biological and ecological)	Appropriate activity before visual order	Responsive environments	Places before buildings	The place		Responsive forms	Urban environment in sense	Place making Public realm Outdoor rooms
2	(See sense)		Visual appropriateness	Respect history	Harmony and context	Retain the best and respect street line			Dialogue with context and history
3	(See fit)	Mixed use Mixed ages Mixed rent Concentration	Variety	Encourage mixed uses		More than one use	Mixed uses		
4	(See vitality)	The street	Human scale	Scale enclosure	Enclosure in scale with context				
5	Access	Permeability	Permeability	Encourage pedestrian Permeability			Public access		Public spaces and movement network
6	Control	Social mix and consultation	Personalization	Social mix	Community	Acceptable personalization	consultation	Individual responsibility	
7	Sense		Legibility	Legibility	Hierarchy	Visual accessibility reflects use			Respect, articulate meaning and connect inside and out
8	Fit (adaptability)	Robust spaces	Robustness and adaptability						
9	(See efficiency)	Gradual not cataclysmic money		Small scale change					
10		Activity richness	Richness	Visual delight	Materials and decoration	Visible integral ornament	Simulating		Natural rich materials

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F. Cognitive parameters influencing Responsive Space

From the vast literature of various theorists and studies, the various factors to achieve responsiveness of public spaces with respect to cognitive aspects were identified. The various attributes are listed below in Table 2.

TABLE II. [3],[8] AND AUTHOR, PARAMETERS IDENTIFIED

No.	Parameters influencing Responsive Space	
	Parameters	***Sub Indicators***
1	Location	Connected network linkages, Degree of accessibility and Choice, Proximity to different types of centers
2	Access	Linkages, Transportation nodes, Point of entry, ROW
3	Permeability	Block layout and size, Choice- alternative routes and access points, Built in Segregation, Physical and visual barriers
4	Variety	Mobility, Use, Form, People and Meaning-Primary and secondary activities, The time element, Proxemics
5	Sense	Physical form and activity pattern, Physical elements, Paths and nodes, Markers
6	Edge Condition	Human scale, Hard and soft edges, Active and passive areas, Degree of robustness
7	Personalization	Level of control Spatial appropriation, Comfort
8	Sense Experience	Sense of smell, Sense of hearing, Sense of touch, Sense of motion, Sense of vision

IV. CASE STUDY

A. New Road in Brighton

New road is located in the center of Brighton and is found to be in proxemics with the shopping centers and Brighton pavilion. It was a vehicle oriented street which got transferred into a pedestrian oriented street by Gehl Architects in 2007 [16].

Fig. 1. *[16] Location map of New Road, Brighton*

The street layout in which New Road is situated is a grid pattern layout. Its morphology shows fine grain uneven texture to the west side of the street and coarse grain and uneven texture to the east side of the street with high density. The land along the street is found to be mixed use consisting of a verity of uses like restaurants, bars/ pub, salon, spa, offices, rooms, a church etc. Varied activities of standing, sitting, walking, cycling and vehicular movement is observed throughout the day and the types of activity depended on the building function. The streets are wide enough having building height of up to 3 floor height. 44m long wooden benches, modifiable street furniture's provides a sense of control for its users [16]. LED lighting provided along the eastern edge of the street provides ample lighting and feeling of safety. Due to its shared space principal it is perceived as the best space to stop and socialize where pedestrians have priority over vehicles. The location of the street and its proximity to other generators makes it an active street. The scale, physical features and visual continuity defines the street, giving it visibility and adds to the character of the street.

B. Ostra Storgatan in Kristianstad

Kristianstad is a municipality which was found in 1614 by the Danish King Christian IV for service, manufacturing and trading [17]. Ostra Storgatan is found in the Ostra center in the central location of the city which is divided by a canal.

Fig. 2. *[17] Location map of Ostra Storgatan, Sweden*

The street layout in which Ostra Storgatan is situated is a grid pattern layout. Its morphology is found to be fine grain even texture with high density. The streets are well connected by other streets like Nay Bolevarden and Sordra Kaserngatan. It is found in close proximity from the central railway station having rivers and open spaces on both sides of the street. Commercial land use is found along the street edge surrounded by residential and mixed use zones. Three commercial streets are found to be parallel to each other with Lilla Torg as a central square market square for trade and crafts. The building height is found to be 4 - 3 floors connected by alleys in between with active frontage having adequate scale and rhythm with large number of glass windows facilitating visual permeability into shops along the ground floor enabling permeability and street watching activities. Services are found in close proximity of 700m. Street furniture's and fixtures like street lights are provided every 20m providing ample lighting with seating spaces shaded by trees and having planters and bicycle stands at regular intervals. Streets are provided with bluestone for roadway and brick paving's for pedestrian pathway without any curb height differentiation [17].

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The arrangement of the street and the permeability thus defines the character and use of the street. The integration of activates within the street and the market makes it a space for waking, talking, sitting, standing, offering alternative choices to the users making it a responsive space.

C. Las Ramblas in Barcelona

Ildefons Cerdá was the urban planner who transformed Barcelona to what it is today since 1960's plan. Barcelona was planned into 520 blocks in grids with diagonal boulevard streets at 45 degree angle. The main focus of the planning was to orient the city towards the Mediterranean Sea, providing of public facilities and amenities in every neighborhood, reusing and redevelopment of brownfield which Las Ramblas is a 1.5km long pedestrian boulevard that connects the city to the waterfront [18], [19].

Fig. 3. *[18] Location map of Ostra Storgatan, Sweden*

The street is found to have a linear orientation connected by alleys with asymmetrical grid pattern in layout connected to the main planned grid pattern with coarse grain and even texture. Street is bound by buildings 5-7 stories high density blocks, connected by small alleys or streets at walkable intervals making it permeable and accessible from the surroundings creating its all-time usage.

There is a central promenade 60 feet width solely for pedestrians free of vehicular intersection with vehicular lanes along the sides of the built edge with sidewalks of 10 feet wide, encouraging people to use the central space [18]. Pedestrian and vehicular movement is segregated by a parking lane in-between. The main central transport hub is less than half a mile to the edge of the port, proximity making it easily accessible from either sides. Series of three boulevard's linked at different intersections with variety and varied activities like artists, musicians, magicians, streets plays etc. take place, catching people's interest to come again for social interactions. Retail frontages that invite has varied character - cafes, restaurants, markets, shops, cultural institutions. Varied textures and ornamentations of Gothic architecture influence creating richness of the place [18]. Doorways every 13 feet create a threshold between the private and public space with buildings having large number of glass windows facilitating visual permeability and alleyways facilitating physical permeability. Flower shops and restaurants provides olfactory senses, the building, material, ornamentation and trees provides varying visual stimuli. Less noise pollution from traffic due to the segregation of traffic with the boulevard of trees. The varied activates along the central promenade and its clear distinction or visibility from the surrounding areas makes it a marker attracting people to this street. Walkability is encouraged through varies activities and attractions throughout the promenade. The liveliness and the comfort has a positive impact attracting people to come back here and spent their time the whole day.

V. FINDINGS AND INFERENCES

TABLE III. COMPARATIVE ANALYSIS OF CASE STUDIES (SOURCE: AUTHOR)

No.	Comparative Analysis	
	Parameters	***Inference***
1	Location	**IDENTITY, APPROCHABILITY** • The streets are found to be in a strategic location with its proximity to both water and land movement networks • Accessible through both means providing alternative choice of movement. • They are found to be connected to the major public movement network in close proximity to other magnets or centers that attract large crowds of people which in turn attracts people to the streets. • The street layout are well-connected hence encourage permeability
2	Access	**CHOICE AND OPPORTUNITIES** • Defined entry points gives clear identity, understanding and visibility provide information of the varied alternative choices, distinguishing it from other spaces. • The length of the street and width of street defines the adequate access of sunlight and air that enriches the street. • Stop and continue points generates social gathering spaces filled with activities and refreshments. • Equal prioritization of various users • Higher the density the more active the street becomes with its ease of walkable accessibility.
3	Permeability	**CONTINUITY** • The block size and shape determines the number of alternative routes at intersection points that determine the alternative routes of travel to reach the destination point • The block size also determines the type of varied uses that consists within a block • The built in segregations within blocks should be avoided to make it more active Physical and visual access barriers can be controlled according to user needs. In all the three cases there is visual permeability in the ground floor spaces with limiting permeability through balconies and windows in the upper floors. • Physical permeability determines the spillover of people. Permeability depends on visibility.
4	Variety	**ACTIVATED SPACES, LIVELY** • The block sizes are small with high density are at walkable distances and

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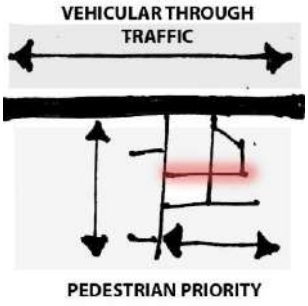
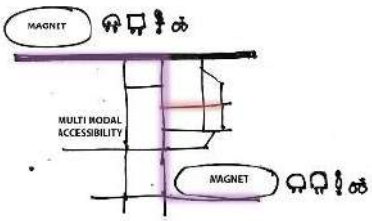
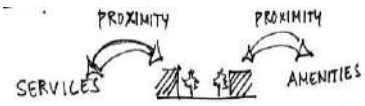
No.	Comparative Analysis	
	Parameters	*Inference*
		proxemics to other modes of transport. • Varied use, form, people - range of activities with affordable space. • The varied type of functional uses within a block keeps it lively throughout a day like the institutions and government buildings that are active during the day the restaurants during the afternoon and the bars, pubs and theaters during the night. • Primary and secondary activities bring in horizontal and vertical mixed activities. • Close proximity to services
5	Sense	**IMAGABLE** • More visibility makes a space easily identifiable from the other surrounding streets. • The continuity and visual appropriation of the street gives a distinct idea of the activity that occurs in the street giving its defined character. • The various sculptures and elements acts as markers at various intersections defines major nodes. • The physical elements, visual alignment, the edge condition, fixtures and furniture's define the character of the street.
6	Edge Condition	**EXPERIENCE, RICHNESS** • Active and passive areas, • The soft edge creates a permeable and stopping spots that brings in activities due to the robustness it creates. • The Human scale and monotony should be taken care of to create active areas in front of shop fronts to avoid hard facades or obsolete spaces. • We see that in all the streets the edges are activated by bringing the activities onto the street where everyone has access. • Visual permeability using transparent materials define the level of control activating the edges. • The heterogeneity and multitude of activities, influences different types of users.
7	Personalization	**LEVEL OF CONTROL** • We see that the control over a space determines its usage. • Movable furniture, pedestrian priority, the material distinction and right of ways all defines our level of control. • Personalization leads to spatial appropriation that generates active frontages..
8	Sense Experience	**MEMORY, MEANING** • The varied musical and street play sounds, the cooking in cafes and the different food and flower scents, the varied tactile textured materials used in flooring and other fixtures, the vertical articulation of trees, the varied activities creates different meanings and memories differently in different people. • Varied meaning and memory due to the social interactions and chances of meeting acquaintances

VI. STRATEGIES AND GUIDELINES

Various strategies and recommendations are listed below which will aid to the better development of urban spaces taking considerations of spatial qualities that will enhance cognitivism, leading to better responsive spaces.

TABLE IV. [3],[7] AND AUTHOR, STRATEGIES AND RECOMMENDATIONS

No.	Attributes influencing Responsive Space	
	Parameters	***STRATEGIES***
1	Location	• Connecting the immediate local network system having pedestrian priority to the main public network system carrying through traffic to travel longer distances. • Connection to other urban magnets and centers through multimodal street design for easy access and efficient movement using all modes of transport. • Proximity to basic services and amenities. **Demonstration**  Fig. 4. *Connection to main public network system*  Fig. 5. *Connection to Urban magnets*  Fig. 6. *Proximity to urban services*

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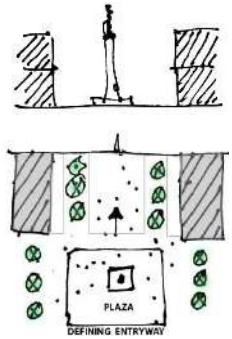
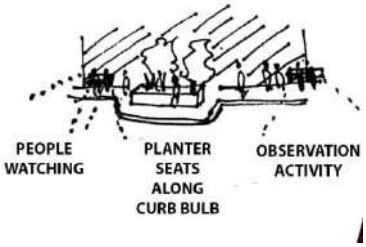
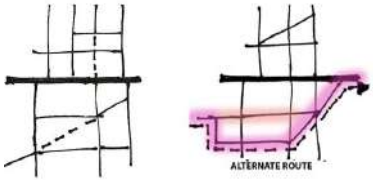
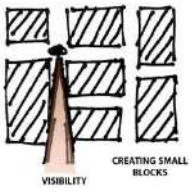
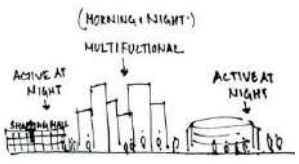
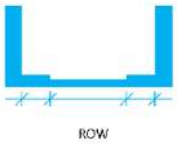
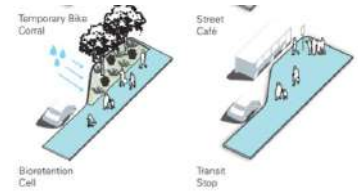
No.	Attributes influencing Responsive Space	
	Parameters	***STRATEGIES***
2	Access	• Defining entry points act as markers increases visibility and identity • The directness of route alignment should be based on the observed desire lines or travel pattern • Streets should be linked to various nodes that are within a walkable distance. • Provision of different travel mode transfers at appropriate walkable points. • During peak hour traffic restrict the access of traffic and funnel the traffic to alternate routes.to reduce congestion. • Prioritizing spaces for pedestrians by providing of green spaces and non-mobile activities **Demonstration**  Fig. 7. *Defining of entry points*  Fig. 8. *Non mobile green activity spaces*  Fig. 9. *Location map of Ostra Storgatan, Sweden*
3	Permeability	• Creating of Small blocks increases both physical and visual access preferably a grid pattern layout (200-500m) • When creating new routes should be linked as an extension of existing routes present in the surroundings. • Providing of alternative routes of access to the street at various strategic points of

No.	Attributes influencing Responsive Space	
	Parameters	***STRATEGIES***
		intersections. • Factors like safety and security precautions should be given like pedestrian crossing for routes that are directly connected to traffic streets to reduce conflicts between different modes of travel. • Proper signages, landmarks, markers to identify routes and continuity of surface material should be maintained to be legible. • Proper surface quality, right of way width for different modes of travel, lighting and passive supervision from edge activates is necessary for the proper usage of the streets. • Creating of semipublic spaces as an interface of transition between the public and private spaces. • Soft edge that engages and activates the space bringing in varied time based activates. **Demonstration**  Fig. 10. *Small block for visual permiability*  Fig. 11. *Transparent soft edges*
4	Variety	• Creating of secondary uses small shops that support primary uses offices, business. • Integrating of old buildings to appropriate functional use. • Creating of inclusive spaces like parks, grounds, malls, markets etc. • Creating of time based functional programming scheme. **Demonstration**  Fig. 12. *Multifunctional center*

No.	Attributes influencing Responsive Space	
	Parameters	***STRATEGIES***
		 Fig. 13. [7] *Time based activates*
5	Sense	• Clear demarcation of right of way for different users of the street using varied tactile materials. • Maintain visual appropriateness in terms of use and form using visual clues rhythms, skyline, detailing or material and textures used etc. • Reinforcing of weak nodes and paths. • Visual permeability allows awareness of the available choices and converging or concave spaces increases legibility. • Continuity of the street is attained by the scale (width to height ratio) creating sense of enclosure and form of built edge **Demonstration**  Fig. 14. *Clear demarcation of right of way*  Fig. 15. [7] Reinforcing of weak nodes and paths
6	Edge Condition	• Providing of seating spaces or conditions that enable people to view the street form a different angle encouraging people watching and to perceive the various functional activities occurring in the street. • Bringing out the indoor activates by providing of seating space outside cafes. • Creating of transparent or open facades that generates a soft edge to stop and enjoy.
7	Personalizatio n	• Provision of different types of spaces that are semi enclosed in nature. • Providing of curb bulbs that could be used as café spaces, landscaped seating spaces or transit stops. • Providing of semi fixed and flexible furniture that provides a limited amount of control in a public space. • Dedicated spaces for street vending, street food and other temporary activates. • Control in the materials, textures, and

No.	Attributes influencing Responsive Space	
	Parameters	***STRATEGIES***
		form of building that it does no • Creating of semipublic spaces using level changes or horizontal distance from street edge using parking spaces or planting of trees or having landscape features. **Demonstration**  Fig. 16. *Creating sense of control through movable materials*  Fig. 17. [7] *Curb bulbs activity spaces*
8	Sense Experience	• Activity programs like events, street performances, fests, street food, street culture, etc. that is flexible can be conducted to increase robustness. • Interactive spaces could be created that generates curiosity and involvement like human chess game, public piano, moveable design seating block etc. • Flexible right of ways by inducing time based activates – hosting different activities in the (morning, evening and night) will act a magnets to bring in crowds. eg. **Manek Chowk** • Façade articulation **Demonstration**  Fig. 18. *Façade articulation*

VII. Conclusion

The study on the need for considering urban consciousness, emphasizes that cognitive science play an important role in creating better responsive urban spaces. We see that spatial cognition creates memory or meaning to a place that makes us define it to its true meaning. The various spatial aspects determine the usage of a space which helps us to organize, orient, find and plan routes where context awareness comes in

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play. The structure and spatial qualities determine the behavioral pattern and choices of people using the space. Planners and designers must be insightful to the way in which spatial use and organization of physical environment in urban areas respond to the ecological, cultural, social, and economic factors. It is necessary to understand the various levels in which all these parameters are affecting our consciousness or cognition putting environmental quality forefront which will naturally reduce the cognitive load generated in the surroundings improving the mental health and wellbeing. It is hence imperative to interconnect all parameters of responsive spaces especially sense and permeability and edge condition that grossly determine personalization factor. The quality of the spatial and physical aspects should also be evaluated and assessed based on the perception of safety, social interaction, service proximity, complexity of use, maintenance, sensory aspects of sound, light, smell etc. creating the sensory load.

Urban design approaches should be oriented taking these considerations of spatial qualities to strengthen the visual quality, the auditory, olfactory and tactile aspects that determine cognitive process within existing public spaces, leading to the creation of better responsive spaces.

REFERENCES

[1] I. Palti, "An introduction to Conscious Cities in Conscious Cities: Architecture and Neuroscience 2016," *Conscious Cities Anthology 1*. London: online, 2016.

[2] I. Palti, & M. Bar, "A manifesto for conscious cities: should streets be sensitive to our mental needs?" Cities, *The Guardian*, pp.1-5, 2015.

[3] I. Bently, A. Alcock, P. Murrain, S. McGlynn, G. Smith, "Responsive Environments: A Manual for Designers," Architectural Press Ltd, London, 1985.

[4] ArchDaily, "Open Call: Conscious Cities Anthology 2018: Official Publication of the 2018 Conscious Cities Festival," 24 Jul 2018. [Online]. Available from:https://www.archdaily.com/898669/open-call-conscious-cities-anthology-2018-official-publication-of-the-2018-conscious-cities-festival/ . ISSN 0719-8884

[5] J. A. Simpson, and E. S. C. Weiner, "The Oxford English Dictionary," Clarendon Press: Oxford, 1989.

[6] A. H. Maslow, "Motivation and personality (3rd ed.)," Pearson Education, Delhi: India, 1987.

[7] J. Lewis and M. Schwindeller, Green Futures Research & Design Lab University of Washington, "Adaptive Streets Strategies for Transforming the Urban Right-of-Way," 2014.

[8] A. Gopal and S. Bhaduri, "Conscious cities of future: Research insights," *Conscious Cities Anthology 2017: Bridging Neuroscience, Architecture and Technology*, 2017.

[9] G. Cooper**,** "Research into Cognitive Load Theory and Instructional Design at UNSW," University of New South Wales, Australia, 1998.

[10] J. J. Gibson, "The senses considered as perceptual systems," Boston, MA: Houghton Mifflin, 1966.

[11] S. Marshall, "Streets and patterns," London, Newyork: Spon Press, 2005.

[12] DETR and CABE, "By Design- Urban Design in the Planning System: Towards Better Practice," [homepage on the internet]. c2000, [cited 2017 February 12]. Available from: https://www.gov.uk/government/publications/urban-design-in-the-planning-system-towardsbetter-practice

[13] B. Hillier & J. Hanson, "The Social Logic of Space," Cambridge, New York Cambridge University Press, 1984.

[14] Mehtap Özbayraktar et al., IOP Conf. Ser.: Mater. Sci. Eng., 2017. 245 072019

[15] R. Hayward,S. McGlynn, & Oxford Polytechnic, "Making better places: Urban design now," Oxford: Butterworth-Architecture, 1993.

[16] M. Holmes, "Evaluating the intervention of Gehl Architects in New Road, Brighton in relation to social conditions," Robert Gordon University, 2017.

[17] Q. Yang, "Lively Streets and Better Social Life Lively Streets and Better Social — A case study of three comparable streets in Kristianstad," Master of Science in Spatial Planning, Blekinge Tekniska Högskola, 2012.

[18] J. Azmi, "Comparison Study: Las Ramblas, Barcelona, Spain," Universiti Teknologi Mara, 2016.

[19] C. Yoo & S. Lee, "When Organic Urban Forms and Grid Systems Collide: Application of Space Syntax for Analyzing the Spatial Configuration of Barcelona, Spain," *Journal of Asian Architecture and Building Engineering*, 16:3, 597-604, 2017. DOI: 10.3130/jaabe.16.597

[20] J. Daly, L. Mahmoudi, T. Hollingsbee, R. Ocampo, "Measuring human experiences of public spaces: A methodology in the making," *Conscious Cities Journal*, Vol 1, 2016.

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Planning Framework for the sustainable management of wetland

A case of Ashtamudi Lake in Kollam

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***Abstract*— Wetlands are fragile eco systems. They are the interface between terrestrial and aquatic ecosystem having either permanently or seasonally and support the features of flora and fauna. Considering the ecological importance of wetlands in maintaining the stability of nature, survival and economic stability of human there need more attention to the conservation and management of wetlands. Despite the implementation of conservation and management of wetland there are still some gaps in the proper coordination among stakeholder & involvement of locals, implementation of policy & legal framework. The study aims to determine the effect of anthropogenic intervention in the wetland system and also determine the existing legal framework and management activities of wetland by considering the case of Ashtamudi.**

Based on the review of literature on the values, function and legal framework of wetland management and analysis the case of Ashtamudi wetland through recognition study leads to identify the issues and mapping the major issues. Select the case studies of national and international best practices of wetland management to understand the policy and strategy taken. Analysis shows that the wetland is mainly affected by the settlement and edge character along the lake region, impact due to urbanization, livelihood activities, and water quality. The result indicates the lack of proper maintenance and management of the wetland system. And also determine the need of coordination among stakeholder and involvement of local community. Further research is needed to focus on sound wetland management plan with proper planning and design guidelines.

Keywords — Wetland, issues and potential, Ashtamudi, livelihood, policy, legal framework

I. INTRODUCTION

Wetlands are the valuable ecosystem in the world's land surface. They include a wide spectrum of biodiversity. Wetland is influenced by both natural and human factors. The increase in urbanization and change in occupational structure leads to the shrinkage of wetland, change in ecosystem and loss of biodiversity. Haphazard developments of tourism also have a major role in degradation of wetland.

Preliminary literature review establishes the values of a wetland, and also determines the policies and legal framework for the management of wetland ecosystem. Ashtamudi Lake is designated as Ramsar site due to the availability of different type of species. Major development and livelihood activities are towards the lake side. CRZ guidelines and management plan are there for the wetland management but there is an illegal and unplanned development along the lakeside. It may be due to the lack of guidelines for the conservation and management plan for lake at local level. The study is to understand the major issues of wetland ecosystem due to anthropogenic activities and to identify the issue that affects the livelihood and housing along the wetland. And to evolve planning framework for the sustainable management of Ashtamudi wetland. The time constraints for the observation study limit the study course to some extent. The study limited to the present status, potential and issues of Ashtamudi lake region. The guideline proposed will be context specific.

II. METHODOLOGY

The research is a diagnostic framework which highlighted the primary cause of the overexploitation of resource and depletion of wetland due to anthropogenic activities. The best practices and measures for the management of wetland in India and abroad will be studied and analyzed. The project shall lead to evolve general solution for the issues identified

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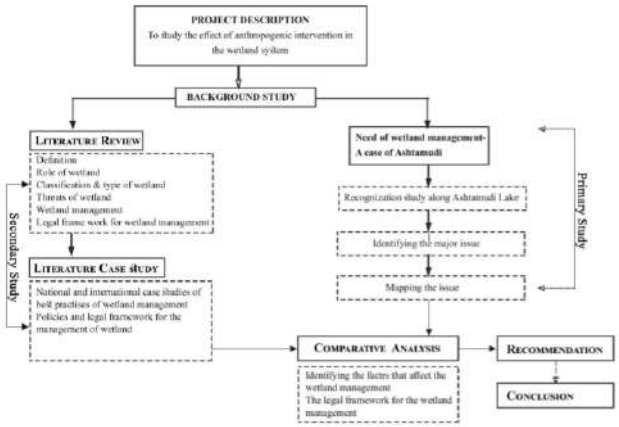
from the literature and primary studies. And also recommended the area to be considered while preparing a wetland management plan for the context identified.



III. LITERATURE REVIEW

A. Wetland - Definition

Wetlands are the transition zone between the dry land and the water body. It is the Eco tone zone with different characteristics other than the water body or dry land. It also serves as the interface between the aquatic and terrestrial ecosystems characterized by hydric soil which may be permanently or seasonally saturated with water. The wetland has distinct characteristics of flora and fauna. According to the Ramsar Convention "wetlands are areas of submerged or water saturated lands, both natural or artificial, permanent or temporary, with water that is static or flowing, fresh or brackish, or salty including areas of marine water, the depth of which at low tide does not exceed six meters."[19]

Wetlands are the area of earth surface that taught the humans the art of cultivation about 10000 year back. The wetland and human beings are in tandem from time immemorial. It is true to say that human beings are molded and human cultures were modified in the vicinity of wetlands [17]. Early civilizations first arose along the Edges of rivers in the fertile soils of flood plains [11].

B. Role of Wetland

Wetlands provide a variety of ecological functions to the environment. They are a habitat for many different species of flora and fauna. Some of the functions of wetlands are [19].

- Water Service
- Storage Reservoir and Flood Attenuation
- Groundwater Replenishment
- Water Purification
- Shoreline Stabilization and Protection
- Carbon Sequestration
- Reservoir of Biodiversity
- Wetland Products
- Pollution Abatement
- Avenues for Recreation

TABLE I- [20] BENEFITS OF WETLAND

Benefits of wetland	
Psychological	Positive effect on mental process
Cognitive	Positive on cognitive mental process
Physiological	Positive on physical function and /or physical health
Social	Positive social effect at an individual, community or national scale.
Spiritual	Positive on individual religion pursuits or spiritual well being
Tangible	Materials goods that an individual can accrue food wealth or possession

C. Distribution of wetland in India

According to the genesis, geographical location, water quality, dominant species, and soil and sediment characteristics. There is enormous diversity of wetland in India. The existence of different climatic zone across the country resulted wide variety of wetland system from high altitude cold desert to hot and humid wetland in coastal zone with its variety of flora nd fauna, According to the first survey by the Department of science and technology in 1976 found out there are 1193 wetland (covering an area of 39045 sqkm) in India. From which 572 were natural, 542 were man made, 7included both natural and manmade habitats and other unclassified. Of these wetlands 19 were coastal, 134 were brackish water & 938 were fresh water in nature. Majority of this wetland were used for reed gathering, waste disposal, fish culture, fishing and irrigation purpose. Some wetlands are used as multipurpose. Where as in second survey revealed that the total area of wetlands in India is 5, 82,860 sqkm and 70% of which are under paddy cultivation.

Fig. 1. [15] Map showing State-wise number of wetlands in India

D. Problem faced by wetland

The wetlands are presently subjected to immense pressure owing to rapid developmental activities and indiscriminate utilization of land and water. The major issues faced by the wetlands are mainly related to pollution, eutrophication,

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encroachment, reclamation and mining. Some of the issues faced by wetlands are mentioned below: [12]

- Impacts on Population, Economy, Ecosystem Diminution of bio resources.
- Reclamation of land for developmental activities has resulted in extinction of various kinds of species.
- The toxic waste dumped into the system enters into the food chain through aquatic organisms and it results to various conditions such as chemosensory disruption, anesthesia, narcosis, cell damage, etc.
- Waterborne and zoonotic diseases
- Mining and reclamation activities have resulted in reduction of water way which affects the water transport in the system.
- Agricultural productivity has been considerably decreased due to the conversion and reclamation of the low lands and other wetland areas for construction and other purposes. This has a direct effect in reduction of food production. The productivity of agricultural land is also affected due to erosion and pollution.
- Scarcity of potable water
- The rapid rate of reclamation for the use of land for different purposes has affected the flood characteristics and causing excessive flooding of the area during monsoon.

E. Threat and Loss of wetland in India

The major threats the wetland faced are encroachment and landfill for infrastructure development, habitat destruction, over exploitation of resource, discharge of waste water, industrial effluents, uncontrolled siltation, overgrazing of livestock, harmful fertilizers and pesticides runoff, weed infestation ..etc. these leads to the reduce of wetland ability to perform useful function- flood control and water retention, to supply services and valuable products.Though accurate result as wetland loss in India are not available . According to the wildlife institute of India survey revealed that 70-80% of individual fresh water marshes and lakes in the Gangotic flood plain have been lost in the last five decades, Only 50% of India wetland remains at present. There are being lost at rate of 2-3 % every year. Indian mangrove areas have been halved almost from 700,000 hectares in 1987 to 453,000hectares in 1995. [3]

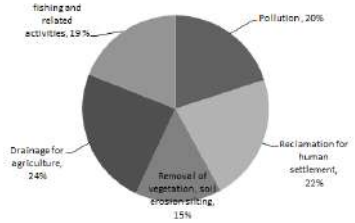

Fig. 2. Threat of wetland in India

F. Legislation for wetland conservation

Notification declaring the coastal stretches of seas, bays, estuaries, creeks, rivers and backwaters which are influenced by tidal action up to 500 meter from the high tideline and land between low tide line and high tide line as the coastal regulation zone notification 1991 under the provision of Environmental (protection) Act 1986. These provided restriction on setting up and expansion of industries including pressure from human activities

There are several legislation have been enacted which have more relevance to wetland conservation. Iaspite of all these there is no separate provision for separate legal instrument for wetland conservation.

Major national initiatives for wetland management in India are:

- Indian Fisheries Act 1857
- Indian Forest Act 1927
- Wildlife (Protection) Act 1972
- Water (Prevention and Control of Pollution) Act 1974
- Environmental (Protection) Act 1986
- Wildlife (Protection) Amendment Act 1991
- Biodiversity Act 2002
- National Wetland Conservation Programme (NWCP) 1985-86
- National Lake Conservation Plan (NLCP) 1993
- National River Conservation Plan (NRCP) 1995
- Ramsar Convention 2002
- National Environmental Policy 2006
- Wetlands (Conservation and Management) Rules 2010
- National Water Policy 2012

G. Wetland Conservation and Management

The major attempts in India regarding the wetland management and classification includes:

A large number of sites have been listed in the national inventory of wetlands initiated by the Government of India in 1960. In 1980, Indian National Science Academy and the National Institute of Ecology conducted an International Wetlands Conference in New Delhi. In 1989, The Ministry of Environment and Forest (MoEF) and WWF published a detailed inventory of Indian wetlands. This inventory covered 93 wetlands of International Importance. The inventory consists of information on their major biota, especially waterfowl, land use and human impacts as well [18]. A wetland directory was published by MoEF in 1990 which covered 2167 natural wetlands with an area of 1.5 million ha and 65253 artificial wetlands with 2.6 million ha. In 1993 WWF India and MoEF identified 54 additional wetlands of international importance. By using IRS data, Space Application Center identified 27403 inland and coastal wetlands with total area of 7.6 million ha in 1996. For creating digital database for GIS application, MoEF sanctioned a project on National wetland inventory for creating State wise wetland atlases in 2000 [10].

- National Wetland Conservation Programme (NWCP) 1985-86
- National Lake Conservation Plan (NLCP) 1993

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- National River Conservation Plan (NRCP) 1995
- Ramsar Convention 2002
- National Environmental Policy 2006
- National Water Policy 2012

IV. Study Area

Ashtamudi known as the Kerala deepest estuary. Ashtamudi Lake is situated in Kollam and it is the second largest wetland ecosystem. It is a palm shaped water body with eight prominent arms. It opens to the sea through a single outlet at Neendakara from several creeks such as, Kumbalathu Kayal, Kanjirakkottu Kayal, Kandanchira Kayal, Kuripuzha Kayal Kallada Kayal, Thekkumbhagam Kayal, Perumon kayal, and Thevally Kayal.

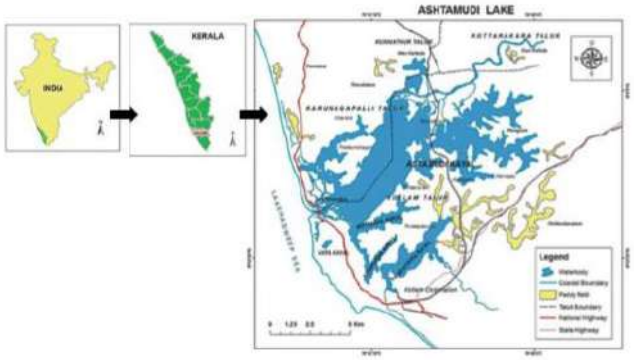

Fig. 3. [2] Location of Ashtamudi Lake

Kallada River which originated from Western Ghats is the major river discharge into the Ashtamudi Lake at Neendakara and finally entre into the Arabian Sea with max depth of 6.4 m at the confluence zone.

The National Highway (NH 47) is passes through the periphery of the lake. The railway network is also passing along the lake and connected to major towns and village. The boat Jetty is located 3 Km away from the railway station and provide boat services.

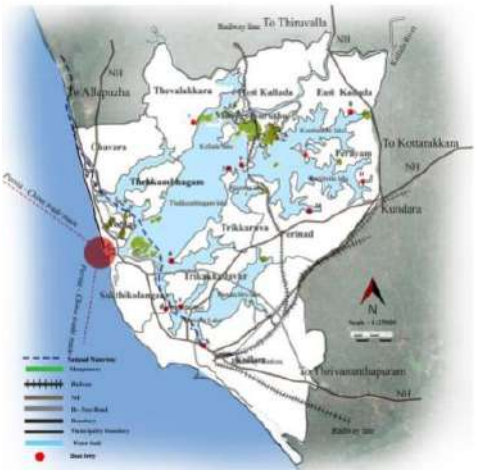

Fig. 4. Map showing connectivity along Lake(Source – Author)

A. *Major Potential*

Five types of geographical units are seen along Ashtamudi Kayal. They are Coastal Plain, Undulating upland, Valley fills, Alluvial plain, Island. Ashtamudi Lake is also acts as flood Storage Lake. The estuary has several species of mangroves. These offers ecotourism in the estuarine of the lake. The wetland housed different species of flora, fauna, water birds, resident species and migratory species.

The estuary is known as second biggest fish- landing center after Vembanad estuary and it has been a source of livelihood for thousands of fishermen. There are many small and big islands in the lake region which are the major factor which contribute to the beauty of the lake. These islands are inhabited or uninhabited by human beings. There are several bridges which connect the banks Island and mainland. These bridges plays an important role in the social and educational progress of people in the island and mainland

B. *Land Utilization along the Ashtamudi Lake region*

The study considered the panchayat along the lake side.

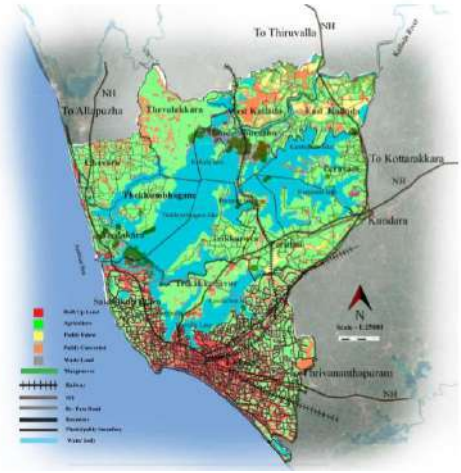

Fig. 5. [2] Land Utilization Map of adjacent Panchayat(Source – Author)

- Chavara

Chavara a small village in south of lake, and the area is reported to be mineral rich with number of fishes and industries for the processing, extraction and export of titanium and other minerals. The untreated effluent from factories is causing pollution of the lake water.

- Thekkumbhagam

Thekkumbhagam Island is the biggest island and known as the heart of the Ashtamudi Lake. The islands provide a flawless natural beauty and also have a feel of rustic life of a village. The Dalavapuram and Pavumba bridges connect the island to the mainland. The National Waterway to the north of Kollam starts from Thekkumbhagam Lake.

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- Thevalakkara

The Kadappa at Thevalakkara were made for centuries. The land is surrounded by water field and paddy lands.

- Neendakara

The long bank near to the coastal area. It is the Kollam intermediate fishing port.

- Thrikkadavoor

A growing urban center which housed several educational institution, 5-s star hotel and business establishment and major real estate venture.

- Sakhthikulangara

It is the confluence region with Arabian Sea. Major fishing harbor in Kerala. It also been a prominent place of seafood exporting, fish landing center, boat building yard, vattakayal…etc

- Muntrothuruthu

A cluster of eight small islands in the Ashtamudi Lake. Coconut coir manufacturing, fishing etc. are the main source of livelihood. It is a major destination of tourism.

- Perayam

Perayam is the one of the industrial hub of Kollam city. The main sources of income of the people are Private Employment, Government Employment, Cultivation (mainly coconut and Paddy) Fishing and some overseas employment.

- Perinad

These area incorporate development activities with the develop of technical and educational institute such as fashion technology, Kerala institute of management, IT park, Perimon engineering college .etc... It also is a center of coir industry.

C. Characteristics of Ashtamudi Creek

Kanjirakode creek is at the South – East end of the lake. The creek is the deepest part of Ashtamudi Lake. On the west of the creek is Perumon Lake and bridge and Kundara is in south east. But this creek face extension due to the dumping of waste from the Government owned public sector unit Kerala Ceramics Limited (KCL) at Kundra. It leads to the extinction of several species of fish varieties, which affect the livelihood of the fishermen. Thevally Lake creek placed at the north side of the lake. The lake side is famous for the Thevally Palace on the south side. The National waterway connects with it. Kadachira Lake creek is in northern side of the Thevally lake. The region is famous for Sree Mahadeva temple at Kadavoor. Kareepuzha creek is in the north western side of Thevally lake. These region having boat bays ranging from Thoppikkadavu to Kavanad (south western side) and from Olikkara to Sambranikkodi (northwestern side). Perumon lake creek region is spread between Perumon and Pezhumthurathu. These areas are connected by Perumon bridge.Kumbalathu lake creek - Inbetween sub island Padappakara and East Kallada. The main bays are Kumbalam, Nellimukkum, Vallathi, Mannukadavu.The Chinese net system (cheenavala) widely used in the surrounding area of the island. The main source of income is from coir industries, agriculture and fishing.

Fig. 6. Map showing connectivity along Lake(Source – Author)

D. CRZ map of delineated area of Ashtamudi lake

The ecologically sensitive mangrove ecosystems with an area of 0.01 km2 is CRZ IA. The protective buffer zone of 50m is provided around the mangrove ecosystems having an area of more than 1000m2 and are CRZ I. The total area within CRZ landward of HTL is 50.82 km2. The total area of CRZ II (landward of HTL) is 16.93km2. The area of CRZ III between 200m and 500m CRZ Regulation Line is 2.62 km2.[4]

Fig. 7. Map showing CRZ zones (Source – Author generate in reference to CZMP Report)

E. Major Livelihood Activities

- Fishing

Neendakara and Sakhtikulangara have a considerable importance in fishing industry. The fishing harbor in Neendakara developed the fishing activities, it been the major source of income in these region.

The main fishing areas along the lake region are:-

Kollam Cooperation, Neendakara, Chavara, Thekkumbhagam, Trikkadavor, Trikkaruva, Thevalakkara.

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Different kind of technique is used for fishing. Padal fishing / bush park fishing is type of technique which used to harvest the fishes Cheenavala (Chinese net) also used for the harvesting of fishes The men are dominated in the fish harvesting activities. Women are engaged with processing, preparing and vending operation. Existence of different species increases the inland fishing activities. Crab value chain various from 120kg as landing cost to 500 Rs as exporting cost. The catch of Ashtamudi area in Karimeen. About 5000 peoples are engaged in the sector full time or part time basis. Annual income of fishermen is 4200-9000; Annual income of fishermen is 2750-3450[23][24].

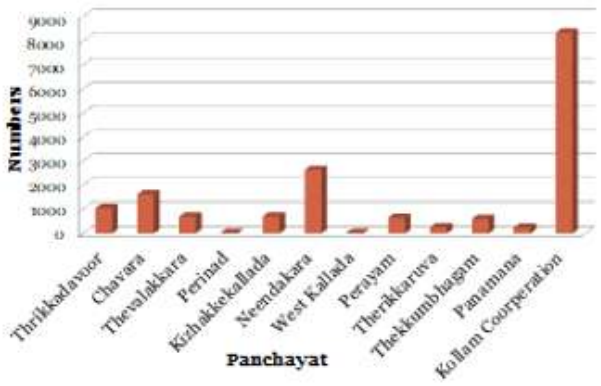

Fig. 8. [23][24] Number of fishermen household in the Panchayat

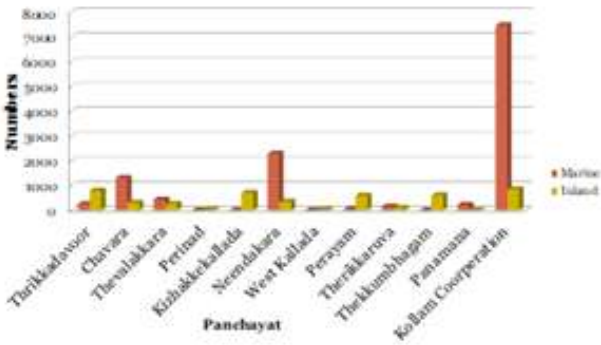

Fig. 9. [23][24] Number of marine and inland fisherman household

Fig. 10. Fishing activity

Issues -

Padal fishing / bush park fishing technique is banned by State Department of Fisheries. Because the Padal fishing is affect sustainability of the fishery resources.

Cheenavala or Chinese net also exploit the fishery resources.

Destruction of Mangroves

Potential from tourism and sports fisheries are not explored.

Lack of facilities in Landing Centers/Fishing Harbors.

Unauthorized introduction of new fishing activity.

- Clam Fishing

About 1.7km2 area of southwest side near the bar mouth is the clam fishing area. The areas surrounded by Neendakara & Dalavapuram village in the north, Chavara, Thekkumbhagaam in the east, Sakthikulangara bar mouth are identified as clam fishing area. The water depth of the fishing area is varies from 1-3 m depth.[25]

The clams in the Ashtamudi backwater and estuarine provides livelihood for the community in the area. They exploit them for meat and shells. These shells are been used by the industries as raw material. Southwest side of the Ashtamudi is highly rich in clam resource. They are been used it for both local consumption as well as for export. About 80% of India clam exports are from Ashtamudi Lake. About 3000 fishermen depend upon the Clam fishing. The fishermen in the area usually get a clam catch weighing 40-50 kg of clams within 3 to 4 hours daily.

Issues of Clam fishing

• Unregulated dumping of untreated wastes in the south west of the lake and urbanization decrease the quality of the water which affect the existence of Clam

• Over fishing and use of mechanical device for fishing exploit the resource.

• Exploitation of undersized clams and reclamation of rich clam beds can cause detrimental effect on the clam resources of the Ashtamudi lake.

• Lack of effective management of resource.

• Lack of proper infrastructure facilities for clam fishing.

• Lack of rule and regulation for clam fishing.

- Coconut Husk Retting

Another major activity of the community nearby the lake is coconut husk retting. Which were usually done by the women's in group or as individual. The new technique used eases the work and reduce the pollution compared to the traditional activity. Kollam Ashtamudi Coir Cooperative Society ensures all the required help for the coir industries. The women are grouped to form a 14 or more members of small group and initiate units in different region of lake for coir production. About 350 Rs as daily wages in which 240 is from the society and 110 from the government. Several beneficiary are also available such pension...etc.... 20 Tonnes of yarns spinning unit in the cluster operating in the private largely informal sector – 90 cooperatives societies function for the sector. It provides employment to about 51,683 workers. 85 kg of fiber costs about Rs 800. 80kg of spun yarn of about Rs 1600.

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Issue - Noxious smell of hydrogen sulphide emission from retting area results in air pollution and related health hazards. Flooding during monsoon disperses these pollutants to surrounding areas ultimately damaging the entire water body.

F. Major Threats of Ashtamudi

Major issues of the lake are due to the discharge of domestic and industrial wastes. Without any proper treatment or segregation of wastes dumped into the lake directly.

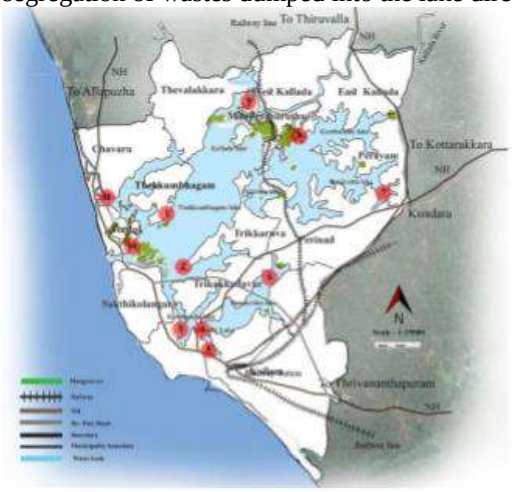

Fig. 11. Issued areas (Source – Author)

Fig. 12. The expansion of agriculture and aquaculture has become a major pressure for encroachment, reclamation, pollution, water eutrophication and loss biodiversity of the lake. The use of fertilizer for crops that seeping to lake cause pollution. The organic and inorganic feeds new artificial technique for the filter of water for aquaculture farms affect the water quality by increasing salinity and discharge of wastes.

The over-exploitation of the fishery resource and use of unscientific method and new technique for fishery affect the mangrove system and lead to pollution in the shoreline. Oil spillage due to the poor handling of fuel and increase in number of houseboat lead to the direct discharge sewage into lake the haphazard growth of tourism activities and pollution accelerated the deterioration of water quality of the lake. Increase in sand mining reduces the filtering capacity of river and lead to saline water intrusion.

Ashtamudi is treated as waste sink; about 60% of houses near lake directly discharge sewage into the lake. Sewage from Muncipal Corportation located at southern kayal at are one of the major source for lake pollution. Hanging toilet along the Ashtamudi lake region also cause pollution. The major waste dumping sites are Mammoottikkadavu, near Kollam Bus stand and Kureepuzha.

Lack of proper management practice of disposing waste from hospital and slaughter cause a severe problem to the quality of water in the lake. The environmental pressure on the land and habitat transformation and reduction in biodiversity are due to the encroachment in to the wetland and change in land use.

V. INFERENCE

The wetland provide source of livelihood and also maintain the balance ecosystem. From the study it is found out that the wetland is affected by different anthropogenic activities.

The activities that directly affect-

- Settlement and edge character along the lake region

Land Use

Encroachment

Reclamation

- Water quality

Haphazard growth of tourism

Oil spillage from boat

Increased use of fertilizers for agriculture

Unscientific fishing methods.

- Impact due to urbanization

Sewage line is directly connected to the lake

Dumping of waster without proper treatment

Effluents form the industries

- Affecting Livelihood

Overfishing and unscientific method for fishing reduces and extinct the species.

Lack of infrastructure facilities

Over exploitation of resources

VI. RECOMMENDATION

Raise awareness among the local stakeholders and community about the degraded exploited and neglected wetland resources

Improve waste management in sustainable manner and measure to taken by prohibiting any kind of discharge into the wetland.

Identifying the area required land use controls, zoning, should be assigned to wetlands, buffer zones, Eco sensitive area etc.

In cooperating traditional knowledge system used for the conservation locally.

Promote environmental friendly and sustainable activities like wise use of wetland resource, ecotourism, conservation

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of traditional knowledge and practice and also encourage income generating scheme, rehabilitation and restoration of degraded wetland etc.

TABLE II- ANALYSIS &RECCOMENDATION

THREAT	LOCATION	RECOMMENDATION
Coir retting practices causes organic pollution	All the stream of wetland	Provide a solid waste management at Kureepuzha. Identify alternative waste disposal sites and waste by-products.
Poor Waste disposal methods.		
Use of agro-chemicals		
Siltation/erosion, Bad fishing methods		
Oil spillage due to the poor handling of fuel and increase in number of housebcat.	Kureepuzha, Kundara, Munroethuruthu, Thekkumbhagam, Neendakara	The use of Propane, biobutanol and natural gas could propel fishing boat into sustainble matters. Sensitize the local community and stakeholders. Introduction to organic farming. Provide a solid waste management system
Use of herbicides and pesticides in agriculture farms		
The haphazard growth of tourism activities	Munroethuruthu, Thevally, Neendakara	Boat fuelling area and better drainage systems near the lake to keep the fish quality at its best for local food and export. regulating, the number of house boats operating in the lake ,Solid waste and sewage generated by them and enabling proper upkeep of parking bay.
Increase in sand mining	West Kallada, East Kallada, Padappakkara	Restriction or regulation for the mining activities.
		Allow the affected area for recovery.
		Sensitize the community. The continuation of small-scale sand mining is recommended in sustainable manner
Increasing the population growth. Displacement of people close to wetlands	Along the wetland area	Regulation for the construction. Zoning and byelaws, Reclamation of lake area is to be avoided
Destruction of wetlands vegetation, Cultivation, Siltation, and Waste disposals	All the stretch of wetland	Wetland research, training, monitoring & assessment
		Development of Communication network
		Demarcating wetland boundaries, Restoration of wetlands, Re- vegetation, awareness, capacity building
Destructive fishing methods such as Padal fishing practices in Ashtamudi Lake. Use of Chinese net for fishing. Over-exploitation of the fishery resource	Entire the system	Construction of fishing landing center. Regulation for the fishing methods and encourage for sustainable practice
Limited funding, Lack of support, Lack of awareness/ knowledge on roles and responsibilities, and Absence of organized resource user groups	All the stretch of wetland	Conduct comprehensive public awareness programme to improve the aesthetic environment near the Lake
Disposal of untreated waste and connected the sewage line directly into the lake.	Around the industrial area, residence, small scale industries along the lake.	Provision of area for landfill, ensure the wastes are treated before dumping into the lake
Waste from the nearby industries		
Degradation of Mangrove ecosystem	Kallada, Munroethuruthu, Sakthikulangara	Mangrove conservation-cum-rehabilitation
		Sensitize on conservative measures
		Wetland research, training, monitoring & assessment
		Development of Communication network

(Source – Author)

The management plan for the Ashtamudi lake region should consider the following for the *integrated sustainable management of wetland.*

Social development

Tourism development

- Development of recreational facilities
- Development the tourism activities to enhance the livelihood activity and income (Eg - Live fishing and eat system)

Riverfront development

Infrastructure development

- Boat Landing
- Boat fueling area
- Fishing facilities – freezer facilities
- Transportation facilitates
- Facilities for loading and unloading

Livelihood Improvement

- Protection of traditional knowledge and rights
- Micro enterprise development on sustainable use of wetland.

Waste Management

- Solid waste management
- Interception and diversion of wastewater
- Low cost Sanitation

Mitigation of floods

- Satellite wetland rejuvenation for flood control

Water quality improvement

Biodiversity conservation

- Conservation of indigenous or native fish species.
- Tree plantation and afforestation
- Rejuvenation of Mangroves

Institutional Development

- Policy and regulatory mechanisms
- Institutional Networking
- Capacity Building
- Monitoring and Evaluation
- Database Management

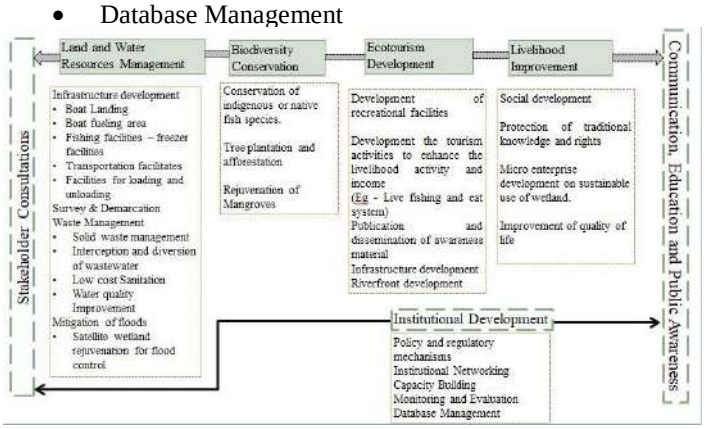

Fig. 13. Flow chart showing element to consider for management plan (Source – Author)

VII. CONCLUSION

The study is mainly focuses on the need of the conservation and management of wetland. Wetland exhibits enormous diversity. Wetlands are most precious life sustaining water resource. It is known to be s Kidney of Landscape.

According to Article 51 A of constitution of India says that it is the fundamental duty of each citizen to protect and manage the natural environment.

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"It shall be the duty of every citizen to protect and improve the natural environment, including forest, lakes, wild life and to have comparison for living creature."

The approach of setting normative policy measures and universal ecological reference point is insufficient and ineffective to the wetland governance and management. The wetland in close proximity to the city re most vulnerable mainly due to the anthropogenic activities. The existing regulation such as CRZ which has control only over the type of occupancy and over the building not considering on the encroachment and conversion of land. From the study it is understand that there is a strong need of policy level intervention for concerning wetland at nation and state level and also which are implemented at ULB level by assessing public partnership

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REFERENCES

[1] N.Balakrishnan Nair and et. al. "Ecology of Indian estuaries VII "Inorganic nutrients in the Ashtamudi estuary"." *Dept. Aquatic Biology Univ. of Kerala, Trivandrum,*, 1989.

[2] A. Krishnakumar,P. Saranya,Revathy Das. *Hydrogeochemistry and Environmental Issues of the Wetlands of Kerala.* New Delhi: Springer, New Delhi, 2017.

[3] Bassi, Nitin, M. Dinesh Kumar, Anuradha Sharma, and P. Pardha-Saradhi. "Status of wetlands in India: Areview of extent, ecosystem benefits, threats and management strategies." *Journal of Hydrology: Regional Studies*, 2014.

[4] CDP. *City Development Plan for Kollam, 2041* . Kollam: Capacity Building for Urban Development project (CBUD) A Joint Partnership Program between Ministry of Urban Development, Government of India and The World Bank , 2014.

[5] Cowardin, Lewis M., Virginia Carter, Francis C. Golet, and Edward T LaRoe. "Classification of Wetlands and Deepwater Habitats of the United States." 1992.

[6] Chackacherry George, Jayakumar. "conservation and management of vembanad-kol wetland, kerala ." *Researchgate*, 2011.

[7] Gopal, B., and M. Sah. "Inventory and classification of wetlands in India." *Vegetatio*, 1995: 39-48.

[8] India, Planning Commision Government of. *Report on Visit to Vembanad Kol, Kerala, a wetland included under the*. Ministry of Environment and Forests, 2008.

[9] K, Jayadev. S. *Status of Wetlands in Kollam District.* Trivandrum: University of Kerala, Department of Geology, 2012.

[10] Kaul, S. *National and International Initiatives in Wetland Management.* Thiruvananthapuram: Kerala Environment Congress, 2007.

[11] Keddy, and A. Paul. "Wetland Ecology: Principles and conservation." 2000.

[12] Kokkal, K., P. Harinarayanan, and K.K. Sabu. "Wetlands of Kerala." *Kerala State Council for Science, Technology and Environment (KSCSTE)*, 2007.

[13] N. Suja , k. S. Mohamed. *The Black Clam, Villorita cyprinoides, Fishery in the State of Kerala, India.* Marine fish Reviewer, 2010.

[14] Peter Taylor, Waterview Consulting. *Lake Michigan Basin Land Cover Change Report, 1985–2010* . Chicago: NOAA Coastal Services Center, 2013.

[15] Saha, Goutham Kumar. *Indian wetland : Problems Prospects and Potential.* Kolkata: Entomology and wildlife Biology Research Laboratory, Department of Zoology Calcutta , n.d.

[16] Sitaram, Nagaraj. "Impact of urbanisation on water quality parameters – a case study of ashtamudi lake kollam ." *IJRET: International Journal of Research in Engineering and Technology* (NOAA Coastal Services Center), 2014.

[17] Wade, M., and E. Lopez-Gunn. "Wetlands in Pacione." In *Applied Geography*, 288-300. 1999.

[18] Ramsar. *Wise use of wetlands: Concepts and approaches for the wise use of wetlands.* Switzerland: Ramsar Convention Secretariat, 2018.

[19] Woistencroft, A.J., C.K. Varshney, and S.A. Hussain. "A Directory of Asian Wetlands." *Scott D.A. ed. IUCN*, 1989: 367-505.

[20] (1999). Sustainable wetland , Environmental Governance.

[21] Statistics. *'Panchayat Level Statistics-2011'.* Trivandrum: Department of Economics and Statitics, 2013.

[22] Limited, Infrastructure Leasing & Financial Services. *Growth Pole Programme: Kollam* . Kerala: KBIP,NCEUS, 2008.

[23] Kolliyil, Sunilkumar, Mohammed ,V. Kripa,Venkatesan Vellathi,Sajikumar k.k. *fishery management plan for ashtamudi lake clam resources.* Kerala: Research gate, 2013.

Disaster Risk Reduction Model

Case Panamaram, Wayanad

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***Abstract*— Disaster Risk Reduction (DRR) has been mainstreamed to achieve sustainable development of cities with the basic objective to decrease the loss of life, property destruction and socio-economic disruption caused by hazards. The component of risk gained importance with the world steadily urbanizing and increasing the number of people living in vulnerable conditions along with the increasing number of natural disasters. DRR lead to a shift from top-down management approach to the decentralization of disaster management initiatives like Community Based Disaster Management (CBDM) that was inclusive of local governing bodies. For the successful implementation of DRR at the local level, there is a need to understand the essentials of the DRR for practice and how risk can be measured. Accordingly, the study aims to develop a self-assessment framework of measurable indicators for vulnerability to strengthen community capacity. Exploratory literature study and vulnerability assessment of the study area identified as vulnerable to hazards, lead to proposals for socially responsive development strategies further contributing to developing a Disaster Risk Reduction Model that would be an approach to improve the efficiency of CBDM initiatives with grass-root level data. This paper is based on the approach adopted for the study and discusses key observations in the study area and recommendations.**

Keywords*— *Pre-Disaster Management; Disaster Risk Reduction; Community Based Disaster Management; Risk Assessment

I. INTRODUCTION

Disaster cannot be controlled was the perception and the only remedy was a relief and humanitarian assistance. Over time, the world view transitioned to the concept of risk created through the exposure of vulnerable conditions to hazards that are natural, a result of anthropogenic factors or a combination of two [5]. With India experiencing a 151 % rise in direct economic losses from climate-related disasters between the years 1998-2017 where extreme weather accounts for 77 % of total economic loss [6], there is an immediate need for efficient assessment of risk and implementation of Disaster Risk Reduction (DRR) strategies.

Thereby the study intends to develop a model for DRR with local governance body playing the major role in implementation along with people participation and improving the capacity at the community level for self-assessment of risk by developing a Self-Assessment Framework of vulnerability indicators.

II. BACKGROUND STUDY AND BEST PRACTICES

DRR is a crucial part of sustainable development. Unmonitored development policies will increase disaster risk and disaster losses. Thus, DRR involves stakeholders from society, government, and every part of the professional and private sectors.

A. Concepts and global initiatives

An exploratory study on concepts and global initiatives in DRR that was conducted suggested that prioritization of risk assessment needs to be conducted with spatial references at the local level considering the diversity in impact and differential exposure of Households (HH). The study included the review of vulnerability assessment in disaster management plans in four Indian cities selected through risk ranking by National Disaster Management Authority and expert suggestions and also the actions that are included in Village Disaster Management Plans in India based on the actions listed by the World Bank [7]

The study suggested the subjective approaches towards measuring vulnerability and the absence of scale for a comparative study of risk scenarios of two different regions at the grass-root level.

B. Best practices

The study of practices of DRR integrated in Development planning adopted by countries like Philippines, United Kingdom, New Zealand, and New York based on the aspects of DRR that included Governance Mechanism, International collaborations, Data Management Process, Technical methodology and Scope of Risk Assessment [6] suggests that housing could be considered as a sector for vulnerability analysis and scenario analysis is the potential technical methodology that can be adopted for the study in absence of historical data for hazard occurrence that was the most critical limitation of the study.

C. Tools and Indicators

Katic (2017) in his work has proposed two tools namely Comparable Social Vulnerability profiling (CSVP) and Index Calculation and Application [4]. Since the study is oriented towards developing a self-assessment of risk at the household level, it needs to be user-friendly. Thereby, this study adopted

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the concept used in CSVP for its characteristics of being user-friendly in the absence of experts.

Literature study that included the research of seventeen authors of which the most important two where Cutter, (2003) [2] and Mishra M. (2015)[8] lead to identifying 39 indicators and 89 sub-indicators and their expected influence towards disaster vulnerability. They were classified under 4 types of vulnerability namely Hazard, Socio-Economy, Physical and Housing.

III. VULNERABILITY ASSESSMENT

To demonstrate an approach there is a need for identifying a vulnerable study area.

A. Identifying Study Area

Five districts in Kerala, under the Multi-hazard vulnerability profile geographically and the population was identified and categorized into highlands and plain or coastal regions. On the basis of literature suggesting that highlands have a higher impact on increasing vulnerability, the study was oriented towards districts in the highlands of Kerala. The hazard vulnerability, impact of Flood 2018 and the socio-economic condition as in the Census of India 2001 and 2011 lead to the identification of Panamaram Gram Panchayath (GP) of Wayanad district to be considered as the study area.

Panamaram GP (as in Fig 1) is a potential growth node due to its proximity to Kalpetta and Mananthavady the present growth nodes in Wayanad. The GP also witnesses the confluence of Panamaram river from Banasura Sagar dam and Karapuzha river from Karapuzha dam (as in Fig 2)

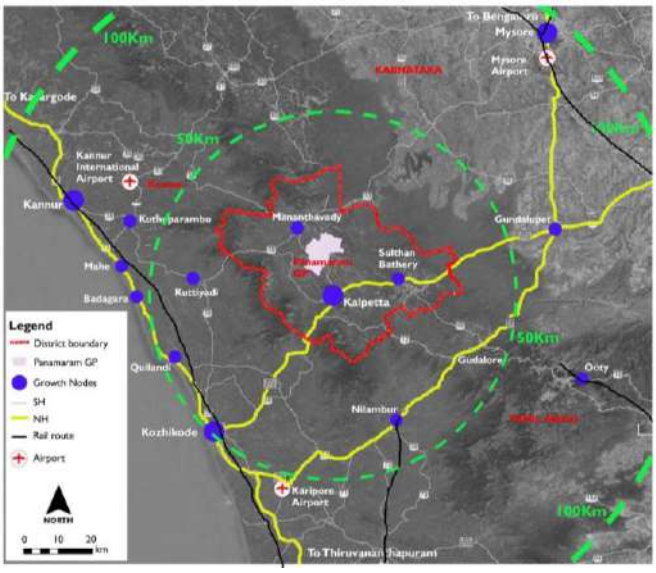

Fig 1 Regional setting of Panamaram GP

Source: District Urbanization Report, Wayanad, (2011); Generated: Using Google Earth Pro 7.3.2.5776, Panamaram, 2019@ Digital Globe accessed in March (2019)

B. Vulnerability assessment- Panamaram GP

Disaster vulnerability assessment of Panamaram GP was conducted based on:

- Ecological vulnerability – Annual rainfall, Eco-sensitivity, Impact on Cauvery River basin (Pollution and land-use change)
- Physical vulnerability - Land use change 2008 and 2015, development pattern (built density generated using ArcGIS software, Location, connectivity and capacity of critical infrastructure
- Socio-economic vulnerability – Education, Income generation, Credit access, Social network and dependence
- Housing vulnerability – Age to location and material of houses, Recovery process, utility services and capacity of relief camps.

The assessment was based on the Post-flood impact assessment conducted by the District Town and Country Planning Office (DTCPO) Wayanad [3] and the primary survey conducted at 2 areas in the panchayath identified through focus group discussion (as in Fig 2).

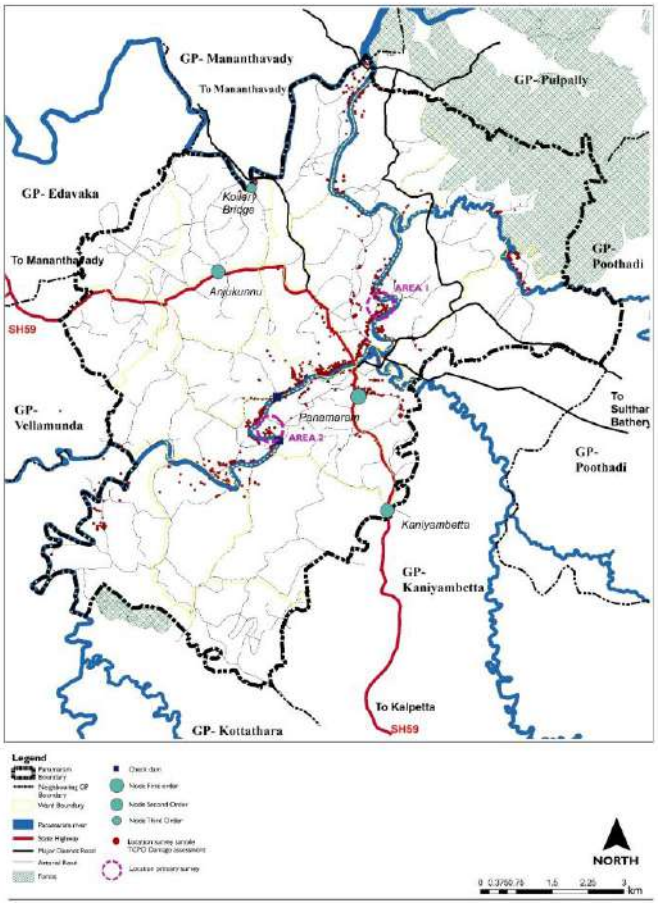

Fig 2. Base map Panamaram Gram Panchayath and Location of Survey sample

Source: Primary study, February (2019); Rebuild Malabar Wayanad, DTCPO Wayanad (2018); Generated: Using Google Earth Pro 7.3.2.5776, Panamaram, 2019@ Digital Globe accessed in March (2019); ArcGIS [ArcMap]. Version 10.2.1, Panamaram, CA: Environmental Systems Research Institute, Inc., 2016.

Some major observations in the assessment are:

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- Banasura Sagar dam and Karapuzha dam both have a huge role in the flood 2018 and needs capacity increase management of Watercourse
- The connectivity between the critical infrastructure and the development pattern is the most important factor to be addressed in physical vulnerability for Risk Reduction in Panamaram GP.
- The location of critical infrastructure and the regulations for locating new infrastructure could reduce the risk of potentially vulnerable scenarios.
- The primary sector contributed to income and a tendency to discontinue education post-primary school
- Low access to formal credit and high dependence for post-disaster recovery
- Ignorance of Annual flood plain in constructing houses due to low access to treated drinking water supply
- Absence of flood proofing and utility service in recovery housing
- Relief shelters do not abide by the standards prescribed by the National Disaster Management Authority (NDMA)

The vulnerability assessment and the primary surveys conducted for the same provided data for assessing the risk of the Panchayath in case of future occurrence of a hazard. Accordingly, structural and non-structural mitigation measures and the administrative agencies and the hierarchy that can initiate the same was recommended.

IV. Recommendations and Strategies

The Risk Reduction strategies include interventions at the Regional level, the Panchayath level and Household level. The environmental vulnerabilities are largely addressed at the Regional level while the physical vulnerability at the Panchayath level. The socio-economic vulnerability and housing vulnerability need attention at the Regional level, Panchayath level and HH level.

A. Self-Assessment framework

The 89 sub-indicators where scored based on the expected behaviour and the impact assessment at Panamaram GP. The vulnerability score of each household was calculated from the response to a scheduled survey. To measure risk the vulnerability in presence of hazard needs to be assessed for which the 3-point Likert scale was adopted and the vulnerability score of physical, socio-economic and housing against hazard score was measured using risk matrix which leads to risk scoring. For hazard vulnerability, the parameter of proximity to the source of the hazard was considered which is Panamaram River in the case of the study area.

The risk score of the households surveyed (as in Fig 3) of areas 1 and 2 in the study area (as in Fig 2) suggests the distribution of the Households under each risk score. The results identify the Households under Low, Moderate and High risk and the result being developed on a single scale helps comparison and prioritization for risk mitigation.

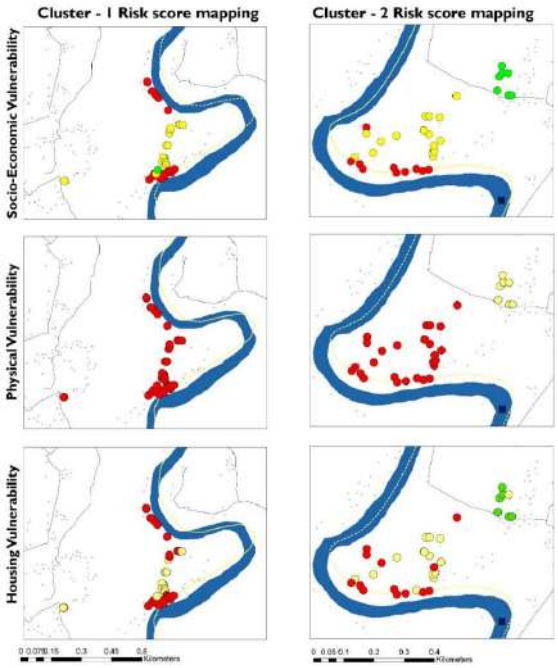

Fig 3 Test result depicting risk score using the Self-assessment framework with a 3-point Likert scale
Source: Author generated

It also suggests that Physical risk has the highest number of households in the high-risk score while the socio-economic risk has the least number of houses with a high-risk score. Thereby, the need for the study area is prioritization in mitigating physical risk. Further, the infrastructure, housing and socio-economic risk reduction strategies are suggested based on the score from the risk assessment survey.

B. Development Regulation

To address the issue of increased built development along the annual flood plains and to avoid further uncontrolled development along the sides of the river, the proposal for development regulation zones in the panchayath was proposed.

The panchayath has been categorised into four development zones with each zone identified on the basis of Topography, Annual flood plain and 100-year flood plain (as in Fig 4).

Zone 1- 100m from the River FTL.

Zone 2- 500m from the River FTL and less than 744m AMSL or 10m of Natural drains.

Zone 3- 100 years flood plain excluding Zone 1 and Zone 2

Zone 4- Area not - in Zone 1, 2 and 3 & excluding notified forest

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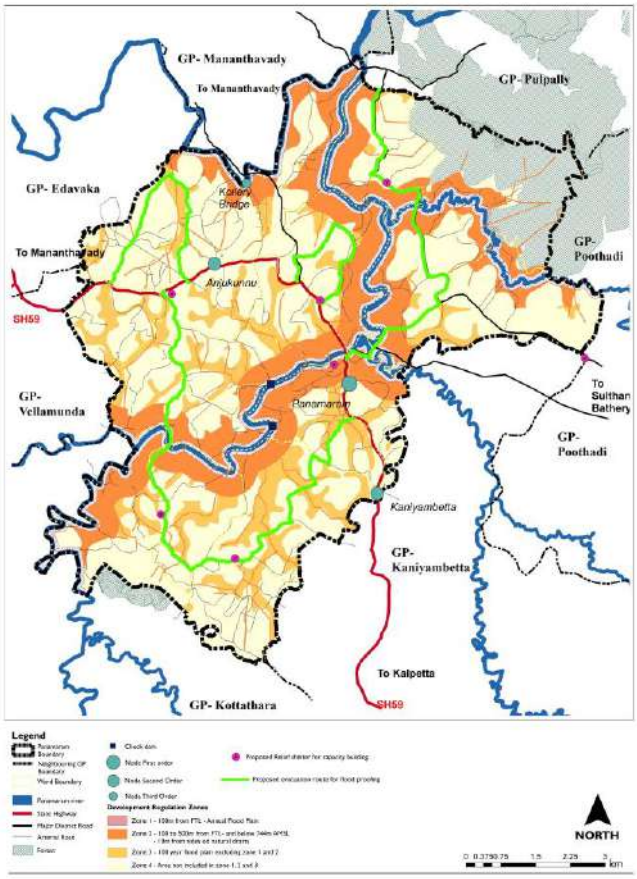

Fig 4 Proposed Development Regulation Zones
Source: Author Generated

The existing land use (as in Fig 5) was studied based on which the potential strategies recommended for each zone was recommended that included actions for adaptation and mitigation through:

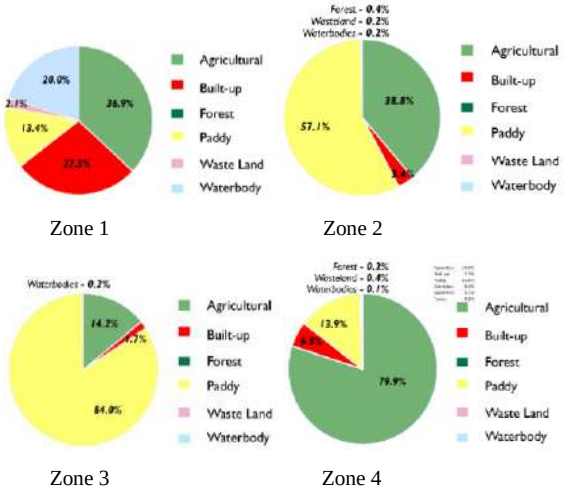

Fig 5 Existing Land use Zone wise

Source: DTCPO survey 2015 Generated: Using ArcGIS [ArcMap]. Version 10.2.1, Panamaram, CA: ESRI, Inc., 2016.

- The identification of zones and their opportunities in terms of land use and the potential threat contributed to orienting the future developments in the GP.
- Floodproofing – dry and wet – Adaptation for critical infrastructure
- The housing risk was addressed by recommending strategies for Floodproofing, Insurance, Relocation and Incentives zone wise and the risk score derived from the self-assessment framework (as in Table 1)

Table 1 Zone wise housing risk reduction strategies

	LOW	MODERATE	HIGH	Risk Reduction
Zone 1	Mandatory till relocation	Mandatory	NA	Flood Proofing
	Mandatory : 100% asset	Mandatory : 100% asset	NA	Insurance
	Mandatory - Phase III	Mandatory - Phase II	Mandatory - Phase I	Relocation
	Incentive for relocation - if land surrendered	Incentive for relocation - if land surrendered	Beneficiary in Government Housing scheme - Prioritized based on	Incentives
Zone 2	Mandatory	Mandatory	Mandatory if not relocated	Flood Proofing
	Mandatory : Built up	Mandatory : Built up	Mandatory through govt schemes	Insurance
	Non-mandatory	Non-Mandatory	Mandatory - If Housing risk high	Relocation
	For water retention and RWH	For water retention and RWH	Beneficiary to livelihood development schemes	Incentives
Zone 3	Mandatory	Mandatory	Mandatory	Flood Proofing
	Mandatory if Housing Risk High	Mandatory if Housing Risk High	Mandatory if Housing Risk High	Insurance
	Non-Mandatory	Non-Mandatory	Non-Mandatory	Relocation
	RWH and Sustainable Agricultural practices	RWH and Sustainable Agricultural practices	RWH and Sustainable Agricultural practices	Incentives
Zone 4	Mandatory : RWH and Sustainable Agricultural	Mandatory : RWH and Sustainable Agricultural practices	Non-Mandatory : If Socio-Economic Risk High	Flood Proofing
	Mandatory : Livelihood	Mandatory : Livelihood	Mandatory : Livelihood	Insurance
	NA	NA	NA	Relocation
	Surrendering Land for Govt schemes	Surrendering Land for Govt schemes	Surrendering Land for Govt schemes	Incentives

The connectivity of the relief camps is ensured through strengthening and redesigning of evacuation route identified (as in Fig 6). The evacuation route is proposed with solutions to avoid inundation. The relief shelters that the evacuation route serve is mapped and the minimum service requirements were calculated based on the standards prescribed by NDMA.

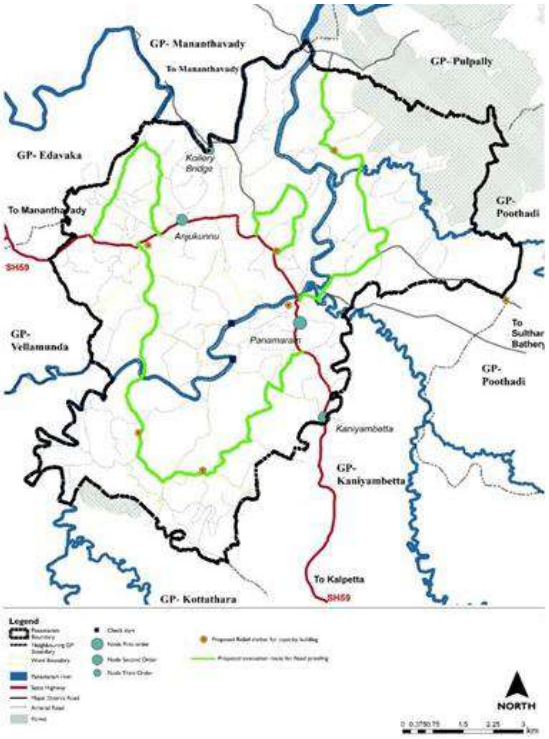

Fig 6 Location of relief camps proposed for capacity development and identified evacuation route

Source: Primary survey, February (2019); Rebuild Malabar Wayanad, TCPD Wayanad (2018); Generated: Using Google Earth Pro 7.3.2.5776, Panamaram, 2019@ Digital Globe accessed in March (2019); ArcGIS [ArcMap]. Version 10.2.1, Panamaram, CA: Environmental Systems Research Institute, Inc., 2016.

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C. Disaster Risk Reduction Model

The strategies related to watercourse management, conservation project integration, technical capacity building, data management, built regulation, community as stakeholder and housing are integrated with the Community Based Disaster Management and initiated through resources available at different levels of administration. The actions at varied administrative hierarchies can initiate an efficient implementation of DRR (as in Fig 7). This would also address the limitation of historical data ensuring data security and quality in future studies and interventions.

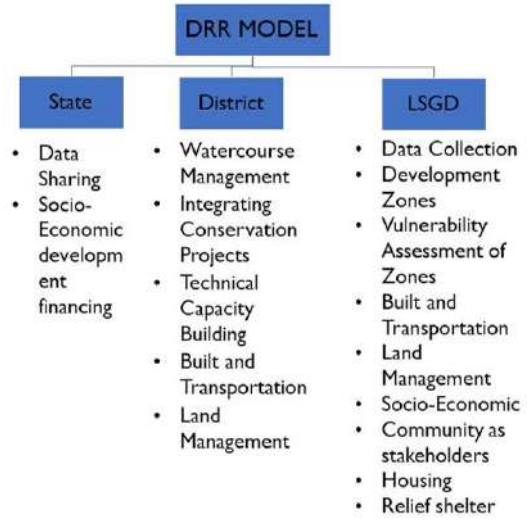

Fig 7 Actions to be initiated at the administrative hierarchy for DRR

V. CONCLUSION

Disaster Risk Reduction (DRR) is the practice that involves the integration of all levels of governance for reducing the loss of life and property in times of disaster. The practice is relevant in the present scenario because of the increasing exposure of vulnerability to hazard in the community. The urgent need to mainstream DRR strategies into the planning process in India has also been advocated over the years by scientists and academicians. But the policies and Disaster Management Plans are addressed at macro levels limiting the integration of local knowledge into disaster reduction planning also limiting the awareness of the community. There are arguments that suggest that the governments at the national level pay less attention to disaster risk reduction at the local level considering that the national income is not impacted by the occurrences of a natural disaster at local levels [1]. Thereby, this study aims to address the gap in documenting the capacity of the local community and help to address the issues and develop policies that can be initiated at the Panchayath level (lowest level administration unit in India).

Throughout the study, the results are limited to the observations and survey data obtained pertaining to a single hazard 'Kerala Flood 2018'. In the future, it is hoped that the better availability of historical data on multi-hazards would be possible. The self-assessment framework can also be developed further for addressing the multi-hazard scenario in varying physiography.

This study demonstrates an approach, a model for Disaster Risk Reduction to integrate disaster risk reduction into development planning that can be initiated at the Panchayath level and enables the community to assess their risk conditions using the self-assessment framework. It would also develop a comparable format for communities avoiding subjective inputs and encourage people participation with increased awareness. Also, address the limitation of availability of historical data.

The study implies that the better investment into assessing the risk leads to the efficient management of risk in development planning and also emphasizes the major role of local knowledge in effectively implementing the risk reduction strategies.

ACKNOWLEDGMENT

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The author's sincere gratitude is due to all the researchers who have contributed to the field of Disaster Risk Reduction especially to **Cutter, S. B**. (2003) that was the springing point for this study.

REFERENCES

[1] Charles Cohen, E. W. (2008). *The Political Economy of "Natural" Disasters.* Harvard Business School.

[2] Cutter, S. B. (2003). Social Vulnerability to Environmental Hazards. *Social Science Quarterly*, pp. 84 (2). 242–261.

[3] IIACalicut. (2018). *Rebuild Malabar Wayanad Post Disaster Assessment of Great Flood of 2018 Comprehensive Report.* Indian Institute of Architects Calicut Centre.

[4] Katic, K. (2017). *Social Vulnerability Assessment Tools for Climate Change and DRR Programming.* Istanbul: UNDP.

[5] UNDP. (2009). *Handbook on Planning, Monitoring and Evaluating for Development Results.* New York: United Nations Development Programme.

[6] UNISDR. (2017). *Words into Action Guidelines National Disaster Risk Assessment Governance System, Methodologies, and Use of Results.* UNISDR.

[7] Margaret Arnold, R. M. (2014). *Climate and Disaster Resilience The Role for Community-driven Development.* Washington D.C.: The International Bank for Reconstruction and Development / the World Bank Group.

[8] Mishra, M. (2015). Analyzing the Dynamics of Social Vulnerability to Climate-Induced Natural Disasters in Orissa, India. *International Journal of Social Science*, 217-234.

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STUDY OF KANADUKATHAN

A Chettinad Village Development

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Abstract— **For centuries man has been creating edifices to document his existence on earth. Globally, we have inherited a large number of such heritage structures. In most cases, the shelf lives of the buildings are nearing expiration. The immediate future for these buildings is breakdown, adaptive reuse or downfall. The ethical high road that is often taken is that architecture is greater than the sum of its parts, an entirety that cannot be understood or appreciated in fragments. However, can a piecemeal existence be the future for a heritage building rather than an impending threat of complete obliteration? Can architecture exist as a series of fragmented components that can be extracted singularly and enjoyed as separate entities? Can architecture enjoy a prolonged shelf life through extracted forms? In south of India, in the state of Tamil Nadu, near the city of Madurai lies an area called Chettinad. Spreading over seventy villages, it exhibits homes belonging to the Nattukottai Chettiar community. Huge 19th century mansions testify the power and community strength through its architecture. Unfortunately, these mansions now lie desolate in ghost towns after the mass migration of the community members from their ancestral villages. Some structures are being subjected to adaptive reuse, while others will eventually go under the axe. What have emerged as interesting by-products are huge warehouses situated in prominent towns like Karaikudi and Kanadukathan that bring down these houses in a systematic format trying to salvage each and every component in its intact form. These are then sold as separate components to Southeast Asian countries and within India too. This paper intends to examine the future of this heritage site , through an detailed study of the evolution of mansions by giving more focus on one of the Chettinad village ,Kanadukathan.**

Keywords—Chettinad , Heritage, Evolution, Demolition ,Future Proposal.

I. INTRODUCTION

India is rich in cultural heritage and historic buildings are in abundance in different regions of the country. Chettinad is one of them, a culturally strong region located in South India significant for its palatial mansions and its unique architecture. This land came to be known as Chettinad (Land of Chettiars) in 1947 which was just a cluster of 96 villages, 74 of which still exist today.The tiny tinsel town of Chettinad is a reflection of its glorious past. Many of these mansions due to negligence are falling into a state of decay or they are being dismantled systematically for the reuse of its materials of construction.Therefore the preservation and appropriate reuse of these mansions becomes necessary for its cultural, social and economic sustainability.

Fig. 1. Location Map of Chettinad

(Image Source : mapsofindia.com)

Chettinad is, generally, the area between Pudukottai (North), Aranthangi (East), Devakottai (South) and Tirupathur (West)[ref fig 1].Chettinad is an area located in the Southeast region of India in the state of Tamil Nadu near Madurai, India .The region is dry and barren with scant rainfall and very long, scorching summers.Land is not conducive to agriculture due to these reasons.Chettinad refers to the 650 square mile area, comprising 96 villages where the Nattukottai Chettiars live.The number of villages is now reduced to 74 due to migration.

II. CHETTINAD

A. Origin and Evolution

Chettinad is inhabited and dominated mainly by the Nagarathars or the Nattukkottai Chettiar community. Chettinad (Land of the Chettiars) was established under the Chola kingdom during the beginning of 13th century over a 1700 square mile area. Chettiars have played a leading role in the business world of the Chola kingdom, dominated the coastal business as ship-chandlers, salt merchants and gem dealers from 17th century. The origin began in the early 13th

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century when the tribe called Nattukotai Chettiars settled in the region due to a massive flood in their original settlement [ref fig 2].

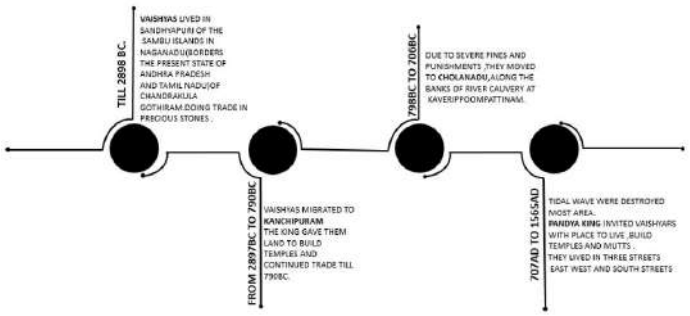

Fig. 2. Evolution diagram of Chettiars

(Image source : Author)

Subsequently Chettiars became the vital element of local finance and trade in several South Asian and Southeast Asian countries that lived under the flags of the British, the French and the Dutch. They did business in the Madras Presidency, Burma, Federated Malay States, Strait Settlements, Cochin, China, Siam, Java, Sumatra and Mauritius. Making money all over Southeast Asia, they shipped home their tremendous wealth where it was reshaped into fabulous family manors that dotted the entire landscape of the region wherein they lived together as joint families and did business together as families[ref fig 3].

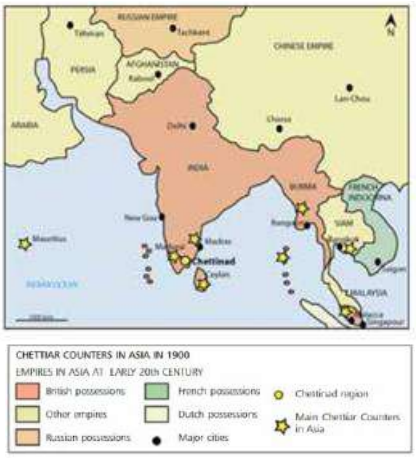

Fig . 3. Migration map

(Image source : Indian Heritage Passport Programme: on the Chettinad trail in Tamil Nadu; a concept paper)

However, at the peak of their success, World War II broke out. The British imperial government requisitioned all foreign companies engaged in any form of commerce, and the Chettiars were forced to return home empty-handed. Some of the Chettiars who had invested in industry, banking and education in Chennai and other parts of Tamilnadu were able to shift from trading to these new avenues. In doing so, they migrated to and started settling as families in Chennai and other parts of Tamilnadu as nucleated families (1920-1930's) leaving behind, their palatial ancestral houses at Chettinad, as venues, for their religious festivals and life cycle ceremonies and rituals. However many of these mansions are falling to decay due to negligence.

B. Chettinad Architecture

Settlement pattern in Chettinad follows a perfect urban grid [ref fig 4] and cultural components of caste, clan, kinship, joint family are manifested in the spatial organization of the Chettinad houses. Therefore dwellings were palatial and identical in principles of planning but with variations in size, details and embellishment. The pattern of settlement and design of mansions are sensitive to context connected with a complex network of rain water harvesting serving the entire village community.The houses all lie on an east-west axis, allowing shadows, coolness and breezes in. The walls are of brick and lime plaster and the roofs use terracotta, creating a cool internal micro climate.

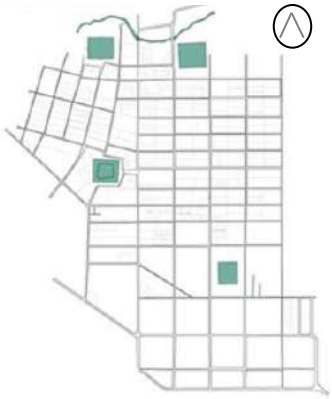

Fig . 4. Pattern of Kanadukathan

(Image Source : The Revive Chettinad Project by UNESCO)

The spatial planning follows the cosmic plan and the dwelling are introverted, with a minimal number of external accesses. The various spaces in the typical Chettinad house are the following :

- The compound wall abutting the front street (madhil suveru)

- The central highlighted access (nadaipaathai)

- The lower paved area and a raised platform (Keezhpaththi)

- Accountant room (Kannakku pillai aria) - Men's relaxing room (Pattagasalai)

- Two or three courtyards ('valavu' , erandam kattu, mundram kattu)

– first of bigger scale to conduct functions and to celebrate festivals, second of slightly larger scale used for household

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activities and the third for the services like cooking, washing etc.

- Corridors surrounding courtyards (suttru paththi)

- Series of rooms at two levels around the courtyards

- first set of rooms for sleeping and second set of rooms for storing valuables (arias or valavu veedu) .

- Staircases at all the four corners accessed from the corridor of the kitchen

- Large kitchen (Aduppadi or samayal arai) with traditional choolas

- Open hearth using firewood

- A dining hall in front (Bhojana hall)

- The rear yard for cattle and rough uses with a well for water supply (pinpuram / kollaipuram)

- The rear doorway exiting into the rear street (pinkadhavu) [ref fig 5]

Fig . 5 . Spatial Planning and Hierarchy

(Image source : Chettinad Architecture, Lifestyle, Architecture and planning concepts, Samyukthaa)

The principle of construction in these mansions is columnar and trabeate, and the use of arches on the facade in later mansions comes as a result of the interface the Chettiars had with the colonial powers. The facades were elaborately embellished with solid void patterned parapets, motifs, finials, niches with stucco sculptures of Hindu Gods and Goddesses, British benefactors, flora, fauna, mythical creations, geometric patterns, etc., columns with capitals (western Doric to Indian traditional), various types of arches, turrets, and a colour scheme using terracotta, white, yellow, red and blue. This established a unique architectural character which can be termed as the Chettinad style.

The mansions are characterized by exquisite wood work seen in the doorways and in the columns and brackets that surround the courtyards using Burma teak, rose wood and satin wood. Most attention is given to the threshold with highly carved and decorated jambs, lintels, panels. The expanded lintel panel above the main door depicts various iconographies from Hindu mythology.

Walls were of baked bricks laid by skilled masons and covered with Chettinad plaster and flooring was provided with local Aathangudi tiles peculiar only to this region. Interiors are embellished with Chinese ceramic and local tiles, imported Italian marble, Belgian glasswork, stoneware and ironware.

III. KANADUKATHAN

One of the 96 villages –a small heritage village located 15kms away from Karaikudi-the chief town.Kanadukathan is the heart of the current tourism trail in Chettinad situated in the district of Sivagangai, comprising around 5000 inhabitants[ref fig 6].It is the village where the palace of the Rajas and two of the mansions converted into heritage hotels are located.Visitors can appreciate the peaceful ambience of the large streets of the village set in a semi-urban context.

Fig . 6 . District Map of Sivagangai
(Image source : Author)

Current scenario of Kanadukathan :

Occupied Residences - Owners donot live on a permanent basis,they gather for large,important occasions or gatherings.In some cases external portions are rented out.

Demolished Residences - Considerable amount of houses are demolished and only the mounds on which they were built remain.All that could have been recycled has been taken ,leading to lucrative antiques business and many architectural elements(pillars and doors in particular).

At Risk Of Demolition - Destruction seems inevitable for various reasons: lack of financial means or joint ownership, dismantling for purposes of sale, and damage to the structure.This could totally wipe out the living evidence of a way of life [ref fig 7].

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Fig. 7. Diagram showing demolished heritage houses in the village of Kanadukathan

(Image source : Indian Heritage Passport Programme: on the Chettinad trail in Tamil Nadu; a concept paper.IN/2010/CL/31.)

The mansions shows drastic changes from the year 1850 to 1950:

A. V.R.M.V House (Before 1850)

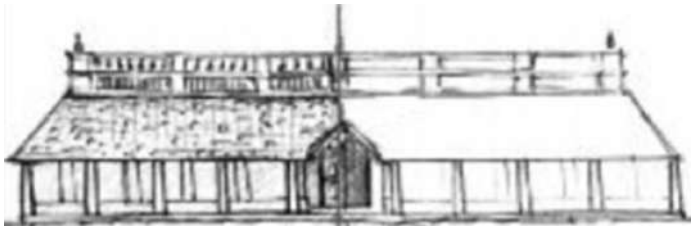

Fig. 8. Elevation of V.R.M.V House
(Image source : Mansions of Chettinad by Meenakshi Meyyappan)

The first houses of Nattukottai Chettiars are simply village dwellings that resemble those of other communities in Tamil nadu[ref fig 8].This indicates that prior to about 1850 the Chettiars were not substantially wealthier.

They were dealers in rice from Kaveri delta of central Tamilnadu salt deposits from Coromandel Coast pearls from Gulf of Mannar.

In traditional Tamil domestic architecture the thinnai is the most public space within the house the place to socialize with neighbors and visitors.

The orientation of the houses to the east or west with a central east-west axis along which all of the interior components of dwellings are arranged in perfect symmetry. Sheltered by a steeply angled roof of terracotta 'country tiles'.

- Carried on wooden framework.
- Low plinth lined with granite.
- As the principal living space for the family,the thinnai accommodates storage chests and other furniture.
- The thinnai gives directly into a spacious court with slender granite columns all around carrying a steeply angled terracotta roof with axial gables.
- Thinnais customarily divided into two equal plinths,separated by a walkway at ground levels that leads from the street to a wooden doorway[ref fig 9].

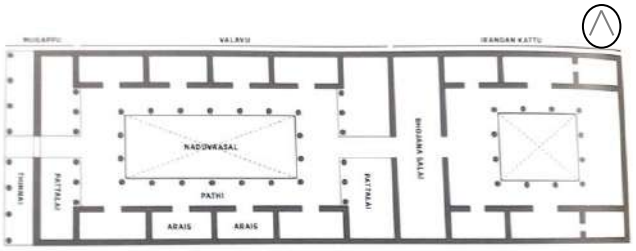

Fig . 9 . Plan of V.R.M.V House
(Image source : Mansions of Chettinad by Meenakshi Meyyappan)

Roof of thinnai is carried on a line of circular wooden columns with tapering shafts,sitting on granite bases,often embellished with petal-like incisions at top.Timber columns of wooden brackets of local wood ,later replaced by Burmese teak and mahogany raised on petalled granite bases to protect from the insects and water damage.European type circular masonry columns run along verandahs,shallow colonettes with European capitals divide wall surface into regular bays.Kitchen walls and service rooms coated with black cement so as not to show smoke.Interior doors remains simple and elegant with intricately worked panel over the lintel.

B. C.V.C.T – C.V.R.M House (1850-1900)

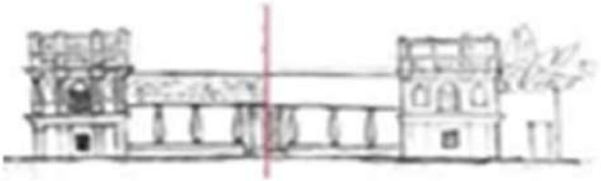

Fig. 10. Elevation of C.V.C.T – C.V.R.M House
(Image source : Mansions of Chettinad by Meenakshi Meyyappan)

It was during this time period that male came to travel abroad.The conversion of typical village house of Chettinad into grand mansions occurred during half of the 19th c.The most important change was that entire plot is elevated above the street.Series of steps constructed to reach thinnai.Steps are framed by balustrades.Thinnai is no longer used as a space for everyday interaction.This loss is compensated by an architectural development called parapet/an upper room architectural borrowings are shown in richly moulded plasterwork a technique used by Tamilnadus domestic and religious architecture [ref fig 10].

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It has one or two plinths,the edges of which are lined with columns.The first space to be encountered after mugappu of Chettinad mansions is an internal thinnai ,known as a pattalai [ref fig 11].Neo classical columns,shallow colonettes framing niches and round headed arches ,domes and pinnacles indicates European origin features were combined with icons of Hindu divinities even peacocks and parrots showing a very non-European effect, along with application of vivid paintwork.

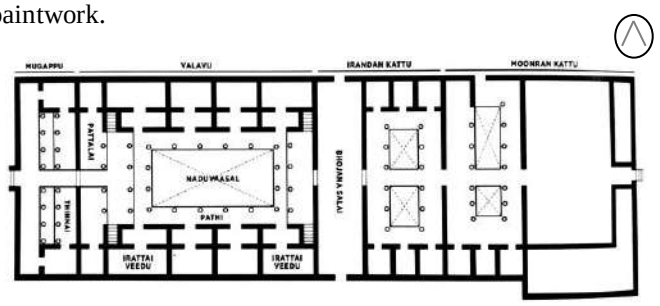

Fig . 11 . Plan of C.V.C.T –C.V.R.M House
(Image source : Mansions of Chettinad by Meenakshi Meyyappan)

The porch and verandah are provided with their own sloping roof of ceramic tiles or metal sheets.The courtyard onto which the thinnai opens is defined by slender granite columns sheltered by a steeply sloping roof with terracotta tiles.Upper rooms from the rear of the house overlook the courtyard.Non local materials begin to be employed for the first time,such as Mangalore tiles for roofs and imported Burmese teak and other woods.

East-west layout is belief in the house as a universe in a miniature,oriented to the rising and setting sun the house interior is expanded horizontally,at the same time exterior are extended vertically the courtyard is increased in size,with additional opening off the sides.

A door at the rear side leads to second courtyard which repeats the essential features of the first courtyard, though at a smaller scale and with simpler columns and doors.Second courtyard reflects the growth in size of the joint family.

C. S.RM.M.A.M House (1900-1930)

Fig . 12 . Elevation of S.RM.M.A.M House
(Image source : Mansions of Chettinad by Meenakshi Meyyappan)

Front hall is the principal architectural innovation of this decade.Garages came as part of porch and has octagon formation [ref fig 12].Porch leads directly into verandah,that runs full width of the house ,concealing the thinnai within Irattai veedus or double rooms consists of two rooms,outer one opening directly off the pathi. It is the only private space. Inner one for keeping wealth and dowry.Outer has barred windows opening directly to verandahs and is for sleeping [ref fig 13].

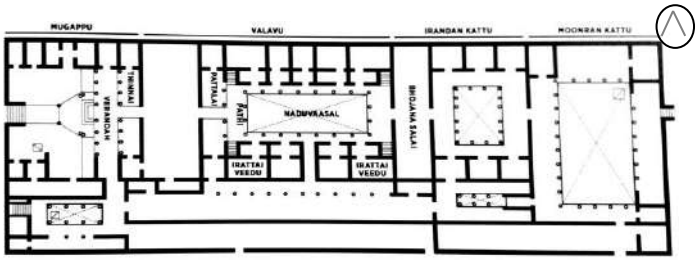

Fig . 13 . Plan of S.RM.M.A.M House
(Image source : Mansions of Chettinad by Meenakshi Meyyappan)

Ceilings above central space of hall is decorated with embossed tin or copper plates,from which European crystal chandeliers are suspended.

Sofas ,chairs and tables ,mirrors ,are first examples of European furniture and fittings.Double storeyed with upper storeyed clerestory windows to admit light.Imported marble floor tiles and ceramic wall tiles.Porch and verandah is distinguished from thinnai by European style masonry columns.Beyond the front hall lies the first courtyard,the beginning of the most private zones.Balustraded gallery running along an upper line of rooms that repeats the configuration of rooms below.Irandan kattu reserved for women and children. It has bhojana salai [Dining Hall] and nadu vassal[courtyard]. This period sees the first appearance of a second much larger dining hall.It has a passageway from first courtyard ,often running the full length of the house plot,for accomadating huge number of guests during special occasions .

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D . M.R.M House (1930 – 1950)

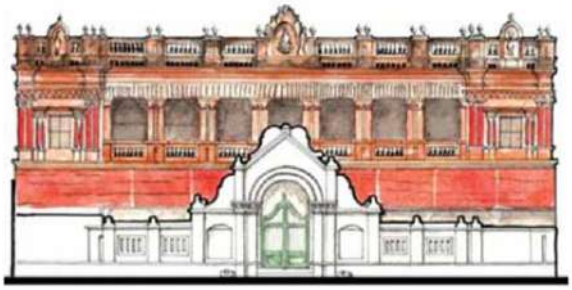

Fig . 14 . Elevation of M.R.M House
(Image source : Mansions of Chettinad by Meenakshi Meyyappan)

These are free standing villa,chettiar houses in this last phase are often entered through a verandah –like porch ,this gives access to a vestibule and a hall with thinnai like raised floor area [ref fig 14].

Conceived as a modernist garden villa,the house is set with cut out geometric patterns in a striking art deco manner. Similar patterns are seen in the parapet details of the house ,containing vividly painted icons of Lakshmi seated between elephants.

Mansions of this era even when treated externally in a modernist manner ,generally have one or more interior courtyards surrounded by colonnades and smaller bedrooms,overlooked by balconies from the upper level[ref fig 15].

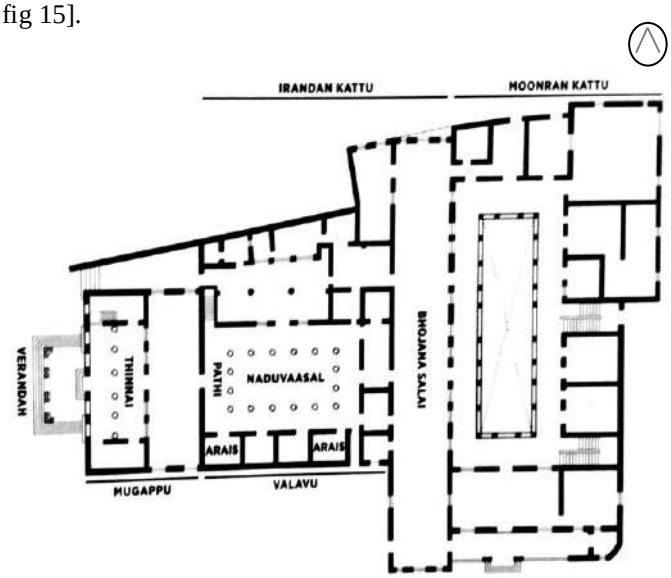

Fig . 15 . Plan of M.R.M. House
(Image source : Mansions of Chettinad by Meenakshi Meyyappan)

The wooden column brackets here replicate traditional lotus designs in contrast to the geometric patterns of the precast concrete panels in the undulating balcony above.

Instead of defining the space with colonnades raised on thinnai like plinths on which guests should be seated,halls interior tends to be furnished with European style ,upholstered wooden chairs and tables ,many designed in fashionable art deco manner.

Parapet designs in cement feature bold art deco designs with interlocking geometric facets, incorporating icons of favoured hindu divinities polished granite columns in the thinnai are either plain and square.

E. After 1950

During various struggles for independence in the years following the second world war,Burma,Malasiya and Ceylon and Indo-China came to regard the Nattukottai chettiars who had settled in these countries in former times as exploitative foreigners ,making it practically impossible for them to continue as traders and land owners.From 1970s onwards there came a new appreciation of the teak columns and intricately worked timber doorways with which most of Chettinad's mansions are furnished.

This had the consequences in the removal of these wooden components from abandoned houses to be sold on the art market.

In recent years there has been an awakened interest in Chettinad's unique architectural tradition.Few of the properties are open to the public , and it is only by special arrangement that they can be visited.Others are converted into hotels, resorts and adapts the front halls ,dining halls and private rooms for visitors .

F. Analysis and Inference

Mansions generally occupy the full length of the plot,running from a street at the front to one at the rear,a distance measuring between 75-110m.The streets are generally narrow,hardly ever more than 8m wide.

The houses are built in e-w direction thus reduces heat in the front and backyard.

Free standing villas gives extra spaces for gardening and for front porch.

Heights became gradually increasing,showing the increase in wealth of Chettiars.The increased height denotes the construction for protection.

The houses are planned in an rectangle shape symmetrical plan of houses maintains the rectangular plan so as to fully accommodate the house plot.Projected eaves [.7m] provides complete shading of the thinnai throughout the day.

Connects the exterior and interior thus enhances interaction at family level and community level.

Chettiars needed visual contact with almost the entire street provided with fully shaded and well lit space. Aligned along the axis and provides good air movement allows direct sunlight inside the house meant for drying activities.

Seasons of the outside world could be conveyed to the inmates through courtyards by bringing nature inside.Planning of courtyards at centre shows that they needed an activity point so as to conduct ceremonies.Due to arid climate they

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needed an space which maintains the inner temperature.Courtyard planning helps in collection of water during monsoon season and also has a channel that collects overflow water towards oorani.Arais act as the only private zone with diffused light to the entire space arranged around the court to facilitate work environment with sufficient openings on those spaces can help in cross ventilation.

Location of rooms adjacent to the court enables the space to get maximum benefit out of the court in double chambered rooms,one room can act a storage space and other for resting purpose.

The first kitchen is mainly for women this space is used for everyday purpose .The surrounding arais are used as storage spaces of utensils and other items .Placement of courtyards at centre allows more air flow and results in cross ventilation.

Planning of irandan kattu is as an private zone and towards the end,which is only accessed by women and children .Placing at end shows the need of an backyard access,so that the servants can enter without using the front.The second kitchen is mainly for women and servants this space is used for functional purpose. Extra addition of kitchen shows the increase in wealth of chettiars.

The surrounding arais are used as storage spaces of utensils and other items, and for stay of servants.

Planning of moonran kattu is as an private zone and towards the end,which is only accessed by women and servant.

Pillars stand as an structural as well as an decorative element.Evolution from wooden to highly decorated art deco style columns itself shows the grandness .

Collected water serves for household use to fill up wells,over abundant water flows into drainage system of village which feeds common ponds and tanks.Use of timber helps in maintaining inner temperature.

The thermal capacity of carved wooden pillar facings in the corridor around the courtyard is low that will reduce the incident solar radiation up to an extent.

IV CONCLUSION – LOOKING TO THE FUTURE

The recent surveys of some villages of the region show that many of the mansions have already disappeared. However this network of 73 villages and 2 towns still comprised of large number of palatial architecture, more than 10,000. The urban grid pattern still remains authentic, as no main alterations have been undertaken in the settlements, preserving the integrity of the town planning. The traditional water management system remains but important portions need to be restored and modernized. According to the preliminary inventory studies, the state of conservation of the palatial houses varies from one village to another. Most of the houses remains intact with the main architectural features. The houses still showcase the lifestyle of the Chettiar community. Despite the loss of about 19% of the buildings, there is still an important number of them in a surviving traditional urban form to claim integrity.

Other landmark features

- Chettinad cuisine
- Temples
- Aathangudi tiles
- Arts and Crafts

The buildings that contain a sturdy and sound foundation and structural system are the best contenders for the process of adaptive reuse. They have been in their location for a long time period and thus have layers of local context and history added to them. By retaining the sound members of the building ,retrofitting the outdated ones,introducing complimentary members, and restoring the landmark features of the structure a new lease of life can be given. Here the features like Athangudi tiles,temples, cuisine and Chettinad saree can be used to retain the value. As time is changing ,population growth is increasing,technology is rapidly advancing but the amount of land available stands at the nearly same amount that it was years ago.Thus land value increases and vacant lots are reducing.These factors coupled together have pushed adaptive reuse into the spotlight as the most preferred solution to tackle abandoned buildings .Thus it is time to embrace a trend that is holistic and creates spaces that amalgamate what was and what is. Looking to the future :

1.*Art Gallery and Museum* - The collection of art and ethnographical objects will be presented more effectively. This collection will form the basis of educational exhibitions for the public, tourists and students, tracing the history, traditions and specific urban planning techniques of Chettinad.

2.*Craft Demonstration* - Local arts and crafts in Chettinad: Athangudi tiles;Chettinad plaster, frescoes; textiles: silk, cotton; basketwork; wood carving; figurines and sculptures in terracotta;bronze work; gold and silver work, jewellery; stone sculptures; Tanjore paintings; concrete sculptures Imported objects: polished marble and granite; lacquerware from Burma; terracotta from China, Vietnam and Burma; ceramics from Japan and Great Britain; stained glass; enamel vessels.

3. *Centre for Training and Production of Handicrafts* - The handicraft centre will ensure: - Provision of training, particularly for women and youth, to give employment opporunities in the production units and restoration sites. This would have the dual purpose of improving their standard of living and also preserving the cultural heritage of the region.- Creation of work for experienced artisans, thus helping the transfer of knowledge from generation to generation.- Training in technical areas as well as in the fields of design, management, commercial techniques and new technologies.- Constant guidance for artisans to master the technical and theoretical aspects of their crafts through a permanent support from the professionals of the Centre and the invited experts.- Logistics of production and marketing [ref.fig.16].

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Fig . 16 . Proposal Plan
(Image source : Author)

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REFERENCES

[1] Das Gurucharan, (2015 May) The World Of Tamil Merchant from e book :https://penguin.co.in/book/non-fiction/world-tamil-merchant/

[2] S.Muthiah (2017 June 1) The Chettiar Heritage

[3] N Samyuktha(2015 August 16) Chettinad Architecture from pdf: https://www.academia.edu/15011828/chettinad_architecture

[4] S.Muthiah (2017 June 1) The Chettiar Heritage

[5] N Samyuktha(2015 August 16) Chettinad Architecture from pdf: https://www.academia.edu/15011828/chettinad_architecture

[6] (2017 June 29) The History of Chettinad Architecture from article: http://www.chidambaravilas.com/chettinad-architecture

[7] Ranee Vedamuthu, Jayanthi Dhakshinamoorthi, and Kumudhavalli Sasidhar (2014 October 14) Adaptive reuse and restoration of a Chettinad mansion,Pudukkottai,Tamil Nadu from Pdf: http://www.hms.civil.uminho.pt/sahc/2014/topic12-fullpaper005.pdf

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Framework for Assessing Land Suitability for Rubber Cultivation in Kerala

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Abstract*—Assessing crop suitability and land suitability analysis is an important step in Sustainable Agriculture. Rubber has great demand in various sectors and was introduced as a plantation crop in Kerala in the beginning of the nineteenth century. Due to its physiographic, soil, climatic and economic favorability, Rubber cultivation gained popularity among farmers which triggered the expansion of Natural Rubber cultivation in Kerala. As a plantation crop, it replaced natural vegetation and forests and as a small holding crop, it led to the conversion of agricultural land. However, expansion and prolonged Rubber cultivation in Kerala over the years has raised concern as several studies have indicated the negative environmental implications associated with Rubber cultivation. Also, there is a huge pressure on the limited resources of the state, which urges for the critical analysis of land development. In Kerala, where rubber is already under cultivation, suitability assessment helps in understanding the potentials and limitations of different areas for setting priorities in allocating costly and scarce inputs. Therefore, the aim of this research is to critically analyze the environmental impacts of Rubber cultivation and to establish the need for land suitability assessment for Rubber cultivation in Kerala. A multi-criteria decision-making framework which includes a set of bio-physical, spatial planning and locational factors was developed to assess the land suitability for rubber cultivation. This multi criteria framework can be used to map and assess the suitability- highly suitable, moderate, least suitable and not-suitable-of an area for Rubber cultivation in Kerala.*

Keywords—Land suitability, crop suitability, Rubber cultivation, plantation crop, multi criteria framework

I. INTRODUCTION

Rubber was introduced as a plantation crop in Kerala in the beginning of the nineteenth century. Due to its physiographic, climatic, soil and economic favorability, Rubber cultivation gained popularity among farmers which triggered the expansion of Rubber cultivation in Kerala and also introduced the entry of small holding farmers into the rubber industry. At present, there are two types of rubber cultivation based on area and ownership identified by the Rubber Board of India, which are small holdings and estate. A small holding is defined as *'a rubber area contiguous or non-contiguous aggregating 10 ha or less under a single ownership.'*(Indian Rubber Statistics, vol.39, 2018). An estate is defined as a *'Land contiguous or non-contiguous aggregating more than 10 ha planted with rubber under a single ownership.'* (Indian Rubber Statistics, vol.39, 2018). According to the Rubber Amendment Act 2009, the rubber growers possessing an area of 10 ha and above an area of 10 ha and above are classified as large rubber growers, (Indian Rubber Statistics, vol.39, 2018). The economic value of Natural Rubber reached a peak in market value in 2011, which encouraged more farmers to shift their agricultural practices into rubber cultivation (Alexander & Beth- Haran, 2016). As a plantation estate crop, it replaced natural vegetation and forests and as a small holding crop, it led to the conversion of agricultural land. The factors which lead to the transition of this mono crop includes population growth, market and demand, internal migration, government policy and incentives. (Chattopadhyay, 2015) At present, Kerala is the highest Rubber producing state in India. Rubber cultivation covers about 21% of the total agricultural land in Kerala and comes second after coconut. (Chattopadhyay, 2015)

A. Need for the study

Over the last decade, several studies have indicated the negative environmental implications of Natural Rubber cultivation, especially after the large-scale expansion of rubber into the North-eastern region of India.

Chattopadhyay et al (2015) have reported some of the environmental consequences of Rubber plantations in Kerala. Karunakaran et al (2013) have analyzed the environmental and economic perspective of rubber cultivation in Kasaragod district. Fox et al (2014) have critically assessed the expansion of rubber and its implications in South East Asia. A study was conducted in Xishuangbanna, China regarding the impacts of rubber plantations on biodiversity and local water balances. A few research studies have also assessed the environmental and socio-economic impacts of rubber in Tripura.

India comes second in the global scenario when it comes to the consumption of rubber after China. To satisfy the demands for rubber in various sectors and to reduce import of rubber, government had supported the expansion of rubber cultivation into favorable areas. But the impacts of prolonged rubber cultivation and a deeper understanding of land suitability for Natural rubber cultivation has not been studied much, In spite of the large-scale expansion. The introduction of Natural Rubber cultivation into the north-eastern region was recent and it was well documented through GIS environment. In the similar way, rubber related studies and mapping related to Kerala will give a thorough understanding of the potentials and limitations of the land related to rubber cultivation.

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B. Aim

To formulate a framework for assessing land suitability for Rubber cultivation in Kerala.

C. Objectives

1) To conduct a background study on the economic, spatial and environmental aspects of Natural rubber cultivation in Kerala.

2) To identify framework for assessing land suitability for Natural rubber cultivation in Kerala, which can be further applied in testing land suitability in GIS environment.

D. Methodology

Methodology for this study can be classified into three stages which include data collection, analysis and mapping. Preliminary literature studies related to rubber, environment and land management led to the identification of issues and need for the study. Further research led to the formation of research questions, defining the aim and objectives for the study. After identifying the aim and objectives, literature case studies related were studied and the combined analysis of literature case studies was conducted. This led to the initial drafting of multi-criteria framework for rubber suitability. Initial framework along with weight for each criterion was identified which was then discussed with experts and agricultural scientists to finalize the framework which included various bio-physical, spatial planning and locational factors related to land suitability for rubber cultivation.

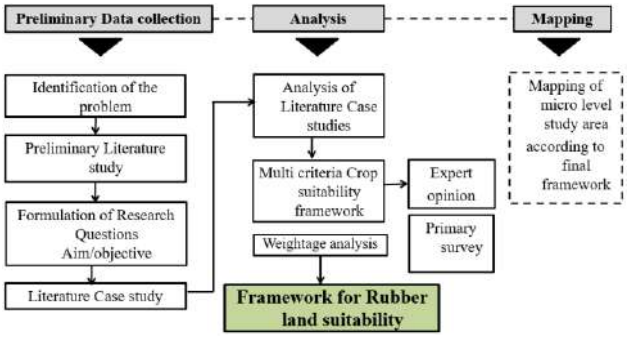

Figure 1. *Methodology Flow chart*
(Source: author generated)

E. Scope

This research has the potential to explore more into agricultural land management, environmental economics and the existing scenario of Rubber cultivation. This study aims to understand the various factors critical for determining the land suitability related to rubber cultivation. Also, this research can identify the potential areas of land suitability for Natural rubber cultivation, which can create awareness among planners, decision makers and agriculturists regarding land management with rubber.

F. Limitation

This study focuses on spatial aspects even though socio-economic aspects are related to it. Therefore, socio-economic aspects are not covered in this study. This research involves complex models, weightage determining methods for analysis.

II. LITERATURE REVIEW

A. Introduction to Rubber

The Rubber tree, scientifically known as Hevea brasiliensis, is native to Central and South America's tropical rainforests. It is the only identified major source of natural rubber and also one of the most successful examples of domesticated cash crop species in the world. The commercial spread of rubber production began in the 1870s, when Hevea seeds were planted in India by the British transported from Brazil. (George & Jacob, 2000)

The rubber tree is made of softwood and has a straight thick trunk characterized by light, brownish grey bark. It grows up to a height of 30m in the wild and is deciduous in nature. The milky latex, extracted from the rubber tree is the primary source of natural rubber. Latex is the white rubber liquid consisting of a mixture of water, hydrocarbons, resins, fats, proteins, acids, salts and sugar. The latex, which seeps from the lower part of the trunk, is the only commodity of rubber which has commercial importance, its bark and branches are used as firewood and pegs.

Figure 2. *Rubber tree*
(Source: www.britannica.com)

The Rubber plant has 7 years of immature phase and has a productive phase of 25 years up to 32 years, after that the land is cleared for planting the next phase of rubber saplings.

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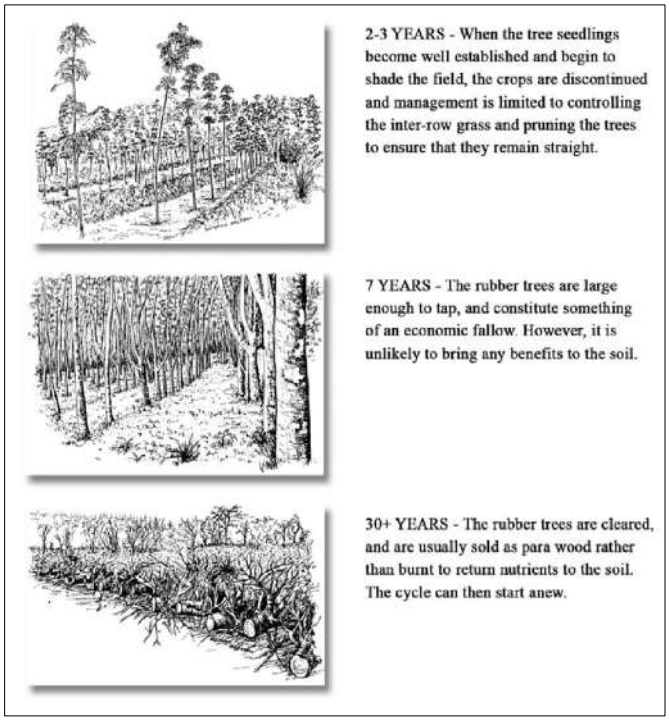

Figure 3. *Lifecycle of Rubber trees*
(Source: Reference [4])

B. History of Rubber cultivation in Kerala

The major growth of the rubber plantation industry in India was initially due to the expansion of the Kerala rubber cultivation in 1860s. Plantation Agriculture, in general, emerged in the native state of Travancore, Cochin and Malabar area of Madras Presidency (which was later constituted as State of Kerala) only during 1860s compared to earlier beginnings in other plantations districts of South India (1820s), Assam and Bengal (1840s) and Ceylon (1830s). The state's plantation history began with plantations of coffee and cardamom, and then shifted to tea and eventually rubber. The geographical and agro-climate suitability for rubber cultivation in Kerala have been good. The liberal rules formulated in Travancore & Cochin for the distribution of forest and waste land, initiated the growth and further expansion of rubber. Initially plantations came on government forest land leased at very nominal prices. In view of the growing demand, the Government of India government passed the 1947 Rubber (Production and Marketing) Act, and further established the Rubber Board. (George & Jacob, 2000)

The first Travancore rubber estate was cultivated at Thattekad on the banks of the Periyar River in 1902. By 1910, the total area under rubber was over 6800 acres. Due to economic favourability, late 1950s witnessed the introduction of small holding sector in rubber cultivation. At present, Kerala has 5,51,050 ha of area under rubber as per 2018 Indian Rubber statistics.

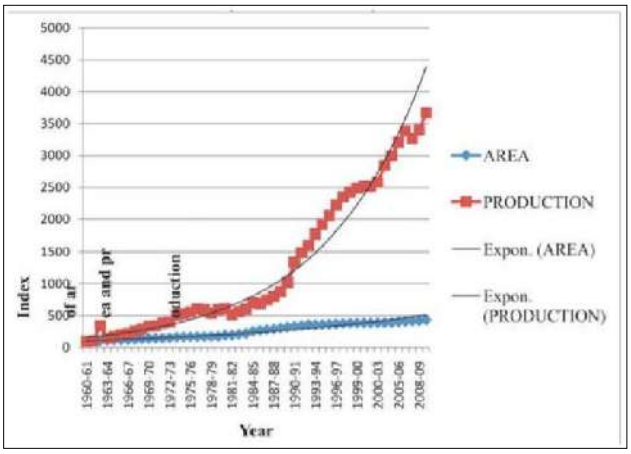

Figure 4. *Growth in area and production of rubber cultivation in Kerala (1960-2010)*
(Source: Reference [9])

C. Spatial distribution of Rubber cultivation in Kerala

The Spatial distribution of Rubber cultivation in Kerala is highly influenced by physiographic, soil and climatic characteristics. The total tapped area under rubber cultivation in Kerala covers about 5, 51,050 ha as per Indian Rubber statistics report, 2018. Kottayam is the highest rubber producing district in Kerala with 1, 14,410 ha of area under rubber, producing 1, 10,000 tons of rubber annually.

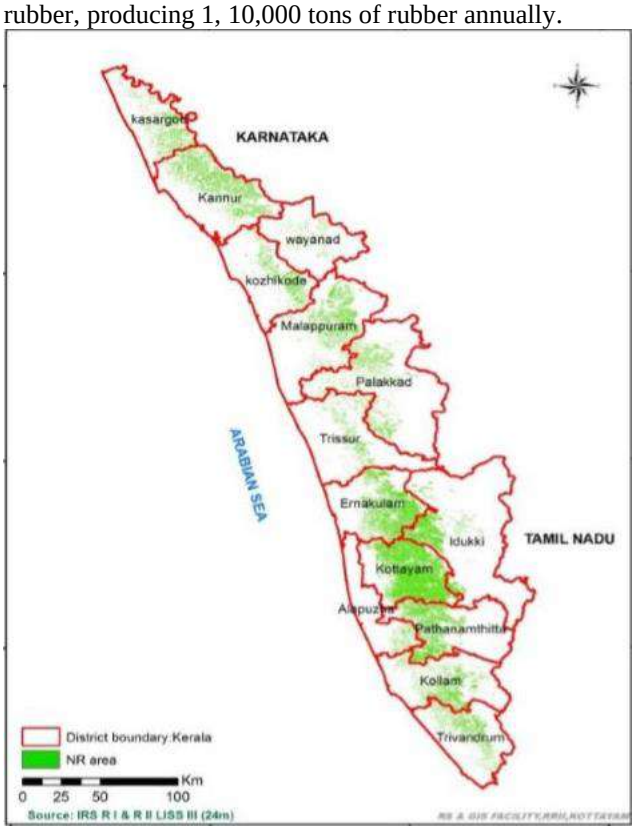

Figure 5. *Distribution of natural rubber cultivation in Kerala* **(**2012-2013)
(Source: Reference [8])

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D. Environmental implications of Rubber cultivation cited by various authors

Over the last decade, several studies have reported the environmental impacts of rubber cultivation, both in the macro and micro level. The Table below lists the environmental implications of Rubber cultivation cited by various authors.

Chattopadhyay, (2015),	Karunakaran, (2013),	Majumder, (2014),
• Land use/land cover change • Degradation of forests • micro climate change • Photosynthetic Active Radiation (PAR) • Soil erosion • Soil nutrient decline • Loss of species and biodiversity • hydrological disruption-stream flow and water use and water quality	• Food security-land use change • land degradation • chemical pollution • Ground water depletion	• Generation of waste water and soil contamination • Impacts on local rainfall and temperature • Effect of rubber on soil • Shrinking of natural forest areas and loss of diversity • Depletion of groundwater table

Figure 6. *Environmental implications cited by various authors*
(Source: author combined based on Reference [5], [6], [9], [11], [14])

III. LITERATURE CASE STUDIES

To study the land suitability for rubber cultivation done in other countries, cases of Thailand and Malaysia were taken.

A. Literature Case study 1: Thailand

Thailand is the highest producer of Natural Rubber in the world, with an increase of 4-7 percent annually in rubber production. Rubber is the major cash crop in Thailand and has been associated with socio-economic development due to its productive value, export income, job opportunities and improved living standards of people in the Rubber plantation industry. Because Thailand has a tropical climate, it has favored the expansion of rubber plantations, especially in Thailand's forest areas where the area under rubber has grown by 1.71 percent per year. The Southern region of Thailand has a higher concentration of rubber plantations with 17, 08,800 ha or 84.62 per cent of Thailand's total rubber growing area. (Ali, Techato, Taweenkun, & Gyawali, 2018)

While rubber is one of Thailand's principal cash crops, in terms of both area and productivity, only limited research relating to rubber, crop requirements and its land suitability has been conducted. An analysis of land suitability is important for the sustainable agricultural development of any crop and for proper land management. In this report, the recommendations of the Food & Agriculture Organization on land suitability are taken as the accepted standard for an examination of land suitability. (Ali, Techato, Taweenkun, & Gyawali, 2018)

a) Aim

The aim of the study was to use Multi Criteria decision making along with GIS application to identify the highly suitable rubber growing areas to achieve the vision of sustainable development of the region. This research also aims to design agriculture policies for crop development.

b) Data collection and Methodology

The Methodology adopted for this research involved both quantitative and qualitative methods of data collection and analysis. The whole process of the study involved five steps which includes defining the area for study purpose, data collection, setting of different criteria related to rubber suitability, assigning weight and score for each criterion and land suitability assessment for rubber.

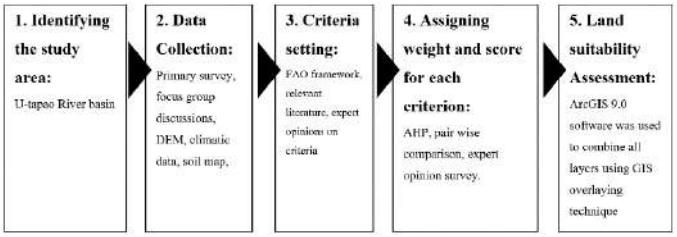

Figure 7. *Methodology framework for rubber land suitability in Thailand (Source: author generated based on literature case study)*

c) Criteria setting

The parameters for land suitability were chosen in this study according to the Food & Agriculture Organization (FAO, 1983), Relevant literature on Natural Rubber available and opinions given by 11 experts using the Delphi technique. The experts were listed, which included academic researchers and agricultural scientists from the (rubber) sector. The main aim was to determine the suitability of land use for rubber cultivation and was evaluated on the basis of two main criteria: bio-physical and socio-economic. The bio-physical category was divided into climate, topography and soil, while the socio-economic category was divided into livelihood and market. The sub-categories were again divided into slope and elevation under Topography, rainfall and temperature under climate and nutrients, texture, depth, PH and drainage under soil. They were then categorized into four classes of suitability: extremely suitable (HS), moderately suitable (MS), low / marginal suitability (LS) and not suitable (NS). The figure below shows the classification criteria and sub-criteria for rubber land suitability analysis. (Ali, Techato, Taweenkun, & Gyawali, 2018)

Classification criteria			Suitability Rating			
Main	Sub	Sub-sub	HS	MS	LS	NS
Bio-physical	Topography	Slope (%)	0–12	12–20	20–35	>35
		Elevation (m)	0–200	200–400	400–900	>900
	Climate	Rainfall (mm)	1500–2500	2500–4500 1200–1500	4500–5000 1100–1200	>5000 <100
		Temperature (°C)	26–28	29–34 25–23	22–20	>34 <20
	Soil	Nutrients	Very high, high	Moderate	Low	–
		Texture	l, scl, sil, si, cl, sicl, sic	sl	sc	c, g, s
		Depth (cm)	>150	50–150	30–50	<30
		pH	5.1–7.3	7.4–8.0 4.0–5.0	3.5–3.9	>8.0 <3.5
		Drainage	Well drained, excessively drained	Moderately well drained	Somewhat poorly drained	Very poorly drained, poorly drained
Socio-economic	Livelihood	Population density (population/km²)	<200	200–400	400–600	>600
		Available land use	Agriculture	Grass & shrub	Forest	Urban & waterbody
	Market	Distance to major road (km)	<1	1–5	5–10	>10
		Distance to factory (km)	<50	50–75	75–100	>100

Figure 8. *Classification criteria in land suitability analysis for rubber cultivation*
(Source: Reference [3])

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d) Determination of Weight and score for each Criterion

The assigning and assessment of weightings to different criteria is an important task in the suitability process using the Multi Criteria Decision Making technique. Although there are different techniques for the development of weight, it was calculated using the analytic hierarchy process (AHP) in this analysis. In order to avoid and reduce individual biases in factor weighting, pair wise comparison between pairs of elements was made to list criteria and factors according to their importance regarding rubber suitability. 'A square matrix was formed to compare each pair of factors and the importance of each factor is assigned based on a scale of (1-9). Solving this matrix will provide the weight of each factor which is then used to find the consistency ratio (CR).' (Ali, Techato, Taweenkun, & Gyawali, 2018)

Layer 1		Layer 2		Layer 3		Total Weight
Criteria	Weight 1	Criteria	Weight 2	Criteria	Weight 3	
Bio-physical	0.916	Topography Soil	0.270	Slope	0.750	0.1855
				Elevation	0.250	0.0618
		Soil	0.150	Drainage	0.148	0.0203
				pH	0.168	0.0230
				Depth	0.287	0.0394
				Nutrients	0.029	0.0039
				Texture	0.356	0.0502
		Climate	0.580	Rainfall	0.580	0.3081
				Temperature	0.420	0.2231
		Total	1.00			
Socio-economic	0.084	Livelihood	0.416	Population density	0.416	0.0145
				Available land use	0.584	0.0204
		Market	0.584	Distance to major road	0.580	0.0284
				Distance to factory	0.420	0.0206
Total	1.00	Total	1.00			1.0000

Note: Total weight = weight1 * weight2 * weight3

Figure 9. *Criteria and sub-criteria and their weightings for rubber land suitability analysis*
(Source: Reference [3])

The Figure above shows the weightage and score of each criterion related to rubber suitability analysis. From this Figure, we can analyze that bio-physical aspects have more weightage than socio-economic aspects.

In the current research, questionnaires were distributed to experts to find the level of significance of each factor and their opinions related to each factor were compared to those related to other factors to determine their significance. (Ali, Techato, Taweenkun, & Gyawali, 2018).

e) Results and Conclusion

Each criterion relevant to rubber land suitability assessment was identified and the highly suitable, moderately suitable and the least suitable conditions for each criterion were mapped separately in ArcGIS software to identify the potential areas of suitability and unsuitability.

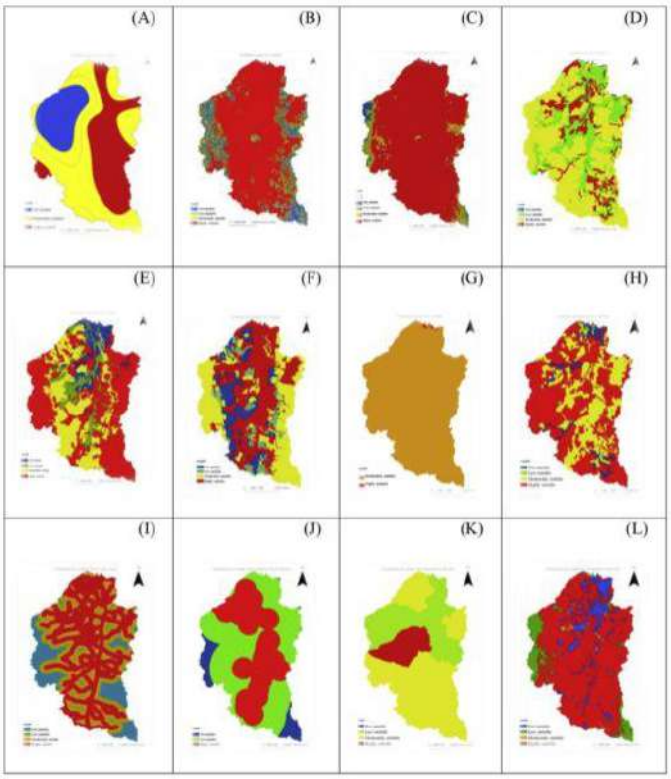

Figure 10. *Land suitability map of U-tapao river basin based on different parameters: (A) Rainfall, (B) Slope, (C) Elevation, (D) pH, (E) Soil drainage, (F) Soil depth, (G) Soil Nutrients, (H) Soil Texture, (I) Distance to major road, (J) Distance to factory, (K) Population density, (L) Available land use map*
(Source: Reference [3])

The overall suitability map was obtained by combining the individual suitability maps (Fig 11). The study concluded that 14.46% (333.34 km2) of the basin region was extremely suitable for rubber, 84.48% (1901.35 km2) was moderately suitable, 2.22% (51.07 km2) was less suitable and 0.83% (19.24 km2) was unsuitable for rubber cultivation. From the overall map obtained, it was found that the most suitable rubber-growing areas lies in the northern part of the basin are due to their fertile soil and ample water resources. The overall suitability map was compared with the land use / cover map for 2009 to examine the potential areas for rubber cultivation. (Ali, Techato, Taweenkun, & Gyawali, 2018). The Figure below shows the overall combined map. The study concluded that overall bio-physical factors are more important than socio-economic factors.

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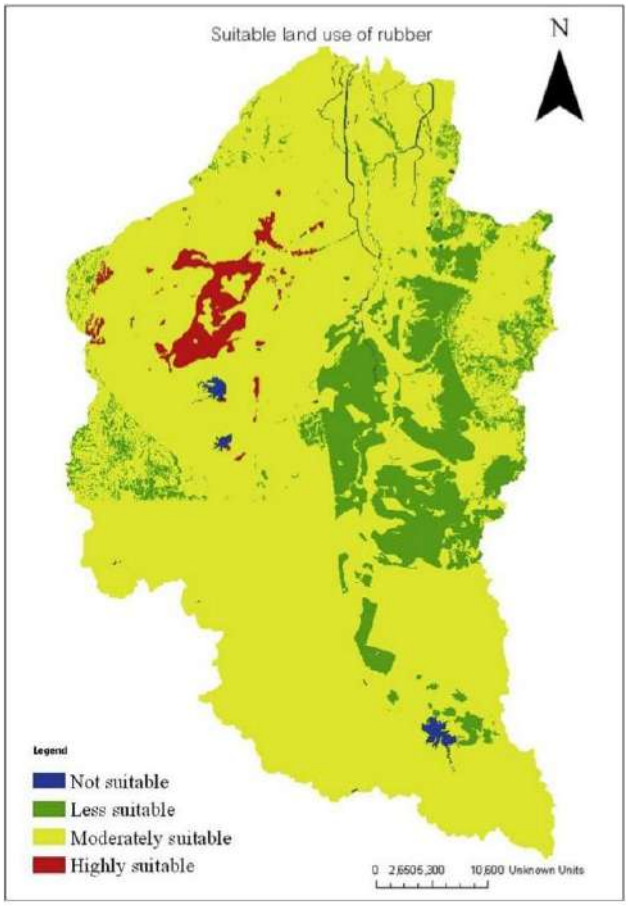

Figure 11. *Map of land use suitability for rubber cultivation in the U-tapao River basin*
(Source: Reference [3])

B. *Literature Case study 2: Malaysia*

a) Introduction

Land suitability evaluation (LSE) is a valuable tool for land use planning in most of the countries. The increased population and urbanization pressure on the available land resources may result in land degradation, which raise the need for Land suitability evaluation.

b) Aim

The aim of the study was to provide for an up-to-date GIS-based agricultural land suitability evaluation (ALSE) for identifying and determining, potential land for rubber cultivation.

c) Methodology

The method of analysis for this research involves identification of the study area which is the Seremban district of Malaysia. Data collection of topography, climatic data, soil map and land use map relevant to rubber suitability was collected. The eligibility criteria for the crop were chosen according to the FAO framework (FAO, 1983), relevant literature, opinions of agricultural specialists and researchers. After the fixing of criteria, suitable weightage was assigned to each factor to analyze the importance of each factor.

d) Result

Through GIS overlaying technique, Rubber land suitability evaluation model structure was developed.

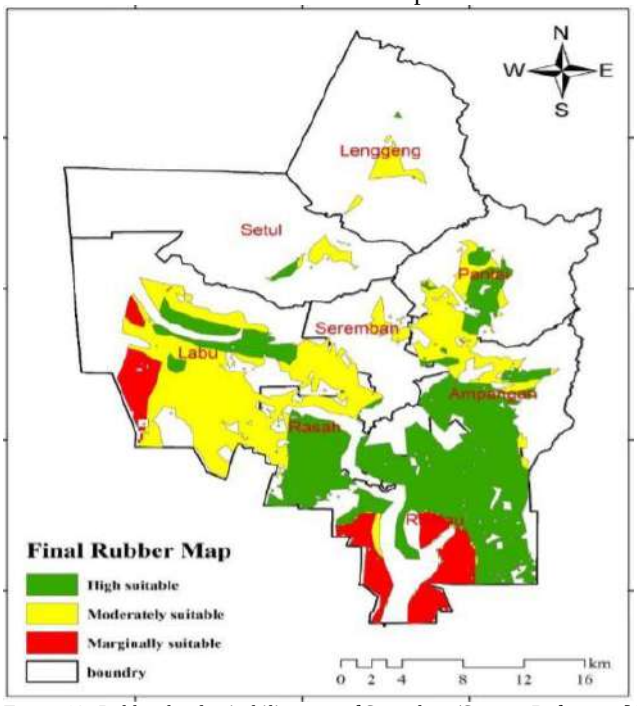

Figure 12. *Rubber land suitability map of Seremban* (Source: Reference [1])

C. *Literature Case study 3: Wayanad*

a) Introduction

This study attempts to assess the soils of Wayanad District, Kerala for their suitability to tea, cardamom and. rubber cultivation.

b) Aim

The aim of the study is to combine non-spatial data (soil, land and climate attribute data) integrated with crop specific criterions to evaluate specified crop suitability.

c) Methodology

The method of analysis of the study included identifying the study area, data collection and land evaluation.

d) Result

The analysis provided the crop suitability requirements which was divided into highly suitable, moderate, less and not suitable classes.

Crop: Rubber				
Soil-site characteristics				
Climatic /land quality				
Mean temperature in growing season (°C)	25-30	24-20 31-32	29-18 33-34	<18 >34
Total rainfall (mm)	>1750	1750-1500	1500-1250	<1250 >6000
Slope (%)	10-15	15-30	30-50 <10	>50
Texture (Class)	scl, l	sil, sicl	sc, c	c
pH (1:2.5)	4.5-5.5	5.6-6.5 3.5-4.4	6.6-7.3 <3.5	>7.3
Effective soil depth (cm)	>100	100-75	75-50	<50

Figure 13. *Rubber requirements in Wayanad District*
(Source: Reference [7])

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IV. ANALYSIS

A. Analysis of Literature Case study 1: Thailand

From the case study of land suitability for rubber in Thailand, we can analyze that the criteria selected for the assessment is divided into three main layers. The first layer of criteria is broadly classified into bio-physical and socio-economic factors in which the bio-physical factors are given more weightage than the socio-economic factors. In the second layer, the bio-physical factor is again divided into low shows the diagrammatic representation of the analysis of literature case study mentioned above.

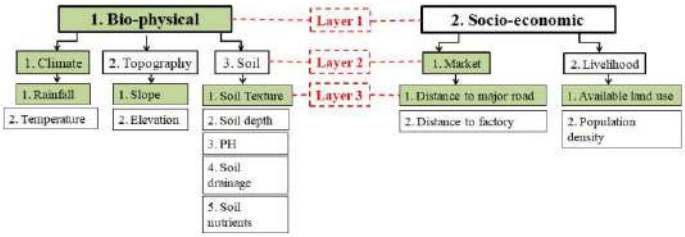

Figure 14. *Criteria and weightage chart for Rubber Land suitability analysis*
(Source: author generated based on Reference [3])

B. Analysis of Literature Case study 2: Malaysia

From the case study of Malaysia, the following analysis have been derived. The Figure below shows the analysis and listing of criteria from literature case study 2.

Land use requirements	Sub-criteria	Land suitability class
Climate	Average annual Rainfall (mm)	2500-3000
	Dry months (month)	1-2
	Slope (%)	<8
	Elevation (m)	200
Hydrology data	Soil drainage	good
Soil	Soil series	
	Soil texture (surface)	SSiL, SiL
	Soil productivity	>1350

Figure 15. *Final analysis of literature case study 2*
(Source: based on Reference [1])

C. Analysis of Literature Case study 3: Wayanad

From the case study of land suitability analysis for rubber in Wayanad, six major criteria are selected to analyze the land suitability for rubber in Wayanad district. They are mean temperature, total rainfall, slope, texture, pH and effective soil depth. Each of the criterions have optimal conditions according to which it is again classified into four categories which includes S1-very suitable land, S2-moderately suitable land, S3-marginally suitable land and N-not suitable land. The optimal range for the crop suitability determines the weightage and score for each criterion. The Figure below shows the final land suitability attributes which should be taken from this literature case study.

SI No:	Soil-site characteristics Climatic/land quality	S1-very suitable (>75)	S2-moderately suitable (75-50)	S3-marginally suitable (25-50)	N-not suitable (< 25)
1	Mean temperature in growing season (°C)	25-30	24-20	29-18	<18
2	Total rainfall (mm)	>1750	>1750	1500-1250	<1250
3	Slope (%)	10-15	15-30	30-50	>50
4	Texture (Class)	scl, l	sil, sicl	sc, c	c
5	pH (1:2.5)	4.5-5.5	5.6-6.5	6.6-7.3	>7.3
6	Effective soil depth (cm)	>100	100-75	75-50	<50

Figure 16. *Crop requirements for rubber in Wayanad*
(Source: Reference [7])

D. Combined Analysis and comparison of Multi criteria for Rubber land suitability based on bio-physical factors

The Figure below shows the combined analysis and listing of bio-physical factors for analyzing land suitability for rubber cultivation.

SI No:		Case study 1	Case study 2	Case study 3	Inference
					
1	Climate	Rainfall	Rainfall	Rainfall	Must have criteria
2		Temperature		Temperature	Must have criteria
3			No: of dry months		Can be incorporated
4	Topography	Slope	Slope	Slope	Must have criteria
5		Elevation	Elevation		Must have criteria
6	Soil	Soil Texture	Soil Texture	Texture class	Must have criteria
7		Soil depth		Effective Soil depth	Must have criteria
8		PH		PH	Moderate
9		Soil drainage	Soil drainage		Moderate
10		Soil nutrients			Can be incorporated
11			Soil productivity		Can be incorporated

Figure 17. *Comparison of criteria for rubber land suitability based on bio-physical aspects*
(Source: author generated based on multi criteria from literature case studies)

The bio-physical factors that affect the productivity of rubber or determine the land suitability for rubber cultivation are climatic parameters like rainfall, temperature. But relative humidity and wind speed criteria is considered in some studies (Menon, 2014). Topographic factors include slope and

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elevation. Soil characteristics include texture, depth, pH, soil drainage and soil nutrients. Also, coarse fragments, cation exchange capacity, base saturation and organic matter is also considered in some studies (Menon, 2014)

E. Analysis of Multi criteria for Rubber land suitability based on spatial planning factors

Apart from the Bio-physical factors regarding land suitability for rubber cultivation, certain spatial planning factors should also be considered while assessing land suitability for rubber cultivation. Regarding spatial mapping, the result of overlapping of land suitability maps related to bio-physical factors will generate an overall map depicting the highly suitable and not suitable area of classifications which can be again analyzed in the light of planning factors such as present land use/ land cover, land value, ground water depth, ground water quality, urban or rural character of the land, proximity to major road and proximity to city urban built up land. The table below lists other criteria relevant to land suitability regarding spatial planning.

SI No:	Factors	Criteria
1	Bio-physical factors	Rainfall, Temperature
		Slope, Elevation
		Soil texture, Soil depth, PH, Soil drainage, Soil nutrients
		Ground water depth, Ground water quality
2	Spatial planning factors	Land use/Land cover, Land value
3	Locational factors	Proximity to major road, Proximity to urban/rural built up, urban/rural character

Figure 18. *Analysis and comparison of Multi-criteria for Rubber land suitability*

(Source: Author generated based on case studies)

V. CONCLUSION

Rubber is one of the largest agricultural plantations in Kerala. It is mainly being raised under small holdings, thereby involving a large number of farmers. But to analyze the growth, potential and limitation of this sector and also to assess the change in the crop pattern trends and management, land suitability analysis must be done. To assess the land suitability for rubber cultivation, the Suitability analysis techniques integrate four basic factors of any land which are bio-physical, socio-economic and spatial planning factors. The framework combining all these factors can be used in the further spatial mapping of land suitability for rubber cultivation. Site specific monitoring of various environmental parameters and in-depth analysis is required to arrive at definite conclusions.

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REFERENCES

[1] Ahmed, G. B., & Shariff, A. R. (2017). GIS-Based Land Suitability Mapping for Rubber Cultivation in Seremban, Malaysia. *International Journal of Applied Engineering Research*.

[2] Alexander, S. T., & Haran, B. (2016). Decline in Rubber prices in Kerala: A Case of Vallicode Panchayat in Pathanamthitta District. *Journal of Economic & Social Development, Vol. - XII, No.*

[3] Ali, S., Techato, K., Taweenkun, J., & Gyawali, S. (2018). Assessment of land use suitability for natural rubber using GIS in the U-tapao River basin, Thailand. *Kasetsart Journal of Social Sciences*.

[4] Arshad, A. M. (2017). Land evaluation for rubber cultivation. *International Journal of Agronomy and Agricultural research*.

[5] Chattopadhyay, S. (2015). Environmental Consequences of Rubber plantations in Kerala. *NRPPD Discussion Paper.*

[6] Fox, J. (2019). Through the Technology Lens: The Expansion of Rubber and its Implications in Montane Mainland Southeast Asia. *Journal of Conservation and Society*.

[7] Gahlod, N. S., Binjola, S., Ravi, & Arya, V. S. (2017). Land-site suitability evaluation for tea, cardamom and rubber using Geo-spatial technology in Wayanad district, Kerala. *Journal of Applied and Natural Science*.

[8] India, R. R. (2014). *Satellite Survey of Natural rubber plantations in Kerala, Tamil Nadu and Karnataka*. Rubber Research Institute of India.

[9] Karunakaran, N. (2013). Shift to Rubber cultivation and consequences on environment and food security in Kerala. *Journal of Rural Development*.

[10] Karunakaran, N. (2017). Determinants and price-volatility of Rubber crop in Kerala. *Journal of Economic & Social Development*.

[11] Majumder, A., Datta, S., Choudhary, B. K., & Majumdar, K. (2014). Do Extensive Rubber Plantation Influences Local Environment? A Case Study from Tripura, Northeast India. *Current World Environment.*

[12] Menon, K. (2014). *National Bureau of Soil Survey report.*

[13] Meti, S., Rao, D., Nair, N. U., & Jacob, J. (2008). Distribution of Natural Rubber cultivation in relation to soil and landscape attributes in India.

[14] Roy, M., Saha, S., & Roy, M. (2014). Ecological Impact of rubber plantations: Tripura perspective. *International Journal of current research, vol 6.*

[15] Samarappuli, L., Wijesuriya, W., Dissanayake, D. M., Karunaratne, S. B., & Herath, H. M. (2014). Land Suitability for Sustainable Rubber Cultivation in Moneragala District. *Journal of Environmental Professionals Sri Lanka: 2014 – Vol. 3 – No. 1.*

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Commons to contested domain

Contemporary trends in transformation of urban riparian edge

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***Abstract*—** Urban River along with its riparian landscape may act as urban common or barrier, which in turn acts as the backyard of the communities. In order to perceive significance of the river ecosystem in urban context, interest of stakeholders involved in the river landscape has to be extrapolated along with ecological aspects of the riparian communities. Riparian Zone as commons is space of social interaction where resources are collectively managed and utilized by the communities. Urban River was a major contributor to the social progress as well as economic development of the communities in ancient times. Recent urbanization has an adverse effect on the urban riparian ecosystem. The encroachment of flood plain, controlling the flow of river by retain wall, excessive construction along river corridor and over polluting of river has led to fragmentation of river. The study also deals current approaches toward the riverfront development and analyzes it on the basis of the variables to understand the shortcomings of these projects.

This paper deals with common pool resource theory, pattern of commoning and tragedy of common for understanding the transformation of urban commons to backyards. The overall impact of urbanization in form of contemporary river front development can be analyzed by initially understanding an effect of a micro community in river through variables identified from the literature studies and suggest the revitalizing measures for regenerating riparian landscape of the community through commoning. The commoning means living and acting together in the society. This study deals with the edge interfaces along the river corridors from its upstream to downstream and also the level of pollution happening in the river along the city limits The communitarian approach has been followed in research for overall development of the community. The social and ecological dimension had been emphasized in the whole process of urban riparian edge regeneration.

Keywords— Urban Commons, urban riparian edge, Common Pool Resource, socio-ecological framework, Inclusive development, Commoning

I. INTRODUCTION: -URBAN COMMON AND RIPARIAN EDGE

"Common is a social form which arises whenever a given community decides that it wished to manage a resource in collective manner, with special regard to equitable access, use and sustainability" [2](the wealth of common by David Boiler)

Commons are considered as the public property or those properties over which a community at large has an interest. Urban Commons include so-called "public goods": community gardens, urban land trusts, collaborative consumption, and "homegrown parks." There are many new initiatives to treat "the city as commons" and to develop policies for a "shareable city."

Contemporary cities have been subject of utopian thinking but same time they are also propagators of neo-liberal theories and accumulators of capital who control urban resources .The most prominent is gentrification of urban commons removing the indigenous character from those commons. Gentrification emerges under the tile of revitalization. Commodification and new capitalism tend to destroy the city as social, political and livable commons.

In order to have a better understanding of urban commons, the urban riparian zone is taken for analyzing the contemporary trends in transformation of urban common with respect to urbanization. Current riverfront development or revitalization are propagators of gentrification and also lead to displacement of indigenous riparian communities. The riparian zone is analyzed on the bases of three theories: - common pool resource theory by E.Ostrom, tragedy of common by G. Hardin and pattern of commoning by David Boiler. The parameter derived from theories help to have a clear understanding of the current urban commons and also the ways to improve the commoning process involved in the urban context.

This research deals with identifying the basic components of the urban common with respect to current urbanization phenomenon of commodification and enclosure of commons. This study aims at verifying the change and trends in current commons and also provides a perspective on agenda on upcoming urban commons. The paper concludes by establishing that the piecemeal intervention of Urban Commons cannot revive its character but an interconnected system of development is necessary for the creation of city of the commons.

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The purpose of study is to gauge the extent of influence of urbanization on urban riparian zone. The transformation of commons to contested domain has been a contemporary trend, which again leads to gentrification and commodification. The study helps to evaluate the factors influencing the contestation of commons and suggest preventive measure for increasing the commonness factor. Despite the various measures by government to improve riparian zone as common or public realm, the complexities that encompass the various components of urban common still need to be sorted. The study also examines the social impact factor of the contemporary development in urban common especially riverfront development.

II. CONTEXT OF STUDY

City space is highly contested space. As rapid urbanization has immense effect over city space, usage of urban space is at the heart of many urban movements and policy debates. Among the most prominent sites of common contestation include efforts to claim vacant or abandoned urban land and structures for affordable housing and community gardening/urban farming in cities and also encroachment of riparian buffer zone along the urban river.

Urbanization has resulted in deterioration and depletion of urban riparian edge. The reduction in the underused public spaces in cities shows that these spaces are undervalued or underestimated. On the other hand, urban riparian edges are enclosed or privatized which threatens the public life of city dwellers. These current trends of under-utilization and privatization of commons are affecting public space and life in contemporary cities. Riparian zone act as an urban common and its transformation has resulted in conversion of commons to backyard. The study is seen as effort to understand contemporary riverfront development and its effect on the commons.

III. THEORETICAL FRAMEWORK

A. Urban common characteristics

The shared resources or commons can be categorized based on four main characteristics, which are depletability, excludability, rivalrous use and regulation.

- The amount of depletion of common, which means whether usage of the resource can reduce the availability it to commoners. For example urban garden can be depleted through overuse whereas radio transmissions whose use by commoners does not reduce the amount of resource.
- Low degree of excludability is other characteristic of urban common. For example a daycare is a excludable resource whereas air is non-excludable.
- High degree of rivalrous use of common can lead to tragedy of common. For example too many visitors to a public pond can affect the quality of space as well as utility to other users, who appreciate the park silence. Protesting in public spaces does not necessarily change the utility of such commons.
- Regulation or governing of common is a major contributor for defining the common characteristics. The process of commoning generally maintains the commons.
- Density and proximity is the network of intangible fibers that are woven into the fabric of the urban commons. Urban common is a dense network of interactions creating a social cohesion.

B. Type of commons

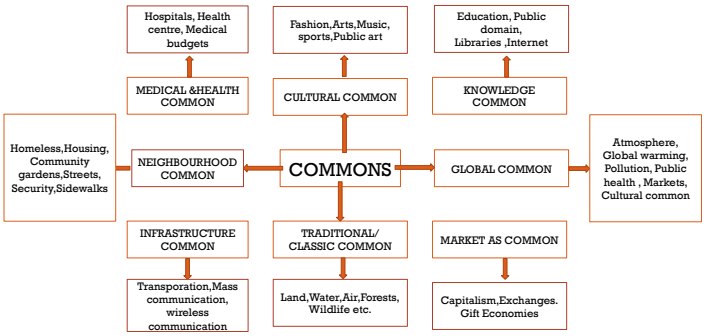

Fig 1.1: A map of commons
Source :_ Author

C. Theories of urban common

The term common pool resource refers to natural or man-made resource, which has high subtractability and low excludability. In order to have a better understanding of the processes and organizing of common pool resources, it is essential to understand the resource system and flow of resource units produced by system. The example of resource system is grazing ground, irrigation canals, bridges, fishing ground, parks, urban forest etc. Resource units are what a commoner uses for resource system.

Access to the common pool resources can be limited to individual, group or community who uses the resource system at same time. The process of withdrawing resource units from resource system is called appropriations .the commoner who withdraw resource units are called appropriators. The analysis of scarce, renewable common resources is done from the perspective of the appropriators. The individual or group responsible for construction, repair and maintenance of the resource system are called providers or producers. Crowding effect and overuse problems are major factors influencing the CPRs.

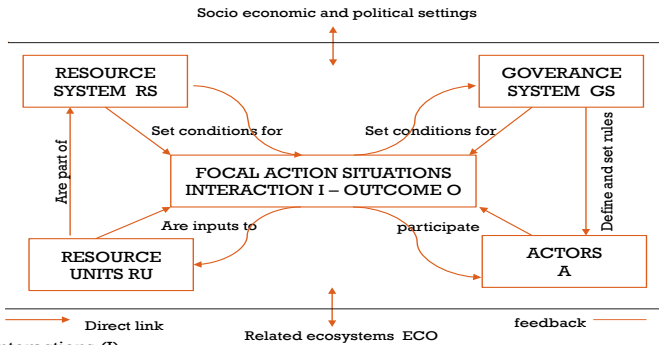

Fig 1.2 Common pool resource Theory Factors
Source: -governing of common by Elinor Ostrom

D. Design principle of urban common

Commons can be governed sustainably and equitably in a community by using eight principles of urban commons by E.Ostrom.

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- Define clear group boundaries, which demarcate difference between user and non-users of common
- Rules and regulation should be developed on the basis of local needs and community
- Community participation needed for development of rules and regulation
- Collective governance to ensure better management of commons
- Monitoring and management of commons has to be done by system developed by community
- Use graduated sanctions for rule violators
- Dispute resolution by improving accessibility
- Bottom to top approach need to be followed in governing of commons and also need to develop a interconnected system of network of commons

E. Tragedy of commons by G. Hardin

The tragedy of the commons is an economic phenomenon where commoners tend to exploit urban commons as the demand greatly outweighs supply, and the resource becomes scarce for public use. Issue and factors affecting the concepts of common should be identified and analyzed to address the challenges in maintaining urban common. The measures to overcome the tragedy of commons are:-

- Regulating consumption and use of common by governmental measure can reduce depletion of commons.
- Collective action can be best method to prevent the privatization of common resource.

F. Patterning of Commoning by David Boiler

"Commoning, a term encountered by Peter Linebaugh (2008) in one of his frequent travels in the living history of commoners' struggles, is about the (re) production of/through commons**.** Commoning represents process by which commoners take decision regarding their communities without considering the profit motives or on the basis of government policies

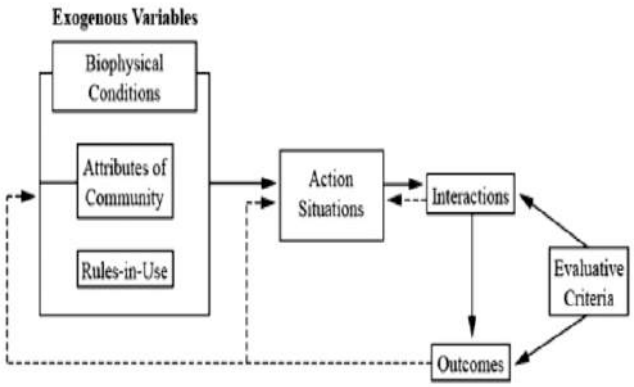

Fig1.3 variables of communing
Source: patterning of communing by David boiler

G. Urban riparian zone

Riparian zone is the transition area between land and river or stream. The riparian vegetation is removed and replaced with human infrastructure as a result of urbanization. The channelization, narrowing and bank reinforcement are impact of urbanization on riparian areas. The fragmentation of riparian areas has led to habitat loss and also visual quality of riparian edge. Riparian areas are known as "bio-highways" that create biological connectivity between urban and non-urban areas. The physical, visual and ecological connectivity between built up of city and urban ecological networks establish surrounding natural areas

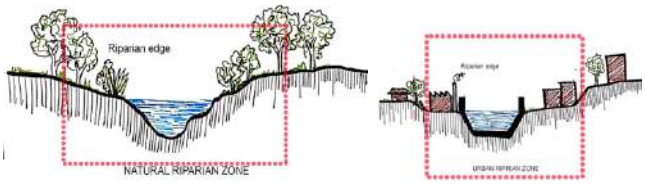

Fig1.4Natural and urban riparian zone, source: - author

H. Parameters of commons with respect to social impact identified for analyzing contemporary riparian transformation

The process of analyzing, monitoring and managing of social changes of a planned development considering both positive and negative factors is called Social Impact Assessment .The main concern is to bring about sustainable and equitable development. The parameters for social impact assessment are resource identity commoning, accessibility, social capital, actors, excludability and rivalrousness

1. The resource system is analyzed on the basis of size, length, width and distance of urban riparian zone. The river typology mainly varies from single threaded, transitional and multi-thread. The river width also has impact on the character of the riparian.

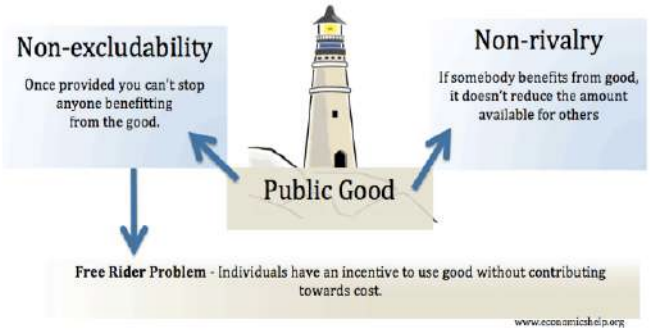

Fig1.4 Commons relation with excludability and rivalry
Source-: www.economicsheip.com

2.Commons can be classified on the bases of the rivalry in consumption and ability to exclude the non-players. Excludability refers to property of good where a person can be prevented from using it. It also refers to both the cost *to* exclude consumers and the cost *of* excluding consumers. Rivalry and excludability are related. Commons

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need not be excluded if there is no rivalry in consumption.

3.Social capital is to achieve a common goal through a set of shared values that allows individuals in a group to work together effectively. The two primary forms of social capital are bridging and bonding. The collective good can be attained if the commons are accessible to all.

4.Accessibility promotes full and effective participation of all and it should be incorporated and included as an integral component of common policy to achieve common good.

5.The traditional and contemporary activities should go hand in hand for a making riparian zone a better common. The traditional activities consist of religious activities, fishing, farming, washing clothes and other household activities whereas contemporary activities are cycling, jogging, entertainment zone, water activities etc. the contemporary activities have made the riparian zone more diverse and inclusive in nature but it reduces the inclusiveness of indigenous community.

6.Commoning describes people living in close connection with commons. It is way of bringing together community or commoners for a particular cause. In case of urban common, commoning is act of mutual support, conflict negotiation and managing that is needed to create a system for shared resources.

IV. METHODOLOGY

The methodology followed in the dissertation is deductive approach which tests the theory of common .The method followed involves identifying various theories of urban common and applying these theories of current riverfront development to analyze the impact of these developments on the riparian common. The methodology followed in research was qualitative methods using interviews and field observations for describing, interpreting, contextualizing, and gaining in-depth insight into urban commons. Interviews, field observations, discussion with experts and photo documentation were the qualitative methods implemented in the research. The other approach of the research was case study approach, which is particularly used when there is a need to obtain an in-depth appreciation of a current situation, issues or context with regards to the topic.

The research deals with three basic theories of urban common to get a in-depth analysis of the factors influencing the creation and maintenance of these commons. The theories are common pool resource theory by Elinor ostrom, Pattern of communing by David Boiler and tragedy of common by G.Hardin. The various constrain and variables in theories are analyzed to have a better understanding of current scenario of urban common and also for formulating strategies for the same.

In order to get a in-depth insight to urban commons, the research has narrowed down the topic to riparian zone as common .The case were selected on the bases of current interventions in the riparian zone so as to understand the transition in urban riparian zones. The major four case studies were taking giving importance to the development approaches of each case. The major three cases were taken in Indian context and one international case study was also taken to evaluate the international trends. The macro, meso and micro level of case studies were taken to have an overall social impact analysis. The parameters for the research were developed from the critical literature review. The comparative analysis done to establish the relevance of these parameters with respect to the urban commons

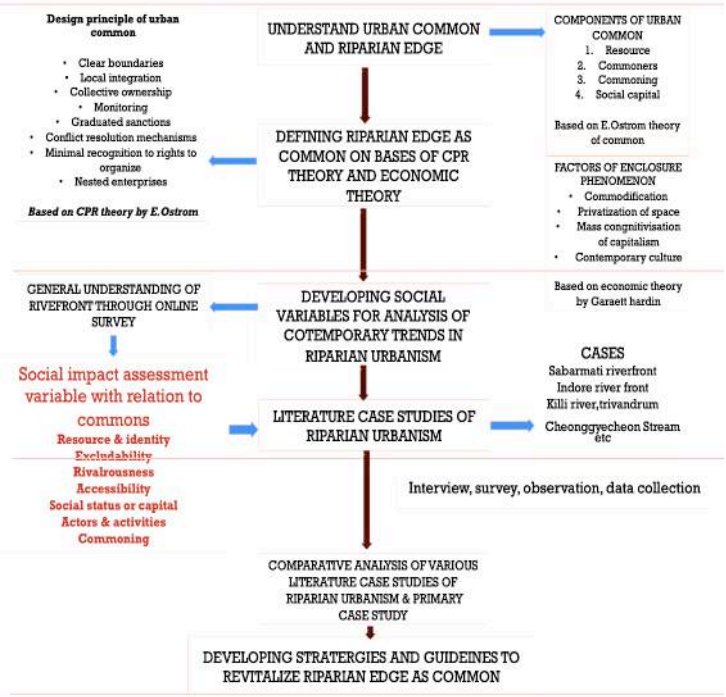

Fig1.5 Framework for research
Source: - Author

V. RESULT AND FINDINGS

The major case studies are selected on the bases of the development approach as well as impact on the riparian community .The case studies are Sabarmati river front, Indore river front and Cheonggyecheon Stream, South Korea. The literature case studies are analyzed on the basis of parameters identified in the critical literature review and data collection. The parameters are resource system, excludability, rivalrousness, social capital, accessibility, actors, activities and communing.

The common factor for each case study is found out on the basis of the parameters .the Sabarmati riverfront was developed on the basis of economic approach and the riparian community was neglected throughout the process, which resulted in the reduction of common factor. The Indore riverfront and Cheonggyecheon, Seoul, Korea has a communitarian approach to the development and emphasis was mainly to revival of the ecosystem along with community relationships. These cases had shown high rate of common factor but there is a gradual reduction in case of Indore due to commoning factor. Community did not do proper management of Indore riverfront. Graduated sanction or regulation was not imposed in Indore, which led to gradual deterotartion of riparian areas

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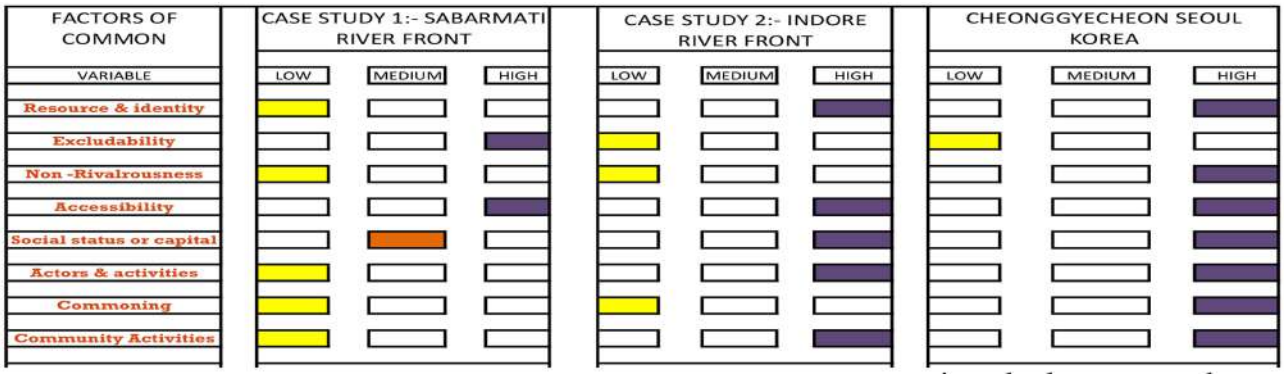

Table 1: common factor of case studies
Source: - Author

VI. GUIDELINES FOR CONVERTING RIPARIAN ZONE INTO COMMONS

a) RIPARIAN EDGE

The important factors to be considered in riverfront development are riverbanks, shorelines, riparian buffers, and river habitats.

- Dense urban riparian buffer help in providing integrated green infrastructure, storm water management practices, improved trail access, improved habitat corridor, open space amenity, integrated design of waterfront access and hardscape elements, marina access, and provision of ecosystem services.

b) Open space buffer typology

- Activities in riparian buffer zone should be balance with landscape feature which improve ecosystem services

c) Connection to riparian edge

- Riverfront should be reinforced as public realm by providing perpendicular connections that bring people. Passages are engaged and reinforced by providing sidewalks, public streets, pathways, and promenades.
- Public activities and events, such as sidewalk cafés, street fairs and vendors will enliven the connections, both as temporary and permanent installations.
- Provide a minimum setback along the riparian zone for the pedestrian access connecting with perpendicular connection
- Public connection should be provided even if it is adjacent to private property
- Character of connection should vary with respect to indigenous community or settlement

d) Riverfront trails

- Cycle paths, pedestrian, jogging track and roller blade track are example of riverfront trails. The trails should move in and out of the plantations
- Avoid planting trees in rhythm to reduce monotony

e) Building design along riparian zone edge

- Building massing should be done considering the views to river
- Ground floor of the building should be more of public in character

VII. CONCLUSION

Urbanization has created space of chaos, contested space, social segregation and losing of public realm .The need of hour is space, which can create social inclusion, mutual sharing, sense of belonging and also economy generating urban space. The urban commons are the best solution for such scenario because these are spaces, which are shared, utilized and maintained by commoners.

The research hypothesis “Common cannot be common, once it is enclosed” was the main concentration point throughout the research. The statement stated that enclosing of a shared resource can lead to loss of commonness in urban commons, to an extent the statement was proved respect.

Understanding of current river front development by enclosing the riparian common and reducing the freeriding of the shared resource showed that the depletion of these resources for a time period could be attained. The long-term effect of deterioration of ecosystem services along the riparian common as well the water quality of the river.

The case mentioned in the study had helped to evaluate various approaches to the riverfront development and its impact on the commons. The economical approach, communitarian approach, revitalization or rebuilding approach and also an unplanned approach to these developments were done to get a better insight and to understand the best way of approaching these developments. The research showed that all approaches had their positive and negative impacts. The suitable approach for development of urban commons will be to create a mixed approach, which gives equal importance to economy as well as community with respect to development. The approach can be stated as community economic development (CED) approach

The study states that riparian zone cannot be treated as commodity or a thing, which needs to be revived. The riparian zone was to be emphasized as a common, which shows the characteristic of a common such as social inclusion, historic evolution, ecosystem services, last, but not the least commoners. The privatization of shared resource can reduce the depletion of resource but led to loss of sense of belonging. The best way to maintain any common is commoning but giving responsibility to the people. The enclosure of common can lead to high excludability and low rivalrousness, which are traits of private goods, not a common.

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REFERENCES

[1] Christian Borch and Martin Kornberge,Urban commons: Rethinking the City, routledge: 1 edition (23 march 2015)

[2] Elinor Ostrom,Governing the commons,@cambridge University Press 1990.

[3] **Studio Gang.** Civic Commons Reimagining Our Cities' Public Assets, Copyright © 2016 Studio Gang Architects

[4] A Guide to Riverfront Development Connecting communities to the water, the claude worthington benedum Foundation Pittsburgh, PA 1521.

[5] **Shareable, sharing** cities activating the urban commons, CC 2018 by Shareable

[6] **Shareable, sharing** cities activating the urban commons, CC 2018 by Shareable

[7] **Yue J (2012)** Urban Rivers: A Landscape Ecological Perspective. Hydrol Current Res 3:125. Doi:10.4172/2157-7587.1000125

[8] **María del Mar Delgado-Serran (2015)** Making Ostrom's framework applicable to characterise social ecological systems at the local level,International Journal of the Commons Vol. 9, no 2 September 2015, pp. 808–830

[9] **Harini Nagendra (2014)** Applying the social-ecological system framework to the Diagonsis of urban lake commons in bangalore,

[10] **Srikumar Chattopadhyay, K N Harilal**, River restoration in kerala: developing a co-evolutionary framework and river restoration action plan for thiruvananthapuram city (final report) Research Unit, Local Self Government (RULSG) Centre for Development Studies Thiruvananthapuram February, 2017

[11] Coastal zone management plan of thiruvananthapuram district, kerala, Prepared for Kerala State Council for Science Technology and Environment, Govt. of Kerala

[12] **Jochen Schanze, Alfred Olfert,** Existing Urban River Rehabilitation Schemes,IOER and TU Dresden June 2004

[13] **Joseph Omond,** Urban Commons and Social Sustainability: An Exploratory Study of Stapelbadden/Stapelbaddsparken

[14] **Rita ernawati ,** Community Initiatives in Developing Sustainable Settlements, Case Study Kampung in Surabaya Indonesia, International Journal of Engineering Research & Technology (IJERT)vol. 3 Issue 6, June – 2014

[15] Common Space: The City as Commons (2016) Zed Books Ltd,, 17 Oval Way, London SE11 5RR, UK. www.zedbooks.co.uk Copyright © Stavros Stavrides 2016

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A spatial framework for exploring the Sense of Community in planned residential areas

Sense of Community (SOC)

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Abstract— **"Loneliness, living alone and poor social connections are as bad for your health as smoking 15 cigarettes a day & increase your risk of death by 29%" [1]. According to Abraham Maslow's Hierarchy of Needs, the need for being loved, belonging, and inclusion are given great significance to attain self-actualization. All these factors elevate the need for a Sense of Community (SOC). Every human being desire belonging to a group in which their needs will be met within their communities.**

But presently, "there is concern about a decline in sense of community due to the urbanization of communities leading to an increase in fear of crime." [2] The rising urban problems are indicted on a declining SOC. This study intends to find the possible spatial elements that can promote a SOC which has been in a declining state.

This research is driven by the point that a SOC is vital to positive intellectual health. It involves understanding the concept of sense of community and identifying its contributing spatial and non-spatial parameters. This will help in the effective planning process of residential areas and promote the living conditions of a community.

This study also critically analyzes the planning principles, design approaches and factors of improving sense of community in planned residential areas.

Keywords— Sense of community, spatial parameters, neighbourhood, community

I. INTRODUCTION

Social factors are considered as one of the elements for an individual to attain self-actualization. "Humans need to feel a sense of belonging and acceptance among social groups, regardless of whether these groups are large or small" [3]. Human beings desire to belong to a group that has a concern for each other and rely on the understanding that our needs will be met within this group. "Sense of community is a key concept which have been the focus of many studies in several discipline including sociology, psychology and built environment" [4]. "Many urban problems are blamed on a declining sense of community" [5]. This research is driven by the detail that a sense of community is vital to positive intellectual health. The aim of this study is to identify the contributing spatial parameters that elevates residents' sense of community by analysis of planned residential areas. It includes understanding the concept of sense of community and identifying the contributing spatial and non-spatial factors. It also comprises of an exploratory study on the spatial parameters that promotes sense of community, and critically analysis on the planning principles, design approaches and factors of improving sense of community in planned residential areas.

II. DEFINITIONS

A. Community

A community is a Section of a city, primarily a residential area, has a high school, large business centre measuring 2 or 3 miles across having a population of 20,000 to 40,000 (2 to 3 neighbourhoods). It can be thought of as a "Community of Neighbourhoods" [6]. A planning unit which is conceived as a housing Area with convenience shopping, open area, Anganawadi and milk booth as minimum infrastructure provision having a population upto 10.000 [7].

B. Neighbourhood

"Neighbourhood is defined as a residential area with homogeneous characteristics of a size comparable to that usually served by an elementary school, serving an area of ¾ to 1 mile square, having a population of 6000-8000". It can also be termed as "Community of Neighbourhoods" [6]. The planning unit is conceived as Housing Area with convenience shopping, open area, Anganawadi and milk booth as minimum infrastructure provision having a population of 5000-15,000. [7].

Hence from these definitions, planned residential areas of population up to 15,000 was taken for study.

III. DEFINING SENSE OF COMMUNITY FROM LITERATURE

This study was conducted by analyzing definitions obtained from existing literature on the concept of SOC. By analyzing

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the definitions obtained from a period from 1970 to 2018, keywords were carefully chosen and its importance discussed. The following table shows the keywords obtained from one of the definitions.

TABLE I.

No	Sense of community				
	Definitions	***Author***	***Year***	***Keywords***	***Discussion***
1	"Sense of community is a concept in the field of community psychology, which has been defined as ''the sense that one was part of a readily available mutually supportive network of relationship," "the perception of similarity to others, an acknowledged interd ependence with others, a willingness to maintain this interdependence by giving to or doing for others what one expects from them, and the feeling that one is part of a larger dependable and stable structure". Sense of community was paramount to quality of life and well-being."	Sarason, S. B.	1974	Interdepen dence similarity to others Mutually supportive network Sense of belonging Well being Quality of life	Sense of belonging and mutual aid are the common factors
2	"Residents of any neighbourhood want to feel part of the development in which they live, be proud of it, and identify with it. Feeling part of a community requires knowing one's neighbours and being able to meet friends easily while on foot."	Unter mann R.,S mall R.	1977	Feeling a part Identity Knowing each other and neighbours	Walking, Interactio n, Identity
3.	"Sense of community as an integral contributor to one's commitment to a neighborhood and satisfaction with it."	Ahlbra nt and Cunnin gham	1979	Neighbou rhood Commit ment & satisfacti on	Resident satisfaction
4.	"The strongest predictors of actual sense of community were expected length of community residency, satisfaction with the community, and the number of neighbors one could identify by first name."	Glynn	1981	length of communi ty residency , Commun ity satisfacti on, no. of neighbors one could identify by first name.	Duration of the stay Resident satisfaction
5.	"Sense of community as reflected in neighborhood attachment and found two empirically distinct but correlated factors they called social bonding and behavioral rootedness. The social bonding factor contained items concerning the ability to identify neighbors, feeling part of the neighborhood, and number of neighborhood children known to the respondent."	Riger & Lavrak as	1981	social bonding behaviora l rootednes s	the ability to identify neighbors, feeling part of the neighborho od, and No. of children known to the respondent
6.	"Sense of community" was defined as a reflection of a community's social environment, integrating factors such as sense of mutual aid, neighborhood security, sense of belonging and membership, shared values, and attachment to place."	1. McMill an & Chavis, 2. Nassar & Julian, 3. Brower	1986 ; 1995 ; 1996	Mutual aid Neighbor hood security Sense of belongin g Members hip Shared values Attachme nt to place	Sense of belonging and mutual aid, safety are the common factors
7.	"Sense of community plays a catalytic role in mobilizing the three components, which are the perception of the environment, one's social relations, and one's perceived control and empowerment within the community."	Chavis & Wande rsman	1990	perceptio n of the environm ent social relations & control empower ment within the communi ty	social relations & control
8.	"It reflects a focus on the social bonds within and between people and place, as well as the physical, symbolic, political and cultural implications of 'community'"	Manna rini, T., Tartagl ia, S., Fedi,A. , & Gregan ti, K.	2006	social bonds	Given importance to place and its relation to people

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No	Sense of community				
	Definitions	***Author***	***Year***	***Keywords***	***Discussion***
9.	"Sense of community is directly influenced by: (1) members' perceptions about the extent or degree to which relevant needs and interests are shared and to which there is agreement about the appropriate behavioral mechanisms through which these needs and interests ought to be fulfilled or pursued – or perceived community homogeneity, (2) perceived community functioning, and (3) perceived community competence."	Yasser M. Mousta fa	2009	Needs and interests are shared Homogen eity functioni ng Compete nce	Needs and interests of the people must be fulfilled in order achieve SOC
10.	"Sense of community is "the extent to which any member [of a neighbourhood] feels connected to and committed to others in the community, which bears on a sense of security and belonging".	Rogers et al.	2009	Sense of security Sense of belongin g	SOC is achieved by connection and commitmen t to the community
11.	"It is when a community is viewed as a resource through which an individual member can fulfill significant human needs, such as feelings of belonging and emotional connections."	Nowell & Boyd	2010	Feelings of belongin g Emotiona l connectio ns.	Community is taken as a resource where every individual is given priority
12.	"Sense of community by the learner may be viewed as consisting of four related dimensions: spirit, trust, interaction, and commonality of learning expectations and goals."	Rikki Rimor, Perla Arie	2016	spirit Trust interactio n commona lity	Mental satisfaction is given priority

a. Definitions of sense of community

IV. CASE STUDIES

The following chapter consists of the study of different relevant planned residential areas, considering the measures taken to achieve successful community promoting a strong Sense of Community. The case studies were selected on the basis of the results achieved from Post occupancy evaluation (POE) and studies conducted by various institutions to assess the sense of community in their specific area of living.

The case studies are

1 Housing Development, Cherry Hill, San Francisco, USA
2 Radburn Garden Community, New Jersey, USA
3 St. Francis Square, San Francisco, USA
4 Aranya Housing project, Indore, MP, India
5 EMS Nagar Pattoor Trivandrum, Kerala

A. Details of selected case studies

The following section gives an idea about each case study and its reasons for developing a SOC in the identified areas.

TABLE II.

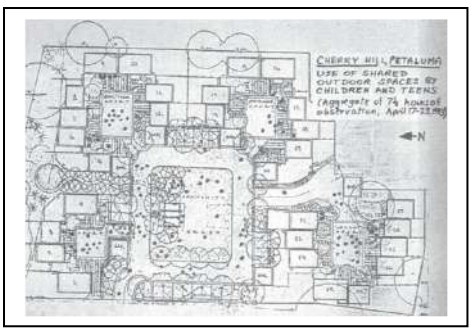
Details of selected case studies					
Title	***Cherry Hill***	***Radburn***	***St. Francis***	***Aranya***	***EMS***
Location	Petaluma, San Francisco	Borough of Fair Lawn, New Jersey	San Francisco	Indore, Madhya Pradesh, India	Pattoor, Trivandru m
Client	Burbank Housing Development Corporation	City Housing Corporation	R.Marqui s, C. Stoller, & L. Halprin	Ar. B.V. Doshi, & Indore Developm ent Authority	Kerala Housing board
Year	1992	1929	1964	1989	1993
Goal	To provide a safe environment and to support a SOC among the residents	To build a planned community which made provisions for the complexities of modern life.	To create a safe, green, quiet communit y	To provide housing by creating a holistic environm ent	To redevelop land as an initiative of the Housing Program
Units	29 townhouses	430 homes, 90 row houses, 54 semi-attached houses & 93 apartments	299 garden apartment -s	7000-12000 people in one sector	198 flats, 18 Individual plots
Inhabit -ants	Low and medium income families with children	Natives	Natives, middle-income families	Third World urban poor	Natives

b. Details of Case studies

B. Pictorial references

The following section gives the site plans of each case studies.

1 Housing Development, Cherry Hill, San Francisco, USA



c. Site plan

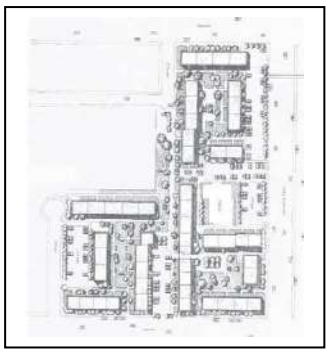
Fig. 1. Site plan, Housing development, Cherry Hill, Petaluma, California, Source: Time Saver Standards for urban design, Watson, Plattus, Shibley, 2003

2 *Radburn Garden Community, New Jersey, USA*

d. Site plan

Fig. 2. Site plan for Radburn community Source: radburn.org

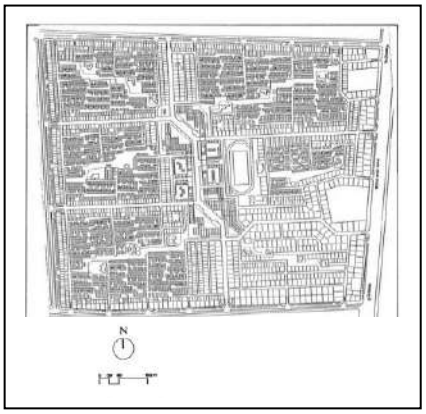
3 *St. Francis Square, San Francisco, USA*



e. Site plan

Fig. 3. Site plan for St. Francis Square. Source: Time Saver Standards for urban design, Watson, Plattus, Shibley, 2003

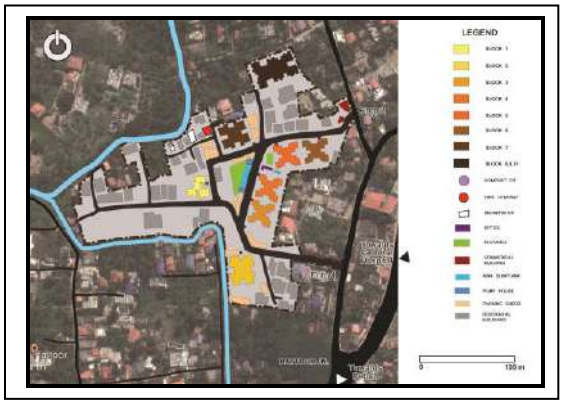
4 *Aranya Housing project, Indore, MP, India*



f. Site plan

Fig. 4. Master plan Source: terrain.org

5 *EMS Nagar, Thiruvananthapuram, India*



g. Site plan

Fig. 5. Primary study, POE conducted in 2019

C. *Comparison of Case studies*

The Case studies were studied individually to identify the spatial elements that contributes a good SOC. The selection of the case studies was on the strict criteria that it must be a planned residential area with population up to 15,000.

TABLE III.

Inference from the comparison of case studies	
Spatial elements	***Inference***
Roads	• Through traffic must be restricted • Separation of vehicular and pedestrian access ways
Courtyard	• Central courtyard spaces create a sense of community leading to interaction
Open spaces	• Open spaces with trees screening the area can create Privacy
Parks	• Parks and Tot-lots create room for commitment and interaction.
Green spaces	• Green spaces should be present for a sound environment
Dedicated spaces for events	• Dedicated spaces encourage events to take place creating behavioural rootedness
Access to public transport	• Should be within walk-able distance
Community facilities	• Should be within walk-able distance
Shops	• Should be within walk-able distance
Security	• Heavy traffic must be restricted within the premises and surveillance required.

h. Comparison & Inference of case studies

D. *Identification of spatial and non-spatial parameters*

The following table explains the process of identification of the spatial and non-spatial parameters by the keywords observed from the comparison of definitions of SOC.

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TABLE IV.

Identification of spatial and non-spatial parameters				
Keywords Identified from definitions	***No. of presence of the keywords in definitions***			
	1	***2***	***3***	***4***
Sense of belonging				✲
Identity	✲			
length of community residency	✲			
Identification by first names	✲			
Attachment to place	✲			
Similarity to others		✲		
Social bonding		✲		
Behavioral rootedness	✲			
Shared values		✲		
Social control	✲			
Competence	✲			
Interaction	✲			
Commonality	✲			
Interdependence	✲			
Mutually supportive network		✲		
Quality of life	✲			
Well being	✲			
Neighbourhood satisfaction		✲		
Neighbourhood security		✲		
Neighbourhood Commitment		✲		
Community empowerment	✲			
Spirit	✲			
Trust	✲			

i. Identification of spatial and non-spatial parameters

The keywords identified from various definitions of SOC have been categorized into groups which all give significance to three major factors promoting sense of community. They are Character and identity, Safety, and Citizen Participation.
Sense of community can be brought by the integrating spatial parameters such as

1. Character & identity,
2. Safety and
3. Citizen engagement.

E. Social factors promoting SOC

Social factors also must be addressed to achieve a good SOC.

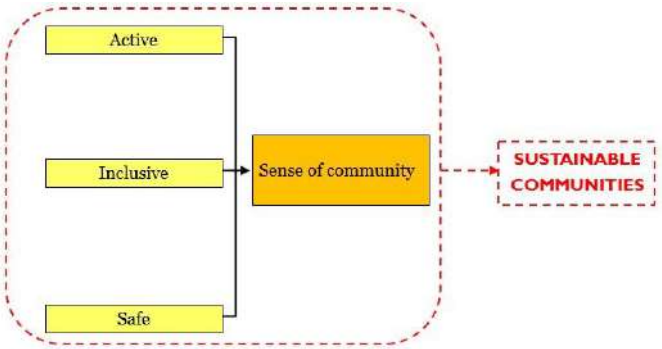

Fig. 1. Conceptual model of relationship between social elements of sustainable communities and sense of community

The above figure represents a conceptual model of relationship between the social factors affecting SOC. A community is expected to be inclusive, active, and safe to promote a good SOC. An important facet to creating a sustainable community is developing a sense of community. The social factors are explained in the following sub-sections.

1. Active

Being active endorses supportive and helpful behaviour in neighbourhoods. It acts an example of bold, informed and strong citizen engagement.

2. Inclusive

There is a necessity for an effective participation within the community at neighbourhood level, including capacity construction to develop the community's knowledge, skills, and confidence.

3. Safe

For a community to be safe, responsible governance arrangements which both facilitate tactical, and visionary leadership must be endorsed. Privacy & security of the individuals of the community must be ensured for effective interaction and a right to belong.

F. Spatial parameters in detail

From the above study, a good Sense of community can be defined as an integration of spatial parameters such as character & identity, safety and citizen participation of the particular area.

1. Character & identity

"Identity of a community refers to personal and public identifications with a specific community" [8]

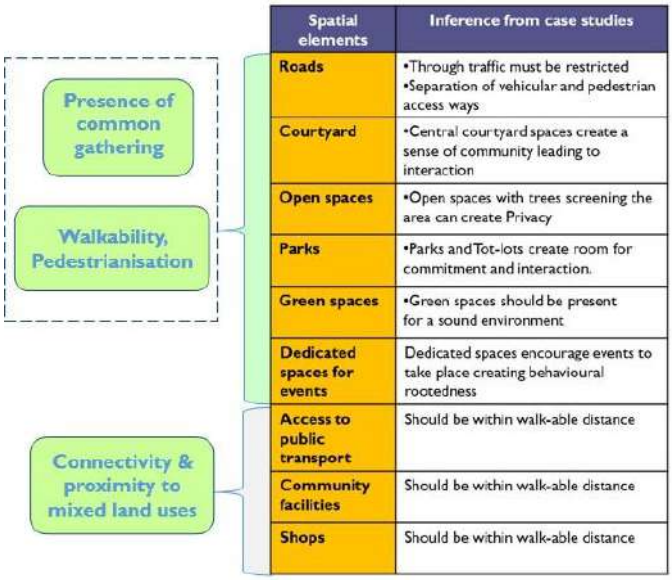

Fig. 2. Spatial elements which promote a sense of community

1.1 Elements that promote character & identity

Common gathering spaces create social interactions
"Social interaction is defined as formal and informal social chances in which residents attend to the quality of their relationship" (Kim and Kaplan, 2004).

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a. Pedestrianisation to enhance walkability

"Pedestrianisation is defined as "to restrict vehicle access to a street or area for exclusive use of pedestrians" (ISOCARP Congress 2008)

b. New urbanism: a concept to enhance walkability

- It is a design movement which promotes pedestrian friendly neighborhoods containing an extensive range of housing and occupation. It focuses on transit-oriented development (TOD) and traditional neighborhood design (TND). Thus it relates to a concept of constructing a SOC.

c. Connectivity & proximity to mixed uses

A Highly connected area makes the residents to be more attached to the area preserving the character and identity of a community. All of these factors will ultimately lead to a SOC

2. Safety

There is a relationship between SOC and safety. A safe community benefits from injury prevention, community safety management systems & crime prevention. Community policing is a concept to enhance walkability. It is the forging of cost effective problem solving partnership between the police and the community.

The community policing program uses different activities and initiatives to accomplish the goal. Formal & informal awareness programs, discussion between officials and residents of a community and door-to-door visits are the methods by which community policing is conducted.

The concept of community policing allows the citizens to take the lead in detecting the issues of crime/order in their particular area with police playing the role of facilitators for enabling the citizens to address the identified issues.

3. Citizen engagement

The opportunity given to the citizens of a community to participate in solving/ conducting the problems/ activities faced by them. Community participation encourages inhabitants to work together – people feel a SOC and realize the benefits of their involvement. To develop a SOC, Community should behave as a sharing stakeholder in maintaining public and private assets. Based on the extent of engagement by the residents of a community, sense of community can be developed.

a. Social capital

It is a measure of the resident's SOC & their ability to act together to pursue shared objectives. (Hugh Barton et al., 2003).

Local Agenda 21 encourages the participation of the local communities in developing collaborative programs. Decision making should be made by the citizens and this should encourage the relationship between government and citizens and greater inclusion of underprivileged groups.

V. INITIATIVES FOR COMMUNITY ENGAGEMENT IN KERALA

1. Safety

a. Janamaithri Suraksha project

The aim of these projects is to create a safer and more secure environment, where the police and community members become guardians of law and order. In Kerala, Janamaithri Suraksha Project was launched in 2008. It demonstrated that when the police and the citizens work together in mutual collaboration, the entire society becomes safer and happier.

2. Citizen engagement

a. 'Haritha Karma Sena'

Kerala has adopted a decentralized approach for the processing of waste at the household, institution and community level. Thus encouraging a waste management through community engagement. The onsite work management is known as 'Green Task Force' or 'Haritha Karma Sena' in Malayalam. A skilled team of women provided technical facilities and clarifications on waste management. The work includes collecting, transporting, processing, disposing, and management of waste in association with the respective Local Self Government Institutions.

VI. FRAMEWORK OF POLICY DIRECTIONS FOR PROMOTION OF SOC

TABLE V.

Character and identity	***Safety***	***Citizen engagement***
Create opportunities for social group	Reduce the possibility of Crime and violence	Construct social capital through the involvement of the residents of a community
Promote accessible local facilities and common spaces for gathering	Reduce the chance of accidents within the neighbourhood by separation of pedestrian and vehicular access	Create local associations to build trust among the residents
		Empower the local community to control local systems by giving leadership to the people in the community
Enhancing the quality of the local environment.	Reducing the usage of car within the neighbourhood by traffic calming measures such as woonerf etc.	Building capacity of families and community to be self-sustained.
		To have a service system that can be used to attain the needs of the residents
Give importance to pedestrianisation to enhance walkability	Encourage a sense of belonging and ownership through residential associations	Government being a facilitator and enabling a community to meet their own needs
Good connectivity and proximity to mixed uses	Limited range of house diversity, with clean places and privacy	To be informed about the problems and solutions, alternatives and opportunities

j. Policy directions

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VII. CONCLUSION

This study mainly aimed to explore the spatial parameters that will essentially promote Sense of community. It was involved with identification of the three main parameters which would give a thrust to the SOC, declining in the present era. The study aided understanding the concept of Sense of Community (SOC) and its contributing spatial parameters which will help in the effective planning process of residential areas and promote the living conditions of a community. The three main identified spatial parameters that promotes SOC are citizen engagement, Character and identity and Safety of the community. These parameters are developed by the presence of spatial elements such as roads, courtyards, open spaces, parks, Green spaces, dedicated spaces for events, access to public transport, community facilities, shops and security. These spatial elements thrust in developing a SOC within a planned residential area. By giving importance to these parameters can create interaction and a sense of belonging within the inhabiting area. The limitation of my study is non- spatial aspects are not inferred within the planned residential areas. The paper has addressed the initiatives taken in Kerala to achieve a good sense of community such as Community Policing and Haritha Karma Sena. It also has strong contents on different housing schemes and planning principles that promote sense of community in Kerala context.

REFERENCES

[1] G. Wilson-Doenges, "An Exploration of Sense of Community and Fear of Crime in Gated Communities," Sage Journals, 2000.

[2] Holt-Lunstad J, Smith TB, Layton JB, "Social Relationships and Mortality Risk: A Meta-analytic Review," 2010.

[3] A. Maslow, A Theory of Human Motivation, 1943.

[4] J. R.Gusfield, "Community: A Critical Response," American Political Science Review, 1975.

[5] Nasar & Julian, "The Psychological Sense of Community in the Neighborhood," Journal of the American Planning Association, pp. 178-184, 1995.

[6] DeChiara, Panero, Timesaver standards for housing & Residential development, 1973.

[7] Urban and Regional Development Plans Formulation and Implementation vol. 1, MOUHA, 2015.

[8] Farahani, Leila Mahmoudi & Mirjana Lozanovska, "A framework for exploring the sense of community and social life in residential environments," 2014.

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Ecotourism Development Plan for Minicoy Island Lakshadweep

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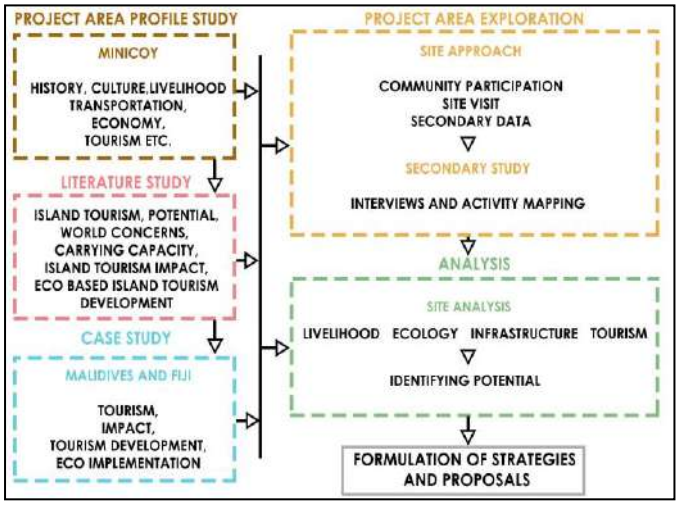
***Abstract*— Island is any subcontinental land enclosed by water bodies. Comparison with the mainland destinations, the economic development of island-like Minicoy is usually challenging due to characteristics like small size, isolated location, limited resources, and high transportation costs. But blessed with a unique natural setting and culture, tourism could be the best alternative. Despite the potential tourism have a huge impact on the island ecosystem. Ecotourism is a type of tourism involving going to a fragile, pristine, and undisturbed natural area. It is the fastest-growing segment of international Island tourism, which contributes to environmental protection and needs sustainable use of resources for Island tourism development. Therefore, the Ecotourism potential was analyzed and zoned to create strategies and proposals for ensuring a continuous well-planned flow of benefits to the Minicoy island with minimal impact.**

Keywords—Island; Ecotourism; Minicoy; Environmental; Planning; Strategies;

I. INTRODUCTION

Minicoy is the second largest inhabited island in the Lakshadweep archipelago with geographic coordinates of 8° 17'N., 73° 03'E. Minicoy is located at the southern limit of the Lakshadweep and is a high Ecologically sensitive island. Under Island Protection Zone (IPZ) Notification, 2011 Minicoy identified as Ecologically Sensitive Areas (ESA) for the protection of the following: Mangroves; coral reefs; sand beaches and dunes, mudflats, protected areas. Also, it has a total extent of 13.97 km reef. It's also the house for rare species of seagrass and turtles. Also, Minicoy stands out from the rest of the Lakshadweep islands due to its unique culture, folks dances and the way of living. Because of these catalysts, tourists get attracted to this island. But Minicoy is affected by many environmental key issues like reef sedimentation, coastal erosion, sewage disposal, solid waste management, the decline in biodiversity, the Diving impact is the lagoon, these could destroy the ecosystem of the island or also maybe the island itself. So, Ecotourism should get implemented in a well-planned manner. For that Ecotourism Strategies and suitable tourism, development location should be identified.

II. METHODOLOGY



[a] *Source: Author, 2019*

Fig. 1. Methodology

III. ECOTOURISM ISLAND DEVELOPMENT

Ecotourism is a component of sustainable tourism. For perceiving sustainable development Ecotourism can be used potentially as a useful tool. This is the essential factor why developing nations are now holding it and adding it in their strategies for conservation and economic development.

Sustainable Ecotourism Development highlighted the following key issues (United Nation World Tourism Organization -UNWTO):

1) Tourism as a key driver of sustainable development in islands

2) Natural and cultural heritage as primary assets for island tourism

3) Partnerships as a basis for achieving more together.

4) Connectivity of islands as a prerequisite for success in tourism

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IV. PROFILE AND ISLAND MAPPING

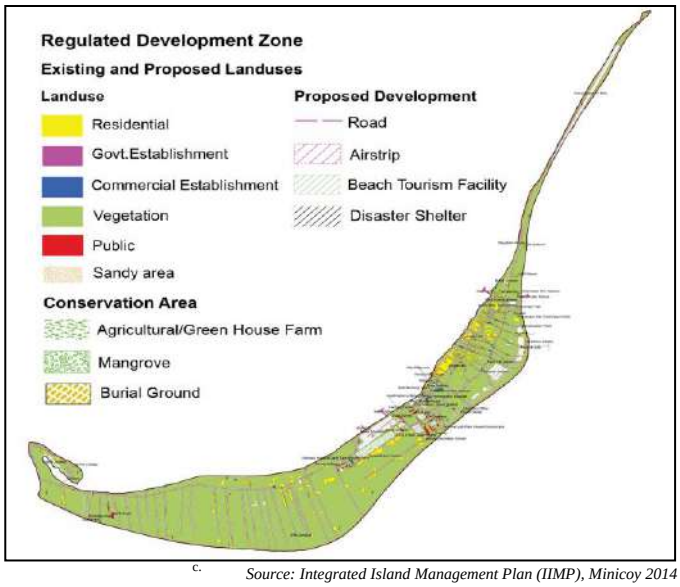
Minicoy island has a land area of 4.4 km2 and lagoon area of 30.5 km2, general profile is shown in "Table 1".

TABLE I. PROFILE

Parameters	*Lakshadweep*	*Minicoy*
Area	32 km2	4.4 km2
Population	64,473	10,447
Households	11,574	1,442
Schedule Tribe	94.80%	95.60%
Sex Ratio	946	947
Density	2015 /km2	2381/km2
Literacy	91.85%	83.90%
Total Workers	29.10%	30.00%
Main workers	16.80%	20.50%
Marginal workers	12.30%	9.50%
Non-Workers	70.90%	70.00%

b. Source: Census of India, 2011

According to "Fig. 2," Land use map the 77% of the land area is vegetation and only 6% of land is used for Residential Built.



c. *Source: Integrated Island Management Plan (IIMP), Minicoy 2014*

Fig. 2. Minicoy Land use/ Landcover Map

A. *Activity Mapping*

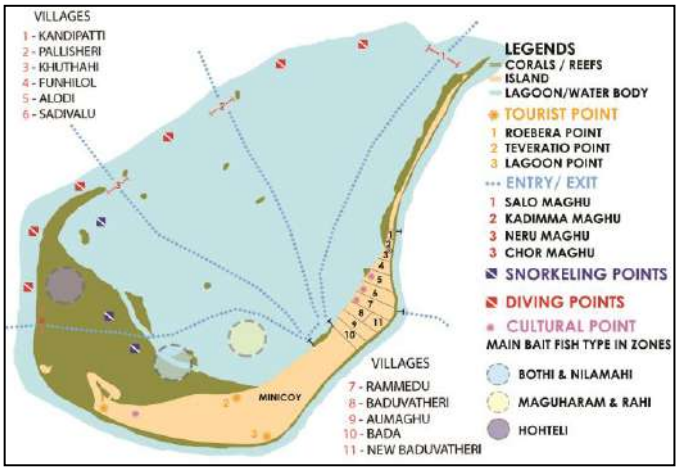
Activity mapping was done with consultation of the village head and with community participation.

1) Culture: Minicoy is known for its unique culture. It is also known for its cuisine, dance forms, music, fishing, architectural features & most importantly people. Minicoy fest is a fest held once every year in Minicoy village "Fig. 3,".

2) Ecology: There exists a large lagoon of approximately 30.6 sq. Km area and an extensive coral reef. The Atoll harbours fragile coral and mangrove ecosystems, other than seagrass. Live corals have been observed on the distant reef slopes on the western side of the lagoon and along the west beach of the northern narrow Island strip.It is known for its unique culture. It is also known for its cuisine, dance forms and music.

3) Tourism: Minicoy is an attractive holiday spot for beach lovers. Other than its natural features, the Light House is one of the oldest tourist sites constructed in 1885. SPORTS built the resort in 1998. There are also three privately owned tourist huts. Water sports offered are boating, glass-bottom boat, snorkelling and swimming in the lagoon. Tourists are also taken to the Villages to have a taste of Minicoy culture.

4) Livelihood: The livelihood of the islanders depends on tuna fishing, coir industry, copra making, boat building, and agriculture. Merchant Navy is a prominent occupation among the islanders. The other livelihood activities include Coral Boulders, Shingles, Sand collection and Octopus hunting.



d. *Source: Author, 2019*

Fig. 3. Activity Mapping

B. *Tourism carrying capacity*

Tourism carrying capacity (TCC) is the maximum number of Tourist that an area's resources can sustain indefinitely without significantly depleting or degrading those resources. The TCC of Minicoy is 179, which is very low. Also, As the environment is degraded, carrying capacity shrinks, leaving the environment no longer able to support even the number of people who could formerly have lived in the area on a sustainable basis.

C. *Costal erosion, Elevation and Slope Mapping*

Shoreline variation was mapped to understand the change in soil erosion and accretion around the island. Also, the slope and elevation "Fig. 4," of the whole island was mapped. This data was essential to understand which coastal side is optimum for tourism development. No Development zone (NDZ) not properly followed, that also causing erosion issues.

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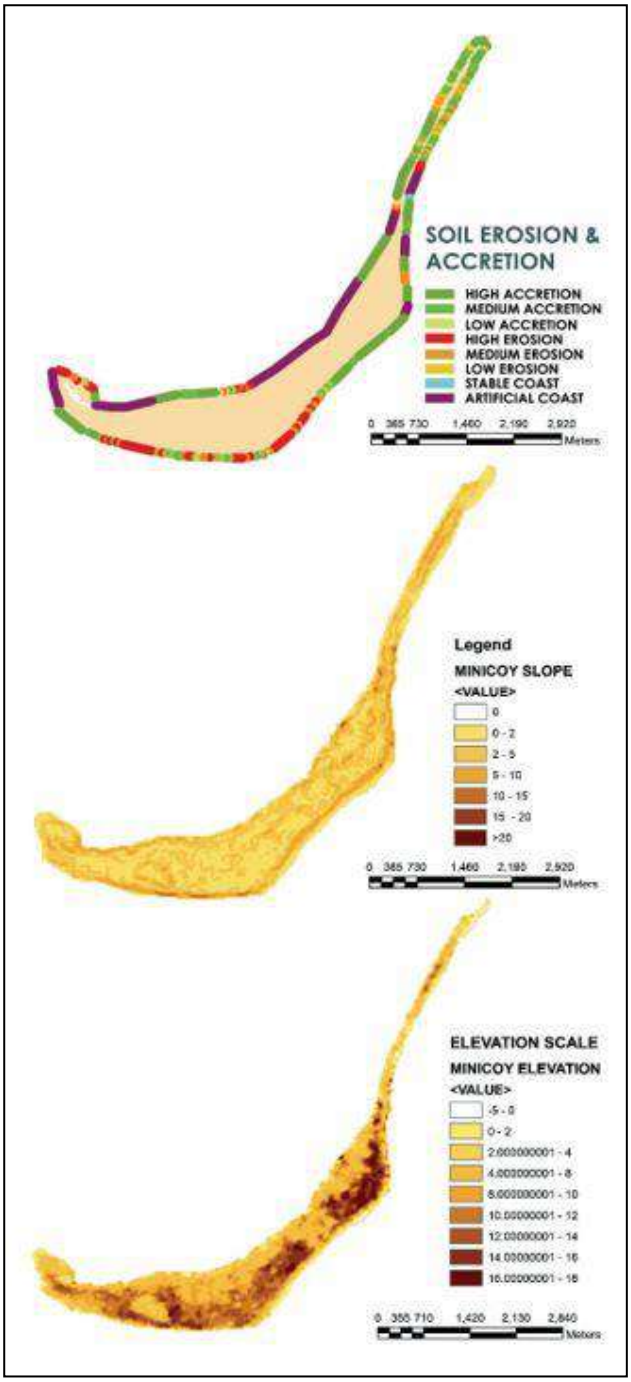
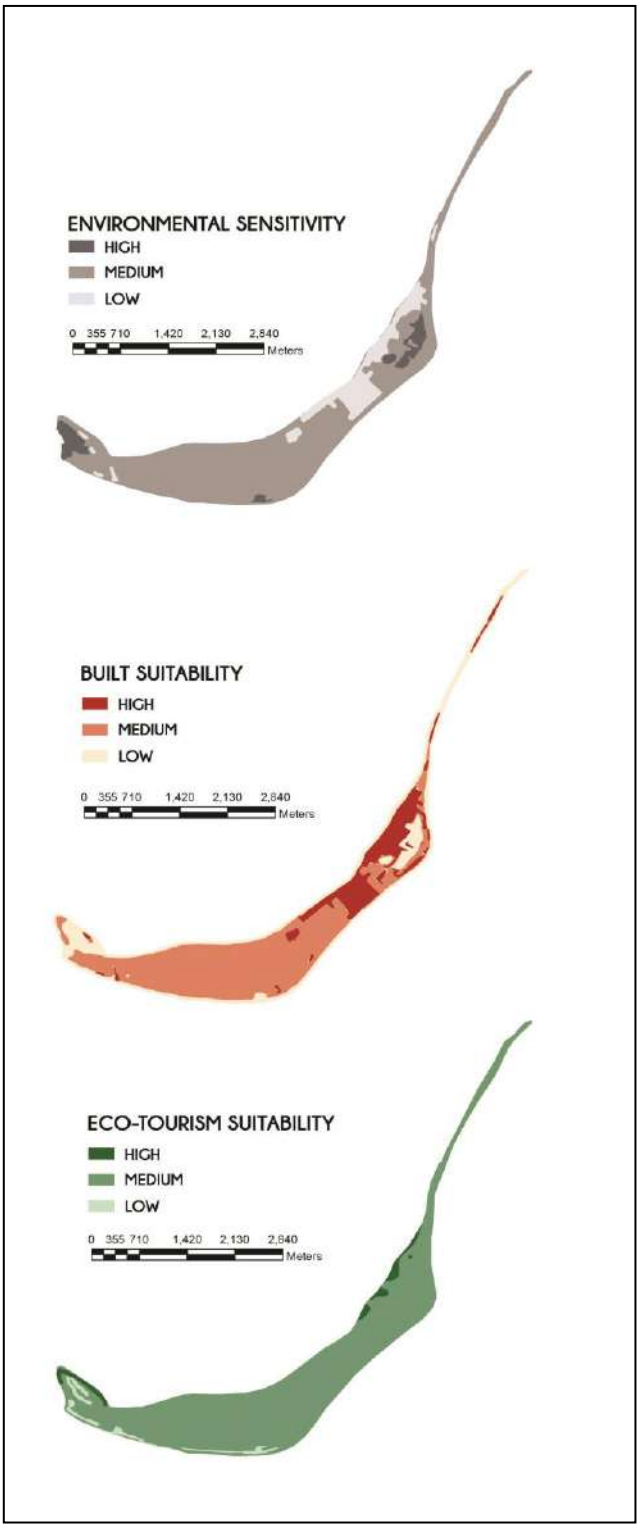


e. *Source: Author,2019- Based on United States Geological Survey, 2019 and IIMP Minicoy, 2013*

Fig. 4. Soil erosion, Elevation and Slope Map

V. ANALYSIS

Eco-tourism, Environmental and Built suitability maps "Fig. 5," was analyzed based on overlays of landcover, Elevation, Slope analysis map, hazard line map, land erosion and accretion. Also, issues and potential of Minicoy was analyzed based on various parameters "Table 2".



f. *Source: Author, 2019 - Data from NITI Aayog D3 Report, 2018 considered for analysis*

Fig. 5. Environmental, Built and Ecotourism Suitability

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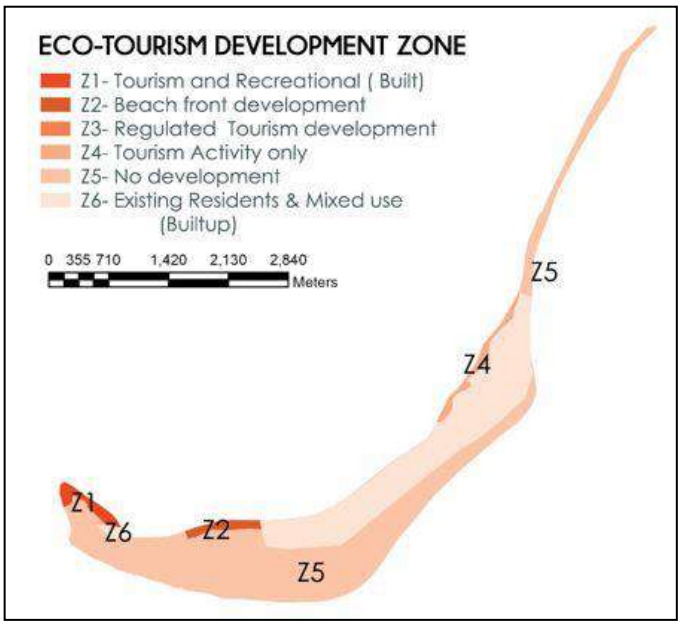
TABLE II. ECOTOURISM ANALYSIS

Parameters	*Issues*	*Potential*	*Inference*
Carrying Capacity	179 Low TCC	Development Regulated based on TCC	Optimum Level of TCC should be Maintained
Tourism Planning	Currently no Tourism plan and Risk Management	Tourism Zoning to Organize Development	Creation of Guidelines for Development
Accessibility	Difficult to access Low frequent ship	Development of seaplane	Currently Not a big issue
Activity	No issues due to low Tourist activity	System to Analyze activity impact	Regular Impact Analysis
Marine Protection	NDZ Not Properly followed	Guidelines and Regulation for Tourism	Guidelines Should be Created
Waste	Incinerator Available no Proper usage	Bio friendly alternate options	Waste issue should be properly treated
Sewage	No proper sewage system	Development of sewage treatment plan (STP)	Proper Sewage Disposal
Community Development	Community not getting that much Benefit	Minicoy fest, Boat Building, Hunting	Incorporation of local in Tourism
Power	90% Diesel Generator (DG)	Tidal, solar wind etc.	Reduce usage of DG

g. Source: Author, 2019

VI. FORMULATION OF STRATEGIES AND PROPOSALS

Minicoy island was zoned "Fig. 6," based on the suitability mapping, and regulation implemented for the development of the island. This strategy is proper because tourism zoning limits tourism development.



h. *Source: Author, 2019 - Based Aayog D3 report, 2018*

Fig. 6. Ecotourism Development Zone

A. Ecotourism Development Regulations

1) Maximum 20 % of Land should be used Tourism Development.

2) Tourism Related Built Shall be done Only after Environmental Impact Assessment (EIA).

3) Maximum Built-up area of tourism Facility should not exceed 30% of the total island Land area.

4) After NDZ setback should be at least five linear meters from the Beach.

5) Corals Used for Construction Shall be Prohibited.

6) Restrictions on shoreline obstruction.

B. Strategies and Proposals

TABLE III. STRATEGIES AND PROPOSALS

Parameters	*Strategies*	*Proposal*
Carrying Capacity	Maintaining Optimum Carrying Capacity	Construction of new resort only if need, also should not exceed TCC
Tourism Planning	New Tourism Guide line for organized development	Island tourism development should be phased based on priorities
Accessibility	Improving mode of transport and trip number	Seaplane Transportation Increase the trip Number
Activity	Tourism activity should be done in less sensitive area	Tourism activity zones
Marine Protection	Proper follow up of NDZ and EIA Regulations	Creation of Marine Protection committee
Waste	Decentralized source levels segregation of waste, Banning plastic Brought by tourist	Composting of waste Biogas production Palletization plastic waste
Sewage	Focus on decentralized waste water treatment plant	Installation of biological waste water treatment system
Community Development	Hiring locals for teaching culture and history of Minicoy	Tourist cultural learning space
Power	Lagoon area Zoning for Floating solar	Floating Solar and roof top solar

i. Source: Author, 2019

VII. CONCLUSION

Ecotourism is 'environment- friendly' tourism which promises to fulfil dual goals of economic development and the conservation of natural environment. Minicoy island has unique natural setting, its own culture, due to these there are lot of unrealized potential for eco based tourism development. But according to the study done it is inferenced there are issue like poor connectivity, soil erosion, dead coral, lack basic facilities etc.

The most critical finding from this study is that for initiate the development, the first step is to strengthen support infrastructure (connectivity, water supply, power, etc.) for providing basic services. This will make the project islands capable of supporting any further development and pave way for new livelihood and tourism opportunities.

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The intention behind delineation of ecologically sensitive zones is not to hinder development but rather, regulate it responsibly with necessary safeguards, as well as exploring new opportunities for recreational & low intensity development.

The identified development zones, suggestive matrix and proposed structure plan do not intend to set conclusive boundaries or regulations, but try to showcase the approach and outcomes by processing the available spatial layers. The proposal was done to outlining the development vision at regional, island and site level that will help prioritize and suitably phase development proposals in conclusion, it is better to avoid intense development in Minicoy, because it will affect the ecosystem of the island. The existing area should be adequately maintained and developed rather than going for entirely new development.

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I would like to thank, Asst. Prof. Ar. Sujith K. M, Asst. Prof. Biju C.A and Asst. Prof. Geetha A, my critics, for devoting their time and expertise to guide. A special thanks to Head of the Department, Dr Ranjini Bhattathiripad for her guidance and assistance.

I also place on record, my sense of gratitude to one and all who, directly or indirectly, have lent a helping hand in this venture.

My true mentor throughout this effort has been my parents. I dedicate this to them.

REFERENCES

[1] IPE-Global. (n.d.). Final Site Development Potential Report. New Delhi: NITI Aayog.

[2] IPE-Global. (n.d.). Inception Report. New Delhi: NITI Aayog.

[3] Management, N. C. (n.d.). Tourism Carrying Capacity Minicoy, Lakshadweep. National Centre for Sustainable Coastal Management.

[4] Studies, N. C. (2013). PREPARATION OF INTEGRATED ISLAND MANAGEMENT PLAN FOR LAKSHADWEEP ISLANDS. Lakshadweep: Department of Science and Technology UT Administration Government of India.

[5] UNWTO. (2013, September 17). EXPERTS AND POLITICAL LEADERS CALL FOR PLACING TOURISM AS KEY IN SUSTAINABLE DEVELOPMENT OF ISLANDS. Retrieved from UNWTO: https://www.unwto.org/archive/global/press-release/2013-09-17/experts-and-political-leaders-call-placing-tourism-key-sustainable-developm

DEVELOPMENT OF A SETTLEMENT PATTERN FOR KUTTANAD

A case of Kainakary

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Abstract
The Kuttanad region, spread across Alappuzha district, Pathanamthitta district and Kottayam district, which is also known as the 'rice bowl of Kerala state' had been susceptible to floods that struck Kerala State in 2018. The Kainakary area which was severely affected by floods, is considered as the most vulnerable area of Kuttanad. In addition to the impacts due to flooding, there are other challenges such as environmental issues, infrastructure issues, livelihood issues and problems associated with settlement pattern. Through this paper an attempt is made to assess the existing settlement pattern, address the current issues and evolve a sustainable settlement pattern for Kainakary area which may be used as a prototypes for similar vulnerable areas of Kuttanad as well.

Keywords: Settlement pattern, Infrastructure,Kainakary, Kuttanad, Cluster

1. INTRODUCTION

The delta region formed by rivers that empty into the Vembanad Lake is called 'Kuttanad'. Flood waters from Vembanad are drained to the sea through the Cochin estuary.Names of many villages are suffixed with the term 'kari' meaning 'ash' or 'burnt', like Thayankary, Ramankary and Kainakary, or prefixed with the same term, like Karimadi. According to geologists, the Arabian Sea in many places, advanced up to the Sahyadri foothills and brought them under water. The trees of the area were submerged in the process. Due to geological movements, there were upliftment and recession of sea at a later period of time. The impact was of the submerged trees getting uprooted and buried in situ under varying levels of silt to give rise to the low-lying marshy saline lands of Kuttanad. The popular stories behind the name 'Kuttanad', relate to a fire destroying the place which was once covered with wood, and hence came to be known as 'shuttanad' or burnt land. This paper throws light into the current issues faced by the inhabitants of Kuttanad and the mitigation measures that could be adopted for the sustainable development of the region..

The Kuttanad taluk was the highest affected by the 2018 flood. More than 90% of the land was affected by flood. Many areas in the Kuttanad lacks potable water and proper transportation and other basic facilities. It is important to preserve the area and provide a sustainable development plan since Kerala gets 31% of its rice from Kuttanad.

The aim of this paper is to evolve a sustainable settlement pattern for Kainakary area of Kuttanad region by studying the present issues and existing settlement pattern.

Kainakary which is the delineated study area of Kuttanad is the most low lying area of Kuttanad.The criteria for study area delineation are the unavailability of basic facilities such as portable water, transportation, and waste management. The sample size selected for field survey at Kainakary is 105 households. The results were documented and the analysis was listed down for the formulation of strategies for Kuttanad and Kainakary.

The best practices studied were of settlement patterns in countries such as Venice, Netherlands and Chile.The parameters identified from the literature study are demographic aspect, social aspect, economical aspect and infrastructure aspect. Based on parameters identified, an attempt is made to provide a sustainable settlement pattern to the delineated study area

The study is concentrated on the housing development and infrastructure facilities of Kainakary area in Kuttanad taluk. The proposal of settlement pattern can be implemented in similar panchayats in Kuttanad region. In the long run the scope could even be extended to disaster preparedness and tourism.

2. BACKGOUND STUDY

2.1 Kuttanad

The Kuttanad region is categorized into: Lower Kuttanad, Upper Kuttanad, North Kuttanad.

(i)Lower Kuttanad comprises taluks of Ambalapuzha, Nedumudy,Kuttanadu(excluding Edathua, Thalavady, Kidangara and Muttar), and the northern half of Karthikapally taluk in Alappuzha district).

(ii)UpperKuttanad-
Veeyapuram and Pallippad in Karthikapally taluk, Edathua,

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Thalavady, Kidangara and Muttar in Kuttanadtaluk; Chenni thala and Thripperumthura villages
in Mavelikkara taluk; Mannar, Kuruttissery, Budhanoor, En nakkad villages in Chengannurtaluk of Alappuzha district; and Parumala, Kadapra, Niranam, Pulikeezhu, Nedumpura m, Chathenkary, Peringara,and Kavumbhagam villages
in Pathanamthitta district.

(iii)North Kuttanad comprises Vaikom taluk, western parts of Kottayam taluk, and western parts of Changanacherry taluk in Kottayam district.

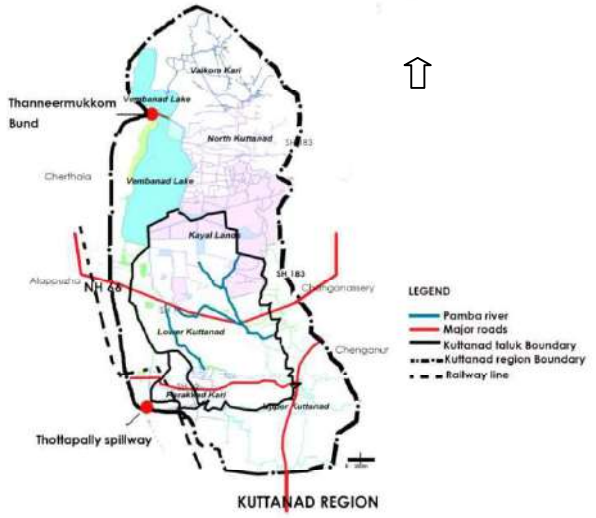

Fig. 1Kuttanad region

(Source - Author generated)

2.2.Land Reclamation at Kuttanad

Coconut logs had been cut and used to demarcate and furnish a frame that used to be fixed inside the lake. Bamboo splinters have been bound on eithersides. The frame of say, 4 to 5 feet width hence made, would then be stuffed with sand and waste. On top of that, clayey soil from the bed of the lake used to be laid. This was consolidated by stamping on it until it gets sufficiently hardened. Thus bunds were created. The water in between the bank and the bund would then be drained out. Water was drained by way of the usage of chakrams (water- wheels), each of which used to be operated by eight to ten persons. From 1898 onwards the farmers ventured reclamations of deep waters

2.3.Study Area-Kainakary panchayat is located in Chempakulam Block in Kuttanad Taluk of Alappuzha district

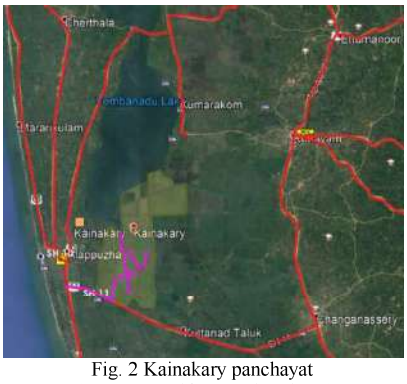

Fig. 2 Kainakary panchayat
(source:generated from GoogleEarth2019)

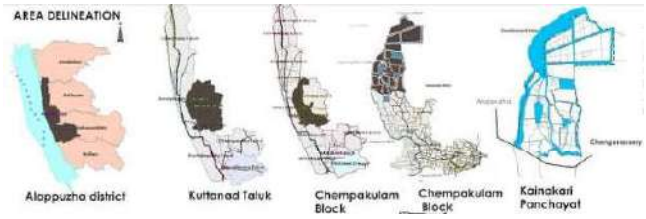

Fig. 3 Study area delineation

(Source - Author generated)

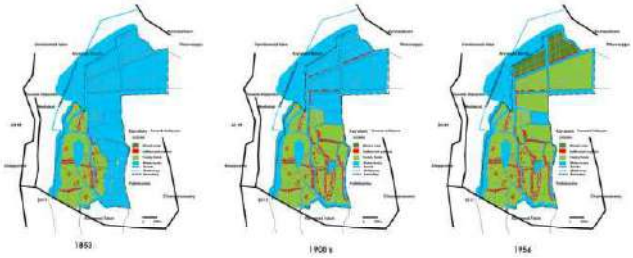

Fig. 4 Evolution of Kainakary

(Source - Author generated through primary survey2019)

During 1800's kayal was reclaimed inorder to form land for paddy cultivation. The kayal lands were Rani, Chithira, marthandam, R Block and C block kayals

The settlements were developed along the river side for the requirement of water for paddy and daily activities.

The houses were constructed near the paddy fields for the ease of access to workplace. Later when demand for paddy increased the other parts of Kainakary were developed. Rest of the land were constructed over forest land that got burned during a forest fire. The Pamba river flows through the panchayat with Vembanad kayal near the kayal lands.

The temples and churches were also formed during that period.

The settlement pattern is linear pattern, along the river banks. Water transport is major mode of transport.

Population change at Kainakary shows a decreasing trend. Population decreased by -9.2% in last 10 years. There are 15 wards in Kainakary of which ward 1 is least populated and wards 3,4 and 5 are highly populated

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Ward	Population		
	Male	Female	SC
1	612	766	206
2	907	1134	42
3	832	1040	86
4	872	1090	102
5	951	1189	94
6	866	1083	55
7	795	994	58
8	785	981	40
9	696	871	120
10	822	1028	108
11	610	763	122
12	751	939	119

Fig.5 Population at Kainakary (source:census 2011)

3. *PRIMARY STUDY*

Socio-economic survey was conducted in Kainakarypanchayat to identify the current issues. Random sampling of 105 households was done

Table 1- Details of primary survey

Ward	No:of Dwelling Units	Sample size of Dwelling Units	Criteria for selection
1	370	5	Scattered housing
2	396	5	Scattered housing
3	400	5	Scattered housing
4	399	10	Most inaccessible area
5	389	30	Most affected by flood
6	382	5	Lack of accessibility
7	359	5	island
8	414	5	Lack of accessibility
9	372	5	Lack of accessibility
10	370	5	Lack of accessibility
11	321	5	Lack of accessibility
12	360	5	Lack of accessibility
13	359	5	Lack of accessibility
14	285	5	Lack of accessibility
15	338	5	Lack of accessibility
Total	5514	105	Lack of accessibility

(Source - Author generated from census 2011 and primary survey 2019)

3.1.Demography

According to the 2011 census report the total population of Kainakary is 25,922.

The number of male population is 12179 and female population is 13203. The percentage of disabled is 1.08%.There is no relative increase in population of Kainakary when compared to the population growth of Kuttanad. This is because, Kainakary panchayat is lowest area lying below the mean sea level in Kuttanad and also due to the unavailability of basic infrastructure facilities.

3.1.1.Religion

In 70% of the sample survey, people living in Kainakary belong to Hindu-Ezhava community and 25% are Christians and 5% are Christian converts.

3.2. Social Aspects

3.2.1.Education

According to the sample survey conducted, the number of school going children above 10 years is more compared to those of 3 – 10 years.

3.2.2.Housing

70% of the houses in Kainakary are pucca houses. About 5% of the houses need reconstruction.

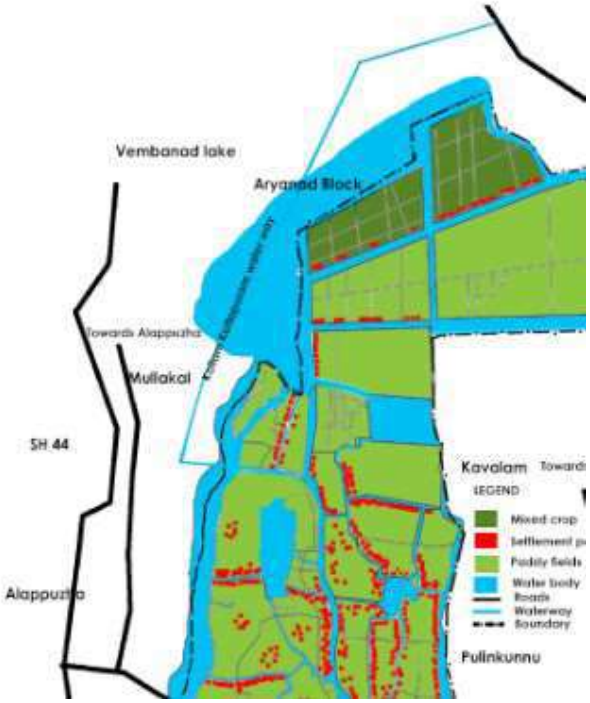

Fig. 6 Existing Settlement pattern at Kainakary

(Source - Author generated)

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Fig. 7 Settlement in ward 4 and 5 of Kainakary

(Source - Author generated)

3.3.Infrastructure

3.3.1.Watersupply

From ward 1 to 8, 80% of the houses lack potable drinking water and the rest of 20% take water from the thodu running alongside their houses

3.3.2.Sanitation

80% of the houses had septic tank and the rest of 20% had rings dug instead of septic tanks.

40% of the houses from 1 - 8 wards had toilets constructed outside the house

3.4..Economical Aspects

3.4.1.Ownership of paddy-

40% of the sample chosen has their own paddy field. 25% takes paddy for lease

3.4.2.Occupation

50 % of the sample has farming as their major occupation.. 40 % are agricultural labourers and 10 % rely on fishing as their means of livelihood

3.5.Analysis and Inference:

The issues persist more in the wards from 1 – 8 as these wards can be accessed only through water ways. There is unavailability of drinking water facility as well. The people face difficulty to travel to their work place as well as for the children to go to their schools. The salt water intrusion from the Thaneermukkom bund is another issue and this causes skin diseases. The salt water intrusion occurs usually after the harvesting of paddy.

4. STRATEGIES AND PROPOSALS

The vision of the project is to make Kainakary a self sustainable panchayat, that serves as a model panchayat for Kuttanad.

4.1. Strategies for Development of Kuttanad

(i) Social Aspects

Settlement pattern: Forming a cluster development within panchayats that are sustainable and self sufficient. Each cluster includes provision for agriculture development, social development and proper infrastructure development through schemes like cluster development for Kerala.

(ii)Economic Aspects:

Marketing of paddy: Provision of markets in all the panchayats of Kuttanad through schemes in Kuttanad projects.

(iii)Environmental Aspects:

Air and water pollution: restriction for allowance of house boats into the residential areas of panchayats of Kuttanad. Avoid the burning up of agriculture land after harvesting season.

There has to be restriction in the intrusion of salt water into the panchayats through schemes provided under Agriculture policy 2015.

(iv) Infrastructure

Health centers: Provision of fully equipped health centers with at least 200 beds and advanced treatment facilities in all the panchayats through schemes like Kuttanad package.

Schools: Provision of secondary education schools needed for a population of 2500 children.

Roads: Provision of proper access roads in all the panchayats and connecting all the panchayats of Kuttanad through schemes in Kuttanad package.

Water supply: Provision of potable drinking water in all the panchayats through schemes under Agriculture policy 2015

4.2. Strategies for Development of Kainakary

(i) Social Aspects:

Women empowerment: Institutions like Kudumbasree and other Co-operative societies need to provide encouragement and value added employment opportunities to women

Hospitals and health centres: A Health centre with proper treatment facility is not present in Kainakary. A primary health centre with a capacity of 200 beds should be provided with all basic treatment facilities.

Schools: According to URDPFI guidelines a secondary school need to be provided for a population of 2500. Since there is no secondary school within the panchayat, a secondary school needs to be provided.

(ii) Economic Aspects:

Marketing of paddy: There are no proper markets to sell agricultural products in Kainakary. According to Kuttanad package and Kuttanad projects a market can be constructed within the panchayat.

Means of livelihood: The means of livelihood of only 60% of people living in Kainakary is agriculture. Since the distance to the paddy field is more and income is less, the people opt for other occupation like daily wage labour.

According to the Kuttanad project a monthly pension can be provided to the low income families.

(iii)Environmental Aspects:

Pollution: Air and water pollution is high in Kainakary. According to Kerala wetland and conservation Act 2015,

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the pollution need to be controlled and adequate water supply has to be provided to the people.

Land Reclamation: according to Kerala wetland and conservation Act 2015,Kainakary is considered as a Ramzar site were in more land and kayal reclamation should not be done.

(iv) Infrastructure:

Transportation: There is no proper road network in Kainakary. Most of the wards can be accessed only by water. According to the Kuttanad package, proper bunds and road network need to be provided at Kainakary.

Sanitation: There are no proper septic tanks and the drainage water flows into a swamp. Schemes like Kuttanad package provide Rs 12,000 for construction of septic tanks to all the households. The funds are provided by the panchayat.

Water supply: Unavailability of proper drinking water facility is a major issue at Kainakary. Through NABARD development scheme for Kuttanad and Kuttanad package, provision for drinking water need to be provided at Kainakary.

5. PROPOSALS FOR KAINAKARY

Social Aspects:

Community development: Implementation of community centers and provision of regular health checkups in the panchayat every month.

Housing: Providing cluster development where in making the panchayat self sustainable. Each cluster will have a provision of potable water and proper sanitation facilities through installation of machines like Omni processor and marketing facility for selling their agricultural produce.

Health centers: There are no proper health centers at Kainakary. Proposal of health centers in one or more clusters is recommended.

Settlement pattern

There is no proper settlement pattern in Kainakary. The settlement pattern is along the river with development in linear pattern. The availability of resources for the people living there is also less. It is better to develop a settlement pattern along the mainland for proper resource mobilization.

Cluster Development:

Each cluster will contain houses on stilts, provision for community development, agriculture development and infrastructure development.

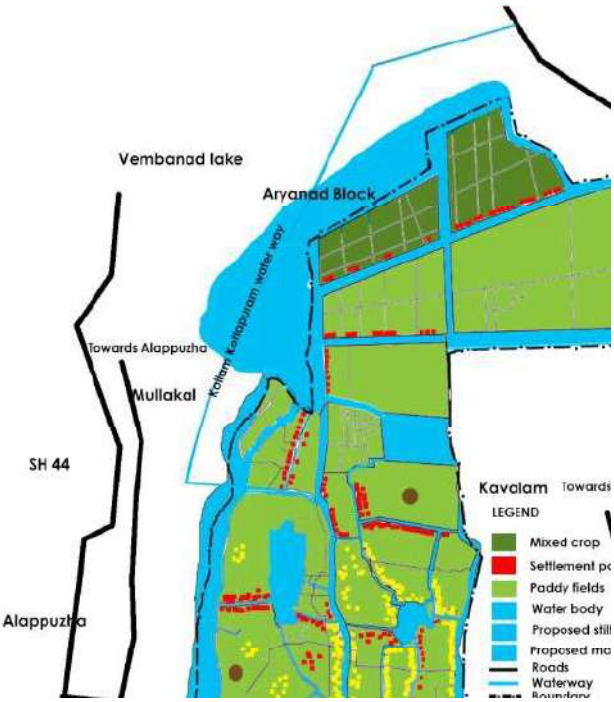

Fig. 8 Proposed Settlement pattern

Infrastructure:

Transportation:

There are no proper transportation facilities in Kainakary. Most of the wards can be accessed only through water. The ward 1 is in the farthest corner of the site and needs an hour to travel to the mainland. There need to be bridges and roads constructed connecting the wards in order to make the travel much more less time consuming and easier.

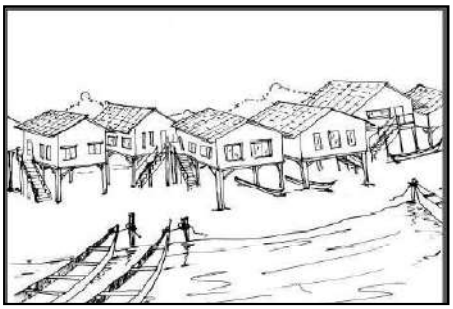

Fig. 9 Option for Cluster development

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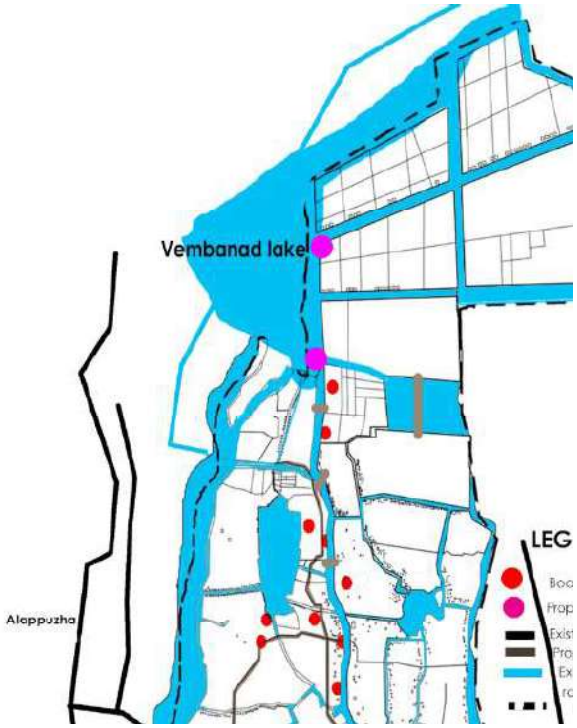

Fig.10 Proposed transportation network

Hospitals:

There are no proper health facilities within the panchayat. The residents have to travel to Alappuzha for treatment. A primary health centre within the panchayat is necessary, as it takes about one hour to travel to mainland.

Housing:

The settlement is to be relocated according to the availability of space in cluster pattern. The number of houses that need to be relocated are 200. The houses that are to be relocated are from wards 4 and 5.

Schools and colleges:

There are four primary schools within the panchayat, two of which are run by church. Children travel in boats to reachschools as there are no proper transportation facilities.

Proposal for a higher secondary school is required for the people of Kainakary

Implementating agency: Existing stakeholders involved in implementation of Kuttanad package such as the Government, panchayat and local bodies along with voluntary agencies could initiate and take up the proposals and strategies for the sustainable development of Kainakary panchayat.

6. CONCLUSION

The existing settlement pattern of Kainakary is along the river side and is linear in form. A proposal of cluster development is given such that there is a provision for basic infrastructure facilities in and around Kainakary.

The cluster contains provision for proper water and sanitation, agriculture production and community development.The housing on stilts is an effective solution for the flood prone areas of Kainakary.The problem of seepage in buildings also can be solved to an extent through usage of stilts. The issue with transportation can be dealt by construction of bridges and roads along the river.

The further studies at Kainakary could be related to the development of a proper drainage pattern, increasing the soil stability and promotion of agro tourism initiatives.

7.REFERENCE

[1] National food security bill 2013. Retrieved March 2019, from Department of food and public distribution: https://dfpd.gov.in/nfsa-act.htm

[2] Kerala,D.O.G.(2011) District Urbanization Report, Alappuzha:Department of Town and Country Planning,Govt.of Kerala

[3] Paddison, E. R. (2016, October). Floating homes: a solution to flooding, crowded cities and unaffordablehousing. Retrieved March 2019, from Support the guardian: https://www.theguardian.com

[4]Bertaud, A. (2002). The issue of Urban Land in the Maldives. Maldives: Thesis.

[6]Rowen, M. W. (2019, January). Encyclopedia Britanica. Retrieved March 2019, from Netherlands: https://www.britannica.com/place/Netherlands

[7] Allexander T. (2012). Study Area-Kuttanad Wetland Ecosystem

[8] Alexander T.,Nair.P.K.K. and Shaji P.K. (2010), Environmental Perspective of Kuttanad wetland with special reference to Kainakary panchayat, Journal of Basic and Applied Biology

[9].Amma K, Jayasree (2012). Thanneermukkam Bund and Thottapally Spillway, Alappuzha

[10]Vikaspedia. (2011).. Retrieved March 2019, from Pradhan mantriKissanSamidhi: http://vikaspedia.in/agriculture/policies-and-schemes/crops-related/pradhan-mantri-kisan-samman-nidhi

[11]Sreejith K.A.(2013), 'Human impact on Kuttanad Wetland ecosystem-an overview', International Journal of Science, Environment and Technology, Vol 2,No.4, 679-690

[12]Vikaspedia. (2015). Vikaspedia. Retrieved 2019, from RashtriyaVikasYojana: http://vikaspedia.in/agriculture/policies-and-schemes/crops-related/rashtriya-krishi-vikas-yojana-1/rashtriya-krishi-vikas-yojana

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Study on the implications of Coastal Regulation Zone (CRZ) notification in the development of Islands

- the case of backwater islands in Kochi, Kerala

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***Abstract*—Apart from the large island groups, Andaman & Nicobar and Lakshadweep, there are several smaller islands located in the coastline of mainland of India. Many islands are undergoing rapid urban expansion with increasing coastal developments. Islands provide important ecosystem services and they have to be protected. Therefore, it is necessary to implement effective management plans for the islands to ensure their sustainable development. Islands in Kerala are commonly known as backwater islands or river islands and they have been brought under the Coastal Regulation Zone (CRZ) notification 2011. Ernakulam district has the highest number of backwater islands in Kerala. Kochi in Ernakulam district is the most populous metropolitan area in Kerala and very much prone to natural disasters. A total number of 30 islands are identified within the Kochi City Region. The Panchayats that are formed entirely by islands were taken as the study area. This included 5 Panchayats in KCR region i.e. Kadamakkudy, Mulavukad, Kumbalam, Kumbalangy and Maradu. Detailed study of the islands in the selected Panchayats were carried out to understand their characteristics and challenges faced by the islands. The study also involved understanding of the implications of CRZ notification in the planned development of islands in Kochi. Encroachment can happen as the islands in Kochi are located at close proximity to the city core, which can further result in land reclamation, urbanization, land conversion and unplanned growth. Planned and sustainable development of island is necessary.**

The study concludes with a set of guidelines formulated after identifying the issues and analyzing the situation in the island followed by the regulations of CRZ and the type of development that is to promoted in islands for sustainable development of island and community.

Keywords— Islands, CRZ, River islands, natural hazards, sustainable development, Integrated Island Management Plan

I. INTRODUCTION

Population in Kerala is estimated to be 33.38 million as per census 2011. Kerala is the 13th most populous state in India with population density of 860 per Sq. km. Coastal regions of Kerala are more populated with the density of population up to 2.5 times the average density of the state. Human activities in the coastal regions can harm the coastal environment and associated ecologies. In order to regulate such activities and protect coastal zones, CRZ notification was introduced in 1991. All the backwater islands in Kerala have been brought under the CRZ notification 2011. The Union Ministry of Environment and Forest released the Coastal Regulation Zone (CRZ) 2019 notification which opens up the coastline of the country for construction and tourism activities. The new notification could result in reduction of No Development Zones (NDZ) significantly [1]. As per the 2019 notification all the islands along the mainland coast and backwater islands are required to prepare Integrated Island Management Plans (IIMP).

Coast of Kerala is prone to natural hazards which is evident from severe cyclonic storm Ockhi and the flood in 2018. There are total numbers of 393 Backwater islands in Kerala, among which 230 islands come under CRZ notification. Ernakulam has the highest number of backwater islands in Kerala i.e. 77 Backwater islands [2]. Kochi is the most populous metropolitan area in Kerala and very much prone to natural disasters. Effective implementation of management plans for these islands is necessary to ensure the sustainability of both the natural resources management and the developmental activities through an integrated approach.

The study aims to understand the implications of CRZ notification in the planned development of islands in Kochi. The objectives include to study islands in general and understand various aspects to be considered for sustainable development of islands, to identify islands in Kochi, to study the characteristics and CRZ implication in islands and finally to prepare framework for sustainable development of islands as per CRZ notification. The study will help to understand the type of development that to be promoted in islands.

II. METHODOLOGY

The study was conducted in two stages. In the first stage general characteristics of islands, their classifications, legal aspects related to management of islands in India were studied through literature reviews. In the second stage the islands of Kochi were studied in detail to understand their characteristics

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and challenges faced. For that the following aspects were analysed i.e. population, occupation, land use, connectivity, proximity to city core, natural hazards, sea level rise, land reclamation and impact on ecology. Along with that implications of CRZ notifications in the development of islands was also analysed. Finally, the study concludes with the analysis and inference proposing framework for sustainable development of islands in Kochi. The following chart shows the sequence of methods adopted for the study.

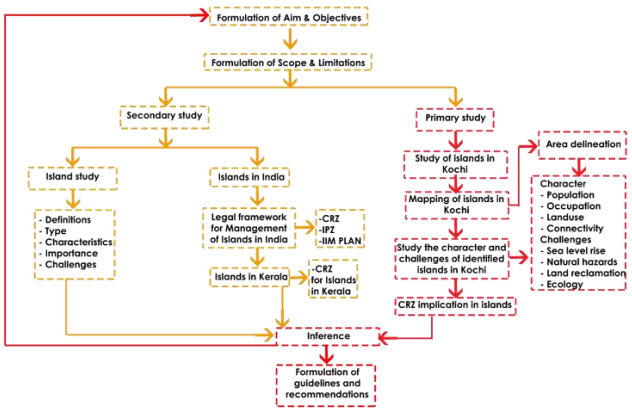

Fig 1 Methodology (Source-Author)

III. LITERATURE REVIEW

A. *Islands in general*

An Island is a body of land surrounded by water and an object which is smaller than a continent [3]. Other terms related to islands include Islets and Archipelago, in which Islets means very small islands [4] and Archipelago means group of islands [5]. Islands are generally classified into three types i.e. Continental Islands, Oceanic Islands and River Islands [6]. Islands located in the mainland coast of India are identified as River Islands. River Islands are islands in a river or lake [5]. Islands have certain characteristics that makes them different from other areas these include unique species of flora and fauna, vulnerability to issues related to climate change and exposure to tides [4].

Natural habitats of coastal islands face serious threats thereby effecting biodiversity in these areas [7]. Coastal islands are home to diverse species of vegetation that play significant role in maintaining ecological balance. These are home to several species of animals, birds, amphibians and fishes. These also help in carbon storage and nutrient cycling. Human activities lead to expansion of urban areas into these eco sensitive parts [8]. Unsustainable methods of fishing, mining, poaching and pollution of waterbodies threaten the ecological functioning of these islands [7]. Some scientists believe rising sea levels put low-lying islands at greater risk for damage from tsunamis, floods, and tropical storms [9]. The present state of rapid habitat alteration calls for conservation of various coastal natural resources and overall development of islands [7].

From the literature study the major threats identified includes urbanization, natural hazards, climate change, lack of connectivity, access to basic infrastructure facilities and lack of management.

B. *Islands in India*

India, the seventh largest country in the world, has a 7517 km long coastline. Apart from the large island groups, Andaman & Nicobar and Lakshadweep islands, there are several smaller islands that dot the coastline of mainland India and are part of the territories of various states and union territories [7]. Indian islands are mainly classified into two types i.e. Oceanic Islands and River Islands. Oceanic Islands include Lakshadweep Islands and Andaman & Nicobar Islands while the islands in mainland are classified as River Islands.

The two main legal frameworks involved in regulating activities in islands of India are Coastal Regulation Zone (CRZ) notifications and Island Protection Zone (IPZ) notifications. The CRZ notification was notified initially in 1991 to regulate activities in coastal areas of the mainland as well as in the islands. The CRZ 2011 notification restricted itself to governing only the mainland of India. At the same time the two island systems i.e. Lakshadweep islands and Andaman & Nicobar Islands, were placed under the purview of a separate notification called the Island Protection Zone (IPZ) notification [10].

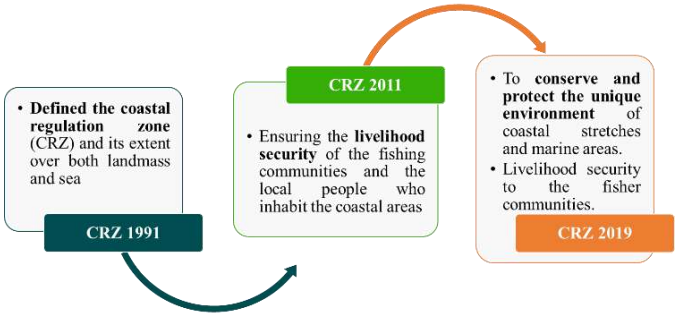

Fig 2 Purpose of CRZ notifications [20], [21]

TABLE 1 COMPARISON OF IPZ & CRZ [10]

IPZ 2011	CRZ 2011
Applies only to the islands of Andaman and Nicobar, and Lakshadweep	Applies only to the mainland coast of India
Island level management plans covers the entire island	Coastal management plans covers only the coastal areas
More inclusive compared to CRZ of traditional local human settlements and fishing activities	Less inclusive compared to IPZ of traditional local human settlements and fishing activities

All the islands in the backwaters of Kerala were brought under CRZ 2011 notification. In this, areas within 50 mts on the landward side was specified as No Development Zones (NDZ). The CRZ 2019 notification covers all the inland backwater

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islands and islands along the mainland coast. It reduced the NDZ to 20 mts from the High Tide Line on the landward side [20], [21]. All the islands that brought under CRZ 2019 notification are required to prepare Integrated Island Management Plans (IIMP). The Integrated Island Management Plan is meant to address vulnerability to human life and property and indicate suitable areas that are safe for locating houses, infrastructure, and the like, and incorporate appropriate safeguards measures to protect the life and property of the local communities and other infrastructure from natural hazards [10].

ACTIVITIES REGULATED	All activities in islands and their aquatic areas are regulated
	All the existing and proposed developments
	Conservation and preservation schemes
	Dwelling units and Infrastructure projects

Fig 3 Activities regulated under IIMPs [10]

C. *Islands in Kerala*

Kerala's coastal belt is inundated by many small rivers and interconnected brackish water canals, lakes and estuaries. There are total numbers of 393 backwater islands in Kerala. Among these 230 islands comes under CRZ notification [2]. There is no specific classification for the islands in Kerala. They are commonly known as Backwater Islands or River Islands. List of islands in the mainland coast of Kerala is given below.

TABLE 2 DISTRICT-WISE LIST OF BACKWATER ISLANDS IN KERALA [2]

SL. No	Districts	Total number of Islands	Islands within CRZ (1991 Notification)
1	Thiruvananthapuram	17	13
2	Kollam	32	23
3	Alappuzha	55	32
4	Ernakulam	77	30
5	Thrissur	38	21
6	Malappuram	32	27
7	Kozhikode	42	25
8	Kannur	45	33
9	Kasargod	55	26
Total		393	230

Ernakulam district has the highest number of islands i.e. 77. Islands in Kerala. These islands are breeding grounds for several fishes, protect the sea shore from natural calamities such as cyclones and Tsunamis and provide livelihoods to thousands of coastal communities. Despite their tremendous ecological values, they have been ignored for several years. Population density in Kerala is high hence planned development of islands is necessary in order to avoid encroachment and unsustainable practices [7].

IV. STUDY AREA

Kochi is the largest city in the south Indian state of Kerala and the second largest along India's western coastline, after Mumbai. It has a population of 12,22,428 as per 2011 census. Kochi City Region (KCR) consists of one corporation, two municipalities and fourteen panchayats [11]. Two rivers, the Periyar and Muvattupuzha, discharge themselves into the backwaters of Kochi.

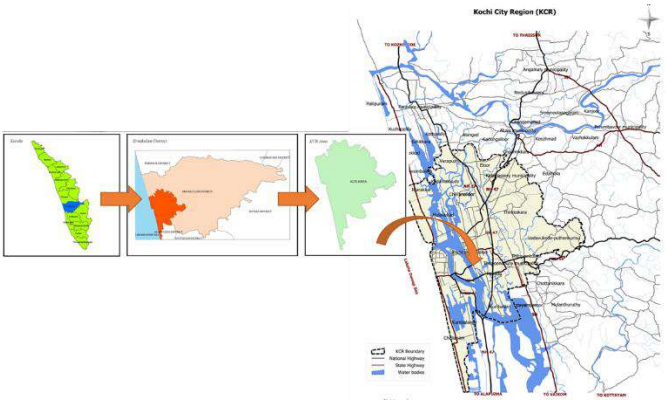

Fig 4 Location map of Kochi City Region (KCR) [11]

A. *Islands in Kochi*

There are total number of 30 islands identified within the Kochi City Region in Ernakulam. The total area of islands in the backwater system of Kochi is 56.4 km2 [12].

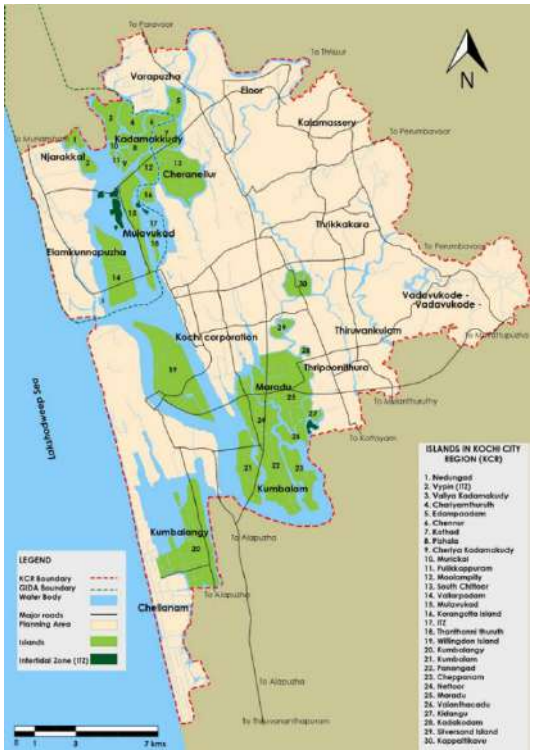

Fig 5 Map of Islands in Kochi (Prepared based on CZMP, 2014)

The Panchayats that are formed entirely by islands were taken as the study area. That included 5 Panchayats in the KCR region i.e. Kadamakkudy, Mulavukad, Kumbalam, Kumbalangy and Maradu. In this Kadamakkudy Panchayat is formed by a

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group of 9 islands i.e. Valiya Kadamakkudy, Chariyam thuruth, Chennur, Kothad, Pizhala, Cheriya Kadamakkudy, Murickal, Pulikkappuram and Moolampilly. Mulavukad Panchayat consists of 3 islands they are Vallarpadam, Mulavukad and Korangotta island (ITZ). Kumbalam, Panangad and Cheppanam islands form the Kumbalam Panchayat while Nettoor, Maradu and Valanthacadu islands form the Maradu Panchayat.

TABLE 3 AREA OF PANCHAYATS IN STUDY AREA [22]

Geographic Unit	Area in ha.	Density Per./ha.
Maradu	1235	36
Kadamakkudy	1292	13
Mulavukadu	1927	11
Kumbalam	2079	14
Kumbalanghi	1577	18

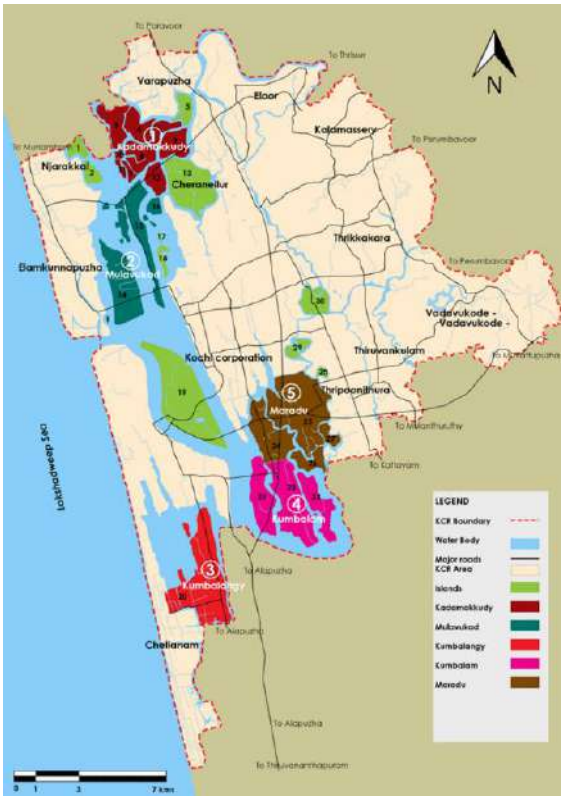

Fig 6 Map of selected islands (Prepared based on CZMP, 2014)

B. *Characteristics of islands in Kochi*

Detailed study of the islands in the selected Panchayats were carried out to understand their characteristics features. The following aspects were considered for understanding the character of islands in Kochi i.e. population, occupation and land use.

a) Population:

Maradu is having highest population density i.e. 3600 per km2 while Mulavukadu has the lowest i.e. 1100 per km2. Due to close proximity to city core i.e. 8 Km and road connectivity there is an increase in built up density in Maradu. Negative population growth is seen in Mulavukadu i.e. -4.41 due to displacement of population for the construction of Vallarpadam terminals.

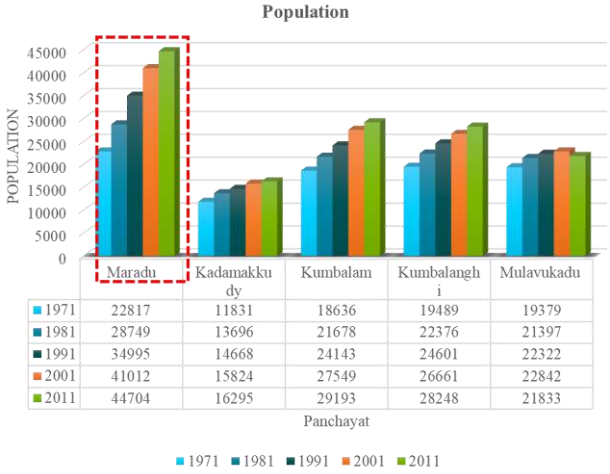

Fig 7 Population [22]

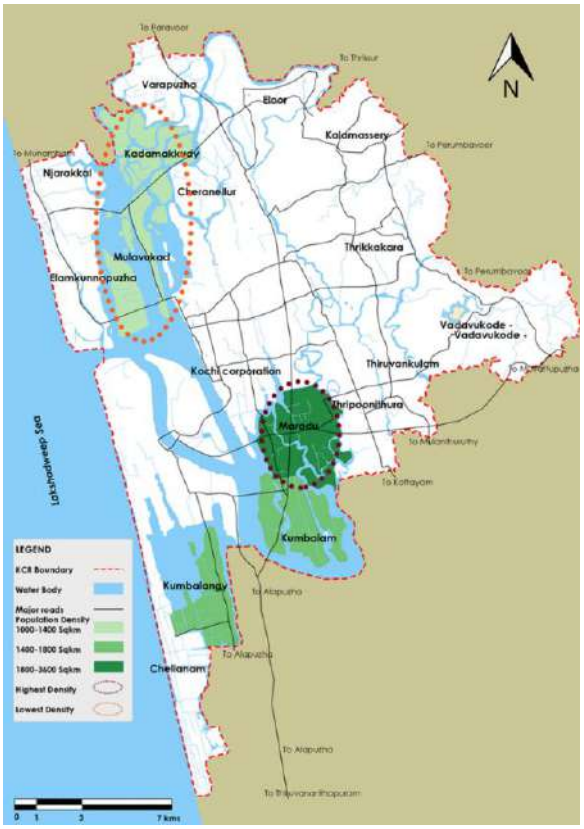

Fig 8 Population density map (Prepared based on census, 2011)

b) Occupation:

Kumbalangy has the highest Work Force Participation Rate (WFPR) comparing with other islands i.e. 41% of people are involved in agriculture and tourism activities. This is followed by Kumbalam i.e. 39% and Maradu & Kadamakkudy i.e. 38%. Kumbalangy has 434 ha. of Pokkali field which is highest compared to other Panchayat in the study area. Mulavukad is having the lowest WFPR i.e. 36%. Shift in occupation from

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agriculture to other workers are happening in these areas which has led to land conversions [12].

TABLE 4 OCCUPATIONAL STRUCTURE [22]

Panchayat	Total workers	Main workers	Marginal workers	Cultivators	Agricultural labourers	Household industry workers	Other workers	Non-workers	WFPR
Kadamakkudy (CT)	6,144	5,406	738	36	51	28	5,291	10,151	38
Kumbalam (CT)	11,317	10,305	1,012	38	85	142	10,040	17,876	39
Kumbalangy (CT)	17,112	15,086	2,026	31	54	176	14,825	25,255	40
Maradu (CT)	16,903	15,335	1,568	21	164	206	14,944	27,801	
Mulavukad (CT)	7,830	6,218	1,612	8	20	39	6,151	14,003	36

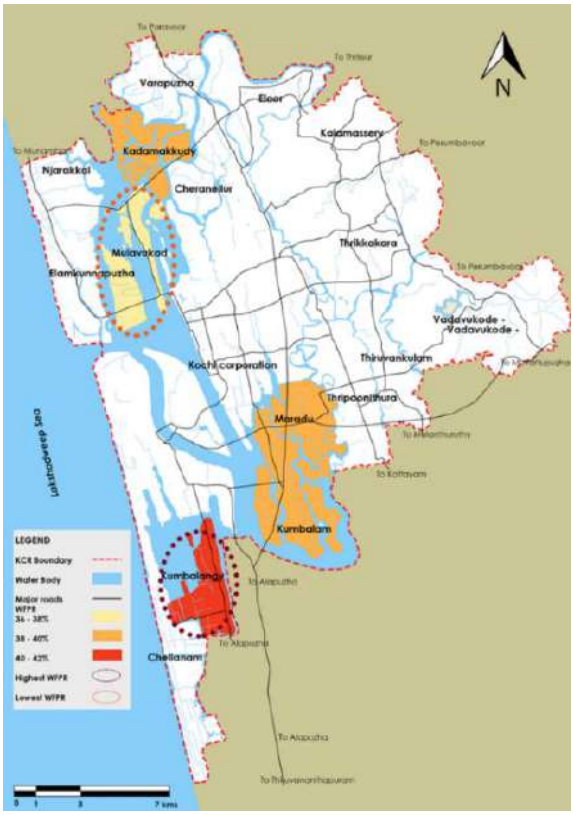

Fig 9 Map of WFPR (Prepared based on Census, 2011)

c) Land use:

Paddy cultivation is seen more in Kadamakkudy ie 40% due to the presence of Pokkali field. Pokkali cultivation is seen nearing extinction due to shift in occupation and those areas are now being used for aquaculture [12]. Only 15 % of total land area in Kadamakkudy is habitable due coastal regulation. Wetland concentration is seen more in Mulavukad due to the presence of mangroves. There is a drastic decrease in the coverage of wetlands due to developmental activities such as roads, bridges, railways, etc. Residential area is seen more in Maradu as a result of rapid urban growth due to the close proximity to urban centre and road connectivity. The eco sensitive areas are identified more in Kadamakkudy and Mulavukadu.

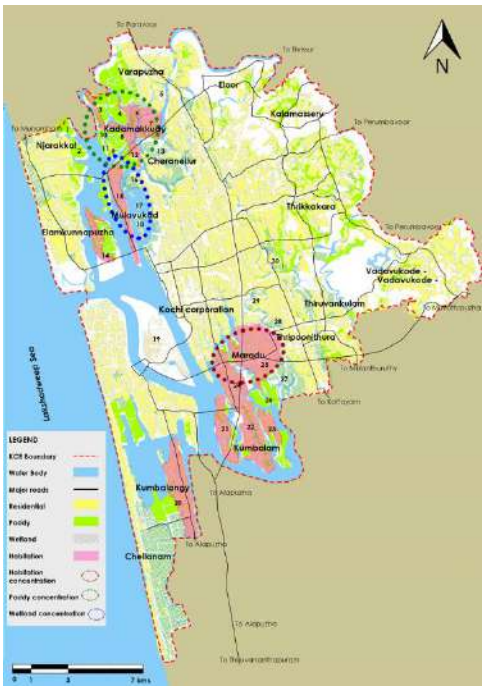

Fig 10 Land use map (Prepared based on KCR master plan, 2014)

C. Challenges faced by islands in Kochi

The following aspects were considered for understanding the challenges faced by the islands in Kochi i.e. natural hazards, sea level rise, land reclamation and impact on ecology.

a) Sea level rise:

Coastal region is vulnerable to coastal inundation due to population growth and development pressures [13]. Low coastal areas and small islands are at more risk to sea level rise than others [14]. Islands in Mulavukad and Kumbalangy will completely go underwater if sea level rises by 2m.

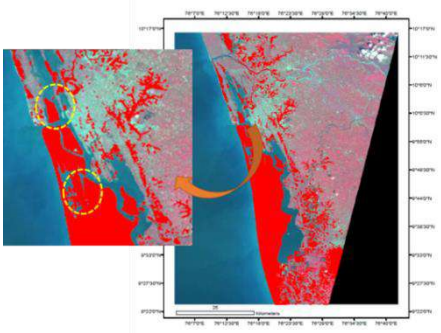

Fig 11 Probable inundation zones for 2 m sea level rise [13]

b) *Natural hazards:*

The total flood prone area in Kerala is 5624.1 km2 among which Ernakulam district is having 718.9 km2 flood prone areas which is the second highest [15]. Then coming to the islands in Kochi 95% of land area in Kadamakkudy Panchayat is prone to flood. While Mulavukad Panchayat is prone to flood as well as tsunami.

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Fig 12 Flood Map (Prepared based on flood map KSDMA, 2015)

c) Land reclamation:

Illegal public encroachment converted the estuary to land area. Reasons for reclamation are urbanisation & population increase, developmental activities, booming of real estate, abandoning of paddy or Pokkali cultivation [12]. Land reclamation is seen more in Mulavukadu and Kadamakkudy Islands. In Mulavukadu about 22% of total land area got reclaimed in the past years (1944-2009). Land are reclaimed mainly for Pokkali Cultivation, area using for ICTT, road and rail construction and for Goshree bridge project.

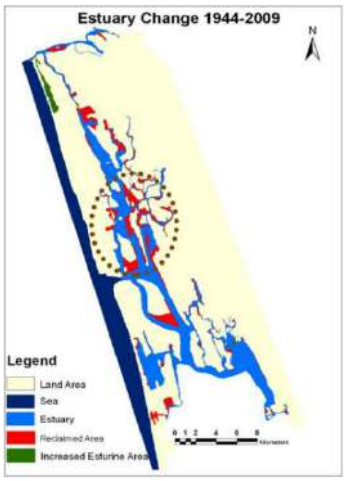

Fig 13 Land reclamation happened in study area [12]

d) Impact on ecology:

In the study area mangrove patches are seen more in Vallarpadam area in Mulavukadu Panchayat. They are affected by urbanization and developmental activities due to proximity to city centre and other areas of commercial as well as industrial activities. This decrease was due to the construction of International Container Trans-shipment Terminal (ICTT), Goshree bridge construction and connecting roads [12]. The next area where mangrove patches are seen is Maradu which got reduced due to the pre-construction mangrove clearance during 2007 and 2009 [12]. Removal of this protective zone for developmental purposes has caused serious erosion problems in these areas.

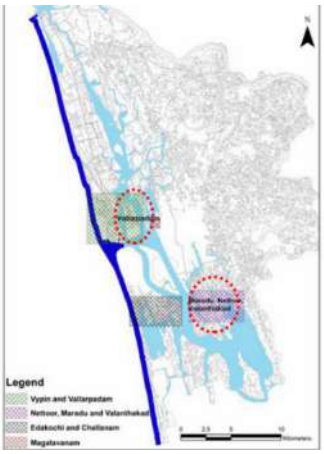

Fig 14 Mangrove patches in study area [12]

V. IMPLICATIONS OF CRZ

Islands that are coming under CRZ notification 2011 were identified within the Kochi city region. As per CRZ 2011 notification backwater islands in Kerala were classified under special area i.e. CRZ V. These are areas requiring special consideration for the purpose of protecting the critical coastal environment and difficulties faced by local communities [16].

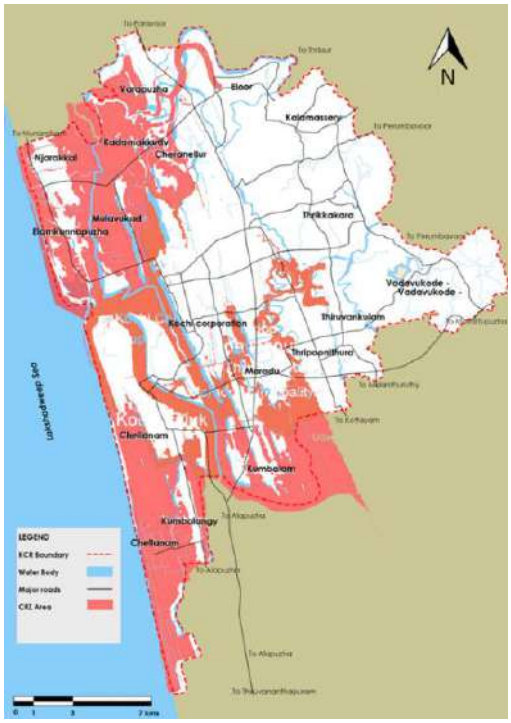

Fig 15 CRZ area in KCR (Prepared based on CZMP, 2014)

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a) CRZ area:

The Pokali fields in the Island areas are categorized as Inter Tidal Zone (CRZ I) i.e. ecologically Sensitive areas. Maradu comes under CRZ II category. While Kadamakkudy, Mulavukade, Kumbalam and Kumbalangy comes under CRZ III Category [16].

Kadamakkudy has a greater area of Pokkali fields i.e. 5.38 km2 compared to other islands in the study area. While Mulavukadu has the highest concentration of mangrove area i.e. 0.524 km2. Maradu comes under the CRZ II category. It can be observed that more than half of the geographical area is covered by residential land use followed by wetlands. Currently CRZ violation and illegal construction in No Development Zone (NDZ) is happening in Maradu ie waterfront apartments such as Holiday Heritage, Kayaloram, Alfa ventures, Holy faith and Jain Housing. Comparing with other Panchayat CRZ III & CRZ IVB areas are seen more in Kumbalam. Currently agriculture, fishing and tourism activities are happening in Kumbalam.

TABLE 5 CRZ AREA IN ISLANDS [16]

Local Body	Length of HTL (km)	Mangroves CRZ IA (km2)	Mangrove Buffer Zone (CRZ I) (km2)	Inter Tidal Zone (CRZ IB) (km2)	Pokali Field (ITZ) CRZ IB	CRZ II (km2)	CRZ III (km2)	CRZ IVB (km2)
Maradu	70.82	0.438	1.049	0.343	0.98	1.57	0.00	2.83
Kadamakkudy	86.87	0.071	0.079	0.601	5.38	0.0	2.04	4.64
Kumbalam	104.83	0.274	0.783	1.195	0.98	0.00	2.52	11.90
Kumbalangy	59.55	0.080	0.297	0.130	2.23	0.00	1.23	2.66
Mulavukade	89.72	0.524	1.814	0.443	2.19	0.00	1.95	7.02

b) Developable area:

The total habitable area excluding CRZ area in the study area is 17.79 km2. In which only 15% of total land area in Kadamakkudy is habitable and 28% of total area in Mulavukad. Lack of availability of developable land can cause housing stress due to increasing population. Maradu is having highest concentration of developable area compared to other Panchayat in the study area i.e. 57% of total land area. While in Kumbalam and Kumbalangy 53% & 44% of total area respectively are developable.

It is seen that residential density in all five Panchayats has increased along with new developments and green patches got reduced. Government has relied on satellite imagery to demarcate CRZ categories with little or no corroboration on the ground [17]. As per CZMP 2014 certain areas demarcated as developable areas are near to shore such as ICT, International convention centres, Lakeshore hospital etc.

Proper study on the carrying capacity of coastal area was not done before accommodating such developments [17]. Impact assessment was also not done in order to understand the changes that may occur to the environment as well as coastal communities which is evident from the displacement of people from Vallarpadam island for the construction of ICTT.

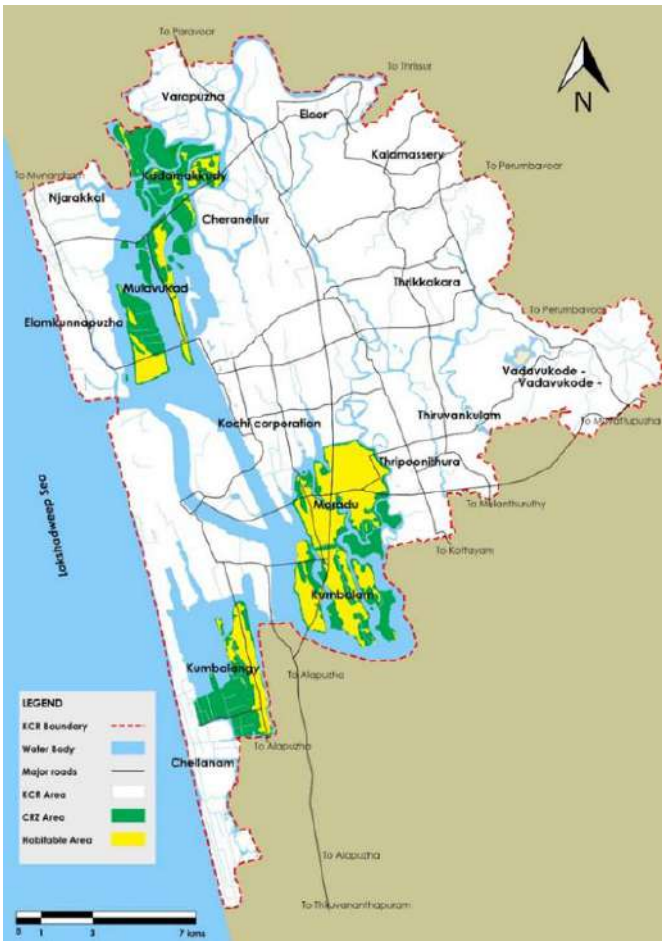

Fig 16 Developable area map (Prepared based on CZMP, 2014)

c) Impact of CRZ on islands in Kochi:

CRZ had a noticeable positive impact to reduce coastal zone destruction on one hand and at the same time had a significant negative impact on the socio-economic life of the island people. The properties in the coastal zone were priced higher than the properties in the nearby zones before the enforcement of CRZ notification. Due to restrictions no economic activity other than agriculture, traditional fishing and animal husbandry are allowed in the CRZ areas [18]. Even though it has a negative impact on the economic growth of the islanders it has also prevented the remaining coastal zone land from being converted for any industrial or construction purpose and helped in conserving the ecosystem.

d) CRZ violation

As per the first Interim Report submitted by Coastal District Committee Ernakulam, there are total number of 542 CRZ violations in the study area. Maradu has not given any report on the CRZ violations and the number of buildings identified are from the pilot survey [19].

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TABLE 6 CRZ VIOLATIONS [19]

SL. No	Name of island	Number of buildings violating CRZ Notification	Remark
1	Maradu	41	High-rise buildings in the CRZ areas
2	Kadamakkudy	162	Single or double storied residential buildings
3	Kumbalanghi	115	110 buildings come under the residential occupancy
4	Kumbalam	110	U/A Number given for 107 buildings which includes one anganvadi, one floor mill, 14- shops, 2- commercial. All other buildings are residential occupancy.
5	Mulavukad	114	112 residential & 2 commercial buildings

e) Implication of CRZ 2019 on islands in Kochi

CRZ notification 2019 has certain relaxations that can cause development pressure on the coastal land. The eco sensitive areas in the islands will be threatened by the construction and tourism activities that are permitted to boost the local economy. Reduction of CRZ No Development Zone from 50 m to 20 m in hazard lines may result in imminent floods. Increased coastal erosions due to legal land reclamation and other structures on the coast which is allowed in CRZ IB area for ports and sea links.

New notification permits FSI for construction project, that had been frozen as per 1991 Development Control Regulation. This can lead to increased development of high-rise structures in the islands which further results in rapid urbanization [17]. New developments can lead to increase in immigration for employment opportunities as the islands are located at close proximity to city core. In-migration is expected to bring economic development in these areas as well as lead to urbanisation and encroachment. Therefore, study on the carrying capacity of islands and impact assessments should be done before giving approval for such developmental projects in these areas.

Fig 17 NDZ for islands as per CRZ 2011 & CRZ 2019 notification (Prepared based on google earth)

VI. Analysis and Inference

Unplanned growth to accommodate the necessities of a fast-developing metropolis has brought damage to the environment of the islands in the study area. From the study it is understood that islands with wetland areas are more vulnerable to reclamation. Pokkali and paddy fields have shrunk in coverage due to population pressures, lack of economic returns as well as urban sprawl. Most of the islands in the study area are prone to flood and tsunami. CRZ notification restrict developable lands in some islands. Even though it has a negative impact on the economic growth of the islanders it has prevented the remaining coastal zone land from being converted for any industrial or construction purpose and helped in conserving the ecosystem. The relaxations in the CRZ notifications 2019 can increase development pressure to these islands through construction and tourism activities. It can further lead to population growth, shift in occupation and land conversion. Sustainable development of islands provides a hierarchy of solutions at greater scale.

TABLE 7 FINDINGS AND INFERENCE (SOURCE-AUTHOR)

SL No	Panchayat	Area in sq km. (Land area)	Population Density per sq km.	Number of islands	Proximity	Road Connectivity	Mobility	WPR	Land use		Habitable area % (excluding CRZ area)	Sea level rise	Natural hazzards	Land reclamation	Inference
									Residential %	Paddy/ Wetland %					
1	Kadamakkudy	9.62	1300	9	11 km	NH966A No road connectivity between islands	Road, Water	38	33	40	15	Not much affected	95% of total area is prone to flood	For Pokkali cultivation	From the study Kadamakkudy and Mulavukadu are identified as the island Panchayat that required further detail study and interventions. In Kadamakkudy only 15% of total area is habitable and in Mulavukadu only 28%. Remaining areas comprises of Pokkali farms, mangroves, fish forms, marshy and other water body which are subjected to encroachment due to close proximity to city core. They also face issues such as land reclamation and lack of connectivity. More over entire areas of both the islands are prone to flood and tsunami.
2	Mulavukad	7.69	1100	3	9 km	NH966A	Road, Water	36	14	24	28	Will go underwater if sea levcl rises by 2m	80% of total area is prone to tsunami	22% of total land area got reclaimed for construction of rail, road and ICTT	
3	Kumbalam	12.27	1400	3	14 km	NH66	Road, Water, Rail	39	40	14	53	Not much affected	70% of total area is prone to flood	For Pokkali cultivation	
4	Maradu	10.27	3600	3	8 km	NH66 NH966A SH15 NH85	Road, Water, Rail	38	50	19	57	Not much affected	55% of total area is prone to flood	For Pokkali cultivation	
5	Kumbalangy	7.12	1800	1	19 km	Locul road network No connectivity from major roads	Road, Water	40	23	19	44	Will go underwater if sea level rises by 2m	50% of total area is prone to tsunami	For Pokkali cultivation	

VII. Strategies for a Sustainable Island Development in Kochi

Studies on best sustainable practices for the development of River islands with similar situation were done in order to understand sustainable developmental approaches suitable for islands in Kochi. Following strategies were framed for the sustainable development of islands in Kochi.

- Strictly implementing CRZ regulations in order to protect the coastal biodiversity.
- Violation and illegal construction in CRZ zones should be strictly monitored.
- Systematic training program on the various provisions of CRZ is to be given to the local people along with politicians and the officials of the villages and municipalities to avoid hardships to the local people.
- Integrated approach must be adopted, contributing to the sustainable development of the protected area and, ultimately, of the entire island.
- Involving stakeholders in management planning to increased sense of ownership, greater public involvement in decision-making and closer links between conservation and development.

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- Control the uses of the protected area and promote only the development of necessary infrastructures.
- Management of protected areas through local knowledge and traditional expertise.
- Conservation and legal construction work in the islands should be done with the support of the local people along with proper understanding of island's natural ecosystems.
- Educating the native population about the ecological and economic importance of wetlands as well as the serious consequences of reclamation of wetlands.
- Promote growth of mangroves along the periphery of the island to reduce the chances of flood entry and soil erosion.
- Enhance the scope of Shelterbelt plantation through Community Participation using suitable species of plants.
- Islanders must be educated to adopt eco-friendly way of living.
- Creation of effective / strong awareness program for environmental awareness and education.
- The local environment awareness on tropical vegetation, flora and fauna etc. should be made an integral part.
- Improve islander's standard of living and basic living needs through educating them in promoting the local culture.
- Carrying capacity of islands should be studied before introducing new developmental projects in the islands.
- GIS-based information system has to be prepared to understand impacts of sea level rise on the islands.
- Strategic environmental impact assessment along with socio-economic impact assessment should be carried out.

VIII. Conclusion

The major factors that can contribute to unplanned growth of these islands are proximity to the city centre, urbanisation pressures, national highways and important roads. These factors may lead to encroachment into these eco sensitive islands which can result in land reclamation, urbanisation, development pressures, land conversion, shift in occupation and migration. All these activities can further lead to sea level rise and natural hazards such as flood and tsunami. The CRZ notifications have positive as well as negative impact on these islands. Proper implementation of CRZ regulations can help in protecting these eco sensitive islands to a great extent. But the CRZ notifications 2019 provides certain relaxations which may threatens the ecological functioning of these islands. Planned and sustainable development of these islands are necessary. Concept of sustainability cannot be easily applied to these islands without proper understanding of the particular area. Sustainable development approach for islands varies for different islands based on their political, social, economic and geographic conditions. Therefore, from the study Kadamakkudy and Mulavukadu Panchayat are identified for further detail study and interventions.

Acknowledgment

I wish to express my sincere thanks and gratitude to Prof. A. Kasturi Rangan and also Dr. P Harinarayanan for their valuable suggestions and guidance during the different stages of my research.

References

[1] 2019. <https://www.thehindu.com>.

[2] Neelima, T., Slipa, B.L., Abhi. R. Aravind, Raveesh, R. & Thomas, K.V. "Morphological Hot Spots of Sea Level Rise Along Kerala Coast." Kerala Science Congress (2011).

[3] Evers, Jeannie. 2012. <https://www.nationalgeographic.org/encyclopedia/island/>.

[4] Targetstudy. Islands. 2017. <https://targetstudy.com/nature/habitats/islands/>.

[5] *Encyclopaedia Britannica*. 2008. <https://www.britannica.com/editor/The-Editors-of-Encyclopaedia-Britannica/4419>.

[6] *worldlandforms*. 2015. <http://worldlandforms.com/landforms/>.

[7] Anant Pande, Yashaswi Singh , Biba Jasmine , Anil Rajbhar , Gitanjali Katlam and K. Sivakumar. "Biodiversity of Coastal Islands of India." Researchgate (2014).

[8] Wenting Cao, Rui Li, Xiaoli Chi, Ninghua Chen, Jianyu Chen, Huaguo Zhang, Feng Zhang. "Island urbanization and its ecological consequences: A case study in the Zhoushan Island, East China." Elsevier (2016).

[9] Sugata Hazra, Anirban Mukhopadhyay, Samadrita Mukherjee, Anirban Akhand, Abhra Chanda, Debasish Mitra, Tuhin Ghosh. "Disappearance of the New Moore Island from the Southernmost Coastal Fringe of the Sundarban Delta - A Case Study." Indian Society of Remote Sensing (2016).

[10] "Island Protection Zone (IPZ) Notification." 2011.

[11] Development Plan for Kochi City Region 2031. Kochi: Kochi Municipal Corporation, 2014.

[12] Dipson.P.T. Spatio-Temporal Changes in the Wetland Ecosystem of Cochin City using Remote Sensing and GIS. Kochi, 2012.

[13] R.Mani Murali, P.K.Dinesh Kumar. Implications of Sea Level Rise Scenarios on Land use /Land cover classes of the Coastal Zones of Cochin, India. Goa, Kochi, 2015.

[14] H. Calado, A. Quintela, J. Porteiro. "Integrated Coastal Zone Management Strategies on Small Islands." Journal of Coastal Research (2007).

[15] Ernakulam District Disaster Management Plan. Ernakulam: KSDMA, 2015.

[16] NCESS. "Coastal Zone Management Plan of Ernakulam district, kerala." 2014.

[17] Verma, Jatin. Critical Analysis of Coastal Regulation Zone (CRZ). 16 May 2019. <https://www.jatinverma.org/critical-analysis-on-coastal-regulation-zone-crz/>.

[18] A. Ramachandran, B. Enserink, A.N. Balchand. "Coastal regulation zone rules in coastal panchayats (villages) of Kerala, India vis-a` -vis socio-economic impacts from the recently introduced peoples' participatory program for local self-governance and sustainable development." Elsevier Ltd. (2005).

[19] Commitee, Coastal District. First Interim Report. Ernakulam, 2019.

[20] "Coastal Regulation Zone (CRZ) notification." 2011.

[21] "Coastal Regulation Zone(CRZ) notification." 2019.

[22] "Census of India." 2011.

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Energy Efficient Planning for Cities

An Approach to Develop Parameters for Energy Efficient City Planning

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***Abstract*—The United Nations' Sustainable Development Goals of 2030 (SDGs) aims to respond to the pressing challenges of urbanization. One of these challenges is energy. Rapid urbanisation in urban areas leads to the emergence of sustainability problems. More than half of the world's population now live in urban areas. By 2050, that figure will rise to 6.5 billion people, that is two-thirds of humanity lives in urban areas. Sustainable development cannot be achieved without a significant transformation of our societies. Extreme poverty is often concentrated in an urban area, the government struggles to accommodate the rising population in these areas. Making cities energy efficient is a sustainable means ensuring access to safe and affordable housing. It involves investment in public transport, promoting non-motorised transportation and clean energy methods, creating green public spaces, and improving land use, using green city principles. The paper employs to develop various parameters were identified, which helps in attain energy efficiency in these sectors of the city. The paper comprises of secondary studies of policies, initiatives study of measuring indices, sector and parameter for the integrated energy-efficient city planning.**

Keywords— Energy efficient; Non-motorised transportation; clean energy; green city planning.

I. INTRODUCTION

The United Nations Sustainable Development Goals of 2030 (SDGs) provide guide-posts to communities as it attempts to respond to many of pressing challenges of urbanization. One of these challenges is energy. Thus, the SDGs have become guide for energy policy-making. Since 1992 the World Energy Council (WEC) and ADEME (Agency for Environment and Energy Efficiency, France) have been collaborating on a joint project "Energy Efficiency Policies and Indicators". The latest report presents nearly 70 countries around the world, evaluates energy efficiency policies.

In World More than half of the world's population now live in urban areas. By 2050, that figure will have risen to 6.5 billion people. In 1990 - 10 mega-cities with 10 million inhabitants, in 2014 - 28 mega-cities with 453 million people. Whereas in India by 2030 India will have 7 megacities with population over 10 million.

Cities are engines for sustainable development. Making cities energy efficient is a sustainable means of ensuring access to safe and affordable housing. Efficient public transport promoting non-motorised transportation, clean energy methods, creating green public spaces and improving land use.

The aim of the paper is to develop parameters for the energy efficient cities. The study focuses on the different sectors of energy efficient city planning and various parameters were identified, which helps in attain energy efficiency in these sectors of the city.

II. METHODOLOGY

The paper comprises of six sections. The first section consists of the study of sustainable concepts like the sustainable city, green city, smart city and the importance of energy efficiency in each concept and working definition for energy-efficient city. The second section consists of the chronological study of energy-efficient planning in World, India and Kerala their policies and initiatives. Third section deals with the study of measuring indices, sector- building, industry, municipality, transportation agriculture. The fourth section consists of secondary studies for deriving parameters like land use, transportation, public utilities, climatic components. Fifth part comprises of the literature case studies of energy efficient planning in cities and checks the identified parameters in forth section with the fifth section. And the sixth part consists of the inference and developed parameter for the assessment of energy efficiency in cities.

III. IMPORTANCE OF ENERGY EFFICIENT PLANNING IN VARIOUS SUSTAINABLE PLANNING OF CITIES

Energy planning deals with a wide range of various aspects, e.g., environmental, economic, social and institutional. It related to various sustainable concepts.

A. Sustainable Cities

United Nations Centre for Human Settlements (UNCHS) Sustainable Cities Programme defined a sustainable city as

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one where achievements in social, economic and physical development are made to last[12].

It's a general definition and neglected the fact that a sustainable city must have a low ecological footprint and reduce risk transfer (economic, social and environmental) to other locations and into the future [12].

B. Green city

According to the World, Economic and Social Survey in 2013, Building of a green city is equivalent to the building of sustainability in a city [7].

National priorities leading to benefits, such as efficient land use, habitat preservation and restoration, effective transport management, efficient use of resource and enhanced quality of life for the occupants [7].

C. Smart city

The term smart city was formally coined by Professor Rudolf Giffinger in 2007 ,Vienna University of Technology (sustainable development studies).

British Standards Institute defined smart city as the effective integration of physical, digital and human systems in the built environment to deliver sustainable, prosperous and inclusive future of its citizens [8].

Different city concepts	Sustainable cities	Green cities	Smart cities
Definitions	United Nations Centre for Human Settlements (UNCHS) Sustainable Cities Programme defined a sustainable city as one "where achievements in social, economic and physical development are made to last"	According to World Economic and Social Survey 2013 - Building of a "green" city is equivalent to the building of sustainability in a city.	Government of India, "smart city offers sustainability in terms of economic activities and employment opportunities to a wide section of its residents, regardless of their level of education, skills or income levels."
Pillars of concepts	• Social development • Economic development • Environment development • Urban governance	• Green infrastructure and storm water system. • Green transport and TOD • Greening- urban agriculture • Environmental quality and water security • Green technologies • Green building • Greening of public services: dirking water and sanitation	• Social infrastructure • Physical infrastructure • Institutional infrastructure • Economic infrastructure
Indicators for Achievement	• Green economy • Climate leadership • Green building • Green transportation • Zero wastage • Access to nature • Lighter foot print • Clean water • Clean air • Local food	• Efficient Land Use • Habitat Preservation & Restoration • Efficient Transportation Management • Enhanced Quality Of Life • Efficient Use of Resource: Water, Energy, Waste	• Smart governance E-governance • Smart mobility • Smart citizens (literacy) • Smart practices ➢ Conservation of resources ➢ Energy efficient methods ➢ Waste management ➢ Wiffi

Fig. 1. *Analysis of various sustainable concepts with energy efficiency (source- Author)*

D. Working definition for Energy Efficient City

Energy efficiency means reducing the energy required for a given level of activity of city by saving of energy from reduction of loss of energy, doing more with non-conventional energy and less use of conventional energy and making the city self-sufficient. The city services provide a reduction of electricity and fossil fuel use and promote widespread integration of solar energy, smart grids and reduction of carbon emission.

Energy efficiency =Energy consumed / Energy Demand, ensuring the demand for energy to be constant for a long period.

IV. POLICIES AND INITIATIVES IN WORLD AND INDIA

The policies and goals defined in the Act were infused into the ongoing programs and actions of the Federal Government. It provided full and fair discussion of significant environmental impacts and s informed decision makers and the public of the reasonable alternatives which would avoid or minimize adverse impacts or enhance the quality of the human environment.

A. WORLD

In 2012, the UN General Assembly has declared International Year of Sustainable Energy for All. The three global objectives established by UN General Assembly to be accomplished by 2030 are ensure universal access to modern energy services, to double the global rate of improvement in global energy efficiency, to double the share of renewable energy in the global energy mix. The chronological energy-efficient initiatives across the world are [6]:

- In 1987 Defined Sustainable cities in the report by the World Commission on Environment and Development or Brundtland Commission.
- In 1992 Rio de Janiero Conference on Environment and Development attended by 178 countries.
- In1992 United Nations Conference on Environment and Development was Agenda 21.
- In 1996 The Habitat Agenda II United Nations .Conference on Human Settlements (Habitat II), Istanbul .
- In 2002 deep discussion on urbanization in the context of sustainable development by United Nations Human. Settlements Programme (UN-HABITAT) in Nairobi.
- In 2012 UN Development Agenda , Rio+20 Declaration and United Nations System Task Team on the Post-2015, fostering ideas
- In 2015 International Conference on Energy Efficiency in Buildings (ICEEB).
- In 2016, Group of 20 (G20) and Asia-Pacific Economic Cooperation (APEC) initiatives had led to 50 countries committing to phasing out fossil fuel subsidies.
- In 2017, IRENA (International Renewable Energy Agency)and the IEA issued a report, Perspectives for the Energy Transition.

B. India

In order to meet the energy needs of citizens and reduce carbon emissions, the Government of India (GoI) has been developing policies and programs. Focusing on supply and demand are two approaches adopted by GoI. Great use of

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renewable energy, mainly solar and wind, is being promoted more. Efforts are being made from the 2001 Energy Conservation Law to improve energy efficiency through a variety of innovative policy measures.

Some of the key policies adopted by the GoI over the past decade are discussing below [6]:

- The Energy Conservation Act (EC Act), 2001, and amended in 2010.
- National Mission for Sustainable Habitat, 2010.
- National Solar Mission, 2010.
- Smart Cities Mission,2015.
- Draft National Energy Policy,2017.

C. Kerala

Some of the key policies adopted by the state government are discussing below [15]:

- 2013 Kerala Solar Energy Policy, The energy Report (WISE).
- 2014 Kerala State Energy Conservation Fund, Kerala State budget Allocation for the Energy sector.

International scenario	Kerala scenario
• Municipal services mostly decentralised • Smart grid and automated system already exist • Cold humid condition: internal heating is needed • Power consumption: depends on nuclear, fossil fuels, wind etc. • Planning of city already exist: built use. • Less denser	• Municipal services needed to well decentralised • Smart grid and automated system not familiar • Warm humid climate: we need cooling system and use can be controlled • Power consumption : hydroelectric power station and fossil fuels . • Cities not ensure Integrated Energy efficient planning • Built use pattern are complicated

The energy-efficient city reflects a cellular model of the self-reliant city based on the redesign of existing urban areas and the planning of new urban expansions conducted with the effort to reduce electricity use and promote widespread integration of solar energy and smart grids.

V. STUDY OF INDICES FOR ENERGY EFFICIENT PLANNING

The section studies about how the energy efficiency of city is measured in national global and national scenario. The study of indices of energy efficient planning.

I. SAARC energy outlook 2030

SAARC Energy Centre has been created through the Dhaka Declaration in 2005 [9].

Vision: The Centre is envisioned as a catalyst for the economic growth and development of the South Asia region by initiating, coordinating and facilitating regional as well as joint and collective activities on energy [9].

Mission: The Centre will provide technical inputs to the SAARC Working Group meetings on Energy, and will facilitate accelerating the integration of energy strategies within the region by providing relevant information to state-of-the-art technology and expertise [9].

Objective: The primary objective is to establishment of the Centre is to have a regional institution of excellence for the initiation, coordination and facilitation of SAARC programs in energy. Countries Joined- Afghanistan, Dhaka, Bhutan, India, Nepal, Islamabad, Sri Lanka [9].

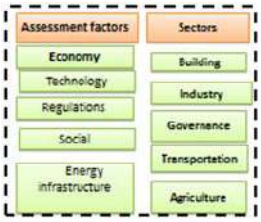

Fig. 2. *Sectors and factor assessed in SAARC Energy Outlook (source :author)*

II. State energy efficiency preparedness index 2018 by Alliance for an Energy Efficient Economy (AEEE)

Bureau of Energy Efficiency (BEE) and NITI Aayog, has published India's first 'State Energy Efficiency Index' for the 29 Indian states and the National Capital Territory of Delhi. The Energy Efficient Index (EE index) - developed taking into account sector-wise[16].

Fig. 3. *Sectors in state energy efficiency preparedness index 2018 (source :author)*

From the study, the sectors of city deals with the energy efficiency are identified to be building, industry, governance, transportation and agriculture.

V. LITERATURE STUDIES FOR PARAMETERS FOR ENERGY EFFICIENT PLANNING

This section employs literature studies to identify the parameters on each sector in a location to make that location energy efficient.

In Parameters for the design of energy-efficient communities are discussed in this literature. There are mainly 2 core aspects of an energy-efficient community they are energy demand and energy generation [4].

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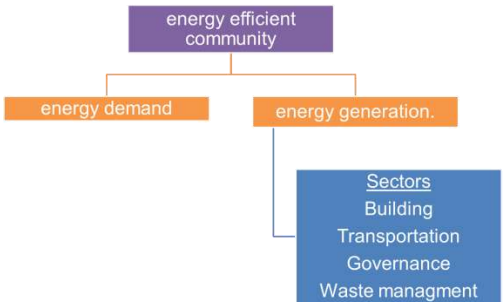

Fig. 4. *Aspects of energy efficient community [4]. (source :author)*

Urban planning	Regulations Climate Land uses	**Other urban elements**	Street network Open spaces
Building	Building typology Parcel Distance between buildings Percentage of glazing Shading elements	**Building solutions**	Façade Roof Ground floor slab Glazing Vegetation

Fig. 5. *Assessment of energy efficient community [4] (source :author)*

Similarly in Energy-efficient city planning, the role and importance of actionable regulations, urban planning has two sectors like land use and construction of laws and sectors which these aspects deal with are building, electricity production, transportation methods [2].

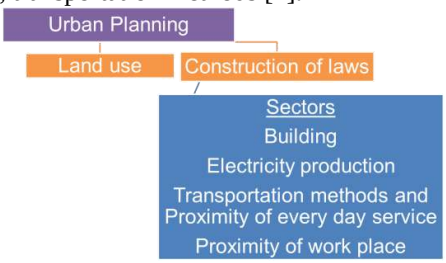

Fig. 6. *Parameters in energy efficient community [2] (source :author)*

From the referred literature reviews, the identified parameter for the energy-efficient city planning is listed below.

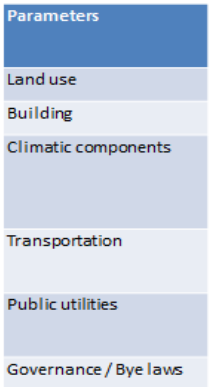

Fig. 7. *Identified parameters of energy efficient planning for city from literature reviews (source :author)*

Assessment of listed parameters above will improve the process of managing energy consumption, reduction of loss of energy, less carbon emission and use of nonconventional energy like solar, wind and other alternative methods in the main sectors like Building, industry, municipal services, transportation.

VI. CASE STUDIES OF ENERGY EFFICIENT PLANNING IN CITIES

The section discusses the literature case studies of energy-efficient planning in cities. This section also checks the parameters identified in the literature study in city case studies

A. Tbilisi land-use master plan for 2030 energy-efficient planning

The land-use planning of Tbilisi city the initiatives was taken for the building and transportation sectors. The parameters and subcomponents of parameters are given below [11] :

Building

1. Energy performance standards for new buildings.
2. Develop a strategy to renovate existing buildings.
3. Once Building Energy Code and standards are adopted at the national level, an implementation strategy is needed for their effective enforcement at the city level.
4. Improve the efficiency of heating systems.
5. installation of solar hot water systems.

Transportation

1. Transport Master Plan that includes sustainability strategies and measures infrastructure to allow a hierarchy of transport options – walk, cycle, metro, buses, private transport and freight.
2. Tbilisi Parking Strategy.
3. Transit-oriented development.
4. Communication and provision of consumer information.

A. City Energy efficiency report for Colombo, Sri Lanka, 10 June 2014

The Energy efficient planning for Colombo city in Sri Lanka in 2014[17] .the initiatives were taken for the building, transportation and industry sectors . The parameters and subcomponents of parameters are given below [17]:

Building

1. Buildings benchmarking program.
2. Audit programs of municipal buildings (schools, offices, residential and hospitals).
3. Setting up of energy efficiency task force to monitor and implement energy efficiency in municipal buildings.
4. Green building guidelines for new buildings (through green building codes and a robust incentive mechanism) and strict energy efficiency codes for existing buildings.

Transportation:

1. Development of non-motorized modes and pedestrianisation, cycling and walking routes and cycle renting schemes.
2. Development of public transport through quality improvement in the bus system, subsidies and incentives to promote public transport.
3. Controlling the growth rate of private cars through parking restraint measures (like high parking fees), park and ride facilities (making it easier for customers to avail.

Industry:

1. Energy Auditor Training Programme.
2. Funding Development & Special Lending Programme.
3. Monitoring & Verification Protocol.

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C. *District Energy initiatives in Rajkot by UN Environment Programme ,2017*

The Energy-efficient initiatives in Rajkot by UN Environment Programme in2017 [18] **.**The initiatives were taken for the building, municipality and transportation and industry sectors. The parameters and subcomponents of parameters are given below [18]

Building:

1. Water supply management.
2. Decentralized water supply system in special locations.
3. Door to door collecting of waste citizens participating in composting.
4. Recycling and scientific disposal of community waste.

Industry:

1. Recycling and scientific disposal of industrial waste.
2. Increase the use of solar energy and connecting the smart grid.

Municipality:

1. Making all municipal services through mobile and online services
2. GIS and GPS based Service delivery. Facilities for Wi-Fi.

Transportation:

1. Public transport system – use intelligent transport system.
2. Non-motorised mobility.
3. Walkability.
4. Smart parking.
5. Smart card facility for using public transportation.

D. *Renewable plan by 2030, for Palakkad district Kerala*

In 2013, WWF-India and World Institute of Sustainable Energy (WISE) brought out the study *The Energy Report – Kerala: 100% Renewable Energy by 2050*. Focusing on short-to medium-term implementation-oriented action plan at the district level. The initiatives taken are listed below [15]:

Building:

1. 100%of efficient fans and lighting, 60 %efficient TV's, AC's and refrigerators by 2030.Stabilized use of wood after 2020 for domestic cooking.

2. 30 % of the solar water heater in the domestic sector.

3. Solar PV target – 1,085MW rooftop PV and 400MW grid-tied PV by 2030.

4. Wind energy target – 200MW by 2030.

Industry

1. Adoption of energy management protocols

2. Government support in encouraging adoption of BAT and BPT for all upcoming projects.

Transportation:

1. Development of public transport through quality. Improvement in the bus system, subsidies and incentives to promote public transport.

2. Controlling the growth rate of private cars through parking restraint measures (like high parking fees), park and ride facilities (making it easier for customers to avail.

Municipality:

1. Reducing water wastage in transmission

2. Switch to solar street lighting

Agriculture:

1. Adopting micro-irrigation techniques.

2. Accelerated switching to energy-efficient pumps/solar water pumps.

VII. COMPARATIVE ANALYSIS OF LITERATURE STUDY AND CASE STUDIES

The comparative study is done to analyze the parameter for the energy-efficient city in each sector. As we can the sector Building, industry, transportation, municipality, agriculture are analyzed with parameters inferred for the literature studies and literature case studies of energy-efficient initiatives in the cities.

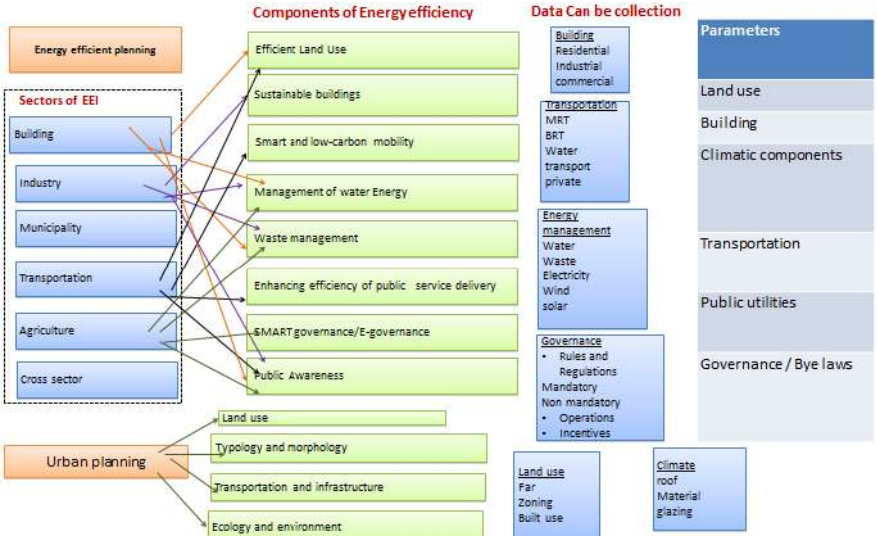

Fig. 8. Comparative analysis of literature study and case studies (source :author)

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VI. INFERENCE

From the study, the concept of the energy-efficient city is the existing city which can manage energy consumption, reduce the of loss of energy, reduce carbon emission and use nonconventional energy like solar, wind and other alternative methods in the main sectors like Building, industry, municipal services, transportation.

Parameters	Sub components
Land use	Zoning
	FAR
	Built use
Building	Green building guide lines
	Number of energy efficient building
	Audit programmes
Climatic components	Roof sections
	Type of material
	Orientation of building
Transportation	Development of public transport (BRT,MRT)
	Development of NMT
	Walkability
	Commute route
Public utilities	Waste management
	Water supply
	Electricity supply
Governance / Bye laws	Sector wise mandatory rules
	Institutions for energy management
	Operational procedure

Fig. 9. List of parameters and sub components of energy efficient city planning, identified in the study (source :author)

VII. CONCLUSION

The current planning process of a city does not ensure energy-efficiency of cities. In such a context, this goal becomes essential to achieve sustainable development of the territory and human activities. This paper discusses a theoretical model and its practical application which relates to managing energy consumption, reduction of loss of energy, less carbon emission and use of nonconventional energy like solar, wind and other alternative methods in the main sectors like Building, industry, municipal services, transportation. The energy-efficient city reflects a cellular model of the self-reliant city based on the redesign of existing urban areas and the planning of new urban expansions conducted with the effort to reduce electricity use and promote widespread integration of solar energy and smart grids. The application of this model aims to improve the global energy performance of city making previsions of energy consumption patterns and solar energy potential, in new strategic expansion areas and exiting ones. The parameters of the energy-efficient city are to support the optimization, adaptation and development in the planning of energy-efficient cities.

Integrated energy efficiency concepts into the urban design and planning process can lead to:

- Efficient public transport
- Promoting non-motorised transportation
- Clean energy methods
- creating green public spaces
- improving land use

Developed parameters can assess current scenario energy-efficient initiatives in cities of Kerala and improve the actions taken integrated energy-efficient planning.

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REFERENCE

[1] Murat Akcin, Asim Kaygusuz, Abdulkerim Karabiber, Serkan Alagoz ,Baris Baykant Alagoz, Cemal Keles. “Opportunities for Energy Efficiency in Smart Cities.” *4th International Istanbul Smart Grids and Cities Congress and Fair, At Istanbul, Halic Congress Centre.* ResearchGate, 2016.
[2] Åsa Hedman, Doctoral Dissertations. “Energy-efficient city planning, the role and importance of actionable regulations.” 10/2016.
[3] David Ribeiro, Tyler Bailey, Ariel Drehobl, Jen King, Stefen Samarripas, Mary Shoemaker, Shruti Vaidyanathan, Weston Berg, and Fernando Castro-Alvarez. “City Energy Efficiency Scorecard.” 2017.
[4] E. Barreiro, J. Belausteguigoitia. “(E. Barreiro , J. Belausteguigoitia; ”City planning and energy efficiency: towards an integrated urban design and planning process.” 2009.
[5] Edgar Santoyo-Castelazo, Adisa Azapagic. “4.2.1 Sustainability assessment of energy systems: integrating environmental, economic and social aspects.” Journal of Cleaner Production , 2014.
[6] Europe, United Nations Economic Commission For. *Analysis Of National Case Studies On Policy Reforms.* New York , Geneva: UNDP, 2015.
[7] IGBC. “World Economic and Social Survey .” 2013.
[8] India, Government of. “SMART CITY.” 2013.
[9] SAARC. “Startergy paper on energy efficiency.” 2012.
[10] SE4ALL. “Global tarcking frame work execuitive summary.” 2012.
[11] SEAP. “Tibilsi Landuse for 2030 .” 2017.
[12] UNDESA, Development Policy and Analysis Division. “World Economic and Social Survey Report .” 2013 .
[13] UNDP. "sustainable cities and communities". 2015.
[14] undp.org/sustainable cities and communities. 2014.
[15]WISE.“Renewable plan by 2030, for Palakkad district Kerala.” 2018
[16] AEEE."State Energy Efficient Preparedness Index".2018
[17] SAARC. “City Energy efficiency report for Colombo, Sri Lanka.” 2014.
[18] UNEP. "District Energy initiative in Rajkot." (2017).

The Influence of Urban Planning in Road safety

Towards more Sustainable cities

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***Abstract*—This study analyze influence of urban planning in road safety. To meet the increasing urban population, many cities are expanding the capacity of the road network, often risking the safety of the road users [3][17]. Road safety needs a multidisciplinary approach. The study begins with a literature study on the various aspects of road safety such as factors causing road accidents and the influence of land use and travel behavior. From the literature study, it was found that road safety can be ensured at micro, meso and macro levels. And to achieve this various strategies can be incorporated at these levels. One of the hazardous forms of development is ribbon development, which is common in many developing countries. 20th-century concepts such as compact city, urban village, transit-oriented development, smart growth, and new urbanism encourage mixed land use, high density, walkability, provision for non-motorized transport and public transport. Both developed and developing countries have adopted measures to decrease road accidents such as land use measures in Quebec, Canada and bus rapid transit in Curitiba. All these suggest the need for integrated land use and transportation plan and strategies at various levels. One of the sustainable ways of solving road accidents is through land-use planning.**

Keywords—Road safety; different levels of road safety; integrated land use and transportation plan.

I. INTRODUCTION

Road accidents are one of the major causes of death in both developed and developing nations. Incidence of accidents mark variations and spatial regularities that follow certain patterns that can inform more about the nature of problems and the extent to which different solutions can reduce accidents [3] [4]. Land use pattern, types of road network, local business and activity pattern influences the accident risk in an area [8]. Road accidents are found to follow some spatial and temporal patterns [3]. Factors that influence road accident changes with space and time. Knowledge of the spatial and temporal variability of the accident can help optimize resources to improve traffic security management [3]. Analysis of the spatial distribution of road accidents is important to assess the impacts of influential factors to analyze road accident spatially for improvement in traffic management [9]. Zonal factors such as traffic behavior, land use, transportation facility, and demographic features influence spatial variability of accidents [7].

II. METHODOLOGY

1. Literature review of various urban planning aspects of road safety
2. Findings by case studies of the influence of urban planning in road safety
3. Various strategies for implementing road safety at urban planning level

III. ROAD ACCIDENT AND ROAD SAFETY

Accident results in loss of life, injury and damage to property. Many of the issues in the transport system are caused by the transportation sector, so there is a need for integration of decisions made by different sectors [20]. Causes of road accidents are road users, vehicle Road, Condition Road design, environmental factors; other causes are improper installation of advertisement boards, etc. and the nature of road accident vary with these factors [4] [12].

Engineering consideration should include land use and zoning regulations to prevent further concentration of activity in the congested areas. The changes in land use, road design, and traffic management have been found to result in a potential reduction of 5% to 10% in the total injury accident [11]. Land use distribution and transport networks and planning influence travel behavior in a city [18]. The movement of people between workplace, residence and leisure generates traffic. The travel distance increases with the increase of the share of vacant land. Travel behavior can be changed by altering the land-use system or transport system. Mixed land use functions affect the behavior patterns of travel agents because the density of residential settlements can reduce travel length and travel time and travel costs [21].

IV. EVOLUTION OF ROAD SAFETY APPROACH

Early gridiron pattern can be seen in the major cities of Indus valley civilization dating to 2600 BC even though it was uncommon prior to the 19th century. Examples are Mohenjo-Daro and Harappa.

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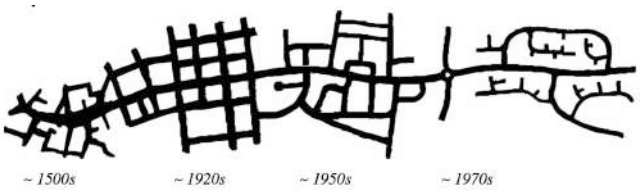

Fig. 1. Evolution of street network. [1]

The gridiron pattern became common in the 19th century after the industrialization. This was to promote rapid land development. Many studies have proved that the gridiron street pattern increases the chance of accidents [29][30]. Gridiron streets were automobile-oriented [6]. The problems with gridiron streets lead the planners to develop Cul de sac suburb pattern to reduce the through traffic in the residential areas and having them take place in the arterial roads. By 1950 this street pattern became prevalent. The modern street network evolved after 1950.

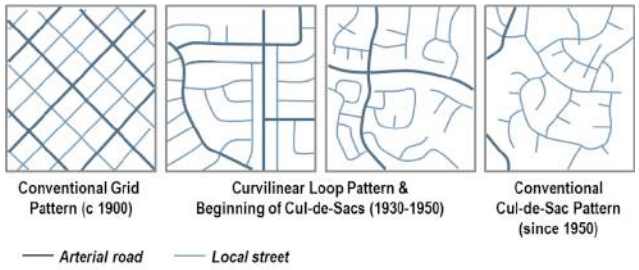

Fig. 2. Different type of street network. [2]

The early road safety approach was such that the planners addressed the functional classification, development of disconnected residential areas and location of retail areas along arterial roads. The approach was that widening and straightening the roads. So that the drivers could see any hazard coming and reduce the speed of the vehicle. Such an approach can be seen in the ideas of Clarence Perry and Clarence Stein in the 1930s [29].

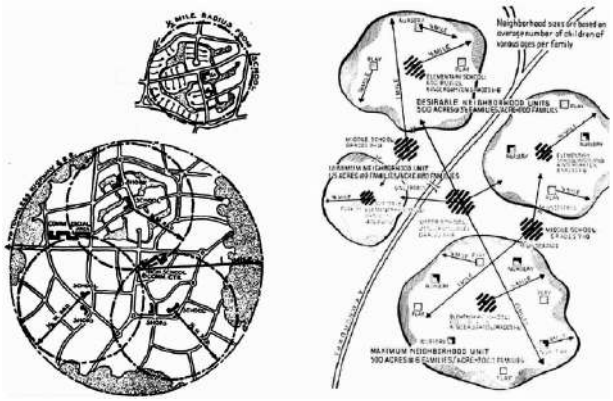

Fig. 3. Cluster of Neighbourhood unit by Clarence Stein. [6]

The main aim was to separate the traffic from the residential by land-use planning. In the neighborhood unit residential areas, civic uses such as schools, churches were included and the uses like commercials were located along the arterial roads. These roads surround the neighborhood. Such an approach to the relation of activities separates traffic flow from the neighborhood.

It was based on three basic safety aspects:

1. The widening and straightening of the arterial road, thus increasing the sight distance and helping the drivers.
2. Separation of land use activity reconfigured the street network. This prevents traffic from entering the residential area. Reduces the number of conflicts.
3. Cul de sac and 3 way intersections replaced the 4-way intersection to reduce the number of conflicts.

V. Regional Development And Road Safety

The size of the city is always important for the type of strategy adopted for road safety. Urban form, land use, and population density should also be considered when evaluating number of accidents [17][20] [29].

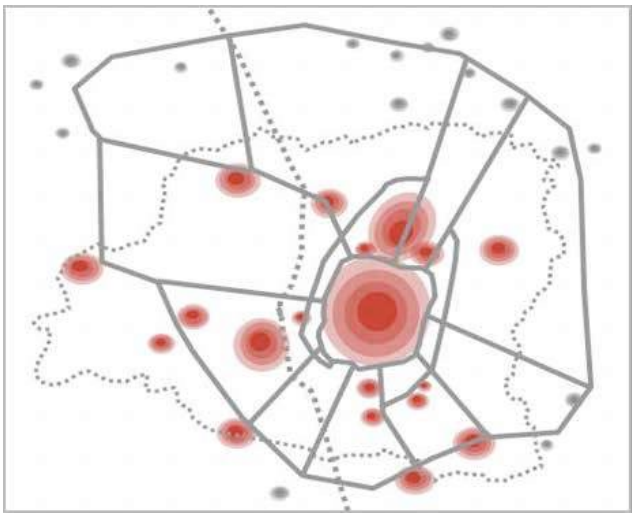

Fig. 4. Polycentric city and connectivity. [16]

Monocentric types of development are usually private car-oriented. Which results in traffic congestion, pollution, and accidents. Urban expansion, increase in population density and development of infrastructure led to urban sprawl [36]. Managing sprawl is critical so that the trip lengths are reduced [37]. The polycentric type of development is usually public transport oriented. The polycentric approach is suitable for large cities. An example of a polycentric city is San Francisco Bay Area. Urban development with a strong land-use mix is favorable to road safety [20].

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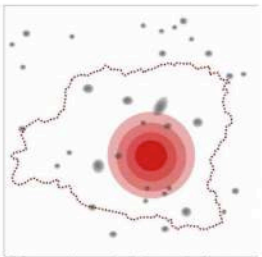
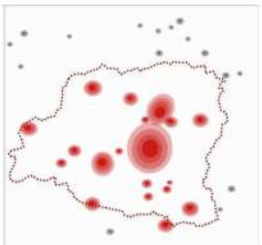
TABLE I. REGIONAL DEVELOPMENT MODELS [16]

Sl no.	Regional development	Characteristics
1.	Mono centric city.  **Figure i Monocentric growth.** *(Source: Development of Toolkit under "Sustainable Urban Transport Project)*	• Centralised growth. • Low-density sprawl • Engulfing neighbouring towns and villages. • This leads to longer trip lengths, increasing dependency on motorised modes of travel. • Urban sprawl. • Congestion of streets. • Accidents. • Pollution.
2.	Poly centric city  **Figure ii Polycentric growth.** *(Source: Development of Toolkit under "Sustainable Urban Transport Project)*	• Decentralised growth. • Retain the size of the parent city and the neighboring centers to grow. • Increased employment opportunity. • Reduced number of trips. • Reduced travel demand and trip lengths

VI. MACRO, MESO, MICRO APPROACHES OF ROAD SAFETY

In a city road accidents and its safety measures can be approached at three levels- macro, meso and micro level.

a) Micro level- At this level road entity, driver and the vehicle is considered. Road safety can be ensured by considering elements such as road users, vehicle and road design.

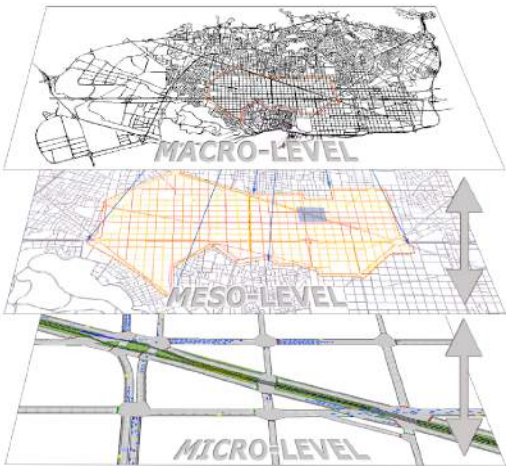


Fig. 5. Micro, Meso and Macro approaches of road safety. [19]

b) Meso level- Meso level is commonly associated with micro level. It is the investigation of factors at the community level, neighborhood, clusters, traffic environment and building surrounding.

c) Macro level- It is the geographic area usually a region or a metropolitan area. These areas are investigated to understand factors such as land use, transportation, infrastructure, and demographics that influence the occurrence of road accidents [19]. This approach provides tools for planners regarding road safety and takes into consideration aspects such as improvement in infrastructure, land use, neighborhood, socio economic conditions and increased walkability [38][39].

VII. RIBBON DEVELOPMENT AND ROAD SAFETY

Ribbon development takes place along both sides of the arterial road. Residential/ commercial/ industrial development occurs along the sides of the road. Ribbon development is road centric and may cause urban sprawl. Urban sprawl results in congestion of roads. The development is characterized by people's tendency to build as near to the main road. The Bangalore ring road is witnessing the ribbon development phenomenon. Ribbon development leads to regular traffic congestion, road accidents, reduced carrying capacity of arterial roads and uneconomic extension of utilities and deterioration of urban living conditions [33]. According to the road accident statistics of the Indian government, Delhi, Chennai, Mumbai, and Bangalore tops the list [40]. Other issues of ribbon development are encroachments by hawkers, vendors, shopkeepers accompanied by parked vehicles, loading and unloading operations. Access of local traffic to the arterial road creates several problems; such as congestion, reduced traffic flow, accidents, etc. The length of the arterial road also has an impact on the number of accidents [20].

Fig. 6. Ribbon development. [22]

Ribbon development along the highways generate [11]:

1. Local traffic and pedestrian flow,
2. Slow vehicles,
3. Reduces sight distance,
4. Mixing intercity and intracity traffic movement,

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5. Traffic congestion and chaotic situation.

The presence of commercial development along the roadsides such as shopping centers/markets generates traffic on the road. Thus the development reduces effective road space and rendering curbside lanes ineffective, which substantially reduces the carrying capacity of arterial roads [32]. According to the Draft Road safety Vision of Kerala- The ribbon type of land use development is one of the causes of road accidents [13].

A. Measures to control ribbon development

According to the Draft Road Safety Vision of Kerala Report, 2014 one of the measures of controlling ribbon development is by controlled land use and can be achieved by [13]:

1. Restriction of or no high-rise apartments and mega malls are to be constructed very close to major road corridors.
2. Ribbon development should be controlled within the right of way and no construction of permanent structures and these areas to be reserved for widening the road according to projected traffic demand for the next 50 years.
3. Green zones should be maintained on both sides of the major arterial and sub- arterial road corridors.
4. Sufficient setback distance should be maintained with respect to the curve radius.
5. The building line should be maintained.
6. No structures, trees, compound walls, etc. should be allowed at curves and junctions obstructing sight distance.

VIII. Pedestrians And Road Safety

Among the road users, pedestrians are considered to be the most vulnerable. They are not provided with adequate space and facilities. Often the facilities for them are poorly designed and are not paid attention and respected by drivers and police [31].

Fig. 7. Foot over bridge in Erode. [23]

Pedestrians often faced to narrow footpaths and which are sometimes encroached. Facilities like pedestrian underpasses and foot over bridges are provided that are underused due to inconvenience and security issues. This leads to a violation of traffic rules such as climbing of barriers and rails by the pedestrians, thus increasing the accidents involving pedestrians. In areas with heavy pedestrian traffic, it is necessary to provide pedestrian corridor at grade whereas the vehicles move up (fly over) and down (underpass). Thus giving priority to the pedestrians. Increasing the width of the carriageway by 2.4 m, providing space for pedestrians and enabling them to cross the road at grade, such facilities to be provided at places with heavy pedestrian movements such as railway stations, metro stations, commercial centers, etc. [28].

IX. Travel behaviour

Land use distribution and transport network and planning influence travel behavior in a city [41]. The movement of people between work place, residence and leisure generate traffic.

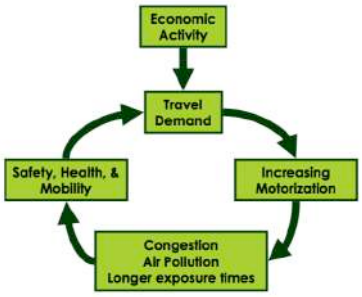

Fig. 8. Travel demand and road safety. [35]

The travel distance increases with the increase of the share of vacant land. The travel behavior can be made to change by altering land use or transportation network [41]. Mixed land use functions affect the behavior patterns of travel agents because the density of residential settlements can reduce travel length and travel time and travel costs [21].

X. Land Use Transportation Integration

For transportation system to be sustainable land use should be considered [41]. One of the traffic issues is the lack of understanding the land use transport model. An efficient understanding of this model can solve many transportation issues. Urban planning theories of the 20th century such as such as New Urbanism, Smart growth, Transit oriented development which consider urban traffic condition to reduce vehicular traffic volume in cities. Integrated land use and transportation planning is a pre condition for adopting the transport and mobility management policies that are much more effective at reducing the number of causes [27].

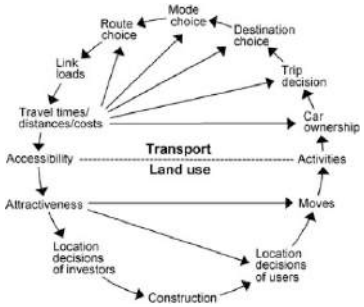

Fig. 9. Transport feedback cycle. [24]

Road transportation effect land use and land use effect transportation. Decisions made in the transportation sector have

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a significant impact on land use. These are significant and should be considered in policy and projects. The impacts created should be evaluated so that an integrated transportation and land use planning can be made satisfying both land use and transportation objectives [26].

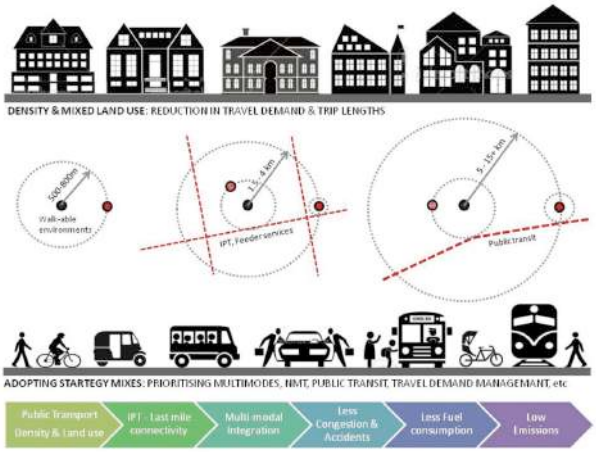

Fig. 10. High density, mixed-use development reduces travel demand. [34]

Land use generates movement and activity. Activity attracts infrastructure investment, public transport and different modes of travel. This consequently increases transportation system, street accessibility. Smart growth development provides many benefits such as reduced automobile travel, reduced traffic accidents, increased walkability, increased cycling activity etc. [26]. The integration of land use and transportation is the intersection of spatial and transportation development [34].

TABLE II. COMPARISON OF COMPONENTS. [SOURCE: AUTHOR]

Components	TOD	New Urbanism	Smart Growth	Compact City	Urban Village
Mixed land use	✔	✔	✔	✔	✔
Public transport	✔	✔	✔	✔	✔
Non motorised Vehicle	✔	✔	✔	✔	✔
Medium density					✔
High density	✔	✔	✔	✔	
Connectivity	✔	✔		✔	
Mixed income development	✔	✔			
Employment	✔		✔		✔
Reduced private vehicle	✔			✔	✔
Reduced parking requirement	✔				
Liveability	✔	✔			
Walkability	✔	✔	✔	✔	
Sustainability		✔	✔	✔	
Traditional Neighbourhood structure		✔			
Urban design		✔			✔
Affordable housing		✔	✔		
Community development			✔	✔	✔
Open spaces/ Public space			✔		✔
Environment			✔	✔	
Cost effective			✔		
Participatory			✔		
Infrastructure			✔	✔	
Energy Performance				✔	
Services				✔	

Table 2 shows the comparison of various components of transit-oriented development, new urbanism, smart growth, compact city and urban village. Mixed land use, high-density development, facilities for non-motorised vehicles, increase in walkability, public transport and community development are the common components. These components promote safe city streets.

XI. CASE STUDIES

A. *Land use planning in Quebec, Canada*

The rate of road accidents has been declined since 2007 in Quebec; this has been due to the commitment of Québec Road Safety Task Force, TQSR. The year 2014 marked the lowest number of road accidents with 336 fatalities, 1570 serious injuries, and 34,300 minor injuries.

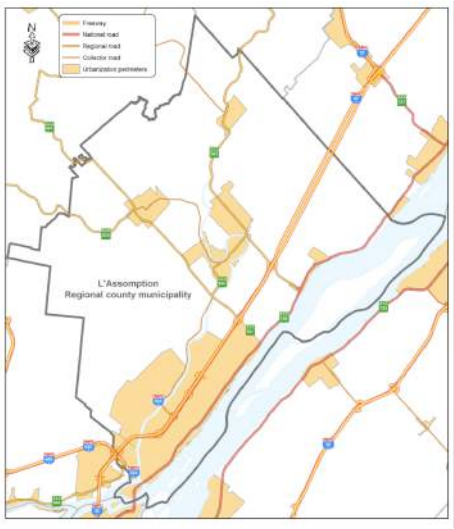

Fig. 11. Urbanisation perimeter. [5]

Land use planning measures in Quebec that promote road safety:

- Delimitation of the urban perimeter. Avoiding linear growth along the road.
- Transportation planning measures such as functional classification of the road.
- Localization of growth areas generating significant movement.
- Provision regarding zoning, sub-division and building.

B. *Curitiba- Greenline*

Curitiba has a well planned and integrated transportation system, which includes dedicated lanes on major streets for a bus rapid transit system [42]. In the mid-1960s, to keep pace with Curitiba's surge in population, traffic congestion, and uncontrolled urban sprawl, the City shifted its urban planning strategy from a radial growth pattern to a linear model with transit-oriented development at its core[43]. This study depicts how TOD enabled Curitiba to reduce downtown traffic congestion and urban sprawl and improve quality of life and access to public space for the residents.

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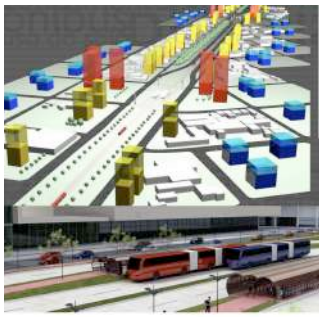

Fig. 12. Green line, Curitiba.

The City's forward-thinking efforts have made Curitiba a global model in low carbon urban development practices. This people-oriented method of urban and transport planning is highly applicable to cities that are increasing in population and have limited financial capital to implement the necessary infrastructure reforms.

XII. Recommendations

A. *Strategies*

Strategies at various levels of planning are required for considering the aspects of road safety that is to be given importance. (Table 3)

B. *Road safety plan*

Road safety team should be formed consisting of members from all discipline such as transportation engineering, architecture, police, medicine etc. This team will be responsible for the development and implementation of the plan. The steps involved are as show in the figure below.

Steps for road safety plan:

1. Establishment of goals and objective.
2. Community participatory approach and involvement of local governing bodies.
3. Data collection- accident data etc.
4. Investigation and identification of hazardous locations and black spots.
5. Special provision for the vulnerable groups and the groups specified in the URDPFI guideline.
6. Identification of project.
7. Economic priorities and prioritisation.
8. Special focus on low cost projects.
9. Project implementation
10. Monitoring.

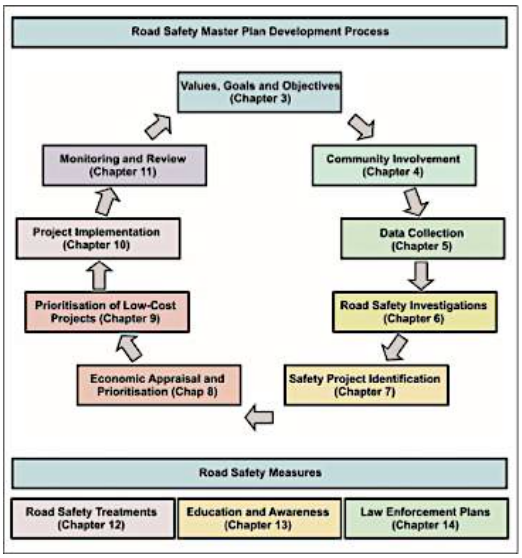

Fig. 13. Steps in a road Safety plan. [25]

TABLE III. Strategies at various stategies for road safety [Source: author]

Micro Approach	Meso Approach	Macro Approach
• Safer vehicles • Road design. • Awareness Programs. • Enforcement of laws • Penalties and punishments. • Education • Encouragement- insurances, incentives. • Treatment and rehabilitation of patients during golden hours. • Reducing personal travel.	• Higher connectivity • Reducing traffic. • Equitable allocation of Road space for vehicles and non motorized vehicles. • Reservation of lanes and corridors. • Safety measures such as- Traffic calming, Skinny roads. • Quality public spaces.	• Integrated land use and transport system. City specific- population, Urban form, economic activity. • Integrated Master plan. • Hierarchy of roads and development. • Zoning regulation. • Inclusive development. • Sustainable development, Sustainable transportation system. • Technical & Institutional measures.

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TABLE IV. PHASE FACTOR MATRIX

Phases		Human/ Host	Injury agent	Environment
PRE CRASH	Crash prevention	Alcohol/drugs, Driving Behavior, Education, Enforcing law, impairment, perception, health, age	Technology of safety measures, Vehicle type, Lighting, Road worthiness, Speed management	Road engineering factors- pavement, grades etc., Traffic engineering factors, Urban form, Land use, Zoning, Inadequate Urban development, Non motorized facility, External factors- weather, temporal variations
CRASH	Injury prevention during the crash	Age, Use of helmet, seat belt etc., Speed,	Speed and direction of impact, Vehicle condition, Occupant restraint, Crashworthiness	Protective road side objects, Warning systems
POST CRASH	Life sustaining	Age, Sex, Pre medical condition, Physical Condition	Ease of access, Fire risk,	Rescue facilities, Access to Emergency facilities, Congestion, Road side factors

XIII. INFERENCE

Various zonal factors such as land use, road network, activity pattern etc. influence the incidence of accidents (Table IV). Their impact various from location to location. At the macro level these factor can be considered in the planning stage. Accidents can be reduced by various strategies, the basic three strategies being exposure control, accident risk control and injury control. Exposure to accident can be reduced at the planning level (Table III).

XIV. CONCLUSION

Road accident is not only a matter of concern in micro level, but also at the meso and macro level. With the increase in private vehicles it is necessary to increase walkability and provide necessary provisions for non-motorised vehicles.

There is a need for:

- A sustainable safety system.
- Discourage ribbon development.
- Mixed land- use.
- Self sustained township
- Development Control regulations.
- Sustainable urban transport.
- Transit oriented development.

To keep improving the road record, innovative actions are required and land use planning measures are part of it. Legal framework for controlling ribbon development Coordination between various stakeholders. Proper enforcement of city master plan. Acquire extra land for fulfillment of the future requirement.

It is necessary to understand the safety issues of street networks. It helps us design the street network. Street networks influence speed control, traffic distribution, distance travelled and modes of transport. Speed control can reduce the severity of the accident. Traffic distribution and modes of travel can reduce road capacity.

The important characteristics of street design in safety are-

1. Functional connection within the neighborhood.
2. Urban grain and density.

Street network should be such that it should promote active transportation, reduce the distance travelled and create a sense of place.

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REFERENCES

[1] Ideacollector. Street Network Types and Road Safety [Internet]. Idea Collector. 2016 [cited 2019Dec20]. Available from: https://notes.devonzuegel.com/post/147206109183/street-network-types-and-road-safety

[2] Street Network Types [Internet]. The Geography of Transport Systems. 2019 [cited 2019Nov27]. Available from: https://transportgeography.org/?page_id=4725

[3] Shahid S, Minhans A, Puan OC, Hasan SA, Ismail T. Spatial And Temporal Pattern Of Road Accidents And Casualties In Peninsular Malaysia. Jurnal Teknologi. 2015;76(14).

[4] Peden MM. World report on road traffic injury prevention. Geneva: World Health Organization; 2004.

[5] Berthod C. Land Use Planning Measures Promoting Road Safety. Land Use Planning Measures Promoting Road Safety.

[6] Park Y, Rogers GO. Neighborhood Planning Theory, Guidelines, and Research. Journal of Planning Literature. 2014Sep;30(1):18–36.

[7] Zhang Y, Bigham J, Ragland D, Chen X. Investigating the associations between road network structure and non-motorist accidents. Journal of Transport Geography. 2015;42:34–47.

[8] Komba DD. Risk Factors and Road Traffic Accidents in Tanzania: A Case Study of Kibaha District. Risk Factors and Road Traffic Accidents in Tanzania: A Case Study of Kibaha District. 2006May;

[9] Cutter SL. Living with risk: the geography of technological hazards. London: Arnold; 1993.

[10] Kadiyali LR. Traffic engineering and transport planning. Delhi, India: Khanna Publishers; 2000.

[11] Srinivasan NS. Accident risk prevention. NATPAC; 1987.

[12] Causes of Road Accidents: Transport Department, Government of Jharkhand [Internet]. Causes of Road Accidents | Transport Department, Government of Jharkhand. [cited 2019Nov27]. Available from: http://jhtransport.gov.in/causes-of-road-accidents.html

[13] Draft Road Safety Vision- Kerala. Draft Road Safety Vision- Kerala NATPAC;

[14] The influence of Urban planning on Road safety. The influence of Urban planning on Road safety [Internet]. 2015Nov5 [cited 2019Sep1]; Available from: https://www.researchgate.net/publication/283498133_the_influence_of_urban_planning_on_road_safety

[15] Cinquina A. [Sweden]: international Masters Program in Environmental Studies and Sustainability Sciences LUMES 2006/08; 2008.

[16] Singh R, Ghate AT, Singh S. Development of Toolkit under "Sustainable Urban Transport Project." Development of Toolkit under "Sustainable Urban Transport Project" India: Government of India; 2013.

[17] Millot M. Urban growth, travel practices and evolution of road safety. Journal of Transport Geography. 2004;12(3):207–18.

[18] Puntambekar K. Travel behaviour studies facilitate integration of land use and transport planning. Urban Transport XVII. 2011Jun;

[19] Montella A, Marzano V, Mauriello F, Vitillo R, Fasanelli R, Pernetti M, et al. Development of Macro-Level Safety Performance Functions in the City of Naples. Sustainability. 2019;11(7).

[20] Galiano JCS, Blanco JC, Aracil PF, Padilla AO. A Case Study Of Identify Importance Of Land Use Planning In Road Safety, Benidorm. Libro de Actas CIT2016 XII Congreso de Ingeniería del Transporte. 2016July;

[21] Dieleman F, Wegener M. Compact City and Urban Sprawl. Built Environment. 2004Jan;30(4):308–23.

[22] Dylan-Lane. Growth of Towns [Internet]. SlideServe. 2014 [cited 2019Oct27]. Available from: https://www.slideserve.com/dylan-lane/growth-of-towns

[23] Pedestrian Bridges Make Cities Less Walkable. Why Do Cities Keep Building Them? [Internet]. Institute for Transportation and Development Policy. 2019 [cited 2020Jan27]. Available from: https://www.itdp.org/2019/10/01/pedestrian-bridges-make-cities-less-walkable-why-do-cities-keep-building-them/)

[24] Miftah AZ, Hesti CK, Sunarwibowo A, Khairani AF, Bandung UM. Youth Travel behaviour and road safety in bandung municipality: a preliminary study. 2nd conference of asean Road Safety 2018.

[25] Diedericks DR, Joubert JW. Towards transportation system integration in the City of Tshwane Metropolitan Municipality. Urban Transport XII: Urban Transport and the Environment in the 21st Century. 2006;

[26] Litman TA. Economic Value of Walkability. Transportation Research Record: Journal of the Transportation Research Board. 2003;1828(1):3–11.

[27] Headicar P. The Contribution of Land Use Planning to Reducing Traffic Growth: the English Experience. EJTIR. 2004Jan;:137–51.

[28] Street Design Guidelines "…for Equitable Distribution of Road Space" - NUTP. Street Design Guidelines "…for Equitable Distribution of Road Space" - NUTP UTTIPEC;

[29] Dumbaugh E, Rae R. Safe Urban Form: Revisiting the Relationship Between Community Design and Traffic Safety. Journal of the American Planning Association. 2009;75(3):309–29.

[30] Ewing R, Cervero R. Travel and the Built Environment: A Synthesis. Transportation Research Record: Journal of the Transportation Research Board. 2001;1780(1):87–114.

[31] Review of road safety in urban areas - World Bank [Internet]. [cited 2019Nov7]. Available from: http://siteresources.worldbank.org/Inturbantransport/Resources/urban_safety_trl_rs_2.pdf

[32] Arefin S. Prohibit ribbon development [Internet]. The Daily Star. 2015 [cited 2019Nov7]. Available from: https://www.thedailystar.net/prohibit-ribbon-development-22007

[33] 99acres.com. [cited 2019Oct17]. Available from: https://www.99acres.com/articles/how-do-we-control-ribbon-development.html

[34] Land Use Planning and Urban Transport - SUTP [Internet]. 2013 [cited 2019Oct12]. Available from: https://www.sutp.org/files/contents/documents/resources/A_Sourcebook/SB2_Land-Use-Planning-and-Demand-Management/GIZ_SUTP_SB2a-Land-use-Planning-and-Urban-Transport_EN.pdf

[35] Motorized Passenger Travel in Urban India [Internet]. 2009 [cited 2019Sep10]. Available from: http://www.indiaenvironmentportal.org.in/files/Air-Emissions-20-Indian-Cities.pdf

[36] Alqhatani M, Setunge S, Mirodpour S. Can a polycentric structure affect travel behaviour? A comparison of Melbourne, Australia and Riyadh, Saudi Arabia. Journal of Modern Transportation [Internet]. 2014Jul [cited 2019Dec2];22(3):156–66. Available from: https://link.springer.com/article/10.1007/s40534-014-0054-y

[37] Ministry of Urban development. Annual report 2013-2014. Ministry of Urban development;

[38] Lovegrove, Richard G, James. Using Community-Based Macrolevel Collision Prediction Models to Evaluate Safety Level of Neighborhood Road Network Patterns [Internet]. TRID. 2009 [cited 2019Sep12]. Available from: https://trid.trb.org/view/909518

[39] Sun J. Sustainable road safety: development, transference and application of community-based macro-level collision prediction models [Internet]. Sustainable road safety: development, transference and application of community-based macro-level collision prediction models. The University of British Columbia; 2009 [cited 2019Oct8]. Available from: https://open.library.ubc.ca/cIRcle/collections/ubctheses/24/items/1.0063125

[40] Praja. Bangalore and Ribbon Development [Internet]. Praja. 2008 [cited 2019Nov12]. Available from: http://praja.in/en/gyan/bangalore-and-ribbon-development

[41] Puntambekar K. Travel behaviour studies facilitate integration of land use and transport planning. Urban Transport XVII [Internet]. 2011Jun [cited 2019Oct12]; Available from: https://www.witpress.com/Secure/elibrary/papers/UT11/UT11028FU1.pdf

[42] Curitiba's Bus System [Internet]. Brazilian Experience. 2019 [cited 2019Oct9]. Available from: https://brazilianexperience.com/curitibas-bus-system-2/

[43] ICLEI. A model for Transit Oriented Development: Curitiba, Brazil [Internet]. GPSC. 2019 [cited 2019Nov12]. Available from: https://www.thegpsc.org/knowledge-products/transit-oriented-development/model-transit-oriented-development-curitiba-brazil

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Maintenance Management Plan for the Agraharams of Valiyasala, Thiruvananthapuram

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***Abstract*— Agraharams are an excellent example of row housing in a limited space. They share common walls and are a unique example of community living. The agraharams of Valiyasala, Thiruvananthapuram are the longest of its kind in the country. They are transforming continuously due to factors like out migration, population growth, and mainly lack of awareness and lack of proper management. Due of lack of awareness about the importance of the heritage, attempts are not made to care and maintain these historic structures as required. Old materials are being replaced by new, which totally disregard the historic character of the area. There is an urgent need for the preparation of a maintenance management plan for these agraharams, which can be used by the house owners as well as other stakeholders for periodic maintenance of these agraharams.**

A maintenance manual has been prepared for the house owners of the agraharams. The study concludes with an inspection checklist for routine and periodical maintenance of the agraharams. Finally, a maintenance log is prepared to keep track of each maintenance activity carried out.

Keywords—agraharam; community; maintenance; heritage; inspection

I. INTRODUCTION

A. General introduction

The agraharams of Kerala were Tamil and Tulu Brahmin settlements comprising two rows of houses running north-south on either side of a road, with a Shiva temple at one end and a Vishnu temple at the other. The concept of agraharams and living together with shared walls contrasted with the settlement patterns of Kerala dwellings. Agraharams are also found in other parts of south India such as Andhra Pradesh, Karnataka and Tamil Nadu. Essentially a cluster of simple homesteads built in a row, the agraharams represent the values of community living and shared space. The street in front of these homes transformed into an active community space serving as a play area for children, a meeting place for elders, a commercial space for vendors, venues for religious processions and meetings, etc. The closely built structures also helped in offering a high degree of security and facilitated community interaction.

These agraharams which had much relevance in the history of Kerala are now becoming endangered and losing their cultural identity because of issues like out migration, population growth, lack of protection and management, etc.

All building materials decay eventually due to exposure to sunlight, rain and wind, and therefore require continued attention to be maintained. Modest spending on regular maintenance can reduce the need for costly repairs, protect the historic fabric of the building and save money in the long term.

Routine, cyclical, non-destructive actions are necessary to slow down the deterioration of a historic place. It consists of periodic inspection; routine, cyclical and, non-destructive cleaning; minor repair and refinishing works; replacement of damaged or deteriorated materials that are not possible to save.

William Morris, founder of the Society for the Protection of Ancient Buildings (SPAB), had specifically identified maintenance as a method of retaining the value embodied in the historic fabric, stating "stave off decay by daily care"[1]. Almost a century and a half later, maintenance is still accepted as the most sustainable and suitable way to conserve buildings[2]

Maintenance is defined by the Burra Charter as the continuous protective care of the fabric, contents and setting of a place. Internationally the importance of building maintenance is well recognized and has been embedded into principal building conservation legislative frameworks and charters. The Venice Charter states: "It is essential to the conservation of monuments that they be maintained on a permanent basis"[3]. The Burra Charter clearly concurs with this stating that, maintenance "is fundamental to conservation and should be undertaken where fabric is of cultural significance and its maintenance is necessary to retain that cultural significance".

[1] Society for the Protection of Ancient Buildings, 2008, p. 1
[2] Dann and Cantell, 2007, p. 185
[3] International Council on Monuments and Sites, 1964, p. 1

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B. Rationale for selection

The agraharams at Valiyasala, Thiruvananthapuram, are the longest of its kind in the country, extending from the Chenthitta Devi Temple on the east to the Kandalur Mahadeva Temple on the west. The settlement came up near the Killi river which was one of the major sources of water for the Thiruvananthapuram city, and at the site which housed the ancient university Kandalur Salai popularly known as the 'Nalanda of the South'. The community living is seen evidently even now, though inhabitants have started migrating out, either leaving their homes abandoned or selling it to other communities.

There is an urgent need for the maintenance of these historic structures. Due to lack of awareness, this historic fabric is being changed constantly and in a rapid rate. Old materials such as the roof, openings, etc. are being replaced with new ones which do not respect the historic fabric. Some other structures are being demolished and new structures come up in their places.

C. Aim

To prepare a maintenance management plan for the historic agraharams of Valiyasala, Thiruvananthapuram.

D. Objectives

i) To understand the concept of maintenance in historic buildings

ii) To study the different types of maintenance that needs to be carried out in historic buildings

iii) To identify parameters for the preparation of a maintenance manual and a maintenance log

iv) To carry out case studies and their comparative analysis to understand how maintenance has been carried out in other historic residential buildings

v) To assess the condition of the agraharams of Valiyasala element-wise and suggest solutions for their maintenance

vi) To prepare inspection checklists for routine and periodic maintenance of the agraharams

vii) To prepare a maintenance log for keeping track of the activities of maintenance of the agraharams

E. Scope of work

The scope of this paper has been limited to the preparation of a maintenance management plan for the agraharams of Valiyasala, Thiruvananthapuram.

II. MAINTENANCE MANAGEMENT PLAN: AGRAHARAMS OF VALIYASALA, THIRUVANANTHAPURAM

A. Introduction

1) General history and significance

The agraharams were built by the Travancore king Maharaja Marthanda Varma in the 18th century for the Tamil Brahmins brought from Tirunelveli, for carrying out temple rituals, administration work and educating his people. The site once housed the ancient university, Kandalur Sala which was known as the Nalanda of the south.

2) Ownership of the agraharams

These agraharams used to be a close-knit community consisting of only Tamil Brahmins. Now out migration is becoming common due to changing lifestyles, hence houses are being rented to people from other communities also. The present ownership consists of private and rented houses.

B. Description

1) Location

It is located by the banks of the Killi river, which was one of the major sources of water for the area. The agraharams at Valiyasala are the longest of its kind in the country extending from the Chenthitta Devi Temple in the east to the Kandalur Mahadeva Temple in the west. It is located 1.5km from the Padmanabha Swamy Temple.

Satellite image of Valiyasala

C. Architecture and materials

The agraharams were simple row houses on either side of the road, with shared walls. The concept of the architecture of the agraharams was simplicity. The major open space for the community was the street. The agraharams differed in their widths depending on the economic and social status of the Brahmins. Natural light and ventilation entered through semi-open spaces such as the *thinna* (verandah) and the *anganam* (courtyard).

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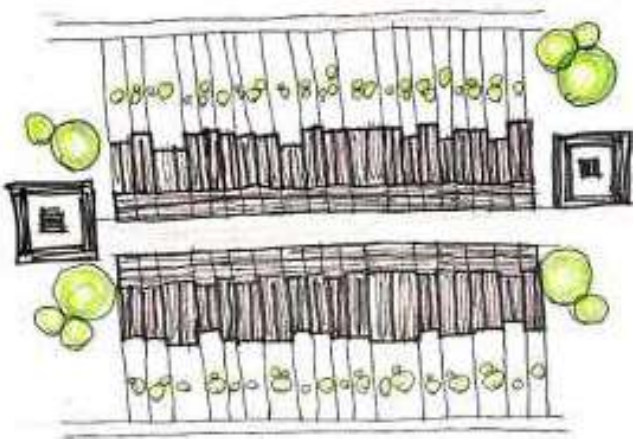
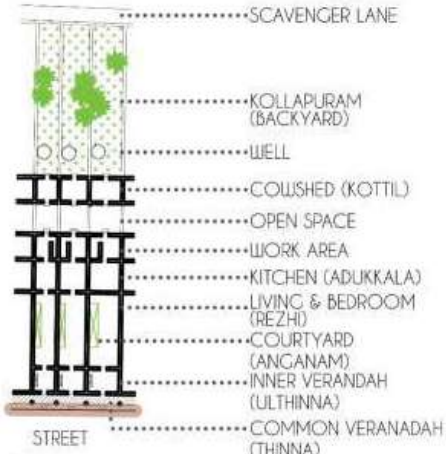


An agraharam 'gramam'



Planning of an agraharam

D. Construction

Roof: Mangalore tiles. Renovations are done using asbestos sheet.

Roof structural members: Wood

Walls: *Cheekal* (local laterite) with lime mortar. New constructions are using bricks with cement mortar.

Columns: Granite or wood were used, and most of them still remain in a good condition.

Floors: Red oxide or mud for ground floor and wood for first floor.

Doors and windows: wood

E. Services

Electricity, water supply, drainage and waste management.

F. Photographs

Aerial view of Valiyasala agraharams

Valiyasala Agraharam street

Chinnasala Agraharam street

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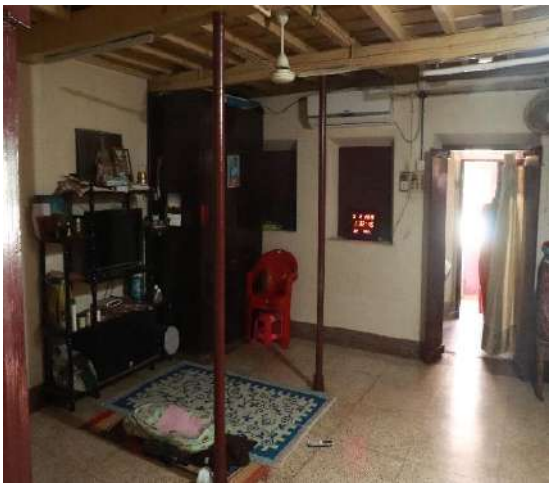
a. Past interventions

Addition of shops by taking up the front rooms

Addition of car porch by taking up the front rooms



Covering up of courtyard for more space inside

Thinna of houses covered

Mangalore tiles replaced by asbestos sheet

Changing of flooring materials

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b. Major issues seen

Roof:

Tile which came off

Broken tiles replaced by sheet

Weathering of tiles

Solutions

-Removal and cleaning of tiles

-Resetting of tiles

-Add glass tiles in between for letting in more natural light

-Replace with new tiles where they are missing or broken

Timber roof frame*:*

Insect attack

Solutions

For heavily affected areas in the wooden roof members:

-Removal of purlins

-Removal and replacement of deteriorated rafters with aanjili wood– Artocarpus hirsutus

-Replacement of deteriorated purlins with new wood (aanjili – Artocarpus hirsutus) as per original design

-Relaying purlins in good condition

-Termite treatment: mixture of terminator and clear base coat helps in termite, insect and fungal attack

Insect attack

Solutions

For wooden false ceiling, the same method as above is applicable depending on the intensity of the decay of wood.

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Termite attack

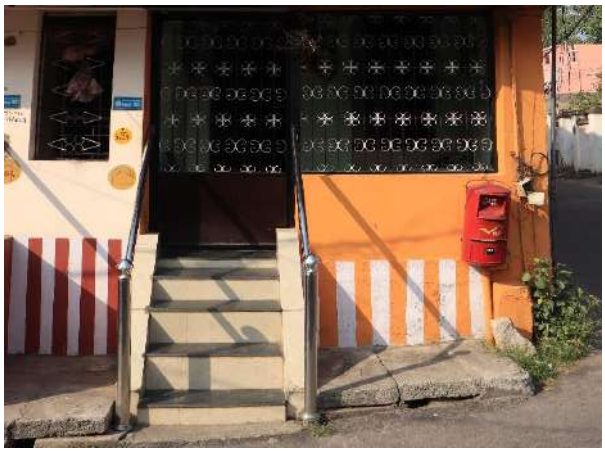
False ceiling coming off

Cob webs on wooden members

Solutions

-Cleaning of cobwebs and spraying or injection of a mixture of terminator and clear base coat which helps in termite, insect and fungal attack

External walls:



Exterior walls painted with bright colours

Blackening of surface

Solutions

-Scraping and cleaning of blackened surfaces

-Repainting bright colours with subtle colours

-Repainting plinth with alternative bands of ochre and white like the traditional design

Internal walls:

Patchwork with cement plaster

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Solutions

-Removal of cement patchwork and examination of crack

-Removal of plaster

-Stitching of crack and pointing with lime mortar

-Replastering with lime

Fallen plaster

Crack on the wall

Solutions

-Examination of the crack

-Stitching of crack

-Replastering with lime

Flooring:

Tiles coming off

Crack on the floor

Solutions

-Removal of the tiles carefully and examination of the base slab

-Repair of the base slab

-Relaying of tiles

-If the tiles are too damaged, replace them with new ones of same material

-Examination of cracks in consultation with a structural engineer

-Grouting using lime mortar is the general practice, though it may vary with the intensity and type of crack

c. Dealing with dampness

The first action should be a careful analysis of where the water is coming from. In cases of severe rising damp, the installation of a new DPC may be considered necessary. The installation involves carefully slicing through the external

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wall in short lengths and inserting the new impervious layer. Alternatively, it can be done by the removal of a full course of brick or stone and its replacement with, say, a dense engineering brick.

Check the roofs regularly for any wet timber member or any signs of water coming in, and treat them immediately.

d. Routine and periodical maintenance

Element/component - Mangalore tiles
Planned repair and maintenance work - Damaged, broken and excessively stained tiles with algal growth to be replaced. Water leakage through roof suggests for the replacement of roof.
Frequency of maintenance- annually/biennially

Element/component - **Wooden roof members**
Planned repair and maintenance work - Structurally unstable members and members with issues such as rots, splits, cracks, etc. need to be repaired or replaced with the same type of wood. Fire retardant and anti-termite coatings should be applied.
Frequency of maintenance- annually/biennially

Element/component - **Walls (brick and laterite)**
Planned repair and maintenance work - Lime plastering and painting. Cracks and missing masonry need to be filled and pointed with lime mortar.
Frequency of maintenance- annually/biennially

Element/component - **Columns (wooden) -**
Planned repair and maintenance work - Timber defects such as rots, splits and cracks need to be detected. Damaged ones to be replaced with new similar ones whenever required. Fire retardant and anti-termite coatings should be applied.
Frequency of maintenance- annually/biennially

Element/component - **Beams (wooden)**
Planned repair and maintenance work - Damaged members to be repaired. Decayed members to be replaced with similar wood. Fire retardant and anti-termite coatings should be applied.
Frequency of maintenance- annually/biennially

Element/component - **Floor (wooden)**
Planned repair and maintenance work - Excessively damaged timber planks with splits which compromise structural strength to be repaired or replaced with similar timber. Fire retardant and anti-termite coatings should be applied.
Frequency of maintenance- annually/biennially

Element/component - **Floor (cement)**
Planned repair and maintenance work - Filling of cracks and grouting wherever necessary.
Frequency of maintenance- annually/biennially

Element/component - **Floor (terracotta tiles)**
Planned repair and maintenance work - Filling of cracks and grouting wherever necessary.
Frequency of maintenance- annually/biennially

Element/component - **Doors and windows (wooden)**
Planned repair and maintenance work - Damaged members should be repaired. Only excessively damaged frames and shutters should be replaced - with similar wood. Fire retardant and anti-termite coatings should be applied.
Frequency of maintenance- annually/biennially

Element/component - **Steps and rails (wooden)**
Planned repair and maintenance work - Damaged members to be repaired. The ones which cannot be repaired have to be replaced with similar wooden members.
Frequency of maintenance- annually/biennially

Element/component - **Services**
Planned repair and maintenance work - Frequently the services including the electrical lines, electrical appliances including bulbs, tube lights, etc. need to be checked and replaced if not working. Check lavatories and report dripping or leaking taps.
Frequency of maintenance- weekly/monthly

e. Housekeeping

Component - Internal surface finishes
Daily/weekly - Floors should be swept with broom daily. They should be cleaned with damp cloth twice a week.
Monthly - Wall surfaces should be cleaned of cob webs or smoke stains. Any edge damages should be examined and rectified immediately.
Biannually/annually - Ceilings should be cleaned of cob webs and smoke stains. Ceilings should be examined for any damages or leaks annually or biannually based on requirement.

Component - External surface finishes
Daily/weekly - Check for any damp patches or seepage on the walls. Try to identify the source of the problem. Check for moss, lichen or algae growing on the exterior walls. Scrape off moss and algae growth and apply ammonia solution.
Monthly - Wall surfaces should be cleaned of any blackening or other stains. Chemicals should not be used unless necessary.
Biannually/annually - Roof needs cleaning once a year. Mangalore tiles which are broken should be replaced. Water outlets should be cleaned to avoid any clogging. Clean all gutters, downpipes and rainwater drains.
Ceiling and attic spaces need to be cleaned and examined for any rodents or insects, and dampness.

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Cleaning: hand-scrubbing with a soft brush and washing with water and using a mild detergent is the simplest and the most effective method.

f. Important Guidelines

Professional opinion - The annual inspection shall be headed by a conservation architect. Before carrying out corrective and emergency maintenance works, it is advisable to seek advice from a conservation architect and/or a structural engineer trained in heritage conservation regarding the actions to be carried out.

Hiring skilled labourers - For any maintenance work, it is advisable to hire a skilled labourer (carpenter, craftsman, etc.) of the particular field as per the advice from the conservation architect and/or structural engineer.

Incentives - Monetary incentives shall be provided to the house-owners by the State Government, for periodical maintenance of the heritage houses.

Safe and suitable repair - All works carried out should be done safely with all necessary precautions, i.e., using required equipment, ladders, etc. should be used wherever and whenever necessary.

Safe access to roof - Access to roof and ceilings of each floor should be done carefully using suitable equipment like ladders.

Maintenance - All maintenance works should be undertaken periodically as per the maintenance manual, and should be as per the specifications.

Maintenance log - A maintenance log should be maintained, which has to be regularly updated. It has to be checked before carrying out each maintenance. The log book should contain a checklist of various works to be done regularly or periodically.

g. Emergency maintenance/ safety measures

Emergency contacts:
Fire-fighting
Electrician
Plumber
Carpenter
Conservation architect
Structural engineer

List of contractors and suppliers

h. Maintenance Checklist for Agraharams

Roof:
1. Check for loose/missing tiles
2. Check for moss growth
3. Check for changes in pitch if there are falling materials or gaps
4. Check the end of rafters, purlins and battens for insect nesting
5. Inspect where the roof meets the walls, for cracks
6. Inspect for water damage in rafters and purlins
7. Look for defects in slope

False ceiling:
1. Check if there is any hollow sound
2. Inspect for any form of water damage
3. Check for any kind of insect attack

Walls:
1. Is the wall leaning/bulging?
2. Check for any creeper/moss growth
3. Check for any bird droppings
4. Masonry walls – check for cracks, gaps or holes
5. Masonry walls – check if the mortar is loose or easily scrapes out
6. Masonry walls – check if there is any presence of efflorescence.

Verandah/Thinna:
1. Check if the roof has detached from the main building.
2. Check for water penetration

Windows:
1. Check window sills for signs of softness
2. Check the connection of the wooden frame with the masonry – for openings (should be sealed)
3. Check if windows have sagged or shifted.
4. Check frames for insect attacks
5. Check for cracks/holes in window panes

Doors:
1. Doors should be painted/polished on all sides to prevent moisture from entering
2. Hinges should be checked periodically for tightness
3. Check for misalignment – sagging/shifting

Steps and rails:
1. Check wooden steps for moisture
2. Check for insect attack
3. Check periodically to ensure treads are securely screwed in place
4. Wooden rails and steps are subject to rot - paint/polish to prevent this

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Floor:

1. Check for water damage
2. Check for any cracks/holes
3. Check if any tiles are coming out

Foundation:

Check for visible cracks from walls/columns

Site:

1. Are dark corners of the site illuminated at night?
2. Could someone gain access to the roof/upper floor window?
3. Are there any flammable items visible on site?
4. Is there any accumulation/debris in the site?

A copy of this manual shall be provided for each residence (both in English and Malayalam). The residents shall refer to this manual for carrying out their maintenance activities.

i. Maintenance log

MAINTENANCE LOG – AGRAHARAMS OF VALIYASALA					
Date	Contractor information	Work performed	Weather conditions	Problems or complications	Supervisor's signature

j. List of stakeholders responsible in carrying out the maintenance programme

1. **Conservation architect**
   He shall lead the inspections annually, and whenever otherwise necessary. He shall give suggestions for carrying out various maintenance and repair of historic building materials.

2. **Architect**
   The architect shall assist the conservation architect in his activities.

3. **Structural engineer**
   He shall inspect structural problems of the agraharams and take decisions along with the conservation architect on how to carry out the maintenance and repair activities.

4. **Representative(s) from the 'gramam' residents association**
   He shall carry out house-to-house visit at regular intervals to make sure that necessary maintenance activities are carried out. He shall also ensure the adequate supply of materials for the programme. He shall make sure that all other stakeholders are readily available whenever required.

5. **Labourers**
   Local craftsmen, carpenters, plumbers, electrician, etc.

F. REFERENCES

[1] Alan M. Forster, Brit Kayan. 2009. "Maintenance for Historic Buildings: A Current Perspective." *Emerald Insight* 27 (3): 210-229.

[2] Anne E. Grimmer, Paul K. Williams. n.d. *30. The Preservation and Repair of Historic Clay Tile Roofs.* Preservation Brief, U.S.: National Parks Service.

[3] Architects, Humphries Poli. 2006. "Preservation Maintenance: A Universal Manual for Developing Conservation Maintenance Plans." Denver.

[4] Chambers, J. Henry. 1976. *Cyclic Maintenance for Historic Buildings.* Washington D. C.: Office of Archeology and Historic Preservation, National Park Service.

[5] Department, Central Public Works. 2000. *Maintenance Manual*. New Delhi: Government of India.

[6] 2011. "English Heritage: Vacant Historic Buildings - An Owner's Guide to Temporary Uses, Maintenance and Mothballing." London.

[7] Fielden, Bernard M. 1982. *Conservation of Historic Buildings.* Great Britain: Butterworth Heinemann.

[8] Frederick J Rushlow, Don Kermath. 1994. *Proactive Maintenance Planning for Historic Buildings.* Champaign: US Army Corps of Engineers.

[9] Hutsebaut-Buysse, Véronique. 2016. "Maintenance in Historic Buildings in Belgium and Portugal." Dissertation to obtain Master Science Degree in Civil Engineering.

[10] Inc., Heritage Consulting. 2011. "Cyclical Maintenance Manual for Historic Bartram's Garden ." Philadelphia.

[11] INTACH. 2018. *Conservation of Heritage Buildings in Shahjahanabad: Manual for Homeowners.* Edited by INTACH Delhi. New Delhi: Shahjahanabad Redevelopment Corporation (SRDC).

[12] Kuriakose, Benny. 2007. *Conservation Briefs - Conserving Timber Structures in India.* New Delhi: INTACH.

[13] 2017. *Looking after Historic Buildings: An Owner's Guide to Maintenance*. Wrexham: Environment & Planning Department, Wrexham County Borough Council.

[14] Loveland, Barry. 2016. *Operations and Maintenance for Historic Structures.* Pennsylvania: Pennsylvania Historical & Museum Commission.

[15] 2007. *Maintenance: A Guide to the Care of Older Buildings.* Dublin: Government of Ireland.

ISBN 978-93-89105-41-4

[16] Myers, John H. n.d. *9. The Repair of Historic Wooden Windows.* Preservation Brief, U.S.: National Parks Service.

[17] Office, NSW Heritage. 2004. "Preparing a Maintenanc Plan."

[18] 1999. *Principles for the Preservation of Historic Timber Structures.* Mexico: International Council on Monuments and Sites.

[19] R. Abdul Rashid, A.G. Ahmad. 2011. *Overview of Maintenance Approaches of Historical Buildings in Kuala Lumpur – A Current Practice.* Penang, Malaysia: Elsevier Ltd.

[20] Robert C. Mack, FAIA, John P. Speweik. n.d. *2. Repointing Mortar Joints in Historic Masonry Buildings.* U.S.: National Parks Service.

[21] Seong Yeow Tana, Abdullateef Olanrewaju and Lim Tat Lee. 2016. "Maintenance of Heritage Building: A Case Study from Ipoh, Malaysia." Malaysia.

[22] Sharon C. Park, FAIA. n.d. *Maintaining the Exterior of Small and Medium Size Historic Buildings.* U.S.: National Parks Service.

[23] Sweetser, Sarah M. n.d. *Roofing for Historic Buildings.* Preservation Brief, U.S.: National Parks Service.

[24] Tan, Seong Yeow. 2016. *Maintenance of Heritage Building: A Case Study from Ipoh, Malaysia*. Malaysia: ResearchGate.

[25] Trust, New Zealand Historic Places. 2007. "Sustainable Management of Historic Heritage Guidance." New Zealand.

[26] Zul-Atfi Ismail, Narimah Kasim. 2013. "Maintenance Management Practices For Building Facility: A Case Study." *International Journal of Engineering Research and Applications (IJERA)* 3 (4): 487-497

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An Assessment of Vulnerability of Fishermen Settlements to Coastal hazards in Kerala

— A case of Kollam District

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Abstract*— *Natural Disasters are often unpredictable, but if we are able to identify the vulnerable area or vulnerable group of people, we could adopt suitable mitigation measures. Even at the global level we could find that the fishermen communities are more vulnerable to natural hazards.

The coastal region of Kerala State is susceptible to multiple hazards like tsunami, cyclone, floods, sea erosion etc. Coastal region are thickly populated with predominantly Fisherfolk, who are thus inturn, highly vulnerable to coastal hazards.

Several packages have been introduced both at the national and state level to alleviate their vulnerability to natural calamities. But they had proved to be inadequate to fishermen community. Only by proper vulnerability assessment, suitable mitigation measures could be adopted to increase the capacity of fisherfolk and thereby reduce the vulnerability. Through this study an assessment of vulnerability of fisherfolk is carried out inorder to identify the current risk factors and propose the remedial measures for the same.

Keywords— ***Coastal hazard; Vulnerability; Fishermen Community; Capacity Building***

I. INTRODUCTION

Socio economic conditions of developing countries are affected by the disaster risks that are accumulating on a daily basis due to lack of proper mitigation measures. This unmitigated growth of risk could be curtailed only by proper understanding of the three major components of risk that comprises of hazards, vulnerability and exposure. We need to understand how these components interact with each other and result in increase of total risk and even continue to trigger more severe losses. Under many circumstances it is found that economic growth alone does not reduce vulnerability but even creates more exposure to different types of risks

At the global level, 36 million fishers depends on fishery sector for their livelihood.(Koya et al.,2017). India is the second largest producer of fish and is contributing about 5.43% of global fish production and ranks second in aquaculture, thus providing livelihood to 14 million people in the country (Das et al., 2014)

This paper throws light into how the vulnerability of inhabitants in coastal regions especially the fisher community in Kerala state, had increased over the past decades. It also gives suitable mitigation measures that could be adopted to reduce the vulnerability and exposure of fisher community to coastal hazards.

Two methods that are employed in this paper are : (i) Vulnerability Assessment and (ii) Post Occupancy Evaluation.

Vulnerability assessment had been done by delineating an area that faces physical, social and economic vulnerability. Maps had been prepared based on Google earth and Arc GIS software. Post Occupancy evaluation had been done by a reconnaissance survey conducted in the delineated study area.

Study area delineated was Alappad Panchayat in Kollam District which is facing many issues such as environmental issues, housing issues, infrastructure issues and socio-economic issues.

Fig. 1. Location map of Alappad panchayat in Kollam district *(Source:Kollam District Disaster Management Plan,2015)*

II. SECONDARY STUDY

A natural hazard turns into disaster when it affects densely populated area and it is beyond the coping capacity of the inhabitants as they need external support for their recovery. Scale of disaster varies according to the resource availability and capacity of the affected people. Hazard is a process, phenomenon or human activity that may cause loss of

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life, health impacts, property damage, social and economic disruption or environmental degradation (UNISDR,2009).Hazard ranges from slow onset hazards like drought, famine, pollution, health hazards etc. to rapid onset hazards like flashflood, fire, cyclone, tsunami etc. The strategy to be adopted, response to be taken and planning intervention to be made varies for each hazard.

According to Wen-Ching Wang, 2018, five types of hazards are categorized based on following characteristics:

a)Climate disasters- Chilling, Drought

b) Meteorological disasters- cyclone, heavy rain

c) Geological disasters- Earthquake, Debris (Sediment Disasters), landslide, Tsunami

d) Ecological disasters- Fire, Forest fire, Toxic chemical substance, Biological pathogen hazard, Industrial pipeline disasters

e) Hydrological disasters-Drought, Flood

A. Vulnerability to Hazards

Vulnerability is the tendency to get damaged by the hazards. It is the conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to impacts of hazards. (UNISDR,2009) Vulnerability can be broadly classified into physical, social, economic, attitudinal and environmental vulnerability (UNISDR,2017).

B. Types of vulnerability

1) Attitudinal Vulnerability- An individual or community who are reluctant to change and does not take any initiatives to adapt themselves to the change. They become more dependent on the external support system. Their behavioural pattern needs to change to respond to the situation.

2) Environmental vulnerability – Mainly due to fragile ecosystem, decline of risk regulating ecosystem services like mangrove forests, obstruction or destruction of natural drainage system, climate change resulting from human activities, poor environmental management, overconsumption of resources etc.

3) Economical Vulnerability – Vulnerable rural livelihoods are usually dependent on ecosensitive ecological zones like the fisherfolk on Coastal areas, tribals on hilly region, farmers on backwaters etc. Dependence on uninsured informal sector like chit fund, blade bankers etc. would also affect their financial status. Over dependence on single industries, lack of skill for alternative gainful employment, globalization of business and supply chains etc. leads to survival of the fittest.

4) Physical Vulnerability- it may result due to faulty construction of building or its infrastructure, poor design considerations and neglect of proper maintenance of structures. This can happen due to unregulated landuse planning practises.

5) Political vulnerability – Minority group are more vulnerable due to political marginalization. Lack of political will power to initiate adequate response mechanism and recovery measures results in increase of vulnerability. Bribery and corruption also adds on to this issue.

6) Social vulnerability- poverty, inequality, gender disparity in addition to social exclusion and discrimination based on caste, creed, religion etc. result in increase of social vulnerability.

7) Housing vulnerability – location of building with respect to the vulnerable area, age of the structure, proximity to source of hazard, housing type, housing conditions, source of finance, extend of damage of building or infrastructure by previous hazard etc. are factors that determine housing vulnerability.

C. Vulnerability Assessment

Vulnerability Assessmemt is an estimate of degree of loss or damage that could result from a hazardous event of given severity, including damage of structures, personal injuries and interruption of economic activities.(Greeshma Mohan,2014).Assessment of Vulnerability is done mostly on the basis of Vulnerability indices. Vulnerability indices are developed as a rapid and consistent method for categorizing relative vulnerability of different coasts. Simplest type of assessment is the assessment of Physical Vulnerability of the coast. More complex type is to examine various aspects of Social and Economic Vulnerability. Coastal Vulnerability Index(CVI) helps to identify high, medium and low vulnerable areas

D. Post Occupancy Evaluation

Post Occupancy evaluation helps to understand current status and long term impacts of projects.POE is systematic collection and evaluation of information about the performance of buildings in use. POE survey data gives the intention of designer/ planner, occupant comfort, residential satisfaction, management etc. It also helps to identify ways to improve housing layout, building design, performance and suitability to serve the purpose.

E. Literature Case study

To understand concepts of Vulnerability Assessment and Post occupancy evaluation of disaster rehabilitation project, two case studies were conducted and the observations were analysed. Both the case studies selected were for understanding the method of Vulnerability assessment

1) Vulnerability of Coastal Fisher Households to Climate Change: A Case study from Gujarat, India [1]

In the study the vulnerability of 1500 fisher households in four coastal villages in Junagadh district of Gujarat, were assessed using PARS (Parameter, Attribute, resilient indicator, score) methodology.

Four parameters were considered as sources of vulnerability

a) Demography b) Occupation c) Infrastructure and d)Fishery components

Selection of coastal villages was carried out by constructing vulnerability index of each village using different parameters as socio-economic parameters, no: of families

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below poverty line, adult-child ratio, average family size, gender ratio, literacy rate, dependency on fishing activities, craft and gear inventories and participation in cooperatives and ancillary activities.

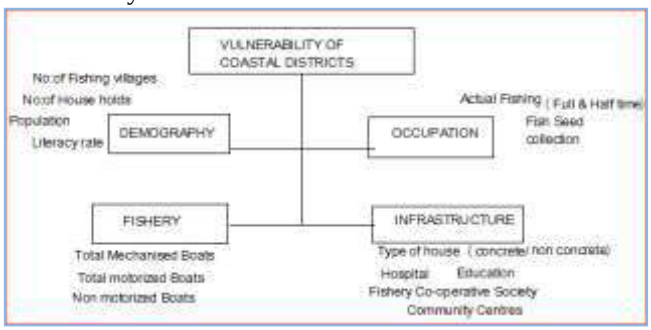

Fig. 2: Framework for assessing the vulnerability of Coastal District (source:Koya et al., 2017)

Design of CLVI (Coastal Livelihood Vulnerability Index)- vulnerability index for selected coastal livelihood was constructed by combining the indices for exposure, sensitivity and adaptive capacity.

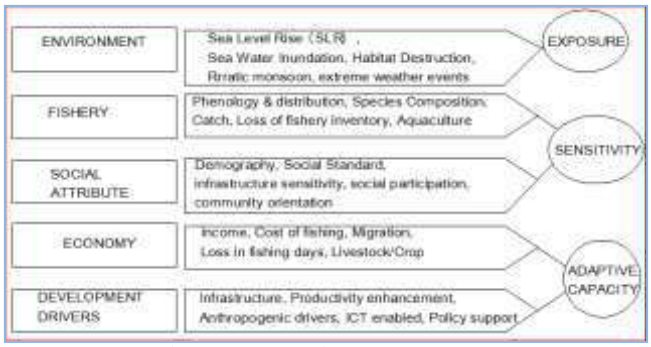

Fig. 3: Framework for construction of Vulnerability index including parameter and attribute used in PARS methodology (source:Koya et al., 2017)

2) Risk and Vulnerability Assessment to Tsunami & Coastal Hazards in Indonesia- Conceptual Framework and Indicator development [3]

Based on the study it was found that, the Knowledge about elements at risk, their susceptibility, coping & adaptation capacity/ mechanism are precondition to set up people centred warning structure, local specific evacuation planning and recovery policy planning. Assessment scales were at two levels- District level and local level assessment.

Decision tree technique used to extract, quantify and weigh relevant indicators controlling assessment. It allows generating assessment in a spatially distributed manner.
Representative indicators for decision steps:

a) Hazard assessment b)Determination of exposure & susceptibility c) Coping capacity d)Ability to recover

Quantification and continuous monitoring of these elements need to be achieved. The most appropriate indicator is historical events and their impacts on environment & society. The critical components need additional data acquisition through surveys eg: questionnaire based household survey.

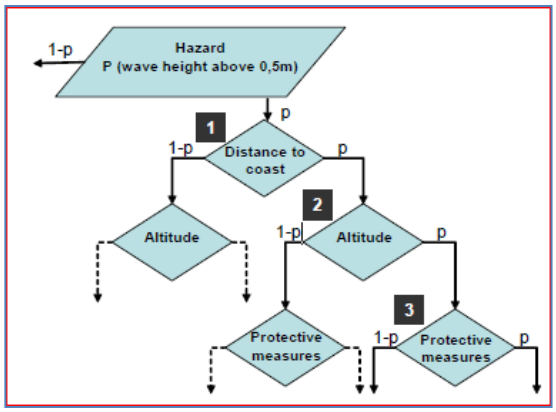

Fig. 4. Decision tree to approximate the risk of Tsunami impact showing the first part describing hazard assessment (source:J.Post, K.Zosseder,2007)

Methodology adopted for Risk & Vulnerability assessment involves the following stages:
(i)Assessment of Spatial distribution of hazard (hazard intensity)
(ii)Determination of hazard impact zones on land for entire coastline
(iii)Undertaking Vulnerability assessment regarding ability of people to receive and understand the warning, dependency ratio, health status, physical capacity, mobility factors etc.
(iv)Investigate ability of people to immediately and appropriately respond in case of Tsunami occurrence.
The sub-district assessment mainly focuses on providing sound information for local authorities in the context of specific disaster preparedness, adaptation and mitigation strategies (eg: Urban planning and evacuation planning).

III. BACKGROUND STUDY

24th December 2004 Tsunami had caused substantial loss of life and property especially in coastal regions of Kerala state. About 219 coastal villages of three southern districts of Kerala state –Kollam, Alappuzha and Ernakulam were affected with a death toll of 238. About 219 villages in Kerala state was affected. 2.4 lakh people had taken refuge in 269 relief camps.

Tsunami Rehabilitation project was carried out by Government of Kerala in association with voluntary agencies and Kerala State Housing Board. Post Tsunami Relief and Rehabilitation in Kerala state was done in three phases:

(i)Short term relief measures(ii)Medium term projects(iii) Long term rehabilitation programmes
Project funding was classified into three types based on funding agency and funding pattern:
(i)TEAP (Tsunami Emergency Assistance Project) funded by ADB (Asian Development Bank)
(ii)TRP(General)- Tsunami Rehabilitation Programme-General package funded by Central Government
(iii)TRP (Special package)funded by Central government gave financial assistance for housing under RGRP (Rajiv Gandhi Rehabilitation Project)
TEAP assisted projects for :
(a)Restoration and recovery of livelihood activities

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(b)Re-establishment of transportation network like roads, bridges, harbours etc.
(c)Restoration of local infrastructure like water supply and sanitation
(d) Awareness generation and capacity building programme
TRP general package was meant for the whole affected district TRP Special Package was given for Alappad panchayat by Govt.of India in 2008 because it was the maximum affected byTsunami 2004.

The Ockhi cyclone in 29th November 2017, had mainly affected fisherfolk in Ernakulam district in Kerala state. Tsunami houses that were vacant or illegally occupied were allotted to Ockhi victims. In addition to that, houses were constructed by Fisheries department and voluntary agencies.
After the floods that had struck Kerala in August 2018,, the Kerala State government had constructed houses under Rebuild Kerala Initiative(RKI) through Kerala State Co-operative Department, Care home projects etc. Now the houses are being constructed under Pradhan Mantri Awas Yojana (PMAY) through the Life Mission.

IV. PRIMARY STUDY

A. Criteria for selection of study area

1)The Coastal District of Kerala State that has the maximum Population density- Kollam district which has a coastal length of 37 km is densely populated when compared to other coastal districts as shown in Table 1. Density of population clearly determines the vulnerability of an area to hazards. This clearly indicates that Kollam district is more vulnerable to Coastal hazards such as Tsunami, Flood, Cyclone, Sea Erosion etc.

Table I District wise Coastal length and Population Density

Districts in Kerala state	Coastal length (km)	No:of Marine fishing villages	Marine fisher folk population (in thousandth)	Fisherfolk population per km length
1)Thiruvananthapuram	78	42	168.701	2162.8
2)Kollam	37	27	93.022	2514
3)Alappuzha	82	30	128.497	1567
4)Ernakulam	46	21	72.526	1576.7
5)Thrissur	54	18	59.971	1110.5
6)Malappuram	70	23	89.869	1283,8
7)Kozhikode	71	34	98.540	1387.9
8)Kannur	82	11	37.840	461.5
9)Kasargod	70	16	43.358	619.4
Total	590	222	788.324	1336.14

Source:Kerala Fishermen Welfare Board, Directorate of Economics and statistics, Matsyafed Information Guide,2018

2) Coastal Fisherfolk Villages in Kollam district were the worst hit in Tsunami 2004, in particular the narrow coastal strip of 10 km in Azhikkal, in Kollam district was entirely devastated. Along the coastal belt of Kollam district 176 people had lost their life and about 1600 were injured.84,773 people were evacuated and accommodated in 142 relief camps. About 6280 houses were destroyed and 11,175 houses were damaged. Alappad village panchayat which was the most affected, had a death toll of 143 out of 238 in Kerala state and also thousands were left homeless[4]

B.Vulnerability Assessment of Study Area

Alappad Panchayat, in Karunagapally Taluk had been selected as the study area, since it is vulnerable to both natural hazards as well as man made threats.
Alappad is vulnerable to natural hazards such as Tsunami, sea erosion, cyclones etc. It is vulnerable to manmade threats such as threats of eviction, displacement, disturbance of natural breeding sites, marine life affected by mining & pollution, illegal construction activities against CRZ regulation. In addition to these there are haphazard development issues, livelihood issues, environmental degradation and consequences of mining & dredging activities

a) Physical- As per the Cadastral Map of Alappad Panchayat, (Fig.5), it is lying in three blocks, Block 1,7 and 8. T.S.Canal that is on the eastern side of the panchayat forms part of the Alappad panchayat. T.S.canal was constructed in 18th century. So one of the peculiarity of panchayat is that it has got saline water on the western side, that is the Lakshadweep sea and fresh water on its eastern side. So both marine fisherfolk and inland fisherfolk are seen in the panchayat.

Fig. 5: Cadastral Map of Alappad (source:Author generated using Arc GIS from the cadastral map obtained from Survey office,2020)

b) Demography- When we compare the population density of Alappad panchayat as per the census report of 2001 and 2011, we find a sharp decline, from 3366p/sq.km to 2967 p/sq.km. This is due to the out migration from the Panchayat. More than coastal hazards, now the coastal fisher folks fear eviction threats as a result of revised CRZ regulation. Literacy rate had increased and many of the younger generations are not interested in fishing and they prefer white color jobs

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c) Social Attribute- As most of the inhabitants who are relocated are having land rights and pucca housing, there is a tendency to sell or lease out land and return back to their initial habitation that is vulnerable to hazards.

Even though many of the fisher folk were drunkards, they are not affected by kidney failures as they drink only once in three days when they return back from sea. Health hazards are less.

d) Environment- Pucca concrete roof structures are constructed by driving piles into the highly ecosensitive area with rare flora and fauna. Alappad is a narrow strip of land which has an area of 7.06sq.km. As it is situated between the Lakshadweep sea and the T.S.Canal, it is acting as a natural barrier or buffer zone, that prevents salt water ingress to the rest of the regions of Kerala. Ecofriendly construction techniques and materials need to be used. Most precious resource that is available is the black mineral sand. Extensive mining is taking place towards the southern tip of panchayat, which is leading to desertification of that area.

Fig. 6:Landuse map of Alappad panchayat
(source:Author generated from Google Earth & Toposheet using Arc GIS,2020)

With regard to the analysis of existing and previous landuse, it was found that: 11.97hectare of land area was eroded by coastal erosion, mining and dredging activities. Whereas,19.09hectare of land area was added by deposition of sediments. Presently 706.26 hectare is the area of Alappad panchayat, out of which about 28 % is water body. There is frequent and dynamic change in Landuse pattern. This increases the vulnerability of the area. There is scattered type of settlement pattern at Alappad. From the Fig. 7, it is seen that some of the survey no.s as per the cadastral map had been blotted away due to dredging & mining activities and sea washing or sea erosion

e) Economic- Many of the fisherfolk donot have any alternate employment opportunity during off-season period. Alappad is currently part of Kollam Coastal Tourism circuit, but the coastal people are not benefitted from that. Health tourism is promoted as part of Amritanandhamayi madam in ward 4. There is high tourism potential in Alappad Panchayat with many areas having waterbodies on either side. Tourism activities could be introduced for the socio- economic upliftment of the local people along with their participation.

Table II Landuse Pattern –Area and Percentage

Sl.No.	Landuse Pattern-Area & Percentage		
	Landuse	*Area(Ha)*	*%*
1	Built Up land	86.63	12.06
2	Clay	0.07	0.01
3	Coconut	101.87	14.18
4	Coconut _ added	0.36	0.05
5	Fallow Land	24.80	3.45
6	Fallow Land _ added	0.16	0.02
7	Mangrove	4.60	0.64
8	Mangrove _ added	0.49	0.07
9	Marshy Land	0.21	0.03
10	Mixed Crops	198.96	27.70
11	Mixed Crops _ added	0.09	0.01
12	Pond	0.44	0.06
13	Sand	54.69	7.61
14	Sand _ added	17.97	2.50
15	Wasteland	6.43	0.89
16	Waterbody	200.99	27.98
17	Waterbody _ added	0.01	0.00
18	Waterlogged	7.47	1.04
19	Eroded	11.97	1.67
Total Area In Hectares		718.23	100

(source: Author generated from Google Earth & Toposheet obtained from Kerala State Landuse Board,2020)

Fig. 7. Sea erosion at the southern tip of Panchayat (source: Author generated by overlaying cadastral map with landuse map, 2020)

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f) Infrastructure- Accessibility is a problem that is facing majority of the settlements at Alappad. There are bridges such as Panikkar Kadavu bridge, Azheekal bridge etc in addition to foot bridge and road ways connecting with the main land. But there is lack of access roads to each of the dwelling units.

g) Development Drivers- Karayogams are involved in renovation works and construction of drains. Kudumbasree is active. Ladies are involved in pickle making, catering service.

C. Post Occupancy Evaluation

Under TRP special package, 724 houses were constructed at Alappad in the first phase for people whose house was fully washed off by Tsunami. In the second phase Rs.3 lakhs was given for those houses that were partially damaged. [12]

One advantage of the Reconstruction and rehabilitation project was that in addition to Central and State government, it involved many stakeholders such as World vision, Amritanandamayi madam, Christian institutions etc. This resulted in speedily construction of the houses within the stipulated time frame. Many agencies had given typical housetypes and the beneficiaries had added on as per their need. A reconnaissance survey was conducted with a sample size of 30 households. Based on that following issues were identified

1) Issues identified

a) Social issue : A major disadvantage in R& R project, was lack of participation of Karayogams in planning and construction activities. Some of the public buildings such as Old age home at Kakkathuruthu Island, that was provided as part of Tsunami fund was not beneficial to the people as it was against their culture to send their aged parents to such homes.

b) Physical issue: Indigenous technology and materials were not used in construction of buildings

Fig.8.Dwelling constructed under TRP scheme at Srayikod (Source: Reconnaissance survey,2020)

Some vulnerable housing stock are still found in the area. And some did not have house number as they had violated CRZ regulation.

c) Economic issue: Govt.of India Company-IREL(India Rare Earths Ltd.) and Govt.of Kerala company-KMML(Kerala Minerals & Metals Ltd.) are not providing employment opportunities to the inhabitants. The community expects a share in the profit obtained by such companies as they are the original natives of the area. In addition to that refilling is not effectively done.

Figure 9. A dwelling unit near shoreline at Azheekal (Source: Reconnaissance survey)

So the landarea is decreasing at a faster pace due to mining & dredging activities. The community fears that the land of Alappad would vanish from globe if such activity persists. Means of livelihood of fisherfolk are also affected due to depletion of land area.

d) Infrastructure issue: Lack of proper approach roads to dwelling units is major issue. In some cases proper maintenance of houses are not done due to the lack of ownership feeling.

2) Discussion

Protective measures such as seawalls and groins need to be provided all along the coast to control sea washing/ sea erosion. There should be representatives of people to continuously monitor and ensure that the dredged area gets refilled back. Community level participation has to be ensured in decision making, planning and implementation stage.

Skill upgradation programmes need to be initialized for fisherfolk to gain additional employment opportunity in off-season period. Transparency has to be ensured in development projects especially the construction and maintenance of infrastructure facilities. At present coverage under Life Mission programmes is very limited. Involvement of more stakeholders in construction activities would ensure better coverage. As population of Inhabitants who reside in No development zone as per CRZ regulation is increasing, suitable measures need to be taken for their adequate rehabilitation such that it would not adversely affect their means of livelihood.

V. CONCLUSION

Alappad panchayat with a very fragile ecosystem need to be preserved. The community's need and choice are not effectively reflected in the reconstruction and rehabilitation programme. Participatory approach is the need of the hour, for sustainable development of indigenous fisherfolk of Alappad panchayat.

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REFERENCES

[1] Koya K Mohammed et al., 'Vulnerability of Coastal Fisher Households to Climate Change: A Case Study from Gujarat,India', Turkish Journal of Fisheries and Aquatic Sciences 17:193-203 (2017)
[2] Planning and Management for Disaster Reduction,United Nations Centre for Human Settlements(Habitat),Nairobi,1990
[3] J.Part, K.Zosseder,'Risk &Vulnerability assessment to tsunami & coastal hazards in Indonesia- Conceptual framework & indicator development,2007
[4] UNDP,'Kerala Post Disaster Need Assessment-Flood and Landslides August 2018
[5] Collins Woerman, City of Seattle –Towards a Resilient Saettle -Post Disaster Recovery Plan Framework ,January 2013
[6] Performance Reviews of Disaster Management Department, Audit Report(Civil) for the year that ended in 31 March 2006- Volume-1
[7] Shyni K.Evaluation of "Post-Tsunami Resettlements in Kerala- Lessons from Alappad, Kollam",Research paper,IIT Kharagpur, 2015
[8] Kumar et al.,'Coastal Vulnerability Assessment for Orissa State-East Coast of India',Journal of Coastal Research, Florida,,p523-534,May 2010
[9] Vrinda Ravindranath K.,'Planning for Coastal Settlements:A Case of Alappad, M.Planning Thesis, APJ Abdul Kalam Technological University,June 2019
[10] Vishnu Ravi Moorthy, Post Disaster Recovery Planning M.Planning Thesis, University of Kerala,January 2015
[11] Pournami Narayanan Usha,'Disaster Risk Reduction Model-Case Panamaram, Wayanad',,M.Planning Thesis, APJ Abdul Kalam Technological University,June 2019
[12] Neena Joseph,'Missing Link between State and community: Post – tsunami Reconstruction and Rehabilitation of Alappad Panchayat, Kerala,India,2015
[13] UNISDR,'Implementing Sendai Framework to achieve Sustainable Development Goals,2015

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WASTE MANAGEMENT IN KERALA URBAN NEIBOURHOOD BY ADAPTING 'ZERO WASTE CITY' CONCEPT, A CASE OF EDAPPALLY

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***Abstract*— Increase in the globalization and urbanization has led to change in the lifestyle of the people. The increasing needs in the lifestyle of the people has led to an increase in the waste generation as well. The waste generation at the alarming rate has led to a serious concern. Zero waste serves as a significant approach towards these waste management concern. There are various techniques of waste management in practice all around the world. Waste concerns are rising for urbanizing areas all over the world. This gives the scope for finding a better solution for urban waste. Zero waste is a method for waste management in which a design can compel users to change our behavior and consumption patterns so we reduce, share, reuse and allotting space for managing discards so that they too can be reused or recycled. Edappally, a fast urbanizing neighborhood of Kochi is facing rising urban waste concerns which provide an opportunity to identify economic and sustainable methods to overcome urban waste in the future. These methods can be identified for Edappally by finding out the deficiencies in spatial requirements as a zero waste city for Edappally. This helps to develop the guidelines for developing Edappally as a zero waste neighborhood.**

Keywords—zero waste concept; waste management issues; holistic approach; community integration

I. INTRODUCTION

Urban waste management is one of the major critical areas of practice and research studies because of the increasing concerns of environmental degradation, health issues, and resource scantiness. Parallel to urbanization and globalization the urban waste generation is increasing in most of the global cities over the last few decades. Waste in the society is generally perceived as inescapable and objectionable. Waste because of everything in packaging and fast food products i.e., the change in lifestyle and increased consumption increases the quantity of waste generated. Most of the waste management expertise realized that there no single or simple solution to solve waste management issues. In the current scenario, there are a lot of various methods followed to deal with the urban waste such as incineration, gasification, landfills, grey water treatment etc. However, any waste that is generated is considered to be a loss of precious resources. The present situation demands an all-inclusive view towards waste management and thus the concept of zero waste can be used as a method to resolve the waste management issues and this can be done through proper urban design strategies and design concepts.

Waste is an indicator of inefficiency of a modern urban society and a representation of misallocation of resources. The quantity of urban waste generated keeps increasing proportionally to the increase in urban population growth, high resource consumption and other economic development that requires more efficiently planned waste management plan and infrastructure facilities. Unavailability of open land is a limitation for providing proper waste management facilities and also the increasing density or urban sprawl. Only 2% of the total world's surface is covered by cities and loading these urban areas with more than half the percentage of world's human population is a major cause for increasing urban waste and the issues related to these generated waste, and also it is suggested that by 2030 about 80% of the total human population will reside in urban areas.

Due to increase in the population shift from rural to urban areas and change in lifestyle the living condition of the people dwell in urban areas become miserable. Also there arises a situation that lacks sufficient infrastructure facilities and proper waste management systems to serve this increasing population. More over majority of the population of such areas don't have sufficient space for waste management inside their own compound. So a better strategy such urban areas for disposing and managing of waste by using zero waste concept as a tool to bring community integration as well as economic stability. That is an urban neighborhood has to be developed into an area that fulfills all waste management facilities that is required for all the user groups, the local residential communities and the commercial sector.

Kochi is the largest and the most populous metropolitan area in Kerala. It attracts the working migrant population from

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neighboring regions and also from other states since two decades. The Info Park at Kakkanad, opening of Nedumbassery International Airport, metro project, construction of new bridge that connects Vypin islands to the main land and also the high impact commercial and residential developments boost the development of Kochi. Yet, it is a fact that the working migrant population in these developing sectors exceeds the carrying capacity of the region and the ruthless exploitation of resources and waste generation parallel to urbanization continuously increasing till today in the Kochi region that leads to several positive as well as negative consequences.

The total urban waste generation of Kochi is 180-250 metric tons per day and the city have only one biodegradable waste treatment plant which is located at Brahmapuram. All other non-biodegradable waste is being dumped outside the plant in an unscientific manner. Open dumping is an unhygienic process and it caused majority of the residents in the neighborhood to migrate because of issues like bad odor and drinking water quality. Also the surrounding water bodies are getting polluted. Although most of the Indian cities are having enough open land to follow the open dumping practices, the more congested and populated cities like Kochi cannot afford to lose a large area of land just for open dumping of the waste.

Edappally Panchayat was formed in 1946 and later in 1967 Cochin Municipal Corporation was formed by amalgamating the three ancient Municipalities and four Panchayats including Edappally. After 2001, Kochi experienced a surge in the degree of urbanization and Edappally developed as one of the major commercial hub in Kochi as well as a prominent residential area. The economic boom has spawned a host of commercial related activities like shopping malls, boost in entertainment sector like tourism that resulted in migration of working group into the district. Like most of the towns in the world, the issue of increasing in the quantity of urban sewage and waste disposal is a major concern in Kochi too. Edappally have the potential to become the premier commercial and transportation hub with the introduction of shopping malls, metro, etc. With the increase in density of the region the quantity of waste generated is also increased but it is lagging behind its waste infrastructure services such as waste management and sewage treatment facilities, so it should give the right policies, guidelines and urban design strategies.

II. ISSUES CREATED BY URBAN WASTE

A. *Environmental issues*

The growing amount of waste generated in the modern society has a huge impact on the natural environment. When more people migrate to urban centers the requirements increases and also parallel to this increased resource consumption quantity of waste generated also increases. This leads to issues such as lack of waste infrastructure facilities, proper drainage systems, hygiene etc., which indirectly affects the environmental quality of the region. Also the air quality of this area is affected. The odor nuisance from the open dumping will be beyond control. Setting of waste management plants, water treatment systems or any other waste infrastructure without proper care will also causes environmental and health issues.

B. *Socio Economic changes*

The unhygienic surrounding and environment condition will decrease the land value of the region, residents in the neighborhood migrate because of issues like bad odor and drinking water quality and in present scenario where there is no land to waste for dumping purpose the method of open dumping cannot be practiced. The development in waste management system will also increases the employment opportunities of economically backward society like rag pickers. However this can also create a class different among different groups in the society.

III. CAUSE OF URBAN WASTE

The waste generated from residential and industrial area of cities is referred as urban waste. The main reasons for rapid increase in the quantity of urban waste generated can be direct and indirect cause, which is listed as the follow diagram:

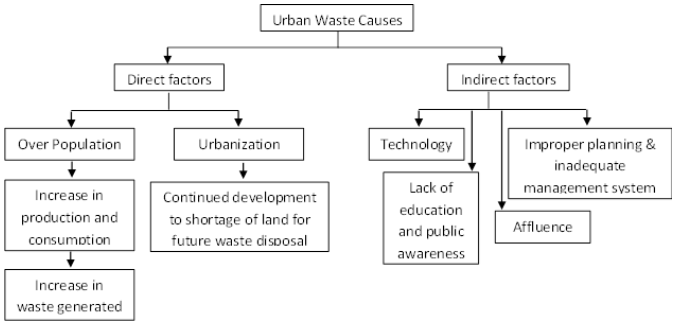

Figure 1: Urban Waste Causes *(Source: Author)*

IV. THEORITICAL FRAMEWORK

Waste management, involves different categories of waste that involves organic waste, paper waste, plastic waste, metal waste, e-waste, sanitary waste, etc. which requires different treatment processes. Historically, the waste management system was developed long before the development of modern civilization. There are six major innovations in the waste management system- open dumping, uncontrolled landfill, composting, controlled landfill, waste to energy, and the final one, zero waste is the most holistic innovation of the 21st century for achieving a sustainable management system.

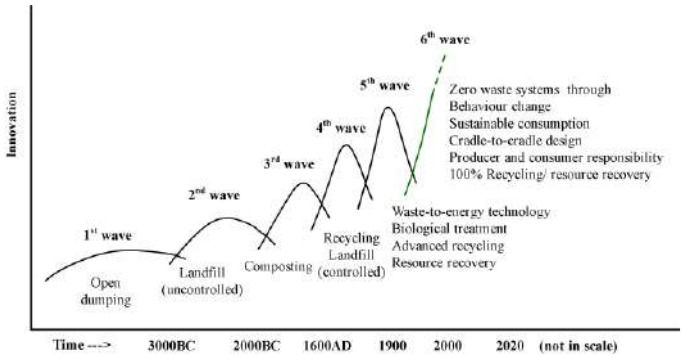

Figure 2: Major innovations in waste management system.

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The zero waste concepts can be used as a significant method for waste minimization, to control environmental degradation, employment generation and community integration. So to derive the parameters and the techniques to implement zero waste concept theoretical studies of zero waste and communities were done. Also different cases from all over the world were analyzed.

Techniques to implement zero waste city

- Restructuring abundant open spaces.
- Construction of decentralized material recovery facilities.
- Decentralized composting units within a convenient walking distance or backyard compositing units.
- Allocation of collection bins at required distance, a minimum convenient walking distance.
- Integration of land use and processing units-surrounding land use should be considered while planning and designing.
- Disconnection of grey water drains to sewers and diverting water to separate treatment system prior to entering drains so the grey water will get treated and the water can be used for other purposes like irrigation.

V. RELEVANCE OF THE STUDY

A. *Kochi*

Ernakulam district of Kerala is widely known as the 'commercial capital of Kerala'. According to census 2001, the population in Ernakulam is 3.09 million and the Cochin Corporation has a population of 5.84,008 within an area of 94.88sq.km. Development of Kochi is in an accelerated pace than any other major urban centers in the state, which in turn, the urban transformation of the entire district. In Kochi, the urbanization trend and change in life style have increased the waste load on cities and thereby polluting the urban environment in an uncontrollable measure. Urban area of Kochi is not able to cater to day to day increase in quantity of waste generated. Waste dumping sites in city are full beyond capacity and under unhygienic conditions.

Urban activities in the Kochi area is of mixed land uses. Sources such as households, shops and commercial establishments and hospitals generated 250 MT/day. In Kochi, there is still no organized waste segregation at source except in some localities. In some places household waste is left open at the nearest open temporary storage dumps and collection occurs whenever transport carriers are available. The existing urban Waste management system demands large scale improvement and augmentation to ensure environmental safety.

B. *History of Kochi*

Various factors can be cited as the basis for this remarkable urbanization growth in the district. These variables can be classified into historical factors and recent factors, i.e., after 2001. Historically, the development of the district was mainly because of the strategic position of Kochi port in the Western coast of India. With the port's development in post-colonial period, Kochi gained the prominence as a major trade center of Kerala, also commerce and many other industries. Thereafter Kochi came to be known as the commercial capital of Kerala.

After 2001, Kochi experienced a surge in the degree of urbanization and construction boom in this region started, mainly an increase in vertical structures, i.e., apartments and other high rise buildings. Later, Kochi emerged as a significant center point of IT, especially after 2004 with the establishment of Info Park at Kakkanad. This has brought about an age selective migration i.e., educated group of youth into the district. In addition to these, many other factors like, the establishment of international container trans-shipment terminal at Vallarpadom, other new modes of transport like airport, rail metro, water metro, also new commercial centers like shopping malls, restoration of heritage centers and uplift in tourism and other entertainment sector and media also gave force to the fast urbanization of Kochi.

This rapid urban development leads to numerous positive as well as negative results. Along with growth in economy, urban development, expanded employment opportunities and improved infrastructure facilities, the fast urbanization of an whole region will also make numerous undesirable effects which will not be overlooked. This hasty urbanization was the main reason for the beginning of urban waste management issues in Kochi. The most common type of waste management practice followed in Kochi is open dumping of waste. Open dumping is considered as the worst method of urban waste management and also for more congested and populated cities like Kochi, which cannot afford to lose a large area of land just for open dumping of the waste. The two departments of corporation of Cochin (Health department and Engineering department) are responsible for the urban waste management of the city. The Brahmapuram plant, which is built in 2001 is the only existing biodegradable waste treatment plant in the city which spreads over an area of 106 acres and all other inorganic waste, including plastic and sanitary is being dumped outside the plant. This plant treats 220 tons of biodegradable waste and receiving 72 tons non-biodegradable waste on an average on a daily basis. However, now this plant is in a dilapidated condition. The total daily production of urban waste in city is 180- 250 metric tons. The per capita waste generation is 482g/day/head.

VI. STUDY AREA

A. *Edappally*

Figure 3: Location map of Edappally *(Source: Author)*

[12] UNEP/GRID- Arendal: Arendal, Norway, 2006. Available online: http://maps.grida.no.go/ graphic/a-history-of-waste-management (accessed on 10 May 2010).

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Edappally is a neighborhood in the district of Ernakulam, Kerala. It is one of the major commercial hub in Kochi as well as a prominent residential area. It is considered.one of the fastest growing region of Kochi. Earlier it was a Panchayat later it got included in Cochin Corporation. The corporation limits start from the Lulu Mall traffic signal towards Palarivattom area. Some of the region it covers includes area under Kalamassery Municipality. Now it is gradually becoming the key transportation hub with the introduction of Kochi Metro. This has increased the land values and initiated a development trend. Edappally is also lagging behind its waste infrastructure services.

VII. PRIMARY STUDY ANALYSIS

A. *Land Use*

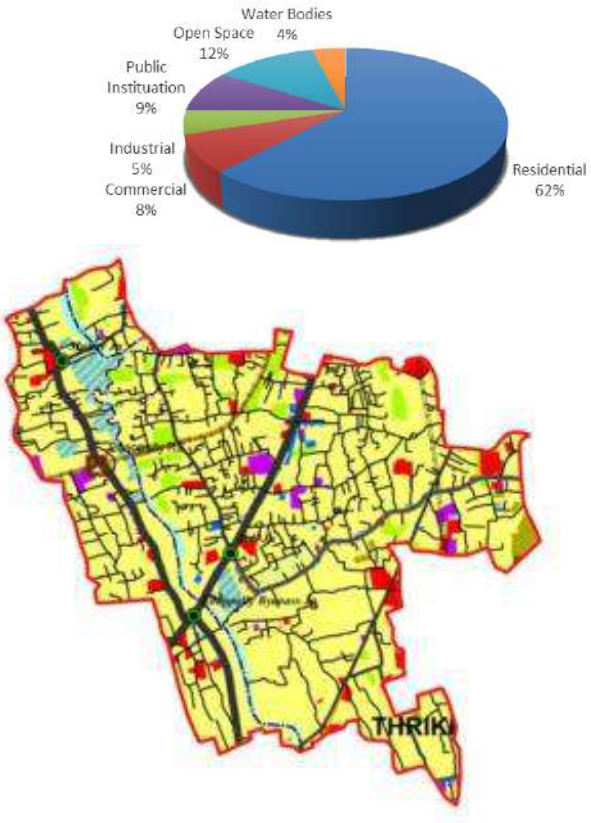

Figure 3: Land Use Map of Edappally *(Source: Author)*

B. *Waste Generation*

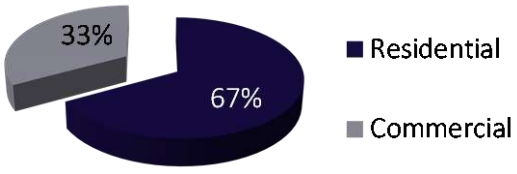

Figure 4: Percentage of waste generated in Edappally region *(Source: Author)*

C. *Primary Collection*

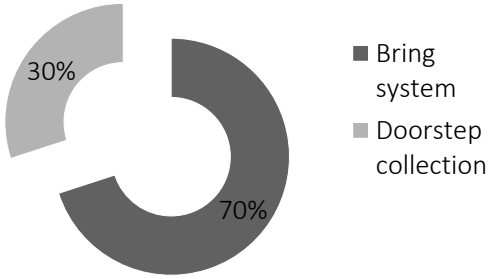

Figure 4: Percentage of primary waste collection *(Source: Author)*

VIII. NEIBOURHOOD LEVEL URBAN DESIGN

IX. STRATEGIES

A. *Collection*

- *Organic Waste, Plastic Waste, Paper Waste*
  - Primary- Door to Door collection method at household level.
  - Each road should have adequate hassle free separate community bins with colour coding for each category waste at 1km distance to facilitate a clean neighbourhood.
- *Glass Waste*
  - Weekly or bi-weekly basis collection and transported to a materials recovery facility.
  - Bottle banks near commercial enterprises.
- *Grey Water*
  - Mandating a well-connected grey water collection system from every household and other institution.
- *Metal Waste*
  - City level decentralised collection centres.
  - Non-private open dump yards in cities can be developed into collection units wherever possible.
- Door to door collection activities can be done by collection agents appointed by ULBs or NGO groups like kudumbashree units.

B. *Segregation*

- Mandating household level segregation.
- Decentralised material recovery centres (MRF) at ward level.
- The authorities can provide legal rights and employment to the informal traders or waste pickers in this sector.

C. *Storage*

- Decentralised storage systems for each category waste, so no garbage heaps/dumps in the ward.

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- Plastic Waste (PET) should have city level decentralised baling units connected to shredding units wherever possible.
- Corporations, Municipalities and Block Panchyaths in Kerala can provide decentralised storage facilities for all type of waste at different levels and also bailing units for plastic waste.

D. Transportation

- The decentralised facilities should have wide accesses to the primary roads in the city.
- The ward level recovery facilities should be at location equidistant from all corners of the ward.
- Interconnected and wide roads should be encouraged.
- All major internal vehicular roads of a city should be at least one truck wide.

E. Processing

- *Organic Waste*
  - Source composting units at ward level connected to organic farming.
- *Plastic Waste (PET)*
  - Centralised Recycling Centre.
- *Plastic Waste (PS, PP, HDPE,LDPE)*
  - City level decentralised shredding units.
- *Paper Waste*
  - City level decentralised paper recycling centres.
- *Glass Waste*
  - Centralised city level glass processing centre.
- *Metal Waste*
  - City level centralised metal recycling plant.
- *Grey water Waste*
  - Grey water treatment plant at ward level connected to organic farming.
- Organic Waste can be processed within households or on a community level with the help of Kudumbashree units or other private agencies. Whereas the plastic waste can be given for recycling to private agencies like Plastic Recycling Company kerala, Evergreen plastics, etc.

F. Disposal

- *Organic Waste*
  - Converted into organic compost.
- *Plastic Waste (PET)*
  - Recycled PET can be purchase by manufacturing companies.
- *Plastic Waste (PS, PP, HDPE,LDPE)*
  - Can be used for Road construction.
- *Paper Waste*
  - Recycled PET can be purchase by sellers.
- *Glass Waste*
  - Recycled glass can be purchase by manufacturing companies.
  - Glass which is not recycled, but crushed can be used as roadbed aggregate or as aggregate in concrete.
- *Metal Waste*
  - Recycled glass can be purchase by manufacturing companies.
- *Grey water Waste*
  - Can be used from public organic farming and public toilet facilities nearby.

X. CONCLUSION

Even though waste is a major concern in most of the urban areas, no effective planning strategies are outlined yet to regulate the management activities. It is essential to build a design that can compel users to change their behavior and consumption patterns, so this will reduce, share, reuse and allotting space for managing discards so that they too can be reused or recycled.

Most of these issues of existing waste management system in our cities are due to inappropriate planning and proposals, a holistic approach, which should include proper categorization of waste and management methods for each type of waste based on this listing is required to solve the existing issues in waste management.

In the study area, more focus is on the front-end i.e., collection and transportation of waste while the real problems lay at the back-end of waste management i.e., treatment, segregation, recycling, and disposal of the waste. An integrated approach is required. A proper waste master plan should be prepared for converting waste as a resource.

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REFERENCES

[1] A.K. Pathak; M.M. Singh; V. Kumar. 2011. “Composting of municipal solid waste: a sustainable waste management.” International Journal of Current Research 339-346.

[2] Ahsan, A., M. Alamgir, M. M. El-Sergany, S. Shams, M. K. Rowshon, and N. N. Nik Daud. 2014. “Assessment of Municipal Solid Waste Management System in a Developing Country.” Chinese Journal of Engineering 11.

[3] Arya Lekshmi, P. T, and T.S Lancelet. 2019. “Trend of urbanisation in ernakulam with respect to kerala.” Journal of Global Resources Volume 5 41-48.

[4] Hannon, Jonathon, and Atiq U. Zaman. 2018. “Exploring the Phenomenon of Zero Waste and Future Cities.” Urban Science 1-26.

[5] K, Dr. Anoop C, Abishek Baby, Sneha Elsa Cheriyan, and Tina Maria Jacob. 2019. “Design of sanitary landfill at brahmapuram solid waste

treatment plant." International Journal of Scientific Research and Review 182.

[6] Kumar, Vinit, and Prof M M Singh. 2011. "Composting of municipal solid waste: a sustainable waste management technique in indian cities." International Journal of Current Research 339-346.

[7] Limited, GJ Eco Power Private. 2019. Final EIA/EMP Report. Working Report, Kochi: L&T Infrastructure Engineering Ltd.

[8] Nizar, M, E Munir, and E Munawar dan Irvan. 2018. "Implementation of zero waste concept in waste management of Banda Aceh City." SEMIRATA- International Conference on Science and Technology 2018 1-12.

[9] Rajkumar, Joshi, and Ahmed Sirajuddin. 2016. "Status and challenges of municipal solid waste." Cogent Environmental Science 1-18.

[10] Zaman, Atiq Uz, and Steffen Lehmann. 2013. "The zero waste index: a performance measurement tool for waste management systems in a 'zero waste city'." Journal of Cleaner Production 123e132.

[11] Zurbrügg, Christian. 2013. "Determinants of resilience in community-led waste management." Waste and Resource Management 93-100.

[12] UNEP/GRID-Arendal. A History of Waste Management; UNEP/GRID-Arendal: Arendal, Norway, 2006. Available online: http://maps.grida.no.go/graphic/a-history-of-waste-management (accessed on 10 May 2010).

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Power, Politics and Identity of Capital Cities

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Abstract*—Cities are physical manifestations reflecting aspirations of the social, economic and political framework of the time. Planning of cities have been taking place since the beginning of civilizations. Therefore, a measure of civilised life can be analysed by understanding the planning schemes of a city. Organization of spaces subsequently led to hierarchical formations within the public realm, with exhibition of the idea of power. Thus, one of the key aspects in decoding cities is to understand the expression of power within them. This also results in the built form becoming a representative of the political stand of the government. It also acts as a political strategy for identity formation. Urban planning and design thereby become tools for capturing culture and power by transfer of these ideals into the city planning scheme. Over the years, cities have mutated to contain the changing forms and varying expressions of power. These cities can be termed as capital cities. Capital cities often exhibit cultural dynamicity resulting in them becoming centres of authority. This paper focuses on understanding power, politics and identity in the formation of modern day capital cities.

Keywords—power; politics; identity; symbolism; capital cities

I. CITY AS A WEB

Cities have always been crucial physical and symbolic representations as well as important instruments in building up the ideals influencing citizenship, activism, ideology, democracy and even economy. Deriving from the studies of Henri Lefebvre, cities can be understood as a social product that follows a unique mode for its own production. They are also stages for inclusive participation and democratic expression of the right to inhabit through access to facilities, services, employment, resources etc. All of these can be linked to the concept of democratic decision-making, forming the most essential right to participate in a city. Thus, cities are physical amalgamations of the society, its governance and interdependence with space.

II. POLITICS, POWER AND PLANNING

The idea of exerting power through planning has been evident in cities since a very long time. Foucault (1976), states that almost all political discussions after the eighteenth century have had their bases rooted in improving the facilities required to lead an efficient common life. Also, planning has never been disconnected but has formed a trilogy with politics and power.

Society has idealized the role of planning to be self-governing and neutral, often revolving around the objective of common good. However, it can be understood that most theories of planning, however altruistic, are functional variations of a capitalist system within the tangible built environment (Kiernan, 1983). For example, development in imperialist countries may have improved the economy and the living standards of the region but are achieved to a great extent by exploiting the labour class of the developing world, which further was a consequence of colonialism. (Warren, 1980; Hoogveldt, 1982). Manuel Castells argues that traditional planning processes could never equitably represent the sectarian diversity within a community and presents social movements are the most suitable and effective in addressing issues by bypassing the divisions of social class, gender, religion etc. [1]

III. POLITICAL IDEOLOGY AND CITY FORM

Political ideologies have often been the force for creation of cities and have also been instrumental in uniting people. Thus, the power of ideologies in the creation of cities cannot be overlooked.

TABLE I. RELATIONSHIP BETWEEN POLITICAL IDEOLOGY AND SPATIAL MANIFESTATION IN BUILT FORM

POLITICAL IDEOLOGY	SPATIAL MANIFESTATION IN BUILT FORM
SOCIALIST	Uniform density and height of built form throughout the city Prevalence of one value system Abolition of private property No 'central business' to conduct, hence CBD absent
CAPITALIST	Varying and zoned skyline Non-uniform density and height Economy driven development, hence presence of CBDs Prevalence of capitalist values
IMPERIALIST/ ATHORITARIAN	Forms of spatial expression based on sectorial bifurcations like religion, community beliefs etc. Grand in scale, varied skyline, clustered

IV. FACTORS DETERMINING ARRANGEMENT OF URBAN FORM

The arrangement of urban form is guided by factors such as geography, planning, politics, social construct, religion and

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history. While geography is a natural factor, the remaining factors are man-made expressions formed over a period of time. [1]

A. Politics and Economic Policies

Economic systems of various countries, like capitalism, have commodified land as the primary factor of production. This has enabled land to be a product that can be sold or put up into the domain of exchange. (Scott 1980, Harvey 1985). Before three decades, socialist states have had very different ideological concepts for city form in terms of development and design. In the case of capitalism, huge variations in the city form can be observed from nation to nation.

These systems have been translated to concepts of land parcelling in locations, quantities and configurations to meet land demands in cities. [1]

B. Social Construct

The urban form is usually an imprint of the social construct of a region. For example, the division of spaces into public and private has also been governed according to the societal construct and so has been the gendered division of labour. Such systems often inherently support the segregation of social classes. [1]

C. Religious Ethics

The Judeo-Christian ethics have often place nature in conflict with man and has turned it into a domain that needs to be conquered. Western ideologies tend to function around contradictions of such kind. (Harvey 1996) Asian ideologies however, relied more on unifying with nature. Colonisation and modern capitalist trends have diluted this character that once was strong.

The modern translation of this concept lies in the domination over nature through commodification and technology. This has also led to natural forms being converted into fantasy driven versions for exploitation or entertainment as seen in examples like parks, botanical gardens, reserve areas etc. [1]

D. History

Historical formations are frequently used in social structuring schemes within an urban form. Through the representation of such formations, the state exhibits its form of law and power, the military, the ability to stage spectacles (for military authority, state funerals etc.), the religious ideologies among many others to form a complex urban code that exhibits dominance within the region. Historical formations also portrays the symbolic dimension of history through physical markers that depict, commemorate, honour or condemn specific events, concepts and places.

However, these markers may have very little connection to any "truth" as the main function of such elements is to unite people, reinforce common value systems and propagate an acceptable history that provides support to the capitalist developments. These are often achieved through approaches to monumental architecture and urban spaces. [1]

E. Planning

Cities, guided by changing ideologies, take over land via the planning apparatus for certain essential features of social interest like education, health, recreation, for the movement of commodities and for its own expression of power. This zoning has been classified as the public realm. Through the formation of the regulated public realm, the form of its associated spaces, its scale with respect to its functions and the quality of the adjacent urban zones are all impacted. By the reinforcement and unique combinations of the above possibilities, spatial relationships containing variations in form, materials, sculptural elements and other ideological devices are manifested in the urban realm.

Thus, the arrangement of urban form lies in the creation, propagation and storage of the 'collective memory' of the place. [1]

V. The Concept of Capital Cities

The popular interpretation of a capital city is one that contains the seat of national government. However, with the world comprising of approximately two hundred nations, few with multiple capitals, this interpretation stands void. Large variations in sizes and functions demands a classification and Peter Hall has classified capital cities into the following categories based on their functions:

- Multi-function capitals: combining all or most of the nation's functions as seen in London, Paris, Madrid, Stockholm, Moscow, Tokyo
- Global capitals: similar to multi-function capitals, representing cities that perform international roles in politics, commerce and trade as seen in London and Tokyo
- Political capitals: Older established commercial centres often lacking other functions created as seat of government as seen in Washington, Ottawa, Canberra, Brasilia
- Former capitals: Often the opposite of global capitals, these cities have lost their dominance as the seat of power but have not lost their historical significance (St. Petersburg, Rio de Janeiro)
- Ex-imperial capitals: similar to political capitals representing imperial cities that have lost their dominance but continue to function as a national capital and may still performs functions of commerce and culture. (London, Lisbon, Vienna)
- Provincial capitals: As a special case in federal nations, some cities hold a de facto status with another capital and retain functions for surrounding regions (New York, Sydney, Milan)
- Super capitals: Centres for international organizations that may not necessarily be national capitals (Brussels, Rome, Geneva)

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Capital cities are stages of display, expressing elements of national significance to tourists and locals alike. They are also sites of touristic pilgrimage, acting as economic magnets for the unemployed. While capitals are hosts to cosmopolitanism and inclusion, they often become stages of segregation while relocating the poor who seek refuge. Most capitals designed from scratch have applied land zoning schemes in extreme. Concentration and independence of administrative zones is often a subtle reminder of power. [2]

VI. Role of Politics in the Formation of Capital Cities

The twentieth century witnessed three important political events that changed the course of capital formations and their representation as the seat of power. [3] They can be summarised as follows:

- The disintegration of both land based (Germany, Russia) and water based (Britain, France) empires
- The development of new decentralised political systems (France, Germany, Australia)
- The development of new international groupings and organizations (League of Nations, United Nations)

Thus, a drastic political change, disintegration of an empire of the division of a nation is required to bring about changes in the role of the existing capital city. In other cases, changes are minimal and these cities may retain certain economic and cultural hegemony over their former territories. However, the scale of the impact is not necessarily national.

VII. Role of Technology in the Formation of Capital Cities

The relationship between capital cities and their adjacent territories are determined by two forms of development - he informational revolution and the development of new systems of high speed ground transportation. [3]

A. Informational Revolution

Services which are dependent on face-to-face exchange of information, remain within the city cores of developed metropolitans in large economies as in the cities of Tokyo, Paris, London and New York. However, specialised activities, such as research institutes and laboratories, often decentralise to sub-centres easily reachable from the city core or to surrounding areas offering lower rents and right kind of medium skilled labour. Shifting of certain head-offices to the city's edge location can also be attributed to informational revolution. This decentralising results in the formation of polycentric metropolitan areas as observed in San Francisco Bay area, South East England, Gurugram and Noida in the National Capital Region of Delhi. This shifting can be credited to growing information systems connecting regions.

B. High Speed Ground Travel Systems

Early superpowers like Europe have been successful in establishing networks linking capitals and important sub-centres. These new networks sustain their terminal cities while weakening intermediate cities. This rend can be observed in the Tokyo-Nagoya-Osaka cities of Japan. Transportation networks find their optimal efficiency between 300-600 kilometres.

VIII. Role of Economy in the Formation of Capital Cities

A present political capital does not necessarily attract economic functions. Such capitals may have developed as a result of their historic requirements. This is evident in the example of European capitals where trading empires expanded in the period between sixteenth and eighteenth centuries. Regal powers and trading intersected and assisted one another resulting in political and economic dominance within the region.

Political and economic roles thus demanded allied functions that could address legal enforcement resulting in formation of courts, lawyers and other sub-functions. Further, these cores became centres of consumption and culture, thereby increasing the local demand for educational institutions, theatres, concert halls and media. These functions assisted one another, demand from one being met by supply from another.

However, many of these functions can independently exist with power and other activities being located in different cities. For example, in Australia, Canberra though being the capital, has been able to retain its cultural status through deliberate governmental action. Cities like Sydney and Melbourne have however, been the established centres of the country. [1] [3] [4]

A. Impact of Globalisation and changing economic policies

Informational economy and globalization favour high order global cities resulting in an increased pressure within them. This is usually addressed by deconcentrating these facilities to smaller cities. Globalisation, when combined with economic policies, results in strategic changes of the economic structure of the city. Early decentralisation approaches backfired because of the resultant shift of industrial sectors and a subsequent decline of the manufacturing industry. Consequently, small zones adjacent to central business districts were targeted for intensive redevelopment through mega projects carried out by public-private partnerships. The modern version of such economic policies are the Special Economic Zones.

IX. Concept of Shifting Capitals

In the past century, numerous countries have had their capitals relocated to a greenfield site or within an existing city. Though the reasons are varied and often involve political motives, inefficiency and congestion within the old capital are the cited reasons.

Shift in capitals can be costly and cause disruption of the existing system of networks. Capital shifts need to be cautiously approached as these cities are often connectors between different regions of the country. Capital cities, now compete amongst one another for top-level global activities. A change would be equivalent to compromising on the position of the city, by implication, the country. Thus, shift in capital is a very sensitive and fragile activity for which utmost cautiousness needs to be taken. [3] [4]

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X. The Urban Design of Modern Capitals

The urban design of modern capitals also portray a broader pattern of politics. Dismemberment of nations led to the formation of many new capitals, many of which were not the capitals when the century began. Thus, a stark transformation is evident in the status quo of present day capital cities. [4]

However, capitals that have their very own memory of colonial trauma imprinted on them portrays a very different urban vocabulary than one that had always been independent. Two alternative strategies, physical eradication and symbolic reappropriation have been proposed by Neil Reich to deal with the architectural fabric of such cities. These strategies have been termed as the "Berlin Wall Syndrome" and the "Bucharest Syndrome" respectively. While the former aims at complete destruction of colonial traces, the latter rather focuses on superseding the memory with re-appropriation and re-use.

Purging an architectural fabric of the very intent it was built for has been achieved quite easily by changing the function. Roland Barthes statement on Eiffel tower - "use never does anything but shelter meaning" has been rightly interpreted by Reich as "use never does anything but generate meaning". For example, the very same colonnades used in the temples in Greece had been adopted in Nazi buildings to depict power in 1930s and later in libraries and museums in Britain. This is possibly why Fredric Jameson has called such buildings as 'inert', owing to the changing meaning depending on the function it carries. However, this neutrality of form changes when political aspirations and perceptions are projected on the form.

The urban design of modern capitals are thus tangible representations that focus on reinforcing the perception of national identity. This perception is built around certain objects of significance and highlights the necessity of aesthetics in the reinforcement of nationalistic ideals among the citizens. Thus, capitals often need to imprint its philosophies onto objects in space to instill and convey an identity unique to the nation. [5]

TABLE II. Comparative Analysis of Selected Capital Cities - Case of Brasilia, New Delhi and Washington D. C. [6] [7] [8]

Geography as a Comparative Factor			***Inference***
	Accessibility	***Topography***	
Brasilia	Coastal landmass with trade and economy dependant on both waterway and road	-	Importance to security and positions of dominance is evident in all the three cases, irrelevant of how democratic the nation's ideals may be
New Delhi	Landlocked landmass with the Yamuna and Hindon rivers flowing through the state	The initial design of imperial Delhi placed the Viceroy's House at the apex point. Grading error led the Secretariat buildings to dominate	
Washin-gton D. C.	The riverside and the hills are located at a very central position - binding the north and the south and the coastlines and the inland		

Power and Political History as a Comparative Factor		***Inference***
Brasilia	Colonisation by the Portuguese resulted in development along the water coastline. The city cores were neglected resulting in reduced development in the interior core of the city. However, afraid of external invasion, the Portuguese shifted their administration base to the interiors - the initial start of the capital Brasilia. Oscar Niemeyer was commissioned to design the capital city. A grand plan with emphasis	Political history plays a crucial role in the spatial expression of any capital city. The expression of freedom and the unlinking with the past is a flexible idea that can be conceived in numerous ways. It could also be based on the country's economic, social and political conditions.
New Delhi	Delhi had always been the capital for several empires and dynasties which ruled in the Indian subcontinent. The British overtook the Mughals and established a shift in capital from Calcutta to Delhi. The region provided good connectivity and close proximity to other British control centres like the military base in Dehradun. Also, the site location was in close proximity to the old Delhi and the forted capital complex of Shajahanabad. Occupying Delhi was a symbolic gesture to "quietly dominate them all" and establish control over the region.	
Washin-gton D. C.	Washington D. C. was the first post colonial capital city. United States, after gaining independence from the British, was the first of the independent countries to setup their capital new, rather than choose an existing urban centre. It was envisioned to become a binding, between the north and south, the coastlines and inland, a grand urban design gesture.	

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Need for the Capital as a Comparative Factor		***Inference***
Brasilia	The country needed political integration, which was clearly absent in a nation where most of the population lived along the coastline. The need for a new administrative centre was encouraged, possibly along a river, in the interior regions of the country that would also help build security.	The need for a capital may be rooted in an expression of power, for political and regional integration or as an expression of unlinking from the past.
New Delhi	Though an ex-imperial capital, Delhi post independence wanted to exhibit its expression of freedom. The existing power centre was well established and was also a passive and non-violent Gandhian way of taking back power.	
Washin -gton D. C.	An expression of independence from the British and also a region binding tthe north and the south, the inlands and the coast.	

Capital Classification and Function as a Comparative Factor		***Inference***
Brasilia	Political capital - created to contain the seat of power - city of exhibition of architect's ideas	A capital is selected based on the functions it already serves or has the potential for.
New Delhi	Political capital - created to contain the seat of power and also an ex-imperial capital - city of revival	
Washin gton D. C.	Political capital - created to contain the seat of power - a precedent for modern day capital	

Built Expression - Planning Principles as a Comparative Factor		***Inference***
Brasilia	Focus on the Capitol Complex, and its representation as the seat of power. The administrative buildings consists of the Three Powers Plaza, and the three wings of the government – The Legislative, The Executive and The Judiciary Non conventional modern architecture, structural innovations, automobile friendly complex Capital complex does not end in a magnificent building - but to an open landscape Distinct landuse principles - housing separated from transportation spine High apartment buildings to free up space for green zones	International planning principles as propagated worldwide were adopted to be at par with the 'modern' times
New Delhi	New Delhi was envisioned to be a capital with great connectivity to the major elements across the city and the surrounding elements around Delhi	
Washin -gton	Precedent for all future capitals of the modern day society	

Built Expression - Planning Principles as a Comparative Factor		***Inference***
D. C.	Grid-iron pattern based on selection of important nodes and viewpoints. Along the cardinal directions with piercing diagonal roads Emphasis on Grand Edifices and Grand Squares The centrality of Washington was the ideal representation of the Federal Government that United States stands for Monumental core with government facilities and museums - a circle of tourism, commercial and media attention	

Built Expression - Scale as a Comparative Factor		***Inference***
Brasilia	Emphasis on monumentality - for government buildings and residences alike as emphasis to skyscrapers was adopted	Monumentality and inhuman scale could not be left out of design - significance of prevailing authority
New Delhi	Monumental core, a reminder of British supremacy in the Indian subcontinent.	
Washin -gton D. C.	Monumental core with government facilities and museums - a circle of tourism, commercial and media attention	

Built Expression - Architectural Style as a Comparative Factor		***Inference***
Brasilia	Based on the ideals of the Athens Charter by Le Corbusier Distinct landuse principles - housing separated from transportation spine High apartment buildings to free up space for green zones	While Brasilia boasted of modernity and sophistication, Washington D. C. and New Delhi emulated grand design schemes with distinct architectural pattern
New Delhi	Drew inspiration from the French Versailles style (Garden City concept) and L'enfant's plan for Washington D. C.	
Washin -gton D. C.	Versailles style of design, with emphasis to the Garden Plan - French origin	

Built Expression - Figure Ground Diagram as a Comparative Factor		***Inference***
Brasilia	 Coarse grain, uneven texture exhibiting separate landuse and functions	Focus points and nodes of character can be easily predicted by analysing the figure ground diagram. Common power nodes are common in all

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Built Expression - Figure Ground Diagram as a Comparative Factor		***Inference***
	Centrally located government complex	the three cases
New Delhi	 Grand axis to the centre - symbolic representation of power and dominance of the government Coarse grain uneven texture at the complex core. Diffuses to fine grain even texture as the city expands	
Washin -gton D. C.	 Strong grid iron pattern exhibiting dominance of the government	

XI. Conclusion

The varying notions of capital cities and their impact on capturing the sentiments of its people can be analysed through various capital city designs. While some capital cities like Washington D. C. took efforts to change its built expression for a second time, countries like India and Brasilia has continued to run its government from the imperial centres. However, it should also be noted that countries like Washington D. C. could actually afford to come up with replans. Most other colonies were drained off their wealth and resources and could not consider an elaborate replanning affair. Also, retaining the imperial capitals and their built form to integrate the democratic ideals adopted is a passive expression of conquering dominance.

However, the common underlying emotion is the expression of freedom variedly expressed in the built form. These capital cities, even though their birth ranges from the eighteenth to twentieth century, have exhibited how the Government has been the supreme and how democracy was overruled by designs that took years to be inhabited.

A strong dichotomy of symbolism exists between built expression of an open democratic system and a strong sense of security and dominance that makes governments seem far away from the ideal it stands for.

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References

[1] Alexander R. Cuthbert, The Form of Cities: Political Economy and Urban Design, pp. 79-100

[2] Peter Hall, Seven Types of Capital Cities, In Planning Twentieth Century Capital Cities, 2006, pp. 25-31

[3] David L. A. Gordon, Planning Twentieth Century Capital Cities, London: Routledge, 2006, pp. 18-24

[4] Lawrence J. Vale, The Urban Design of Twentieth Century Capitals, London: Routledge, 2006, pp. 32-54

[5] Neil Leach, Erasing the Traces: Berlin and Bucharest, In The Hieroglyphics of Space: Reading and Experiencing the Modern Metropolis, London and New York: Routledge, 2002, pp. 80-91

[6] S. D. Joardar, New Delhi: Imperial Capital to Capital of the World's Largest Democracy, In Planning Twentieth Century Capital Cities, 2006, pp. 199-212

[7] S. F. Geraldo Nogueira Batista, Brasília: A Capital in the Hinterland, In Planning Twentieth Century Capital Cities, 2006, pp. 181-198

[8] I. Gournay, Washington: The DC's History of Unresolved Planning Conflicts, In Planning Twentieth Century Capital Cities, 2006, pp. 132-146

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Form Based Code as a tool for creating sustainable mixed use neighbourhoods

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***Abstract*— Form Based Codes have emerged as a powerful alternative to conventional zoning and building regulations. It focuses mainly on the physical form rather than the segregation of uses. Concept of sustainability and sustainable cities have emerged in the 21st century as a result of concerns about over exploitation of resources, climate change, increased rate of pollution etc. Form Based Code can be used as an effective tool for the creation of sustainable neighbourhoods.**

In the first part the concepts of Form Based Code and sustainability are studied based on the literature available. From this study parameters of economic, environmental and social dimensions of sustainability interlinked to Form Based Codes are derived for the analysis of the case studies. Three international literature case studies of Form based Codes of Hercules, California; Cincinnati, Ohio; and Flagstaff, Arizona are analyzed based on these identified parameters.

From these literature case studies, it is found out that some of the sustainable aspects like employment opportunities, percentage of green spaces, sustainable mobility, air quality and noise, compact and complete neighbourhood, heritage, urban safety, public participation are existing in most of the Form Based Codes. While the environmental aspects like topographical considerations, water management, waste management and use of alternative energy sources are not considered in most of the codes. Flagstaff act as an effective case study which addresses most of the sustainability aspects in its Form Based Code. From all these studies general guidelines and framework for Form Based Code for the creation of sustainable neighbourhoods are derived, these are derived from the limited number of literature studies and literature case studies. These can be further elaborated and added upon with more extensive studies. That will be beneficial for creating sustainable neighbourhoods for better future of the world we live.

Keywords—Form Based Code; Sustainability; Mixed use neighbourhood.

I. INTRODUCTION

Development regulations are for the controlled growth and development of our cities. The main focus of these regulations and controls are for the creation of sustainable human settlements. Form Based Code is a regulatory tool that has been formed as a response to the outdated conventional regulatory tools, such as conventional zoning, zoning design guidelines. These conventional tools only focuses on blanket development controls which lack to address the aspects of integrated built forms and creation of quality public realm.

Sustainability is a major concern in the present context of uncontrolled urban growth. The creation of sustainable neighbourhoods will help to improve the quality of life of the inhabitants. Even though Form Based Codes are associated and discussed in the basis of sustainability some of the aspects are not discussed or addressed. It is necessary to address the parameters of sustainability in Form Based Codes for better future development of our neighbourhoods.

II.SYNOPSIS

A. Research Question

How Form Based Code can be used as a tool for creating sustainable mixed use neighbourhoods?

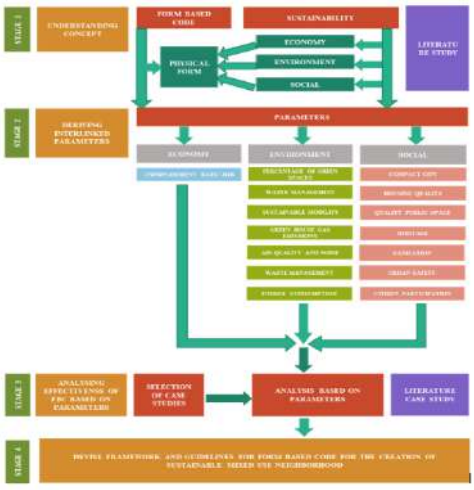
B. Aim

To devise Form Based Code for developing sustainable mixed use neighbourhoods.

C. Objectives

- To understand the concept of Form Based Code and sustainability.
- To derive parameters which are interlinked with these concepts.
- To understand and analyse effectiveness of Form Based Codes in development of sustainable mixed use neighbourhood based on these parameters.
- To derive comprehensive framework and guidelines for Form Based Code for the creation of sustainable mixed use neighbourhoods.

D. Methodology



E. Relevance of the study

Form Based Codes have emerged as an alternative to conventional zoning and building regulations focuses on comprehensive development and aims to economic, social and environmental sustainability while ensuring community involvement.

Concept of sustainability and sustainable cities have emerged in the 21st century as a result of concerns about over exploitation of resources, climate change, increased rate of pollution. Urban policies and strategies are infused with the language of sustainability, and large number of initiatives can be found all around the world. The aspects of sustainability should be addressed from the neighborhood level because initiatives towards sustainability should start from grass root level that will have great impacts. FBC as an effective tool can be used for the creation of sustainable neighborhoods. By analyzing Form Based code in the aspect of sustainability will be beneficial for remolding it for the creation of sustainable neighbourhood developments. For that it is important to check the extent and degree to which aspects of sustainability addressed in the existing Form Based Codes. By creating a general framework will ensure to address the sustainability aspects of the future developments.

III.LITERATURE REVIEW

A. Form Based Code

According to the definition of Form Based Codes Institute, USA

"A form-based code is a land development regulation that fosters predictable built results and a high-quality public realm by using physical form (rather than separation of uses) as the organizing principle for the code. A form-based code is a regulation, not a mere guideline, adopted into city, town, or county law. A form-based code offers a powerful alternative to conventional zoning regulation".

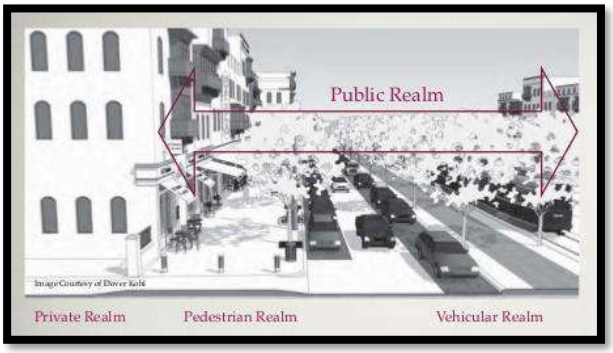


Figure 1:Figure showing public and private realm (Source:https://www.slideshare.net/APA_Orange/introduction-to-form-based-codes)

Form Based Codes are created to physically define streets and public spaces as places of shared use, and to create compact, pedestrian friendly mixed use neighborhoods. These codes have been adopted in a number of cities and towns all around the world as an alternative to conventional zoning. Instead of organizing by uses FBC generates zones according to character and intensity. It addresses the concerns of community, the existence of small and large lots in residential areas and the coexistences of compatible uses.

When comparing with the conventional zoning regulation tools Form Based Codes focus on the creation of integrated built forms which creates quality public realm. while the conventional tools concentrate on the land use segregations and control of development intensity through uncoordinated parameters such as F.A.R, setbacks, coverage, etc.

Figure 2: Illustration showing basic features of Conventional Zoning, Zoning Design Guidelines and Form Based Codes (Source: https://formbasedcodes.org/definition)

In the past half centuries urban development, the regulations are more concerned about the land uses which tries to prevent undesirable juxtapositions and incompatible scale of developments etc. which resulted issues like separation of compactible uses, sprawl and disassembling of cities. As a response to this issues form based codes emerged in the 1980s which mainly focuses on shaping physical form of communities that integrate all concerns of community.

According to Peter Katz of the Form-Based Codes Institute, advantages of form-based codes include the following. It is prescriptive in nature, encourage public participation in the planning stages, prevent the need for megaprojects, Results reflects diversity of architecture, materials, uses and ownership, It work well in established communities because it effectively codify a neighborhoods existing DNA, because of the shorter, concise and organized rules it is easier for non-professionals to work with these rules, it prevent the issues related with subjective interpretations which is a prevailing issue associated with design guidelines.

B. Sustainability

Concept of sustainability and sustainable cities have emerged in the end of 21st century as a result of concerns about over exploitation of resources, climate change, increased rate of pollution etc. The three dimensions of sustainability are the socio cultural, environmental and economical. We have to address these Three dimensions to achieve sustainable development.

Figure 3:Venn diagram representing the standard dimensions of sustainable development. (Source: Science for Environment Policy, in-depth report: Indicators for Sustainable Cities)

The concept of need for sustainable development was first addressed in the 1987 Bruntland Commission Report. which is formed as a result of the concerns like negative environmental consequences of economic growth and globalization. The report tries to find possible solutions to the problems such as

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rapid and haphazard urban growth which is the by-product of industrialization and population growth. According to the Bruntland Commission Report of 1987 sustainable development is defined as: "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs."
sustainability is often thought of as a long-term goal (i.e. a more sustainable world), while sustainable development refers to the many processes and pathways to achieve it.

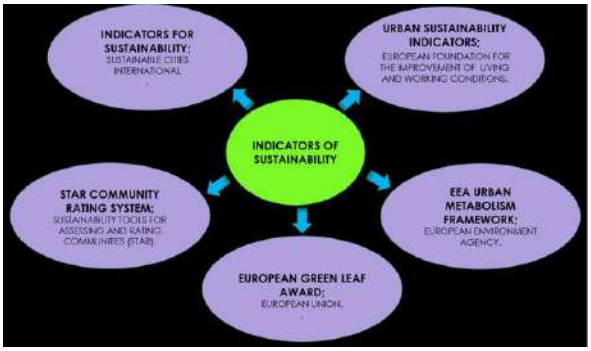

Figure 4: Figure showing some of the selected indicators of sustainability (Source: author)

From these indicators sustainability parameters which are interlinked to physical form are derived for analyzing the Form Based Codes. These are;

Economic parameters

1. Job/Employment rate

Environmental parameters

1. Green spaces (percentage of preserved area)
2. Water management (quality, availability)
3. Sustainable mobility
4. Greenhouse gas emissions-global climate
5. Air quality and noise
6. Waste management (waste/reuse/recycle)
7. Energy consumption/efficiency

Social parameters

1. Complete neighbourhood/ Compact city
2. Housing quality
3. Quality public space
4. Heritage
5. Sanitation
6. Urban safety
7. Citizen participation

IV. LITERATURE CASE STUDY

Three case studies are selected for the analysis of the sustainability aspects in Form Based codes, that are form based codes of Hercules, California; Cincinnati, Ohio; and Flagstaff, Arizona.

A. Case Study 1: Hercules, California

Hercules is a city in western Contra Costa County, California. Form Based Code of Hercules was enacted in the year 2001. The City of Hercules created the vision for the Central Hercules Plan through a design session involving the community and a team of design professionals. Traditional urban design conventions are utilised to create the standards of the code including the street standards. The regulating plan divides the Central Hercules into 4 districts, which are Waterfront District, Central Quarter, Civic centre and Hill town.

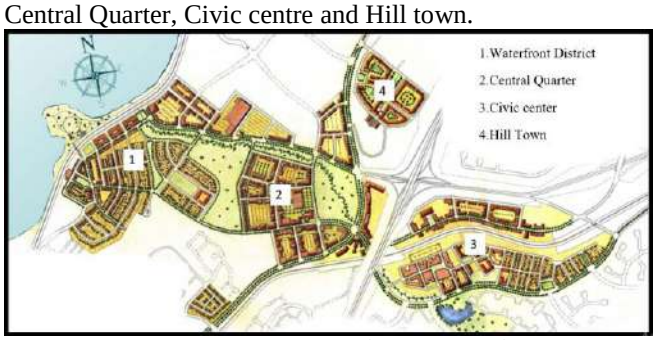

Figure 5: Regulating Plan of Hercules, California
(Source: Regulating Code for Central Hercules plan)

Development under this Code is regulated by street type. The various street types are related to each other in a hierarchical manner.8 street Types are defined in this code.

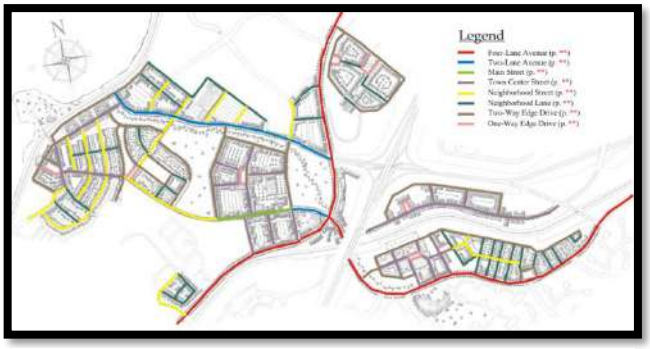

Figure 6: Hierarchy Of Street Type; Hercules, California
(Source: Regulating Code for Central Hercules plan)

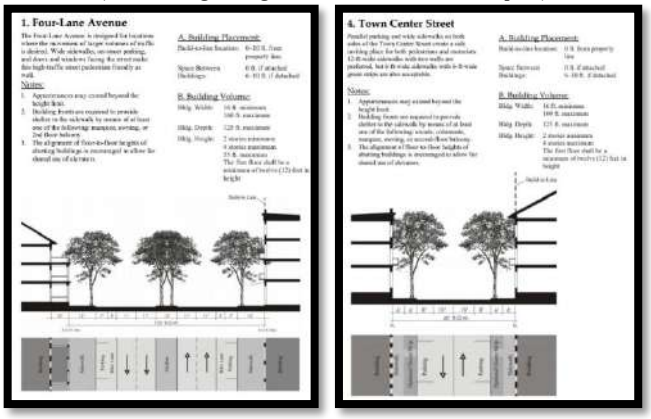

Figure 7: Example of Street Type Standards
(Source: Regulating Code for Central Hercules plan)

The Central Hercules Form Based Code encourage the creation of compact, pedestrian friendly neighbourhoods. The vision for the code was developed through community participation approach which will address the concerns of the user community. Traditional urban design conventions are utilised to create the standards of the code including the street standards. Street type standards define the basic characteristics, building placement and building volume in relation to the street type. The Notes describe about the basic requirements in general according to the use of street. The Minimum and

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Maximum Height of the buildings are given there by assuring the enclosure quality of the street types.

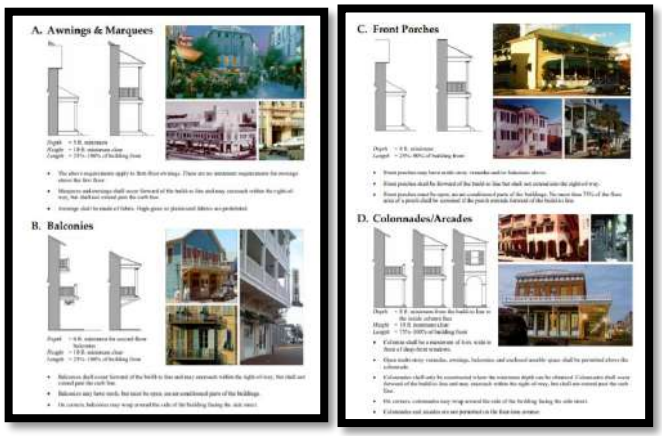

Figure 8: Example of Projecting Facade Elements Standards
(Source: Regulating Code for Central Hercules plan)

Projecting façade elements standards define the minimum depth, height and length of the elements. helps to improve the pedestrian walkability and open projected elements helps to improve safety in the streets.

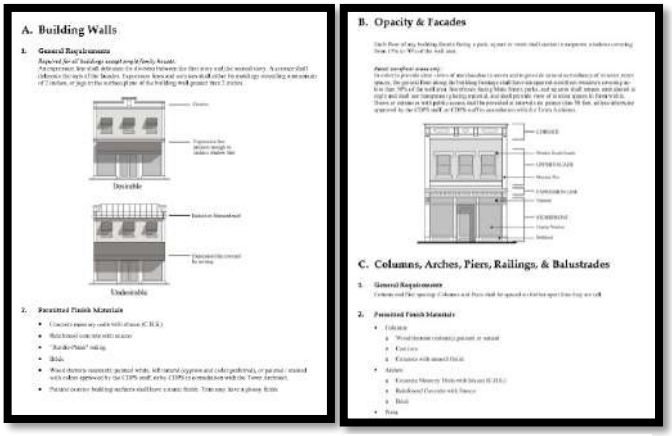

Figure 9: Example of Architectural Regulations
(Source: Regulating Code for Central Hercules plan)

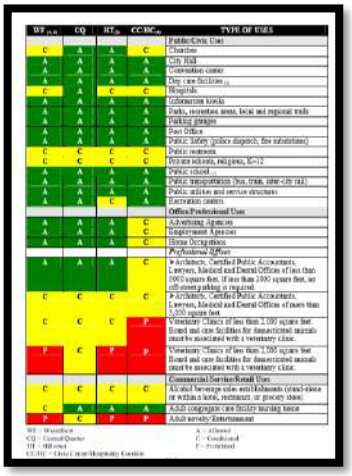

Figure 10:example Approved and conditional uses regulations (Source: Regulating Code for Central Hercules plan)

The architectural standards define the architectural elements which is coming within the public realm. Thereby assuring the desirable visual results without compromising the functions. The character of the place is maintained through these standards.

Approved & conditional uses regulation restrict or controls the undesirable uses within each of the four character districts. The uses are defined as Allowed, Conditional and Prohibited. This gives control to the authority in the mixed uses thereby maintaning the character without disturbing the harmony of the place.

The creation of mixed use neighbourhoods by the use of this code helps to reduce the commutation distances between live-work-recreation spaces. The creation of local economic opportunities is attained through this mixed use neighbourhoods. Also this code helps to improve the pedestrian environments in the streets and aids to create quality public realm through the definitions of building form standards, street standards, architectural standards etc. As a result of all of this decrease in the use of vehicular transportation modes, increase in the pedestrian mode of transportation thereby improving sustainable mobility. Reduction in the unsustainable transportation modes will have greater impacts in the rate of air and noise pollution. The aspects of physical infrastructure development as well as activity generation is included for improving and encouraging walkability in the streets. The commercial active spaces and projected balcony spaces and windows looking towards the streets will improve the safety in the streets. This will eliminate the chances of creation of negative spaces. The effective preservation of green open spaces both public as well as private are achieved through the regulation plan. The aspects of alternative energy resources, water management, waste management and sanitation are not included in this case and also the changes in topographical conditions are not addressed in this code.

B. Case Study 2: Cincinnati, Ohio

Cincinnati is a major city in the U.S. state of Ohio, and is the government seat of Hamilton County. Cincinnati is set on the north bank of the Ohio River in a narrow, steep-sided valley on the Ohio-Kentucky border in south western Ohio. Cincinnati Form Based Code developed in the year 2013.

Figure 11: Cincinnati Transect (Source: Cincinnati FBC)

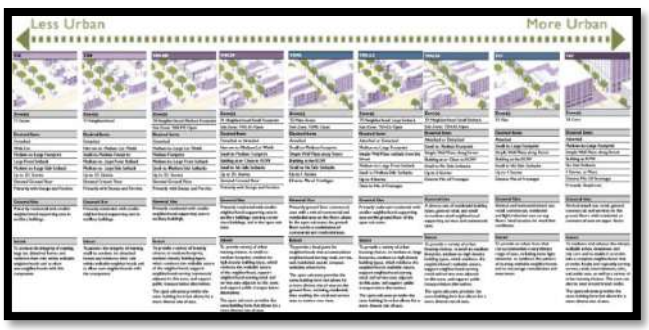

Figure 12: Cincinnati Transect Summary (Source: Cincinnati FBC)

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Plan Cincinnati categorizes the City into three types of places or contexts: natural places; walkable urban places; and drivable places. The Cincinnati transect is divided into 9 transects from less urban to more urban (T3 to T6). The development regulations in the Form Based Code are developed based on the context and setting of each transect. Desired form, General Use and Intent of each transect are clearly defined in the transect summary part. The city, neighbourhood and individual block level guiding principles are defined to achieve the vision which is derived with community participation. The character of each transect is defined clearly and controlled through this code.

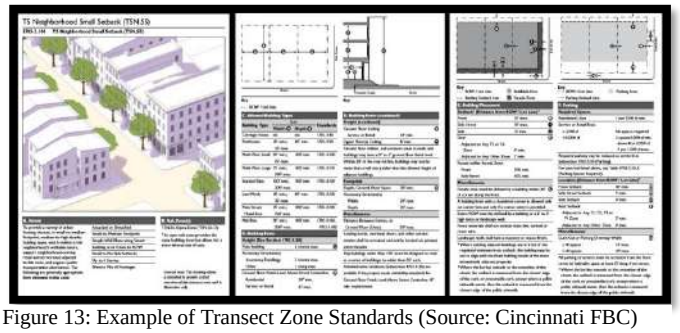

Figure 13: Example of Transect Zone Standards (Source: Cincinnati FBC)

Figure 14: Example of standards specific to Building type (Source: Cincinnati FBC)

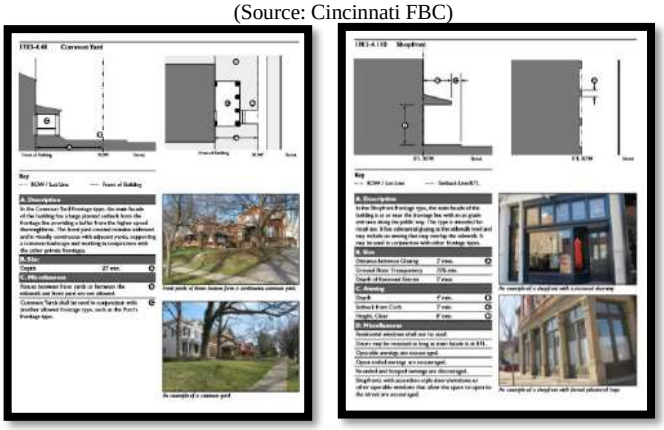

Figure15: Example of standards specific to Frontage type (Source: Cincinnati FBC)

The code defines the standards specific to building type as well as frontage types apart from the transect zone standards. Similar to the case study of Hercules it allows for the creation of compact, pedestrian friendly mixed use neighbourhoods but standards are defined elaborately in detail in this case when comparing with the first case. The public space standards are clearly defined with basic characteristics and minimum requirements in all hierarchical levels.

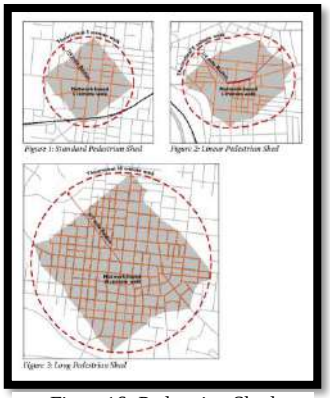

Figure16: Pedestrian Shed standards (Source: Cincinnati FBC)

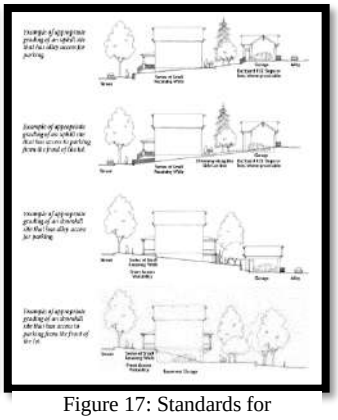

Figure 17: Standards for Topography and Hillside Overlay Districts (Source: Cincinnati FBC)

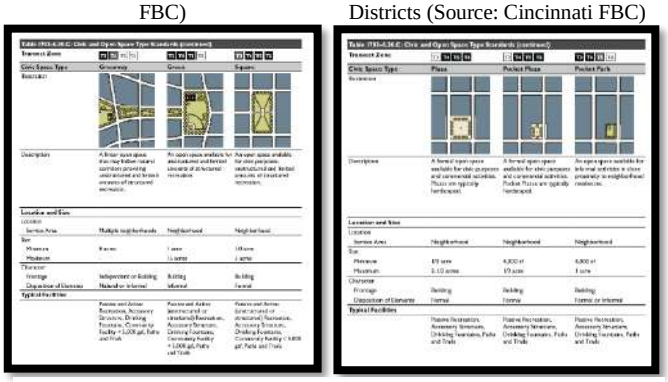

Figure 18: Public space standards (Source: Cincinnati FBC)

Changes in the topographical character is addressed, which gives certain standards for buildings and access roads when constructing in the hillside overlay districts. Historic landmarks and districts are defined to include the characteristic of heritage into the code. Similar to the first case study aspects of alternative energy resources, water management, waste management and sanitation are not included in this case.

C. Case Study 3: Flagstaff, Arizona

Flagstaff is a city in and the county seat of Coconino County in northern Arizona, in the south western United States. Located next to the largest contiguous ponderosa pine forest in North America. The Flagstaff Form Based Code enacted in the year of 2011.

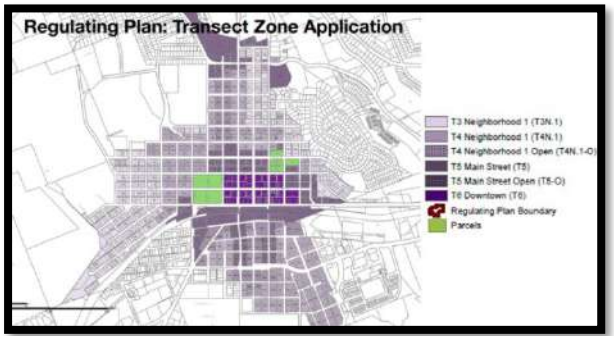

Figure 19: Regulating plan of Flagstaff Transect zones (Source: Our Flagstaff Land Development Code Rewrite: Charrette Summary Report)

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Flagstaff is divided into 6 transects zones starting from T1 to T6. The Transects are divided according to the character and purpose of the area. Desired Form, Intent and General Use of each transect is defined in the summary. The Flagstaff Form Based Code is one of the best example of how sustainability aspects are incorporated into the Form Based Code.

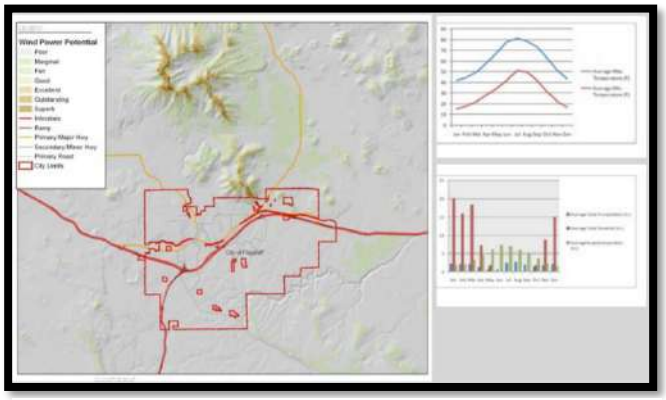

Figure 20: Wind power potential map of Flagstaff, Arizona (Source: Our Flagstaff Land Development Code Rewrite: Charrette Summary Report)

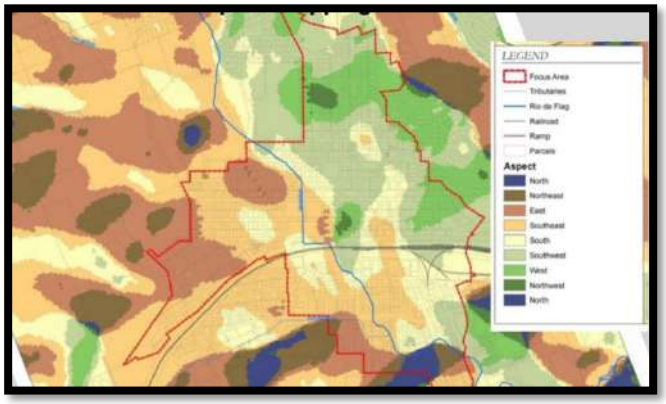

Figure 21: Solar aspect map of Flagstaff, Arizona (Source: Our Flagstaff Land Development Code Rewrite: Charrette Summary Report)

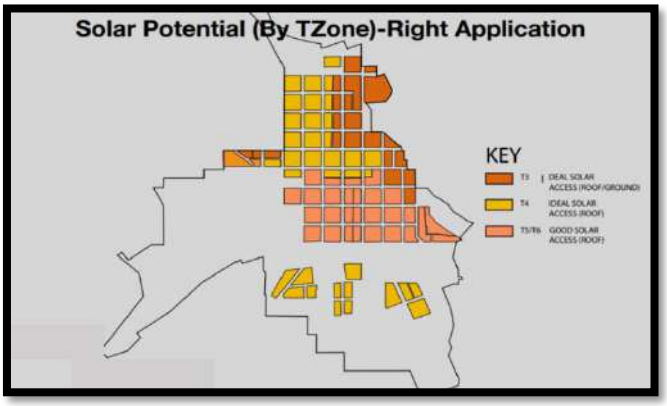

Figure 22: Solar power application transect map (Source: Our Flagstaff Land Development Code Rewrite: Charrette Summary Report)

Apart from the aspects of sustainability which is addressed in the above two case studies this code includes chapter for sustainability features, which focuses on Storm Water Features, Water Conservation, Energy features etc. Application of alternative energy resources such as wind power and solar power is implemented through the analysis of solar aspect map and wind power potential map etc. With the analysis of this studies each transects are defined with the implementation of the use of these energy resources.

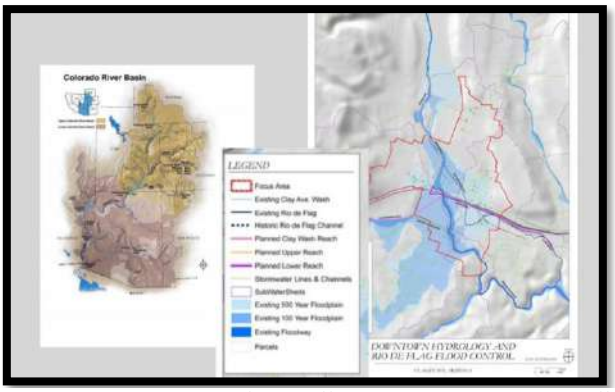

Figure 23: Hydrology map of Flagstaff, Arizona (Source: Our Flagstaff Land Development Code Rewrite: Charrette Summary Report)

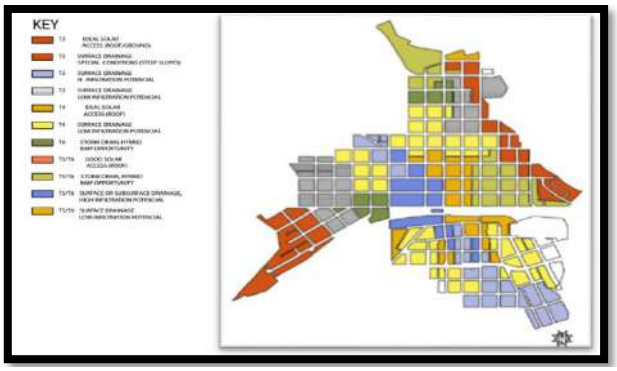

Figure 24: Storm water application transect map (Source: Our Flagstaff Land Development Code Rewrite: Charrette Summary Report)

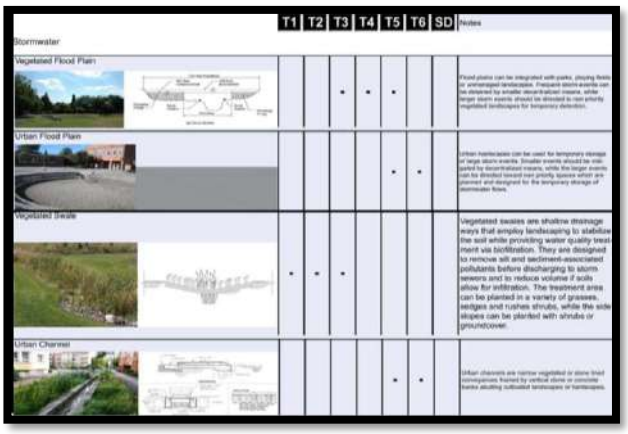

Figure 25: Details of Storm water application standards (Source: Our Flagstaff Land Development Code Rewrite: Charrette Summary Report)

Other important feature of this code is the implementation of water management plan, which includes Storm water, Rainwater Harvesting, Waste water management. This water management plan is prepared with the analysis of hydrology map of Arizona. Storm water applications are assigned for each transect with the analysis of the surface drainage, infiltration potential and slope characteristics of the areas.

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When comparing with the other case studies this one addresses most of all the aspects of sustainability. This case study is a useful reference for the formulation of general framework for Form Based Code for the creation of sustainable mixed use neighbourhood.

V. CASESTUDY ANALYSIS

Table 1:comparative analysis of the sustainability indicators included in all the three case studies (source: author)

	HERCULES	CINCINNATI	FLAGSTAFF
ECONOMIC INDICATORS			
Job / Unemployment rate	●	●	●
ENVIROMENTAL INDICATORS			
Green Spaces	●	●	●
Water Management (Quality, Availability)	●	●	●
Sustainable Mobility	●	●	●
Greenhouse Gas Emissions-global Climate	●	●	●
Air Quality and Noise	●	●	●
Waste Management (Waste/Reuse/Recycle)	●	●	●
Energy Consumption/Efficiency	●	●	●
SOCIAL INDICATORS			
Complete Neighbourhood/ Compact City	●	●	●
Housing Quality	●	●	●
Quality Public Space	●	●	●
Heritage	●	●	●
Sanitation	●	●	●
Urban Safety	●	●	●
Citizen Participation	●	●	●
● INCLUDED ● NOT INCLUDED			

Form Based Codes are used for the creation of compact, pedestrian friendly mixed use neighbourhoods. In all of the three case studies discussed this aspect is clearly established and achieved. The sustainability factors attached with these characteristics such as creation of local employment opportunities with mixed land use, reduction in the use of vehicular transportation due to the reduction in travel distances between live, work and recreation spaces as well as improvement in pedestrian friendly environment, reduction in use of renewable energy for transportation, decrease in noise and air pollutions associated with vehicular transportation modes are achieved in all of these case studies. Community Participation in the creation of the vision and objectives of the code address the social sustainability factor.

The other aspects of sustainability such as topographical and ecological considerations should be included in these codes for creating better sustainable neighbourhood. Topography has a greater impact on the built use, the building form and the access to the building, so it is important to consider the topographical conditions of the area right from the transect regulating plan level. Water management is one of the major concerns of the future. The proper use and application of storm water is important while creating the Form Based Code. Rain water harvesting strategies can be incorporated into the plan from city level to individual plot level for a sustainable future. The application of alternative energy sources such as solar and wind power can be included in the Form Based Code. So we need to redefine form based codes with considering these aspects for an integrated and sustainable development for a better future of the world.

VI. RECOMMENDATIONS

Form Based Codes are context specific and it is difficult to define specific strategies for them. Some of the general guidelines and recommendations which is to be considered while the creation of Form Based Codes derived from the studies are stated below;

A. Economic considerations

- Employment: The form Based Code regulations built use control should ensure to provide adequate percentage of job opportunities in the neighbourhood level. The percentage of built use should be derived based on the analysis of demography, prevailing trends in commercial sector, future economic scopes in the area.

B. Environmental considerations

- Green spaces: Well defined open space structure of the area should be integrated into the regulatory plan. Adequate percentage of open green spaces should be provided all hierarchical levels with proper definition of character, quality standards and functions of the area.
- Topography: The topographical conditions of the area should be considered into right from the transect regulating plan level to the building form and other standards like the street standards including access roads into the buildings.
- Hydrology/Water Management: storm water management plan should be incorporated into the Form Based Code considering surface drainage, infiltration potential and slope characteristics of the areas. Application strategies from transect level to individual plot level should have to define. The hierarchical level application should have an integrated management of the storm water for the area.
- Sustainable Mobility, Greenhouse gas emissions, Air quality and Noise: The public space standards and building form standards should ensure to create pedestrian friendly environment and also non motor vehicular mode of transportation. It should be well integrated with the total mobility of the area in all hierarchical levels and should be incorporated into the regulatory plan.
- Waste Management: an integrated waste management plan should be integrated into the regulatory plan. Decentralized waste management units with standards

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defining the catchment area location should be defined. Position of city level recycling units and plants should be also defined for better management of waste.

- Energy consumption/ Efficiency: The application of alternative energy sources should be included in the Form Based Code. Resources Like Solar energy, wind energy can be utilized by defining proper applications in each transects, through the study of solar aspect maps, wind potential maps. The applications can be defined from city level to individual block levels for an effective use of the resources.

C. Social considerations

- Complete Neighbourhood/compact city: The built use allocation and transect regulatory plan should ensure to create a complete and compact neighbourhood/city. The uses should be compatible with each other and percentages of built uses should be based on the characteristics of the place.
- Housing Quality: The percentage of Housing typologies based on both ownership as well as economy and social status, location and the basic standards of housing qualities should be well defined in the Form Based Code.
- Quality Public space: Public spaces location, character, quality standards and functions should be clearly defined in the form based code. The standards should ensure to create Inclusive public spaces.
- Heritage: The heritage characteristics and context of the place should be addressed while defining the standards. Well defined conservation management plan should be integrated into the regulatory plan. Heritage zone should be clearly defined in the regulatory plan.
- Sanitation: An integrated sewage management plan should be incorporated into the regulatory plan considering the sources, processes disposal and alternative uses in all hierarchical levels.
- Urban safety: Form Based Codes should ensure to create safer built environments and public realm. It should also prevent the creation of negative spaces through the definitions of building form standards and public space standards.it can be achieved through ensuring physical and visual connectivity into the spaces.
- Citizen participation: the process of deriving the vision and Form Based Code for the development of the area should ensure to involve community participation.

VII. CONCLUSION

It is difficult to define Form Based Codes in general because it is site and context specific in nature. In the context of rapid urbanizations and haphazard development Form Based Codes has the potential to develop as a powerful tool for the creation of sustainable mixed use neighbourhoods. For that it is important to address the three dimensions of sustainability and all aspects involved with that which are interlinked with the physical form of the neighbourhood/city. some of the sustainable aspects like percentage of green spaces, sustainable mobility, employment opportunities, air quality and noise, compact and complete neighbourhood, heritage, urban safety, public participation are existing in most of the Form Based Code. The general framework and guidelines which is considering all the aspects of sustainability is derived from the limited number of literature studies and literature case studies. which can be further elaborated and added upon with more extensive studies. That will be beneficial for creating sustainable neighbourhoods for better future of the world we live.

ACKNOWLEDGMENT

We express our heartfelt gratitude our teachers, Dr. Bejene S. Kothari, Ar. Alok Dinesh, Ar. Biley Menon for their guidance and constructive critics.

REFERENCES

1. Form-Based Codes Institute (FBCI) Form Based Codes, Draft (2006) Available: https://formbasedcodes.org, Form-Based Codes Defined
2. Local Government Commission. (2005) Form-Based Codes: Implementing Smart Growth, Local Government Commission, Sacramento, CA.
3. Science for Environment Policy (2018) Indicators for sustainable cities. In-depth Report 12. Produced for the European Commission DG Environment by the Science Communication Unit, UWE, Bristol. Retrieved from http://ec.europa.eu/science-environment-policy.
4. Regulating Code for the Central Hercules Plan (2001) Available: https://formbasedcodes.org/content/uploads/2014/02/hercules-regulating-code.pdf.
5. City of Cincinnati Form-Based Code (2013) Available: https://www.cincinnati-oh.gov/planning /assets/File/CFBC%20Full%20Document%20Amended%202-10-14.pdf.
6. Flagstaff Zoning Code (2019) Available: https://www.codepublishing.com/AZ/Flagstaff/html/Flagstaff10/Flagstaff10.html.
7. Roger E. Eastman. (2013) Form-Based Codes, Flagstaff & Education: blog, education [online] Retrieved from https://formbasedcodes.org/blog/education/form-based-codes-flagstaff/.
8. Opticos Design, Inc. and Lisa Wise Consulting, Inc. (2010) City of Cincinnati, Ohio Form-Based Code Best Practices Report. Retrieved from https://www.cincinnati-oh.gov/planning/linkservid/B8C76FBA-E187-10DC-43EC759E0C1ED31C/sho.wMeta/0.
9. Opticos Design, Inc. and Lisa Wise Consulting, Inc. (2009) Our Flagstaff Land Development Code Rewrite: Charrette Summary Report Flagstaff, Arizona. Retrieved from Our Flagstaff - City of Flagstaff - AZ.gov.

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URBAN RESILIENCE INDEX AS AN INSTRUMENT TO SUSTAINABLE DEVELOPMENT

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Abstract— **Resilience is an organism's innate ability to resist a drastic change in its surroundings. It is the ability to bounce back. Over centuries humans have concentrated in cities due to agglomeration of economic opportunities and superior facilities. But concentration of this huge populace has also increased the vulnerabilities of these urban centers. Climate change and consequence of human development have further exacerbated the vulnerability of these urban centers. Studying resilience helps to understand the vulnerability of these urban centers and enable them to increase their capacity to bounce back. Resilience Index is an effective tool to understand and quantify resilience, that aids in reinforcing the areas which are less resilient and more vulnerable. The main aim of this study is to understand the concept of Urban Resilience - its various objectives and parameters, understanding the various facets which make up the Urban Resilience Index, examining the various frameworks that are in practice. A comparison of the various framework with the Sustainable Development Goals is done to modify the existing framework for Resilience Index so as to achieve Sustainable Development.**

Keywords— Urban Ecology; Urban Planning; Resistance; Mitigation; Preparedness; Resilience Index; Sustainable Development

I. INTRODUCTION

Resilience is the capacity of an ecosystem to respond to a perturbation or disturbance by resisting damage and recovering quickly. The perturbation or disturbances might be of any nature, from floods to drought, to manmade disasters like pollution and climate change, to epidemics. The concept of Resilience was introduced by the Canadian ecologist C.S. Holling, which was used to assess the persistence of natural systems in the dynamically changing world.

Urban resilience is the ability of any urban systems along with its citizens to continue on its trajectory despite any shocks and stresses it might go through and adapting and transforming itself positivity on the path towards sustainability. A resilient city plans, adapts, and prepares to respond to hazards of any nature, both expected and unexpected, and is greatly influenced by the quality of governance that is prevalent in the city that is in consideration. [1]

Understanding resilience requires understanding the various facets and dimensions that make up that city and requires a study into all these aspects. By strengthening these dimensions, a city can be more resilient and sustainable in nature. Resilience Index is a method through which resilience of a city can be measured and a baseline of a city's resilience can be created. The measurements also portrays the strengths and potentials as well as the weakness of the city in consideration. Some of the common methods of resilience index are – Climate and Disaster Resilience Index (CDRI), City Resilience Index (CRI) and Community Based Resilience Analysis (CoBRA).

A. Need for Resilience

Since 1980s the amount as well as the severity of the disaster have been on the rise. This has led to significant economic losses due to the rise in such disasters. Economic losses from 'natural' disasters are now reaching between $150-$200 billion each year, up from $50 billion in the 1980s, while projected future disaster losses in the built environment alone are estimated at $314 billion per year (UNISDR, 2015a).[2]

The occurrence of such disasters has enabled the vicious cycle of poverty to continue. It is projected that by 2030 about 325 million extremely poor people are expected to live in 49 countries exposed to natural hazards and climate extremes, with most of them concentrated in South Asian and Sub-Saharan Africa. [2]

B. Qualities of Resilient Systems

Reflective is the inherent property of the system to accept the changes that are occurring in today's world. Robust is the system's ability to withstand the stresses. Redundant is the ability of the system to use spare resources in case of an emergency. Flexibility is the system's ability to adapt easily to any change or transformations. Resourcefulness means the

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ability of the inhabitants to meet their goals and target with the available resources. Inclusiveness means the inclusion of all in the decision-making processes. Integrated refers to the alignment of the decision makers and the needs to the system. [3]

C. Scale of Resilient Systems

Depending on the need and requirements, resilient systems can vary from an Individual who is knowledgeable and skilled, to a Household level with skilled and knowledgeable personnel, to Community, Local Governmental, National Level, Regional or Global level.

II. URBAN RESILIENCE

Urban Resilience is generally defined as the measurable ability of the urban systems including its inhabitants to maintain continuity despite the shocks and stresses. [4]

Urban resilience refers to the ability of an urban system-and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales-to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity. [4]

Under this definition of Urban resilience, it is lively in nature and there are multiple ways of resilience. Cities which do not plan or are unable to recover from the shocks and stresses tend to accumulate the negative effects of theses stresses, with the city eventually crumbling functionally and putting its people at risk. [4]

A. Dimensions of Urban Resilience

In order to understand the various aspects of the city in question, there is a need to define the various dimensions that are needed to study the resilience of a place. Although ideally the dimensions must be formulated contextually, generally to ensure that all the aspects have been considered, the following dimensions, viz., Materials and Environmental Resources, Society and Well-Being, Economy, Built Environment and Infrastructure, Governance and Institutions, have to be considered. [4]

B. Characteristics of Urban

Urban systems are a culmination of ecological, social, and technical components. Globalization has led to the intensifications of relations between these urban centers and the hinterlands surrounding these cities, with the exchange of materials, water, energy, capital, etc.. City and ‘hinterland’ are highly interdependent, making clear delineation of urban boundaries problematic. [4]

C. Notions of Equilibrium

Resilience literature considers 3 main states of equilibriums, which are as follows - single-state equilibrium, multiple-state equilibrium, and dynamic non-equilibrium. [4]

Single state equilibrium is the one in which the systems return to the original state after the perturbations have passed. Multiple state equilibrium is the one in which system has various stable states and during a disturbance, it flips from one state to another. Dynamic non equilibrium state is the state which has no stable state and is constantly evolving. In the recent years, with regards to resilience, there has been a shift from single state equilibrium, to multiple or dynamic state equilibrium. [4]

D. Pathways To Urban Resilience

The literature when talking about Resilience, talks about three main pathways to a resilient state. They are persistence, transition, and transformation. Persistence mainly corresponds to the system’s ability to retain its status quo without changing itself self, which is what the earlier definitions of resilience attributed to. Transition is the slow shift from the present state to a more resilient state, while transformation is a more rapid shift. In particular, when a system is in a robustly undesirable state, efforts to build resilience might seek to purposefully and fundamentally change its structures. [4]

E. Urban Sustainability And Urban Resilience

Urban resilience and Urban Sustainability mean different things despite sharing some similarities. Cities because of their inherent nature are said to be largely resilient and complex systems. As the cities keep growing more money is put into developing and expanding the infrastructure. This is projected to be about $95 Trillion in the next decade, and the difference between sustainability and resilience should be sought to help ensure that this infrastructural growth is beneficial to the masses. Any city has various pathways it could develop in, with Business as usual to positive transformations, whose resilience can vary. While sustainability is seen as the goal to achieve, resilience is the capability to strengthen the pathway to sustainability. [5]

F. Understanding of Adaptation

This aspect mainly deals with the nature of adaptability that the system is to face. They can be “Specified Resilience” or “General resilience”. Specified Resilience is the ones in which the systems are planned to be resilient to a few or limited disturbances, while general resilience is broader in scope and is considered to be more adaptable in nature. [4]

G. Timescale of Action

Time is an essential factor when it comes to resilience, with the cities which have a short time to reach a resilient state being more resilient in nature. Most Research acknowledge the importance of rapid recovery post-disturbance. Temporal emphasis is often contingent on whether the focus is on rapid-onset disasters or more gradual climactic change. [4]

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H. Measuring Urban Resilience – Resilience Index

Resilient communities are far less vulnerable to hazards and disasters than less resilient places. For this assumption to be validated and useful, knowledge of how resilience is determined, measured, enhanced, maintained, and reduced is vital. In the hazards arena, most of the resilience models involve engineered systems. In these frameworks, the properties of resilient infrastructure—robustness, redundancy, resourcefulness, and rapidity—reduce the probability of failures. Yet these frameworks often fail to capture antecedent social factors that occur at the most local levels or to account for the vulnerability or resilience of the natural environment. [4]

Resilience measurements have two qualities, one is inherent, in which the measurement during the normal state, and adaptive which is just post a disaster.

III. Existing Frameworks of Resilience Index

Various frameworks of measuring resilience index exist and some of these frameworks are discussed in brief.

A. Climate Disaster Resilience Index (CDRI)

Climate Disaster Resilience Index (CDRI) has developed about climate change in Tokyo University by Shaw (2009). This model presented five dimensions for urban resiliency and for each dimension developed its indicators. CDRI also assess the urban resiliency in nine Asian countries including Indonesia, Thailand, Sri Lanka, Vietnam, Philippines, India, and Japan. [6]

This framework consists of a questionnaire based on 5 dimensions each with 5 parameters defining it in detail. Each of the 5 parameters are define by 5 variables. In short, 125 variables help define the resilience of the city in consideration. [6]

The five dimensions in question are - Physical, Social, Economic, Environmental, and Institutional. The respondents, the municipalities, were asked to pick a score of 1 to 5, to grade the various parameters of that dimension. Mean Index or AWMI (for each dimension) was calculated by using Weighted Mean Index (WMI) method, which was the score for that particular dimension of the city. The scores obtained are represented graphically in a spider diagram. [6]

In the study organized in 12 cities in India, Port Blair and Nagpur were seen to have the highest CDRI scores. Even though theses scores can't be compared due to the differences in the context, there are some similarities in the results. The cities which have good physical infrastructure, less unemployment, and relatively good flat terrain are said to be more resilient. [6]

B. City Resilience Index (CRI)

City Resilience Index is a new framework that was formulated by ARUP and Rockefeller Foundation in 2014 under the City Resilience framework, which provides a holistic articulation of city resilience, structured around four dimensions and 12 goals that are critical for the resilience of our cities. [7]

CRI aims to measure the resilience of a city over time rather than assign a score to the city's resilience. This initiative aims to create a network of 100 resilient cities, not with the aim of ranking them, but with aim to enable knowledge sharing to make these cities more resilient. [7]

The frame essentially has 4 dimensions, 12 goals, and 52 indicators. The four dimensions are – Health and Wellbeing, Economy and Society, Infrastructure and Ecosystems, and Leaders and Strategy. The questionnaire comprises of 156 questions. The framework utilizes both Qualitative Measurements which can used to evaluate the quality of the various indicators while Quantitative Measurements can help in gauging the performance of the various indicators. As Resilience is an abstract concept, the measurements over a period of time can help establish a baseline as well as the performance post disaster. [7]

Surat was one of the pilot cities selected to trial CRI in the world. Based on the findings of CRI, a Surat Resilience Strategy was formulated in 2017 with the aim of Surat more resilient, and also share knowledge with the other cities in the network. The strategy had 7 pillars of focus, each with its sub goals to make the city more resilient. [8]

C. Community Based Resilience Analysis (CoBRA)

Implemented by United Nations Development Programme (UNDP) with financial support from the European Commission Directorate General for Humanitarian Aid and Civil Protection (ECHO) in four Regions in Africa, CoBRA primarily focuses on community. This method is contextually based and has no predefined indicators for the 5 dimensions for assessing resilience. The indicators of Resilience are decided by the community by having a number of focus group discussions (FGDs) and key informant interviews (KIIs). It can provide a valuable basis upon which to develop a small set of locally specific indicators and to support strategic planning processes. [9]

Based on the finalized parameters of resilience, based on the FGDs and KIIs, the people are asked to score the various parameters twice, once in the normal times and one just after the last major disaster. The variation in the scores can help establish how resilient these communities are, with inverse relations between the two. The data is then shown in a spider diagram. [9]

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This method was implemented in 4 regions of Africa, viz., Marsabit, Turkana and Kajiado counties, Kenya & Karamoja sub-region, Uganda. [9]

IV. Sustainable Development Goals

The Sustainable Development Goals (SDGs) were born at the United Nations Conference on Sustainable Development in Rio de Janeiro in 2012. The objective was to produce a set of universal goals that meet the urgent environmental, political and economic challenges facing our world. [10]

Goal 11 aims at making cities and human settlements inclusive, safe, resilient and sustainable. Under this particular goal about 11 goals and targets have been defined. More than half of us live in cities. By 2050, two-thirds of all humanity—6.5 billion people—will be urban. Sustainable development cannot be achieved without significantly transforming the way we build and manage our urban spaces. [10]

By endorsing a stand-alone goal on cities (Goal 11), known as the 'urban SDG', – make cities and human settlements inclusive, safe, resilient and sustainable – the international community recognized urbanization and city growth as a transformative force for development. This first-ever international agreement on urban-specific development acknowledges sustainable urban development as a fundamental precondition for sustainable development. [10]

A. Targets and Goals – Goal 11 [10]

1. By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums
2. By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons
3. By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries
4. Strengthen efforts to protect and safeguard the world's cultural and natural heritage
5. By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations
6. By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management
7. By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities
8. Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning
9. By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels
10. Support least developed countries, including through financial and technical assistance, in building sustainable and resilient buildings utilizing local materials

V. Comparative Analysis Of The Various Frameworks

This chapter aims to understand how the various framework stack up to one another and how they rank up with the Sustainable Development goals. In order to compare the various frameworks, the parameters with which to compare were first detailed out.

A. Parameters For Analysis Of The Various Frameworks

The following are parameters that have been defined to analysis the various frames of Resilience Index.

1) Context of Study

Context or the areas in which the studies have been applied is considered here.

2) Dimensions, criterions and indicators

In order to comparative assessment of the comprehensiveness of the resilience models, their dimensions, criterions and indicators will be discussed. It should be noted that the vast dimensions of resilience do not mean comprehensiveness and sometimes the multiplicity dimensions and criterions will be caused to complexity.

3) Scale

Each model has described its framework between the community and national level the scale of the models and their dimension can directly affect each other.

4) Methodology

How to analyze data and provide resilience assessment method is another important issue in evaluating the performance of urban resilience models.

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5) Capabilities and Limitations

The models have aspects which makes them advantageous over one other while also having certain limitations.

B. Comparative Analysis Of The Various Frameworks

With the parameters defined earlier, the three frameworks are compared with each other in this section.

TABLE 1 – COMPARATIVE ANALYSIS OF THE VARIOUS FRAMEWORKS

Parameters	CDRI	CRI	CoBRA
Developer	Tokyo University, Japan	Rockefeller Foundation and ARUP	United Nations Development Programme Drylands Development & European Commission Directorate General for Humanitarian Aid and Civil Protection
Context	South East Asia	100 Cities all over the world	4 Regions in Africa
Dimensions	• Physical • Social • Economic • Organizational • Natural	• Health and well being • Economy and society • Infrastructure and ecosystems • Leadership and strategy	• Financial • Human • Natural • Physical • Social
Scale	• City • Region	City	• Community • Region
Methodology	• Non spatial • Spreadsheet based • Questionnaire Survey	• Non spatial • Spreadsheet based • Questionnaire Survey	• Non-Spatial • Focus Groups Based
Capabilities and Limitations	• Applied in 9 Asian cities • Concentrated more on climate changes • Nominate the scoring to the indicators • Application of simple data analyze model • Not contextual based • Only one temporal instance	• Applied in 100 cities all over the world, so large volume of data. • Relative performance over time • Sharing data and methods of solving issues within the network of cities. • Limited to just the 100 cities • Complex Data Analysis • Not contextual based	• It allows the community to define resilience, as it is contextually based. • It provides a basis for identifying quantitative impact and outcome indicators. • CoBRA considers two temporal instances while assessing • A CoBRA assessment is not a standalone measurement of resilience. • CoBRA cannot be used to evaluate individual programmes or services.

TABLE 2 – COMPARISON WITH SDG GOAL 11

SDG 11	Target 1	Target 2	Target 3	Target 4	Target 5	Target 6	Target 7	Target 8	Target 9	Target 10	Total
CDRI	0	1	1	0	1	1	1	0	1	0	**6**
CRI	1	1	1	0	1	1	0	1	1	0	**7**
CoBRA	1	0	1	0	1	0	0	1	0	0	**4**

The three methods are different in the way they measure resilience and in the application of the data. The dimensions through which resilience is measured are slightly different from one another, with each measuring the Economic, Social, and Physical aspects of the area being studied. The scales vary between the three of the frameworks, with CoBRA being the smallest at a community level, with CDRI being the biggest focusing on Regional level. All the three frameworks are Non-Spatial in nature with limited or no mapping. While CDRI and CRI are questionnaire and Survey based, CoBRA is based on focus group discussions. All three primarily gather data which is used to strengthen the resilience of the place through strategies and plans.

C. Comparative Analysis With SDG: Goal 11

When comparing the three frameworks with the Sustainable Development Goal 11, it is seen that CRDI and CRI are similar and with CoBRA being the least compactible with SDG Goal 11. CRI meets most of the Sustainable Development Goals: Goal 11, with about 7 of the 10 targets being met. Also, CRI also has the broadest scope of factors being considered when compared to the other two frameworks.

Target 4 and 10 of the SGD are not met by any of the frameworks. CRI, despite having health and well-being, infrastructure and ecosystems dimensions, it fails to meet the Target 7 as the indicators fails to address Urban Green Spaces. CDRI misses Target 8 despite dealing with economic aspects,

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as the indicators doesn't deal with the regional aspects of the economic dimension.

VI. Conclusion

The ideal framework for Resilience Index to achieve Sustainable Development is considered to be the one in which all targets of Sustainable Development Goals: Goal 11 has been met while also ensuring that various parameters of what defines Resilience are also considered. The ideal framework for Resilience index should be a Combination of the three frameworks studied. It should be a simple arithmetic model like in CDRI, and have a really wide range of indicators and should be applicable all over the world like CRI, while taking into consideration two temporal instances, one during the normal phase and one during the most vulnerable times, and should also be tweakable to suit the local context in which the indexing is being done as done in CoBRA.

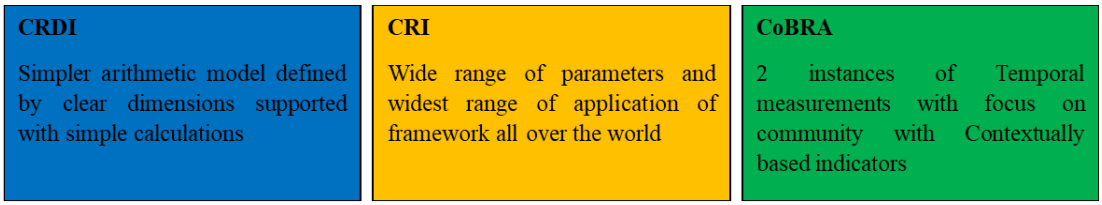

Figure 1 Strengths of Frameworks

The Conceptual Framework must be to rank the various cities under their resilience to better understand their strengths and weakness, and to make the cities more resilient. The dimensions should consider Physical, Social, Economic, Organizational, and Natural aspects, which will help understand the cities under consideration in a detailed manner. The indicators should have the most match with the Sustainable development goals, with the indicators missing from Sustainable Development Goals added to the list of indicators. The framework developed should also be applicable all over the world, with certain questions being tweaked based on the local context, thus enabling us to have local aspects incorporated into the framework. The methodology for the framework should be Non-Spatial in nature with Spreadsheet and Questionnaire based inputs, with the initial parameters set by establishing a focus group to determine the local contextual parameters to be considered. The surveying should also incorporate two time periods to gauge how the cities responded both during normal times, as well as during disasters. The major applications should be to Gather information, and formulation of Policy recommendations and resilience strategies, and to rank the various cities.

Further the targets 4 and 10 of the SDG also needs to met as well, to make the index an instrument for sustainable development. Target 4 can be met by incorporating the indicators to consider Natural and Cultural heritages. Target 10 of the SDG can be achieved by ensuring transfer of knowledge to improve resilience between the cities in which the framework is applied.

Thus, by understanding the resilience of a place using resilience Index, a city's stride towards sustainability can be strengthened. Resilience is way of strengthening the pathway towards sustainability. By making the cities more resilient, the chances for the city to become more sustainable increases, thus making Resilience Index an Instrument to Sustainable Development.

References

[1] Urban Resilience Hub. Retrieved 18th January 2020, from http://urbanresiliencehub.org/what-is-urban-resilience/

[2] Tanner, T., Surminski, S., Wilkinson, E., Reid, R., Rentschler, J., Rajput, S. 2015. The Triple Dividend of Resilience. Overseas Development Institute (ODI), International Bank for Reconstruction and Development/International Development Association or The World Bank.

[3] The Rockefeller Foundation & ARUP. 2014. City Resilience Framework.

[4] Meerow, Sara & Newell, Joshua & Stults, Melissa. 2016. Defining urban resilience: A review. Landscape and Urban Planning. 147. 38-49. 10.1016/j.landurbplan.2015.11.011.

[5] Elmqvist, T., Andersson, E. Frantzeskaki, N. et.al .2019.Sustainability and resilience for transformation in the urban century, Nature Sustainability volume 2, pages267–273 (2019)

[6] Kyoto University & SEEDS India. 2010. India Profile: Climate and Disaster Resilience Index.

[7] The Rockefeller Foundation & ARUP. 2015. City Resilience Framework

[8] Surat Resilience Strategy.(2017). Resilient Surat/SCCT.

[9] UNDP. 2014. Understanding Community Resilience: Findings from Community-Based Resilience Analysis (CoBRA) Assessments.

[10] UN-Habitat. 2016. SDG Goal 11 Monitoring Framework

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POST DISASTER PLANNING INTERVENTIONS IN NEPAL

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Abstract – **In April 2015 Nepal witnessed one of the biggest earthquakes of its history. This earthquake has had a significant and lasting impact on its citizens. This disaster also led to the destruction of many iconic structures of the country. The main aim of the study was to understand the various steps taken by the Government as well as the people of Nepal in the rebuilding and rehabilitation, as well as in the disaster management processes post the Earthquake. Major problems faced during the disaster crisis was the lack of preparedness by the public as well as Government to organize the relief operations effectively. Through the quakes, a proper Disaster Management Structure (DMS) was envisaged to formulation, thereby marking a positive outcome out of the disaster. New acts and measures are foreseen to strengthen and capacitate the search and rescue team. As a result, National Reconstruction Authority (NRA) was formed to manage and oversee reconstruction activities in the disaster hit regions.**

Keywords— earthquake; preparedness; DMS; acts; NRA; reconstruction.

I. INTRODUCTION

Nepal is a country that is bordered by India to its East, West and South while China occupies the Northern part. The high altitude from sea level and climatic conditions with heavy monsoon downpours have made Nepal vulnerable to natural hazards like floods, earthquakes, landslides, windstorms and glacial flood burst outs. More than 80% of the pollution of Nepal is vulnerable to natural hazards and thereby, Nepal is ranked 4th amongst other countries worldwide in terms of its vulnerability to climate change. Nepal is ranked 11th worldwide for its susceptibility to earthquakes. [1] At a magnitude of 7.6, an earthquake struck the district of Gorkha on 25th April 2015. Gorkha district is placed at a distance of 76 km from Kathmandu towards the northwest. It was observed that more than 300 aftershocks followed the major quake. One of the aftershocks at a magnitude of 7.3 struck on 12 May. This was reportedly the second highest magnitude of quake. It was reported that more than 8700 causalities and 22,000 people were injured during the course of the earthquakes. Nearly one third of the total population got affected due to the quakes. 31 districts out of 75 were affected and furthermore, 14 were declared "severely damaged" or "crisis hit". With reference to masonry buildings scale of damage, collapsed buildings are listed under severely affected and very worse affected are noted to be crisis hit. Hit with heavy losses mean heavy damages while hit refers to mild damages. Slightly affected indicate slight damages. Several government buildings, residences, heritage sites, health care facilities, educational institutions, roads, bridges, agricultural fields, water system, etc. got affected due to the destruction. It was estimated that the total cost of the losses tentatively aggregate to USD 7 billion. [2] Post the earthquake on 25th April, the National Emergency Operation Center (NEOC) at level four was activated, that followed the guidelines of National Disaster Response Framework of the year 2013 and the standard operating procedures of NEOC. [3]

The NEOC SOP1 quotes that at level 4, decisions are set by the Cabinet Ministers. Hence, the Government of Nepal on 25th April, through its Cabinet Ministers requested for international assistance. [4]

Figure 1 Prioritization of affected districts [5]

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Nepal has been confined in internal conflicts for peace and development over the recent decades. Few of the major concerns in the governance of Nepal are its political instability, lack of accountability, lawlessness and corruption. In addition, plans and policies pertaining to disaster risk reduction are curtailed by disputes of implementation capacities among ministries and concurrent departments at National and local level. [6] In the absence of state advisory, national and international non-governmental managements of the country are involved. However, this reduces and affects the potential development of internal bodies in building national capacity and government ownerships.

Disaster risk management strategies are not seemingly accompanied by thorough understanding of institutional potentials. The earthquake of 2015 could stand and serve as an opportunity to assess and evaluate the national capacity to react and respond to such disasters. It is also to be understood that such disasters of high scale are rare opportunities to study and strengthen the weaker sections as such disasters rarely happen even in the most impacted countries like Japan. Studies available have pointed the disaster policies, humanitarian responses and inferences from the quakes of 2015, thereby focusing on the international responses, public health concerns, community resilience military relationships and coordination of government aid. [7] Nonetheless, none of the studies have attempted to explore the potentials of national institutions for disaster risk management. This study intends to elaborate the post disaster interventions that happened in Nepal.

A. Primary Study

The project conceived as part of the academic project, involved the visit to the town of Panchkal, Kavrepalanchok District, Nepal. The study team visited the reconstruction sites of Habitat for Humanity (HFH) in the village. The team also interacted with the officials from HFH to understand their various steps and practices involved in the reconstruction and rehabilitation process after the earthquake. The HFH team also gave an insight into the steps and measures that were taken up by the Government of Nepal after the earthquake.

Figure 2 Study team in Nepal (Primary Study)

Figure 3 Meeting at Habitat for Humanity's Office (Primary Study)

II. DISASTER MANAGEMENT

A continuous and integrated process of planning, organizing, coordinating and implementing measures which are necessary or useful for-

- Prevention of danger or threat of any disaster. Reduction of risk of any disaster or its severity or consequences.
- Preparedness to deal with any disaster.
- Prompt response to any threatening disaster situation or disaster.
- Assessing the severity or magnitude of effects of any disaster.
- Evacuation, rescue and relief.
- Rehabilitation and reconstruction.

Figure 4 Management cycle [8]

III. ORGANIZATIONAL STRUCTURE FOR DISASTER MANAGEMENT

Major Disaster operations in Nepal fall under the Natural Calamity Relief Act of 1982 for immediate relief and rescue operations as well as preparedness activities; established the Central Natural Disaster Relief Committee (CNDRC). The CNDRC is responsible for preparing national compliance on

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preparedness, response and recovery actions, and ensuring its implementation restocking relief and rescue materials as per the needs; collecting and disseminating relief materials and funds during emergency operations; and, providing direction to the district and local committees.

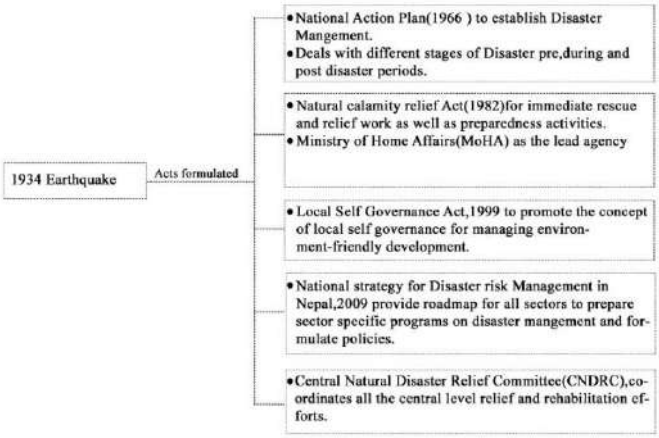

Figure 5 Acts formulated after 1934 earthquake (Primary Study)

IV. Disaster Management Structure

The disaster management structure was divided into 3 tiers. The structure is divided into three tiers, viz., Central Natural Disaster relief Committee (CNDRC), Regional Disaster Relief Committee (RDRC), and District Disaster Relief Committee (DDRC), which is namely headed by the cabinet.

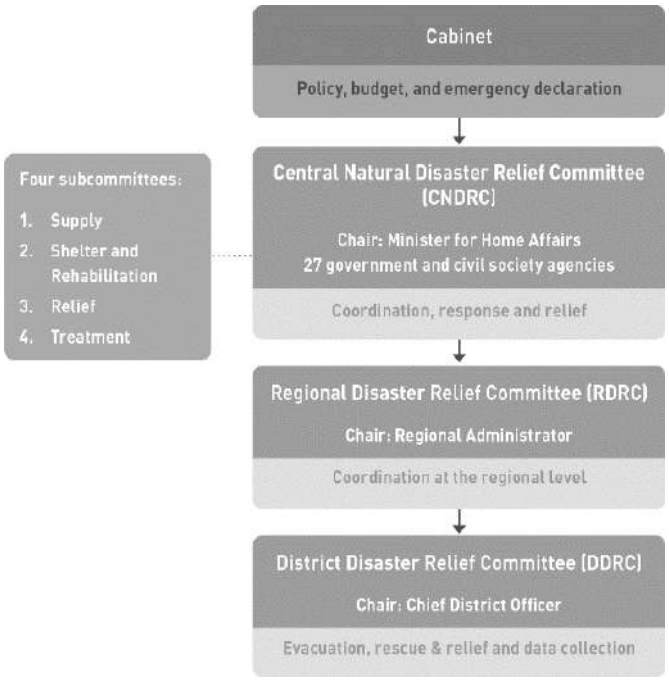

Figure 6 Structure of Disaster Management Structure of Nepal [8]

V. Experiences From The Relief Operation

Table 1 Experiences From Relief Operations [1]

Response	Government of Nepal's response was quick and swift during the initial phase of search, rescue and relief response but the system was not well organized and prompt
Communication & Information networks	Nepal's communication infrastructure crumbled immediately owing to the earthquake both literally and figuratively (EIAS 2016). Mobile networks, landline telephones, means of mass communication (such as television) were all paralyzed.
Resource Mobilization	More than NRs. twenty-one billion, nine hundred ninety million (NRs. 21,990,192,958) was released towards disaster relief and response activities from the Central Natural Disaster Relief Fund (CNDRF).
Relief Materials and Services	Proper identification of relief materials needed on ground was not updated accordingly
Search & Rescue operations	Failed to reach in due time to many of the affected people of remote, rural and hilly areas. It was basically because of the lack of road network, transport resources, and adverse weather condition.
International cooperation and disputes	The relationship between Nepal government and the international community was not encouraging. There was the problem of mutual trust and allegation between the two sides, many disputes aroused during the relief work.

VI. Lessons Learnt

With regards to Command and Coordination Mechanism, as with all major disasters, the 2015 Earthquake became a test case for the Government's coordination mechanism at various levels. Although CNDRC remained active and functional throughout, its effectiveness fell short of the urgency of the circumstance. On the one hand, there was a multi-tier mechanism of command, control and coordination, on the other, there was a parallel entity created for overview and monitoring, which primarily comprised of political representation. In addition, in each electoral area of the earthquake affected districts, one Search and Rescue (SAR) Command Post was set up, under the leadership of MoHA Joint Secretary sent from Kathmandu, comprising of a team of senior officials from the Nepal Army, the Nepal Police and the Armed Police Force to look after issues of debris management, corpse management, and distribution of relief materials and to take preventive measures to control outbreak of epidemic.

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A Need for a new Disaster Management Act to address the present challenges was felt. Strengthening the capacity of National Search and Rescue Team specially by focusing on Security forces was also needed.

A necessity for assured international supports in Search and Rescue relief and recovery along with Helipads in Rural Areas, and provision of Helipads in each VDC was also felt. A major issue was lack of emergency warehouse and adequate stockpiling of appropriate supplies and equipment's. One window system is very important in Rescue and Relief to distribute food and nonfood items in remote areas and to the backward and deprive people.

The Lack of awareness, preparedness as well as coordination among disaster management stakeholders clearly evident. The weak nature law enforcement and monitoring of building codes and town planning and lack of training for professionals in earthquake resistant construction practices have been found as the major factors of infrastructure damage, which was further compounded with lack of adequate preparedness and response capacity among various stakeholders. The biggest lesson is that to be safe from earthquake is to build earthquake resistant infrastructures. There should be no compromise in building compliance. Also the organization of appropriate and essential equipment/s based on the nature of disaster can assist for the quick search and rescue works.

A strong need was felt for Modern technology and strategic communication/risk mapping/satellite mapping/earth observation tools and techniques, which are vital in reducing the disaster risks; and in life-saving. Finally, Recovery should follow a community based approach which encourages communities, utilization, of social networks, and built self-reliance efforts using local skills and knowledge. It will largely be an owner driven recovery program.

VII. Establishment Of National Reconstruction Authority

The National Reconstruction Authority is a government agency of Nepal that coordinates reconstruction following the April 2015 Nepal earthquake. The National Reconstruction Authority (NRA), a coordinating and facilitating body formed by the Government of Nepal to manage, oversee and coordinate the reconstruction work was constituted on 25 December 2015, following the enactment of the NRA Act on 20 December.

By law, its functions include the following

- Assessing the damages caused by earthquakes,
- Fixing the priorities of reconstruction,
- Preparing policies,
- Plans and programs,
- And facilitating implementation.

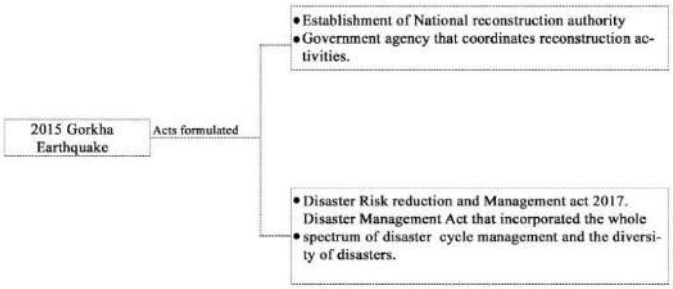

Figure 7 Acts formulated post the earthquake (Primary Study)

A. Frameworks under NRA

1) *Formulation of Post Disaster Recovery Frameworks* - In May 2016, the NRA brought a new Post Disaster Recovery Framework (PDRF) (NRA 2016). The PDRF lays out strategic recovery objectives and summarizes institutional arrangements and financing strategies, as well as implementation and monitoring systems, to help plan and manage recovery and reconstruction. It also sets out sector priorities that will contribute to the achievement of the strategic recovery objectives

2) Private House Reconstruction - Private house reconstruction is one of NRA's top priority areas. In two years after the devastating earthquake that destroyed over 765,000 houses, reconstruction of private houses has gathered little momentum.

Figure 8 A private house under reconstruction (Primary Study)

3) *Relocation of Hazard-Prone Settlements* - NRA has enforced a new procedure to make necessary arrangements for the beneficiaries and families of the hazard-prone settlements that have been affected by the earthquakes. The "Procedures for the Relocation and Rehabilitation of Hazard prone Settlements, 2073 (2017)"

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has been enforced from 7 April 2017. In such a case, the beneficiaries will be encouraged to create users' groups involving at least 10 families in each settlement so that the committee can select a safe location for the development of an integrated settlement. Then, the beneficiaries will be required to submit the land purchase certificate to NRA.

Figure 9 Village under reconstruction (Primary Study)

VIII. Disaster Risk Reduction And Management Act 2017

The earlier Natural Calamity Relief Act of 1982 did not cover emerging concept of Disaster Risk Reduction. There was a strong consensus among all partners that the country required a new Disaster Management Act that incorporated the whole spectrum of disaster cycle management and the diversity of disasters. It was decided to establish a separate dedicated institution for Disaster Risk reduction and management and also to adopt disaster mitigation and resilience strategies in Government, private sector and other sectoral development programs.

A. Highlights

The new act led to the creation of an Expert Committee at all tiers of the disaster management. The leadership at the highest level is headed by council. A separate new dedicated institution under the Executive Committee, National Disaster and Risk Reduction and Management Authority - NDRR&MA is to be established. Executive chief is appointed from a panel of Experts. Also, a Disaster Response Controller is to be created.

This act includes all the phases of Disaster Management Cycle

- Volunteerism
- Disaster Response Squad Team
- Research & Study
- Early Warning System
- National Emergency Operation System and emergency operation centers
- Disaster Risk mapping, assessment,
- Technologies use for DRR: Soil science, GIS, Remote Sensing, EWS, etc and Indigenous technologies
- Involvement of Civil Society and Private Sector in Disaster Management
- Provision for Approval to Foreigners during Disaster
- Disaster Emergency Declaration
- International Humanitarian and other Support
- Reward
- Annual Reporting
- Compensation

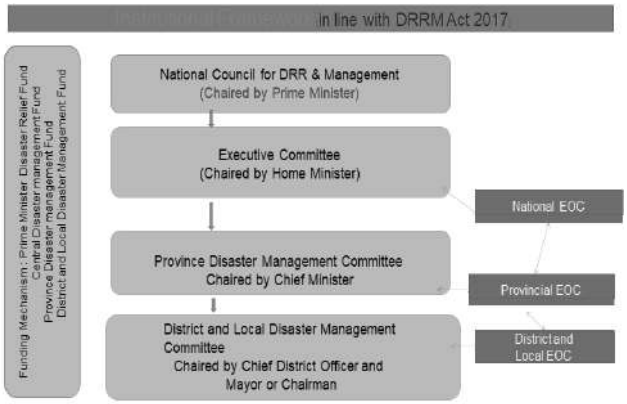

Figure 10 Flagship priority areas with key achievements

IX. Key Achievements Through Reformations In Nepal

Table 2 – Key Achievements Through Reformations

ASPECT	COORDINATORS & FOCUS	PROJECTS
School and Hospital Safety	**Coordinator:** Asian Development Bank (ADB)/Ministry of Education /World Health Organization/Ministry of Health and Population **Focus:** Reducing mass casualties and damage in hospitals and schools through retrofitting, training and raising awareness	• 65 schools retrofitted by MoE and 260 schools retrofitted by an ADB/AusAid led initiatives • 60 Hospitals (50 bed) were assessed for structural and non-structural hospital safety and crisis functionality
Emergency Preparedness and Response	**Coordinator:** UNOCHA/Ministry of Home Affairs **Focus:** To enhance the GoN's response capacities at the national, regional and	• 83 open spaces secured by Government of Nepal in Kathmandu Valley • Regional and Municipal emergency operation center

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	district-level in a coordinated manner with all in-country resources including the armed forces, as well as integrating incoming international humanitarian and military assistance	established in 36 districts • National Disaster Response Framework (NDRF) 2013
Flood Management in the Koshi River Basin	**Coordinator:** World Bank (WB)/Ministry of Irrigation **Focus:** Address the risk of floods in Nepal. Managing water-induced disasters, focusing on the Koshi Basin. Short-term goals focus on enhancing institutional capabilities in flood management while long-term goals focus on implementing effective flood mitigation	• Building resilience to climate-related hazards programs • Rapid field assessment of Koshi River • 15 km embankment constructed
Community-based Disaster Risk Management	**Coordinator:** International Federation of Red Cross and Red Crescent Society (IFRC)/Ministry of Federal Affairs and Local Development **Focus:** Capitalize on Community-Based Disaster Risk Management (CBDRM) at Village Development Committee (VDC) level by developing a set of minimum characteristics for disaster-resilient communities and adopting a minimum package of common elements to be included in all CBDRM projects. Aims to make 1000 VDCs disaster resilient	• Over 650 communities were approached for Community Based Disaster Risk Management Program • Project tracking system developed to assess project compliance • 20 districts consultation completed for community resilience against natural disasters
Policy/Institutional Support for Disaster Risk Management (DRM)	**Coordinator:** United Nations Development Programme (UNDP)/Ministry of Home Affairs **Focus:** Institutional, legislative and policy frameworks for DRM system building and embedding DRM into Nepal's development efforts. Ensure new risk is minimized	• Training of masons and engineers in Kathmandu • Disaster Risk Management focal point established in 23 government ministries/departments • Risk-sensitive land use plan agreed for Kathmandu

Source: Adapted from (GoN MoHA and DPNet-Nepal 2015; Jones et al. 2014).

X. Conclusion

The earthquake of 2015 brought out the fallacies that the nation of Nepal had with regards to disaster preparedness and management. The nation relied on archaic laws which weren't updated since 1934. The nation had created a new authority to monitor the rebuilding and reconstruction process of Nepal, with NRA in 2015. This agency sought to improve the disaster management and preparedness processes in Nepal. This led to the creation as well as the betterment of the existing acts of the country.

As a part of reconstruction of the dilapidated houses during the earthquake, many agrarians were actively involved in the construction of their own houses, thus bringing in an overall inclusivity to the rebuilding process of Nepal.

Acknowledgement

This study was part of the academic project of M.Plan Studio 2020. The authors would like to thank the Faculty in charge, all other students for having collected information on various topics and Habitat for Humanity (Nepal), without which this paper would not have been possible.

References

[1] Government of Nepal Ministry of Home Affairs Disaster Preparedness Network -Nepal 2015; Government of Nepal 2017

[2] Government of Nepal National Planning Commission 2015.

[3] Government of Nepal Ministry of Home Affairs 2015.

[4] Government of Nepal Ministry of Home Affairs 2017.

[5] Government of Nepal National Planning Commission (2015) Post Disaster Need Assessment Report.

[6] Government of Nepal Ministry of Home Affairs and Disaster Preparedness Network -Nepal 2013; Manandhar et al. 2017.

[7] Cook et al. 2016a; Hall et al. 2017; Thapa 2016.

[8] Disaster Management Reference Handbook (August 2017), Center for Excellence in Disaster management and Humanitarian Assistance

EFFECTIVE LAND MANAGEMENT FOR CONSERVING PADDY FARM SECTOR

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***Abstract*—this study analyses the prospective of various components leading to agrarian crisis and the significance of paddy farm sector in primary sector. The analysis follows identification of various land management practices for conserving the paddy farm sector. The study concludes with various strategic plans for conserving the paddy farm sector of Kerala, through proper land management practices**

Keywords—agrarian crisis, Paddy farm sector, Land management practice.

I. INTRODUCTION

Agriculture has been given a prime place in India since the beginning of the era of planned development. India is an agrarian country with around 60% of its people depending directly or indirectly upon agriculture. The progress of entire economy is dependent upon the agriculture sector to a great extent. The climatic changes, change in the land use pattern, occupational pattern, scarcity in Irrigational facilities, low agricultural income etc. is leading to a serious issue of Agrarian crisis and other environmental problems. . Agriculture sector which contributes a major occupation of India needs to be conserved and revived. Paddy farm sector is a major component in the agriculture sector of India. Paddy fields in India are typical wetland ecosystems which provide numerous important ecological and economic functions. Landowners using their right to opt for crop of their choice convert paddy fields for other crops and also for non-agricultural purposes. It is argued that economic return from paddy cultivation is not attractive to induce conservation. Landowners, most of them not full-time farmers basically argue for profit maximization through the freedom of individual choice to shift away from paddy and it seems that they have accepted conversion inevitable to ensure adequate return. The fact that wetland agro-eco-system provides valuable goods and services to society are more often than not, overlooked. Conversion of paddy involves irreversible transformation of the ecosystem. Despite the fact that Kerala ranks top in literacy and environmental awareness, there was a 65% fall in the wetland area under paddy in the last 30 years. Unabated massive conversion still continues and that may result in a total abandonment of rice cultivation in the near future. The issue of conversion at present is viewed as a choice decision of landowners. Although the laws are against land use change, farmers resort to conversion for maximising their economic returns. In their effort to maximise current economic returns, farmers ignore the possible ecological and environmental impacts of conversion.

A. Need of the Study

In the present scenario, rice cultivation is no longer seen as economically viable as it does not provide what is regarded as an adequate return. Moreover, land at present is seen only as a real estate needed for residence and status and it is also considered as the safest and best investment. Therefore economic rationale of the private owners of paddy fields suggests them to convert for non-agricultural purposes. In such a situation, we should consider the environmental, social benefits of rice cultivation than the economic importance. Therefore, it is very important to conserve the existing rice cultivation areas through proper land management practices and other agrarian policies.

B. Research question

Can the Effective land management policies and practices help to conserve the paddy farm sector and strengthen the agriculture sector?

C. Aim of The study

To examine the ways of effective management of land for the conservation of paddy farm sector.

D. Objectives of The study

The study focuses on the importance of paddy cultivation in primary sector and its role in solving agrarian crisis. It involves, the examination of the present scenario of paddy cultivation and the need for conserving the paddy farms, to solve the environmental issues. An assessment of the initiatives and various land management policies made by the government and other NGOs for conserving the agricultural farmlands has been done. The Study concludes by establishing a framework for developing and conserving the paddy cultivation considering the past issues, present scenario and future prospects.

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E. Methodology

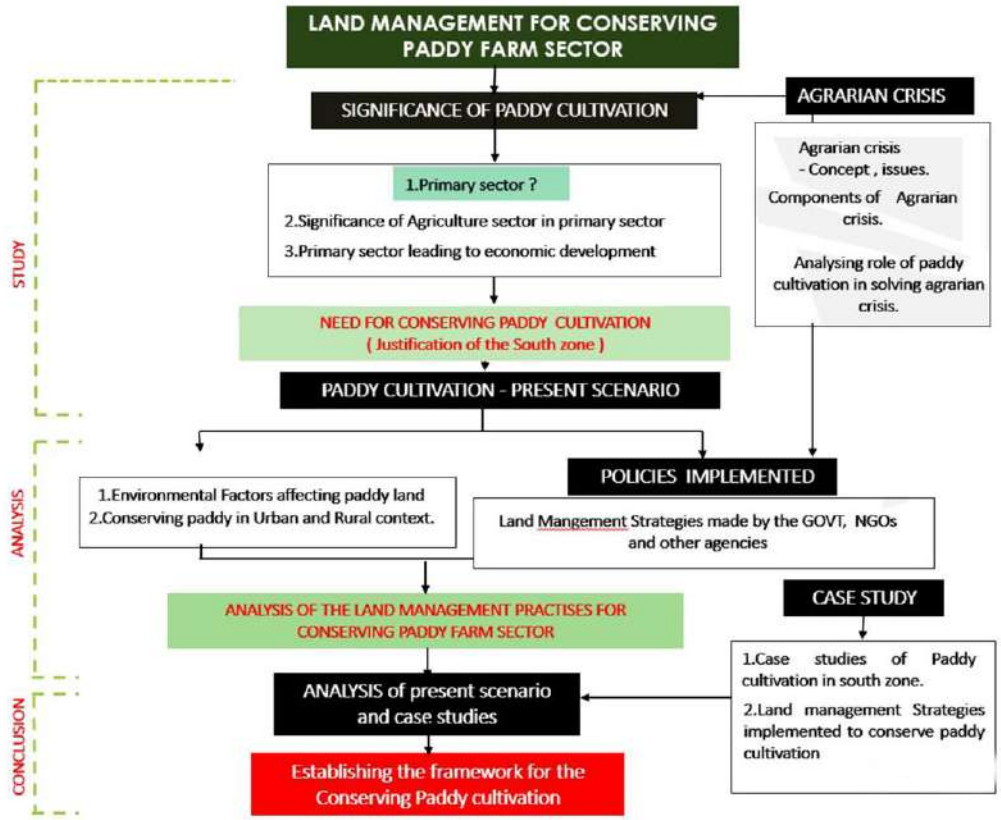

Fig 1.Methodolgy

F. Scope and Limitation

The paddy fields, the staple food of the people of south zone is the main component of the agriculture sector and can play major role to solve the agrarian crisis , and environmental impacts of urbanization .The economic development of an area can be easily brought up by strengthening the primary sector through proper land management for conserving paddy farms. Study is limited to the analysis of the paddy farm sector of the agriculture sector and the land management practices for rice cultivation.

II. AGRARIAN CRISIS

The Agrarian crisis leads to the threatening livelihoods of small and marginal farmers. The decreased income of the farmers is the main issue. Agrarian policies and support systems as a solution for this problems are not much successful in solving the issues of Agrarian crisis. India is an Agrarian country with around 60% of its people depending directly or indirectly upon agriculture. So the present scenario of Agrarian crisis is of very much significance in the context of the economy of India. One of the main consequences of this agrarian distress has been that the marginal and small farmers, who find it increasingly hard to sustain on farming, are getting pushed out from agricultural sector. Proper establishment and implementation of policies and schemes are required.

A. Agrarian crisis as a danger for Indian economy

India's gross domestic product (GDP) growth for the second quarter has laid bare the deepening distress in its villages. Farm incomes haven't risen even though the government has announced a hike in minimum support prices. The country's agricultural output, measured as gross value added, grew at a sedate pace of 2.8%, far slower than the 5.3% in the June quarter. This was on top of a low base of 2.6% growth last year. Economists said that the GDP deflator for agriculture is negative for the first time in many years. In other words, farmers are earning less than what they were before. Indeed, if the recent marches to New Delhi by thousands of farmers are any indication, the farm sector has already sent up emergency flares. Although agriculture contributes less than one-third of the output of the entire economy, rural centres are key demand areas.

B. Components Of Agrarian Crisis

The present scenario of Agrarian crisis is as result of various factors. The climatic changes as a result of urbanisation etc has led to agriculture failure and results in low farm productivity. Fragmented supply fails in proper market network. In many areas Improper wages has made a huge occupational shift among the people who practised agriculture. The present

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scenario of Agrarian crisis is as result of various factors. The climatic changes as a result of urbanization etc has led to agriculture failure and results in low farm productivity. Fragmented supply fails in proper market network. In many areas Improper wages has made a huge occupational shift among the people who practiced agriculture.

III. PADDY FARM SECTOR

The primary sector of the economy includes any industry involved in the extraction and collection of natural resources; such as farming, forestry, mining and fishing. The primary sector tends to make up a larger portion of the economy in developing countries than it does in developed countries. Primary sector makes direct use of natural resources. The primary sector is an economic description, concerned with the extraction of raw materials. The primary sector tends to make up a larger portion of the economy in developing countries than it does in developed countries. Primary sector makes direct use of natural resources. The primary sector is an economic description, concerned with the extraction of raw materials. This sector includes agriculture, forestry, animal husbandry, fishing, mining etc. Primary sector shows a decreasing trend in the recent years. For better living conditions, increased income and sustainable environment, conserving paddy farm sector and strengthening primary sector is very important. It can be achieved through Modernising of agriculture practices. Agriculture is one of the main components of primary sector.

A. Agriculture in primary sector

Agriculture has been given a prime place in India since the beginning of the era of planned development. The progress of entire economy is dependent upon the agriculture sector to a great extent. Systematic command area development is very important for the efficient use of agriculture land. This sector generally takes the output of the primary sector and manufactures finished goods. Agriculture plays a vital role in India's economy. 54.6% of the population is engaged in agriculture and allied activities (census 2011) and it contributes 17.4% to the country's Gross Value Added for the year 2016-17 Despite employing 51% of the workforce, agriculture and allied activities produces just 15% of the national GDP, indicating a poor usage of the available workforce and a failure of modernization of agriculture and other activities allied to it. Modernising agriculture will lead to increase in more yield of crop per unit area and increase share of its GDP. This creates a chain of actions where, rural families will have an increased income, increasing their purchasing power, which in turn expands the existing market. Given the importance of agriculture sector, Government of India took several steps for its sustainable development. Steps have been taken to improve soil fertility on a sustainable basis. There has been a continuous decline in the share of agriculture and allied Sectors in the GVA from 18.6 percent in 2013-14 to 17.4 percent in 2016-17. Falling share of agriculture and allied sectors in GVA is an expected outcome in a fast growing and structurally changing economy. So it is very important to conserve the agriculture sector.

B. Paddy Farm sector

Attaining food security for a growing population and alleviating poverty while sustaining agricultural systems under the current scenario of depleting natural resources, negative impacts of climatic variability, spiraling cost of inputs and volatile food prices are the major challenges for the agriculture sector. Paddy farm sector is one of the major sector in the various agriculture sectors in India. Rice is the most important human food crop in the world, directly feeding more people than any other crop. In 2012, nearly half of world's population – more than 3 billion people – relied on rice every day. Rice has also fed more people over a longer time than has any other crop. It is spectacularly diverse, both in the way it is grown and how it is used by humans. Rice is unique because it can grow in wet environments that other crops cannot survive in. Such wet environments are abundant across Asia. The domestication of rice ranks as one of the most important developments in history and now thousands of rice varieties are cultivated on every continent except Antarctica. India is one of the world's largest producers of rice and brown rice, people of the eastern and southern parts of the country. Rice is the most important food crop grown in India. Rice production in India forms a major part of the economy. In Kerala, it occupies 7.46 percent of the total cropped area of the state. However, the area under rice has been falling at an alarming rate ever since the 1980s. From 8.82 lakh hectare in 1974-75, the paddy area has come down to 1.96 lakh hectare in 2015-16. In India, it is very important to improve the productivity of Rice since it covers large area . Thus revival of paddy cultivation in India can solve the various impacts of the agrarian crisis and can contribute to the improvement of national economy.

C. Paddy Farm sector of Kerala

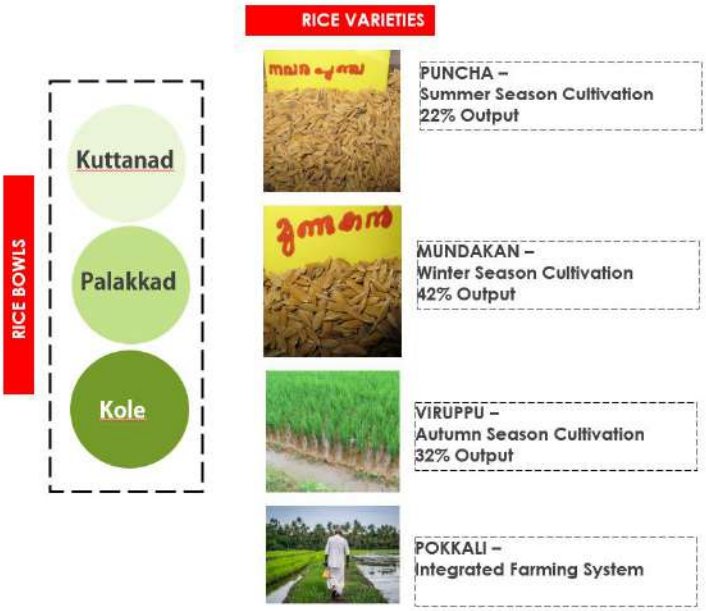

Fig 2.Rice Varieties Of Kerala

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IV. CONSERVATION OF PADDY

Wetland paddy fields perform numerous important ecological processes that benefit humans. Many of these functions provide goods and services, which are important to human society and such functions, produces value. The functions and value of a wetland depends upon the location of the wetland, its adjacent environment, water source and quality, its biological diversity and a host of other characteristics .As a result of this ecological and social importance, it is very important to conserve the paddy farm sector.

A. Functions of wetland paddy

Ecological functions of paddy fields plays a significant role in improving the quality of life .Some of the major functions are :1) Maintenance of fertility and productivity through Biogiochemical cycling, Biosphere stability,Primary production , Biodiversity 2)Hydrological function : Ground water recharge,Ground water discharge, Absorption and control of floodwater 3) Water purification function 4)Habitat of plants, predators and micro-organisms 5) Economic services to human utilisation : Production of fish, Medicinal plants, Grass and green leaves for livestock population and Recreation facilities. Though the environmental resources are under private control, several stakeholders are involved in their use. People in the locality consider them an open access property for collecting grass/fodder, catching fish, gathering medicinal plants and collecting wild vegetables for consumption and materials (like reed, cane and wild grass) for housing and handicrafts.

TABLE 1 USES OF WETLAND PADDY FIELD

Agents	Uses of Wetland Paddy Fields
Land Owners	Cultivation of paddy,returns from cultivation
Farm workers	Employment and income
Residents of the valleys	Assured supply of safe drinking water
Poor people living on the valley	Access to common access resources like grassfodder, firewood, medicinal plants, vegetables, reed , cane and other resources for employement and housing.
Children	Space for recreation
Government	Control of flood and water logging

Source:dd architects

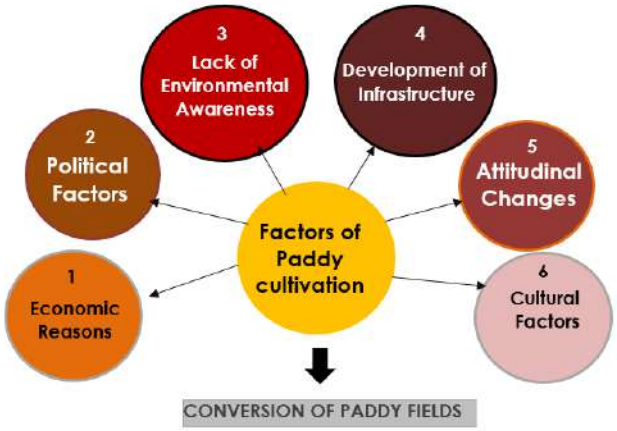
Landowners may use the converted piece of land for purposes of their choice depending on the location. Though a few farm workers may get employment opportunities, poor people in the locality lose access to CPR when the converted land gets enclosed. Residents of the valley irrespective of their economic status lose access to fresh water flowing through springs and side canals of paddy fields. Children in the rural areas lose open space for recreation. Since it is the duty of a welfare government to assure safe drinking water to all, the financial burden of the government will rise during the summer months. So the society at large, except the direct beneficiaries of land conversion, namely the landowners or legal custodians of environmental resources, becomes the loser.

TABLE 2 AGENT, COST AND BENEFITS OF PADDY

Agents	Costs	Benefits
Land Owners	Cost of Reclamation	High profit/rent
Farm workers	Loss of employement, Denial of access to open access resources , Drinking water scarcity , Loss of grass and medicinal plants.	Nil
Residents of the valleys	Fall in ground water level, Drinking water shortage, Flood, Loss of access to common access resources.	Improved road access
Owners of rice fields close to the converted fields	Difficulty in getting and draining water,Pest infestation,Increased use of pesticides and insecticides, High cost of cultivation, Problems due to high frequency of flood and water logging.	Nil
Government	High cost of supply of drinking water during summer, Increased expenditure on public health,flood relief etc.	Farm roads, Village roads.
Non-farm workers	Drinking water scarcity during summer	Employement in the non-farm sector.
Transport workers	Drinking water scarcity during summer	Employment in the transport of soil
Real estate buisiness	Water scarcity	High profit

Source:dd archtects

B. Factors of extensive paddy conversion



High input cost, low product price, non-availability of labourers in peak seasons inadequate and inappropriate techniques to handle high yielding variety (HYV) seeds, high susceptibility of HYVs to pests and diseases, inadequate institutional support, non-availability of inputs in time and lack of credit are reported to be the major reasons for the decline of paddy cultivation. In their effort to maximize current economic returns, ‘farmers’ ignore the possible ecological and environmental impacts of

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conversion. If we look at the issue of conversion from their economic perspective, given the private costs and benefits, rice cultivation is no longer seen as economically viable as it does not provide what is regarded as an adequate return. Moreover, land at present is seen only as a real estate needed for residence and status and it is also considered as the safest and best investment. Therefore economic rationale of the private owners of paddy fields suggests them to convert for non-agricultural purposes.

V. LAND MANAGEMENT

Land management is the process of managing the use and development (in both urban and rural settings) of land resources. Land resources are used for a variety of purposes which may include organic agriculture, reforestation, water resource management and eco-tourism projects. Land management can have positive or negative effects on the terrestrial ecosystems. Land being over- or misused can degrade and reduce productivity and disrupt natural equilibriums. The various successful land management practices for conserving paddy farm sector is mainly through transfer of development rights and land pooling strategies.

A. Origin of Land management

In 1860, Congress began passing a series of laws to facilitate the settlement and development of vast areas of public domain west of the Mississippi River by citizens and masses of immigrants moving to America for a better life. Among these laws were the Homestead Act (1862), Timber Culture Act (1873), Desert Land Law Act. In 1916, Congress passed the Stock raising Homestead Act to enable ranchers to acquire land for ranch headquarter sites, but the federal government retained the mineral rights in those patents.1930 - Emergence of the Bureau of Land Management.1934 - The Taylor Grazing Act and the U.S. Grazing Service ,Objective was to stop injury to public grazing lands by preventing over-grazing and soil deterioration, to provide for orderly use, improvement and development, and to stabilize the livestock industry dependent upon the public range. A variety of environmental laws were passed in the late 1960s and early 1970s , it include the National Environmental Policy Act, the Clean Water Act, the Clean Air Act, the Wilderness Act, the Endangered Species Act and the Wild Free-roaming Horses and Burros Act.

B. Land management through TDR

Transferable development rights (TDR) is a method for controlling land use to complement land-use planning and zoning for more effective urban growth management and land conservation. The TDR process can be considered a tool for controlling urban sprawl by concentrating development. TDR is a legal mechanism offered in some local government jurisdictions as a form of development control. TDR a way to avoid constitutional takings issues caused by rezoning areas that would otherwise eliminate a significant amount of value from the property. The procedure offers landowners financial incentives or bonuses for the conservation and maintenance of the environmental, heritage or agricultural values of their land. TDR is based on the concept that with land ownership comes the right of use of land, or land development. TDR programs are a way to permanently protect blocks of productive farmlands. Developers give farmers cash for their development rights. Farmers can use the money in any way they please (e.g. pay down debt, start a retirement account, pay operational expenses). The farmer still owns the land and retains the right to farm it.

Fig 3.Components of TDR

C. Land management through Land pooling

Land pooling, known as land readjustment or land reconstitution is a land acquisition strategy where ownership rights of privately held land parcels are transferred to an appointed agency, with these land parcels being pooled as a result. The technique for promoting efficient, sustainable and equitable land development in the urban fringes is land pooling/readjustment .The concept of land readjustment has been used in various countries of the world for at least two hundred years. It has been most successfully used in Japan and Republic of Korea in recent years. The agency uses some of the pooled land for infrastructure development and sale, while the rights to new parcels in the pooled land are transferred back to the original landowners in some proportion to their original property. From the public agency's perspective, this is a fiscally conservative scheme: the agency need not pay land acquisition costs, the sale of land will provide some revenue, and compensation comes from landowners now owning land that has increased in value following development. It has been utilized in Gujarat under the mechanism of Town Planning Schemes (TPS), where the area of a single TPS can range from 100 to 1,200 hectares and cover 100 to 2,000 individual parcels of land.

D. Kerala's battle to protect paddy land

Kerala's drinking water availability and food security depend on the protection of two factors, first, the Western Ghats which ensure sufficient rains and water to Kerala and second paddy and wetlands which act as natural water reservoirs and allow for the percolation of water into the ground; thereby raising the ground water levels and recharging wells. Currently, both these are in jeopardy; however the threat to paddy lands is acute and extremely serious. Paddy lands in Kerala have become a desired asset for the capital and cash

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rich real estate industry. Land has become a prime speculative asset and its price has escalated to astounding levels, therefore the demand for the lower priced paddy fields has increased. People with power are purchasing and converting paddy lands into 'land banks'. It is clear that in many a project paddy lands are acquired not because there are no other lands available, but because the price of non-paddy land is high (thereby reducing profit margins) and investors do not want to deal with issues of vacating people.

E. KERALA CONSERVATION OF PADDY AND WETLAND ACT, 2008

An Act to conserve the paddy land and wetland and to restrict the conversion or reclamation thereof, in order to promote growth in the agricultural sector and to sustain the ecological system, in the State of Kerala. It has come to the notice of the Government that indiscriminate and uncontrolled reclamation and massive conversion of paddy land and wetland are taking place in the State. On and from the date of commencement of this Act, the owner, occupier or the person in custody of any paddy land shall not undertake any activity for the conversion or reclamation of such paddy land except in accordance with the provisions of this Act. . In 2008, the Kerala assembly passed a bill to protect paddy and wetlands called The Kerala Conservation of Paddy Land and Wetland Act, 20081.

F. RAMASAR Convention

The Ramsar Convention on Wetlands of International Importance especially as Waterfowl Habitat is an international treaty for the conservation and sustainable use of wetlands. It is also known as the Convention on Wetlands. The Convention's mission is "the conservation and wise use of all wetlands through local and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world.

VI. CASE STUDY

The type of strategy depends on the context and the factors affecting the present scenario of the site .The revival and conservation of the paddy farm sector is mainly carried out by successful land management strategies. The revival leads to the socio-cultural and economic benefits of the area.

A. MONTGOMERY COUNTY, MARYLAND

The Agricultural Reserve is a designated land use zone in Montgomery County, Maryland. The 93,000 acres (380 km^2) zone was created in 1980 by the Montgomery County Council to preserve farm land and rural space in the northwestern part of the county. County residents and government planners began to notice the loss of agricultural land and open space as early as the 1950s, associated with the increase in suburbanization following World War II .About one half of the county's farm land was converted to non-farm ownership by the 1960s. The Maryland-National Capital Park and Planning Commission noted a loss of 18,768 acres (75.95 km2) acres of farm land over an 8-year period in the 1970s, an average of 2,346 acres/year.

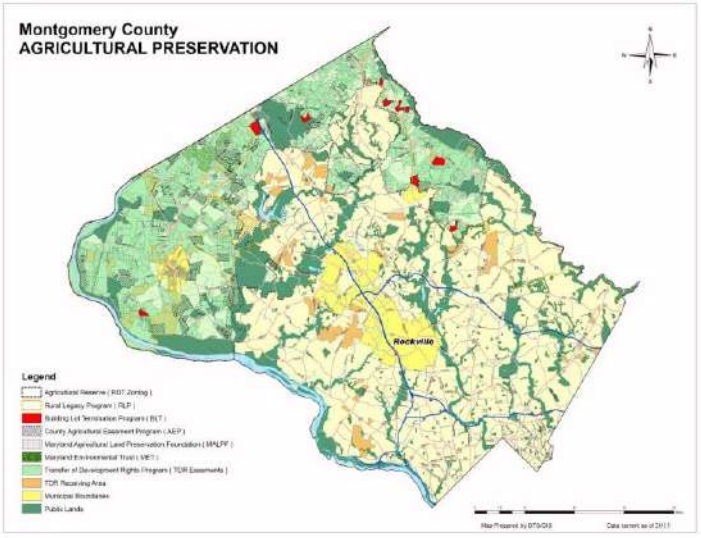

Fig 4.Montgomery county , Master plan.

The 1980 legislation authorized the County government to define a Rural Density Transfer Zone within the Agricultural Reserve, wherein development of new housing is limited to one house per 25 acres. (Previously it was one house in 5 acres). The County Council compensated the rural property owners for their loss of developability, through TDR. The council assigned one TDR for every five acres of rural land in the designated area. A TDR could be sold to someone who wanted to build elsewhere in the county, at a greater density than would otherwise be allowed in that non-rural zone. About two-thirds of those rights were transferred to receiving area development projects elsewhere in the county. In 2008 the County established a Building Lot Termination Program as an additional measure to address fragmentation of farmland. The program authorizes creation of easements on lots where the TDR program may not be applicable, to restrict non-agricultural land uses in the reserve zone. Similar in concept to a TDR, the easement creates a marketable credit for a landowner, and removes the right to build a dwelling unit on a lot. The landowner may sell the credit to a developer for use in another designated zone within the county. The program has preserved 1,025 acres (4.15 km^2) acres of agricultural land as of 2016.

B. KOLE WETLAND CONSERVATION AND EXPERIENCE ZONE, THRISSUR.

The Kole Wetlands act as a natural drainage for the city where the water is carried out to river and from there to the Laccadive Sea, thus keeping Thrissur city safe from floods. One of largest, highly productive and threatened wetlands in Kerala .The Kole Wetlands has been declared in Ramsar Convention for protection. It is known that the Vembanad-Kole system together contains the floodwater and saves about 3500sq.km thickly populated area of Alappuzha, Ernakulam and Thrissur districts of Kerala from flood damages. Management planning for Thrissur Kole wetlands calls for maintaining the site's values and functions while at the same time delivering ecosystem services now and into the future.

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The goal of management planning for Thrissur Kole wetlands is to conserve its rich biological diversity and maintain full range of ecosystem services in order to sustain livelihoods of dependent communities. The project ensures the protection of paddy fields and ecosystem is sustained. Less energy usage and waste generation, keeps the sustainable environment. The project also makes Noise and plastic free zone.It leads to the economic development of the entire area by promoting farm toursim.Revenue generation for Tourism, farmers, local vendors and fishermen is carried out by this project. Training programes are made for the young people of the community as guides for tourists. It Involves the community in running and managing the project and providing job opportunities. Further development, there can be agricultural museum, proposal for home stay etc. Eventually Pullu can evolve into a model Eco friendly sustainably managed tourism destination for the state.

Parameters	Case Study 1 **Maryland Agriculture reserve , WC.**	Case Study 2 **Ullannor , Palakkad.**	Case Study 3 **Pullu padam, Thrissur**	Case study 4 **Goa farming**
Land Ownership	Community	Public-Private	Public – Private	Private
Techniques	Transfer of Development rights	Watershed programme	Public- Private partnership	Land Pooling
Ecological Benefits	1)Conservation of Agriculture land. 2) Agriculture reserve zone .	1) Ground water recharge. 2) Revival of Paddy lands.	1) Conservation of paddy farms. 2) Preserving the endemic species. 3) Flood control.	1) Revival of Agriculture sector. 2) Resistence of Landuse convertion.
Economical Benefits	1) Farm Toursim. 2) Market network.	1)Employement opportunities. 2) Improving Agriculture sector.	1) Farm tourism. 2) Commercial stretch.	1) Employement opportunity. 2) Service provider 3) Market network
Socio-Cultural Benefits	Council formation among the people.	Women empowerment.	Preserving the identity and culture.	Community initiative

Fig 5.Comparitive Analysis

VII. CONCLUSION

Several social and cultural changes and economic forces have led to massive conversion of wetland paddy lands. Although the paddy fields in Kerala are typical wetland ecosystems that provide numerous useful functions, there was a 65 percent fall in the area under rice cultivation since the past 30 years. One of the major reasons cited for abandoning paddy cultivation is that it is considered a loss making proposition. Sustainability on one hand and mindless development on the other hand are two ways open to us. Paddy lands converted for temporary benefits, will lead to sacrificing of long term food security and drinking water availability . Even in developed nations land use patterns are not changed for building activities. The fact that we are in a land scarce state can't afford projects that require large tracts of land need to be accepted. Stringent restrictions on land use and land transactions and place restrictions on indiscriminate buying of paddy land needs to be imposed. Protecting paddy lands that are our food reserves should become the priority The land management can be brought into action through various strategies. The agrarian crisis if solved, can strengthen the primary sector and will consequently lead to economic development. Government and non government agencies can also play an important role in the conservation of paddy farm. Implementation of various agrarian schemes and policies should be made to promote the agricultural practices. Environmental issues needs to be given more priority than the economic development of an area.

REFERENCES

[1] Architects, DD. "Pullu eco-tourism." 2019.
[2] economy, Centre for Indian. n.d.
[3] Gopikuttan, G. "Paddy land conservation in Kerala." 2004.
[4] hindu,The.https://www.thehindubusinessline.com/opinion/hw-the-agrarian-crisis-can-be-eased/article28128069.ece. 2019.
[5] "http://wgdpkerala.org/images/pdf1/Ullannur%20detailed%20report%20with%20completion%20report.pdf." Water shed program (2014).
[6] https://en.wikipedia.org/wiki/Montgomery_County,_Maryland_Agricultural_Reserve. n.d.
[7] https://en.wikipedia.org/wiki/Transferable_development_rights. n.d.
[8] Hussain, Siraj. https://www.downtoearth.org.in/. Friday May 2019. 2019.
[9] iyer, Aparna. https://www.livemint.com/. monday July 2019.
[10] Joseph, E T. "Pokkali farming , Kadamakudi." Ernakulam, 2019.
[11] keddy, Paul A. "Wetland ecology." n.d.
[12] Vagdevi H. S. & Kiranbabu. "Role and importance of Primary sector." 2015.

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