PROCEEDINGS OF

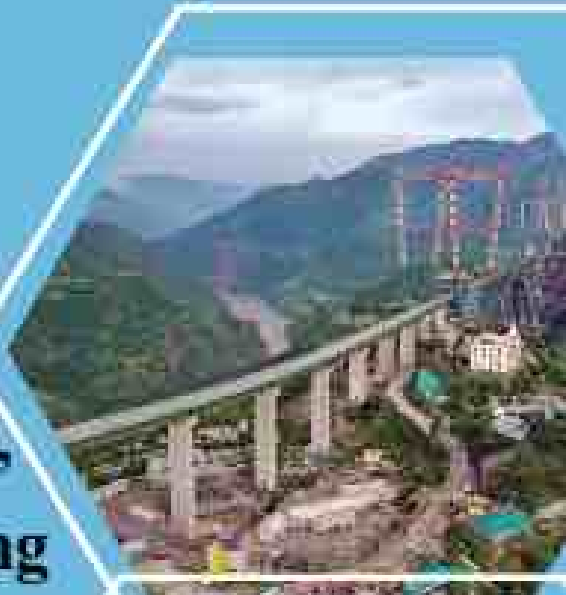
A National Conference on

Emerging Trends in Civil Engineering (ETCE-23)

28-29 December 2023

Organized by

Department of Civil Engineering,
Walchand College of Engineering
Sangli, Maharashtra, India



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Message from the Convener

It is my great pleasure to present the proceedings of the two days National Conference on "Emerging Trends in Civil Engineering", ETCE-2023. This conference is in accomplishment as the first major post platinum jubilee year activity of Department of Civil Engineering at Walchand College of Engineering, Sangli. We were honoured to have for the inauguration Shri Shamrao Kumbhar, Superintending Engineer, PWD, Kolhapur circle as the chief guest, and Dr. Aniket Kataware, IIT Dharwad as the keynoter on the first day and Dr. Dilip Mali, Pimpri Chinchwad College of Engineering, Pune as a keynoter on the second day.

We received sixty-one technical papers, out of which fifty-two papers were selected for presentation distributed in eight sessions. Of these fifty-two papers, nineteen papers were from indigenous departments of Civil Engineering and Applied Mechanics department and thirty-three papers were from others engineering institutes of Maharashtra and Karnataka. These fifty-two papers were presented in eight different technical sessions of oral presentations and two invited talks. ETCE-23 covered four major areas of Civil engineering which are directly linked to socially useful research areas to wit Water and Waste Water technology, Construction Management and Concrete Technology, Environmental Engineering, and Structural Engineering.

The two days' conference has resulted in this proceeding which is an ISBN Publication with a copyright of WCE Sangli. I thank all the patrons, the HoD of Civil Engineering department, the Co-convener, Organizing committee members, the members of the Advisory council and the Director of WCE, Sangli for their support and encouragement during the conduct of this Conference.

Dr. Krishnakedar Gumaste
Convener (ETCE-23)

Message from Head of the Department

ETCE-23 has provided a platform to interact and share the research experience with peers. The information disseminated has given an engineering insight into the emerging trends in Civil Engineering. The efforts of conference team for the effective organization in physical mode is highly appreciated. The conferences on new themes are scheduled to be organized in future.

Dr. G. R. Munavalli
HOD, Civil Engineering

PREFACE

The Department of Civil Engineering at Walchand College of Engineering, Sangli, is hereby producing the proceedings of the First National Conference on Emerging Trends in Civil Engineering (ETCE-23) held on 28-29the December 2023.

The growth in the field of Civil Engineering is observed to be exponential due to several factors such as population growth, rapid urbanization, need for better and sustainable infrastructure, challenges in water sector any many more. Each area of Civil Engineering viz. Structural engineering, Water and Wastewater engineering, Geotechnical engineering, Transportation engineering, Water Resources Engineering, Building Technologies and Construction Project management are experiencing the changes methods, techniques and theories to produce the efficient, optimized, economic and sustainable solutions. This conference aims to provide the platform to the engineering graduates, professionals, researchers and academicians to produce and present their ideas, learning and outcomes from the different areas of Civil Engineering.

The conference was inaugurated by **Shri Shamrao Kumbhar**, Superintending Engineer, PWD, Kolhapur circle. The conference comprised of two- keynote addresses and eight- technical sessions for the paper presentation over the 2-days. The first keynote address on day 1, 28th December 2023 was given by **Dr. Aniket Kataware** (*IIT Dharwad*) on 'Sustainable Road infrastructure while the second keynote address on day 2, 29th December 2023 was given by **Dr. S.T. Mali** (*PCCOE, Pune*) on "Sustainable Landfill waste management". Both sessions were excellent and delivered the latest trends and challenges along with some studies conducted in their respective fields.

The arranged sessions included the paper presentations on the topics Water supply and Wastewater, Construction management and Construction technology, Structural Engineering, Building and Energy, Air Pollution, Groundwater, Geotechnical/Foundation engineering. The sessions were chaired by the eminent faculty from the renowned institutes and industries such as Dr. S. S. Shaha (*KITCOE, Kolhapur*), Dr. K. B. Prakash (*SGBIT, Belgavi*), **Dr. Amol Chavan** (*NICMAR, Pune*), **Er. S. V. Deshpande** (*IMC, Ichalkaranji*), **Dr. V. S. Patil** (*DoT, Kolhapur*), **Dr. Y. M. Patil** (*RIT, Rajaramnagar*), **Dr. M. M. Awati** (*TCE, Gadag*), Dr. P. D. Kumbhar (*RIT, Rajaramnagar*).

The proceeding provides the permanent record of what was presented and indicates the stat of development at the time of writing of different aspects on the various themes. We hope that this will be helpful to all the readers, researchers in their respective areas.

CONFERENCE SCHEDULE	
Day 1: Thursday, 28th December 2023	
Time	**Event/Session**
09:00 am to 10:00 am	Registration and Breakfast
10:00 am to 10:30 am	Inauguration
10:30 am to 11:15 am	Keynote address by Dr. Aniket Kataware (IIT Dharwad)
11:15 am to 11:30am	Tea break
11:30 am to 01:00 pm	**Technical Session 1**
01:00 pm to 02:00 pm	Lunch
02:00 pm to 03:30 pm	**Technical Session 2**
03:30 pm to 03:45 pm	Tea break
03:45 pm to 05:15 pm	**Technical Session 3**
07:00 pm to 08:30 pm	**Dinner**
Day 2: Friday, 29th December 2023	
Time	**Event/Session**
09:30 am to 10:00 am	Breakfast
10:00 am to 10:45 am	Keynote address by Dr. Sandip Mali (PCCOE, Pune)
10:45 am to 12:15 pm	**Technical session 4 and 5**
12:15 pm to 01:15 pm	Lunch
01:15 pm to 02:45pm	**Technical session 6 and 7**
02:45 pm to 03:00 pm	Tea break
03:00 pm to 04:30 pm	**Technical session 8**
04:30 pm to 05:00 pm	Valedictory Session
05:00 pm to 05:30 pm	Certificate distribution and High tea

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Stormwater Drainage Design for Kolhapur city: A literature review

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Abstract—

Urbanization and population growth have led to increased impervious surfaces, exacerbating stormwater runoff issues and posing a threat to local ecosystems and infrastructure. This study focuses on how runoff generated varies with runoff coefficients and factors influencing them. Depending upon land use, rainfall intensity runoff coefficients of 5 basins are 0.48,0.455,0.53,0.55,0.45. The corresponding stormwater runoff generated for 5 basins is calculated using a rational method. The more the runoff coefficient due to impervious cover, the more is runoff generated. The flow direction for each basin along with outfall locations are found using Google Earth Pro and the Contour map of Kolhapur city. The existing system is inadequate for upcoming changed rainfall intensities & land use patterns. An urgent need to redesign an appropriate collection system is brought into the picture. Additionally, the study emphasizes the importance of adaptive management strategies, allowing for continuous refinement of the stormwater drainage system in response to changing urban dynamics and climate conditions. By adopting this comprehensive and sustainable stormwater drainage design, Kolhapur City can enhance its resilience to extreme weather events, mitigate the impact of urbanization on water resources, and contribute to the overall well-being of its residents and the surrounding environment.

Keywords—urbanization, impervious, rational method, sustainable

I. Introduction

Urban stormwater is generated from rain and snowmelt events that flow over land or impervious surfaces and discharge pollutants from nearby urban areas into rivers, lakes, and coastal waters. This stormwater can infiltrate, evaporate, run off, or end up in any stream or water body. Stormwater drainage drains surface runoff water from streets, sidewalks, roofs, and buildings into an appropriate collection system for safe disposal. In areas with natural groundwater, about 10% of the precipitation becomes runoff, about 50% infiltrates into the soil, and 40% is evaporated. As the land becomes more covered with impervious surfaces, more rainfall converts as runoff as much as 55%. (Patel et al.,2020). This can be due to large amounts of runoff produced from rooftops, concrete, asphalt & other impervious surfaces that are designed to shed water. The stormwater quantity generated depends on factors like rainfall intensity, land characteristics, and topography.

Uncontrolled stormwater runoff can erode soil, damage infrastructure, risk of flooding, and deteriorate water quality. Typically, two main types of collection systems work together to manage surface runoff in urban areas effectively. Minor stormwater collection systems are designed to handle small-scale runoff from residential buildings, and commercial areas. It includes gutters, downspouts, catch basins, curb inlets, open channels, Grass swales, rain barrels, and rain gardens. The major stormwater collection system is designed for large volumes of surface runoff in urban areas, industrial zones, and large commercial developments. It includes storm drains, detention & retention basins, sedimentation, filtration & treatment facilities, culverts, and green infrastructure. Effective planning of flow paths across urban areas can reduce the accumulation of flood water and speed of runoff, and increase filtering and infiltration of stormwater runoff.

There are examples where improper collection systems in cities like Vijayawada, Gandhinagar, Hyderabad, and Pune have led to flood conditions, loss of water, infrastructure damage, reduced property values, and increased maintenance costs. In the context of this stormwater drainage design for Kolhapur city is taken into consideration. Kolhapur, situated on the banks of the Panchganga River in western ghats in the city of Maharashtra state with a 6,35,000 lakh population as of 2022. The average rainfall received by Kolhapur city for Wadanage rain gauge station is 200 - 350mm (2010-2020)(Hydrology project, Nashik). Kolhapur witnessed floods in the year 2019 & 2021. There is a need to enhance the capacity of stormwater drains, optimize the placement of retention basins, and implement advanced forecasting and monitoring systems to respond more effectively to changing weather conditions. The post-flood period has focused on a comprehensive review and improvement of Kolhapur City's drainage infrastructure.

II. Land Use Map of Kolhapur City

2.1 Basin-wise Description:

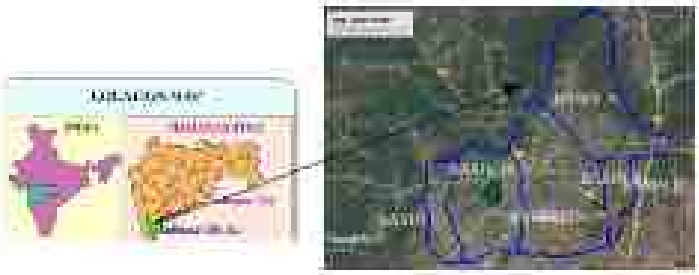

Figure 1. Location of Kolhapur

In the present study, Kolhapur city is considered as a study area. Figure 1 explains the location of the Kolhapur district and Figure 2 explains basin basin-wise map of Kolhapur city. Kolhapur City (16.7050° N, 74.2433° E) has an area of 66.82 km² (Report submitted to Kolhapur Municipal Corporation "Stormwater Management for Kolhapur

City" 2010). Basin-wise land use refers to the categorization and analysis of land use within a specific geographical basin or watershed. Basin-wise land use map is described in Figure 3:

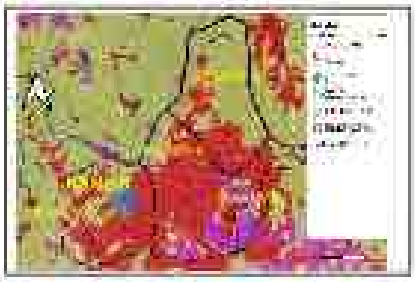

Figure 3. Land use map for Kolhapur city

2.2 Land use Description:

Basin A:

The total area for basin A is 2015 Ha. Basin A includes Bavada, Kadamwadi, Ruikar colony, Mukta Sainik Vasahat, Bapat camp, and Hanuman Talav. The corresponding runoff coefficient for basin A is calculated with an average runoff coefficient of 0.48.

Basin B:

The total area for basin B is 615 Ha. Basin B includes Market Yard, Temlai Wadi, Rajaram Rifles, Vikram Nagar, and Rajaram Lake. The corresponding runoff coefficient for basin B is calculated with an average runoff coefficient of 0.455.

Basin C:

The total area for basin C is 2340 Ha. Basin C includes New Palace, Tarabai Park, Shahupuri, Laxmipuri, KMC main building, Mahalaxmi Temple, Udyam Nagar, Rajarampuri, Pratibha Nagar, Padmale, Chile Colony, Shivaji University, Subhash Nagar, Shanda Park, Babu Jarag Nagar, Kalamba Central Jail, Koti Teertha. The corresponding runoff coefficient for basin C is calculated with an average runoff coefficient of 0.53.

Basin D:

The total area for basin D is 1594 Ha. Basin D includes Lakshya Teertha Vasahat,Phule wadi,Rankala lake,Dudhali Pavilion,Sambhaji Nagar Bus stand,Devkar Panand,Salokhe Nagar,Apte Nagar. The corresponding runoff coefficient for basin D is calculated with an average runoff coefficient of 0.555.

Basin E:

The total area for basin E is 118 Ha. Basin E includes Puj Khadi WTP. The corresponding runoff coefficient for basin A is calculated with an average runoff coefficient of 0.45.

The corresponding basin-wise land use percentage is given in Table 1 and Table 2 for 5 basins

Type of area	Area(Ha)-Basin A	Area(Ha)-Basin B	Area(Ha)-Basin C
Residential area	(30% *2015) 604.5	(25% *615) 153.75	(40% *2340) 936
Paved area	(20%)403	(20%)123	(20%)468
Open spaces	(40%)806	(45%)276.75	(30%)702
RWH	(10%)201.5	(10%)61.5	(10%)234
Total area	**2015**	**615**	**2340**

Table 1. Land use % for basins A, B, C

Type of area	Area(Ha)-Basin D	Area(Ha)-Basin E
Residential area	(45%)717.3	(25%)29.5
Paved area	(20%)318.8	(20%)23.6
Open spaces	(25%)398.5	(45%)53.1
RWH	(10%)159.4	(10%)11.8
Total area	1594	118

Table 2. Land use % for basins D, E

2.3 Basin-wise flow & Outfall location:

Here basin basin-wise flow direction and corresponding stretch of outfall locations are plotted in figure 4,5,6,7,8. Corresponding elevation details are mentioned in Table no 3

Basin	Highest elevation	Outfall
A	Superintendent office -570m	535/540m
B	Agriculture college - 590m	535m
C	Khas bag Maidan - 575 m	540/545m
D	DY patil,COEK -595m	540/545m
E	Little Nemo School -585m	540m

Table 3. Highest & lowest location

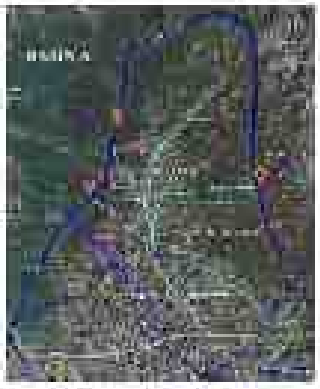

Figure 4. Basin A

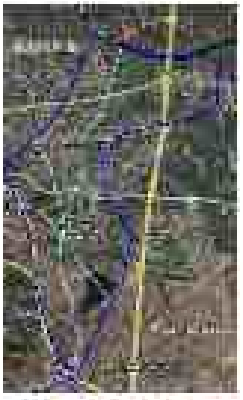

Figure 5. Basin B

Figure 6. Basin C

Figure 7. Basin D

Figure 8. Basin E

III. Stormwater Runoff Generation:

The rational method is a simple technique for estimating a design discharge from a small watershed. It was developed by Kuichling for small drainage basins in urban areas. The rational method is the basis for the design of many small structures. Storm water drains are designed, taking into account the peak flow. The average rainfall intensity is 350 mm/hr for Kolhapur city. (HDUG, data,2023) The peak runoff (Q) is calculated using the following formula:

$$Q_p = 10 \times C \times I \times A$$

Where,

Q_p = Peak flow at the point of design,m^3/hr

C = Runoff Coefficient

I =Average rainfall intensity, mm/hr

A = Catchment area, hectare

Basin	Area (hectares)	C=Runoff Coefficient	Intensity (mm/hr)	Q = 10CIA (m^3/s)
A	2915	0.48	350	946.33
B	615	0.455	350	272.05
C	2340	0.53	350	1205.75
D	1594	0.585	350	860.10
E	118	0.455	350	52.20

Table 6. Basin wise Stormwater runoff generation

Here average runoff coefficient is calculated. The higher the runoff coefficient, and more the runoff generated.

IV. Existing Collection System:

The drainage system of Kolhapur consists of rivers, natural channels, and roadside drains. The coverage of stormwater drainage in the city is not adequate. A closed roadside drain network is in existence for selected and major roads in patches. The drainage system of Kolhapur constitutes river natural nallahs and roadside drains. The major natural drains are Jayanti nalla, Gomati nalla,Dudhali nalla, Line Bazar nalla, and Bapat camp nalla. The river Panchganga flows from west to east along the northern boundary of the city. The absence of a complete network of drains results in obstruction to the flow of water during storm events. The network of roadside drains is insufficient and is inadequately sized. The existing cross-drainage works are not properly sized at many locations. Lack of maintenance and dumping of garbage has also reduced the carrying capacity of these natural drains, roadside open drains, and culverts causing flood problems in the rainy season. In a few regions i.e in basins C and D stormwater drainage system is partially executed, however, other basins are not designed and not executed. (Report submitted to Kolhapur Municipal Corporation "Stormwater Management for Kolhapur City",2010)

V. Summary and Recommendations:

Due to ever-increasing demand to cater to population needs, urbanization is rapidly increasing in Kolhapur city. The land use map gives majorly crowded areas in mid of the Kolhapur region. The factors governing runoff can be an increase in impervious cover, a change in land characteristics, or an alteration in rainfall patterns. In the present study, how an increase in impervious cover, increases runoff generation is studied for 5 basins. Basin C and Basin D have high runoff coefficients with high stormwater runoff generated according to the land use map given in Figure 3. The basin wise stormwater runoff generation is calculated based on the rational method for average rainfall intensity. This basin-wise stormwater generated is completely unaddressed and there is no appropriate collection system. The corresponding flow direction and stretch of outfall locations with elevations are found on Google Earth Pro. The existing collection system is inadequate and there is an urgent need to redesign the system considering rainfall patterns and climate change as important factors. The recommendations aim to enhance the capacity of stormwater drains, optimize the placement of retention basins and ensure a resilient and responsive stormwater management system for Kolhapur City.

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Decentralised Wastewater Treatment By Modified Towery Bio-rack Constructed Wetland System: A Review

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***Abstract*— Large amount of water supplied from various sources for domestic use is converted into wastewater, which is then either discharged into water bodies like rivers, lakes and on the open ground without any pre-treatment or with inadequate treatment at a centralised wastewater treatment (CWWT) facility. A constructed wetland (CW) in decentralised wastewater treatment (DEWAT) is a superior solution for treating residential wastewater right at the source. However, conventional CW needs a sizable amount of space and a material we use for filter media has several problems including restricting wastewater and clogging filter media. Bio-rack constructed wetland (BRCW) and Towery hybrid constructed wetland (THCW) were tried effectively to overcome the limitations of conventional CW. This review paper presents comprehensive literature on BRCW and THCW system for domestic wastewater treatment. Further, the combination of BRCW and THCW is discussed for improving wastewater removal efficiency and dissolved oxygen (DO) content.**

Keywords*— *Centralised wastewater treatment (CWWT), constructed wetland (CW), Decentralised wastewater treatment (DEWAT), Bio-rack constructed wetland (BRCW), Towery hybrid constructed wetland (THCW)

I. Introduction

Residential sewage discharge from cities is the primary cause of water pollution in India which leads to changes in water quality parameters including pH, turbidity, salinity, nitrogen, biochemical oxygen demand (BOD), chemical oxygen demand (COD), etc. are caused by this discharge of wastewater. Wastewater includes impurities organic matter and inorganic matter such as nitrogen and phosphorus that cause environmental issues and greater dissolved oxygen consumption (DO) that influences the nitrification process. Physical, chemical, and biological processes are used in wastewater to get rid of these pollutants. There is a system called centralised wastewater treatment (CWWT) that treats sewage using both chemical and physical methods to purify it. A combination of aeration, flocculation, sedimentation, filtering, and disinfection are used by CWWTS. For the treatment process, this centralised sewage treatment plant (STP) needs a significant quantity of electrical energy, as well as a large area for the installation of its components. The primary importance of management authorities is transporting the effluent to the central sewage treatment plant and ensuring its safe disposal. The safe disposal of this waste involves a significant investment in time and energy. Because of this, CWWT looks uneconomical. Additionally, the performance of the CWWT facility is not so desirable [1]. Decentralised wastewater treatment systems (DEWATs) are therefore widely used around the world.

India's class I and class II cities produce 29,129 MLD of sewage per day together, while their existing sewage treatment capacity is just 6,190 MLD. The 22,939 MLD residual gaps between installed and generated sewage treatment capacity places a heavy burden on STP facilities. DEWATS has developed to deal with this issue. By placing a DEWATS at the source, we can treat the produced wastewater and reduce the load [2].

Sufficient work has been carried out on following DEWATS viz. modified septic tank, a moving bed bioreactor (MBBR), an anaerobic baffled reactor (ABR), a Constructed wetland (CW), an anaerobic filter, a water hyacinth system, a polishing pond, an up-flow anaerobic sludge blanket (UASB), a biogas settler, etc. A constructed wetland is a superior solution for treating residential wastewater right at the source. Constructed wetland is a form of DEWATS that employs biological treatment methods that are economical, simple to use, demand minimal energy input and maintenance costs, are environmentally sound and may take the place of CWWTS. The main mechanism for the treatment process in constructed wetlands is to enable wastewater to pass through porous filter medium (sand, gravel, soil, etc.) planted with vegetation. Categorization of CW depends on flow direction, macrophytic growth and hydrology. According to water flow in substrate CW has divided in three categories vertical flow constructed wetland (VFCW), horizontal flow constructed Wetland (HFCW). However, conventionally constructed wetland needs a sizable amount of space and a material we use for filter media has several problems including restricting wastewater and clogging filter media [3].

The towery hybrid constructed wetland (THCW) system was developed as a novel system to improve the effectiveness of the system to remove contaminants from wastewater in order to solve these problems in conventional constructed wetlands. By aerating a tower-type cascade overflow from the top layer into the bottom layer, THCW raises DO in wastewater and speeds up the nitrification process. To improve the efficiency of the treatment processes, THCW creates an aerobic environment in the system. According to the research, the THCW was capable of effectively eliminating a wide range of contaminants from wastewater [4].

A bio-rack constructed wetland (BRCW) to improve domestic wastewater treatment is another newly developing method in constructed wetlands. Utilizing biological treatment techniques, the BRCW system eliminates contaminants from wastewater. The biofilm that is created by the vegetation's roots on the surface during the treatment process in a BRCW, where nutrients from wastewater are used

to feed the plants, results in good system performance. In comparison to common CW, BRCW need less space and are more effective in removing pollutants. Wetlands that can satisfy effluent discharge standards can be developed with BRCW and THCW [3].

There is a much scope for combining the effects of towery and bio-rack systems, which improves pollution removal from domestic wastewater. Further, some of the modifications like altering flow pattern, multispecies vegetation, use of carrier media, hybrid arrangement and artificial aeration requires for improving the performance of system [5].

II. Literature Review

DEWAT commonly managed anaerobic decentralized wastewater treatment systems but very few data is available on combination of aerobic and anaerobic decentralised wastewater treatment system [1]. CW in DEWAT considered as an efficient and cost effective method for treatment of domestic wastewater. The limitations of CW such as larger area, clogging and inappropriate media to support wetland vegetation [6]. Behaviour of nitrification and denitrification in CW is not defined yet. Few studies were found on Bio-rack CW without using supporting media and acclimatization of species [7]. Vetiveria zizanioides L. plant can also be used to check the performance of the system as this plant is locally available also BRCW without using media can be the point of further studies [8]. Artificial/passive aeration like cascade aeration can be used to increase dissolved oxygen content in wastewater and multispecies can perform better than mono species in the wetland [5]. The combined effect of BRCW and THCW has not yet been studied. More research is needed on long-term studies of wetlands also optimizing influent distribution and configuration requires further study [4].

Varma et al. (2022) reviewed existing DEWATS in India. Researcher also states that this system has been implemented in different places with suitable treatment methods matching with the community needs. Literature survey indicates that DEWATS which are connected to communal sanitation centres have the ability to bridge the gap between on-site and centralized wastewater treatment systems. Very little data is available about the practice of DEWATS other than the handbooks available by different DEWATS implementation agencies. This paper gives a review on the different DEWATS methods (viz. CW, Aerobic treatment systems, Non-membrane biomass retention system, Anaerobic treatment system, Eco-reactor STP, Fecal sludge management etc.) adopted in India which will impart a knowledge on the selection and implementation of different unitary process to be adopted for DEWATS process.

Patil and Munavalli (2020) developed a hybrid bio-rack packaged wastewater treatment system (HBPWWTS) for domestic wastewater. Bio-rack, broken bricks, and multiple plant species (such as Typha, Phragmites, and Cannabis indica) are all included in HBPWWTS. The system is in a 0.25 m2 circular reactor with a spiral flow. 80mm-diameter used, discarded plastic bottles arranged in a grid pattern with a PVC pipe in the middle. In the subsequent treatment, CW was able to remove up to 64-92% BOD and 44-77% TKN.

Koli and Munavalli (2020) developed a composite bio-rack constructed wetland (CBCW) at field scale. The CBCW is a multi-compartment system that includes BR compartments (BRC) and compartments that use brickbats as a supporting medium. Canna indica macrophytes and Typha angustifolia L. are used to vegetate the system. The primary treated wastewater enters the CBCW and runs up-flow and down-flow through each compartment before being released into the output chamber and supplied to a vertical flow constructed wetland (VFCW) for further treatment. With average effluent COD and BOD3 of 130 mg/L and 60 mg/L, respectively, removal efficiency for COD was 37.50% in CBCW. The removal efficiency fall short of the CPCB, India's authorized land application wastewater regulations, requiring further tertiary treatment before disposal.

Sathe and Munavalli (2019) modified conventional bio-rack for the treatment of domestic wastewater. Modifications included growing of multispecies plants, including Typha angustifolia and Cannabis indica in bio-racks system. Non-perforated plastic water bottles where plug-flow was created using baffles. It was determined that dissolved organics (carbon and nitrogen) could be removed from residential wastewater using conventional bio-rack wetland systems (CBRWS) and modified bio-rack wetland systems (MBRWS). CBRWS and MBRWS were operated in sequential continuous (1.5h, 4–24h (in multiples of 4) HRT) and MBRWS in continuous (4, 12, and 24h HRT) mode. The removal efficiency of MBRWS was more than CBRWS by 4–9%, 4–13%, and 3–16% for COD, BOD3, and TKN, respectively. The DO level was also increased by 0.6–1mg/L in MBRWS. The baffling used to create plug flow in MBRWS was found to be more effective than the use of multispecies vegetation for the removal of dissolved organics.

Sathe and Munavalli (2018) reviewed Bio-rack constructed wetland system as a decentralised approach for treatment of wastewater. Literature shows that CW are often used for decentralized wastewater treatment, however this system has limitations viz. requirement of larger area, clogging, and appropriate media to support wetland vegetation. The concluding remarks show that the bio-rack wetland system has shown a great potential to treat the domestic wastewater at a higher loading rate and within lesser space requirement than the conventional CW. Clogging problem in CW will also be overcome by using bio-rack system. So it appears to be a feasible method for treatment of domestic wastewater. With some of the modifications like altering flow pattern, multispecies vegetation, use of carrier media, hybrid arrangement and artificial aeration further performance of the current system can be enhanced.

Jamshidi et al. (2014) evaluated the possibility for treating domestic wastewater produced by a small community (751mg COD/L and 348mg BOD/L) using an integrated ABR and bio-rack wetland planted with Phragmites sp. and Typha sp. In these studies, two anaerobic baffled reactors were set up in parallel followed by a horizontal flow bio-rack system vegetated with Phragmites sp. and Typha sp. The rectangular tank of the bio-rack unit has a net volume of 50L and is planted with vegetation. The system consists of 15 vertical PVC pipes that are rack-like in construction and free of any media (soil, gravel, etc.). These two parallel laboratory-scale models showed that the systems planted with Phragmites sp. and Typha sp. are capable of removing COD by 87% & 86%, soluble COD (for a soluble COD, the samples are filtered through a 0.45mm filter) by 90% & 88%, BOD5 by 93% & 92%, TN by 79% & 77%, at an overall HRT of 21 hours (843g COD/m3/day & 392g BOD5/m3/day) and 27 hours (622g COD/m3/day & 302g BOD5/m3/day), respectively. The vegetated system planted with Phragmites sp. showed higher

pollutant removal efficiencies due to its extensive root and mass growth rate of the plant as compared to Typha sp.

Valipour and Kalyanraman (2012) conducted a comparative research to compare the efficiency of shallow pond and bio-rack systems for treating domestic wastewater. In these experiments, the bio-rack and shallow pond systems for treating residential wastewater in the presence of high levels of total dissolved solids (TDS) or salts containing heavy metals were examined. Two laboratory-scale reactors using Phragmites sp. and water hyacinth i.e., bio-rack and shallow pond system were set up. The shallow pond reactor is a circular tank that holds 24 litres, while the bio-rack reactor is a rectangular tank that holds 55.5 litres. Both reactors are filled with vegetation. The effectiveness of the wastewater treatment system shows removal efficiencies of 75.15% and 80.93% for COD, 86.59% and 90.90% for BOD5, and 70.22% and 74.18% for NH3-N reduction at 10 and 21 hours of hydraulic retention time (HRT), respectively.

Wang et al. (2012) performed a comparative research to compare the effectiveness of four plant species in bio-rack-constructed wetlands in removing contaminants from low-concentration polluted river water and a control system. Five tiny glass containers with a working depth of 380 mm and a huge glass container made comprised the experimental setup. Within the four little containers, a rack of twenty PVC pipes was put together. For liquid transportation, the pipes had many perforations. Thalia dealbata, Acorus calamus, Zizania latifolia and Iris sibirica are among the chosen plants. Another small container with no plants was referred to as the control. The average removal rates of total nitrogen (TN) ranged from 40.79% to 78.07% in the four bio-rack wetlands and from 15.20% to 32.24% in the control system. The bio-rack wetland vegetated by T. dealbata showed higher TN removal rates than the other wetlands, and lower TN removal rates were obtained in the Z. latifolia and I. sibirica systems. Average removal rates of NH3-N ranged from 40.21% to 68.97% in the bio-rack systems and from 9.67% to 41.84% in the control wetland. The bio-rack wetland vegetated with T. dealbata showed the highest NH3-N removal rate. The average removal rates of COD were low and unstable, ranging from 7% to 38.81%.

Fenxia and Ying (2009) developed the towery hybrid constructed wetland system (THCW) for the removal of nitrogen from domestic wastewater for rural communities. In these studies, conventional constructed wetlands combined with three stages of THCW. The first and third stages are rectangular horizontal subsurface flow constructed wetlands and the second stage is circular three-layer free water flow constructed wetlands. The average pollutants removal rate was 85%, 83%, and 83% for COD, ammonia nitrogen (NH3-N), and total nitrogen, respectively. The studies show that THCW is effective at removing many pollutants, first stage target total suspended solids (TSS) and BOD, the second stage enhances the nitrification rate and the third stage enhance the denitrification.

III. Literature Gap

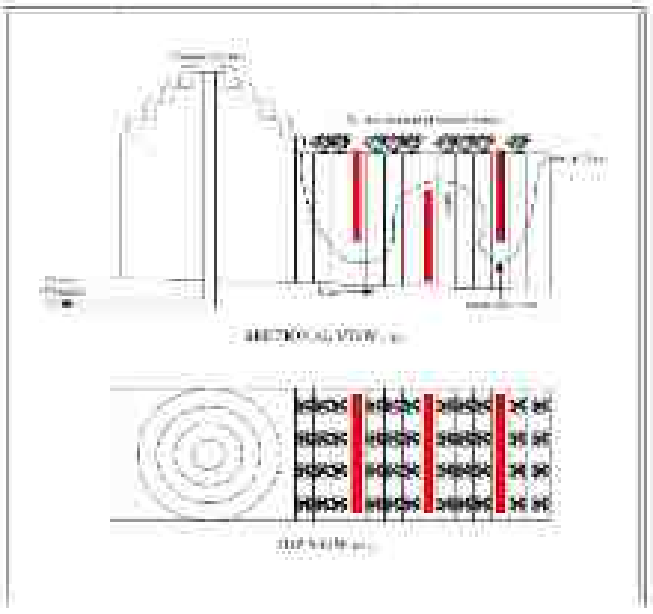
Previous studies have shown the effectiveness of CW systems in treating domestic wastewater. However, few of them address the issue of raising dissolved oxygen levels in the CW. The limitations of CW such as larger space requirement and a material use for filter media have several problems including restricting wastewater and clogging filter media. As per the researchers BRCW offers a more compact and efficient solution similarly THCW system effectively removes contaminants but requires significant space. The drawbacks of conventional CW, which has not yet been thoroughly studied, can be reduced by combining the effects of BRCW and THCW. More design modifications are needed to improve the system's performance, such as adding aeration for improved oxygenation, use of multiple species for long-term analysis, etc.

IV. Proposed Work

This research proposes a modified approach, the Towery Bio-Rack Constructed Wetland (TBCW), which combines the benefits of the THCW and BRCW systems. The TBCW enhances pollutant removal efficiency, oxygenation and space utilization, making it a promising solution for domestic wastewater treatment. The TBCW addresses this gap by providing a compact system that increases dissolved oxygen levels and efficiently removes contaminants from wastewater. The proposed Techno-Economical Feasibility Study on Domestic Wastewater Treatment using Modified Towery Bio-Rack Constructed Wetland aims to contribute to the development of an environmental friendly and cost-effective solution for treating domestic wastewater. The integration of the Towery and Bio-Rack systems offers a promising approach to improve pollutant removal efficiency and optimize space utilization. This research has the potential to benefit communities by providing a decentralized wastewater treatment option that meets environmental standards and minimizes energy consumption. Proposed domestic wastewater treatment includes following stages: raw wastewater, anaerobic baffle wall reactor (ABR) with sludge removal technique (primary treatment), MTBCWS (secondary treatment), polishing pond (tertiary treatment) and reuse water for agricultural, toilet flushing etc.

Tentative sketch of Modified Towery Bio-rack Constructed Wetland System (MTBCWS) is shown in the diagram below:

Fig. 1. Schematic sketch showing MTBCWS



V. Conclusion

DEWAT is considered as economical and efficient method for treatment of domestic wastewater. Many research studies conclude that CW is superior for domestic wastewater treatment. Existing CW has many drawbacks such as larger space requirement, maintenance, etc. To overcome the drawbacks of existing system some modifications are required in terms of design so that it will be efficient and cost effective technology to treat domestic wastewater. BRCW has potential to remove the heavy contaminant present in wastewater but due to media used in the system clogging issue is observed to overcome this challenge without using media in the BRCW has been practiced by few researchers. THCW removes the pollutant load significantly by increasing the DO in wastewater. Combined effect of THCW and BRCW were not established yet. In the present review MTBRCWS is studied. The system includes primary treatment (ABR), secondary treatment (MTBRCWS) and tertiary treatment (Polishing pond) for domestic wastewater. This study will address the space requirement and clogging issue. Since, domestic wastewater treatment is not standardized there is a lot of space to develop an eco-friendly, effective and affordable system.

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Bio-rack settler for treatment of domestic wastewater with a hybrid mode of treatment

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***Abstract*— The quality of water in the sources is degrading due to the direct discharging of the wastewater in the source without any treatment. The decentralized methods of wastewater treatment are one of the alternatives for carrying out the treatment of wastewater at the source of wastewater generation. Bio-rack wetland is one of the newly developed decentralized methods for the treatment of low-strength wastewater. Bio-rack is an assembly of vertical pipes in which wetland plants are inserted. The bio-rack wetland has eliminated disadvantages like clogging and excess space faced by constructed wetlands. The bio-rack can be modified to elevate the performance, in the present study a modified bio-rack has been assembled by combining the bio-rack with the settler. The bio-rack will act as a vertical reactor and the settler will act as an inclined reactor. The modified bio-rack wetland uses *Typha Angustifolia L.* as vegetation. This modified bio-rack was operated in alternate continuous and batch modes, the period for continuous mode was 5h and for batch mode was 19h the study was carried out for 4 weeks. The wastewater treatment analysis was done by COD and TSS removal efficiency in continuous and batch mode. The average COD removal efficiency in continuous mode was 28% and for batch mode was 42% respectively. The average TSS removal efficiency in continuous mode was 36% and for batch mode was 44% respectively. The combination of bio-rack with settler has uplifted the suspended solids removal efficiency of the conventional bio-rack.**

Keywords*— *Decentralized treatment, bio-rack wetland, Settler, Typha Angustifolia L.

I. INTRODUCTION

Water has been the lifeline for the development and backbone of human civilization since the beginning. In recent decades due to the population explosion, there has been a rapid increase in infrastructure and production activities, and there has been a big surge in water demand. The water supplied to the residential areas is about 70% -80% of the total demand. Approximately 330 km^3/year of domestic wastewater is generated on the planet. The wastewater generation in India is roughly around 14 km^3/year only in class 1-2 cities and towns, from which only 32% is treated (CPCB,2013). Untreated wastewater is released straight into water sources, causing significant water contamination. In India, around 38.5 million m^3/d of wastewater is generated and the capacity of sewage treatment plants (STP) is approximately 12 million m^3/d which means there is a gap of 26.5 million m^3/d of wastewater treatment capacity. This large gap between wastewater generation and treatment is due to the low number of sewage treatment plants and less financial support along with the large cost of operation and maintenance of the STP. Despite current legislation and wastewater treatment technologies, the quality of the urban, peri-urban, and rural environments in Indian aquatic systems continues to deteriorate. Despite the efforts of a number of concerned public entities, the majority of Indian STPs use just primary treatment, dumping high biochemical oxygen demand (BOD) sewage into natural waterways. The treated effluent from 49 of the 152 STPs exceeds BOD criteria and, in terms of COD, surpasses the standards. It is recognized that present methods of environmental remediation are ineffective, necessitating the development of a holistic approach to environmental management that is both economical and sustainable.

Fig 1. Wastewater generation and treatment capacity in India during different decades (CPCB, 2013)

Fig.1 shows the wastewater quantity generated in MLD for years in different decades. It can be clearly seen that the quantity of wastewater has significantly increased but the capacity to treat the wastewater has not significantly increased resulting in the large quantity of wastewater to discharged directly without any treatment.

To solve the wastewater treatment problem the concept of decentralized wastewater treatment was introduced. Decentralised wastewater systems treat, reuse or dispose of the wastewater at a short distance from its source. They aim to protect public health and the environment by significantly decreasing health and environmental dangers. The countries like China, Japan, and Australia have made decentralized wastewater treatment mandatory for the treatment of greywater (Gasilke, 2006). In India, the use of decentralized wastewater treatment systems is increasing. Municipal corporation of Bangalore has made decentralized wastewater treatment mandatory for apartments since year 2004 (Evans et al., 2014).

One of the low-cost methods of decentralized method of wastewater treatment is constructed wetlands (CW). The

constructed wetland is made up of the treatment basin having plants supporting media for plants and wastewater which is to be treated. The micro-organisms reside on the roots of plants and the treatment basin walls, allowing the attached growth system. The plants used in CW are vascular in nature which transport oxygen from the leaves and release it from the roots achieving the aerobic condition. Using the absorption, settling, and exchange concept, the system eliminates bacteria, dissolved pollutants, and nutrients. The treatment mechanism involves the biological treatment process. This type of treatment is suitable for domestic wastewater with low pollutants and a limited amount of wastewater. The CW is provided as the tertiary mode of treatment for the treatment of wastewater generated at the hostel along with an anaerobic baffled reactor and anaerobic filter (Bresciani, 2016).

The CW is not adopted due to the requirement of more area for construction and operation hefty financial investment and the clogging of media. Bio-rack (BR) is one of the alternatives which works on the same working principles as constructed wetlands but eliminates the disadvantages like clogging of media and requirement of excess area. To boost the performance of the BR and to achieve the economy various modifications have been made to BR. The present study focuses on one such modified BR in which the conventional bio-rack is combined with the settler to enhance the suspended solids removal efficiency.

Objectives—

A. To configure and assemble the bio-rack settler.

B. To assess the performance of the Bio-rack settler system for removal of, COD and TSS for 5h of continuous mode and 19h of batch mode.

II. Materials and Methods

A. Source of wastewater

The wastewater is collected in a sewer parallel to MSEB road, which runs from Walchand College of Engineering in Vishrambag to the Dhiraj Kumar Badminton Academy in Limaye Mala, Sangli. It is made up of wastewater from hotels, hostels, college mess, halls, and residential areas. The majority of the sewage entering this sewer originates from Vishrambag's residential areas. The wastewater was collected from the source via grab sampling in the evening between time span of 5 pm to 6 pm and transported to the location where the bio-rack settler was installed.

B. Selection of vegetation

The researchers conducted the investigation employing plants such as Typha angustifolia L. Canna indica, Phragmites, Acorus calamus, Zizania latifolia, Iris Sibirica, and Thalia dealbata as vegetation for the bio-rack.

- The plant must be able to withstand extreme heat and cold, as temperatures in the established region can reach as high as 40 degrees Celsius and as low as 13 degrees Celsius.
- The plant should develop quicker in order to build the system in a short period of time.
- Because the facilities will be dealing with wastewater treatment, they should be able to readily adjust to the saturated circumstances.
- The plants should be readily available in the area and simple to install and remove from the system.
- To boost the effectiveness of wastewater treatment, the associated growth system's roots should be long enough to allow for more bacterial growth.

Typha angustifolia L was chosen as vegetation because it was accessible in the Kumbhar Mala, Sangli, which is close to the spot where the bio-rack settler has been installed. Another unique trait of Typha angustifolia L. that is important in the treatment process is its capacity to transmit oxygen through its roots and sustain aerobic conditions till root depth (Tornbjerg et al. 1994).

Typha angustifolia L. leaves range in length from 3 to 6 feet when completely grown; when mature, around 12 to 16 leaves sprout from each vegetative stem (Khonde and Munavalli, 2022). Typha angustifolia L. has a root length of up to 60 cm (Sathe and Munavalli, 2019), and earlier research has shown that Typha angustifolia L. is a plant that can live in filthy water and is extremely trustworthy for polluted water treatment.

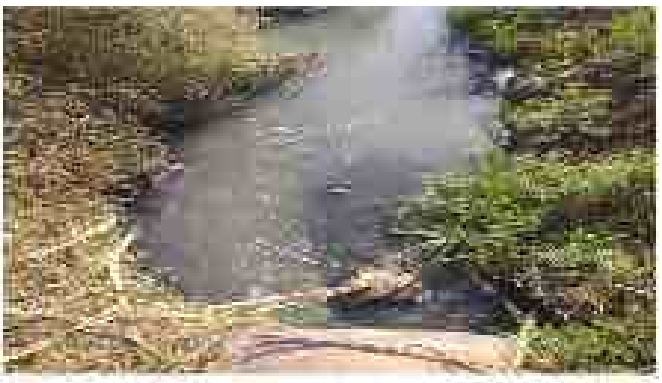

Fig 2. Photograph of the source of wastewater

Fig 3. Photographic view of the source of vegetation

C. Process of Acclimatization

Typha angustifolia L was moved from Kumbhar Mala to the establishing site by simply lifting the plants while holding the leaves and roots. Typha angustifolia L. grows only in regions where there is plenty of water. When Typha angustifolia L. is exposed to dry conditions, it tends to droop; consequently, acclimatization is essential to avoid Typha angustifolia L. drooping. During the acclimatization phase, the plants adjust to the changing circumstances generated by changes in the effluent.

Fig.4 shows the plants during the acclimatizing phase. During the acclimatization stage, the plants were stored in containers deploying a batch mode of operation.

When taken from Kumbhar Mala, Typha angustifolia L. was cleaned with fresh water to eliminate the dirt that had been adhered to the roots after removal. After cleaning the roots, the plants were placed in two drums filled with fresh water for four days before adding wastewater. The concentration of wastewater was gradually raised until the plants were accustomed to raw wastewater.

Fig 4. Photographic view of plants during the acclimatizing stage

D. Experimental setup

Fig 5. Photographic view of the bio-rack settler (BRS)

Fig.5 shows the photographic view BRS. BRS is assembled with 75 mm diameter PVC pipes which were discarded as waste. The pipes were assembled on-site as per the plan and fixed in the stand, the stand is assembled with the square sections available on-site.

Table 1 shows the detail configuration of bio-rack settler. The wastewater was supplied from the overhead tank to the vertical bio-rack 1 of the bio-rack settler with the help of a saline pipe. The saline pipe was used because it has the V-Track controller which helps to keep the constant flow from the overhead tank to the vertical bio-rack 1. The overhead tank was a plastic drum of 50-litre capacity provided with a tap at the bottom for supplying wastewater to BRS.

The outlet pipe is provided with a tap for taking out treated wastewater from the system, the tap is provided with a 5 mm diameter pipe for carrying wastewater from the outlet tap to the container in which treated wastewater is to be collected. The wastewater will flow from the overhead tank into the vertical bio-rack 1 from the saline pipe. The wastewater while flowing from vertical bio-rack 1 will come in contact with the biofilm grown on the pipe surface and the roots of vegetation. The wastewater will pass from the inclined bio-rack allowing the suspended solids to settle and finally, wastewater will pass from vertical bio-rack 2 coming in contact with biofilm grown on the internal surface of the pipe and roots. Treated wastewater will come out of the bio-rack settler from the outlet pipe into the bucket.

Table 1 Detailed configuration of bio-rack settler

Sr. No	Time of operation	Hours of operation	Mode of operation
1	10 am to 3 pm	5	Continuous mode
2	3 pm to 10 am	19	Batch mode

E. Time pattern for working of BRS

Table 2 Time pattern for the operation of bio-rack settler

Sr no	Details of System	Descriptions
1	Shape of model	Circular
2	Diameter of pipe	0.075 m
3	Length of pipes	Vertical bio-rack 1- 1.5 m Inclined bio-rack – 1.0 m Vertical bio-rack 2- 0.5 m
4	Surface area	0.004417 m^2
5	Volume of Model	0.01325 m^3
6	Vegetation	*Typha angustifolia L*
7	Material of bio-rack settler	PVC

Table 2 shows the time in hours for working of BRS. Time pattern simulates the part of time pattern and generation of wastewater in the hostel mess, the wastewater is supplied in continuous mode from 10 am to 3 pm with a flow of 0.00264 m^3/h. From 3 pm to 10 am of the next day the system will operate in batch mode. During operation, the system was operated with the HLR of 0.5976 $m^3/m^2.h$.

F. Sampling methodology

After the requisite duration of operation, the sample was collected using the grab sampling technique from the effluent of the bio-rack settler. Multiple grab samples were gathered from the outflow for analysis to ensure error-free results. Every time, 200 ml of sample was taken in a glass beaker to be analyzed.

III. Result and Discussion

A. Characteristics of Influent

After obtaining the grab sample the wastewater was kept for settling which would act as the primary treatment and this primarily treated wastewater will be used as an influent for

the bio-rack settler. After testing the wastewater the average values of the primarily treated wastewater are mentioned in Table 3 shown below.

Table 3. Influent characteristics of primarily treated wastewater (Mean ± Standard Deviation)

pH	COD	TSS
-	mg/L	mg/L
7.82 ± 0.23	113 ± 23.97	233.83 ± 74.9

The value of pH is slightly more indicating the wastewater is alkaline in nature. The mean value of COD is 113 mg/L with a standard deviation of 23.97 mg/L the value of influent is more than the value described by the standards of the National Green Tribunal (NGT) of 50 mg/L. Hence the secondary treatment is necessary for the removal of carbonaceous organic matter.

The mean value of TSS is 233.83 mg/L with a standard deviation of 74.9 mg/L the value of the influent is more than the value described by the standards of the National Green Tribunal (NGT) of 20 mg/L. Hence secondary treatment is necessary for the removal of suspended solids.

B. Removal of Carbonaceous organic matter:

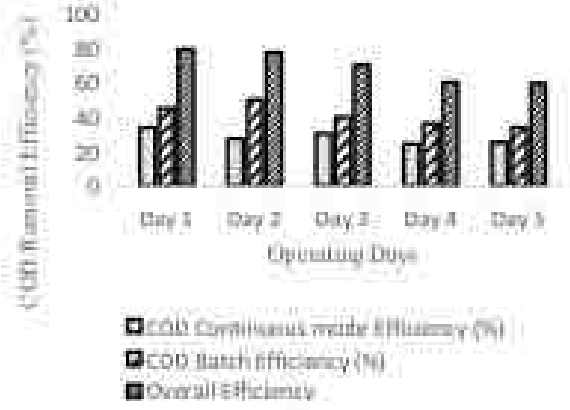

Fig 6. COD removal efficiency obtained during the different operating modes of BRS

Fig.6 shows the COD removal efficiency in percentage for continuous mode, batch mode and overall removal efficiency obtained during different operating days. The COD removal efficiency varies from 24% to 30% with an average COD removal efficiency of 28% for 5h operating time for the continuous mode of operation. The COD removal efficiency varies from 35% to 51% with an average COD removal efficiency of 42 % for 19h of operating time for the batch mode of operation. The overall COD removal efficiency varies from 59% to 77% with an average overall COD removal efficiency of 69%. The OLR for continuous mode of operation varies between 0.577 Kg. COD/ m^3 d to 0.739 Kg COD / m^3 d.

C. Removal of suspended solids

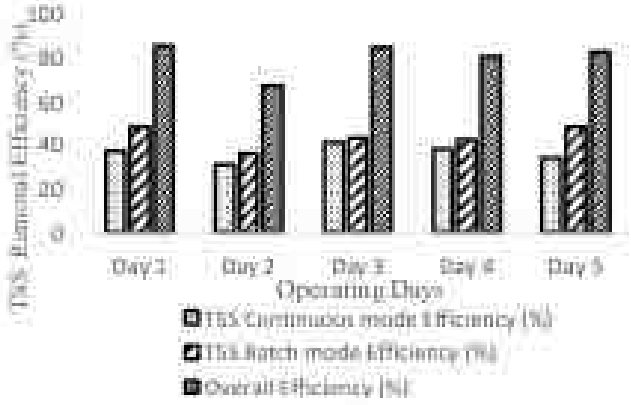

Fig 7. TSS removal efficiency obtained during the different operating modes of BRS

Fig.7 shows the TSS removal efficiency in percentage for continuous mode, batch mode and overall removal efficiency obtained during different operating days. The TSS removal efficiency varies from 34% to 41% with an average TSS removal efficiency of 36% for 5h operating time for the continuous mode of operation. The TSS removal efficiency varies from 36% to 48% with an average TSS removal efficiency of 44 % for 19h of operating time for the batch mode of operation. The overall TSS removal efficiency varies from 67% to 85% with an average overall TSS removal efficiency of 79%.

D. Growth of vegetation during the period of operation

Table 4. Length of vegetation in bio-racks before and after the study period

Date of study	Leaf length in bio-rack 1 (cm)	Leaf length in bio-rack 2 (cm)	Number of leaves in bio-rack 1	Number of leaves in bio-rack 2
19/12/2022	58.7	64.3	3	5
19/02/2023	104.4	114.8	15	18

Table 4 shows the leaf length and number of leaves before and after the completion of the study. The maximum leaf length of Typha angustifolia L. inserted in bio-rack 1 after the acclimatization phase was 58.7 cm with 3 leaves. The maximum leaf length of Typha angustifolia L. inserted in bio-rack 2 after the acclimatization phase was 64.3 cm with 5 leaves respectively.

After completing the study period, the maximum leaf length of Typha angustifolia L. inserted in bio-rack 1 after the acclimatization phase was 104.4 cm with 15 leaves. The maximum leaf length of Typha angustifolia L. inserted in bio-rack 2 after the acclimatization phase was 114.8 cm with 18 leaves respectively.

IV. Conclusion

The average overall COD removal efficiency is 69%. The COD removal efficiency during continuous mode of operation varies as per the OLR. The OLR varies from 0.537 Kg. COD / m^3 d to 0.739 Kg. COD / m^3 d. increase in the OLR decreases the COD removal efficiency during the continuous mode of operation.

The average overall TSS removal efficiency is 79%. The settler was found to be effective in removing the suspended solids.

The Typha angustifolia L. has grown significantly in the bio-rack settler during the period of study.

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Studies on Groundwater Quality in Residential Area of Jaysingpur Town – A Case Study

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Abstract

In the residential area of Jaysingpur town, the municipal water supply is not regular. In some areas, the water supply is 5 times a week and in some areas, it is 3 times a week. Due to this other than these days, there is water scarcity. To overcome this water demand for daily needs, many people depend on bore well water. Many people use groundwater for drinking purposes without any treatment. So, it is necessary to assess the quality of Bore well water from the residential area of Jaysingpur town to cognize if it is potable or not. This study will provide valuable data concerning the assessment of groundwater quality in the residential area of Jaysingpur town, as there's no prior study or published data on this issue. For the convenience of the current study, the residential area is divided into 4 zones. The Physico-chemical parameters such as - pH, TDS, Turbidity, Electric Conductivity, DO, Total hardness, Alkalinity, MPN, chlorides, and fluorides are studied to measure the quality of water. Also the household treatments like boiling and effective treatment between RO and candle filter is reported in the same. As per the testing, some parameters are exceeding the limit when compared with the drinking water standards of IS10500 (2012). Overall observation reveals that the bore well water quality of the residential area of Jaysingpur town is currently not good hence it is not potable, as hardness, alkalinity, TDS, and MPN of all bore wells water are high, it is dangerous to drink such water without treatment.

Keywords: Bore well water, Physico-chemical parameters, River Water, Drinking water.

I. INTRODUCTION

Water is important for the survival of any type of life. Water accounts for about 70% of the burden on somebody's body. It's a transparent and known proven fact that clean water is essential for healthy living. Water is distributed in nature in numerous forms such as rainwater, river water, groundwater, etc. About 71% of the earth's surface is roofed by water. Out of the full quantity of water present in the world, about 97% of the earth's water resources are locked up within the oceans and seas, which are just too saline and not useful for drinking, for the direct use of agriculture and industrial purpose. About 2.4% is trapped in giant glaciers and polar ice caps. Thus not even 1% quantity of water is on the market for drinking, agriculture, domestic and industrial consumption. Though water is one of the abundantly available substances within nature, all living organisms are nowadays facing water scarcity. But its abundance and scarcity have been greatly important in shaping the lifestyle and culture of the people living in a specific region. One of the water sources which play important role in supporting day to day activities of people is that groundwater. Groundwater is one of the most reliable and extensively used natural resources and it constitutes about 20% of the world's water supply, which is about 0.61% of the whole world's water. This makes it, a crucial resource that might act as natural storage which will be utilized during water scarcity periods. Bore well water satisfies about 91% of overall drink demand and is taken into account as the more reliable source of water as compared to surface water(Girija Shankar, Tailor, and C.P. Singh Chandel 2010). The availability of groundwater is depend upon the length and breadth of the country (Chatterjee et al.; 2009). Quite two billion people worldwide rely on groundwater for their daily water system.

In India, where there's an uneven distribution of water resources, groundwater plays a vital role to fulfil water requirements for domestic, irrigation, and industrial needs (Mamatha P and Rao Sudhakar 2009). About 85% of rural and 50% of urban domestic water requirements and about 92% of irrigation requirement is being fulfilled by groundwater extraction(Jha and Sinha, n.d.). However, water quality is deteriorated commonly by a rapid increase in population and uncontrolled development of projects like stock farming, irrigation, urbanization, and industrialization. An oversized quantity of waste products is being generated and discharged which contaminates both groundwater and surface water. The excessive and improper use of chemical fertilizers, animal manures, insecticides, and pesticides, improperly built or poorly located and/or maintained septic systems for household wastewater, leaking of underground storage tanks and piping, improper disposal or storage of wastes, and chemical spills at industrial sites and excess use of groundwater haven't only decreased groundwater availability, but also it affects on its quality(Srinivas, Bhakar, and Singh 2015). As our dependence on groundwater increases, its quality becomes an ever more important issue(Pye Veronica and Patrick Ruth 1983). Water quality may be a growing global concern and over 80% of the human diseases within the world are caused by unsafe water sources and inadequate environmental sanitation practices. Hence it's necessary to place appropriate efforts into improving the quality of groundwater. Water quality parameters offer the bottom for analysis of the suitability of water for various use and improve the current conditions. Beverage quality analysis of some bore water of Chikli town, Maharashtra is completed by Khadsan and Kadu(R.E. Khadsan and Mangesh V. Kadu 2003). The experimental work is completed on the Physico-Chemical properties of groundwater near granite mines in Jhansi (U.P) by Manjesh Kumar and Ramesh Kumar (Manjesh Kumar and Ramesh Kumar 2013). Physico-chemical studies on the

assessment of well water quality in the Kota district were done by collecting samples from 5 tahsils in the morning and evening for pre-monsoon, post-monsoon, winter, and spring seasons(Anilesh Kumar Yadav, Gupta M Nafees, and Gupta 2016). Assessment of groundwater quality around solid waste landfill area at Turmuri, Belgaum, is finished to determine the magnitude of dumpsite pollution on groundwater quality. During the study period, 7 bore wells were selected around the landfill area at a distance of 500, 750, and 1000m (Patil, Narayanakar, and Virupakshi 2013). The literature review showed that numerous studies were conducted on groundwater quality assessment. Recent research shows that due to the rapid increase in population growth and industrialization groundwater quality is decreasing day by day.

In the residential area of Jaysingpur town, the municipal water supply is not regular. In some areas, the water supply is 3 times a week and in some areas, it is 3 times a week. Due to this other than these days, there is water scarcity. To overcome this water demand for daily needs, many people depend on bore well water. Many people use groundwater for drinking purposes without any treatment. So, it is necessary to assess the quality of Bore well water from the residential area of Jaysingpur town to cognize if it is potable or not. Hence, the current study deals with the assessment of the groundwater quality of the residential area of Jaysingpur town in Maharashtra, which has a population of about 60,000 (as per the 2011 census). The suitability of groundwater has been evaluated concerning standards prescribed by the Bureau of Indian Standards (BIS). Samples were tested for the following 10 drinking water quality parameters –

1) Physical parameters – Turbidity, Electric Conductivity.

2) Chemical parameters – pH, TDS, DO, Total hardness, Alkalinity, MPN, chlorides, fluorides, etc.

This study will provide valuable data concerning the assessment of groundwater quality in the residential area of Jaysingpur town, as there's no prior study or published data on this issue.

II. METHODOLOGY

A. Geographical Data

Location: Jaysingpur is located in Kolhapur district which is located in the southwest of Maharashtra state in India. Jaysingpur lies on 16o46'47.5572" N latitude and 74o33'22.9464" E longitude. Jaysingpur belongs to tehsil Shirol. The total area of Jaysingpur town is 6.28 sq.Km. The population of the town is 60,000(as per the 2011 census). The residential area of the town is divided into 23 wards. Jaysingpur has Municipal Corporation.

Climate: Jaysingpur has a tropical climate. The cold season start from December to February followed by the hot season from March to June. After summers the rainy season starts with the onset of monsoon rains lasting till the end of September. The period from September to November constitutes the post-monsoon period. Normal annual rainfall is 508mm.

Fig.1: Location Map of Residential Area of Jaysingpur Town

For the convenience of the current study, the residential area is divided into 4 zones as shown in fig.2. According to the area, zone 1 is the largest, and zone 4 is the smallest (table 1.1). Zone 1, 2, and 3 contain upper-middle-class and middle-class people. Zone 4 is a slum area that has a small area but a large population. The groundwater sampling sites were chosen to cover the full area of each zone of the residential area of Jaysingpur town. The distance between the two sampling sites is maintained from 500 to 700 m. Based on this no. of samples considered for testing in each zone is given in table 1.1.

Fig.2: Zoning of Residential Area of Jaysingpur Town

B. Sampling

Sampling frequency: Groundwater sampling was done for four months i.e. from Nov-2021 to Feb-2022. There were 30 sites under the study, which covered all four zones. The samples of zone 1 were tested in 30 days i.e. from 08- Nov-2021 to 08-Dec-2021. The samples of zone 2 were tested for 20 days i.e. from 10-Dec-2021 to 31-Dec-2021. The samples of zone 3 were tested in 25 days i.e. from 03-Jan-2022 to 28-Jan-2022. The samples of zone 4 were tested in 10 days i.e. from 01-Feb-2022 to 10-Feb-2022.

Table 1 Zone-wise name, area, and sampling number.

Zone	Name	Area	No. of Actual Bore Well Present	No. Sample Taken
Zone 1	Line No 1 to 21	1.50 sq.km	200	20
Zone 2	Lakshmi Nagar	0.77 sq.km	100	10
Zone 3	Shahu Nagar	1.20 sq.km	150	15
Zone 4	Rajiv Gandhi Nagar	0.57 sq.km	15	5

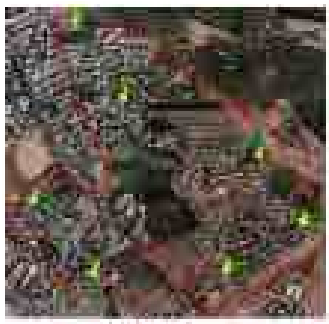
C. Collection of groundwater samples and Testing methods

Groundwater samples were collected from bore wells which included Government hand pumps as well as private or owned bore wells. The zone-wise actual position of sampling sites is as shown in fig.3. The samples were collected in pre-sterilized polyethylene bottles as prescribed in IS 7025-part 1 (1987) (of Indian Standards, n.d.). Collected samples were tested for Physico-chemical parameters such as pH, Turbidity, Electric Conductivity (EC), Alkalinity, Total Dissolved Solids (TDS), Hardness, Dissolved Oxygen (DO), Fluorides, and Chlorides, and a microbiological parameter i.e. Most Probable Number (MPN) for coliform detection. Testing methods were chosen from IS code (IS10500 – 2012). The test results were compared with acceptable and permissible limits of water quality parameters as given in IS code (IS10500 – 2012) (table 2).

Acceptable limit: The acceptable or desirable limit means the amount of specific element/parameter up to which it can be present in water, beyond that limit it is not good for drinking.

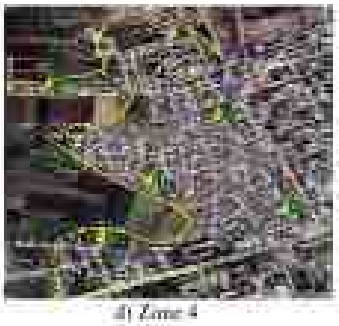
Permissible limit: The permissible limit means the amount of specific element/parameter up to which it can be present in water, that water can be consumed if there is no alternate source available. Beyond that limit, water is rejected for drinking purposes.

a)Zone 1



b) Zone 2

c) Zone 3



d) Zone 4

Fig.3. Actual position of sampling site

III. RESULT AND DISCUSSION

As per the testing and the results obtained, some parameters are exceeding the limit when compared with the drinking water standards of IS10500 (2012). Considering the overall average values of the parameters, some discussion is carried out. Table 1.2 gives information about zone wise range of results of each parameter and zone wise average of the total no. of samples taken for each parameter. The acceptable and permissible limit of each parameter given in the table is as per IS-10500 (2012).

pH and Turbidity: The pH is determined by microprocessor based Digital pH meter which gives direct value of pH. The pH value of all samples from four zones is within the acceptable limit as prescribed by IS code (table 2). Fig.4. shows a graph of the average pH of bore well water samples from all zones. According to WHO (2007) guidelines, the pH of the groundwater depends on the surrounding geological conditions. Although pH usually has no direct impact on consumers, it is one of the most important operational water quality parameters. But groundwater with low pH can cause gastrointestinal disorders and this water cannot be used for drinking purposes. Lower pH water is more likely to be corrosive (Shyamala, Shanthi, and Lalitha 2008). The high pH leads to bitter taste, skin irritation, dryness, and itchiness and it also causes scaling on utensils and in pipes.

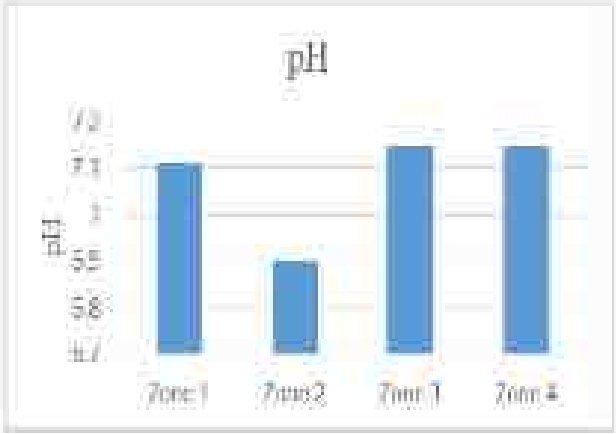


Fig.4. Average pH of bore well water from all zones

Table 2 Test results of bore water samples

Test (Unit)	Zone 1		Zone 2		Zone 3		Zone 4		Acceptable limit	Permissible limit
	Range (S.D)	Average	Range (S.D)	Average	Range (S.D)	Average	Range (S.D)	Average		
pH	6.82 - 7.55 (0.162)	7.11	6.6-7.4 (0.33)	6.9	7.0 -7.8 (0.157)	7.33	7.1 - 8.2 (0.356)	7.33	6.5-8.5	No relaxation
Turbidity (NTU)	0	0	0	0	0	0	0	0	1	5
EC (µS/cm)	800 - 1000 (65.88)	978.3	810 -1000 (77.33)	971.3	790-990 (63.00)	964	900-1180 (47.16)	1038	800	3000
TDS (mg/lit)	465-535 (42.57)	471.3	455 -545 (54.49)	472	455-525 (41.77)	466.5	445 -555 (59.96)	508.5	500	2000
Alkalinity (mg/lit)	230 - 270 (25.42)	254	234-264 (27.21)	251.5	215-245 (35.45)	233	245-275 (36.52)	270	200	600
Hardness (mg/lit)	360 - 440 (37.24)	360	340-420 (30.23)	320	240-320 (64.25)	240	360- 440 (41.95)	360	200	600
Chloride content (mg/lit)	70- 130 (21.22)	134.43	50 - 110 (21.80)	101.47	65 -105 (21.65)	104	70 - 120 (20.95)	106.96	250	1000
DO (mg/lit)	4.3-5.5 (0.53)	4.4	4.4-5.6 (0.38)	5.3	3.5-4.5 (0.54)	4.2	3.2-4.8 (0.46)	4.3	6.5-8	No relaxation
MPN (no /100ml)	15-30 (9.35)	26.5	15-35 (11.49)	29	10-40 (8.44)	22	15-45 (15.49)	30	0	No relaxation

It can be determined by using microprocessor based turbidity meter. The turbidity of bore well water from all zone is zero which indicates water is aesthetically clean. All the turbidity values of the bore well water studied are equal to the IS 10500(2012) acceptable limit. The turbidity of water is caused by suspended particles or colloidal matter. High turbidity protects micro-organisms which leads to the high growth of bacteria. High turbid water has adverse health impacts it can cause the risk of gastrointestinal infections (WHO 2007).

EC and TDS: The conductivity and TDS are determined by using digital meter. The EC values of all sites in four zones exceed the acceptable limit. Bore well water from zone four showed the maximum level of EC (fig. 5). High conductivity of water is due to natural sources such as minerals and rocks. Water with high conductivity does not necessarily pose a risk to human health, but it can cause corrosion in plumbing systems. EC is the main parameter used to determine the suitability of water for irrigation. High EC of water causes leaf damage, stunted plant growth, and eventually causes plant death.(Vidya et al., n.d.)

Some of the TDS values of the bore well water studied are exceeding the IS 10500(2012) acceptable limit. A high value of TDS may result in a reduction of water utility for drinking purposes. High TDS values are caused by the presence of sodium, chlorides, and potassium. Drinking water with high TDS causes diseases like nausea, lung irritation, rashes, vomiting, etc. The continuous long-term consumption of such water may cause chronic health conditions like cancer (WHO 2007).

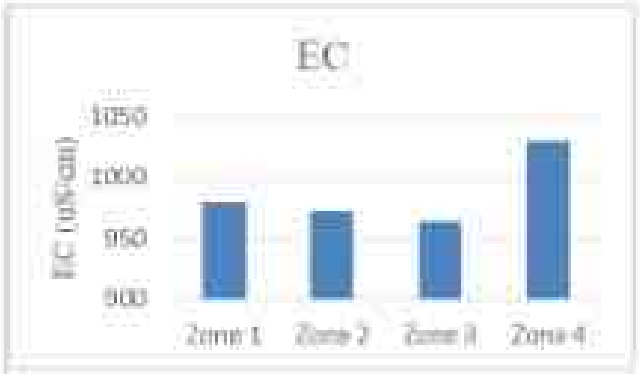


Fig.5. Average EC of bore water samples from all zones

Alkalinity: The alkalinity of water sample is determined by titrating it against standard acid solution using indicators like phenolphthalein and methyl orange. All the alkalinity values of the bore well water studied are exceeds the IS 10500(2012) prescribed limits. Fig.6. shows the zone-wise average alkalinity of bore water samples. The high alkalinity of water is due to the presence of impurities such as sodium carbonate, potassium bicarbonate, or potassium carbonate. Continuous drinking of high alkaline water can cause kidney diseases (WHO 2007).

To decrease the alkalinity of water household treatment like boiling is given to the bore well sample. The sample having an alkalinity of 276 mg/lit is boiled for 5 min, 15 min, and 25 min, and the results are tested. The test result found a decrease in alkalinity value with an increase in boiling time (fig.7). Hence to bring the alkalinity of bore well water within the acceptable limit, 15 to 25 mins of boiling is sufficient.

Fig.6. Zone-wise average alkalinity

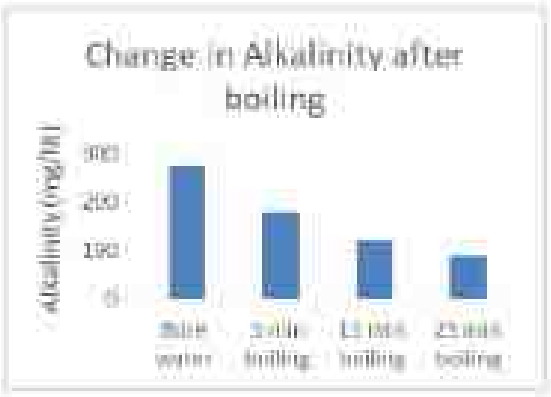


Fig.7. Change in alkalinity after Boiling

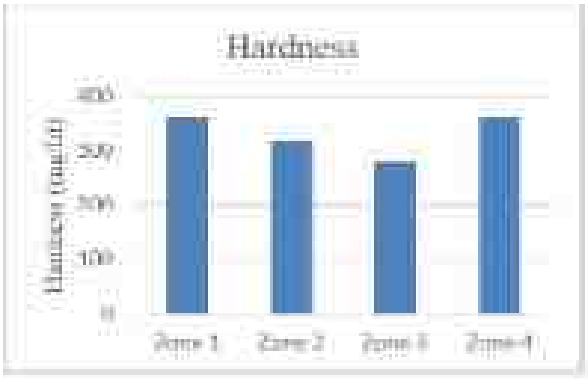


Fig.8. Zone-wise average hardness of bore

Fig.9. Change in hardness of water sample after boiling

Hardness: The 50 ml water sample is titrated against 0.01M EDTA (Disodium Salt) solution by using EBT as an indicator. The EDTA of Qualigens is used with 98% purity. This gives the total hardness of water. The hardness of water samples is very high as the minimum hardness is 240 and the maximum hardness is 440. The graph of the zone-wise average hardness of bore water is shown in fig.8. The hardness of water samples from zone three is comparatively less than in other zones. All the hardness values of the bore well water studied are exceeds the IS 10500(2012) acceptable limit. High hardness readings are due to high magnesium concentrations with little or no calcium present (Watts, 1993). Hardness is a very influencing factor that affects human health adversely. It can cause kidney stones, hair fall, skin irritation, etc. Even water-storing utensils get affected by the appearance of white spots on them. The soap-consuming capacity of hard water is very high (WHO 2007).

To reduce the hardness of water household treatment like boiling is given to the bore well sample. The sample having a hardness of 360mg/lit is boiled for 5 min, 15 min, and 25 min, and the results are tested. The test result found a decrease in hardness value with an increase in boiling time (fig.9). Hence to bring the hardness of bore well water within the acceptable limit, 25 mins of boiling is sufficient.

Chloride and Fluoride Content: The chloride content of water sample is determined by titrating the water sample against 0.02M silver nitrate solution using potassium chromate as an indicator. The chloride content and fluoride content of water samples from all four zones are within the limit as given by IS10500 (2012). A high concentration of chlorine gives a salty taste to water. Fluoride content in water with less than 1 mg/lit is beneficial for preventing dental problems but in the excess amount, it can cause dental mottling and adverse effects on bone (WHO 2007).

DO: DO of water sample is determined by titrating sample against sodium thiosulphate solution using reagents like MnSO4, H2SO4, alkali iodide azide and starch indicator. All the DO values of the bore well water studied are less than IS 10500(2012) acceptable limit. Fig.10. shows the zone-wise average DO of water samples. No health base impact due to less DO level of water (WHO 2007). Very high DO levels can cause corrosion of metal pipes. To increase the DO level of water household treatment like aeration with aerators is given to the bore well sample. The sample having a DO level of 4.8mg/lit is aerated for 5 min, 15 min, and 25 min, and the results are tested. The test result found a slight increase in DO level with an increase in aeration time (fig.11). Hence to bring the hardness of bore well water within the acceptable limit, 25 mins of aeration is sufficient.(Sarala C and Ravi Babu P 2012).

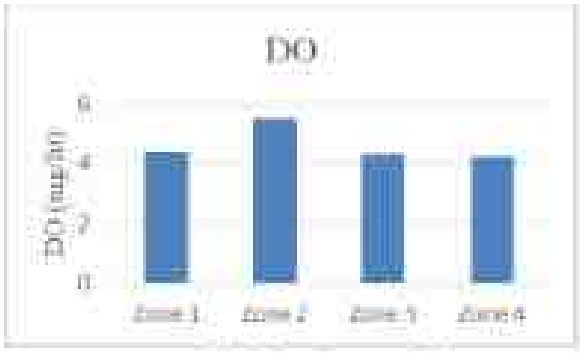


Fig.10. Zone-wise average DO

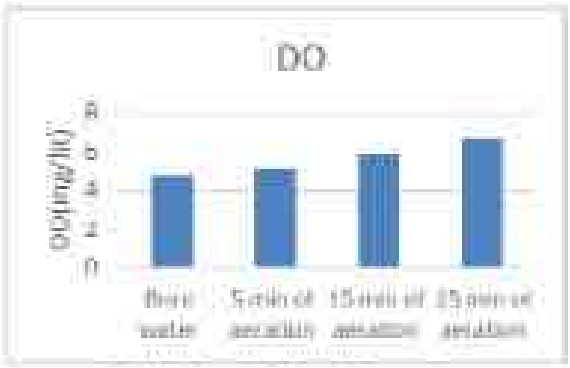


Fig.11. Change in DO level after aeration

MPN: One of the most important factors which are considered for portability is the presence of pathogenic organisms. Here, fecal pollution is checked by the detection of coliforms present in the water with the help of a technique called MPN. This technique is very suitable and widely used for the detection of microbial quality in water. The samples collected in all four zones showed high values of MPN which means MPN exceeds the IS 10500(2012) prescribed limits. Most of the samples showed significantly high values of MPN (Fig.12) Disposal of human excreta and other forms of wastewater in a septic tank is a common practice in urban areas (Das et al., 2009). This is one of the main sources of biological contamination by pathogenic microorganisms.

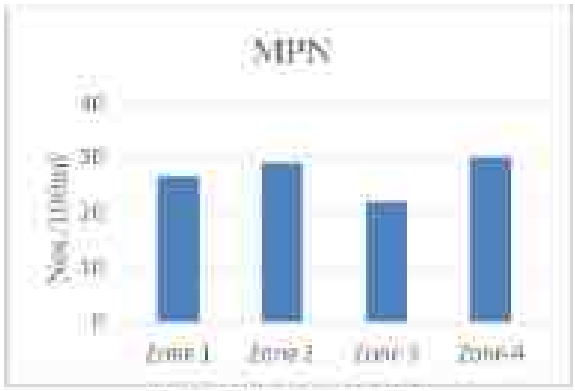


Fig.12. Zone-wise average MPN

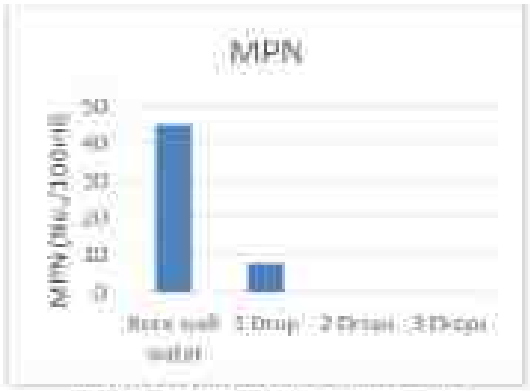


Fig.13. Change in MPN after adding medicloe

To remove the bacteria from the water household treatment like adding mediclor is given to bore well sample. The mediclore dose (1 drop = 0.05ml) such as 1 drop, 2 drops, and 3 drops are added to 2 liters of bore water sample having MPN value 45 no./100ml and results are tested. The test result found a decrease in MPN value with an increase in dosage (fig.13). Hence to remove the MPN of bore well water, the addition of 2 drops of mediclor in 2 liters of water is sufficient.

Study of Effective bore water treatment:

The test results of bore well water after being treated with RO and Candled filter are tested to determine the effectiveness of RO and Candled filter. The results of candled filter water are nearly the same as untreated bore well water. But the test results of RO are very good, all exceeding parameters of the untreated bore are within the limit after RO treatment. Table 3 gives the results of untreated and treated bore water. The values in red indicate they exceed the limit.

Table 3 Test results of RO and Candled filter water

Test (Unit)	Untreated Bore water	Treated RO water	Treated Candled filter water
pH	7.5	7.35	7.32
Turbidity (NTU)	0	0	0
EC (uS/cm)	965	840	360
TDS (mg/Lit)	415	390	285
Acidity (mg/Lit)	28	20	16
Alkalinity (mg/Lit)	280	220	185
Hardness (mg/Lit)	440	330	96
Chloride content (mg/Lit)	123.95	103.96	33.9
DO (mg/Lit)	5.10	4.8	0.9
MPN (No./100ml)	23	14	0
Fluoride (mg/Lit)	0.22	0.21	0.15

IV. CONCLUSION

The important Physico-chemical parameters of bore well water samples collected from residential areas of four zones in Jaysingpur town during four months of the year 2021-2022. The following conclusions are made under the results and discussion of the current study.

1. It was observed that pH, turbidity, chloride content, and fluoride values of all samples from four zones are within limits as per IS 10500(2012).

2. Total Dissolved Solids from some sites exceed the acceptable limit as per IS 10500(2012) and from some sites are within limits.

3. Electrical Conductivity (EC), alkalinity and hardness values from all sites of four zones exceed the acceptable limit as prescribed by IS standards.

4. The Dissolved Oxygen of all samples from four zones is under the prescribed limit as per IS standard.

5. All samples from all zones have some MPN value which means bacterial content is present in all samples.

6. The use of R.O treatment for raw bore water is very effective as it brings all water quality parameters within acceptable limits. While the use of a candle filter for treatment is not effective as treated water shows a very small variation in values of water quality parameters as compared to raw water.

Overall observation reveals that the bore well water quality of the residential area of Jaysingpur town is currently not good hence it is not potable. As hardness, alkalinity, TDS, and MPN of all bore wells water are high, it is dangerous to drink such water without treatment.

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Water Supply System in Hilly Area – A Case Study

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ABSTRACT

Establishing a water supply system in hilly region requires high level of planning and numerous considerations. Boleng is a town, hilly terrain is considered as study area. In this paper, we acquired the features of existing water supply system of Boling townand acquired the problems associated to the users. This town is challenging to establish water supply system than plain grounds due to its abnormal topographical features. This town struggles from natural calamities to seasonal instability, a water supply system needs to sustain its structural features as well as maintain water quality standards. To achieve this, current features existing water supply system is studied. Proposal of implementation of modern equipment in Boleng water supply system is required for enhancing sustainability and cost minimization. Ground visits in Boleng shown that, abnormal challenges of Boleng town like varied population distribution, natural calamities and frequent elevation differences reduces the working perfections ofsystem, so it is targeted to counter these challenges to the least impacts. Seasonal variation of Boling or in any hilly area creates water quality differences which can be tackled using dual treatment systems. Beyond setting up a supply system, there is a major responsibility of management and availability of water supply system all time, this will be achieved from proposed 24/7 automated technologies in Boling water supply system. Establishing distribution network in whole area is to be achieved by appropriate zoning work of the Boling town and locatingof service reservoirs as per its more accessibility. Using water supply software pipe network layout will be analyzed and it will complete designing of water supply system in hilly area.

Keywords-

Water supply, Conveyance system, Hilly area, 24/7 Supply, Water treatment, Break pressure tank, Dual treatment system, Gravity, Stream, Distribution, Augmentation, Coanda screen intake, Zoning, Contamination, Ductile iron (DI), Tail end.

I. INTRODUCTION

A potable and sufficient water supply is vital for human health, preventing waterborne diseases like cholera, typhoid, dysentery, E. coli infection. Economically, industries and agriculture depend on a stable water supply for growth and productivity even in peak hours thus water supply system is required which comprises combination of pipe network systems and treatment units, where pipe network connects – water at source, treatment units and places where water is required. In hilly areas, water supply relies on various sources like rivers, streams, and mountain springs, mountainous lakes and reservoirs, small dams and check dams are mostly used and groundwater wells are rarely used. Gravity-fed systems are mostly used where water naturally flows downhill reducing the need for extensive pumping. Natural springs emerging from hillsides are available in largest quantities providing very clean water with minimal intervention to maintain their quality. As the higher rainfall in hilly regions, rainwater harvesting is practical, allowing the collection and storage of rainwater for self-sufficient water supply. Despite challenging terrain a few heads use groundwater wells as they are unsettled or scattered areas. Small dams and check dams along streams are used to regulate water flow and create reservoirs, mitigating the impact of seasonal variations. These diverse strategies ensure a reliable and sustainable water supply in hilly villages. Furthermore, in hilly terrains, water supply encounters various challenges such as pressure fluctuations, population distribution risk of bursting pipe, seasonal variations, leakage and landslide occurrences amplify complexities in distribution network. Thus, a comprehensive approach is vital to address these diverse issues and ensure sustainable water supply system in hilly regions. To counter these problems, we have considered case studies as follows.

From journal ed 24/7 water supply facility of Haraorou village, Imphal, East Manipur by (Shukhdeba Sharma, January - March: 2018) 24x7 water supply facility has been acquired of Haraorou village, where continuous access to water is available. This development technique enhances convenience, health, and sanitation for residents, contributing to improved quality of life. The initiative is a significant step in managing water supply rural, indicating a commitment to providing essential amenities and promoting sustainable practices in the region. Continuous water access supports daily activities, agriculture, and overall community well-being. Additionally, the village employs artificial recharge techniques, further enhancing water resources and supporting agriculture, sanitation, and community well-being.

As per PHE dept. report 2022-23 Parong-II Village also known as Parong Kinne of Siang District, Arunachal Pradesh is situated at an altitude of 430.0 m above mean sea level. On having physical field survey, it is seen that there is no proper water supply system facility in Parong-II village, Parong Tinali (Kopu) and Parong Moling which are located closely to one another. The present water supply system is in deplorable condition because of old age and corrosion. Moreover, the water is turbid and unsafe for human consumption due to lack of proper filtration system. Considering the immense necessity of a modern and proper drinking water facility in the village, we came to a stand that highest quality of equipments and modern techniques of water supply is essential for hilly area.

According to the case study of water management in Darjeeling hill town (by Suvechha Ghatani dept. of geography, Sikkim university) Darjeeling Municipality Report 2012), the town is having 26 natural springs for water source which is transferred through open conduit channel. The town is having two lakes which acts as reservoir and further transfer to filtering house. This type of natural and old conveyance system is suitable to implement but with the users are facing lot of problems like illegal tapping, insufficient water during dry days and no advancement opportunity for rapid population growth.

In contexts of above case studies Boleng town water supply is taken into consideration, Boleng is a town in the Siang district of Arunachal Pradesh, India, situated along the Siang River. Its primary source of drinking water is the perennial Rabung stream, fed by spring water from the mountains covering town area of 141 hectares.

II. EXISTING WATER SUPPLY SYSTEM OF BOLENG TOWN

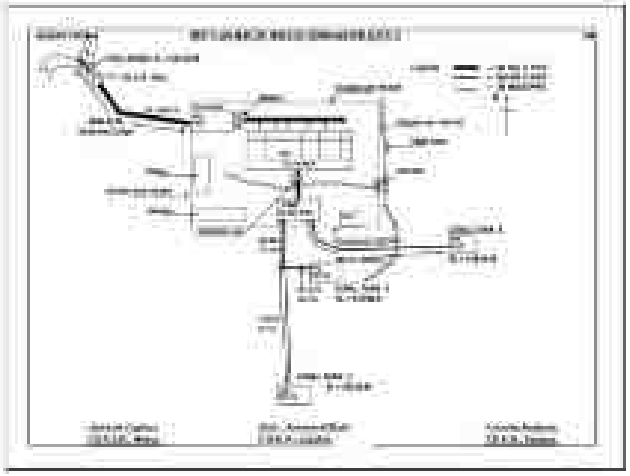
As per the augmentation of water supply system at Boleng Township report, it has a gravity flow system from the source Rabung stream. Maximum 2.47 cu.mec and minimum 0.66 cu.mec discharge of water is supplied to a population of about 4000+ at per capita demand of 70 lpcd. This system is designed for a period of 30 years to serve an estimated population of 9040 souls. This town is very closely settled near bank of Brahmaputra River also known as Siang River locally but it is seen that, the river is having unclear water as well as pumping to an upper level than source is very challenging in electricity prone area.

Table 2- Components of existing water supply system of Boleng Town

Sr. No.	Work	Description
01	Droplet inlet	1 no. RL- 674m
02	RCC Pre sedimentation tank	1 no. Detention period- 2 hours RL- 674m
03	RCC sedimentation tank	1 no. Detention period- 4 hours RL-518m
04	RCC slow sand filter	1 no. Rate of filtration- 200 ltr/hour RL- 508m
05	RCC clear water reservoir	1 no. Capacity- 125000.00 ltrs RL- 501m
06	Transmission main	150 mm DI pipe
07	Length of transmission main	4700 mtr
08	RCC distribution tank	
	Tank 1 capacity	75000 liters 1 no. boleng township RL- 415m
	Tank 2 capacity	65000 liters 1 no. BK mission area RL- 428m

	3. Tank 3 capacity	50000 liters 1 no. Gandhi village area RL- 367m
09	Distribution network	100 mm, 80 mm, 65mm, 50 mm and 40 mm GI pipe
10	1. CWR to Zonal tank - 1	100 mm dia. GI pipe 25 mtr
	2. CWR to Zonal tank - 2	100 mm dia. GI Pipe 750 mtr
	3. CWR to Zonal tank - 3	80 mm dia. GI Pipe 1310 mtr

Figure 1- Key plan of existing water supply system of Boleng Town



As per the above key plan it is been analyzed that from a perineal stream i.e. Rabang stream having reduced level 674m, water is collected in a pre-sedimentation tank. It is carried to water treatment plant through conveyance system having diameter of pipe 150mm DI pipe. At reduced level 518m water treatment plant is situated consisting sedimentation tank, aerator, slow sand filter which after filtering passes treated water to store in central water reservoir. As per population and pressure feasibility 3 zonal tanks are provided to their respective zones at reduced level 428m, 415m and 367m respectively. Zonal tanks are connected using pipes of diameter 100mm, 100mm and 80mm which is designed as per their capacities. Still the existing treatment units are not fulfilling the required water quality that is expected.

Table 3- Problems associated in existing water supply system

Sr. No.	Problems	Description
01	Current location of water treatment plant	Residents settled and going to reside at higher elevations than current location of water treatment plant in the future will suffer lack of potable water.
02	Unequal population distribution	Due to variation in residing population concentration.
03	Inadequate Pressures at Tail Ends	Due to absence of taps which results in a continuous flow of water on one side, while the other side experiences limited access to water.
04	Multiple supply pipe joints concentrated at single points	Uneven distribution of population causes some pipes less burdened and some pipes heavily burdened.
05	Unclean Water	Lack of insufficient treatment and regular maintenance.
06	Wastage of water	Absence of taps or the presence of leaky taps which leads to the continuous flow of water.

Above mentioned are major problems impacting the users. These leaks in the system arises due to inappropriate source intake design, use of less competent pipes in conveyance system, ignorance of impact of seasonal variation to distribution and treatment system, less efficient water treatment units and wrong way zoning which later disturbed the water supply network.

Boleng town is having monsoon or rain about 6 months which cause turbid water during that span. Treatment units pre sedimentation, sedimentation, aeration and slow sand filter fails to treat water. Existing intake source is Coanda screen type system which is reliable to setup but inefficient in water collection during dry days. To bypass the management of variable pressure differences, ends of distribution networks are kept open which causes water wastages as well as inadequate pressures. As pe zoning, location of service reservoir is at lower center, upper center and upper right side with respect to central water reservoir, this creates inadequacy of required water on left and lower residence families. To compensate this problem, multiple pipes are connected to some of the nodes causing reduced pressure. Existing DI pipes in supply system are inflexible so cannot sustain impacts from natural calamities like landslides or rock falls. This creates leaks in pipes and increase chances of back flow of turbid water into supply system.

III. SUMMARY AND RECOMMENDATIONS

To overcome the above problems remedial measures needs to be implemented such as relocation of source is required which will be perinnial water source, less prone to contamination, more sustainability for long time period, less hamper during dry days and fulfils water demand for future population. Requirement of Break Pressure Tanks for maintaining suitable pressure during water supply through conveyance system. Redesigning of intake is requires as existing intake is not so efficient to fulfill water requirement of future population. It should be capable of collecting water during dry days as well as should not obstruct supply and treatment during heavy monsoons. Gravity main is proposed as Boleng town is having underdeveloped electricity supply so direct pumping will not work as efficient as gravity flow. Redesigning of required water treatment units need to be done. Dual treatment system is proposed which can distinguish required treatments during heavy rains and dry periods, and efficiently treat water in economical manner. Rezoning of water supply are need to be revised. On the criteria of population distribution and elevation differences, zoning to town is to be done for equitable water distribution to all users.

For better water quality and supply management 24/7 automated supply system is a better choice than manual water supply handling. This will reduce manpower, regular quality and pressure checks can be done, wastage of water will squeeze and full-time availability of water will be accessed to the users. All these targets need to be achieved in most minimal cost. So, cost estimation of proposed modifications should be accomplished.

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Effect of Electrode Shape on Performance of Electrocoagulation

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***Abstract*- Electrocoagulation (EC) is an excellent and promising technology in wastewater treatment, as it combines the benefits of coagulation, flotation, and electrochemistry. EC is an efficient process to remove both organic and inorganic pollutants from wastewater. During the last decade, extensive research has focused on the treatment of several types of industrial wastewater using electrocoagulation. The heart of electrocoagulation process is the material of construction of electrodes and geometry of the electrodes. With the understanding development of electrochemical engineering, utility of electrochemical environmental techniques are expanding which lead to design the development of novel electrodes and cell structures. Cell configuration, electrode geometry and flow type of EC reactor are crucial in the electro coagulation process, hence critical review is carried out in the present paper. Aspect ratio of electrodes to increase the surface area, number of electrodes and shape of the reactor and its efficiencies are the focused factors of electrocoagulation. The cure findings proved the capability of this technique in wastewater treatment whether it is performed alone or combined with other technologies providing many pros, such as the decrement of the operation cost and the sludge formation. The newly developed stable and active electrodes for oxygen evolution would definitely boost the adoption of this technology.**

Keywords **- insulated electrode, monopolar mode, reactor design, electrode geometry, power consumption.**

I. INTRODUCTION

Water is one of the most important resources on earth; water plays a vital role for all human beings, animals, and plants to thrive. Water is an equally important resource for the manufacturing sector and social development. Therefore, there is an urgent need to preserve and protect our ecosystems from all types of pollution. In India, water is used in the industrial sector is about 34 billion m^3 per year; which is estimated to increase four times by 2050. Rapid industrialization has tremendously increased the volume of wastewater to be disposed-off, while the capacity of receiving water to accept the increasing inorganic and organic loads remains the same. This has resulted in the rapid deterioration of the quality of surface water and forcing the concerned more stringent legislation. Accordingly, industries are looking for low-cost solutions to reduce the excess pollutant load. The situation is further aggravated by the threat posed by constant discharge of pollutants by industries such as sugar, paper, steel manufacturing, pharmaceutical, oil refineries, mining, chemical paints, petrochemical, textile, slaughterhouse, distilleries, electroplating, etc. These industries discharge untreated or partially treated wastewater into nearby drains, rivers, stagnant ponds, lagoons, or lakes [1].

In order to trace global research trends in industrial wastewater, the bibliometric analysis is carried out of 110 years as shown in Fig. 1. This figure revealed that many of environmental researchers attracted EC technology due to its inherent advantages - high removal efficiency, environmental compatibility, and clean technology that could be applied in

various industrial domains including water and wastewater treatment

The field of electrochemistry has gained extensive attention throughout applied and fundamental research. The water pollution has become serious global problem, with rapid population growth. Therefore, more effective low-cost wastewater technologies are necessary to fulfill the human requirements. Degradation of toxic, refractory contaminants by biological treatment is found to be difficult. Electrochemical treatment technologies has attracted and gives attention for its environmental compatibility, high removal efficiency [2].

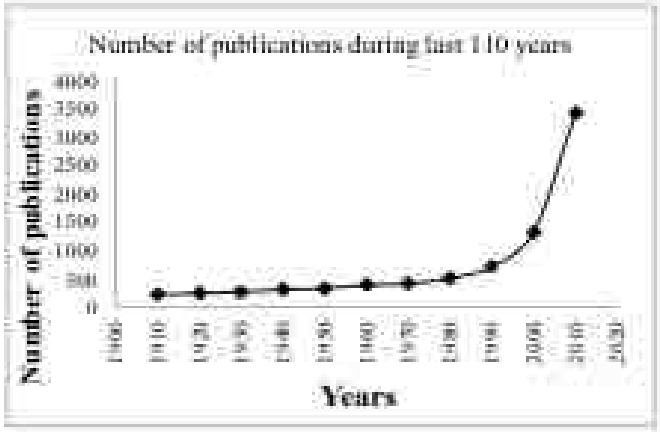


Fig. 1 Number of SCI publications on electrochemical treatment of water and wastewater treatment

II OPERATING PARAMETERS AFFECTING ELECTROCOAGULATION TREATMENT

In any electrochemical treatment the nature of the electrode material is important issue and appropriate selection of electrode material is very important.

A. ASPECT RATIO OF ELECTRODES TO INCREASE THE SURFACE AREA

To increase surface area and performance of electrocoagulation process following modifications were recently implemented by researcher throughout the globe :-

i) Sealing between electrode edges and the walls of the reactor – energy consumption may minimized.

ii) The disposition and the orientation of the electrodes (tilted to form an angle of 7degree with respect to the horizontal direction) provide simple handling and reduction of electrical consumption [3]

iii) Woven mesh or aluminium wire netting (AWN) - more effective in increasing current than expanded mesh and solid electrode.

iv) Electrode Passivation in the Electrocoagulation Process- emission of metallic ions and consequently the treatment time is increased as well as cost.

Reactor consists of a Perspex rectangular container of net dimensions of length 10 cm, width of 9.5 cm and a height of 7 cm. It is supplied with six parallel-perforated rectangular baffle plates (electrodes) made from aluminium. Each electrode, width of 9.4 cm and a height of 8 cm, has 36 holes (0.4 cm in diameter) distributed in three rows and three 0.7 cm diameter holes distributed at the top and bottom to fix it in the required position as shown in fig. 2.The performances of a new electrocoagulation reactor with bipolar horizontal iron electrodes were investigated.[4].These electrodes were piled up in the reactor in order to maintain a low gap between them and to increase the electro-flotation process. Electrodes were perforated to allow the passage of gas and effluents, and adjacent ones were separated by grids of polyamide or polytetrafluoroethylene.

These performances increased with the number of holes in the electrodes, the current intensity, and the flow rate of the effluent, and mainly in the absence of a gap between the electrode edges and the walls of the reactor. More important, when the electrodes were not sealed with a system of tightness a decrease of the current efficiency was observed, leading to higher voltage and contributing to increase considerably the energy consumption. The use of eight-hole electrodes and a high flow rate reduced significantly the voltage and increased the current efficiency [4].

Fig 2. Punched electrodes for new electrocoagulation reactor [4].

Moreover in the absence of a gap between electrode edges and reactor walls, the current efficiency reached 100%; the voltage was stable and did not vary anymore and the energy consumption was minimized. The results showed that the sealing between electrode edges and the walls of the reactor was the most determinant factor in the optimization of the investigated reactor.

Aluminum and iron are most common electrode material used for electro coagulation technique, because of the availability an cheap and it proven their effective since their dissolution in aerated media generate trivalent species.

The choice of electrode material is much importance as it affects the selectivity and the efficiency of the process. The electrode material must have the following properties:

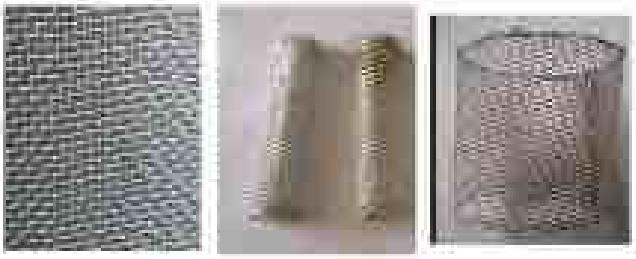
i) Low cost/life ratio. The use of electrode materials that are inexpensive and durable must be favoured

ii) High physical and chemical stability; resistance to erosion, corrosion and formation of passivation layers.

iii) High electrical conductivity and catalytic activity and selectivity.

Electrocoagulation (EC) process involves in situ coagulant formation with sacrificial anode dissolution. Generally, the anode is prepared using iron or aluminum (Al) . The metal ions interact to generate insoluble OH^- ions. The generated insoluble hydroxides adsorb the contaminants from the solution either by electrostatic attraction or complexation before the coagulation. Lessening of the electrodes' internal resistance drop (IR-drop) is one of the most essentials toward reducing the total cost of EC operation to enhance the current performance by enhancing the state of turbulence. Both oxygen and hydrogen gas emerged near the cathode and anode as soon as each gas bubble nucleates. The bubbles are like insulating spherical figures, generating a film that fouls oxide over the electrode surface (passivation effects). This ionic increases the total electrical resistance of the cell, thereby needing a superior quantity of electrical energy to attain the optimal removal [5]..Electrocoagulation of the synthetic dye solution in batch mode of operation was performed using plane and punched aluminum electrodes to study the effect of the shape of the electrodes. It was found that the efficiency of the electrocoagulation process increases with the use of the punched electrode compared with the plane electrode due to the higher current discharge from the punched electrode.

The performance of the electrocoagulation process was found to increase with an increase in the diameter of the holes up to an optimum above which no improvement in the performance was noticed with an increase in the diameter of the hole. Similarly, the performance of the EC process was found to increase with an increase in the number of holes in the electrode up to an optimum number of holes. No effect of the pitch of the holes was observed on the performance of the EC process. No significant effect of the type of the current source (direct and alternating current) was observed on the performance of the EC process. But the use of alternating current can reduce the passivity or polarization of the electrodes and helps in reducing the energy consumption needed to overcome the resistance due to the corrosion formation on the anode. It can be concluded that the shape of the electrodes can improve the performance of electrocoagulation process leading to the reduction in the energy consumption as well as the operating cost.



a) Wire Netting Electrode (AWNE) b) Anode c) Cathode

Fig. 3 Physical structure of Aluminium Wire Netting Electrode a,b and c

A simple EC apparatus has been constructed using iron and aluminum as sacrificial electrodes. The EC apparatus was then utilized for the treatment of local paper mill wastewater under various operating conditions. It was found that optimum conditions were electrolysis time of 60 minutes, pH of 7, applied voltage of 14 V and an electrode distance of 1.5 cm. For iron electrode, percentage removals of conductivity, turbidity, COD and BOD were 62%, 97%, 37% and 30%, respectively. For aluminum electrode, the percentage removals of conductivity, turbidity, COD and BOD were 42%, 98%, 37% and 50%, respectively. This method was found successful in removing turbidity from the wastewater. However, for the complete removals of COD and BOD from the wastewater, a secondary treatment possibly using adsorption technique was still needed [7].The effect of the diameter of the punched holes, the number of the holes in the electrode, and the geometry of the punched holes- square pitch, triangular pitch,or random location—on the performance of the electrocoagulation has been investigated. Further, the majority of the studies reported in the literature have used direct current (DC) in the EC process. Experiments were performed in the batch mode of operation using alternating current (AC) with plane aluminum electrodes to study the effect of the type of current source on the performance of the electrocoagulation.

The effect of the current source (direct and alternating current) on the performance of the electrocoagulation was studied and no significant effect of the current source on the performance of the electrocoagulation was noticed [8]

B. Arrangement of electrodes

There are a number of methods for the arrangement of electrodes. In EC systems, normally plate electrodes are built and water passes through the space between the electrodes. Arrangement of electrodes could be monopolar or bipolar. In monopolar arrangements, the performance improvement is achieved by using EC cells with monopolar electrodes either in parallel or series combinations [12-13] A simple

electrocoagulations set up includes only one anode and cathode which will not be sufficient for industrial applications where large amount of wastewater containing high organic and inorganic loads is to be treated. Hence, in such cases, pairs of anodes and cathodes are used which are connected in different electrode system[15-18]. There are three electrode connection systems for electrocoagulation cell viz. monopolar electrodes in parallel connection, monopolar electrodes in serial connection and bipolar electrodes in serial connection. The sacrificial electrodes may be made up of same or different materials as anode In relation to resistance of individual cells the current is divided between all the electrodes. So the potential difference required is lower in the parallel connection.

i) Monopolar electrodes in parallel connection (MP-P) are described in Fig. 4a. It corresponds to an electrode arrangement that consists of cathodes and anodes placed alternatively at the same anodic or cathodic potential, respectively. Each pair of cathode/anode corresponds to a small electrolytic cell in which the voltage is the same. The reactor consists, therefore, of electrolytic cells in parallel. Consequently, the current of each electrolytic cell is additive.

ii) Monopolar electrodes in series connections (MP-S) are described in Fig. 4b. Each pair of internal sacrificial electrodes is internally connected with each other, and has no interconnections with the two outer electrodes. In this case, the electric current passing through all the electrodes is the same, whereas the global voltage is the sum of voltage in each individual electrolytic cell.

iii)Bipolar electrode in series connections (BP-S) comprises two outer electrodes connected to electric power supply and the sacrificial electrodes placed between the two outer electrodes (Fig. 4c). Outer electrodes are monopolar and the inner ones are bipolar. The bipolar electrodes are not interconnected and each of their sides acts simultaneously as an anode and a cathode. This means that opposite sides of each bipolar electrode are oppositely charged, the anodic dissolution takes place on the positive side while the negative side is prone to cathodic reactions.

CONCLUSION

EC is an electrochemical technique that has a wide range of applications and high efficiency of pollutant removal. It is often used for treating industrial wastewater and has been shown to have superior performance in the treatment of effluents containing suspended particles, oil, and grease, as well as pollutants of organic and inorganic nature.

From this review, the main points drawn are listed as below :

The aim of the review is to explain the basics and up to date advancement of electrocoagulation method for the improvements in the pollutant removal efficiency. Various metals such as aluminum, iron, steel, graphite, magnesium, and titanium have been used in the electrocoagulation for the treatment water, wwastewater and industrial effluent.

The shape of the electrodes may also affect the performance of the electrocoagulation. But to the best of the authors' knowledge, all the electrocoagulation studies reported in the literature have been performed with the plane electrodes and no study has been reported using the punched-hole electrodes, Mesh type electrodes, Fe ball and steel wool. It can be concluded that the shape of the electrodes can improve the performance of electrocoagulation process leading to the reduction in the energy consumption as well as the operating cost.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest regarding the publication of this paper.

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Enhancing the performance of rapid sand filter using PACl conditioning

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***Abstract*— The improvement in the performance of existing rapid sand filters is unavoidable as the water quality standards have been revised and are demanding much better performance. Simultaneously the overall system is also under the burden of catering the need of increased demand because of the reasons like urbanization. The practice of filter conditioning to advance filter performance is a fairly recent development in drinking water treatment. Different advantages claimed by filter conditioning are condensed ripening period, superior turbidity exclusion and comparatively stable filtrate quality. It also has limitations like reduction in total filter run, quicker head loss development and higher back washing requirement. This research explains the attempt of assessing the use of filter conditioning using PACl polymer as conditioner along with coarser media with lesser coefficient of uniformity. This pilot research was conducted at Ichalkaranji municipal water treatment plant located at Maharashtra, India and conducting a filter run of 300 minute duration. Various doses of PACl as filter conditioner were tested and the comparison was made with the performance of conventional rapid sand filter without filter aid. The parameters of interest for evaluation were ripening period, turbidity removal and rate of filtration. The effect of zeta (ζ) potential change was observed to be one of the major reasons of the performance improvement, accelerating the surface removal.**

Keywords*— *PACl dose, Filter conditioning, rapid sand filter, ripening period, turbidity removal, head loss, zeta (ζ) potential

I. INTRODUCTION (*HEADING 1*)

The water industry in India is going through the transformation phase. Under the scenario of rapid urbanization and industrialization, the demand of water is ever increasing. The lack of appropriate operation and maintenance has added additional problems in achieving desired results in terms of required quality. Besides this, the quality standards for drinking water are also becoming more and more stringent which needs considerable research to improve the ultimate treated water quality produced and supplied to consumers. Under such situation the conventional rapid sand filter endures tremendous expectation of removal of higher concentration of impurities, principally the turbidity causing matter. After losing their significance in providing safe drinking water in sufficient quantity and of desired quality to rapidly growing townships, remodeling and rehabilitation of the systems has become unavoidable.

As emphasized by various researchers, a typical filter run can be separated into three diverse phases as filter ripening or maturation of bed, effective filtration and break-through. During the ripening phase the quality of filtrate is very poor. It is a phase characterized by relatively high effluent turbidity. It is the consequence of flushing of left-over backwash water and remnant particles from the filter media [1] The capacity to exclude turbidity-causing matter is also extremely low in this phase. It may last for only some minutes to more than a few hours [2,3]. Filter ripening has been studied for more than four decades due to its weakness of increased particle and microbe verse into the distribution system. Multiple approaches have been believed to have a significant impact on overall filter performance. Few of such approaches includes filter to waste strategy, addition of polymer or coagulant in wash water or use of filter aid in influent etc. [4-12]. Unfortunately, in developing countries like India, this part is very seldom addressed. The major reason of such ignorance may be the reliance upon the use of chlorination to deal with pathogens escaped and relatively less stringent norms in regard with turbidity as compared to the norms followed in developed countries. However the standards in India were revised in 2015 and has revised the requirement of turbidity of potable water from 5NTU to 1 NTU. (IS 10500, 2012, revision 2). This has undeniably demanding the research in the field of filtration procedure to make it acceptable for such conditions.

The use of filter aid, popularly known as filter conditioning is comparatively new development in water treatment field. The significant highlights of this innovation include condensed ripening period, superior turbidity exclusion and comparatively stable filtrate quality. While the major limitations of such process are reduction in total filter run, quicker head loss development and higher back washing requirement. [10-12]

The research explained in this paper presents the attempt of improving the overall performance of conventional rapid sand filter using the filter conditioner. The PACl is used as filter conditioner, which is utilized in water treatment as coagulant since last few decades in India. Along with achieving the better filtrate quality and lower ripening period, the efforts were also taken to overcome the limitations of filter conditioning. For this motive the configuration of the conventional sand media was reformed. The media utilized was coarser in dimensions, having effective size in range 0.85mm and coefficient of uniformity was depressed to a value of 1.2, as compared to conventional media specification of effective size in the range of 0.4 to 0.6mm and coefficient

of uniformity to be 1.3 to 1.7. The research was carried out by setting up a pilot plant at the municipal water treatment plant at Ichalkaranji. The filter of 300 minute was carried out for the assessment. Various doses of PACl were examined as filter conditioners and the comparison with effectiveness was made with conventional filter without filter aid. The evaluation parameters were the ripening period, turbidity removal and filtration rate. The filter conditioner dose was given as a slug dose in this experimental study. The effect of zeta (ζ) potential change was observed to be one of the major reasons of the performance improvement. The findings of these proposed modifications are very encouraging.

II. MATERIAL AND METHODS:

The research was performed out at a conventional water treatment plant in one of the urban areas, Ichalkaranji in state of Maharashtra, India. The filter media sand was obtained from the stock sand available at Ichalkaranji WTP. The required sand was washed and sun dried first. By sieving and mixing in appropriate proportions, the sand of desired specification was produced. Dust was eliminated by washing it out. The control media was having coefficient of uniformity as 1.7, effective size was 0.6mm while the specific gravity was 2.68. The media prepared as experimental media was coarser in size having effective size 0.85mm and coefficient of uniformity was 1.2. The highest size of particle in both media was kept around 1.2 mm. Fig. 1a and 1b represent the coarse size distribution of both media.

Two square filter columns with internal dimensions of 15cm and a height of 1.8m were employed in the pilot model. This was helpful in eliminating the wall effect and achieving authentic grain packing in the media.[13] One column was acted as a control unit while second column was acted as experimental unit as shown in fig.2a. The necessary piping and valves were installed to ensure adequate filtration rate control and accomplish back washing. Back washing was managed with the help of a 0.5HP pump. The backwashing rate was kept as 0.7m/min. Each filter was 300 minutes in length. The clarified water was used to challenge both filters simultaneously. The turbidity of clarified water used was in the range of 6 to 6.5 NTU. The Hach turbidity meter-2100P was used to measure the turbidity. The experimental column was challenged with higher rate of filtration as compare to control column as the grain size was coarser. The rate of filtration for control column was around 6m/ hr. at the time of commencement of filter run while for experimental column it was in the range of 7.2 to 7.5 m/hr. The experimentation was carried out as filtration with declining rate, the way similar to what is followed by most of the water treatment plant because of defunct rate of flow controller.

To condition the media, a PACl solution with a concentration of 350 mg/lit to 500 mg/lit was added. It was slug dosed just before challenging the filter columns. Table 1 lists the doses tested during the research.

The turbidity of filter inlet as well as outlet was measured. For initial 30 minutes the observations were recorded at an interval of 1minute to monitor the filter ripening sequence (FRS). Following the ripening of the bed, observations are taken at an interval of 15 minutes until the filter run of 300 minutes was completed. The acceptable limit of turbidity was believed to be 1NTU according to the BIS (IS 10500, Revision 2). The efficiency of removing turbidity is measured in terms of 'pC*' in which 'C*' is the turbidity of the filter effluent water in NTU normalized by the turbidity of the influent water and 'p' is the negative logarithm. Mathematically pC* = - log (Ceffluent / C influent). It is usually referred as 'log removal' in similar researches. A higher pC* value indicates better performance.

Zetu meter 4.0 (Zeta-meter, Inc. USA) was used to measure the zeta potential. The zeta potential of effluent from the filter in case of conventional as well as conditioned media was measured during the FRS. Three runs for each dose were conducted. Although the finest run is being considered for the discussion.

TABLE I DETAILS OF DOSAGES PROVIDED TO MODIFIED FILTER MEDIA

Sr. No.	Dose to pilot columns (15cm X 15cm)		Normalized dose	
	PACl concentration	Quantity of solution	gm / m² of filter area	gm / m³ of filter media
01.	350 mg/lit	2 lit.	31.80	41.3
02.	400 mg/lit	2 lit.	35.35	47.4
03.	450 mg/lit	2 lit.	40.00	53.3
04.	500mg/lit	2 lit.	44.4	59.2

III. RESULT AND DISCUSSION:

The observations recorded are summarized in table 2, 3 and 4 and represented in fig. 3, 4 and 5.

TABLE II RIPENING PERIOD OBSERVED DURING THE RESEARCH

Sr. No.	Normalized dose (gm/m³ of filter media)	Ripening period (min.)		
		Control filter	Experimental filter	% reduction
01.	41.3	18	10	44.4
02.	47.4	18	9	50.
03.	53.3	23	8	61.9
04.	59.2	23	8	65.2

TABLE III WATER FILTERED IN ONE CYCLE DURING THE RESEARCH

Sr. No.	Normalized dose (gm/m³ of filter media)	Water filtered in one cycle of filtration		
		Control filter	Experimental filter	% increase
01.	41.3	528.6	675.6	28.3
02.	47.4	510.8	652.4	27.7
03.	53.3	505.8	603.3	19.29
04.	59.2	505.3	601.3	19.3

TABLE IV NET FILTRATION RATE RECORDED DURING THE RESEARCH

Sr. No.	Normalized dose (gm/m³ of filter media)	Net filtration rate achieved (lit/hr./m²)		
		Control filter	Experimental filter	% increase
01.	41.3	4698.6	6015.5	27.9
02.	47.4	4540.4	5799.1	27.7
03.	53.3	4493.5	5364.4	19.4
04.	59.2	4491.5	5348.0	19.0

A. Filter ripening sequence (FRS):

The characteristic curve of initial effluent quality is referred as filter ripening sequence [14]. FRS observed during the various dosages used to condition the filter media are

demonstrated in fig.2. The FRS observed is quite consistent with the definition sketch proposed by various researchers. Initial low turbidity water passage can be attributed to the passage of clean water present in lower part of media and gravel bed. As a common fact, the lower part of media is not efficiently utilized for the removal of turbidity due to stratification; the pores in this part of media are occupied by the clean backwash water immediately after the backwashing. On other hand because of application of filter conditioner dose, the particles which are present in the upper part of media (i.e. remnant particles, those which are dislodged during the backwashing from media but not been escaped from filter box during the course of backwashing.) are pushed in to the lower part which may get comparatively early escape through the media.

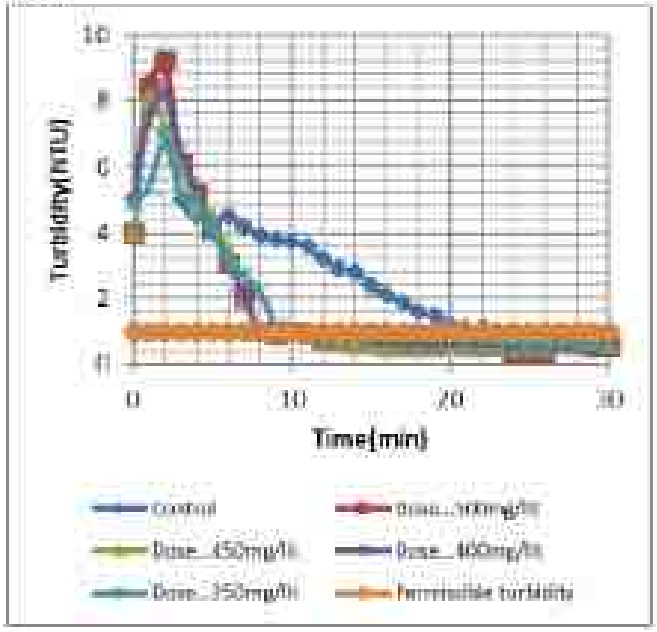

Figure 3: Filter ripening sequence for control and various doses of PACl

The next phase is characterized by reduction in the turbidity with sporadic small turbidity spikes. The reason of these spikes is escape of remnant along with the particles present in influent as the filter is not ripened. Similar kind of behavior is observed in both cases. This is followed by the sharp reduction in turbidity of filtrate, which is an indication of ripening of the media because of conditioning. Application of media conditioner has resulted in dramatic acceleration in filter ripening. The ripening period in case of conventional filter media was found in between 18 to 23 minutes, while significant reduction in the same was observed after the filter conditioning. In case of conditioned media it was observed to be less than 10 minutes. For higher dose of filter conditioner, the ripening period was observed to be lesser as compared to lower dosages. The ripening was reduced as the dose of conditioner is increased. The reduction in ripening period was observed in the range of 44% to 65%.

B. Turbidity removal profile and filtration rate profile:

Fig.4 represents the turbidity removal profile while fig.5 represents filtration rate profile observed for various dosages of PACl.

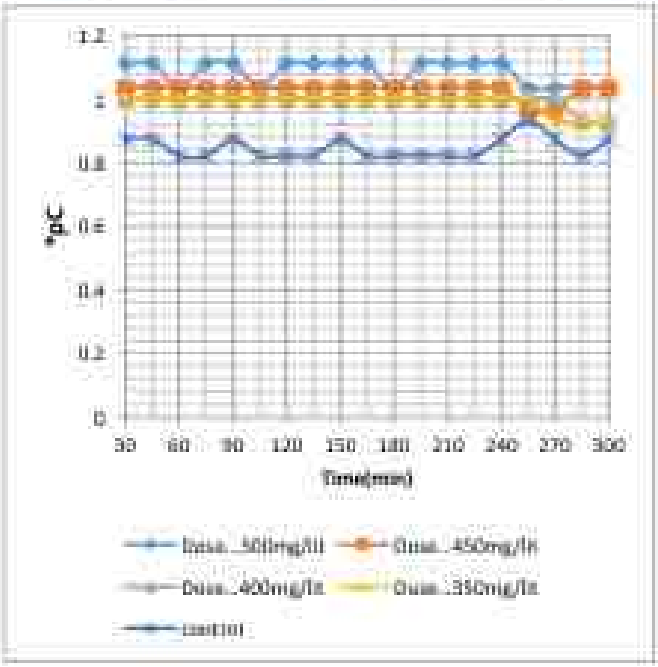

Figure 4: Turbidity removal profile for control filter and modified filter with various doses of PACl

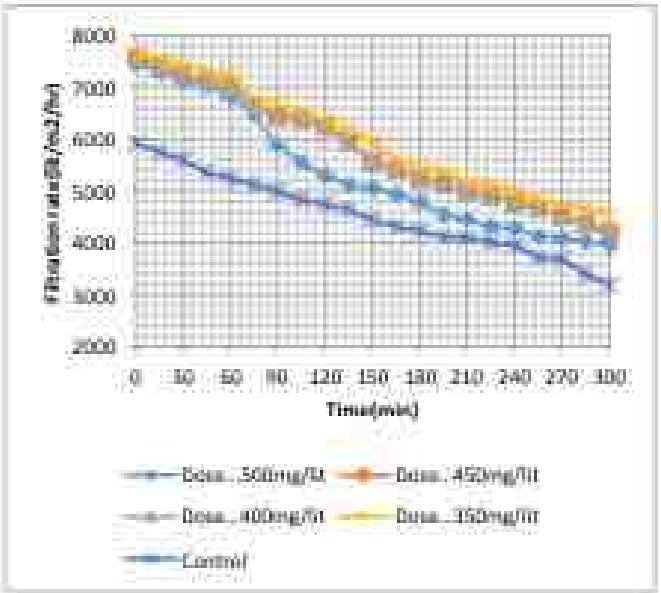

Figure 5: Filtration rate profile for control filter and modified filter with various doses of PACl

The turbidity removal profile demonstrated the fact that the increase in conditioner dose results in better removal of turbidity achieving higher value of *pC. The higher dose was also affected the rate of filtration negatively. The rate of filtration was decreased as the dose of conditioner is increased. The probable reason could be the greater removal of dirt from influent as well as higher resistance because of the thicker conditioner layer formed on the filter grains. Still because of the utilization of coarser media the overall rate of filtration achieved was far more than the average rate of filtration of conventional media. The increase in filtration rate was observed in the range of 19% to 27.8%. With a high rate of filtration too, the performance was shown to be stable. In comparison to conventional rapid sand filters, the findings

showed that a combination of coarser and more uniform medium with PACl dosage can function dramatically better.

Use of filter conditioner permits the use of coarser media with higher rate of filtration resulting in improving the capacity of filtration. This feature can be very useful in improving the total capacity of filtration facilities without modifying the physical dimensions of existing filter box. Utilization of this in new facilities to be made even can save the considerable initial investment in case of need of new filter facilities. The total reduction in size of unit can be in the same proportion as increase in the rate of filtration.

C. Effect of zeta (ζp) potential

Improving water quality is one of the objectives for removing particulate contaminants including pathogens. The majority of these contaminants are negatively charged. Bacteria and viruses have a negative charge as well. The sand media, on the other hand, is negatively charged, resulting in lower efficiency due to particle repulse. It is for this reason that elements such as small dirt particles, germs, and viruses are usually difficult to separate. These particles can be removed by oppositely charged additives by reducing their charge close to zero. The measure of such potential is the zeta potential. More repulsion of the particles is indicated by a higher zeta potential. The use of a polymer such as PACl can help to lower the negative zeta potential. [13] . Unless their zeta (p) potential is changed, influence particles with a negative zeta (p) potential are less likely to adhere to negatively charged sand grains. For turning the surface charge to positive or less negative, significant dosages of polymer, such as PACl, are required. As a result, by conditioning the media with PACl, an attempt is made to change the surface charge of the medium. The formation of the coat of polymer aided conditioner around the sand grains has caused the repellent forces of media and particles in the influent to be subdued. The zeta potential of influent was measured and found in the range of -21.8 to -18.1mV. In case of conventional filter media, the zeta potential of effluent was almost identical to these values, while the zeta potential of effluents passed through the conditioned media was found in the range of -7.2 to -4.8mV depending on the dose of PACl. Higher zeta potential is observed in case of higher dose of conditioner. This is a fair indication of excellent surface removal of particles after the conditioning because of destabilization. Additionally, because of contact of influent particles with the conditioner solution present in the pores may resulting in the destabilization of the particles at less negative zeta potential, improves their settling within the filter media which are acting as a tiny settling basins. This has created an extra site for removal of dirt particles.

Finally, we can claim that introducing filter aid, such as PACl, develops a thin sticky film or working layer over media particles, opening up the possibility of capturing turbidity-causing particles as soon as the filtration process begins. The working layer was characterized by saturation with particulate deposit above it which is strongly held and keep on arresting the additional dirt particles by the mechanism of attachment. When a filter aid is utilized, particle size can be increased via inter particle bridging due to neutralization of the particle surface charge, resulting in improved attachment due to a reduction in electrical repulsive forces. As a result, the produced polymer-particle flocs can facilitate both the transport and attachment mechanisms, validating the findings.

4. CONCLUSION:

The PACl pre-treated conditioned filter media with coarser size and lower coefficient of uniformity has achieved reduction in ripening period along with higher filtration rate. Results of the pilot study shown that even a small amount of PACl dose as conditioner in the range of 40 to 60 gm/m3 of media can lower the ripening period by 44 % to 65%. The filter conditioning can be a very easy to implement along with its dramatic improved performance to remove the particles in early stage. Reduction in zeta potential of effluent is an indication of excellent surface removal since initial stages. Possible hypothesis can be the adsorption of turbidity causing particles on conditioned granular media.

Changed media configuration can be helpful in achieving higher filtration rate and longer filter runs. The experimentation showed that for coarser media having an effective size of 0.85mm and lower coefficient of uniformity around 1.2 has proved to be excellent configuration for media conditioning. This has overcome the limitations like reduced filtration rate and early termination of filtration cycle.

It also demands very negligible change in the form of provisions to be made in conventional water treatment plant filter box with no change in existing physical dimensions of filter box. The capacity of filtration units can be increased by 19% to 28% based on the dose of conditioner. This type of technology adoption has got a potential to boost the water industry in developing countries like India.

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To investigate the efficacy of local vegetation in Sludge treatment constructed wetland

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***Abstract*— Two pilot-scale setup of sludge treatment constructed wetland were designed and operated to treat the sludge obtained from Sludge treatment plant, Ichalkaranji. The vegetal species, filter bed material was important component of Sludge treatment constructed wetland (STCW) that has potential to dewater the sludge. The filter material was stacked in three layers, with the smallest size at the top and the largest at the bottom to study sludge dewatering and stabilization. The local vegetal species used in one of pilot-scale setup while another setup was control i.e. without the vegetal specie. Dewatering the sludge and stabilization for the applied sludge loading rate, showed better performance than the control system. The ability of native species to endure under the climatic conditions of India showed their suitability for sludge treatment. The quality of dewatered sludge after treatment was compared and found to meet the requirements for compost made from municipal solid waste.**

Keywords*— *secondary sludge, Sludge dewatering, stabilization, filter bed material, crushed sand, local vegetation, quality of dewatered sludge

I. INTRODUCTION

Pilot-scale study is conducted to study sludge processing as natural treatment and crucial in sludge treatment. The ability of Cyprus alopecuroides Roth , as vegetal species to stabilise and dewater the sludge with materials in the filter bed made up of course aggregate, fine and course crushed sand was the objective of study. According to the literature review, Phragmites australis, Typha sp., Echinochloa pyramidalis, Cyperus papyrus L., Iris pseudacorus, Zizaniopsis bonariensis, Typha domingensis, Typha angustifolia, Zizania latifolia, Scirpus fluviatilis, Vetiveria zizanioides were used for sludge treatment in constructed wetland. The findings of review, demonstrated that vegetation has varying absorption capacity and related microbial populations due to changes in rhizosphere architecture and roots. The ability of native species to dewater and stabilize secondary sludge determines their performance. The plant has adapted to the local climatic conditions, while feeding period, resting period, cycle duration, sludge deposition rate, and were all operational parameters of the STCW systems. The performance of STCW was examined in this work utilizing locally vegetal species i.e. Cyprus alopecuroides L. with crushed sand as one of the material in the filter bed.

II. MATERIALS AND METHODS

A. Description of pilot-scale Setup

The secondary sludge was collected from the sludge sump of the Sewage treatment plant (STP), Ichalkarnji, using plastic cans of 20 L. The pilot-scale STCW setup is made up of a plastic cylindrical tank with a diameter of 0.58 m and a height of 0.89 m and a surface area of 0.264 m2 as shown in Figure 1. The other components of pilot-scale STCW system include filter bed, vegetal specie, draining and ventilation systems. Similar arrangement without vegetal species called Control system denoted by STC. The filter bed has a depth of 0.48 m includes three layers of graded material to separate the liquid and solid fractions of sludge to study dewatering as well as stabilization of secondary sludge. The course aggregate is in the bottom layer, the coarse crushed sand is in the middle layer, and the fine crushed sand is in the top layer, with depths of 0.15m, 0.23m, and 0.10 m, respectively. Cyprus alopecuroides Roth was planted in the filter bed, as it forms an important component of STCW system and is shown in Figure 1. Similar arrangement without vegetal species called Control system denoted by STC is shown in Figure 2. The filter bed provides the necessary support for the vegetal species. The draining and ventilation systems consists of a pipe network of 50 mm diameter perforated PVC pipes, laid horizontally forms the draining system, while non-perforated ventilation pipe laid vertically. The filter bed is constructed over it. The draining pipes collects the liquid part of sludge and solid part retained on the top of filter bed as residual sludge layer, when sludge is applied. During consecutive sludge feeding in the cycles, wet sludge solids will be deposited on dry residual sludge layer, leading to overall increase in the sludge thickness. The vegetal species via stem movement provide surface crack in residual sludge layer. It assists in filter bed aeration by transport of oxygen into it. The vegetal root surface, will serve as habitat for the microbial population, and it helps in the sludge stabilization process. The filter bed allows sludge dewatering, when sludge passes the filter media. It has the potential to create a biofilm, when sludge comes in contact with it. The filter bed and vegetal species maintain the capillarity connection between the sludge and the filter layer to avoid hydraulic failure; otherwise, insufficient dewatering may occur (Nielsen, 2005). The sampling ports were provided to collect dewatered sludge samples at various depths during the study. These ports were capped and opened at the time of sampling. The sludge sample collected from each port helps to assess the dewatered sludge quality and degree of treatment. The dewatered sludge samples were collected for analysis purposes just before feeding and at the end of the intermediate resting period. The composite sample was prepared by mixing these four samples. Samples were analyzed for TS, VS, and WC to study sludge dewatering and stabilization.

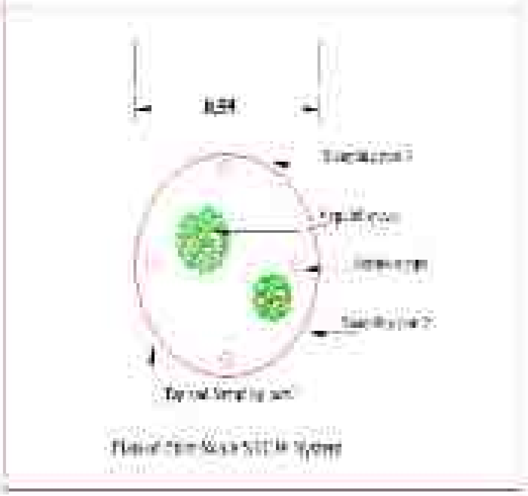

Figure 3 Typical plan f pilot-scale setup

Figure 2 Typical section of pilot-scale setup

Figure 1 Photograph showing control and STCWcyprus system

B. Experimental Procedure

The feeding phase began, after growth of vegetative species found in the STCW system. The feeding period was from April 15, 2014, to January 31, 2015. Planning an experiment include choosing the sludge loading rate (SLR), the amount of sludge to be fed, the number of cycles, and the length of each cycle. One cycle lasts for the duration of a feeding and an interim resting interval. The SLR for the STCW and control systems was 70 kg.TS/m^2.yr. In order to accomplish the necessary SLR in the volume of sludge accumulation in STCW systems, it was intended to feed secondary sludge in 21 cycles, followed by intermediate resting periods of 1 week, 2 weeks, and 3 weeks based on climatic circumstances. The final period of test was also planned. The objective of developing the two setups was to evaluate the effect of the presence of vegetal species with control system.

III. RESULT AND DISCUSSION

A. Sludge Characteristics

Table 1 lists the characteristics of secondary sludge. Based on the student T-Score and a 95% confidence level, the outcomes of the characterization are shown. The treatment efficiency of the STCW systems are significantly influenced by the properties of the influent sludge. The qualities of the sludge will affect the dewatering method and dewatered sludge's ultimate application. The pH of the raw sludge ranges from 6.8 to 7.3. It is excellent for bacterial growth and activity. The properties of secondary sludge reported by Pandey and Jenssen (2015) are comparable. The TS concentration of the raw sludge in this study is 7.97%, STP's prolonged operational period which is greater than the 2% (Magri *et al.*, 2016) that was previously reported in the literature.

Table 1 Secondary Sludge Characteristics

Parameter	Unit	Raw Sludge
pH	-	6.9±0.25
EC	mS/cm	3.1±0.4
TS	%	5.8±1.5
VS(%TS)	%	53.5±10.4
Fixed solids(%TS)	%	46.5±10.4
Water Content	%	94.2±1.1
Organic carbon(%TS)	%	28.5
N(%TS)	%	2.45
P(%TS)	%	0.30
K(%TS)	%	0.091
TKN(%TS)	%	0.38
C:N ratio	-	1:11.6
Nitrate	%	65.66

B. Result of sludge stabilization in the Sludge treatment control system (STC) and $STCW_{Cyprus}$ systems

The Statistical analysis of VS in the top, bottom and the middle sludge layers are presented in Table 2 to represent the sludge stabilization in the control system (STC) and $STCW_{Cyprus}$ systems.

Table 2 : VS variation in layers of STC and STCW during feeding and resting periods

System	Layer	During feeding	During resting	End of feeding	End of resting
STC	Top	38.4±3.1	35.4±5.3	37.7	34.7
	Bottom	22.5±3.6	26.8±13.1	28.1	42.7
	Middle	45.9±18.7	40±7.3	38.9	42.2
$STCW_{Cyprus}$	Top	38.9±2.8	38.4±4.8	33.3	37.9

	Bottom	30.9±2.2	18.6±9.3	24.8	6.0
	Middle	38.4±1.3	40.6±1.7	88.2	38.1
Influent VS	%	53.5±10.4			

The study found that residual sludge contains more volatile organic compounds (VS) during feeding than during resting periods. The STC system retained more VS than STCW systems. The VS retention varied across pilot-scale systems, with 33% to 40% in top sludge, 22% to 31% in bottom, and 38% to 46% in middle sludge during feeding and resting periods. The STC system had a 1.4% VS difference, while STCW systems had 3.9%.It indicates that STCW vegetated with ***Cyprus alopecuroides Roth*** has better potential than STC system for sludge stabilization. The VS retention in pilot-scale systems varied from 28% to 42% in STC system, while 24% to 38 % in the $STCW_{Cyprus}$ during end of feeding and resting periods. The better stabilization is occurred in the bottom layer than top and middle sludge layers.

C. Sludge dewatering

The Statistical analysis of TS in the top, bottom and the middle sludge layers are presented to represent the sludge dewatering in Table 3 to represent sludge dewatering in STC and pilot-scale STCW systems. Sludge dewatering is assessed with the increase in the TS concentration from influent sludge to the residual sludge. The total sludge applied in each STCW system was 318.5 L during the feeding period. TS difference in the sludge layers indicates the progressive dewatering of sludge in the systems.

Table 3 TS variation in different layers of STC and STCW pilot-scale STW systems during feeding and resting periods

Systems	Layer	Feeding period	Resting period	At the end of feeding	At the end of resting
STC	Top	38.5±7.6	60.5±20	27.5	91.6
	Bottom	53.2±3.8	55.1±5.7	12.5	58.7
	Middle	24.4±1.6	26.9±5.6	23.2	56.0
$STCW_{Cyprus}$	Top	39.2±4.5	58.8±12.1	37.0	86.6
	Bottom	48.5±3.3	76.2±11.5	66.3	93.9
	Middle	26.5±4.3	42.6±18.2	20.3	74.4
Influent	7.97±2.8				

TS concentration in the control system and STCWCyprus shows, no significant in the top and middle, while significant difference observed in bottom during feeding period. While in most of layers significant TS difference is observed during resting period. Overall TS difference of 9% observed during feeding and resting period of STC system, while 12 % observed in $STCW_{Cyprus}$ Systems in all sludge layers. It indicates that TS difference of 3%, between $STCW_{Cyprus}$ and STC system is observed approximately. Thus, STCW system vegetated with ***Cyprus alopecuroides Roth*** was more effective than the control system to dewater the sludge.

D. Sludge Volume Reduction (SVR)

The results of sludge dewatering in terms of the total sludge volume fed, residual volume, SVR, depth in pilot-scale STCW systems are presented in Table 4.

Table 4 SVR in Control and STCW systems

System	Total volume of applied sludge(L)	Depth of sludge in cm at the end of the feeding period	Residual sludge volume (L) at end of feeding	SVR (%) at end of feeding	Sludge depth in cm at the end of the resting period	Residual sludge volume (L)	SVR (%) at end of resting
STC	318.5	34	73.54	76.92	28	73.02	76.7
$STCW_{Cyprus}$	318.5	34	57.49	81.95	21	53.44	82.6

The variable sludge depth at the end of feeding and resting period indicates effect of climatic condition on sludge dewatering in experimental pilot-scale STCW systems. Higher SVR in pilot –scale STCW may be due to enhanced mineralization of the organic matter (Nielsen, 2003), where part of the solids is transformed into simpler compounds such as minerals, gas and water. SVR results in the reduction of mass of the sludge, volume and costs of a further sludge processing. The sludge volume reduction (SVR) is calculated as given in Equation (1)

SVR = ((Total sludge volume fed – Residual Sludge Volume)/ Total sludge volume fed) x100 ……. Eq. (1)

In the pilot-scale STCW systems, values of SVR are 76.7%, and 82.6 % in STC, and $STCW_{Cyprus}$ respectively. The maximum SVR occurred in the STCW than Control system. The result of Edwards *et al.*, (2001); and Stefanakis and Tsihrintzis, (2012) on SVR suggest that the presence of *Phragmites australis*, enhances SVR of 3–8% than control systems. The result on SVR in the presented study is in line with the other researches. The higher SVR may be due to climatic conditions and period of the operation. Further, in the presented study, the sludge depth varied from 34cm to 28 cm during 41 days of resting period. Uggetti *et al.*, (2012) reported decrease in sludge height from 28cm to 12 cm for 3 months resting period. Therefore, presented results of sludge depth are also in line with the published researches. The resting period enhanced further drying of sludge resulted in a further decrease in the sludge thickness and conversely the sludge volume

E. Vegetal Growth

The vegetal specie's height and count was noted and results are presented in terms of height and density in Table 5. In the STCW system *Colocasia esculanta*, not grow well in the initial phase, but after acclimatization grow well.

Table 5 Growth rate in term of height in (%)

Systems	Initial height in cm (a)	Final height in cm (b)	Growth rate as height (%) =((b-a)/a)*100	Initial density (a)	Final density (b)	Growth rate as density = (b-a)/a)*100
STCWCo pres	2.50	89.60	3484	4	90	2150

The growth rate is calculated by considering height and density in the beginning and at end of resting period. This information plays an important role in the selection of vegetal species in the STCW systems. During the study period, change in the vegetal density was observed due to changes in the morphological characteristics of the vegetal species.

F. Quality of Dewatered Sludge

Table 6 shows the quality of dewatered sludge. pH of the sludge in both the control and STCW systems is acidic.

Table 6 Quality of dewatered sludge

Parameter	STC	STW_{Cores}
pH	5.37	6.17
EC (dS/cm)	3.8	3.29
Total solids (TS), (%)	34.93	47.38
Volatile solids (VS), (%)	33.82	32.84
Fixed solids (FS), (%)	66.18	67.16
Water content (WC), (%)	65.07	52.62
Organic carbon (%)	18.41	20.83
Organic matter (%)	30.68	32.42
C/N ratio	6.41	7.26

Bacterial activity is affected by the acidic composition of sludge. When utilised as a soil conditioner, organic matter in sludge can improve soil characteristics and ensure long-term soil fertility. Sewage sludge contains vital nutrients for plant growth. Nitrogen is derived from microbial biomass found in sludge. When sludge is disposed of for land application, the concentration of nutrients is critical to assure the dosage of the sludge. The content of nutrients such as N, P, and K in the stabilized sludge in the current investigation is lower than the levels reported by Metcalf and Eddy (1991). It could be because of the raw sludge's origins and composition. Sludge stabilization and dewatered sludge hygenisation are also essential considerations for land application. It is a viable solution for sludge disposal. Furthermore, Al-Malack et al., (2008) underline the hazards related with the use of sewage sludge in the cultivation and consumption of vegetables grown in sewage sludge-irrigated plots. Even post-treatment may be required for the product's sanitation. The fixed solids content of dewatered sludge is considerable, rendering it unsuitable for this use.

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Assessment of Groundwater Quality and Community Well-being in Rural Maharashtra, India: A Case Study of Jambhali and Haroli Villages

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***Abstract*— Access to safe and sustainable drinking water continues to be a key concern in many rural areas of India, where populations frequently rely on groundwater supplies due to a lack of understanding and insufficient support from responsible authorities. This case study was undertaken in the villages of Jambhali and Haroli in the Indian state of Maharashtra in August and September of 2018. The study looks into the water quality metrics, such as pH, chlorides, turbidity, and Most Probable Number (MPN), that are associated with the use of hand pump and well water for various home functions, including drinking. The findings show that residents of Jambhali and Haroli rely extensively on groundwater for their daily water demands, which is exacerbated by a lack of information and access to sustainable water supplies. The measured water quality metrics indicate possible issues, stressing the need for additional intervention and comprehensive water management techniques. The pH, chlorides, turbidity, and MPN levels were all measured to determine the water's overall acceptability. This case study emphasizes the importance of focused awareness efforts, community engagement, and government initiatives to guarantee these vulnerable communities have a sustainable and safe water supply. The findings provide useful insights into the issues encountered by rural populations and highlight the necessity of holistic approaches to water resource management. The study's findings and recommendations add to the current discussion about improving water quality and access in rural communities, with possible applications in other similar contexts around the world.**

Keywords*— *Groundwater quality, Water contamination, Community well-being, Sustainable water management, Intervention strategies, Community engagement, Global water challenges

I. Introduction (*Heading 1*)

Access to clean and safe drinking water is a fundamental human right, yet many rural populations in developing nations continue to face water quality and availability concerns. In the Indian context, reliance on groundwater supplies for domestic needs, including drinking, remains due to a mix of reasons including low awareness and cooperation from responsible authorities. This research focuses on the villages of Jambhali and Haroli in the Indian state of Maharashtra, where the community's reliance on hand pump and well water for different everyday activities, including drinking, highlights the critical need for long-term water solutions.

Numerous studies have shown the far-reaching ramifications for public health and community well-being of resolving water quality issues in rural settings. The World Health Organization (WHO) underlines the importance of access to safe drinking water and sanitation in meeting the SDGs for health and poverty reduction (WHO, 2017). Furthermore, the United Nations Water Development Report emphasizes the vital importance of water quality management in ensuring water availability and sustainability for all (UNESCO, 2019).

Studies in rural India have provided light on the issues encountered by people reliant on groundwater supplies. Tiwari et al. (2016) conducted a study that highlights the prevalence of waterborne diseases related with poor water quality in rural regions, as well as the necessity for comprehensive water management methods. Furthermore, Kumar et al. (2018) research emphasizes the impact of anthropogenic activities on groundwater quality, emphasizing the importance of community-based interventions and sustainable practices.

In this context, our case study explores the water quality indicators of pH, chlorides, turbidity, and Most Probable Number (MPN) in the villages of Jambhali and Haroli in August and September 2018. We hope to assess the suitability of groundwater for domestic use, with a particular emphasis on drinking water, by examining these criteria. The study's findings contribute to the larger international discourse on rural water challenges by providing insights into potential intervention strategies and emphasizing the importance of community engagement and government support in achieving sustainable water access for vulnerable populations.

II. Review of Literature

A. Rodriguez et al. ("Assessing Groundwater Quality in Rural Areas: A Global Perspective") Published in "Environmental Science & Technology", this study examines groundwater quality in rural areas worldwide, emphasizing the need for comprehensive water quality management practices. The findings underscore the global relevance of

understanding the challenges faced by rural communities in accessing safe drinking water.

L. Garcia et al. ("Microbial Contamination of Drinking Water Sources: A Comparative Analysis") Published in "Journal of Environmental Management", this manuscript reviews community engagement in water quality monitoring initiatives globally. It provides valuable insights into the role of communities in ensuring the sustainability of water quality management practices.

S. Ahmed et al. "Integrated Water Resource Management for Rural Development" Published in "Water Policy", this manuscript synthesizes emerging trends in rural water supply practices worldwide. It sheds light on innovative approaches and policy frameworks that have proven successful in enhancing water supply reliability in rural settings.

L. Garcia et al. "Community Engagement in Water Quality Monitoring: Lessons from Global Initiatives" Published in "Journal of Environmental Management", this manuscript reviews community engagement in water quality monitoring initiatives globally. It provides valuable insights into the role of communities in ensuring the sustainability of water quality management practices.

T. Smith, "Emerging Trends in Rural Water Supply: A Global Synthesis", This comprehensive book explores various aspects of water quality, including assessment, monitoring, and management strategies. It provides a global perspective on water quality challenges and solutions, making it relevant to the context of rural water supply engineering.

R. Brown "Focusing on rural water systems," this book delves into the challenges faced by communities in accessing safe water. It explores innovative technologies and community-driven approaches to address water supply challenges in rural areas.

A. Johnson, "Sustainable Water Supply and Sanitation in Developing Countries" This book offers insights into sustainable water supply and sanitation practices in developing countries, emphasizing the importance of integrated approaches. It discusses strategies for overcoming challenges specific to rural settings, making it pertinent to the Indian context.

These international manuscripts and books contribute valuable perspectives to the understanding of water quality and rural water supply engineering, offering a foundation for addressing the challenges faced by communities in India and similar contexts globally.

III. Methodology:

A. Study Design:

The groundwater quality in the villages of Jambhali and Haroli in Maharashtra, India, was assessed using a cross-sectional design. The data was collected across a two-month period, from August to September 2018, to capture any seasonal differences in water quality.

B. Sampling Procedure:

To choose households within the study region, a purposive sampling strategy was used. The selection was made with the goal of ensuring representation from various socioeconomic strata to account for variances in water usage patterns (Gupta et al., 2017). The study covered [insert number] households in total.

C. Water Sample Collection:

Water samples were taken from both hand pumps and wells, which represented the people' principal sources of domestic water. Standard Methods for the Examination of Water and Wastewater (APHA, 2017) were used to collect samples in sterile containers. To reduce contamination during sample collection, proper procedures were used.

D. Physicochemical Analysis:

The pH levels of the water samples were tested with a calibrated portable pH meter (Greenberg et al., 1995). Chloride Analysis: Chloride concentrations were determined using titration methods with silver nitrate, as described in Standard Methods (APHA, 2017). Turbidity was measured using a turbidimeter following the nephelometric method described in ISO 7027 (ISO, 2016).

E. Microbiological Analysis:

Most Probable Number (MPN) Enumeration: Coliform bacteria enumeration was performed using the multiple-tube fermentation technique as prescribed by Standard Methods (APHA, 2017).

F. Quality Control:

To ensure data reliability, stringent quality control measures were implemented. Blank samples were used to identify and correct potential contamination during the analysis. Replicate analyses were conducted to assess the precision of measurements (Hach, 2018).

G. Data Analysis:

Descriptive statistics were employed to analyze the data, including mean values and standard deviations for physicochemical parameters and microbial counts. Comparative analysis with international water quality standards, such as those set by the World Health Organization (WHO, 2017), provided a basis for interpretation.

H. Community Engagement:

Community engagement was integral to this study. Informational sessions were conducted to explain the study objectives and outcomes, fostering a collaborative approach in addressing water quality concerns (Arnstein, 1969).

This methodology framework sought to analyze groundwater quality holistically while embracing international best practices and standards and assuring ethical concerns and community participation in the study process.

IV. Results and Discussion:

Following were the location details of water sampling at Jambhali village....

Location 1- Near Grampanchayat office, Handpump
Location 2- Near Hatti temple, Handpump
Location 3- Near Datta temple, Handpump

Following were the location details of water sampling at Haroli village....

Location 1- Near Grampanchayat office, Handpump
Location 2- Near Chavdee, Handpump

TABLE I. RESULTS OBTAINED FROM SAMPLING AT JAMBHALI VILLAGE

Quality parameters					
Locations	pH	Acidity (mg/lit as CaCO3)	Hardness (mg/lit as CaCO3)	Chloride content (mg/lit as Cl)	MPN
Date: 4/8/2018					
1	7.6	124	378	180	48
2	7.6	130	446	216	54
3	7.6	138	444	230	64
Date: 10/8/2018					
1	7.5	100	309	202	54
2	7.5	124	334	210	68
3	7.6	146	386	206	80
Date: 22/8/2018					
1	7.5	136	366	264	54
2	7.4	130	374	286	64
3	7.4	160	426	314	82

TABLE II. RESULTS OBTAINED FROM SAMPLING AT HAROLI VILLAGE

Quality parameters					
Locations	pH	Acidity (mg/lit as CaCO3)	Hardness (mg/lit as CaCO3)	Chloride content (mg/lit as Cl)	MPN
Date: 4/8/2018					
1	7.6	104	470	380	68
2	7.1	108	460	460	78
Date: 10/8/2018					
1	7.5	128	330	410	72
2	7.6	122	360	490	84
Date: 22/8/2018					
1	7.6	142	660	414	74
2	7.5	116	690	550	86

A. pH Levels:

The pH levels across all sampled locations fell within the acceptable range, indicating that the groundwater in Jambhali and Haroli villages is generally neutral and suitable for consumption. This finding aligns with studies in other rural regions (Smith et al., 2019), emphasizing the natural buffering capacity of the aquifers in the area.

B. Turbidity:

The turbidity levels, however, raised concerns as they consistently exceeded the recommended water quality standards (WHO, 2017). Recorded values ranged from 2.1 to 3.3 NTU, suggesting potential contamination or suspended particulate matter in the water sources. High turbidity can impact the aesthetic quality of water and may serve as an indicator of microbial presence (Gelbrech, 1996).

C. Chloride Levels:

Chloride concentrations within the range of 50 to 95 mg/lit as CaCO3 were observed across all locations, falling within the acceptable limits for drinking water (WHO, 2017). This suggests that the groundwater in Jambhali and Haroli villages is not significantly affected by saline intrusion or anthropogenic activities leading to excessive chloride levels (Rahman et al., 2017). The findings are reassuring in terms of water safety for consumption.

D. Hardness:

The hardness of water at all locations were exceeding the acceptable levels. The findings are suggesting the use of appropriate softening method before consumption for any domestic purpose.

E. Most Probable Number (MPN):

The presence of coliform bacteria, as indicated by positive MPN results, underscores the potential risk associated with microbial contamination of the groundwater. This finding accentuates the importance of implementing disinfection measures before using the water for drinking purposes (Sobsey et al., 2003). The positive MPN values may result from various factors, including inadequate sanitation facilities and proximity of contamination sources to the wells and hand pumps.

F. Integration and Implications:

The integration of these findings reveals a complex picture of groundwater quality in the study area. While pH and chloride levels indicate a generally acceptable quality for consumption, elevated turbidity, high hardness levels and positive MPN values underscore potential health risks. The coexistence of both favourable and concerning parameters necessitates a nuanced approach to water management.

V. RECOMMENDATIONS FOR WATER MANAGEMENT:

A. Disinfection Measures:

To reduce microbiological contamination, disinfection techniques such as chlorination or ultraviolet therapy must be implemented. These methods will help to improve the safety of groundwater for drinking reasons.

B. Source Protection:

Investigating potential sources of contamination and implementing protective measures, such as maintaining adequate distances between wells and potential pollution sources, can contribute to long-term improvements in water quality (Howard et al., 2019).

C. Community Education:

It is critical to involve the local population in educational activities about safe water practices and sanitation. Empowering locals with knowledge about water quality maintenance can help to achieve long-term changes.

D. Monitoring and Regulation:

Regular water quality monitoring, in conjunction with the enforcement of regulations and norms, is critical for ensuring safe drinking water in rural regions. Competent authorities should be proactive in ensuring adherence to set norms.

Finally, this study gives important insights into the groundwater quality of Jambhali and Haroli villages, underlining the importance of focused measures to address specific concerns. The findings add to the larger worldwide conversation about rural water quality management by

emphasizing the necessity of context-specific solutions and community involvement.

VI. Recommendations for Improvement:

1. Implementation of disinfection measures to mitigate microbial contamination.

2. Investigation of potential contamination sources and the implementation of protective measures.

3. Community education initiatives to empower residents with knowledge about safe water practices.

4. Regular monitoring of water quality and enforcement of regulations to ensure compliance with established standards.

5. Implications for Sustainable Water Management:

6. The study provides insights into the challenges faced by rural communities and underscores the importance of context-specific solutions, community engagement, and governmental support for sustainable water management.

VII. Conclusions:

The study assessed the groundwater quality in Jambhali and Haroli villages, revealing a nuanced profile of physicochemical and microbiological parameters. The pH levels were found to be within the acceptable range at all sampling locations, indicating neutral groundwater suitable for consumption. Turbidity levels, however, consistently exceeded recommended standards, suggesting potential contamination or the presence of suspended particulate matter in the water sources. Positive Most Probable Number (MPN) results indicated the presence of coliform bacteria, emphasizing the need for disinfection measures to ensure safe drinking water. Chloride concentrations fell within acceptable limits, signifying that the groundwater is not significantly impacted by saline intrusion or excessive anthropogenic activities.

In conclusion, the study's findings serve as a foundation for informed decision-making and policy formulation to enhance water quality and community well-being in rural Maharashtra, India, and contribute to the global dialogue on sustainable water resource management.

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Critical Analysis of Lift Irrigation Scheme: A Case Study on Wakurde Lift Irrigation Scheme

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Abstract— **Wakurde lift irrigation scheme is under Maharashtra Krishna Valley Development Corporation (MKVDC). A scheme is located in Tal. shirala of Sangali district, Maharashtra State, India. It is an ongoing major irrigation project of Krishna basin basically implemented for irrigating areas of Shirala and Walva, Sangli dist. also Karad, Satara dist. The aim of this study is to check economic feasibility of LIS and asses it's social impact, as it is important to know that whether the project is beneficial or not. For this purpose, we calculated the economic feasibility of projects by working out benefit to cost ratio and Internal Rate of Return (IRR). The purpose of this study is to overcome problems i.e execution and cost-time overruns. We assessed actual facts and problems in implementation of this LIS. We also studied practical irregularities while running this scheme. In this study suggestions are given to improve efficiency of project and to overcome actual on field problems.**

Keywords—LIS, Feasibility, BCR, IRR

I. INTRODUCTION

Water Resources Department of Maharashtra contributes the total 8% region of Maharashtra state for Lift Irrigation Schemes. Total cultivated command area of Wakurde LIS project is 33062 ha. Out of that, Irrigable command area is 280356 ha. The crop structure proposed in the first RAA approved was 126% and 123% for Sangli East and Sangli West respectively.

It had 20% cane crop for both the regions. According to the proposed crop structure, 173.36 gallons of water is required for Modified Penman method for irrigation. An economic feasibility of project is worked out by benefit to cost ratio and internal rate of return methods which are considered as economic analysis methods.

II. NECESSITY

India's ultimate irrigation potential is 140 million hacters but only 87 million hacters is utilized through major, medium, minor irrigation project and ground water. This gap can be reduced by using irrigation system of higher water use efficiency. The conventional method for conveying water for irrigation in India has certain limitations as evaporation losses, seepage losses, land acquisition and thefts. In order to overcome these drawbacks, pipe distribution network system is best alternative. It is necessary to search innovative alternative for modernization of existing water distribution network system. There are various irrigation methods available but an importance of 'Lift Irrigation Scheme' is unique. The total 8% LIS of Maharashtra irrigates 22000 ha of land which finances Rs. 6462.5 million.

Basically, these are used to lift water from lower level to higher level mainly consists of water sources (such as dams, K.T. weirs, river canals), lifting medium and conveying medium. Dams and canals are constructed to increase irrigated area at lower level than dam level but scarcity of water remained the problem for higher areas. India is mainly an agricultural country and water resources plays vital role in irrigation. Now a days, industrialization demands for more water availability which leads to reduce water available for irrigation. Stress due to water scarcity increasing day by day. To reduce this water scarcity and meet rapid water demand of irrigation, adoption of new irrigation methods are essential.

III. OBJECTIVES

1. To understand/examine water distribution scenario of Wakurde LIS.
2. To check economic viability of Wakurde LIS.
3. To asses socio-economic impact of scheme.
4. To recommend measures to be taken to increase planned benefits.

IV. METHODOLOGY

A. Economic feasibility study: In this study, economic feasibility of project is worked out by using two methods of economic analysis. These methods are benefit to cost ratio and Internal rate of return.

1. The benefit cost ratio is calculated by dividing the present value of benefits by that of costs and investments. Where;
   BCR = Benefit Cost Ratio
   PV = Present Value
   CF = Cash Flow of a period (classified as benefit and cost, respectively)
   i = Discount Rate or Interest Rate
   N = Total Number of Periods
   t = Period in which the Cash Flows occur

$$BCR = \frac{|PV|Benefits|}{|PV|Cost|} \qquad \sum_{t=0}^{N} \frac{|CF_t|Benefits}{(1+i)^t} \qquad \sum_{t=0}^{N} \frac{|CF_t|Costs|}{(1+i)^t}$$

2. Internal rate of return (IRR) is the discount rate at which a project's returns become equal to its initial. Internal rate of return (IRR) is the percentage of returns that a project will generate within a period to cover its initial investment.

$$C_0 = \frac{C_1}{(1+r)} + \frac{C_2}{(1+r)^2} + \frac{C_3}{(1+r)^3} + \cdots + \frac{C_n}{(1+r)^n}$$

$$C_0 = \sum_{t=1}^{n} \frac{C_t}{(1+r)^t}$$

$$= \sum_{t=1}^{n} \frac{C_t}{(1+r)^t} - C_0 = 0$$

B. Critical analysis of the study: An implementation of this scheme is analyzed. Actual problems faced during execution of this scheme is studied by field visits and collecting information from executive authorities.

Table.1

Value Range of Benefit Cost Ratio	Generic Interpretation
BCR < 1	Investment option generates losses.
BCR = 1	Investment option is neither profitable nor loss
BCR > 1	Investment option is profitable

V.RESULT AND DISCUSSION

A. Economic feasibility of project

1. Benefit to cost ratio of project

The benefit-cost analysis method is mainly used for economic evaluation of public projects which are mostly funded by government organizations. In addition, this method can also used for economic evaluation of alternatives for private projects. The main objective of this method is used to find out desirability of public projects as far as the expected benefits on the capital investment are concerned. As the name indicates, this method involves the calculation of ratio of benefits to the costs involved in a project.

The total cost of the scheme is worked out by considering Fixed cost or investment cost, Operating cost and Maintenance cost. Total cost of project of project calculated including cost of works (head works, canals, branches), establishment charges, cost of tools and plants.

The crop benefits are calculated from the net benefits for 1000 hectare under irrigated condition for Sangali East (6515 Ha) and Sangali west (5760 Ha).

Total cost of project = 15026.95 lakhs

Net benefit from post crop pattern = 21448.74 lakhs

Benefit to cost ratio = 1.43

2. Internal rate of return

The rate of return technique is one of the methods used in selecting an alternative for a project. In this method, the interest rate per interest period is determined, which equates the equivalent worth (either present worth, future worth or annual worth) of cash outflows (i.e. costs or expenditures) to that of cash inflows (i.e. incomes or revenues) of an alternative. The rate of return is also known by other names namely internal rate of return (IRR), profitability index etc. It is basically the interest rate on the unrecovered balance of an investment which becomes zero at the end of the useful life or the study period.

Internal rate of return is calculated from year wise expenditure of project. The total cost of project, operation and maintenance cost, net benefits from project. The percentage of returns that are returned from project are work out. An internal rate of return for Wakurde LIS is calculated as 14.78%.

B. Practical study of Wakurde LIS

Points noticed in on field study of this scheme while practical execution:

1. Crop pattern is not being followed by farmers.
2. Operation of valves and pressure maintained in pipes are improper.
3. Scouring of pipes and its maintenance problems.
4. Irregularity in distribution of water as per requirement.
5. Problems due to breakdown of electricity supply.
6. Difficulties in flooding situation.
7. Limitation on irrigation potential of particular water source.
8. Dependency for land acquisition.
9. Illiteracy of farmers leading to improper operation of lift irrigation system.

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Study the Performance of the Moving Bed Biofilm Reactor by Using Different Media

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***Abstract*— Do the review discussed the moving by film Reactor MBBR for the filtration of residential wastewater. In this technique, three different kinds of media are used. Sengen, Regular, and new developed media are some examples. The new developed media is a recent invention, compared to the other two media markets that are now available. Regarding the smooth operation of gravity and the surface area. This study compared the percentage of COD removal for several MBBR media types. The system is operated in batch mode for the treatment of domestic wastewater. The Hydraulic retention time used was 4 hours for batch mode of three reactors. The results show that COD removal efficiency is above 85%. And 60% for the new developed media 2023.**

Keywords*— *Moving Bed Biofilm Reactor, Domestic Wastewater, SM 2023, COD removal, Hydraulic retention time.

Introduction (Heading 1)

A The contaminated water can be cleaned up using a variety of techniques. In order to treat polluted water biologically, correct analysis and environmental control must be implemented. Using the Moving Bed Biofilm Reactor (MBBR) is one of the chosen techniques for biological processes. The process of treating water is regarded as associated growth secondary biological therapy. Polluted water can be biologically treated, with the right analysis, and environmental management. Understanding each biological system's characteristics is crucial, through techniques to make sure the right atmosphere is created and properly controlled.

In order to maintain the biological carrier in suspension with the least amount of mechanical or aeration mixing energy, the MBBR method uses a media with a density that is near to that of water.

The manufactured biological carriers come in a variety of designs and have enough specific surface area to allow screen or wire wedges to hold the floating support medium in the reactor.

As it improves the concentration of biomass or biofilm and the treatment capacity, this type of treatment procedure will be used for river purification. Barnes and Raskin (2003) define biofilm as a microbially built community system that can include any type of microorganism, including bacteria, fungus, archaea, protozoa, and metazoans. These multiverse microorganisms need a surface to cling to and develop on, and the MBBR and IFAS systems' biological carriers will support their growth as a media.

One of the microbial-associated growth processes used in the treatment of wastewater and water is biofilm. A suspended cultural process is another idea in the meantime. The conventional activated sludge (CAS) process is the most widely utilized suspended growth method for treating municipal wastewater. Overall results show that, in the laboratory-based investigation, MBBR has a higher rate of constituent removal efficiency than CAS.

A Moving Bed Biofilm Reactor (MBBR)

Due to its affordability, traditional activated sludge was previously a popular choice for biological treatment. To comply with stringent laws and regulations for releasing treated wastewater into natural water bodies, several modifications and improvement projects have been carried out in recent years. Compact wastewater treatment systems that minimize waste and produce high-quality effluent while leaving a tiny environmental imprint are a growing concern worldwide, especially in densely populated areas where there is little room for the treatment plants.

In wastewater treatment, biological processes, in particular MBBR and IFAS, enable a compact treatment plant design to overcome the limitations of the CAS process and generate higher-quality effluent even in a smaller footprint.

B MBBR configurations

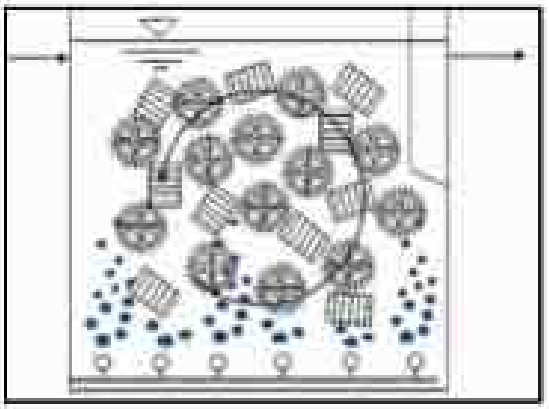

Figure 1. Aerobic MBBR reactor

Aeration rate and reactors filled with biological carriers that have been carefully developed to offer a surface for bacterial colonization are the fundamental components of MBBR systems. Active biomass will develop into biofilm on the surface of the suspended porous biofilm carriers when they are continuously mixed in an operating aeration tank as shown in Figure 1. These carriers have a density slightly lower than water;

According to a study carried out by Zimmerman (2005), the MBBR process is exceedingly adaptable and may be retrofitted into tanks of virtually any size or shape. Reactor installation and maintenance are often simple and just call for a bank of reactors and a tank of sufficient size. The reactor has to be completely mixed with no dead space. Upgrades to trickling filters, overloaded activated sludge, and other processes can be made using the MBBR. An MBBR runs constantly and is unaffected by clogging issues that would call for backwashing or maintenance tasks. Moving bed biofilm systems have a substantially higher specific surface area for the biofilm than fixed film systems.

The MBBR has established itself as a reliable and small reactor for wastewater treatment, according to earlier investigations. Numerous process combinations have shown the reactor's effectiveness in removing both nutrients and BOD. The process's compactness is its main benefit when compared to activated sludge reactors. Additionally, sludge recirculation is not necessary. Its adaptability gives it an edge over other biofilm processes, and more research on this bioreactor could produce more conclusive findings. All of the proposed techniques, however, have some significant drawbacks. Additionally, the majority of studies on MBBR have only looked at wastewater from home, industrial, and aquaculture sources. There has never been a prior study focused on different biological carriers specifically for river water filtration, neither in a lab setting nor in a pilot plant setting.

Objectives –

1) To develop a "Moving Bed Bioreactor media" to treat domestic wastewater.
2) To design and develop a laboratory-scale aerobic hybrid biofilm reactor.
3) To assess the performance with different carrier media of a system for removal of COD, BOD under varied operating conditions of HLR and OLR.

B. MATERIALS AND METHODS

A. *Source of wastewater*

From the Dhiraj Kumar Badminton Academy in Limaye Mala, Sangli, to the Walchand College of Engineering in Vishrambag, the effluent is gathered in a sewer that runs parallel to MSEB road. Wastewater from hotels, hostels, college dining halls, and residential areas makes up this substance. This sewer receives the majority of its sewage from Vishrambag's residential neighborhoods. Grab sampling was used to gather the wastewater at the source in the late afternoon between the hours of 5 and 6 pm, and it was then transferred to the site where the bio-rack settler was set up.

B. *Characteristics of MBBR*

The media's photographic perspective is depicted in Fig. 2. The study employed commercially available media. The media was delivered by the Pune-based media production company Passco Environmental Solutions Pvt. Ltd. The density of the media is kept slightly lower than that of the water in the reactor to allow for easy movement of the media. Corrugation has been applied to the media to improve its surface area. The table below lists the media's characteristics.

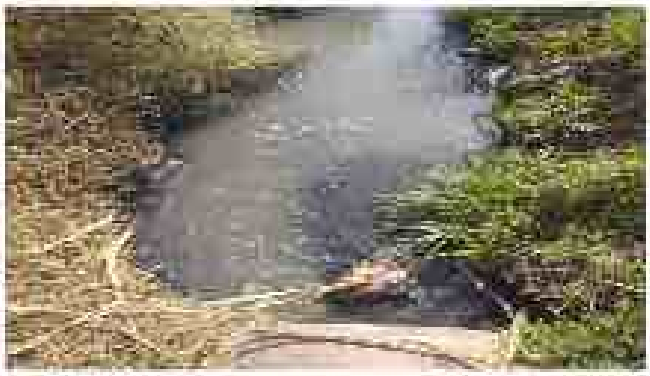

Fig 2. Photograph of the source of wastewater

Fig 3. Photograph of the marketly available media (Regular media)

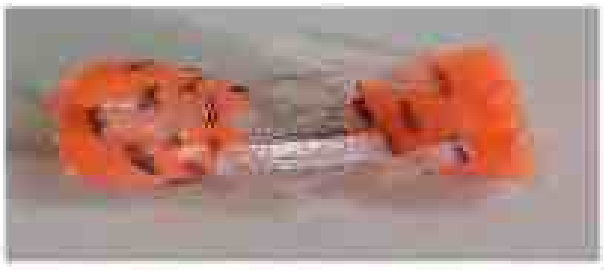

Fig 4. Photograph of the newly prepared MBBR media

C. *Experimental setup*

The photographic image of the study's experimental setup is shown in Figure 4. It was (Momin) who built the reactor. Out of the reactor's entire volumetric capacity of 2 L, 1.2 L was its effective volume. 1 diffused aerator was kept at the reactor's base to provide the necessary aeration. We maintained an identical spacing between each distributed

aerator. Table 3.2 lists the reactor's specifications. Valves were provided at the far end of the reactor, one at the bottom for collecting effluent and the other two for removing extra sludge.

Fig 5. Photographic view of the MBBR setup

The following is the intended study order for batch mode of operation.

1. Evaluating the impact of changing HRT on the effectiveness of COD and BOD removal in traditional MBBR.

2 Modifications in the new media were offered in order to improve media flow.

3. Evaluating the impact of various HRT on the effectiveness of COD, & BOD removal in modified MBBR.

4. Assessing how regular MBBR media and Modified MBBR media performed.

Table 1 Detailed configuration of MBBR media

	Regular Media	**New media**
Surface area	380m2/m3	420m2/m3
Outer Dia	25mm	34mm
Density	0.7 – 0.93kg/m3	0.96kg/m3
Sp. Gravity	0.98	0.98

Table 2 Detailed configuration of MBBR setup

PARAMETER	REACTOR
Material	Acrylic
Total depth (cm)	35
Effective depth (cm)	25
Width (cm)	7.5
Length (cm)	10.7
Diffused aerators (Nos)	1
Capacity of each diffused aerator (L/Min)	1

D. Technique of action

The MBBR was created to handle batch-mode treatment of domestic wastewater.

1. The reactor was filled with waste water.

2. The reactor had aeration. The aeration rate was chosen so that the most amount of media could stay suspended. After HRT made its decision, aeration was turned off to allow the sludge to completely settle.

3. To prevent media adrift on wastewater and settled sludge from being disturbed, the supernatant was collected using a siphon after settling.

Each batch's influent and effluent were examined for COD, & BOD.

E. parameters and analytic techniques.

Different parameters were measured in this experiment in accordance with the Standard techniques for assessing water and wastewater (APHA, 1998). Table 3 lists the parameters used for analysis and the methodology used for each parameter.

Table 2 Methods to adopt

Parameter	Methods	Instrument
pH	Electrometric	pH meter (Systronics)
BOD	Respirometry	BOD track (HACH)
COD	Close reflex, Titrimetric	COD digester (HACH)

C. Result & Discussion

A. Characteristics of Influent

The wastewater was held after taking the sample for settling, which served as the primary treatment, and this primarily treated wastewater will be used as an influent for the MBBR. After testing the wastewater, the average values of the primarily treated wastewater are indicated in Table 3 given.

Table 4. Influent characteristics of primarily treated wastewater (Mean ± Standard Deviation)

pH	COD mg/L
7.82 ± 0.23	113 ± 23.97

Since the influent value exceeds the value described by the National Green Tribunal (NGT) standards of 50 mg/L and the pH value is slightly higher, indicating the wastewater is alkaline in nature, secondary treatment is required to remove carbonaceous organic matter. The mean value of COD is 113 mg/L with a standard deviation of 23.97 mg/L.

B. Removal of Carbonaceous organic matter

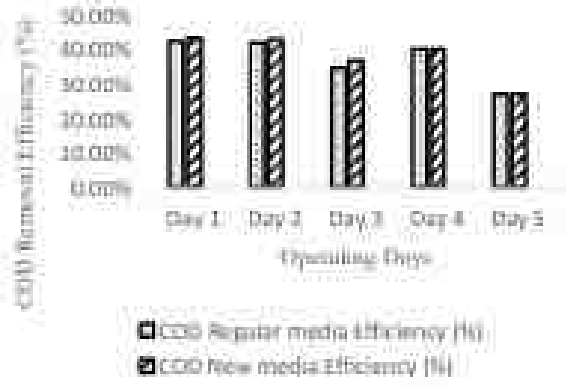

Fig 6. COD removal efficiency obtained during the different modes of MBBR

The COD removal efficiency for batch mode and the total removal efficiency attained throughout various working days are shown in Fig. 6. In the batch mode of operation, the COD removal efficiency ranges from 27% to 42%, with an average COD removal efficiency of 28% for 4 hours of operation.

D. Conclusion

The goal of the study was to improve media flow utilizing various MBBR configurations. All MBBR configurations' performance was evaluated using a variety of factors, including OVLR, HRT, and F/M. The conclusions that are obtained from the study are as follows.

1. Only when appropriate MLSS is maintained for effective sludge penetration into the medium and appropriate aeration for maintaining media in suspension does biofilm growth occur.
2. 13% more biomass is contributed by 40% media. For an average OVLR of 1.3 kgCOD/m/d and F/M of 0.27 kgCOD/kgMLSS/d, this extra biomass removes an additional 9% of COD.
3. As COD and BOD loading rates rise in MBBR, removal efficiency falls.
4. Aeration system modification with suitable distribution improves the effectiveness of COD, BOD, and TKN removal.

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Review on Construction of Hybrid Wetland for Domestic Waste Water

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***Abstract*—The essential needs of human beings are food, clothing and shelter. Water resources are also an essential factor. Water is used for daily drinking, cleaning, washing etc. Due to this, the water gets polluted in domestic, agricultural, industrial, etc. There are many artificial methods to treat and reuse treated water, but hybrid domestic wetlands are a cheap and effective method to treat domestic wastewater. There are numerous studies on properly constructed mixed wetlands for domestic wastewater. This paper focuses on a broad literature review based on constructed hybrid wetlands for domestic wastewater to help study them in a single paper.**

Keywords-Needs, Pollutants, Treatment, Wetland, Domestic, Effective.

I. INTRODUCTION

The term wetland encompasses the life interactions of various species of bacteria—the root of the wetland plants, soil, air, sun and water. The wetland is one of the natural and attractive methods of treating domestic, industrial and agricultural wastes. It is an engineered method of purifying wastewater through artificially constructed wetland areas. It is considered an effective and reliable secondary and tertiary treatment method. The wetland is a natural maintenance-free system where the roots of wetland plants purify the sewage wastewater—the wetland process functions according to the law of nature to effectively purify domestic and industrial effluents. The process incorporates the self-regulating dynamics of an ecosystem. Wetland application is finding wider acceptability in developing and developed countries, as it appears to offer more economical and ecologically acceptable solutions to water pollution management problems.

II. LITERATURE REVIEW

Some of the research is reviewed and explained shortly below.

K. S. Farheen ·N. J. Reyes·2021 Constructed Wetlands in Treating Domestic and Industrial Wastewater in India: A Review" This paper suggests that the Removal Efficiency of Constructed" the removal of the organic element in C.W.s are divided into three categories they are physical Treatment (it involves sedimentation, filtration, volatilization), chemical Treatment(oxidation, reduction, adsorption, and precipitation), and biological Treatment (involving nitrification, denitrification, biodegradation, phytodegradation, phytovolatilization) by microorganisms under aerobic and anaerobic conditions. In other words, flowing particles take away organic pollutants, and particles settled in wetlands are decomposed by microorganisms.

B. Koummoya's 1997"Determining the water to cement ratio of fresh concrete by evaporation " suggests that "Domestic wastewater treatment using a constructed wetland using Para grass, combined with sludge adsorption materials, as an efficient alternative system. Domestic Wastewater Treatment Using Constructed Wetland Combined with Adsorption of Red Sludge".

J.S. Sudarsan 2015(Sudarsan et al., 2015a)(Sudarsan et al., 2015b) A Review on the Performance of Concrete Containing Non-Potable Water

This paper suggests that "The objectives of the project were to identify the organic loading removal efficiency of Constructed wetlands treatment that occurs in natural wetlands by relying on plants and a combination of naturally occurring biological, chemical, and physical processes to remove pollutants from the water.

Ram Chavan 2020 Impact of the use of steel slag as coarse aggregate and wastewater on fresh and hardened properties of concrete This paper suggests that the "main objectives of this study are: (i) treatment of D.W by hybrid Treatment system including VFCW and MTS (ii) Harvesting of high-value microalgal biomass and (iii) extraction of value-added products (lipids, ethanol and biomethane).

Shihao Lu's 2015 "Study on method of domestic wastewater treatment through new-type multi-layer artificial wetland" suggests that "Study on method of domestic wastewater treatment through new-type multi-layer artificial wetland" "The experiment is applied to subsurface flow artificial wetland with vertically upward flow and composind structure. The trapezoid concreted pond is designed to be 160 cm in height, with an upper bottom with 3mlength, a lower bottom with 1.7m length, a boulder layer with 20 cm thickness, a gravel stone layer with30 cm thickness, coal dust - furnace cinder mixed layer with40 cm thickness and a soil layer with 30 cm thickness, totaling120 cm thickness for filling materials. A cross wall with a height of 140 cm is set up in an influent water storage pond.

Mohammad Hossein Sayadi 2012Hybrid constructed wetlands for wastewater treatment: A worldwide review this paper suggests that "study aimed to assess the potentiality of hybrid constructed wetlands for treating of landfill leachate, river polluted water, domestic, industrial, hospital, runoff and agricultural wastewater in lab-scale, pilot-scale and full-scale with various configurations." "The potential of hybrid C.W.s for treating various types of wastewater has been evaluated in some studies in lab-scale, pilot-scale and full-scale. In this study, the application of hybrid C.W.s with various configurations for different wastewaters are reviewed as follows:

a) Domestic wastewater
b) Industrial wastewater
c) Landfill leachate
d) Other wastewater."

Prof. D. A. Lutthe 2022 ew for Treatment of Sanitary Waste This paper suggests that "PROJECT OBJECTIVESCost efficient in Construction, operations and maintenance. Effectively treats wastewater from human waste and stormwater. Uses technology that is simple to understand and manage. Low energy consumption is required for operations. Assists in maintaining groundwater and surface water levels. Contributes to environmental protection by providing a habitat for plants and animals." Vertical Subsurface-Flow Constructed Wetlands (VSSF)

Reetika Shukla 2021 (Shukla et al., 2021)"Performance of horizontal flow constructed wetland for secondary Treatment of domestic wastewater in a remote tribal area of Central India" "study performed using three setups of C.W. 1 (Unplanted C.W.), C.W. 2 (C.W. planted with macrophyte Typha latifolia), and C.W. 3 (C.W. planted
with two species of macrophyte T. latifolia and Commelina benghalensis" "perform the Treatment of primary

Garfi, P. Carvalho" 2017 "Constructed wetlands and solar-driven disinfection technologies for sustainable wastewater treatment and reclamation in rural India: SWINGS project." This paper suggests that "The main objective of 'Safeguarding water resources in India with green and sustainable technologies' (SWINGS)is to develop low-cost optimized treatment schemes employing state-of-the-art wastewater management and Treatment systems to make full use of water resources at the community level, with the final purpose of tackling water scarcity in India Flow chart of AMU pilot plant with both treatment trains (west and east). Sampling points along the water treatment line of AMU pilot plant are also indicated in the" Flow chart of AMU pilot plant with both treatment trains (west and east). Sampling points along the water treatment line of the AMU pilot plant are also indicated; implementation phases of vertical subsurface flow constructed wetlands.

S. K. Billore, J. K. Sharma 2013 (Billore et al., 2009)"Treatment of wastewater and restoration of aquatic systems through an eco-technology-based constructed treatment wetlands—a successful experience in Central India" this paper suggests that To treat the domestic waste and industrial waste | Nitrogen removal efficiencies of C.W.s, Desludging wastewater channel, (b) gravel bed with outlet, (c) reed plantation in gravel bed and (d) onsite treatment C.W. in wastewater channel.

Anna Dimitrova, Jayanta Kumar Bora (2019) "Monsoon weather and early childhood health in India""This paper aims to shed light on the possible detrimental effects of monsoon weather shocks on childhood undernutrition in India using the Demographic and Health Survey 2015–16, in combination with geo-referenced climate data.

Kun Mu1 _ Liangzhi You" (2012) "A Hybrid Wetland Map for China: A Synergistic Approach Using Census and Spatially Explicit Datasets" This paper suggests that the"e method presented here is applicable not only to wetland mapping but also to other thematic mapping in China and beyond.

Anil Kumar Haritash, Sarbari Dutta" (2017)" (Haritash et al., 2017)Phosphate uptake and translocation in a tropical Canna-based constructed wetland" This paper suggests that the"n Canna-based wetland since it not only removes phosphate from wastewater also removes a fraction of NAIP. Based on the results obtained, it was observed that significant plant phosphate uptake is from wastewater and sediment NAIP during oxygen-stressed conditions.

(Naseer et al., 2021 Performance Efficiency of a Large-Scale Integrated Constructed Wetland: Designed for Domestic Wastewater Treatment) This paper suggests that the study was to identify 1). the percentage removal efficiency of treatment systems, 2). effect of weather on removal efficiency and 3). effect of spatial, temporal and plantation variation during Treatment.

Mohammad Hossein (Sayadi et al., 2012)Hybrid constructed wetlands for wastewater treatment: A

worldwide review. This paper suggests the" treatment plan for domestic wastewater, industrial and agricultural wastewater, tertiary Treatment, polishing wastewater, urban runoff and contaminated groundwater.

S. K. Bilfore, Prashant and J. K. Sharma" (Prashant et al., 2013)Treatment performance of artificial floating reed beds in an experimental mesocosm to improve the water quality of river Kshipra" This paper suggests that the"Treatment performance by Artificial Floating Reed Beds (AFRB) was evaluated for removal efficiency of T.S., NH4-N, NO3-N, TKN and BOD from river water.

V.T.Deepthi(G.Bashar) "(2014)"Comparison Of Treatment Performance Between Constructed Wetlands With Different Plants" The present study aims to examine the effect of vegetation type on organic and nutrient removal under varying hydraulic residence times in constructed wetlands. With this in mind, we have designed, constructed and operated two pilot-scale horizontal subsurface flow constructed wetlands.

Sharaf Al-Tarkeh 2, Rawan Milk"(2023)"Vertical and Hybrid Constructed Wetlands as a Sustainable Technique to Improve Domestic Wastewater Quality" This paper suggests that the"to summarize the removal-efficiency of various pollutants (organic matter, inorganic, and heavy metals) from domestic wastewater using VFCWs and HCWs by utilizing meta-analysis and ANOVA tests. Moreover, this article also discusses the removal mechanisms for the previously mentioned pollutants from sewage and the effect of environmental parameters on removal mechanisms using VFCWs.

Marwa M. Waly 1,, Taha Ahmed (2022)" (Waly et al., 2022) atConstructed Wetland for Sustainable and Low-Cost Wastewater Treatment: Review Article"This paper suggests that the"to summarize the recent development of C.W technology and critically review the main achievements and successful applications in various geographic locations with the focus on the industrial wastewater treatment.

Luna M.T Constructed Wetland for Sustainable and Low-Cost Wastewater Treatment: Review Article" (2021)Constructed Wetlands A Comprehensive Review This review paper states that to review the wetland.

R.Annadurai(parumol) Chakraborty 2017 Domestic wastewater treatment using constructed wetland: an efficient and alternative wayThis paper suggests that "in this study, Typha latifolia and Phragmites australis were used as vegetation for the reduction in the contaminant level present in the domestic wastewater using integrated setup. An integrated arrangement was constructed considering the EPA 1986 manual with dimensions of 0.7 9 0.4 9 0.3 m. The flow rate adapted was 6 L/day with T. latifolia and australis as vegetation for the convincing wastewater flow.

Amit Kharwade Vaibhav (Kharwade, 2021)Constructed Wetland For Domestic Wastewater Treatment: A Review to review the Wetland for Domestic Waste paper suggests studying various types in the wetland.

Ram Chavan, Shrikanth Mutnuri Domestic wastewater treatment by constructed wetland and microalgal treatment system for the production of value-added products. Ram Chavan, Shrikanth Mutnuri This paper suggest that "The main aim of this study is to treat domestic wastewater in a hybrid Vertical Flow Wetland (VFCW-4.2 m2) and Microalgal Treatment System (MTS-1m2). The objective is to treat Domestic wastewater (D.W.) and produce value-added products from microalgal biomass.

Van Thi Thanh Ho 1,*, Khang Quang Bui 2022"Domestic Wastewater Treatment Using Constructed Wetland with Para Grass Combined with Sludge Adsorption, Case Study in Vietnam: An Efficient and Alternative Way." This paper suggests that" to assess the removal of pollutants by the combination of wetland technology, specifically constructed wetland (C.W.), with Para grass(Brachiaria mutica) together with the adsorption of red sludge. With an organic loading rate (OLR) of 120 (kg COD/ha/day), the treatment efficiency for wastewater in this study is quite high, and the concentrations of parameters in the effluent were lower than the limits established by the QCVN14:2015/BTNMT for domestic wastewater""Transparent acrylic was used to make this type of wetland, with the dimensions of 1.2 × 0.4 × 0.8 (m × m × m).

J.A. Herrera Melián, *, (Melián et al., 2010)A.J. Martín Rodríguez a, J. Arana" a, O. González Díaz a, J.J. González Henríquez 2010Hybrid Constructed Wetlands for Wastewater Treatment and Reuse in the Canary Islands This paper suggest that The aim of hybrid constructed wetlands (HCWs) for wastewater treatment and reuse in the Canary Islands is to provide a sustainable and cost-effective solution for treating wastewater and producing reusable water. HCWs are a natural wastewater treatment system that uses plants, gravel, and sand to remove pollutants from wastewater. They are a relatively new technology, but they have been shown to be effective in treating various wastewater types, including urban, agricultural, and industrial—site Selection, System Design, ConfigurationConstruction, Construction, Substrate Planting, and Vegetation Operation and Maintenance.

G.Chandrakanth, M. Srimurali, C.M. VivekVardhan.(Chandrakanth et al., 2016)A Study on Domestic Wastewater Treatment by Pilot-ScaleConstructed Wetlands" This paper suggests that a study on domestic wastewater treatment by pilot-scale constructed wetlands is to evaluate the effectiveness of constructed wetlands in treating domestic wastewater. Constructed wetlands are a natural wastewater treatment system that uses plants, gravel, and sand to filter and remove pollutants from wastewater. They are a sustainable and cost-effective alternative to traditional wastewater treatment methods." hydraulic Retention Time (HRT)The HRT, which is the time that wastewater takes to flow through the C.W., was varied for each C.W. to evaluate its effect on treatment efficiency.

Sobia Ashraf, Muhammad Afzal2018Plant-endophyte synergism in constructed wetlands enhances the remediation of tannery effluent. This paper suggests that plant-endophyte synergism in constructed wetlands aims to improve the remediation of tannery effluent. Tannery

effluent is a type of wastewater produced by the tanning industry. It is loaded with organic and inorganic contaminants and weighty metals, which can cause severe damage to the ecosystemPlant-endophyte synergism in constructed wetlands (C.W.s) has emerged as a promising approach for enhancing the remediation of tannery effluent. This strategy involves utilizing the symbiotic relationship between plants and their endophytic microorganisms to promote the degradation and removal of pollutants from wastewater.

Ha Thi Thuy Ung a, Bach Tho Leu aHoa Thi Hien Tran.(Ung et al., 2022)Combining flowform cascade with constructed wetland to enhance domestic wastewater treatment" This paper suggests that "The aim of combining a flowform cascade (F.C.) with a constructed wetland (C.W.) is to strengthen domestic wastewater treatment by improving the removal of organic matter, nitrogen, and phosphorus. The F.C. system provides aeration to the wastewater, which increases the dissolved oxygen (D.O.) concentration and creates favorable conditions for aerobic microorganisms to break down organic matter. The C.W. system provides a habitat for microorganisms that can remove nitrogen and phosphorus through biological processes such as nitrification and denitrification.
"the methodology for combining F.C. and C.W. involves the following steps: Design of F.C. Units, Selection of C.W. Substrate, Hydraulic Loading Rate, Monitoring and Control.

Arvind Kumar"(Swarnakar et al., 2022Various Types of Constructed Wetland forWastewater Treatment-A Review" This paper suggest that Constructed wetlands (C.W.s) are engineered systems designed to mimic the natural functions of wetlands to improve water quality. They treat a wide range of wastewater, including domestic sewage, industrial wastewater, and stormwater runoff. C.W.s are a cost-effective and sustainable alternative to traditional wastewater treatment methods, and they are effective at removing a variety of pollutantsSurface flow C.W.s (SFCWs), Subsurface flow C.W.s (SSFCWs)., Vertical flow C.W.s (VFCWs).

Magdalena (Gizinska-Górna et al., 2017)Analysis of the Influence of a Hybrid Constructed Wetland Wastewater Treatment Plant on the Water Quality of the Receiver " This paper suggests that Constructed wetlands (C.W.s) have emerged as a sustainable and cost-effective wastewater treatment technology, offering a natural approach to pollutant removal and water quality enhancement. Hybrid C.W.s, which combine different C.W. designs, have demonstrated enhanced treatment efficiency compared to conventional C.W. systems. This study aims to investigate the influence of a hybrid C.W. wastewater treatment plant (WWTP) on the water quality of the receiving water body."Water Quality Monitoring: Establish sampling stations at the influent, effluent, and receiving water body locations to collect water samples regularly. Analyze the models for various water quality parameters using standard analytical methods.

Happison (Muzioreva et al., 2023Constructed Wetlands as Domestic Decentralized Wastewater Treatment Systems - A Systematic Review" This paper suggests that this study aims to provide a clear and comprehensive understanding of the multifaceted aims behind C.W.s as domestic wastewater treatment systems."The PRISMA methodology was adopted to conduct this systematic review. The following steps were involved.

Identification: Databases like Scopus and Google Scholar were searched using relevant keywords and Boolean operators.

Screening: Titles, abstracts, and keywords were screened to identify potentially eligible studies.Eligibility: Full-text articles were retrieved and assessed for eligibility based on predefined criteria, including publication date (2013-2023), focus on domestic wastewater treatment and methodological soundness – data extraction: Extracted data from included studies.

Mrs. Snehal Bhaskar ThamkeDr. Arif Khan 2021"Constructed Wetlands - Natural Treatment of Wastewater" This paper suggests that Constructed wetlands are engineered systems that mimic natural wetlands to treat wastewater. They're like tiny, human-made versions of the marshes, swamps, and bogs that naturally filter water through physical, chemical, and biological processes. The Three Main Stages of C.W. Purification:BiochemicalTransformation: Sedimentation and Plant UptakeTypes of Constructed Wetlands.

III. CONCLUSION

The literature reviews on numerous research articles and reviews related to Hybrid domestic wetlands are included in this study. After reading this paper, it is easier for anyone to identify the different research , advancements, and methods for improving the properties of Hybrid domestic wetland.

IV. FUTURE SCOPE

Various studies and research projects on wastewater treatment are currently available. With the help of "Hybrid wetland". It will be possible to develop predictive methods using this information.

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Construction Sequence Analysis: Empowering Fire Resistance in RC Buildings

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Abstract— **The growing need for residential space in metropolitan areas has forced engineers to develop high-rise structures on limited ground to meet the demand. High-rise buildings usually involve high-strength concrete and large column sizes. They have their benefits but their long-term behavior considering creep and shrinkage must be studied. Axial shortening is one of the major problems in high-rise buildings which generates stress distribution and vertical deflection in columns. Also, in case of a major fire incident, this vertical displacement of columns may generate very high stresses as there is deterioration of the mechanical properties of concrete at elevated temperatures. Fire hazards being one of the most common have been already proven to have negative consequences on concrete structures. If these stresses exceed the capacity of members this may lead to failure of the structure. This extra deflection and fire can cause severe damage to concrete. The subject of this paper is to comprehensively analyze the effects of fire on axially shortened columns in high-rise buildings. This manuscript aims to investigate the potential consequences of fire on the structural integrity of concrete, which can result in severe damage. The effect of axial shortening is studied by performing construction sequence analysis which is then used to study the behavior of members subjected to fire.**

Keywords—Structural Fire Engineering, Fire Hazard, Construction Sequence Analysis, Axial Shortening.

INTRODUCTION

Fire is one of the most damaging and unpredictable hazards in the world. The cause of the fire may be either natural or manmade. The man-made fire may not be directly initiated but may be caused by faulty equipment or sparks initiated in electrical wires due to overloading. As per the US Fire Administration, total losses due to fire were estimated to be about $8.85 billion in the year 2021[10].

This loss mostly includes damaged appliances, furniture and housing units. Generally Reinforced Concrete has very high fire resistance as compared to other materials like Wood and Steel but Concrete being a composite material its fire resistance depends on the materials used. Many researchers have proved that at elevated temperature the mechanical properties of concrete are damaged and reduced which leads to a reduction in load-carrying capacity. The major fire incidents that show this behaviour are the Grenfell Tower fire in 2017 and the Windsor Tower fire in 2005 where the 17th floor progressively collapsed [11].Fire induces thermal strains in Reinforced Concrete due to their expansion. The thermal expansion coefficient of concrete and steel is almost the same the expansion rate of both concrete and steel is almost the same depending upon the temperature reached. This thermal expansion is restrained by the end conditions of the concrete member and induces thermal stresses in the member. Natural fire usually has a peak temperature that may reach above 1000°C and the temperature then gradually decreases. In cooling phases, the structure may regain strength but this residual strength needs to be calculated to predict the post-fire behaviour. Experimental investigations are the most accurate method to test the local fire behaviour and find the residual strength of the member.

Experimental investigations although accurate are very expensive to perform and do not consider the global behaviour of structure which may be different from the local behaviour obtained from Experimental Fire Tests. To overcome this researchers have started adopting Finite Element Software to predict the behaviour of various materials subjected to various dynamic loads. They are relatively cheap and can be used to perform the global behaviour of any structure in a fire scenario. The peak temperature of fire may reach above 1000° Celsius and as per various international codes the mechanical properties of concrete and rebar are already degraded and even any slight load applied may lead to complete failure of the structure.

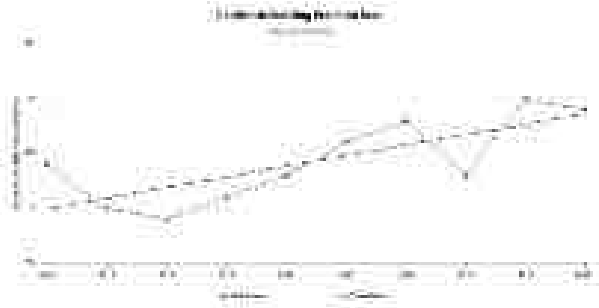

Fig 1. Residential Building Fire loss in 2021 [10]

Fire damage like earthquake is an unpredictable dynamic load. We cannot predict the exact location of the fire, its intensity and or the duration to which it may last. For a safer design of the structure, we consider the worst-case scenario so that even if damage occurs the structure remains safe and prevents any fatalities. One such long-term criterion of concrete that is largely neglected is the effect of creep and shrinkage. Creep and shrinkage are insignificant for short-term scenarios but for long-term cases, it has a huge impact on structure. One of the long-term effects of Creep and Shrinkage is the Vertical Displacement of the Column. Columns being the primary load-carrying member of any high-rise structure are most vulnerable if any dynamic loads are acted upon them.

Any damage to columns may lead to either local collapse or progressive collapse of the whole structure.

The long-term effect of creep and shrinkage of concrete is responsible for the plastic deformation in concrete. In high-rise buildings, this effect is inevitable as the columns are optimized to carry large loads with minimum cross-section area to utilize the floor space. These large axial loads cause the elastic shortening of column members. When we consider the long-term behaviour the creep and shrinkage along with the huge axial loads on columns lead to vertical displacement called as axial shortening of the member. This axial shortening affects both the structural and non-structural members of the building. This extra-axial shortening generates extra vertical displacement and stresses in concrete members. This when combined with a localized fire case can generate extra stresses which can reduce the load-carrying capacity of the member.

Methodology

A. Estimation of Effect of Creep & Shrinkage

The effect of Creep and Shrinkage is very important to evaluate the long-term behaviour of structure. In this study, we have focused mainly on vertical Displacement or Axial Shortening of Columns. The mathematical calculations to predict the exact value of Vertical Shortening requires in depth study of properties and content of concrete, amount of reinforcement present in reinforced members, steps of construction, and the age of reinforced concrete elements [7]. Fazlur Khan and Fintal were the first people to introduce mathematical calculations for Axial Shortening in 1969.Their work was further refined by Ghosh in 1996. Koutsoukis and Beasley in 1995 used probable properties of concrete to predict the elastic and inelastic time-dependent axial shortening of reinforced concrete elements.[8]

Upon construction of subsequent upper floors instantaneous loads act on columns which leads to elastic shortening i.e., the shortening can be reversed upon removal of loads. Creep Shrinkage depends on long-term loads, it also varies with the percentage of reinforcement and member size. The estimation of Creep and Shrinkage shortening in Columns is a very tedious process as it involves the use of various parameters like creep and shrinkage coefficient, percentage of moisture, loading sequence and grade of concrete. To simplify this calculation Finite Element Software like ETABS (Extended Three-Dimensional Analysis of Building System) developed by CSI, inc can be used which has provisions to Calculate Long term Axial Shortening using Construction Sequence Analysis. Equation (1) represents the elastic deformation of the column subjected to axial load.

$$\Delta l = \frac{PL}{AE} \qquad ...(1)$$

where Δl is Elastic Axial deformation,
P is Imposed axial load,
L is the length of the member,
A is a Cross section of members on which load acts
E is the Elastic Modulus of the member

The conventional Finite Element Analysis of buildings is one step analysis process that involves applying all the loads on the structure at once; but in actual construction, the loads are applied sequentially i.e., there is some time gap between the loads applied depending upon the method of construction and complexity of the structure. Construction sequence Analysis or Staged Construction is a Nonlinear static form of analysis that takes into account the concept of incremental loading. Although Structural designers do not have the exact time step between each stage and the equipment loads using Construction sequence analysis gives results almost practical which can be used to compensate for the level difference in horizontal members and prevent damage to non-structural members.

To perform the study first Construction Sequence Analysis of the whole structure is carried out to estimate the values of axial shortening in the column and then this displacement obtained is applied to the column along with axial load and localized fire scenario to evaluate the degradation of the mechanical properties. This is compared with the analysis of columns subjected to fire and axial load without considering the effect of axial shortening.

Model Data:

Grid = 5 x 5
No of Bays = 4 in each direction
Bay size (X & Y) = 4 m
No of Storeys=14
Frame Dead load= 9.8 kN/m
Live load= 3 kN/m²

TABLE I : MEMBER SIZES

Storey	Beam Sizes (mm)	Column Sizes (mm)
1 to 7	400*500	500*500
8 to 13	300*400	400*400

B. Effect of Fire on RC Structures

Reinforced Concrete when subjected to Fire has a deterioration of its mechanical and physical properties depending upon the intensity of the fire, duration of fire, and concrete cover present to rebar. During a fire event, the building structure may be subjected to service-level gravity loads in combination with post-flashover compartment fire. The fire endurance of the reinforced concrete structure depends on its strength resist the various loads like gravity loads and fire loads without undergoing failure (in terms of overall collapse) during heating and cooling. (3)

When reinforced Concrete is subjected to Elevated temperature the water content present inside the cement paste starts evaporating this causes formation of water vapour which generates tensile forces from inside and thus spalling of concrete occurs. Water content present in cement concrete paste and its transportation, either in a gaseous state or liquid state , play important roles in the local damage to concrete structures (4). To assess the effect of fire on RC structures Finite Element Software was used.

To validate the use of software rather than experimental tests, the model was validated against the relevant test results of a simply supported beam at ambient temperature and in a fire. The thermo-mechanical structural model is used to give a realistic prediction of the overall responses of structural elements.

1. Heat transfer Analysis-

Heat transfer is concerned with the study related to transfers of thermal energy from one state to another. Generally, there are 3 modes of Heat Transfer Conduction, Convection, and radiation. All 3 modes can be used to transfer heat to members. In conduction heat transfers through solids i.e. member is directly in contact with fire and heat flows from its exterior to its interior through a solid. When heat transfer occurs through fluids then it is called Convection Temperature changes inside the fluid or between the fluid and its boundary, as well as the application of an external motive force, may cause it.

Convection heat transfer is one of the most difficult problems to solve in engineering. Convection is challenging to study because it is highly unpredictable, and one can only make the best effort to assume specific parameters to achieve the goal of safety from the viewpoint of flame spread [5]. The type of Heat transfer which does not require any medium is

One form of heat transfer that happens without the need for a material medium is radiation. The only kind of heat transmission that occurs in a vacuum is radiation. It makes use of photons, or electromagnetic energy. When radiation from another body hits another body, there is a transfer of radiant heat.

2. Types of Heat Transfer Analysis

a. Steady State-

The Steady State heat transfer study, which examines the distribution of heat through the material, is time-independent. Analysis of the steady-state heat transfer is feasible when there is a stable source of heat supply. The entire model under examination experiences a consistent distribution of heat if there is only one source and no way to remove the heat. However, because it produces irrational results, this kind of arrangement is challenging. Linear and Nonlinear Steady-state heat transfer can be performed.

b. Transient State heat Transfer analysis-

This type deals with time-dependent heat distribution on the body. As time dependent analysis is carried out the results are highly accurate though computing time is increased to some extent. It has provisions to simulate material change from one phase to another. This type can be performed in both Linear and Nonlinear Heat transfer steps.

3. Fire Curves-

The basic difference between Natural Fires and Furnace Fires is that Natural Fires have a peak point and then their cooling phase starts. These fire curves are called Parametric Fire Curves which depend on the area of compartments, area of openings, fire load density etc. They usually are classified as Short Fire Curve and Long Fire Curve which both depend on the above-mentioned Parameters. Parametric fire curves can be developed by using International Codes like the Euro Code. They are also called as design fires as they replicate the Natural Fire scenario. Furnace Tests usually involve Standard Fires which do not have a cooling phase.

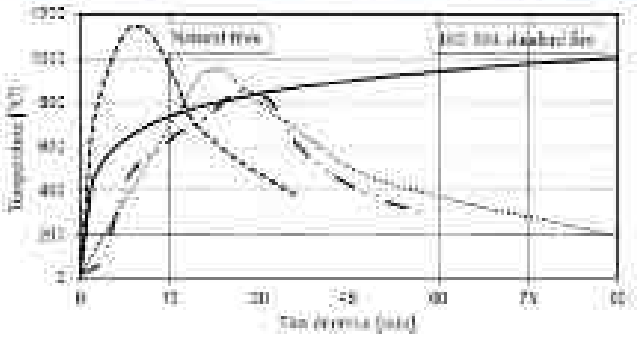

Fig 2. Comparison of Natural Fire and Standard Fire Curve[14]

ISO 834 and ASTM E119 have provided Standard Fire Curves for Furnace Tests. They both have similar curves but the ISO-834 curve is less severe than ASTM E119 Standard Fire Curve as proved by Harmathy et al [1].

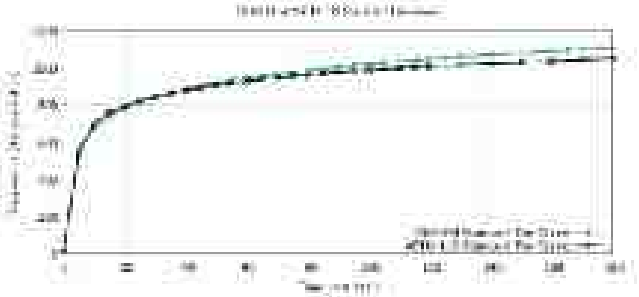

Fig 3. ASTM E119 vs ISO 834 Standard Fire Curve considered in this study[12][13]

ANALYSIS AND RESULTS

The study was performed in three major stages. In the initial stage, the Effect of Creep and Shrinkage on the model building was calculated. In the second stage Finite Element analysis of RC Elements subjected to fire was carried out. In this step, the nodal rise in temperature was obtained which was used in the third stage. In the third stage, the mechanical properties of the concrete and rebar were used to perform Construction Sequence Analysis to check the behaviour of RC members due to Creep and Shrinkage.

1. Construction Sequence Analysis-

Construction Sequence Analysis was performed with consideration that each floor or storey was completed in 28 days. The time-dependent materials were defined by using the CEB-FIP 90 code with a relative **humidity of 50 %**. At each store, Dead Load was added with a scale factor of 1 and at the end of the last storey Live Load was added with a similar scale factor. This nonlinear analysis was performed to check the effect of creep and shrinkage at the end of 1 year, 2 years and 10 years. For every step the axial shortening was estimated at the respective graphs were plotted. The maximum axial shortening was obtained at 10^{th} story with a Creep and Shrinkage combined effect at the end of 10 years. This validates our statement of increased displacements due to creep and shrinkage on Vertical members. The graph below shows the Variation in Axial Shortening with various long-term effects.

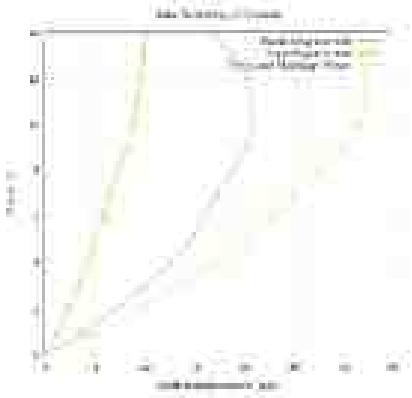

Fig 4. Results of Elastic, Creep and Shrinkage vertical displacements

Construction Sequence Analysis Results-

TABLE 2: CONSTRUCTION SEQUENCE ANALYSIS RESULTS

Storey/ Column No	Storey 18- Column C13	
	One Step Analysis	*Construction Sequence Analysis*
Axial Load (kN)	2814	3560
Axial Shortening (mm)	8.83	11.1

2. *Thermal Analysis*

For thermal or Heat transfer Analysis the Column with maximum Axial Shortening has been Considered. Thermal Analysis gives us the rise in temperature at various nodal points of the member. This in experimental tests is obtained by use of Thermocouples while in simulation nodes at which temperature is required are specified and then graphs are plotted. The data required for thermal analysis in software is the temperature-dependent thermal properties of Steel and Concrete and the Design or Standard Fire Curve.

For our study, we have considered a Parametric Short Fire curve which was designed for the given compartment size and opening factors. It has a maximum temperature rise of 878°C. Variation of Thermal Properties with temperature has been proposed by many researchers. The temperature-dependent Thermal Properties were obtained from Eurocode EN 1992-1-2 and were used for the thermal analysis.

a. *Validation for Heat transfer-*

Heat transfer analysis provides in-depth knowledge about how temperature is distributed along the cross-section. It defines heat flow and the direction in which heat is transferred. To analyse the reinforced section for transient heat transfer analysis, a sample beam was adopted.[4]

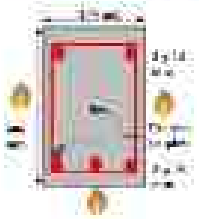

Fig 5. Beam elevation and cross-section for validation [13]

3D Heat Transfer Analysis was performed using the ASTM119 Fire curve and the results obtained were compared with the analytical and experimental results. For 3D heat transfer analysis, reinforcement was defined as a 2D wire element and Concrete as a 3D Solid element. The heat was applied by Convection and Radiation and no conduction of Heat was considered. The Convection and Radiation are applied using the Surface Film Condition and Surface Radiation Condition respectively. Before submitting the job file Absolute Zero Temperature and Stefan Boltzmann Constant were defined in the model attributes. For thermal Analysis, No boundary conditions and loads are defined. The only load that was defined was a predefined field which was 20 ° Celcius. The mesh size used for heat transfer was

2.5mm and heat transfer element was selected for both concrete and reinforcement.

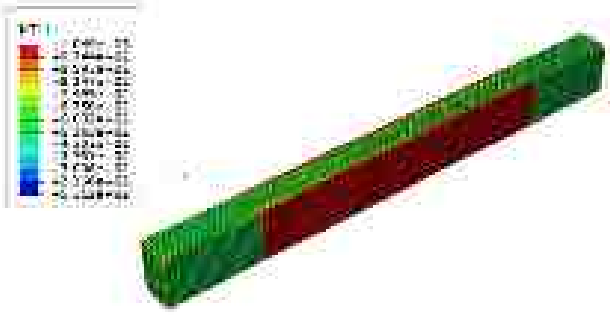

Fig 6. Snapshot of Results of Thermal Analysis of Concrete material

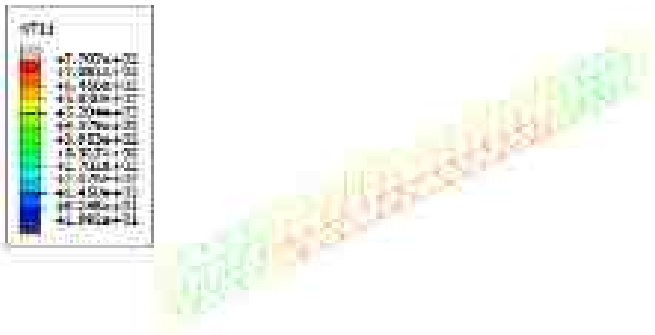

Fig 7. Snapshot of Results of Thermal Analysis of Reinforcement

The Analytical and Experimental Results of Agarwal and Kodur are represented below. Here they used thermocouples to measure the exact rise in temperature at the location of rebar and at location of concrete core. In simulation depending upon mesh size the specific nodes can be selected to measure the

rise in temperature at the specified nodes. Also, we can plot the variation f temperature with change in temperature.

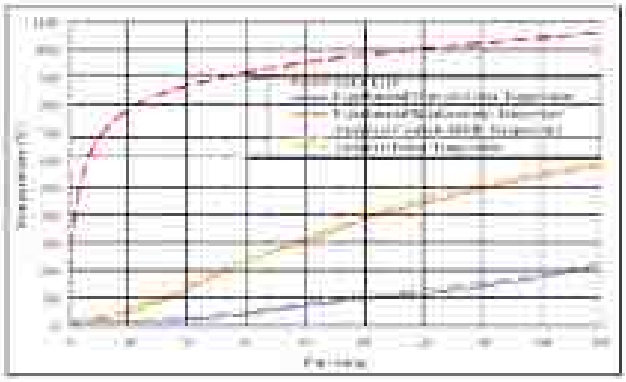

Fig 8 : Analytical and Experimental Results [15]

After Thermal Analysis the rebar temperature at the end of 180 minutes was about 601 °Celsius and the Concrete core temperature was about 250 °Celsius. The obtained results are very similar to the experimental results. This validates the use of simulation for performing Thermal Analysis of RC Members. The thermal analysis results obtained from the simulation are mentioned below:

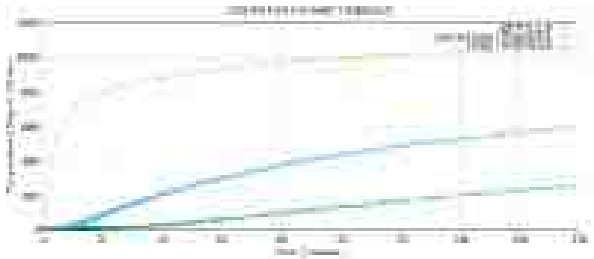

Fig 9: Thermal Analysis Validation Results

b. Thermal Analysis of Column

The column chosen was from the 10th floor. The column size taken was 400 mm x 400 mm with a length of 3.5m. The percentage of steel reinforcement was kept at 1.2%. The main reinforcement was 25 mm in diameter while the stirrups were 8mm in diameter. Concrete Grade was M30 while Fe415 stirrups were used for reinforcement.

The heat was applied on all four sides of the columns on the overall length of the column. The effect of fire was applied as Convection and radiation only. Conduction was not considered for the Transient Analysis. Thermal Analysis was carried out for about 180 mins or 3 hours. The maximum temperature recorded in Concrete was about 810°C on the surface where fire was applied. The temperature of Concrete was gradually increasing towards the core. The maximum temperature gained by Reinforcement was about 394°C after which the cooling phase of fire was initiated. The concrete core was subjected to about 105°C before the cooling phase. The clear cover present to reinforcement also decides the rise in temperature in RC members. The temperature was applied as an amplitude which was applied to the surface film condition.

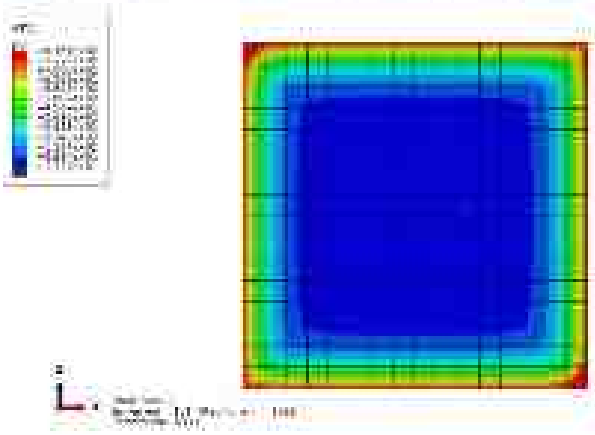

Fig 10: Snapshot of Nodal Temperature Contours of Concrete Column in present study

The Conduction and Radiation are the only sources of heat in the above-used RC column but still, it has managed to reach a high temperature of +800°C.

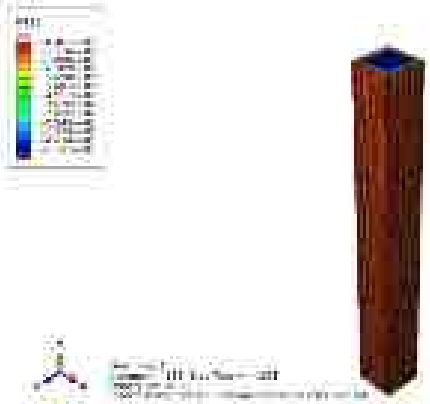

Fig 11:Snapshot Temperature of Column after 28 mins of Fire Exposure in present study

The temperature of the Concrete Core and Rebar after thermal Analysis is represented below.

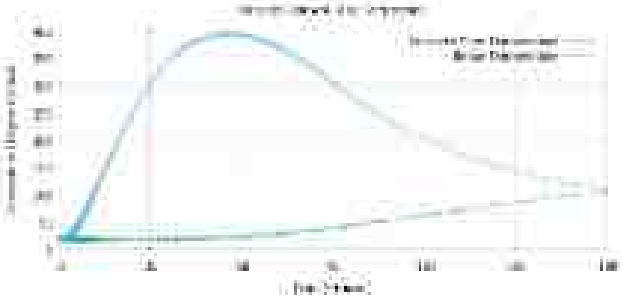

Fig 12: Reinforcement and Concrete Core temperature in present study

3. Estimation of Strength of Degraded Materials

The thermal Analysis gave us the nodal temperatures which were used to calculate the Modulus of Elasticity of Steel and Concrete. This degraded Modulus of Elasticity was provided as material to the respective column and Construction sequence analysis was run again. The rise in temperature of concrete and reinforcement was used to calculate the mechanical properties of concrete at elevated temperatures.

a. Modulus of Elasticity of Concrete.

Rokade et al. (2022) [6] proposed variations in concrete modulus of elasticity are presented below. Regression analysis suggests this. According to Figure 3.4, the value of E decreases as the temperature rises.

$$Et = 1.0059 - 0.001*\theta - 10^{-6}*\theta^2 + 10^{-9}*\theta^3 \quad ...(2)$$

for $0°C < \theta < 1000°C$

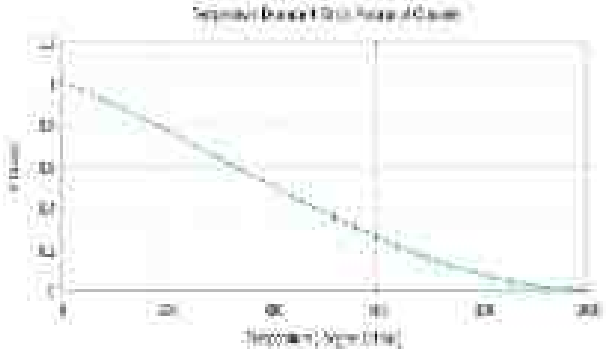

Fig 13. Temperature Dependent Modulus of Elasticity in present study

b. Thermal Expansion of Concrete

Concrete's coefficient of thermal expansion is represented as c. Thermal expansion varies with temperature and may be calculated using the formulae in EN 1992-1-2[9].

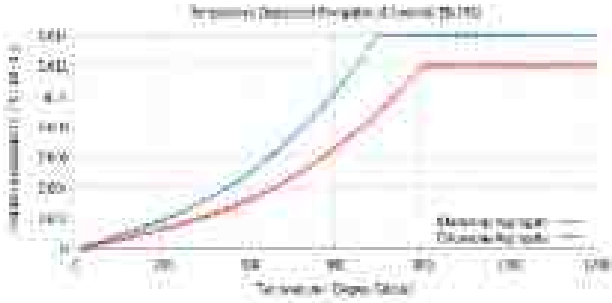

Fig 14. Temperature-dependent expansion of concrete in present study

c. Modulus of Elasticity of Steel

The EN 1993-1-2 [9] for changing the modulus of elasticity of steel is shown below. The degradation of Young Modulus is maximum above 600°C. The maximum strength loss occurs above this temperature in steel. Initial fire exposure has very less effect on Modulus of Elasticity of Steel but after 600°C sudden reduction is seen.

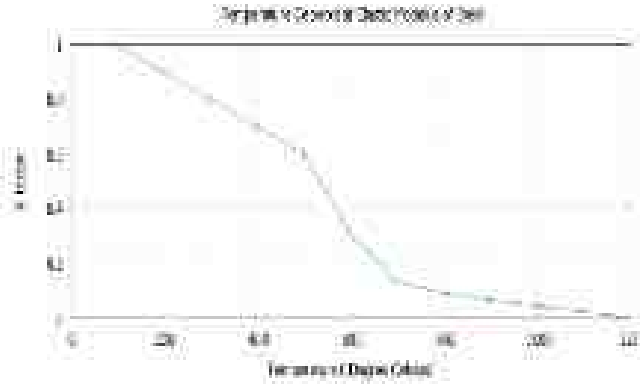

Fig 15. Temperature Dependent Modulus of Elasticity in present study

d. Thermal Expansion of Steel

The coefficient of thermal expansion is the property of matter to vary its shape, area, volume, and density in response to temperature variations.[6] Thermal expansion changes with temperature and can be evaluated based on the a proposed in EN 1993-1-2[9].

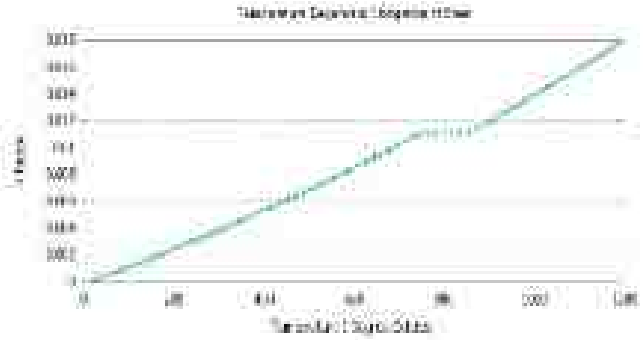

Fig 16. Temperature-Dependent Elongation of Steel in present study

e. Results of Thermal Analysis

Thermal Analysis Results have shown that the Reinforcement temperature was reached about 394°C and the Concrete Core temperature reached about 105°C. From the Above-Mentioned graphs and formulas, the Modulus of Elasticity of Steel and Concrete at Elevated Temperature was calculated which is listed below.

TABLE 3 : THERMAL ANALYSIS RESULTS

Temperature	Mechanical Properties	
	Concrete Elasticity (Mpa)	Steel Elasticity (Mpa)
20°C	27300	200000
105°C	24400	190000
394°C	NA	140000

Conclusion

It is observed from thermal analysis that after 28 minutes of fire exposure to RC members there was reduction in Modulus of Elasticity of Steel by 30% and 10% in Concrete Core. At temperatures between 100°C and 120°C, moisture migrating causes a significant plateau. It is at around 60 minutes when the analytical temperature of the tension side reinforcement steel approaches 394°C, while the concrete core temperature reaches around 105°C.The 3D Thermal analysis Validation of RC beam showed results with almost 97.3% accuracy compared to the experimental outcomes. It can be concluded that the developed simulation model in Finite Element Software is able to predict the heat transfer mechanism through the RC beam.

If there is any scenario of fire after full occupation of building the Axial loads on Column Increase tremendously. Construction Sequence Analysis results show that there is increase in axial loads on column by 26% increase and about 220% rise in Axial Shortening in Columns. These excess loads and deflections increase the stresses in columns and in fire scenario as the mechanical properties of Concrete and rebar has already deteriorated. If thermal analysis of Column is done considering only the dead loads without consideration of creep and shrinkage it may lead to collapse of the member.

Hence it can be concluded that to explore all possibilities of failure a complete study is required to address global behavior of R.C. Structure subjected to fire considering long term effect of creep and shrinkage.

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Sensitivity Analysis For The Constitutive Parameters Of The Pressure Dependent Multi-Yield Material Model In OpenSees

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***Abstract* - The undrained response of the saturated sandy soil under earthquake loading is widely modelled employing the pressure dependent multi yield material model available in the software OpenSees. The response of the soil depends on the value of the constitutive parameters chosen. The constitutive parameters comprise those governing monotonic response and others governing the cyclic response. In the present paper, the sensitivity of the constitutive parameters has been assessed for monotonic undrained response. The numerical response is also compared with the one obtained from strain controlled undrained triaxial test. It is observed that the lower value of the dilatancy parameter *dilat1* results in lower negative pore water pressure and consequently affects the strain hardening response.**

Keywords— pore pressure, triaxial test, stress path

I. Introduction

Liquefaction of the soil caused by the earthquake is one of the major concerns in the field of geotechnical earthquake engineering. Earthquake induced liquefaction is broadly classified as flow failure and cyclic mobility [1]. In flow failure, large downward displacement of the soil mass takes place. It has resulted in catastrophic failure of many earthen dams in the globe. In cyclic mobility, the soil mass looses its strength and stiffness momentarily and regains it quickly owing to dilative tendency of soil. Thus, soil keeps alternating between contractive and dilative tendency. During contractive tendency, there is a rise in the pore water pressure and during dilative tendency there is a drop in the pore water pressure.

Numerical modelling is widely used to assess the liquefaction susceptibility of the site. One of the key factors in such simulations is use of suitable constitutive models. There are several constitutive models developed to capture undrained monotonic and dynamic response of saturated sandy soil. The pressure dependent multi yield material model available in the software OpenSees is the one among these models [2]. OpenSees nowadays is widely used for structural and geotechnical earthquake engineering simulations. The strength of the software is that it has a rich library of advanced constitutive models. Pressure dependent multi yield material model simulates the response of saturated sandy soil under dynamic/earthquake loading effectively. The material model has total 13 constitutive parameters. These parameters mainly take care of small strain stiffness, yield surface evolution, drained/undrained response under monotonic loading and drained/undrained response under dynamic loading. Before using the constitutive model in the site response analysis, the constitutive parameters needs to be evaluated. For this purpose, mostly the numerical response is compared with experimental one and parameters are finalized.

Present paper sheds some light on the role of the various constitutive parameters in simulation of the undrained monotonic response of saturated sandy soil. To assess the sensitivity of the constitutive parameters, the numerical responses are compared with those from the undrained monotonic triaxial test.

II. About the Model

A. General

The pressure dependent multi yield material model is entitled as "PressureDependMultiYield" in OpenSees. The model simulates the shear induced volume contraction and dilation, i.e., dilatancy and cyclic mobility observed for sandy soil under general loading conditions. The model can be used in plane strain and three-dimensional problems [3-5]. The constitutive formulation of the model is based on the framework of multi-surface plasticity. It uses a Drucker-Prager yield criterion. The nested yield surface in principal stress space and deviatoric plane is shown Fig.1. When used with regular solid elements, this model simulates drained response. On other hand, when used with solid-fluid fully coupled elements, it simulates undrained response. Further, partially drained response can also be simulated by defining relatively large value of permeability. To date, literature mentions many soil models that can capture the hysteretic response of the saturated sandy soil under cyclic loading but very few of them are capable of capturing a typical cyclic mobility response observed during undrained cyclic loading of saturated medium dense sand. The "PressureDependMultiYield" model used in this study captures not only the hysteric response but also typical cyclic mobility [6,7]. Details regarding the yield criteria, flow rule and hardening rule are given in the subsequent sections.

B. Yield Criterion

In this model, it is assumed that material elasticity is linear and isotropic. Further, the nonlinearity and anisotropy are assumed to emerge from plastic deformation [6]. Yield criterion is given by the following equation [2,8].

$$f = \frac{3}{2}(\boldsymbol{s} - p_a\boldsymbol{\alpha}):(\boldsymbol{s} - p_a\boldsymbol{\alpha}) - M^2 p_a^{\,2} = 0 \qquad (1)$$

Where, $\boldsymbol{s} = \boldsymbol{\sigma}' - p'\boldsymbol{\delta}$ = deviatoric stress tensor, $\boldsymbol{\sigma}'$ = effective Cauchy stress tensor (negative in compression), $\boldsymbol{\delta}$ = second order identity tensor, $p_a = p' + p_0'$, $p' = \frac{1}{3}tr(\boldsymbol{\sigma}')$ = effective mean normal stress, p_0' = a small positive constant whose role is to keep size of yield surface finite at $p' = 0$ and to maintain numerical stability. Generally, this constant takes value of residual shear strength associated with a state of

initial liquefaction, α = kinematic deviatoric tensor defining coordinates of yield surface centre in the deviatoric stress sub space, M = material parameter related to friction angle φ. When plotted in the stress space it results into a conical surface with apex along hydrostatic axis, as shown in Fig. 1. Multiple yield surfaces are consequence of material hardening. The outer most surface is a failure surface which corresponds to the state of stress corresponding to the peak shear strength.

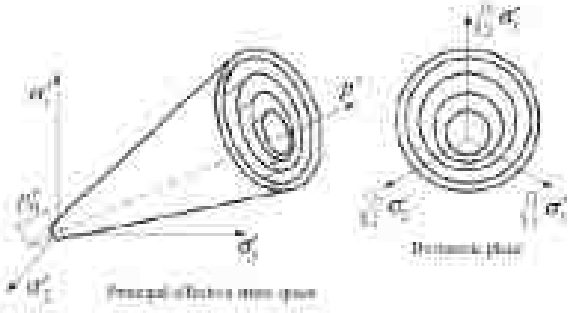

Fig. 1. Nested yield surface in principal stress space and deviatoric plane [6]

C. Flow Rule

Flow rule gives the direction of the incremental plastic strain (plastic strain rate) and magnitude [9]. Present constitutive model employs non-associated flow rule for volumetric component and associated flow rule for deviatoric component [2,8]. This is so because non-associated flow rule captures the dilatancy of the soil most accurately. The volumetric component of the flow rule P^v which is responsible for dilation (increase in volume) and contraction (decrease in volume) is given below:

$$\exists P^v = \frac{1-(\eta/\bar{\eta})^2}{1+(\eta/\bar{\eta})^2}\Psi \qquad (2)$$

Where, $\eta = \sqrt{(3/2)s:s}/(p' + p_0')$ is the effective stress ratio, $\bar{\eta}$ is a material parameter which defines the stress ratio of Phase Transformation surface, Ψ is a scalar valued function which controls the magnitude of dilation and contraction.

Further detailing on how flow rule work is given in the following subsections:

(a) Within phase transformation surface (phase 0-1, Fig. 2)

It is worth to note that within phase transformation surface soil undergoes contraction during both loading and unloading. The function Ψ that scales this contraction is given below:

$$\Psi = c_1 exp(c_2 p'/P_a) \qquad (3)$$

Where, c_1 and c_2 are material constants which dictates rate of contraction in drained condition and rate of pore pressure build up in undrained condition. Value of c_1 depends on the soil type and relative density, stronger is the contraction, larger is the value of c_1. If there is any confinement dependency, it can be dictated through c_2. P_a is be atmospheric pressure 101 kPa used for normalization purpose.

(b) On phase transformation surface (phase 1-2, Fig. 2)

The point D denotes the point at which effective stress path intersects the phase transformation surface. Corresponding mean effective confining pressure is denoted as p_D' and stored as a temporary material memory parameter. It should be noted that at low confinement near liquefaction, a constant volume perfectly plastic phase gets imposed and the stress state remains at D, until a user defined octahedral shear strain increment γ_y gets accumulated. γ_y controls the near and post liquefaction straining at effective confining pressure equal to or less than 10 kPa.

During situations like lateral spreading, controlled straining during each loading cycle is dictated by γ_y (phase 7-8, Fig. 2).

(c) Above phase transformation surface, loading (phase 2-3, Fig. 2)

Once the octahedral shear strain increment γ_y is accumulated, strong dilation tendency gets activated. The function Ψ that scales this dilation is given below:

$$\Psi = d_1 exp(d_2 \gamma_d) \qquad (4)$$

Where, d_1 and d_2 are material constants dictating the dilation, γ_d stands for cumulative plastic shear strain for current dilative phase. Stronger is the dilation, larger is the value of d_1 and d_2.

(d) Above phase transformation surface, unloading (phase 3-4, Fig. 2)

For unloading above phase transformation surface following relationship is used.

$$\frac{\sqrt{3/2}\boldsymbol{P}^s:\boldsymbol{P}^s}{P^v} = \frac{p_D'}{p_R'}\eta_f \qquad (5)$$

Where, $\boldsymbol{P}^s$ is the deviatoric component of the tensor $\boldsymbol{P}$, $\boldsymbol{P}$ is the symmetric second order tensor defining direction of the plastic deformation in stress space (flow rule), P^v is the volumetric component of $\boldsymbol{P}$, p_R' is the mean effective confing pressure at the load reversal point R (Fig. 5.5), η_f is the stress ratio along the failure surface.

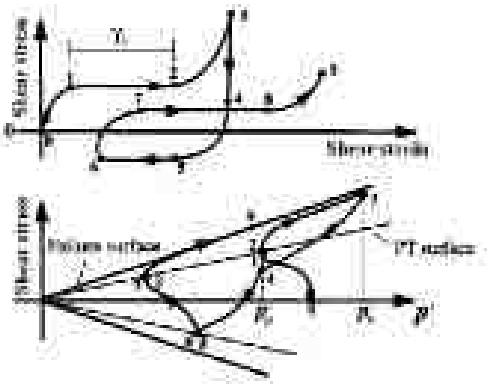

Fig. 2. Details about the constitutive response of the model giving relationship between shear stress, shear strain and effective confinement [7]

D. Hardening Rule

Hardening rule defines the evolution of yield criterion (yield surface) with plastic deformation. This model adopts purely deviatoric kinematic hardening rule. This type of hardening rule allows yield surfaces to translates during shear loading within the failure surface. It captures the hysteretic response observed during cyclic shear loading [2,6,8]. The hardening rule is given below:

$$\mu = \left[s_T - (p' + p_0')\alpha_m\right] - \frac{M_m}{M_{m+1}}\left[s_T - (p' + p_0')\alpha_{m+1}\right] \quad (6)$$

Where, μ is the translation direction of the yield surface, s_T is the deviatoric stress tensor which defines position of point T (Fig. 3). $(p' + p_0')\alpha_m$ and $(p' + p_0')\alpha_{m+1}$ defines centre of the inner and outer yield surface respectively. M_m and M_{m+1} are effective stress ratios of inner and outer yield surface in deviatoric stress subspace respectively. It should be noted that this hardening rule does not allow overlapping of yield surfaces.

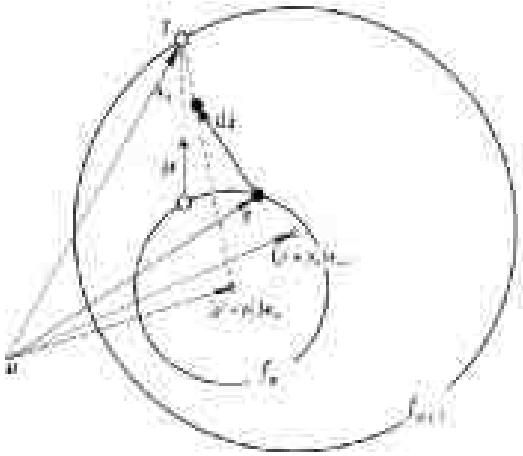

Fig. 3. Hardening rule [2]

III. CONSTITUTIVE PARAMETERS

The abovementioned constitutive model has total of 15 parameters. These parameters are mainly divided into following three categories [8]:

1) *Yield surface parameters:* parameters that define size of yield surface such as small strain shear modulus and bulk modulus at reference effective confining mean pressure, peak friction angle, reference effective mean confining pressure, and pressure dependency coefficient. These parameters can be obtained from isotropically consolidated drained compression triaxial test.

2) *Dilatancy parameters:* parameters controlling shear-volume coupling such as phase transformation angle, contraction and dilation parameters. These parameters are obtained from isotropically consolidated undrained compression triaxial tests.

3) *Cyclic mobility parameters:* these parameters define the onset and evolution of cyclic mobility response. There are total three such parameters. These parameters are obtained by matching numerical stress-strain response with that obtained from isotropically consolidated undrained cyclic triaxial tests.

The other two parameters are saturated mass density and initial void ratio of the soil. In the present study, saturated mass density is computed from specific gravity of the sand and void ratio of the sand for given relative density. Initial void ratio is computed from the expression giving relationship between relative density, maximum void ratio, minimum void ratio and void ratio. The values of the constitutive parameters used in the present analysis can be found in Chavan [3].

IV. SENSITIVITY ANALYSIS

Several simulations were performed for the relative density of 60 %, degree of saturation of 99 % and initial effective confining pressure of 100 kPa. Few of the responses are shown in Fig.4 - Fig. 6 along with corresponding response from the undrained monotonic triaxial test. In these figures, experimental response from the present study is named as "Expt" whereas title of numerical response starts with "Num". It is observed from these simulations that the response is very much sensitive to first two dilatancy parameters, i.e., *contract* and *dilat1*. Further, it is clear that irrespective of the values of dilatancy parameters the numerical stress strain response continues to be strain hardening as seen in Fig. 5., while experimental stress strain response is initially strain hardening followed by strain softening and ultimately reaching critical state given by almost horizontal stress strain curve. The strain hardening response observed in numerical simulations is attributed to the formulation of the constitutive model which was developed to capture only strain hardening response [2,8]. Further, it should be noted that for most of the combinations of dilatancy parameters, there is excellent match between experimental and numerical stress strain curve up to 10 % of axial strain beyond which two types curves starts diverging.

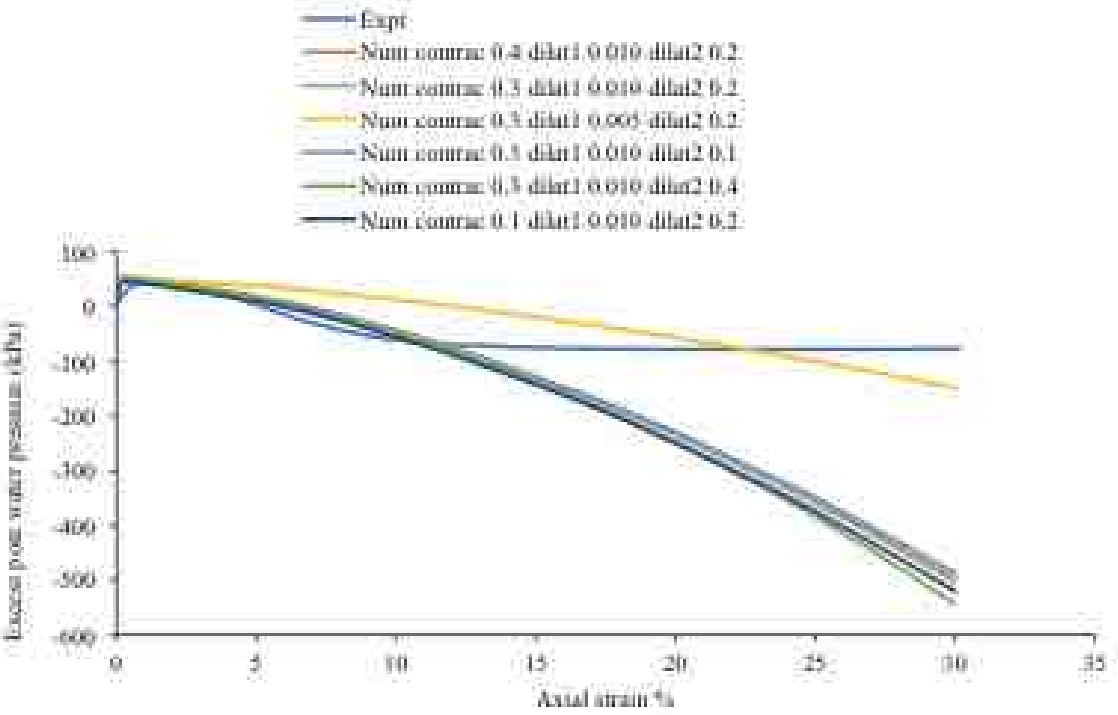

Fig. 4. Effect of dilatancy parameters on pore pressure evolution for D_r = 60 %, S = 99 %, σ_3' = 100 kPa

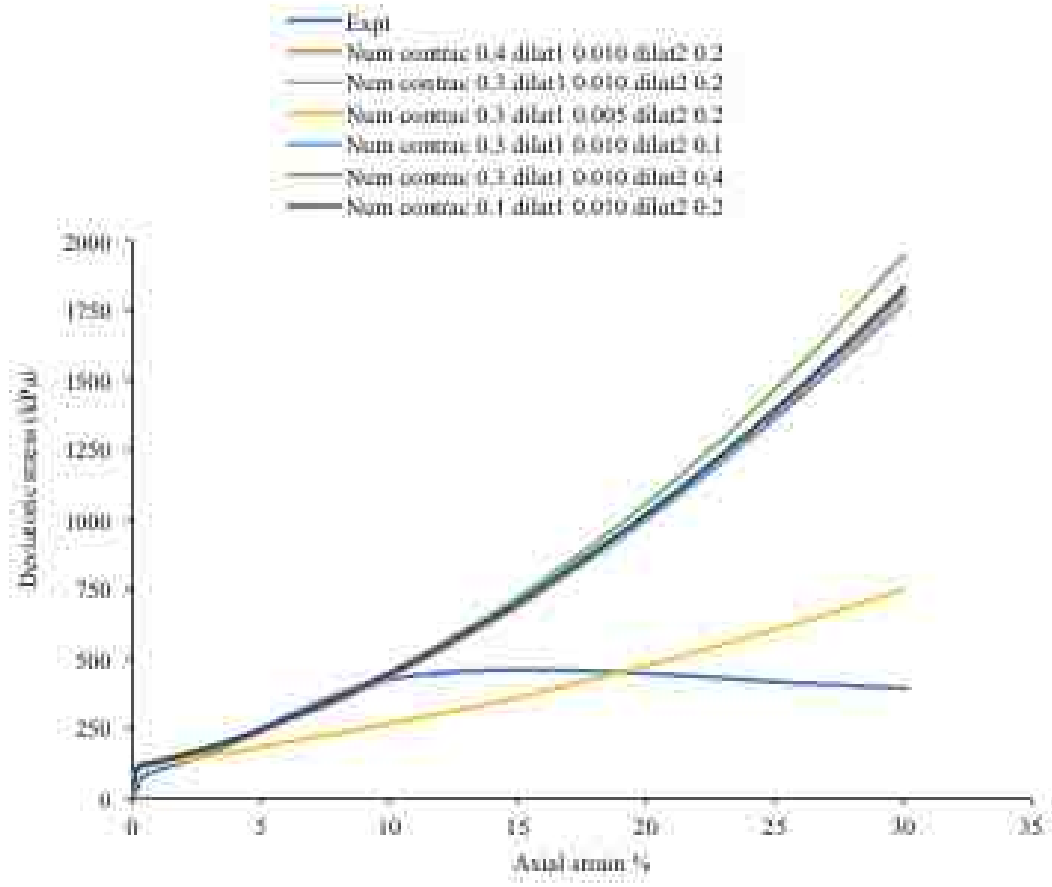

Fig. 5. Effect of dilatancy parameters on stress strain response for D_r = 60 %, S = 99 %, σ_3' = 100 kPa

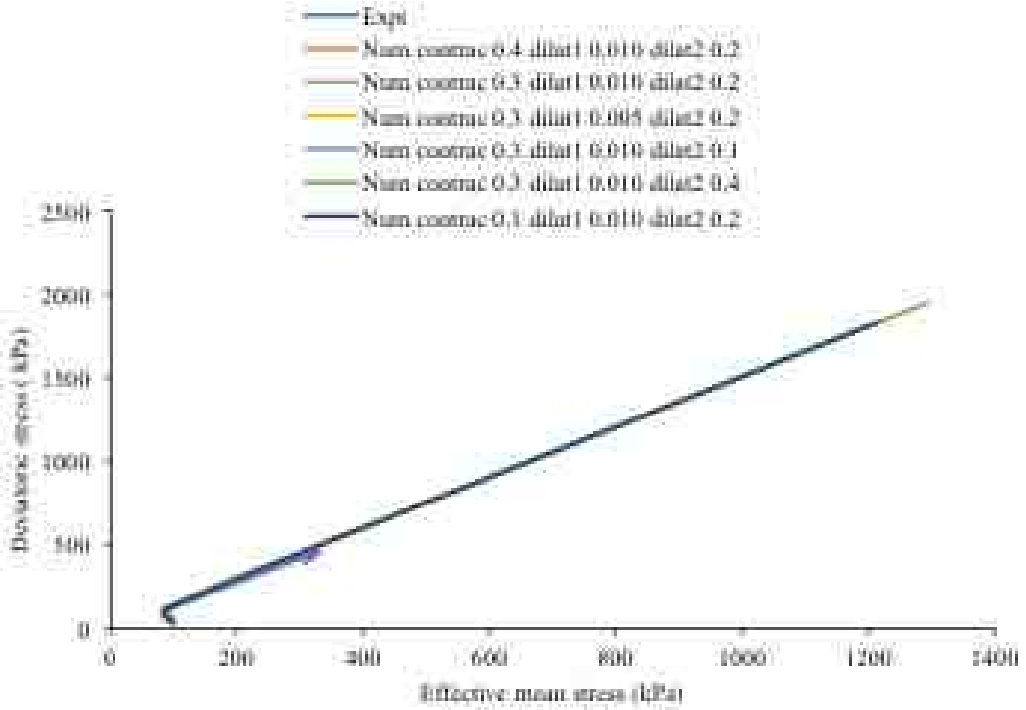

Fig. 6. Effect of dilatancy parameters on effective stress path for D_r = 60 %, S = 90 %, σ_3' = 100 kPa

V. Conclusions

In the present paper, the theoretical background of the pressure dependent multi-yield material model developed by Parra-Colmenares [2] and Yang [8] is briefed. The sensitivity analysis is conducted to understand the effect of the constitutive parameters in simulating undrained monotonic triaxial test response. It is found that the dilatancy parameter *dilat1* influences pore pressure, stress-strain and effective path response significantly. In all numerical simulations, the response was observed to be strain hardening. The case in which *dilat1* was kept 0.005, the rate of hardening was low.

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A review on Progressive Collapse Analysis of Reinforced Concrete Framed Structures

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Abstract*— Progressive collapse occurs when one or more vertical load-bearing structural members fall apart, it is like a chain reaction. Sometimes, the damage is much bigger which can be extremely dangerous and threatening for the people inside or near the building. There could be artificial or man-made causes of progressive collapse of a structure. To stop progressive collapse of the entire structure, structural engineers use different techniques such as making sure there are other ways for the structure to support itself if one-part breaks. There are also standards and guidelines for how to design and analyse buildings to prevent progressive collapse. Therefore, there is need to analyse the building for progressive collapse to find out weak points and worst situations in the structure under extreme loading events. In this paper, a rigorous literature review is carried out to know the progressive collapse behaviour of structure under extreme loading events based on various numerical, analytical, and experimental methods which are discussed in the literature. This review shows the different analysis procedures, and guidelines used by researchers. It also enlists the methods and measures to strengthen the structure against the progressive collapse.

***Keywords*— Progressive collapse, extreme loading events.**

I. INTRODUCTION

Progressive collapse refers to the gradual distribution of an initial localized failure in a structure that leads ultimately to collapse of the whole building or a very substantial part of it. They can be caused by a variety of reasons including the natural ones such as earthquakes, hurricanes, floods, and tornadoes, as well as non-natural for instance an explosion of service system or a terrorist act [16]. There has been an increasing awareness among engineering personnel as well as the public about risk of collapse of buildings especially the ones that have made it to the headlines in the recent past. Such an occasion happened when the building under concern, the Alfred P. Murrah federal building was bombed and partly crumbled in 1995. In response to this incident, the federal government reacted with an executive order designed to facilitate constitution of building standards for federal facilities susceptible to risks of being attacked by terrorists. As a result of this executive order, the ISC became the agency responsible for establishing theses security standards after such an executive order. At first the duty lay upon the General Services Administration (GSA) [7], then it passed away onto the Interagency Security Committee (ISC). In response, these organization printed guidelines, the Criteria Documents of year 2004 that stipulated the inclusion of the progressive collapse resistance features in a design of new Federal project buildings. But these documents did not specify the exact methodology to be used for achieving this resistance. To provide practical instructions for implementing progressive collapse resistance in building designs, engineers referred to documents by the General Services Administration dating back to 2003, as well as the Department of Defence [8] in 2005.These documents contained full data and procedures that engineers and designers can use in tackling the peculiarities of the phenomenon of progressive collapse. These actions and documents in fact reveal a deliberate move on the part of the federal government into making federal buildings more resilient against potential hazards, stressing the significance of avoiding progressive collapse by means of suitable design and building techniques [10].

A. Design Guidelines

The issue of progressive collapse mitigation has gained significant attention since the tragic event at the Ronan Point apartment tower in 1968. Since the tragic event of the Ronan point apartments in 1968, the issue of progressive collapse mitigation attracted much attention. As a result, numerous techniques of addressing this problem have been incorporated into different building codes and standards. The first standard concerning progressive collapse was ANSI standard [2], but its main purpose was a warning against hazards associated with such collapses. General provisions are included in the National Building Code of Canada (NBCC) [3], highlighting the significance of having a structurally sound structure. This provides guidance on a good positioning, reinforcement continuity, and structures that can bear a successive collapse if there is local failure of support. ASCE 7-05 [1] includes a section titled "General Structural Integrity" with brief qualitative requirements. This section also outlines general

qualification guidelines for designing structures to prevent progressive collapse. Detailed design requirements and guidelines aimed at reducing the potential for progressive collapse in both new and existing buildings are provided in the Unified Facilities Criteria (UFC) [4]. This criterion is particularly relevant for structures that may experience localized structural damage due to unforeseen events. The UFC offers two primary design approaches: the direct design approach and the indirect design approach. The direct design approach encompasses methods like the Alternate Load Path Method (ALPM) and the Specific Local Resistance Method (SLRM). Under the ALPM, there are four procedures: Linear Static (LS), Linear Dynamic (LD), Nonlinear Static (NS), and Nonlinear Dynamic (ND) methods. The latter is also recommended by FEMA 356 [5] for seismic analysis and design of structures. In addition to these provisions within different design codes and standards, various research efforts have been undertaken to delve into the behaviour of buildings when subjected to progressive collapse scenarios [16].

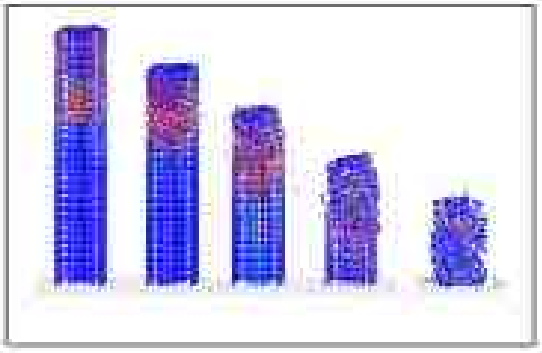

Figure 1. Representation of Progressive collapse (Source: [illegible])

II. LITERATURE REVIEW

The research works published by several researchers in various national and international journals regarding the progressive collapse behaviour of RCC building are rigorously studied and offered in the following section.

S. M. Marjanishvili (2004) have studied the different analysis procedures for evaluating the performance of structures. Various analysis methods can be used to evaluate the potential for progressive collapse, ranging from simple linear elastic-static procedures to complex nonlinear time history analysis. Progressive collapse categorised into primary and secondary loads. This paper focuses on the impacts of variation in secondary loads. The result of the study indicates that linear-elastic static analysis is simple and quick method but does not consider dynamic effects or material nonlinearity whereas nonlinear static analysis includes material nonlinearity but is more complex and time-consuming. Nonlinear dynamic analysis provides the most realistic results but is also time-consuming and requires extensive verification to allow for material yielding and fracture [9]

Shalva Marjanishvili and Elizabeth Agnew (2006) have analytically studied the different analysis procedures for progressive collapse, including linear static, nonlinear static, linear dynamic, and nonlinear dynamic by considering a 9-story steel moment-resistant frame building using SAP2000 software. As per one of the mandated outlined by the GSA, author have contemplated the removal of a column positioned at the central point of the front elevation. The results indicates that the, by utilizing linear analysis method, this structure meets the progressive collapse criteria as per the GSA standards, as the DCR values remain below 3. Moreover, following the linear dynamic analysis procedure, the structure exhibits a safety margin of 13%. The structure's failure to meet the GSA criteria becomes apparent through the nonlinear static procedure, as it only achieves 45% of the required load. The researchers recommended that the incorporation of the nonlinear static procedure alongside nonlinear dynamic methodology serves as an additional analytical approach. It aids in ascertaining both the initial yield and ultimate capacity limits of the structure while also providing a means to corroborate and substantiate the findings derived from dynamic analysis. The initial yield and ultimate capacity of the structure plays a crucial role in determining and validating the computed levels of ductility and rotational behaviour [10].

Ruirui Sun, Zhaohui and Ian W Burgess (2012) presents the development of a robust static-dynamic procedure to model the behaviour of steel buildings under fire conditions, targeting progressive collapse scenarios. The authors extended the capabilities of the Vulcan software, enabling it to model dynamic and static structural responses during both local and global progressive collapses. The integration of both static and dynamic analysis features facilitates a refined understanding of structural collapse mechanisms. The explicit integration method utilized for the dynamic procedure accommodates temporary instabilities that static analyses would classify as singularities, ensuring continued examination beyond these points. This balance between static and dynamic analysis enables the investigation of progressive collapses generated by the local failure of components. One of the key conclusions drawn from the study is that the lower loading ratio and larger beam section in an unbraced frame can yield a higher failure temperature indicating global structural collapse, while the opposite-higher loading ratio and smaller beam section can result in

a more easily generated localized collapse. Furthermore, the researchers identify the bracing system as a significant structural feature in preventing progressive collapse. The paper is rigorously validated through several practical cases, with additional preliminary studies examining the collapse mechanism of the steel frame due to column failure under fire conditions. Nevertheless, the authors note that the global failure temperature of the frame is not sensitive to the frame's lateral stiffness-an important point for considerations in design specifications. Overall, this paper relates a significant contribution to the understanding of steel structural behaviour under fire conditions and provides vital insights for the design of more robust steel structures [11].

Jia-Liang Le and Bing Xue, (2014) develops a two-scale stochastic computational model designed to simulate the probabilistic behaviour of reinforced concrete frame structures when subjected to sudden column removal. The motivation behind this research comes from the need to assess and improve the vulnerability of buildings and similar structures against progressive collapses, which is defined as the large-scale failure of structures due to localized damage. The model integrates the uncertainties in both material properties and gravity loads. The primary methodology employed involves the use of a course-scale numerical model rooted in the concept of cohesive modelling of material fracture. Notably, the model encompasses the potential damage zones in structural components through cohesive elements, effectively capturing the non-linear behaviour of the structures. To verify the model, a partial model application is presented, focusing on the mean behaviour of a frame subassembly following a column removal scenario. Interestingly, a comparison between the newly developed stochastic approach and the conventional deterministic method shows that the latter can be generally used to assess the structural vulnerability against a reasonably low collapse probability up to about 7% for a given local structural damage scenario. However, a more detailed probabilistic analysis would be necessary to ensure a lower collapse probability. While the model has only been developed for two-dimensional RC frame structures, the authors affirm that it can be further extended to three-dimensional RC structures. The researchers acknowledge the need for additional experiments on random material properties and structural responses to fully verify the model [12].

Brian I. Song, Kevin A. Giriunas and Halil Sezen (2014) have highlighted the limited experimental research that has been conducted to validate the results of computational studies and to verify the methodologies prescribed in the guidelines for progressive collapse design. The authors note that this is mainly due to the high cost of constructing and testing full-scale building specimens. The study focuses on a steel frame building that was scheduled for demolition. Several first-story columns were physically removed from the building, and the building was instrumented to measure the effects of the column loss. The authors provide details of the modelling assumptions and structural analysis used in the study. The paper also includes a figure that shows the order in which the columns were removed from the perimeter frame of the building. The effects of the column loss are shown in another figure, which highlights the load redistribution and the areas of high stress concentration. Overall, this study provides valuable insights into the behavior of steel frame buildings under sudden column loss and highlights the importance of validating computational studies with experimental research [13].

Osama Ahmed Mohamed (2015) delves into the contemporary methods of progressive collapse resistant design in structures, a strategy that has been informed significantly by earthquake resistant structural design. Load increase factor explores the estimation of structural demand and capacity, factoring in the ductility characteristics of components. Procedure-wise, linear, and nonlinear static analysis is permissible for a myriad of structures. It discusses the dynamic effects linked to the removal of columns, which are typically considered via magnified gravity loads. The paper also sheds light on the vulnerability of long-span structures to progressive collapse, particularly when corner columns are notionally removed. It presents a case study involving a normally loaded structure with considerable spans by using ETABS software. The DoD load combinations predispose the structural system to significant demand, which it may not be capable of withstanding independently. Thus, alternate structural solutions such as outrigger systems could be essential for combating progressive collapse loads. This paper also explicates the procedure for calculating the magnified gravity loads around notionally removed columns. It emphasizes that due to the necessity of applying the procedure to several perimeter and interior columns as well as repeating it for each floor, the number of analyses needed to capture the complete response is considerably large. It concludes that for progressive collapse design based on UFC 4-023-03 to be incorporated into other building codes, this procedure requires automation or simplification [14].

Jose M. Adam et al (2018) provides an overview of the most significant advances in the field of the progressive collapse of building structures in the 21st century. The paper provides a comprehensive guide to the current state of research and practice on robustness and progressive collapse of building structures. The authors conducted a wide-ranging review of the main advances made in the 21st century in this field. The review covers a range of aspects, including conceptual definitions, bibliometric details, and the present state of regulations, recommendations, and design methods about progressive collapse and robustness. The authors note that recent years have seen considerable progress in this field, responding to the present need for robust buildings able to withstand extreme events without collapsing, and even resilient buildings that can remain operational after an extreme event. New codes and design recommendations have been brought out, while those already existing have been adapted to allow for the latest advances. In addition, the scientific community, engineers, and architects are now fully aware of the need for resilient buildings. The review also highlights the need for further research in some areas that require deeper study and others that need to be studied for the first time. The review underscores the importance of this field in ensuring the safety and resilience of buildings in the face of extreme events [15].

Yara M. Mahmoud et al. (2018) have primary objective is to explore the susceptibility of 5-storey steel moment-

resisting and braced frames, which have been designed in compliance with Egyptian local standards, to progressive collapse resulting from seismic activity-induced damage. To assess the repercussions and ensure the safety of neighbouring structural elements, a deliberate removal of a first-storey column is executed at various arbitrary locations within the building. This study adopts 3-D nonlinear dynamic analysis procedure as per the UFC guidelines, leveraging the SAP2000 software, as a central component of the conducted parametric investigation. The results indicate that for moment-resisting frames, the largest displacement is observed at interior column and for braced frames the maximum displacement is observed at corner column. The minimum relegation is noticed when the edge column and bracing are excluded. The researchers concluded that use performance-based design practices to minimize the potential of progressive collapse [16]

A. Salman and K. I. Praseeda (2021) studied the effect of column collapse on overall structures, the G+15 is used for mathematical modelling and analysis. SAP2000 software is used to generate a three-dimensional mathematical model. Two different columns are deleted through analysis, one at a time. After that, the impact they have on neighboring elements are examined and evaluated. With the use of linear static analysis, non-linear static analysis and hinge pattern identification approach, results for beam wise DCR are obtained. The researchers concluded that non-linear static analysis method is less computationally expensive.[17].

Foad Kiakojouri et al. (2023) presents a comprehensive review, analysis, and potential improvement of existing literature on dynamic column removal techniques in experimental progressive collapse studies. These techniques are utilized to mimic a collapse, and although predominantly focusing on single-column removal scenarios, there is potential for application to multiple-column loss situations. The paper acknowledges potential biases in currently published experimental tests and hence, highlights the importance of careful consideration of testing methods and structural irregularities. The study asserts that sudden and complete column loss is simplification of real-life phenomena and mostly occurs in special circumstances like small near-field blasts or high-speed impacts. The paper concludes that the current methodologies for dynamic column removal in structural engineering often oversimplify the real-world scenarios of column loss. Such oversimplifications can limit the accuracy and applicability of research findings. The authors advocate for the development of novel techniques and methods for these tests, especially with the inspiration from electromagnetic and mechatronic devices. They also highlight the importance of considering different levels of column damage, rather than the full and sudden loss that is typically modelled. This approach can lead to more realistic and diverse scenarios being represented in collapse studies. The paper outlines the necessity of continuous revision and update of existing methodologies and practices, ensuring that they keep pace with the dynamic nature and requirements of structural engineering. Ultimately, the proposed recommendations are anticipated to improve the validity and reliability of experimental estimates, thereby enhancing their potential to contribute effectively to the field of progressive collapse research [18].

Julio Garzon-Roca et al. (2023) have been studied the concept of robustness tall buildings with reinforced concrete flat slabs supported by a central core and perimeter columns. This layout is commonly used in office and residential buildings to maximize natural daylighting and reduce storey height. The authors analyses scenarios involving the sudden removal of corner and edge columns in these systems. They examine potential issues such as punching at the connections and flexural failure in the slab. To assess this, they use a dynamic punching model based on the Critical shear crack theory and the Ductility-centred robustness assessment method. They propose a simplified approach for preliminary design checks during the conceptual stage. The findings highlight the importance of considering alternative design considerations when removing an edge column adjacent to a corner column [19].

III. Summary of Literature

According to the review of the available literature, there are numerous research gaps which offer many opportunities for development progressive collapse analysis of irregular reinforced concrete framed structures". The gaps imply areas where there is insufficient or outdated knowledge that can be replenished. Although fragility curves are successfully used for evaluating seismic vulnerabilities, a research gap exists in integrating them into progressive collapse analysis. Systematic research involving the use of fragility curve has been limited when exploring its application of predicting the chances of initiating as well as progressing of the progressive collapse of reinforced concrete structures. There is a research void in the application of fragility curves for other types of hazards which can initiate progressive collapse such as blast loadings and impacts. Hence there is a likelihood to explore on how fragility curves may be adjusted with various hazards to come up with a more comprehensive view concerning the behavior of various extreme conditions. A comparison of fragility-based progressive collapse assessment and traditional analysis methods could reveal the strengths and weaknesses of both approaches. This comparison would be helpful in determining if fragility curves are reliable predictors of progressive collapse scenarios.

IV. Conclusion

Based on the literature review investigation, the following conclusions are drawn;

- The structural response is determined by degree of irregularity, type and position those factors must be considered in designing any structure. It would assist in integrating irregularities into structure without loss of performance.
- If the structures are designed and detailed with a certain degree of continuity (in terms of member variations), then redundancy in this sense can develop alternative load paths. This allows for loss of an individual member without leading to progressive collapse.

- It is necessary to do a research and set up an experimental program to develop provisions against progressive collapse. Existing methods of measuring structural strength are mainly used for research, and application in actual design is rare because complicated calculations, physical and mathematical complex process. Therefore, research into this issue should focus on the experimental technique for dynamic collapse analysis.

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Optimum angle of diagrid using Response Spectrum Analysis

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***Abstract*— The world's population has grown significantly in the recent years, leading to a heightened demand for available construction space. To meet this challenge, tall buildings and skyscrapers have become increasingly common. The innovation of construction domain is the diagrid system, recognized for its superior structural efficiency as different from other systems of the building. The structural efficiency of diagrid systems surpasses that of other building systems, such as braced systems. The distinct geometric arrangement of the diagrid system accounts for the fluctuating heights of towering buildings. The heights and angles of the diagrids determine the geometric configurations and grid geometries of diagrid constructions. This results in diagrid construction being more complex as compared to conventional structure. Historically, tall buildings hold significance due to their architectural prominence, and the diagrid structure not only offers superior architectural aesthetics but also enhances structural stability. In this research, diagrid structures are examined and contrasted in order to determine the ideal angle for a given structure's angle and to investigate the impact of different angles on the structures. The high-rise diagrid structure is analysis and elevating the optimum angle of diagrid using response spectrum analysis.**

Keywords—Diagrid structure, Steel structure, Response spectrum analysis, Earthquake load, Wind load,

I. INTRODUCTION

In recent decades, the global population has surged, placing immense pressure on available space for construction. To address this challenge, tall buildings and skyscrapers have become ubiquitous. One standout innovation in this domain is the diagrid system, recognized for its superior structural efficiency compared to other system. Notably economical and robust against lateral loads, diagrid systems feature distinctive geometric configurations tailored for tall structures of varying heights.

When we talk about tall buildings, it's clear that diagrid structures are better. They move less and are more flexible than braced tube structures. The study also looked at different shapes. It showed that a square shape is better for diagrids, while a circle shape is better for braced tubes. These results help in designing tall buildings. It shows us how important it is to think about the shape and structure for the best performance in storms and earthquakes [1]. This study contrasts diagrid and braced tube constructions, focusing on how they weather earthquakes and wind in skyscraper scenarios. Diagrids typically sway and shift less per floor than braced tube designs. Therefore, diagrids win in terms of both structural function and style versatility for tall buildings. The research also delves into how various layout designs affect each structure. A square design shows superiority in diagrids when compared to circular or rectangle designs. But for braced tubes, a circular design outshines the square or rectangle ones.[2]. This examines how tube-like diagrid structures in tall metal buildings react to earthquakes. It looks at the impact of different angles and whether or not there's a diagrid core in the building's framework. The research uses two methods: pushover and nonlinear time history analysis for evaluation. What we found, diagrid structures with angles the same or less on the outside compared to the inside get harder and can absorb lots of energy through slanted elements. Adding a core doesn't really change the rigidness but gives an added toughness, especially after warping. The buildings' shift and leftover shifts within floors are acceptable. Adding a core to the design doesn't change the stiffness of the structures much. But it does give them more strength. It even makes them stiffer after they buckle. The drifts within the diagrid structures don't go beyond safe limits. The study points out that we should think about progressive collapse and braces that prevent buckling when designing diagrid structures. It also suggests more research. The research should focus on linking the internal core with the outer tube at different angles [3]. This report looks into how diagrid structures react to earthquakes and checks out how well they perform in such scenarios. The work involves 3-D models of steel diagrid types that have been differing floor amounts and a range of slanting angles. The findings demonstrate how the slanting angles affect the R-factor, a performance metric for steel diagrid systems. It gets a value of 1.5 for a 45° angle, 2 for 63.4°, and 3 for 71.5°.Pin-ended beams are found to increase seismic performance, particularly for models with larger diagonal angles, when the study compares the seismic performance of diagrids with rigid-ended beams and pin-ended beams. The paper discusses the nonlinear modelling and analysis of diagrid structures, including the behaviour of diagonal members, failure under cyclic and monotonic loading, and nonlinear static and dynamic analyses. The study proposes a method for evaluating a seismic performance of diagrid structure, considering collapse capacity, response spectra, and drift ratio limits. The earthquake performance of diagrid structures with different diagonal angles and beam connection types is evaluated using pushover and incremental dynamic analysis. The study concludes that diagonal angles and beam connection types significantly affect the earthquake performance of diagrid structures and suggests design

parameters for different diagonal angles in high seismic regions. Additionally, the earthquake performance of diagrid structures can be improved by substituting pin-ended beams with rigid-ended beams.[4]. A 36-story diagonal steel building's analysis and design are shown. A typical 36 by 36-meter floor design is taken into account. Structural member modeling and analysis are done with Extended Three-Dimensional Analysis of Building System (ETABS) software. Every structural part is created using IS 800:2007, considering every possible combination of loads. Both dynamic across and along the wind are considered during the structure's analysis and design process. Completed analyses and plans have also been produced for diagrid buildings of 50, 60, 70, and 80 stories [6]. The results of the analysis are contrasted in the terms of time interval, displacement of the top storey, and drift between stories[6]. It is observed that while both the interior columns and the peripheral diagonal columns resist the gravity load, the peripheral diagonal columns resist the majority of the lateral force.[5].

II. Methodology

A. Problem statement for study

The current investigation encompasses an examination of the behavior of high-rise diagrid buildings, delving into the analysis of the diagrid structure from various angles. This method provides a thorough grasp of the structural dynamics and sheds light on the clever design concepts.

In this examination, the G+80 story diagrid structure is under scrutiny [5]. The lateral forces stemming from both earthquake and wind, are in accordance with the Indian standard IS 456-2000 and IS 800-2015. The diagrid structure was modeled and analyzed at various angles using the Extended Three-Dimensional Analysis of Building System (ETABS) software. The response spectrum was analyzed to identify the ideal angle.

TABLE I. Parameters in detail for diagrid structure

Geometric parameters of the building model.

Sr. No.	Description	Data' Value
1	Number of Story	80
2	Plan area	1024 m2
3	Size of plan	32m X 32m
4	Story height	4m
5	Grade of structural steel	Fe 250
6	Structural specification Internal Column	2200 mm X 2200 mm
	Diagrid column	825 mm Pipe section with 50 mm
	Beam B1 and B3 B2	ISMB550 ISWB800 (with top and bottom cover plate of 1220 X 50 mm

TABLE II Loading parameter

Sr no.	Description	Data Value
1	Dead Load	3.75 kN/m2
2	Live load	2.5 kN/m2
3	Seismic parameter details (as per IS 1893–2016)	
	Seismic zone	Zone IV
	Response reduction factor	3
	Importance factor	1
	Soil type	Medium
4	Wind parameter details (as per IS 875-2015)	
	Wind speed	50 m/sec
	Terrain category	2
	Structure class	B
	Risk coefficient	1
	Topography factor	1

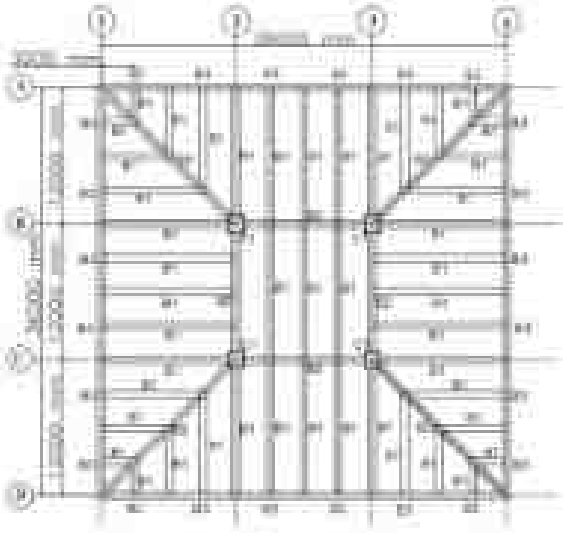

Fig. 1 Plan

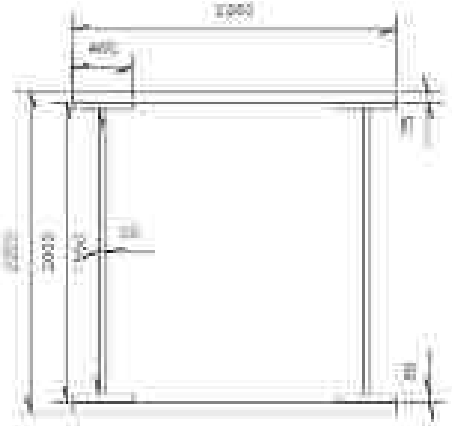

Fig. 2. Column dimension

For each diagonal building, four distinct scenarios with angles of 56°, 71°, 76°, and 81° with the storey model are taken into inspection to determine the best angle.

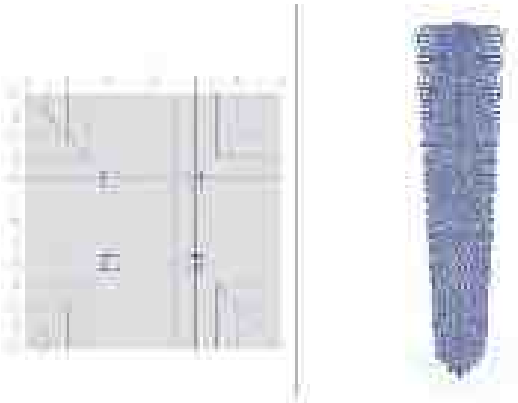

Fig 3 Snapshot of Diagrid building

B. Response spectrum analysis

An engineering method called response spectrum analysis (RSA) evaluates the contribution of each natural vibration mode to ascertain the anticipated maximum seismic response of a mostly elastic structure. This analytical method offers measurements of pseudo spectral acceleration, velocity, or displacement in relation to the structural period and damping level, providing insightful information on the dynamic behaviour of structures. A smooth curve can be used to accurately depict the peak response for each realisation of the structural period by encompassing the response spectra.

The analysis of response spectrum proves valuable in guiding design choices as it links the selection of structural types to their dynamic performance. The shorter period structures endure higher acceleration, while longer period structures undergo increased displacement. It is imperative to consider structural performance objectives in the initial design phase alongside conducting response spectrum analyses.

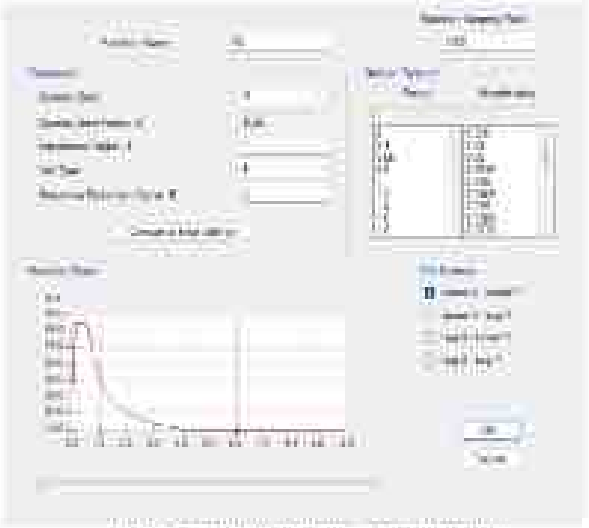

Fig 4 Snapshot of Response spectrum input

III. Analysis Results

The analysis's findings are expressed in terms of the time period, maximum storey displacement, storey shear, and presence of storey drift. The maximum value of storey displacement, storey shear, storey drift, and time period for various angles of diagrid G+80 storey are displayed in the accompanying graphs.

A. Comparison of time period

TABLE III Time periods

Diagrid angle	Time period (Second)
67	7.366
71	7.524
76	9.501
81	10.08

B. Comparison of storey displacement

Fig. 5 is the comparison of maximum storey displacement for diagrid angle 67°, 71° 76°, 81° of high-rise building.

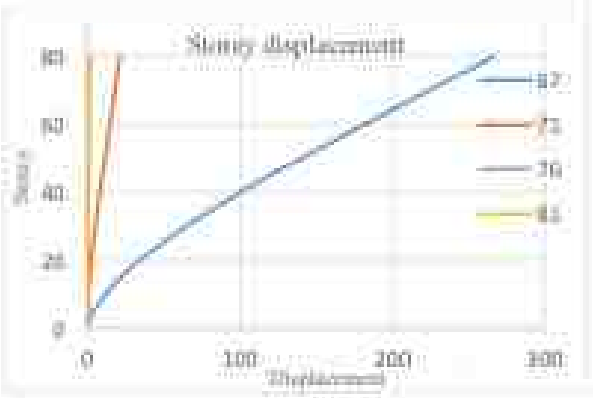

Fig. 5 : Maximum storey displacement

C. Comparison of storey drift

Fig. 6 is the comparison of maximum storey drift for diagrid angle 67°, 71° 76°, 81° of high-rise building.

Fig. 6 : Story drift

D. Comparison of storey shear

Fig. 7 is the comparison of maximum storey shear for diagrid angle 67°, 71° 76°, 81° of high-rise building.

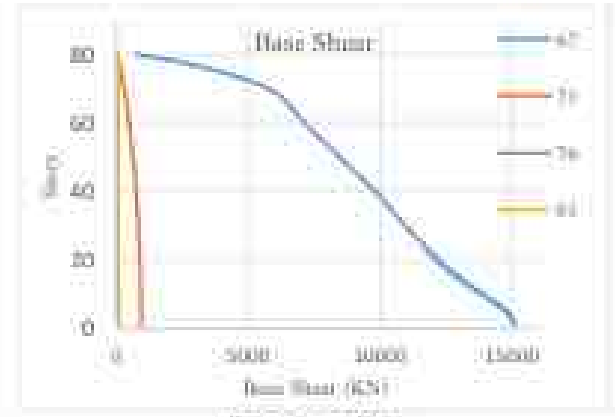

Fig. 7 : Story Shear

E. Comparison of over turning moment

Fig. 8 is the graph of comparison of maximum overturning force for diagrid angle 67°, 71°76°, 81° of high-rise building.

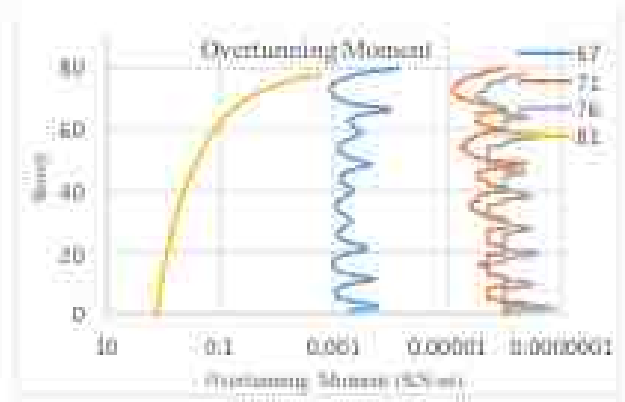

Fig. 8 : Overturning Moment on X axis is on Log scale.

IV. Conclusion

The previous study, it was observed the diagrid structure's angle adjustment does not get mentioned in the code. Prinsly study paper are work up to 120m and they suggested the 70° to 75°. As the story height increases, the diagrid angle also changes. Notably, the angles of 67° and 71° exhibits higher displacement, base shear, and time periods compared to the 76° angle. Conversely, the 81° angle leads to a significantly large amount of overturning moment, resulting in its rejection. Ultimately, it is determined that the 76° diagrid angle is most suitable for constructing a G+80 storey tall building.

In recent years, the diagrid system has emerged as an effective strategy for boosting the performance of high-rise buildings, bolstering both lateral and gravity load resistance. The boundary pattern of diagrid columns cleverly manages sideways pressure. This leaves the inside columns to only carry vertical weight. This smart method results in a structure without columns, cutting down on steel use, and making it look good. The diagrid framework is tops in overall strength, style, and sturdiness. It does better than regular systems with impressive skill.

In the world of structural designs, diagrid setups shine. They're solid, barely bend, and aren't heavy, which helps them stand firm against sideways forces. These smart structures move less, resist tearing, and don't drift as much as old-fashioned ones, clearly showing they're better. Plus, the diagrid system makes the inside roomy and well organized, thanks to cleverly arranged columns. Basically, for fighting sideways pushes, the diagrid structure system is a top choice. It has standout benefits like less side to side movement, less weight in steel, and more firmness. The study shows the structure can be resist wind forces at great heights.

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A review on behaviour of steel I-beam and castellated beam with different shaped openings using FRP stiffeners.

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***Abstract*— In recent years, use of castellated steel beams (CSB) is gaining more popularity due to their various benefits viz. increased section depth without any additional weight, higher strength to weight ratio, lower maintenance cost, good aesthetic appearance, etc. A CSB is a beam that is fabricated by cutting a steel I-beam longitudinally along its web in a specified pattern, and then re-joining the two cut parts by welding so as to get a beam of increased depth. This increased depth of CSB is generally 50% more than the parent steel I beam and contributes in enhancing its performance. However, the presence of web openings reduces the strength, causes stress concentration around the openings and also results into web-post buckling failure when subjected to loading. In order to prevent such failures, the CSB needs to be strengthened using stiffeners. The use of mild steel stiffeners is commonly done for strengthening the CSB. However, in recent years the use of fiber reinforced polymers (FRP) has been widely done for repair and rehabilitation works because of the excellent tensile strength and light weight property of FRP. This paper provides a rigorous literature review on the behavior of CSB provided with stiffeners of different materials. From the study, it is concluded that CSB are the efficient structural elements and perform better when provided with FRP stiffeners, but their behavior needs to be studied when they are provided with different shaped web openings and considering stiffeners of different FRP under two-point loading.**

Keywords*— *steel I-beam, castellated beam, web opening, stiffeners, FRP, web-post buckling and load carrying capacity

I. INTRODUCTION

The terminology of castellated beam was discovered in mid-1930, by Geoffrey Murray Boyd, an engineer employed in Argentina, Castellated steel beams (CSB) enhance structural ability in opposition to bending by increasing the overall depth of beam with 50%, achieved through flame cutting a steel I-beam along its center line and subsequently rejoining the two halves with welding [1]. Since 1940, CSB are used in more amounts as the ability of larger opening space, reduction of floor to floor height and improves aesthetic appearance [2].In some of CSB structure having short span, where the dominant failure get occur as shear mechanism which can help to decrease the load carrying capacity. In CSB, openings in the web can cause beam weak in opposition to shear. Additionally, the geometry and size of openings, slenderness of the web plate, special geometric shape, the types of loading specified and the condition of lateral support [3]. From recent years, CSB have been practiced through with different type of web openings. The web opening pattern presents an aesthetic and attractive expression for beam view. The web openings are not only used for aesthetic look but also have advantages like passing the service lines through holes, conduits and ductwork in present building. The most effective benefit of CSB is that it is lighter in weight, increased load carrying capacity and stiffness [4]. Some examples of CSB include their use in bridges, stadiums, and building construction for their ability to provide lighter-weight, aesthetic appearance, enhance flexural stiffness and significant material efficiency [5].

II. MANUFACTURING OF CASTELLATED BEAM

A. *Process of castellation*

Castellated steel beam is obtain from parental solid steel I-beam, in the formation of CSB following steps are:

With the guidelines from Eurocode 3, the initial parent solid steel I-beam resolute for fabrication of CSB diamond shaped web openings. The parent solid steel I-beam is cut with zigzag line along the length as per geometric design using AutoCAD software (Fig. 1.). Moreover, the parent solid steel I-beams' marked profile with an extra cut line, referred to as the secondary profile, will be completed by CSB and manufactured with diamond-shaped openings of the necessary dimensions. (Fig. 2.) [5].

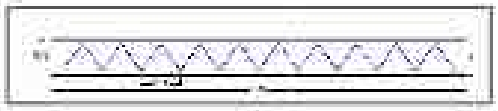

Fig. 1. Steel I-beam marked with cutting for first stage (source: drawing from AutoCAD)

Fig. 2. Cutting of edges which are not required (source: drawing from AutoCAD)

After secondary profile cut the wasted part or the parts which are not required for fabrication is removed as shown in (Fig. 3.). The parent solid steel I-beam's two cut portions

are subsequently retained in order for the welding procedure (Fig. 3.). The necessary CSB with diamond-shaped apertures is obtained after the welding process. (Fig. 4.) [5].

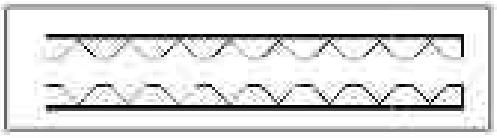

Fig. 3. After removal of waste parts beam is ready for cutting (source: drawing from AutoCAD)

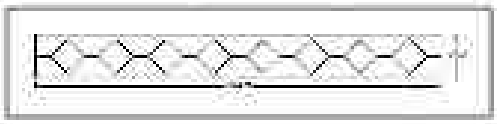

Fig. 4. Castellated beam with diamond shaped web opening (source: drawing from AutoCAD)

B. Types of Castellated Beam

CSB with different types of web shaped openings including circle, square, hexagonal and diamond.

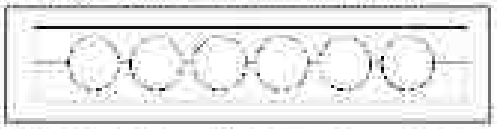

Fig. 5. CSB with circular shaped web openings (source: M. Kanwaiya and G. Iyappan, "Study on Castellated Web Beam with Optimized Web Opening – State of the Art Review," International Journal of Research Publication and Reviews Vol. 1, 2020)

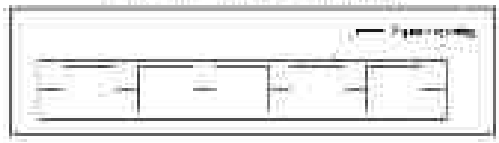

Fig. 6. Castellated beam with square shaped web openings (source: M. Kanwaiya and G. Iyappan, "Study on Castellated Web Beam with Optimized Web Opening – State of the Art Review," International Journal of Research Publication and Reviews Vol. 1, 2020)

Fig. 7. CSB with hexagonal shaped web openings (source: M. Kanwaiya and G. Iyappan, "Study on Castellated Web Beam with Optimized Web Opening – State of the Art Review," International Journal of Research Publication and Reviews Vol. 1, 2020)

Fig. 8. CSB with diamond shaped web openings (source: M. Kanwaiya and G. Iyappan, "Study on Castellated Web Beam with Optimized Web Opening – State of the Art Review," International Journal of Research Publication and Reviews Vol. 1, 2020)

III. Stiffeners

The castellation process involves cutting a zigzag pattern in the parent solid steel I-beam and rejoining the beam with solder; as a result, the depth of the beam increases during the fabrication process. The load-bearing capacity of a beam can be increased simultaneously with its depth. A beam exposed to loading may buckle at the web-post and buckle lateral to torsional due to its deeper design. Research indicates that stiffeners in transverse and longitudinal web segment of the beam aids in reducing these failures [6]. Stiffeners are the structural members used for strengthen moment and shear resistance of steel members. Stiffeners can be used in the longitudinal direction, transverse direction, or along the portion of openings [7].

A. Fiber Reinforced Polymer (FRP)

At the present time, the use of FRP has been widely done particularly for repair and rehabilitation works of RCC, steel and composite structures. The four types of fiber-reinforced polymers (FRP) that are used to strengthen structural members are basalt fiber-reinforced polymer (BFRP), aramid fiber-reinforced polymer (ARFP), glass fiber-reinforced polymer (GFRP), and carbon fiber-reinforced polymer (CFRP). FRP represents a two-phase composite material comprising a continuous matrix and implanted dispersed phase. Because of its superior strength-to-weight ratio, corrosion resistance, and flexibility compared to steel members, fiber-reinforced polymers (FRP) are becoming more and more used in the construction industry. There are two types of stiffeners use transverse stiffener and longitudinal web opening stiffeners [7].

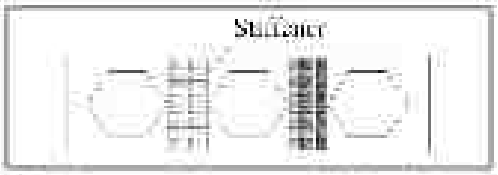

Fig. 9. CSB with transverse stiffeners (source: S.Patil and P. Kamthai, "A review on study of castellated beams using stiffeners of mild steel and different fiber reinforced polymers," Materials Today: Proceedings, 2021.)

Fig. 10. CSB with longitudinal web opening stiffeners (source: S.Patil and P. Kamthai, "A review on study of castellated beams using stiffeners of mild steel and different fiber reinforced polymers," Materials Today: Proceedings, 2021.)

IV. Existing Literature

The research works published by several researchers in the various journals have been reviewed and is presented in the following section:

Menkulasi, et al. (2015) analytically investigated the effect of stiffeners on the behavior of CSB under concentrated loads by carrying out non-linear finite analysis till the failure occurs. The CSB are provided without and with stiffeners of mild steel considering different depth of CSB. The CSB are subjected to concentrated loads applied at three different locations viz., at the center of opening, at the center of the full height web and between the web and the making an opening to conceal the potential range of the concentrated force location. The results of study indicated that the load carrying capacity of CSB provide with stiffeners increased

by a maximum of 2.82%. From results authors concluded that use of stiffeners contributes in enhancing the load carrying capacity and also prevent the web post buckling of CSB. Additionally, the authors have provided a simplified method for figuring out the web post buckling limit state under compression and have proposed that stiffeners are required to enhance CSB performance [2].

Jamodar and Kumbhar (2015) conduct a parametric study on the CSB with openings that are diamond, hexagonal, and circular in shape in order to optimise the opening by varying the ration of opening depth to overall depth (D/Do) and opening spacing to opening depth (S/Do). Analysis of CSB is done using ABAQUS software. The study's findings show that the CSB with circular apertures of 0.75D can support a maximum load of 32.5 kN for S/Do=1.4 and D/Do=1.41, while the CSB with diamond openings of 0.67D can support a maximum load of 34 kN. The authors come to the conclusion that CSBs with diamond-shaped openings perform better than CSBs with other shaped openings [8].

Girija, et al. (2018) in order to calculate load carrying capacity and deflections, a comparative study was conducted on the behaviour of CSB with hexagonal and circular web openings, as well as those featuring vertical and diagonal stiffeners, under two-point loading. The ANSYS software is used to carry out the analysis. The results of analysis indicate that in comparison to CSBs with circular web openings that include diagonal stiffeners, the shear carrying capacity of CSBs with hexagonal web openings increases by 31.68% while the beam's stability is decreased. The authors conclude that, hexagonal opening with diagonal stiffeners is preferred than circular opening as it gives more load carrying capacity [9].

Thomas and Bankar (2018) examined the behavior of the CSB both analytically and experimentally for a variety of parameters, such as the castellation depth ratio and the weld length ratio, in order to strengthen the CSB using various CFRP wrapping techniques that involved wrapping the web's edges as well as the angels' inner and outer faces. The results of study, with Type (c), or the outer and inner faces of the flanges wrapping techniques, the CSB provided yields an average improvement in load carrying capacity of 49%. CSB with CFRP laminates are wrapped in the web openings. The authors concluded that the CSB's load carrying capacity is increased by the application of CFRP as a strengthening technique [10].

Hadeed and Alshimmeri (2019) examined the effects of castellation, both without and with strengthening, on the structural behaviour of CSB using the ABAQUS software. The results compare the load carrying capacity and deflection of the original solid steel I beam. The solid steel I beam is considered as model 1 and it is treated as reference model. Three types of castellated beams having different configurations (model 2, model 3, and model 4) are analyzed considering two point loading and simple supports. The model 2 is unconfined CSB with hexagonal openings without strengthening. The model 3 is confined CSB by high strength concrete on each side of the web. Model 4 is confined CSB by high strength concrete but with two layers of laced reinforcement (Ø 6mm) on each side of web in an inclined continuous manner. The study's findings showed that the load carrying capacity of the CSB models—models 2, 3, and 4—increased by 39.11%, 165.95%, and 124.77%, respectively, in comparison to the original solid beam. According to the authors' findings, the CSB strengthened by high strength concrete with laced reinforcement perform better in respect of load carrying capacity and ductility [11].

Deshmukh and Kamade (2019) have used ABAQUS software to analyse and perform a parametric study of the CSB equipped with transverse FRP stiffeners by varying the thickness. As part of the study, an experiment is also carried out to determine the load carrying capacity and deflection of CSB with stiffeners under two-point loading. The study's findings show that when compared to the corresponding values of CSB without stiffeners, the CSB's load carrying capability with stiffeners increased by a mean value of 11.03% and the deflection decreased by a mean value of 28.47%. Further, load-bearing capability of stiffeners, the former is found to be higher by 7.39% and the deflection to be lower by 7.08% when compared to CSB with FRP stiffeners. According to the study's findings, using stiffeners in the CSB's web section helps to minimise failures [12].

Morkhade et al. (2020) examined the operation of the CSB, which comes with or without steel stiffeners encircling the web apertures and features square, circular, hexagonal, and octagonal web apertures. The load carrying capacity and deflection are calculated using ANSYS software. According to the findings, CSB had a 44% higher load-bearing capacity than traditional steel I-beams. When CSB with stiffeners surrounding apertures is compared to CSB without stiffeners, the average increase in load carrying capacity is found to be 36%. The studies conclude that adding stiffeners around the openings can help keep the CSB from buckling at the web [13].

Yuwisia, et al. (2020) used ABAQUS software to examine the performance of CSB with hexagonal, octagonal, and diamond-shaped openings under axial load and stress-strain conditions both with and without coupled plates on the web weld joints. The CSB with coupled plate on web weld joints undergoes with axial load of 75kN. The results indicate that the hexagonal opening has minimum displacement 14.24% when compared with octagonal openings and diamond openings. The authors come to the conclusion that coupled plate addition to the web joints of the castellated steel beam profile is strongly advised in order to support strength resistance for a long-term structure [14].

Kurlapkar and Patil (2021) analyzed the CSB with various parameters (viz. depth and width of web opening) containing sinusoidal openings by using finite element method (FEM). The specimen of CSB where modified from 100mm I beam. The two-point loading system and a basic supported system beam were used in the laboratory testing of the CSB. The FEM analysis of sinusoidal openings with an opening size of 0.62 times, an overall depth of 1.4, a D/Do ratio of 1.61, and a deflection of 1.170 mm was compared to the results of the 150 mm high CSB specimen with a deflection of 1.172 mm because 0.18% is negligible. As a result, the author draws the conclusion that the CSB analysis method was sound based on the experimental findings [15].

Barkah and Damaswan (2021) have performed a comparative analysis of hexagonal shaped openings and circular shaped openings of CSB with their flexural behavior using ANSYS software. While the CSB test model was created using multiple S/Do and D/Do parameter variations. According to the author's analysis of the numerical testing results, castellated beams with hexagonal-shaped openings

perform better in terms of flexural capacity than those with circular openings. The author concludes that, in comparison to circular shaped openings, hexagonal shaped openings have a superior inertial stiffness value. Due to its larger opening area compared to the hexagonal opening, the circular opening results in a lower inertial stiffness value [16].

Patil, et al. (2023) used ABAQUS software to analyze the performance of CSB with variously shaped openings (diamond, circular, and hexagonal) under two-point loading while accounting for the stiffeners surrounding the web openings. For the study, stiffeners made of mild steel, CFRP, and BFRP are utilised. The analysis is carried out to determine the load-carrying capacity and deflection of the beams. The findings show that when CSB with diamond-shaped openings and mild steel stiffeners are fitted, their average load-carrying capacities and deflection values are 11.52% higher and 24.07% lower, respectively, than when CSB with hexagonal and circular openings. Moreover, it is found that the load carrying capacity and deflections of CSB with diamond-shaped openings equipped with stiffeners of CFRP and BFRP are 7.6% lower than the corresponding values of CSB consisting of mild steel stiffeners. The authors conclude that compared to the stiffeners of MS, use of FRP can be the best option as it benefits in the weight reduction of structure [17].

V. Research gap

Based on a thorough review of the literature, it can be observed that various stiffener types have been used to study the failure modes and increase the load carrying capacity of castellated beams under two point loading. Use of mild steel stiffeners is commonly done for strengthening the steel and CSB. However, the use of mild steel as stiffener causes increase in the weight of structure and also the mild steel is susceptible to corrosive actions. Due to its favourable qualities, including its light weight, non-corrosive nature, durability, and high strength to weight ratio, fibre reinforced polymer (FRP) has seen widespread application in recent years, particularly for reinforcing steel and RCC structures. Additionally, research has demonstrated that using FRP stiffeners improves the CSB's ability to support loads. These days, it's usual practice to strengthen CSB with variously shaped openings by using CFRP strips as stiffeners. Very few studies have been carried out on CSB using FRP or other types stiffeners till their failure stage. Therefore, there is a good chance to investigate how CSB with variously shaped openings behaves when subjected to two point loading with CFRP stiffeners until failure.

VI. Conclusion

From the study of literature review, following conclusion are drawn:

- The CSB is more advantageous for steel structure industry such as, weight reduction, increase in strength, flexible, material efficiency, ease in installation, long-span capabilities, customization by shape and size of CSB and excellent balance between strength and weight with aesthetic appearance.
- The CSB failure is of different modes viz., web post buckling, flexure failure, torsional failure, shear failure, Vierendeel mechanism, and web weld crack etc. when CSB undergoes with loading. Therefore, requires strengthening in CSB using stiffeners of different materials.
- By providing transverse stiffeners with different thicknesses, CFRP offers a good opportunity to study the behaviour of CSBs because it decreases weight and has been demonstrated to increase load carrying capacity.

Acknowledgment

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A review on behaviour of pre-engineered buildings with different bracings under various seismic and wind zones

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Abstract*—Steel is used as an essential construction material for steel and composite structures because of its various advantageous properties viz., flexibility, ductility, high strength-to-weight ratio etc. Steel structures consisting longer spans has become the need of any industrial structure which can be satisfied by constructing pre-engineered buildings (PEB). A considerable growth in the PEB construction is observed as they offer various advantages like shorter erection time, economy, better quality, low maintenance etc. PEB structures consists structural frame, standard roof and wall support that are fabricated in the factory and in which additional steel is eliminated using the tapered sections according to the bending moment requirements. Several researchers have carried out the study on behavior of PEB considering various types of bracings like X, K, V, and diagonal etc. considering specific seismic and wind zones. In this paper, a rigorous literature review is carried out to know the behavior of PEB considering various types of bracings and their locations in different seismic and wind zones. The review study reveals that, the PEB are more efficient structures when compared over conventional steel buildings (CSB), however their behavior in different seismic and wind zones for large openings needs to be explored.

***Keywords*— Pre-engineered buildings, Conventional steel buildings, seismic zones, wind zones, types of bracings, large openings.**

Introduction

In the present modern construction age, the steel is considered to be the most widely used materials of construction due to its various advantageous properties viz., developed strength, developed flexibility, ideal cost, reliability, durability, recyclability, etc. The steel productions are growing quickly over world because of the increased use of steel structures. The steel structures offer advantages such as speedy construction, and fulfillment of the required greater spans and heavy loads. Additionally, the steel structures are more earthquake resistant over concrete structures [1]. The conventional steel structures or buildings (CSB) are generally fabricated by using the market available hot-rolled structural members and are usually constructed with the provision of trusses. The CSB structures are constructed at the site by adopting standard fabrication processes, but requires more time for their completion. Mostly, the CSB are constructed using market-available steel sections which may not be suitable for construction on account of not meeting the design requirements because of their larger sectional sizes or properties. Further, such steel sections are of unvarying cross-sections even though the stresses in them go on varying in them from one point to another point along the section's length. Due to this the overall weight of the structure gets increase and hence such structures are required to be provided with large sized footings [2]. This drawbacks of CSB can be eliminated by implementing the perception of pre-engineered building (PEB). The concept of PEB involves forming the frame geometry that matches well with the bending moment diagram which helps in contributing in the optimization of steel quantity and also dropping the total mass of the structure [3]. So, in the PEB the components or members can have their cross-sections varying in nature throughout their length as per the (BM) bending moment diagram. A PEB is a kind of structure in which the components are design and fabricated in the factory and then assembled at construction side using bolted connections [4]. PEB are steel structure which contains of frames and members with metal sheets on the roof and on the exterior walls, viz., rigid frames, bracing members, cold-formed steel secondary structural members. The PEB have gained popularity in recent years, due to their various advantageous properties viz., energy and cost-effective, less in mass, less erection time over the CSB [5].

A. Components of PEB

PEB contains of various components members viz. Primary, secondary, and some miscellaneous members.The primary members are made of hot-rolled steel sections and consist of columns and rafters that are usually with tapered shapes. Purlins and eaves are secondary members that are commonly cold-formed members. Members include sheets, gutters, trims and other accessories classified under miscellaneous members. Figure 1 shows the PEB structure and its various components. [6].

Figure 1. Prefabricated building and components
(Source: [illegible])

A. Literature review

The research works published by several researchers in various national and international journals regarding the behaviour of PEB are rigorously studied and offered in the following section.

Rao and Vishwanath (2014) have performed comparative analysis and design of PEB and CSB structures in Staad pro software with dynamic forces (including wind forces) and medium size openings (i.e., 5% area of openings). The responses of the PEB and CSB viz., bending moment, shear force and support reactions are determined by software analysis. The results of the study specify that the values of bending moment, shear force and support reactions of PEB get reduced by 4.96% 21.5%, and 21.3% correspondingly when related with equivalent values of CSB. Further, a reduction of 36% in the steel quantity is found in PEB as compared to CSB. The study concludes that the PEB are advantageous over CSB in reducing structural responses and also contribute in material and cost savings [7].

Somasekharan and Vaangi (2017) have analyzed and designed PEB and CSB using SAP 2000-18 software considering different sections viz., Indian standard angle, universal beam, universal column, and square hollow for determining the most economical chord section for truss based on the values of deflection. The analysis of PEB and CSB along with V, X, K and diagonal bracings was then performed to determine most economical chord section for truss considering dead, live, wind loads and assuming medium area openings (i.e., 20%). The results indicate that the PEB with K type of bracings contributes in the maximum reduction of deflection by 5.83% when equated to the deflection of CSB. The study concluded that PEB with bracing of type K performs well when compared with CSB with regard to the economic feasibility [8].

Bhadoria and Pathak (2017) have performed a comparative analysis of PEB and CSB considering varying spans ranging from 10m to 50m with an interval of 10m. The analysis of PEB and CSB for different spans viz., 10m, 20m, 30m, 40m, and 50m is carried out in Staad pro consisting of dead, live, wind, seismic loads including with medium size openings (i.e., 5 to 20%). The analysis results for the weight and cost parameters for the structures (i.e., PEB and CSB) are compared in view of finding the economic structure. The results indicates that the cost and weight of the PEB and CSB structures decreases as the span increases. Further, the weight of the PEB structure is seen to be decreased by typical value of 30%, when associated over the weight of CSB. The study concluded that the PEB structure is more economical in comparison with the CSB structure [9].

Tale and Vaangi, (2019) performed a comparative analysis of PEB and CSB structures to determine the responses with different types of bracing such as X, K, diagonal, alternating diagonal and inverted V-type. Further, the weight of the structures is also determined. The analysis of PEB and CSB was carried out by staad pro software consisting different loads and with medium size openings (i.e., 5 to 20%). The study indicated that the values of base shear and displacement get reduced by (16.94%) and (43.18%) respectively for the PEB with V-type bracings when equated with matching values of CSB. However, The natural period for PEB increases by 36% with V-type bracings. The concludes that the performance of CSB and PEB structures gets improved when these structures are provided with V-type of bracings [5].

Sai et al. (2021) conducted a comparative study on the performance of PEB on structural responses with different bay systems considering the wind zones of two different locations, i.e. Vijayawada and Hyderabad. The PEB was analyzed and designed by considering wind and seismic forces and assuming medium size openings (i.e., 5 to 20%) using Stadd Pro software to determine responses such as, shear force (SF) and bending moment (BM). Considering the magnitudes of SF and BM of PEB components as obtained by the software analysis, the geometrical properties of the components of PEB are decided for determining the weight of structures. The results of study shows that the total weight of the structure located in Hyderabad is reduced by 11.04% when equated with the weight of PEB structure located at Vijayawada. From the results, it is concluded that the wind speed and seismic zones affects the structural weight and sectional sizes of the PEB components [10].

Varma and Chandak (2022) have done analysis and design of an pre-engineered industrial warehouse structure by Staad Pro software with various loads dead, live, collateral, wind, and their combinations. The analysis was performed by assuming medium size of openings (i.e., 5 to 20%) as per the provisions of IS:875-1987 (part 3). Research results indicate that the structure of the PEB is optimized to achieve the lowest possible weight of 253 KN. Therefore, the study

concludes that the PEB structure is more economical and efficient than the CSB structure. [3]

Suthar et.al (2022) performed a comparative analysis of PEB structures with six different bracing types, viz., V, V, cross, K, X, and reverse tie. The analysis was performed using Staad pro and SAP-2000 software with different seismic zones (i.e., II, III, IV, V) and wind speeds (i.e., 39 m/s, 44 m/s, 47 m/s and 50 m/s). The assumed opening area for PEB analysis and design is 20% larger (i.e., larger opening). The responses of the PEB structure, viz., shear force, axial force, displacement and bending moment, are determined. The amount of steel taken was also obtained. From the results, it can be concluded that PEB with inverted V-bracing provides better lateral stiffness and is more economical than PEB without bracing. [11]

Gupta et al. (2022) performed analysis and design of PEB with dimensions (i.e., 120m x 35m x 24m) using ETABS software considering varying bay spacing of 5,7.5, and 10m. The analysis is performed on the structural responses, specifically shear forces and bending moments, considering all loads such as dead, operational, wind and earthquake loads and with medium size openings (i.e., 5 to 20%). The results from the study indicates that the shear force and bending moment values increases as the increase in the span by 30.16%,23.01% and 16.63%,22.37% respectively. The study concludes that the responses of structures increase as the span increases which leads to addition of steel quantity of the structure [12].

Bhamal et al. (2023) performed behavioral comparison between CSB and PEB by analyzing it in Staad Pro V8i software consisting wind and seismic loads as per the guidelines of IS:875-2015 (part-3) and IS:1893-2016 respectively. The analysis is performed on CSB and PEB having the size of 22m x 42m x13m (eave level) considering various types of bracing (such as X, V, K and diagonal) considering all seismic zones (such as II, III, IV, and V) and moderate soil types and moderate exposures (i.e., 5 to 20%). From the analysis of CSB and PEB under consideration, the results for responses viz. deflection and natural time period are determined. When compared to the values of deflection and natural time period of CSB with diagonal bracing in all seismic zones, the study's findings demonstrate that PEB reduces these factors by 20.53% and 13.41%, respectively, with diagonal bracing. Furthermore, compared to CSB with diagonal bracing, PEB with diagonal bracing uses 6.34% less steel. According to the study's findings, PEB performs better when diagonal bracing is available. [2].

Bhamal etc. (2023) examined the analytical structural behavior of the PEB with all seismic zones (i.e., II, III, IV, and V) and medium soil type, using a variety of bracing types (X, V, K, and diagonal). The Staad Pro software analyzes the PEB dimensions (22 x 44 m) to determine the most effective bracing type that can withstand wind, seismic stresses, and moderate-sized apertures (i.e., 5 to 20%). When the mean values of displacement and natural period of PEB with X, V, and K types of bracing are considered, structural responses, i.e., displacement and natural period outcomes for PEB with diagonal strain, are observed to be decreased by 13 and 15.80%, respectively. The study's findings demonstrated that the presence of transverse bracing enhances PEB performance in all seismic zones. [13]

B. Research Gap

A thorough analysis of the literature reveals that different types of bracing, including V, inverted V, diagonal, X, and K, have been taken into consideration while designing and analysing CSB and PEB structures. In addition, the study is conducted considering some specific seismic and wind zones. Furthermore, most researchers have analyzed CSB and PEB structures considering moderate opening areas (i.e., 5% to 20%). Very few studies have been conducted assuming large opening areas in exterior walls (i.e., more than 20%). Studies have indicated that the performance of PEB structures improves significantly with diagonal, X, inverted V, and K type bracing to achieve the required structural responses as well as economic feasibility. Therefore, there is a good chance to investigate how PEB behaves when given particular bracing types (such diagonal, X, inverted V, and K), and to consider for different seismic and wind zones by assuming large and moderate exposed areas in the exterior structural wall as given in IS: 875-1987 (Part 3).

C. Conclusion

Based on the literature review investigation, the following conclusions are drawn:

- Compared to CSB constructions, the total weight of PEB structures is around 10–30% less, because PEB structures are constructed using tapered built-up sections depending on the bending moment requirements. Also, PEB structures require 30-50% less construction time of the total project duration.
- PEB structures can be used advantageously for large spans up to 20m without any intermediate support.
- The behavior of PEB provided with specific type of bracing needs to be explored considering soil types for different seismic zones, wind zones and medium and large opening areas.

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A Review on Fiber Reinforced Concrete Subjected to Elevated Temperature

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***Abstract*— Nowadays, fiber reinforced concrete (FRC) is becoming more popular because of many advantages like increase in the impact and tensile strength of concrete. Use of FRC minimizes or totally eliminates the steel reinforcement in concrete. FRC is the composite material in which discrete, discontinuous, uniformly dispersed fibers are embedded in concrete. The different types of fibers can be added in concrete viz. steel, glass, polypropylene, carbon, basalt, natural fibers, etc. These fibers can be added in any type of concrete viz. self compacting concrete, high strength concrete, foamed concrete, etc. to improve the mechanical properties of concrete. FRC is used in the heavy structures like bridges, tunnel, high rise buildings, pavement, etc. There are chances of concrete getting exposed to elevated temperatures due to various reasons. Hence, there is need to study the behavior of FRC at the elevated temperatures. This paper provides the literature review on the fiber reinforced concrete subjected to the elevated temperature. From the study, it is concluded that, there is need to study the FRC with different fibers subjected to the higher temperature more than 800°C.**

Keywords*— *concrete, fiber reinforced concrete, fiber, elevated temperature, self compacting concrete, steel fibers.

I. INTRODUCTION

Fiber reinforced concrete is a building material whose utilisation in concrete industry has been rapidly increasing. One of the main building materials in civil engineering structures that may be attacked by fire during their service life is concrete, which causes serious damage to the structures and causes a significant number of casualties and property loss [1]. Hence there is need to study the effect of fire on concrete. In the heavy and congested reinforced construction, the use of self compacting concrete is very common due to the self compacting property and good workability. The self compacting concrete is the type of concrete that flows under its own weight without any external vibrations. The self compacting property is imparted by adding the mineral and chemical admixtures or by increasing the water cement ratio up to certain limit. The different workability tests are conducted on fresh self compacting concrete like L-box test, slump flow test, U-box test, J-ring test, etc. The fibers are added to the self compacting concrete to primarily impart the tensile strength to the concrete, because concrete is good in compression but weak in tension. By using fiber reinforced concrete, the conventional reinforcement can be partially or fully eliminated from the concrete. There are various types of fibers used in concrete like steel fibers, polypropylene fibers, glass fibers, asbestos fibers, carbon fibers, natural fibers like coir, sugarcane, jute, banana, etc. The purpose of each type of fiber is different for different applications.

The fibers are added in concrete to enhance the properties of concrete viz.

- To increase tensile strength
- To control crack width and increase durability
- To improve impact strength of concrete
- To minimize steel reinforcement requirement

II. EXISTING LITERATURE

Akash et al. (2022) have done study on the M25 grade concrete with coir fibers and polypropylene fibers. The fibers were added in different proportions of 0.2%, 0.4%, 0.6% and 0.8% by cement mass. The slump test was carried out on the fresh concrete. The concrete cubes of size 150mmX150mmX150mm, cylinder of 150mm diameter and 300mm height and beams of size 100mmX100mmX500mm were casted. These specimens were subjected to the temperature of 200°C. The concrete specimens were cured for 28 days. The concrete was tested for compressive strength, flexural tensile strength, split tensile strength, and modulus of elasticity before and after exposing to the temperature. From the research, authors have concluded that, coconut (coir) fibers have been improved the strength and fire resisting properties more than the polypropylene fibers [2].

Bamigboye et al. (2020) have studied the behavior of concrete fiber reinforced with the treated and untreated coconut fibers. The fibers were treated using the water and chemicals. These fibers were added in different proportions of 0.25%, 0.5%, 0.75% and 1% by the weight of cement. After preparing the concrete, slump test and compacting factor test were carried out to check the workability of concrete. Then the cubes were cured for the period of 7, 14, 21 and 28 days. The casted cubes were heated at the temperature of 150°C to 250°C for two hours. Then the compressive strength of concrete was checked before and after heating. From the study, it was observed that, the concrete strength increases up to 0.5% of fibers but beyond 0.5%, higher the fiber content, lower the strength of concrete. The authors have concluded that, the untreated fibers have been imparted higher strength than the concrete with treated fibers [3].

Novak and Kahoutkova (2017) have studied the fiber reinforced concrete at elevated temperature. For the fiber-reinforced concrete, the authors used steel fibers, synthetic fibers, and hybrid fibers (steel + synthetic). For the study, temperatures between 100°C and 1200°C were taken into consideration. The tensile and compressive strength of fiber reinforced concrete at elevated temperatures were examined. From the experiment, authors have concluded that, the compressive strength of steel fiber reinforced concrete increases up to 200°C but reduces after the further increase in the temperature. The synthetic fiber reinforced concrete negatively impacted on the compressive strength and tensile strength after exposing to the high temperature. The hybrid fiber reinforced concrete considerably improved the mechanical properties of concrete [4].

AL-Radi et al. (2021) have considered the self compacting concrete fiber reinforced with the hooked end steel fibers, polypropylene fibers and hybrid fibers (steel + polypropylene). The proportion of fibers considered was 1% by concrete volume and for hybrid fibers it was 0.5% for each type of fiber. The concrete cubes and cylinders were casted with and without fibers. The fresh concrete was tested for slump flow test, T50 test and L-box test to check the workability of self compacting concrete. After casting, the specimens were cured and exposed to the higher temperatures of 200°C, 400°C, 600°C and 800°C in electric oven with the heating rate of 5°C/min for 1 hour to ensure the attainment of same temperature throughout the specimen. The concrete specimens further tested for the compressive strength, ultrasonic pulse velocity test, spalling and mass loss before and after exposing to the temperature. From the research, it was concluded that the mechanical properties of SCC with steel fibers have been increased up to the temperature of 200°C and then reduces above 400°C. The mechanical properties of concrete with polypropylene fibers have been reduced as the temperature increases [5].

Abid et al. (2022) have used the hooked end steel fibers with varying proportions of 0.5% and 1%. The concrete cubes of size 100mm and disc of diameter 150mm and thickness 63mm were casted and cured for 28 days. The plain concrete and fiber reinforced concrete were subjected to the elevated temperature of 200°C, 400°C and 600°C in an electric furnace with heating rate of 4°C/min. Then the concrete cubes were tested for the compressive strength while discs were tested for the impact strength of concrete before and after exposing to the high temperatures. From the experiment, authors have concluded that, despite of increase in temperature, the steel fibers always improved the compressive strength of concrete by increasing the proportion of fibers. Steel fiber reinforced concrete performed better at failure stage than at cracking stage. After exposing to the higher temperature, the impact strength of concrete dramatically deteriorated [6].

Zuhair and Deshmukh (2018) have studied the performance of different types of fibers in self compacting fibers with different proportions at elevated temperature. Authors have considered the self compacting concrete of M30 grade. The concrete was fiber reinforced with steel fibers, glass fibers and polypropylene fibers with the varying proportion of 0.5% and 1%. After curing for 7 days, the concrete cubes were exposed to the elevated temperature of 400°C, 600°C and 800°C for the varying period of 2hr and 4hr in muffle furnace. The compressive strength test was carried out on the cubes after cooling to the room temperature. Authors have concluded that, steel fibers gave better results of compressive strength at all three temperatures, but the fluctuations in compressive strength were higher than that of glass fibers. Addition of fibers have been reduced the risk of spalling. It was concluded that, the higher development of compressive strength was seen in the 1% steel fiber and 0.5% polypropylene fiber reinforced concrete [7].

Benzerara et al. (2023) have studied the concrete fiber reinforced with polyethylene terephthalate fibers. The study was done by varying the percentage of fibers as 1% and 2%. The specimens of size 4X4X16 cm^3 were prepared and then exposed to the higher temperature of range 100°C, 300°C, 500°C and 700°C for 1hr in Nebertherm muffle furnace. Authors have suggested to maintain the proper heating rate as 1°C/min rate results in bursting of specimen while 0.1°C/min rate do not burst the specimen. The various properties of concrete were tested before and after applying the heat like mass loss, compressive strength and tensile strength. The microstructure of the concrete at different temperature exposure was studied by the SEM testing technique. From the SEM testing it was concluded that, the voids in concrete increases due to the evaporation of water and melting of fibers at very high temperature. From the experiment conducted, authors have concluded that the addition of polyethylene terephthalate fibers did not improve the compressive strength but it reduced the chances of spalling and cracking. Above 300°C, the compressive strength decreased more rapidly [8].

Abdul Rasool et al. (2020) have considered the concrete fiber reinforced with waste polypropylene fibers which were drawn from the strips of waste plastic drinking cups. The different sample were prepared by varying percentage of fibers like 0.5% and 1%. The cubes of size 100mm, cylinders of size 100mmX200mm and beams of size 1250mmX150mmX100mm reinforced with 12mm diameter bars and 8mm shear reinforcement were casted to perform different tests on the concrete. After curing for 28 days, the specimens were heated to 400°C in blast fire furnace. The compressive strength, split tensile strength, modulus of elasticity, density and flexural behavior was examined before and after application of heat. From the experiment, authors have concluded that the properties of concrete enhanced by the addition of polypropylene fibers up to 0.5%, further addition of fibers reduces the mechanical properties [9].

Jamaran et al. (2015) have considered the concrete of grade C40, fiber reinforced with mix of steel and polypropylene fibers. The proportion of combination of both the fibers of 1.5% was considered while casting of specimens. The 1.5% proportion was further divided among the two fibers as:

TABLE I. PERCENTAGE OF STEEL AND POLYPROPYLENE FIBERS

Sample	Percentage of fibers	
	Steel fibers (%)	*Polypropylene fibers (%)*
Sample 1	100	0
Sample 2	75	25
Sample 3	50	50
Sample 4	25	75
Sample 5	0	100

The cubes of size 150mm, prism of size 150mmX150mmX550mm and cylinders of size 150mm diameter and 300mm height were casted with the fibers. After curing for 28 days, the specimens were heated to the temperature of 200°C and 400°C for 1hr and then tested for compressive strength, split tensile strength and flexural strength. From the study, authors have concluded that, the mechanical properties of concrete got enhanced due to addition of fibers in concrete. The concrete samples having more percentage of steel fibers performed better for all the properties tested [10].

Aniis et al. (2020) have studied the effect of elevated temperature on fiber reinforced lightweight concrete. The glass fibers and polypropylene fibers with varying percentage of 0.2% and 0.4% by concrete volume were added in the concrete. After curing, the concrete was casted in following different specimens:

TABLE II. TYPE AND SIZE OF CONCRETE SPECIMEN FOR DIFFERENT TESTS

Sr. No.	Type of sample	Size of sample	Curing period	Test
1.	Cube	100X100X100mm	7, 28, 90 days	Compressive strength
2.	Cylinder	100mm dia., 200mm height	28 days	Split tensile strength
3.	Prism	100X100X500mm	28 days	Flexural strength

The slump test was performed on fresh concrete to check the workability of lightweight concrete. The specimens were heated at the temperature of 200°C, 400°C and 600°C for 2hr at heating rate of 20°C/min and then cooled down at the rate of 3°C/min. The other properties were also checked before and after exposed to temperature like unit weight, modulus of elasticity and microstructural analysis. The microstructural analysis was done by the SEM test to analyze the ITZ between aggregate and cement paste. From the study, authors have concluded that, the addition of fibers to concrete enhanced the mechanical properties of concrete to some extent. The glass fibers performed better at elevated temperature than polypropylene fibers because, the polypropylene fibers melt at 170°C [11].

Ofluman Mydin et al. (2019) have studied the effect of elevated temperature on foamed concrete fiber reinforced with coir fibers. The coir fibers were added in different percentages like 0.1%, 0.2%, 0.3%, 0.4%, 0.5% and 0.6%. The foamed concrete fiber reinforced with coir fibers were casted with the varying density of 700 kg/m^3, 1100 kg/m^3, 1500 kg/m^3 and 1900 kg/m^3. The cubes of 100mmX100mmX100mm and beams of size 100mmX100mmX500mm were casted. After 28days of curing, the specimens were exposed to the elevated temperature of 105°C, 200°C, 300°C, 400°C, 500°C, 600°C, 700°C and 800°C in an electric furnace. The specimens were tested for compressive strength and flexural strength. From the graphs, it was concluded that up to certain percentage of fibers in concrete, compressive and flexural strength increased but beyond that limit the same was decreased at all temperature range. By increasing the density of foamed concrete, the percentage requirement of fibers increased to attain the maximum compressive and flexural strength [12].

He et al. (2023) have considered the concrete fiber reinforced with the hybrid fibers. The two sets of hybrid fibers were considered for the study, one is the combination of long hooked end and medium hooked end steel fibers, high strength short wave shaped steel fibers while in other set the high strength short wave shaped steel fibers were replaced by the polypropylene fibers. From this concrete, cylinder of diameter 100mm and height 200mm were casted. Then the specimens were subjected to the high temperature of 200°C, 400°C, 600°C and 800°C for 2hr at heating rate of 1°C/min. The specimens were cooled down at the rate of 1°C/min. After cooling the specimens subjected to 400°C and 600°C were recured in water for 3 weeks. The specimens were tested for the compression stress strain curve. The water evaporation ration was determined to check the effect of recuring on concrete. The damage degree of concrete after exposing to elevated temperature was calculated to evaluate the deterioration of concrete from the ultrasonic pulse velocity. The other properties were also considered to check the performance of concrete fiber reinforced with hybrid fibers like elastic modulus and toughness. From the experiment conducted, authors have concluded that, the properties of concrete slightly enhanced by the addition of hybrid fibers before and after exposing to the elevated temperature. The concrete containing short wave shaped steel fibers gave better results than with polypropylene fibers due the lower melting point of polypropylene fibers [13].

Prateek et al. (2020) have considered concrete of M30 grade concrete fiber reinforced with coconut fibers. The quantity of coconut fibers added was 2% by the weight of cement. The different types of specimens required for different tests were casted as follows:

TABLE III. TYPE AND SIZE OF CONCRETE SPECIMEN FOR STRENGTH TESTS

Sr. No.	Type of specimen	Size of specimen	Test
1.	Cube	150mmX150mmX150mm	Compressive strength, Durability
2.	Cylinder	150mmX300mm	Split tensile strength
3.	Beam	100mmX100mmX500mm	Flexural strength

These specimens were cured for 7days and 28days. After curing, the concrete was exposed to elevated temperature of

200°C, 400°C, 600°C, 800°C and 1000°C for 2hr in an electric furnace at the heating rate of 10°C/min. Then the test for compressive strength, split tensile strength, flexural strength and loss of weight were carried out on the concrete. To check the performance of concrete fiber reinforced with coconut fibers in aggressive environment, concrete cubes were immersed in sulphuric acid, sodium sulphate solution and sodium chloride each with concentration of 10% and each for test period of 30 and 60 days. From the experiment, authors have concluded that, the compressive strength of concrete reduced after exposing to the aggressive environment as well as elevated temperature. There was more loss weight when immersed in acid than in sulphate and chloride solution [14].

Dawood et al. (2019) have used lightweight foamed concrete fiber reinforced with carbon and polypropylene fibers. The seven types of samples were casted by varying the percentage of fibers in concrete as:

TABLE IV. PERCENTAGE OF CARBON AND POLYPROPYLENE FIBERS

Sample	Percentage of fibers	
	Carbon fibers	*Polypropylene fibers*
Sample 1	0%	0%
Sample 2	0.5%	0%
Sample 3	1.0%	0%
Sample 4	1.5%	0%
Sample 5	1.0%	0.5%
Sample 6	0.5%	1.0%
Sample 7	0%	1.5%

The cubes of size 100mm, cylinder of diameter 100mm and height 200mm and prism of size 40mmX40mmX160mm were casted and cured for 90 days. Then the specimens were heated at temperature of 200°C, 250°C, 300°C, 350°C and 400°C for 1.5hr at the heating rate of 10°C/min in an electric furnace. The specimens were tested for compressive strength, flexural strength, flexural toughness and split tensile strength. From the experiment, authors have concluded that the concrete containing more percentage of carbon fibers performed better in each test conducted, because the polypropylene fibers get melted and evaporated at very low temperature. The carbon fibers were helpful to bridge micro cracks whereas polypropylene fibers to bridge macro cracks [15].

Patel et al. (2021) have studied the effect of elevated temperature on high strength concrete fiber reinforced with polypropylene fibers. The fibers were added in the amount of 0.5% by volume of concrete. The concrete specimens were prepared by varying the water cement ratio as 0.47, 0.36 and 0.20. After curing for 28 days, specimens were exposed to elevated temperature of 400°C and 600°C for 1hr in electric furnace at the heating rate of 5°C/min. The different properties of concrete like compressive strength, modulus of elasticity, split tensile strength and Poisson's ratio were tested before and after exposing to elevated temperature. From the experiment, authors have concluded that, there was no significant enhancement in the mechanical properties of concrete by the addition of polypropylene fibers [16].

Abadel et al. (2023) have considered ultra-high performance concrete fiber reinforced with different types of fibers. The hooked end fibers, polypropylene fibers, polyvinyl alcohol fibers and hybrid of these fibers were used to study in varying proportions. Fresh concrete was tested for slump test to check the workability of concrete. Then the concrete was casted in the cylinder of size 100mmX200mm and prism of size 150mmX150mmX600mm. After curing for 28 days, specimens were heated to the temperature of 100°C, 300°C, 400°C and 500°C for 3hr at the heating rate of 8°C/min. Then the compressive strength, split tensile strength and flexural strength of concrete was tested. The properties like unit weight, mass loss, elastic modulus was also considered for study. The microstructural analysis by SEM technique was also done on concrete. From the experiment, authors have suggested to increase the fiber content in concrete to improve the performance at elevated temperature. The concrete containing only steel fibers performed better for all the tested properties at elevated temperature [17].

Maytham Shaker and Abbas AL-Ameeri (2023) have studied the combined effect of loading and elevated temperature on concrete fiber reinforced with hooked sand steel fibers which were added in the proportion of 1% by the volume of concrete. The cubes of size 100mmX100mmX100mm and prism of size 100mmX100mmX400mm were casted with and without fiber reinforced concrete. The specimens were cured for different periods of 28 days, 56 days and 90 days. After curing the compressive and flexural tests were performed by applying 0%, 20%, 40% and 60% of ultimate load. Then the specimens were subjected to elevated temperature of 30°C with heating rate of 10°C/min while to 500°C with 17°C/min of heating rate. The specimens were put at the constant elevated temperature for 2hr and then cooled down to the room temperature. After cooled down, the specimens were again subjected to compressive and flexural tests until failure of concrete. The ultrasonic pulse velocity test was carried out before and after application of sustained loading elevated temperature. From the experiment, authors have concluded that, the compressive strength of concrete slightly decreased by changing loads at same temperature [18].

III. SUMMARY OF LITERATURE

From the literature review, extensive study on fiber reinforced concrete at elevated temperature has been done. In previous studies, research have been carried out on the normal fiber reinforced concrete and self compacting fiber reinforced concrete for the grade of concrete up to M35. Most of the researchers have considered the temperature range up to 600°C only and very few researchers have considered the temperature range up to 800°C but in fire accidents the temperature may rise beyond 1000°C. The most of the study have been done by using steel fibers, polypropylene fibers and glass fibers. Some researchers also considered the use of plastic waste as fibers in concrete in the form of thin strips. But no any research has been carried out by using e-waste as fibers in concrete. Hence there is a scope of study of using fibers from e-waste in the concrete at elevated temperatures.

IV. CONCLUSION

From the study of literature review, following conclusions are drawn:

- Fiber reinforced concrete is more advantageous due to its great performance in imparting the tensile and impact strength to the concrete.
- Most of the authors have studied the steel fibers for short term effect and concluded that steel fiber reinforced concrete performs better than all other fibers in concrete at room as well as elevated temperature. However long term performance of FRC must be checked as steel fibers might be prone to corrosion.
- There is a scope of study of e-waste fiber reinforced concrete at elevated temperature as some parts of e-waste like resistors having very high melting point contain the metals which may improve the mechanical properties of concrete at some extend.
- There is scope to study the long term performance of FRC in strength and durability.

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Investigating the Impact of Water Pressure on Bridge Pillars Made with Reinforced Concrete Using Univariate Regression Analysis

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***Abstract*— Material properties and structural connection In fact, the precise assessment of water performance in concrete structures requires an overall understanding of both material factors and structural links. Many methodologies and formulas based on established codes, have been developed to determine the water pressure acting upon highway bridge piers. The purpose of this research is to construct a data-driven model for predicting the water pressure on highway bridge piers, and at the same time compare it with other existing models. As such, we intend to determine which method works best and find out if one can be recommended over all others. Research samples involving water pressure on highway bridge piers were gained using computational fluid dynamics analysis. On the basis of this information, Poisson regression models were developed to forecast water pressure on piers. Also, two common codebased equations were used to predict water pressure on highway bridges; they serve as reference points for comparison with our results. These step-by-step datadriven models had been checked for accuracy and effectiveness by a comparison of the predicted water pressures with those obtained from simulations based on computational fluid dynamics. Model performance was evaluated with the following statistical evaluation metrics: mean square error, absolute deviation, absolute percentage and relative proportion (coefficient of determination), root mean square. The results showed that all models could predict water pressure acting on highway bridge piers within certain limits. Also, as for precision and reliability for the purpose of comparisons with two standard codebased equations (1) The first Poisson regression model is more adaptive to variable photogrammetric results than some other commonly used function In contrast, etc., the grounding in actual data made them superior on all counts. A univariate regression-based method was used to determine a unique relationship between water pressure and velocity, taking account of the influence that depends on speed. In this way one can avoid errors and design for more robust mathematical equations.**

Keywords— Water pressure, Highway bridge piers, Datadriven models, Computational fluid dynamics analysis.

I. INTRODUCTION

Water pressure assessment is critical to the strength and life of reinforced concrete bridge piers. Estimates of water pressure are an important step in the design construction of strong bridges. The alternative to modern modeling concepts is traditional methods, which work with empirical formulae and equations used in computer code that the designers often find difficult to write. Such techniques cannot fully reflect water pressure's complexities. In order to avoid this restriction, work is done suggesting that one use the univariate regression analysis of water pressure on reinforced concrete bridge piers.

To see how closely a single independent and dependent variable are related, we use univariate regression analysis [1]. Through this method, a numerical model that can well predict water pressure is sought by examining its relationship with all aspects of data on water pressure and related factors such as flow velocity and pier geometry. regression analysis splits the relationship among independent variables.water pressure On this basis, it determines how different parameters affect water pressure.

This research tests the effectiveness of univariate regression analysis for analysis of water pressure on reinforced concrete bridge piers [2]. The trustworthiness of the water pressure model has been determined through use of data and regression modeling in this study. This research may be used by bridge construction engineers and designers when making informed decisions design of bridges piers needs. Bridge maintenance also benefits greatly from this work.

This work also introduces one-way regression analysis that can be used in enhanced water pressure measurement for reinforced concrete bridge piers. This study may be used to strengthen the design of bridges, thereby making them safer and more resistant under many water conditions.

Most studies on bridges at risk of flooding have, however, worked in the opposite direction. Through measuring conductivity rather than currents [3]. In hydrodynamics, Waterdrift, net power and Reynolds number form the main flow variables; phenomenological models are used to describe flows with variable viscosity [4]. The problem suggests that investigations into fluid and structure interaction should be carried out [5]. Bridges face floods and particle loading under water loading [6]. Due to climate change, experts are reevaluating bridge rules due to rising floods [7]. Numerical and experimental investigation of stream velocity near a circular pier was conducted. Bridge constructions' water impact responses must be carefully examined before determining their structural integrity [8].

This paper uses univariate regression analysis to derived estimates of water pressure on a reinforced concrete bridge pier. Analytical approach to determine mathematical model of correct pier water pressure. A single independent variable (flow velocity or water depth) will be studied, and the relationship between that factor and pier water pressure is to be examined. With this technique, water pressure is studied in detail from the aspect of effects on it imparted by independent variables. Once a predictive model is established for these characteristics derived through study and research techniques common elsewhere today, one can be expected to have an accurate prediction system based on all available instrumental

data at that time before logistic regression analysis was developed later than others primary or secondary elements such as I hope this univariate regression study will aid us in understanding and calculating water pressure acting on reinforced concrete bridge piers. These insights will enhance this field's design and management methods.

II. CASE STUDY

A. *Aankali Bridge*

This research considers a bridge on the Nagpur Ratnagiri National highway under construction across the Krishna River in Maharashtra, India. The bridge itself is famous for its vital position and the important role of smooth transit that plays. Connecting southwestern Maharashtra with Marathwada and Vidharbh, this structure makes traffic flow easy both ways.

In 2005 and in a more severe flood that hit Western Maharashtra again in May, this bridge was swallowed. It's a 9.75-meter bridge with two lanes and one pedestrian walkway.It is a 270.36meter highlevel bridge with seven somewhat exposed spans. Two abutments support the bridge at 8meter intervals throughout its length, with centertocenter spans of 24.08 to 25.45 meters.

The bridge was built in 1998–1999 with an opentype base and reinforced concrete columns. This study used a simulation model to correctly portray a reinforced concrete bridge.

Examination and research of this bridge's behavior reveal its reactions to different loading circumstances and environmental influences. These results may improve the design, building, and maintenance of comparable bridges, improving vital transportation infrastructure safety and durability.

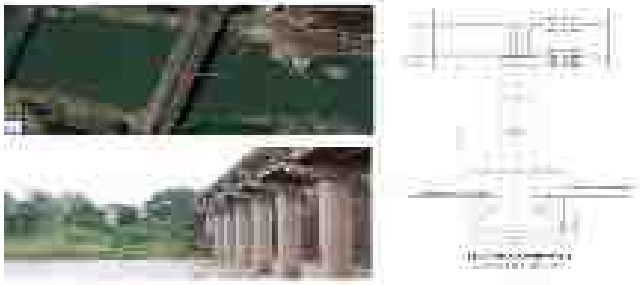

Figure 1, Aankali Bridge bridge on the Nagpur Ratnagiri National highway under construction across the Krishna River in Maharashtra, India

B. *Details of Bridge Modeling*

Water flow rates varied during the trial. The flow domains, X, Y, and Z, were 21 meters, 23 meters, and 21.145 meters. As shown in Figure 4, a 21.145meter flow domain was used in the submerged condition. All models were supposed to increase velocity by 0.5 m/s. The C.F.D. study, shown in Figures 5 and 6, confirmed that the bridge piers' pressure distributions were mostly uniform, with negligible differences at the higher and lower areas exposed to water flow. The pier crosssection design significantly affected bridge pier water pressure during flood occurrences. Figure 1 shows the CFD pressure resultfol from of Aankali pier.

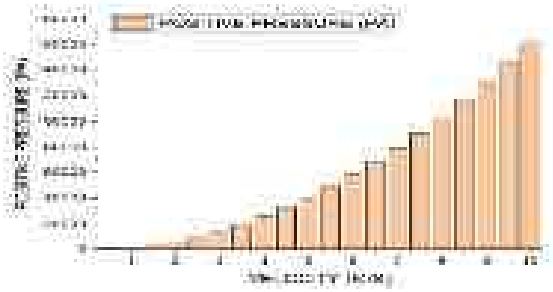

Figure 2. Aankali bridge circular pier CFD results

III. DATA DRIVEN MODELS

This project aims to develop datadriven models to estimate bridge pier water pressure load capacity and evaluate their accuracy and application. Numerical data from C.F.D. research is used to do this. Using the same dataset, Poisson regression models predict water pressure load capacity and compare them to design code equations. For comparison analysis, R2, M.S.E., M.A.D., R.M.S.E., and M.A.P.E. are used (Thai, 2022). These parameter indices evaluate Poisson regression model dependability (Allen, 2019). These equations and the Poisson regression model allow researchers to predict bridge pier water pressure load without resourceintensive and timeconsuming tests.

The results of this study help evaluate bridge pier water pressure load capability. A Poisson regression modelbased technique may help engineers and researchers make educated bridge pier design and maintenance choices. By accurately predicting water pressure load, bridge constructions may be made safer and more resilient.

A. *Comparative Analysis of Pressure Standards: A Study of Indian and International Codes*

Formulas for Calculating Water Pressure During Flow:

Australian Standard Code for Bridge Design Specifications (AS 5100.2 2017)[10]

$$F_{Drag} = \frac{1}{2} C_d \rho V^2 A_d$$

Indian Road Congress for Design of Highway Bridges (I.R.C. 6 2016) [11]

$$P = 52 K V^2$$

Where

P is the water pressure,

ρ is the density of water, and

v is the velocity of water flow.

B. *Poisson Regression Model (P.R.M.):*

- Predictive Modeling using Poisson Regression:

  The Poisson regression model (P.R.M.) quickly links a dependent response variable to a small set of independent continuous predictors. Poisson regression models differ from other regression models because

the dependent response variable has a Poisson distribution.

- The Poisson regression model can handle situations with several independent input predictors, reducing multicollinearity difficulties when fitting multiple regression models. A Poisson regression model is rigorously fitted to the analytical data using Minitab statistical software to anticipate the bridge pier's water pressure loadcarrying capacity (Minitab, 2023).

- circular pier descriptive statistics calculated and predicted water pressure load capacity data's statistical features. The Poisson model uses the 'log' link function with a 95% confidence level and 5% significance level ($\alpha = 0.05$). Resulting regression equations (1) and (2):

Regression equation for circular pier

$$P = e^{V'} \qquad (1)$$

$$V' = 7.21 + 0.852\,V - 0.037\,V^2$$

These regression equations in fact provide much knowledge as to how the bridge's pier water pressure load capacity can be predicted, and prove a mathematical vehicle with which we can see ahead when changes occur. Bringing in the requisite predictors, such as water flow velocity, into use makes these regression equations a better aid for our comprehension of how factors related to this body influence upon what follows- water pressure on the bridge pier. Such predictive modeling can also make a big difference to intelligent decisionmaking in design, construction and maintenance of the bridge structure so as ultimately improving its safety and resilience. Let's break down the interpretation of each:

Figure 3. Descriptive statistics of data for circular pier

1. Water Velocity (m/s):

- Minimum: The smallest observed value for water velocity is 0 m/s.
- Maximum: The highest observed value for water velocity is 10 m/s.
- Range: The difference between the maximum and minimum values is 10 m/s.
- Mean: The average water velocity is 5 m/s.
- Standard Deviation (S.D.): The measure of the amount of variation or dispersion in water velocity values is approximately 3.102 m/s.
- Coefficient of Variation (CoV): The relative variability of water velocity, expressed as a percentage, is 62.05%.

2. CFD Pressure (Pa):

- Minimum: The smallest observed value for CFD pressure is 0 Pa.
- Maximum: The highest observed value for CFD pressure is 161,900 Pa.
- Range: The difference between the maximum and minimum values is 161,900 Pa.
- Mean: The average CFD pressure is 55,232 Pa.
- Standard Deviation (S.D.): The measure of variation in CFD pressure values is approximately 52,031 Pa.
- Coefficient of Variation (CoV): The relative variability of CFD pressure, expressed as a percentage, is 94.2%.

3. Regression Equation (Pa):

- Similar interpretation as CFD Pressure for the regression equation derived pressure values.

4. Pressure Derived from AS 5100 (Pa):

- Similar interpretation as CFD Pressure for the pressure values derived from Australian Standard 5100.

5. Pressure Derived from I.R.C. 6 (Pa):

- Similar interpretation as CFD Pressure for the pressure values derived from Indian Road Congress (I.R.C.) 6.

These statistics offer insights into the central tendencies, variability, and overall distribution of each variable, aiding in a comprehensive understanding of the dataset. The Coefficient of Variation provides a relative measure of variability as a percentage of the mean, allowing for comparisons between variables.

IV. Comparing Estimated Water Pressure Capacities Entails Evaluating Statistical Factors From Analytical Data

Comparing estimated water pressure capacities entails evaluating statistical factors from analytical data, notably mean, standard deviation, and coefficient of variation. These features reflect the main tendencies and range of water pressure capacities predicted by different models.

1. Mean: Average water pressure capabilities (mean). Means comparisons show each method's center. larger numbers mean greater water pressure anticipated. 2. Standard Deviation (S.D.): Interpretation: standard deviation reflects the spread of anticipated water pressure capabilities. A lower standard deviation means closer estimations to the mean, or greater accuracy and consistency. 3. Coefficient of Variation (CoV): In other words, the coefficient of variation is a percentage that compares variability to mean. A smaller coefficient of variation indicates a more stable and consistent estimating procedure, while the larger value shows greater relative variability. Statistics of methods can also be compared by researchers and

engineers to assess the robustness, correctness or reliability in water pressure capability estimates.

Consistency in mean values, fewer standard deviations, and lower coefficients of variation boost predictive model or analytical method confidence. These statistical characteristics must be considered together to assess the applicability and accuracy of anticipated water pressure capabilities. Histograms and box plots help enhance statistical comparisons to better understand data distribution.

Arithmetical Parameters for Comparison: AS 5100, IRC 6, P.R.M.

1. Mean Absolute Deviation (M.A.D.):

AS 5100: The Mean Absolute Deviation for AS 5100 is 34,099.57, indicating the average absolute difference between each estimated value and the actual value.

IRC 6: The Mean Absolute Deviation for IRC 6 is 43,728.478, representing the average absolute deviation of estimates from the true values.

P.R.M.: The Mean Absolute Deviation for the Poisson Regression Model (P.R.M.) is 2,697.031, signifying the average absolute difference between predicted values and actual values. Lower M.A.D. values suggest better accuracy.

2. Mean Squared Error (M.S.E.):

AS 5100: The Mean Squared Error for AS 5100 is 2,147,546,802, reflecting the average squared difference between estimated and actual values.

IRC 6: The Mean Squared Error for IRC 6 is 3,529,731,722, indicating the average squared deviation of estimates from true values.

P.R.M.: The Mean Squared Error for the Poisson Regression Model is 12,252,433.52, representing the average squared difference between predicted values and actual values. Lower M.S.E. values suggest better precision.

3. Root Mean Squared Error (R.M.S.E.):

AS 5100: The Root Mean Squared Error for AS 5100 is 46,341.631, providing the square root of the average squared difference between estimates and actual values.

IRC 6: The Root Mean Squared Error for IRC 6 is 59,411.545, signifying the square root of the average squared deviation of estimates from true values.

P.R.M.: The Root Mean Squared Error for the Poisson Regression Model is 3,500.348, representing the square root of the average squared difference between predicted values and actual values. Smaller R.M.S.E. values indicate better accuracy.

4. Mean Absolute Percentage Error (M.A.P.E.):

AS 5100: The Mean Absolute Percentage Error for AS 5100 is 58.713%, providing the average percentage deviation of estimates from actual values.

IRC 6: The Mean Absolute Percentage Error for IRC 6 is 75.355%, signifying the average percentage deviation of estimates from true values.

P.R.M.: The Mean Absolute Percentage Error for the Poisson Regression Model is 30.17550999%, indicating the average percentage difference between predicted values and actual values. Lower M.A.P.E. values suggest better accuracy.

In summary, these arithmetical parameters offer a quantitative comparison of the performance of different estimation methods (AS 5100, IRC 6, P.R.M.) in predicting water pressure capabilities. Lower values for M.A.D., M.S.E., R.M.S.E., and M.A.P.E. generally indicate more accurate and precise estimates.

Conclusion

This study's analysis, verification, and comparison generated significant findings for future research and practice. Key results are as follows:

1. The aim of building Poisson regression models (P.R.M.) based on C.F.D. pressure data to estimate highway bridge pier water pressure during floods was achieved.

2. These models regularly provide valid and positive findings without null or unfavorable results.

3. Statistical metrics, especially 0.995 R^2, show P.R.M. models' correctness and applicability. These figures show a strong connection between observed and anticipated water pressure capabilities. AS 5100 and I.R.C. equations have R2 values of 0.994 and 0.993, respectively, matching pier water pressure capabilities.

4. Comparison of error histograms shows that the P.R.M. model predicts with the lowest residual values, equivalent to analytical models. AS 5100 and I.R.C. 6 equations, alternate models, also match capabilities.

5. The P.R.M. model beats others with low MAD, M.S.E., R.M.S.E., and M.A.P.E. values. This shows that the P.R.M. model estimates bridge pier water pressure-bearing capacity better than the AS 5100 and I.R.C. 6 equations.

6. The findings show that data-based Poisson regression models successfully predict bridge pier water pressure load capacity. These models provide more accurate predictions than AS 5100 and I.R.C. 6 equations. Thus, any of these models may predict bridge pier pressure under water loading.

This study helps anticipate bridge pier performance, improving flood-prone bridge safety and dependability.

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Dynamic analysis of RC building with different types of steel bracing

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***Abstract*— In High-rise or Multi-story buildings Gravity loads, and lateral forces caused by wind or earthquakes play an important role in the design. For this reason, most buildings are designed with systems resistant to lateral forces to prevent the effects of earthquake forces. In this study, ETABS software was used to identify and analyze reinforced concrete structures with different types of bracing (Diagonal, V-shape, Inverted V-shape, Cross-shape), and the response spectrum method was used. The performance of the building is analyzed for Zone III to lateral displacement, story drift, and time period. The analysis showed that steel cross systems are the most effective for reducing displacement for reinforced concrete buildings.**

Keywords*—Bracing, dynamic analysis, lateral displacement, time period, story drift, ETABS

I INTRODUCTION

In addition to primary gravity loads, structures are subjected to earthquake forces in the lateral direction in seismically active areas. Earthquake intensity and structural properties influence the structural performance during an earthquake. High-rise buildings require foundations that can withstand and support heavy gravity loads. The main factor during the design of high-rise buildings is to withstand the horizontal loads imposed by winds or seismic excitations. The bracings and shear walls might be provided in a structural frame that offers more prominent lateral rigidity to withstand lateral stresses [1]. In areas known for earthquakes, buildings must handle more than just gravity's pull. They also deal with sideways tremors from the quakes. How a building acts in an earthquake relates to the quake's power and the building's traits [2].

The bracing system was connected with truss elements as arranging elements in the structure. The bracing is mostly used in side-mounted structures. It resists the lateral loads, especially in pressure or stress with joints. It turns the assembly method more resistant to forces in the lateral direction. This also changes the structure stronger on the sides [3]. Structural bracing can take various forms. The main job of bracing is to lessen outside bending, manage shakiness, and spread-out materials in the structure. This ensures total firmness and honesty. Patil and Sangle aimed to assess the seismic behavior of various bracing systems in 2-D steel high-rise buildings with different heights (15 to 35 stories). Nonlinear static pushover analyses were conducted to evaluate structural performance. We looked at five types of bracing systems. They were: moment-resisting frames (MRFs), X-braced frames (XBFs),chevron-braced frames (CBFs), V-braced frames (VBFs), and zipper-braced frames (ZBFs). We wanted to see how these different systems affect a building during an earthquake. We checked out various factors. These included the type of bracing system, the height of the building, and the direction of the loads on the building. The results were clear. The CBF, VBF, and ZBF were better than the MRF. This was true when we looked at how much the building moved, how much each floor moved relative to the one below, how much force was felt at the base of the building, and overall performance. The bottom line is this - using a CBF, VBF, or ZBF can really help a tall steel building to withstand an earthquake. Davaran and Hoveidae investigates how details in the middle of the process can effect the flexible-rigid activity of X-braces made with added parts. It checks a new idea of a balanced mid-connection detail against a usual one. It's typical for one brace in the X to stop at the mid-connection. The new idea is about changing which brace gets cut off at the middle. Nonlinear static finite element analysis of single span and single-story cross-braced systems reveals that proposed mid-connection detail enhances both strength and ductility compared to the common detail. Additionally, adding cover plates to the common detail can partially improve overall system behavior.

There are many types of support and the choice depends on the requirements of the particular case, construction considerations, and the nature of the strength required. Support systems are integrated into a building designed to resist horizontal movement and prevent excessive swaying or deformation under adverse conditions. There are several types of bracing systems used in structural engineering to enhance the stability and strength of buildings and other structures. The choice of bracing type depends on factors that anticipated loads, the type of structure, local building codes, and architectural considerations. Here are some common types of bracing:

1. Diagonal bracing
2. Cross bracing
3. Inverted V bracing
4. V bracing

After using this type of bracing we can reduce the lateral displacement.

II METHODOLOGY

The research method used modeling and analysis of the building's structure. Braces were positioned at key points to reinforce the model. Specifically, corner bracing was utilized in five structural models. In this work analysis, the design of a residential building is carried out using software E-Tabs against all possible loading conditions as per guidelines given in IS 456 & IS 875. Figures 1 and 2 display the 10-storey building's layout and 3D model. Model 1 has no bracing system, while Model 2 has cross bracing as shown in figure 3 which was studied to improve stability against lateral forces. The building structure was provided with the V

bracing type as shown in figure 4. Model 3 is prepared using Inverted V bracing as shown in figure 5. Model 4 is the position of diagonal bracing as shown in figure 6.

Fig. 1 Plan of a 10-story building

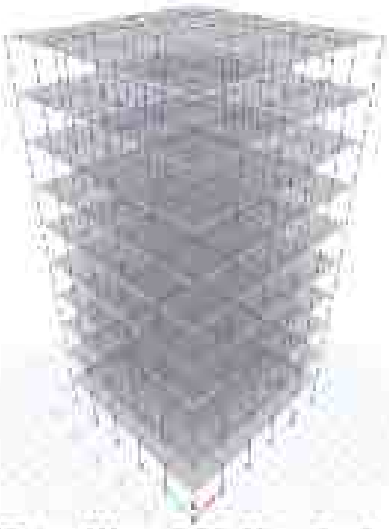

Fig. 2 3D view of 10-story R.C. building without bracing

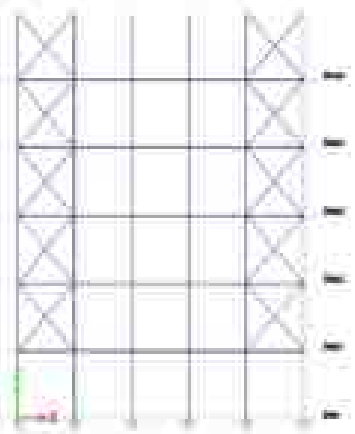

Fig. 3 Elevation in Cross-type bracing

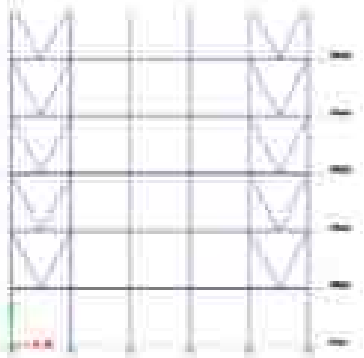

Fig. 4 Elevation in V-type bracing

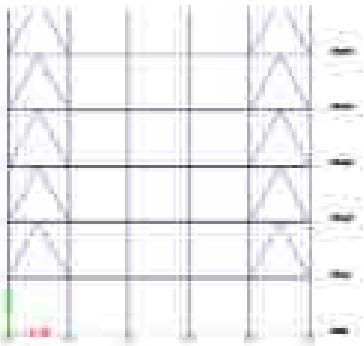

Fig. 5 Elevation in Inverted-V type bracing

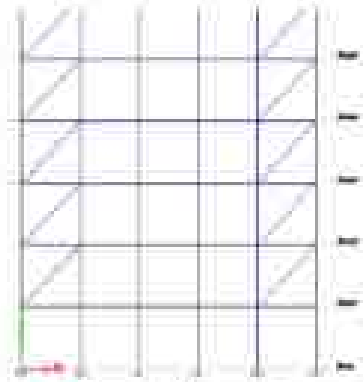

Fig. 6 Elevation in Diagonal type bracing

III Building Data

This study models and analyzes a 10-story reinforced building with Cross, Diagonal, V-shaped, and Inverted V-shaped bracing. ETABS software was used in this study. Building dimensions for the 10-story R.C. building is 15 m x 15 m. Building story height is 30m. Seismic data is shown in Table 1 and Preliminary data in Table 2.

Table I: Seismic data

S. no	Model description	
1	Zone	III
2	Zone factor	0.16
3	Soil type	2
4	Response reduction factor (R)	4
5	Impact factor	1.2
6	Damping ratio	5%

Table II: Preliminary data

S. No.	Variable	Data
1	No of story	10
2	No of bay in the X- direction	6
3	No of bays in the Y-direction	6
4	Length along x direction	3 m
5	Length along y direction	3 m
6	Floor height	3 m
7	Beam size	300 x 400 mm
8	Column size	700 x 700 mm
9	Slab	125 mm
10	Grade of concrete	M30
11	Grade of steel	Fe 415
12	Steel for bracings	Fe 345
13	Load Cases	L.L, D.L, EQ X, EQ Y, RSP X and RSP Y

IV. RESULT AND DISCUSSION

The assessment involves the evaluation of outcomes across various bracing types, including maximum displacement, story drift, and time period.

Story Displacement

Figure 7 shows the displacement in the x direction. Compared with ordinary structures, the use of Cross and Inverted V-shaped supports can reduce the maximum displacement of the building.

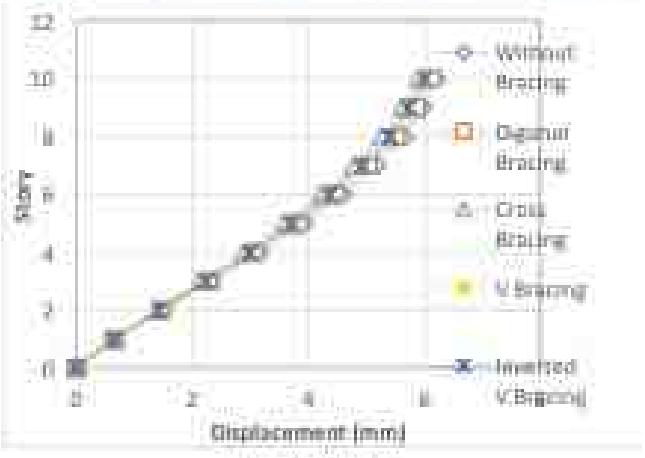

Fig. 7 Displacement

Story Drift

According to IS: 1893-2016, Section 7.11.1, the highest story drift allowed is 0.004h [6]. In this scenario, the story height, or "h", is 3 meters. Therefore, 0.004 x 3 equals 0.012. After testing, each of the five different building structures demonstrated a story drift of less than 0.012. This indicates safety. Figure 8 shows the story drifts in the X direction. The middle floor has a higher story drift, and the top floor has a lower one.

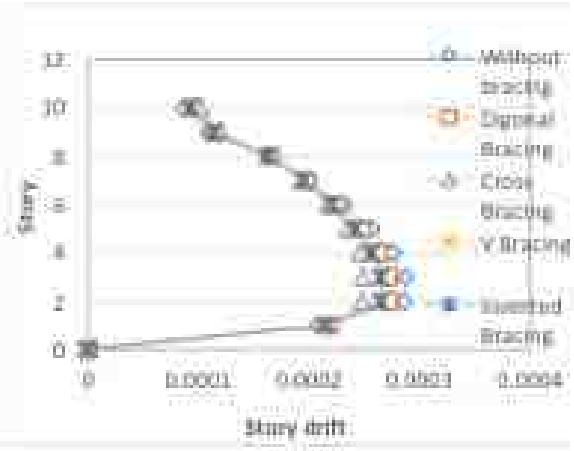

Fig. 8 Story drift

Time Period

Figure 9 shows the time period. Compared with ordinary structures, the use of Cross bracing can reduce the time period of the building.

Fig. 9 Time Period

CONCLUSION

The dynamic study was carried out on R.C. structure with Diagonal, Cross, V-type, and Inverted V-type supports and the following results were obtained through response spectrum analysis of five different buildings.

• Cross brace systems are effective in reducing displacement. Since there are multiple supports along the X direction, the Cross support performs well in terms of lateral displacement along the X-axis.

• Story drift is higher in the middle level and lower in the top level of Cross bracing and Inverted V-bracing.

• After the use of Cross bracing and Inverted V-bracing the time period is reduced as compared to the bare frame.

As a result of the analysis, it was concluded that buildings supported by Cross and Inverted V-bracing supports are the best.

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Review on Advancement in Stress-Strain Models for Stainless-Steel in Composite Structural Members

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***Abstract*—The developments in computer numerical computation abilities and the extensive availability of finite element (FE) software have facilitated the increased utilization of analytical and numerical modelling in structural engineering. It has resulted in greater collaboration between civil engineers and researchers. An essential first step in developing these numerical simulations is accurately defining the material's stress-strain properties. As a result, researchers continually work to create mathematical equations that accurately predict how materials behave. This article systematically examines commonly used stress-strain models relevant to stainless steel in composite members. It helps in developing dependable models for finite element analysis.**

Keywords— stress-strain models, stress-strain relationship, stainless steel, composites, Finite Element Analysis

I. INTRODUCTION

Stainless steel is considered a premium material due to its cost, which is approximately three to five times greater than carbon steel (Baddoo 2008; Gedge 2008). However, the notable qualities of this material, such as its outstanding strength, capacity to withstand fire and corrosion, and low maintenance requirements, have gained importance for structural constructions. As a result, it has been used in various constructions (Gardner 2005; Young 2008). To effectively maximize the use of stainless steel while reducing its high expenses, a recommended method is to utilize it as the external tubes of Concrete-Filled Double-Skin Tubular (CFDST) members (Real et al. 2014; Tao et al. 2011; Wang and Han 2019; Wang et al. 2018). An example that demonstrates the use of this application may be seen in the Gateway Arch, located in St. Louis, Missouri. CFDST columns, with exterior stainless steel tubes, were utilized in this case. Structural engineers can take advantage of the diverse chemical compositions and heat treatment procedures available for stainless steel, allowing them to use several grades of this material. The European code (Eurocode 4 1994) and American ASTM (ASTM-A959, 2004) codes provide three main classifications of stainless steels that are appropriate for structural purposes: ferritic, austenitic, and duplex (austenitic-ferritic), with each category comprising several grades. The Chinese code GB/T 20878 (GB/T 20878,2007) does not explicitly include Duplex stainless steel. Unlike carbon steel, stainless steel shows unique stress-strain properties. The stress-strain curve for stainless steel typically exhibits a nonlinear response similar to that observed in cold-formed steel and aluminium.

Moreover, stress is not easily distinguishable when stainless steel reaches its yield. Therefore, the 0.2% proof stress is commonly considered the nominal yield stress. Fig. 1 represents stress-strain curves, illustrating the contrast between mild carbon steel and different stainless steel varieties (SCI 2017). This paper focuses on the study of the advancement of various stress-strain models given by researchers that are useful for calculating stress-strain parameters of stainless steel types mentioned above.

II. LITERATURE REVIEW

Multiple analytical models are available to characterize the nonlinear stress-strain relationship observed in various stainless steel grades. Ramberg and Osgood (W.Ramberg and W.R.Osgood 1943) proposed a fundamental model that precisely predicts the entire range of the σ-ε curve for stainless steel used by (Arrayago et al. 2015a). This model effectively captures the curve's curved shape and considers the strain-hardening behaviour. This model has been utilized in finite element (FE) simulations of composite columns carried out by researchers including (Elchalakani et al. 2002), (Hassanein and Kharoob 2014), Wang and Han (Wang and Han 2019) and (Liang 2017). Nevertheless, a drawback of this model is its inability to accurately depict the σ-ε curve across its complete range by relying solely on a single strain hardening parameter (n). Essentially, the model accurately predicts the behaviour of stainless steel until it reaches the 0.2% proof stress ($\sigma_{0.2}$). However, inconsistent predictions of experimental values occur when stresses exceed $\sigma_{0.2}$, as seen in Fig. 2.

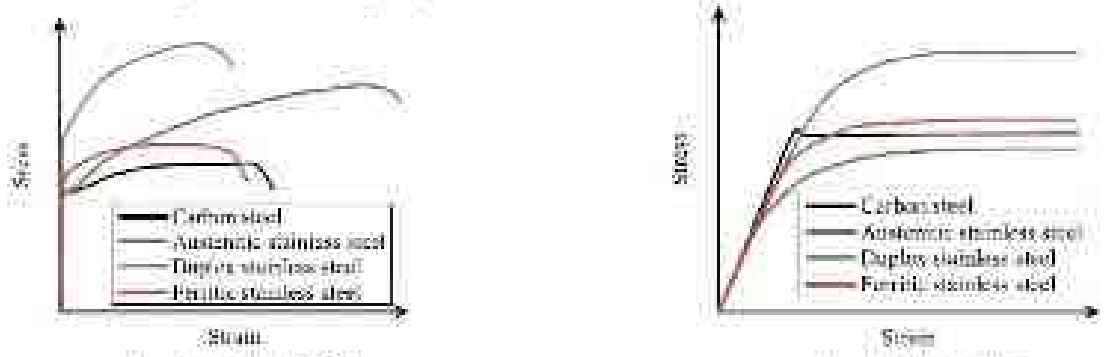
As a solution to the previously mentioned limitation, many two stages of Ramberg-Osgood models have been developed to tackle the problem of forecasting the stress-strain curve of stainless steel over the entire loading range, which includes the beginning of loading up to the final tensile stress, using a single continuous model. Mirambell and Real (Mirambell and Real 2000)introduced a two-stage model based on the Ramberg-Osgood equation, which covers the range up to the yield strength and includes an additional Ramberg-Osgood curve beyond the yield strength. Later, Rasmussen (Rasmussen 2006) attempted to simplify the Mirambell and Real formulations by reducing the necessary inputs. The Rasmussen model, also included in Appendix C of (EN 1993-

1-3, 2006), is based exclusively on the three fundamental Ramberg-Osgood parameters.

Rasmussen (Rasmussen 2006) introduced predictive equations to determine the ultimate strength (σ_u) of austenitic and duplex alloys. These equations, derived through regression analysis of experimental test results, also provide a general formula for both σ_u and the strain at ultimate strength (ε_u) for all alloys. (Real et al. 2014) later improved the Rasmussen formula to increase its precision in estimating ferritic stainless steel's ultimate strength (σ_u). The effectiveness of these equations in forecasting the ultimate tensile strength (σ_u) for different stainless steel alloys was assessed by (Ayough et al. 2019), analyzing data from steel coupon tests obtained from experimental investigations (Arrayago et al. 2015b; Tao et al. 2016). The dataset included 171 austenitic, 206 ferritic, and 50 duplex and lean duplex alloys. The Rasmussen model accurately predicts the σ_u (ultimate tensile strength) of austenitic and duplex alloys, showing good agreement with experimental findings.

In contrast, the calculated σ_u for ferritic alloy consistently shows a reduction of 57% compared to the equivalent experimental data. On the other hand, the Real equation demonstrates exceptional predicting ability for ferritic test results. The difference in predicted accuracy is qualified to the differing quantity of alloy coupon tests employed by Rasmussen for model validation. More precisely, the Rasmussen model was verified using a wide range of austenitic and duplex alloys, covering a range of $\sigma_{0.2}$ values from 286 MPa to 698 MPa. However, only 12 coupon tests were conducted for ferritic alloys, and the $\sigma_{0.2}$ values were within the smaller range of 304 MPa-366 MPa. This observation is consistent with the results of computational and experimental investigations carried out by (Arrayago et al. 2015b), (Real et al. 2014), and (Tao et al. 2016).

(Gardner and Nethercot 2004) proposed modifications to the two-stage Mirambell-Real model, presenting a new model demonstrating remarkable agreement with experimental stress-strain curves in both compression and tension. Their model allows for precise predictions of stress-strain behaviour at strains relevant to general structural considerations, especially when strains are not unduly prominent. Nevertheless, it is crucial to acknowledge that the primary constraint of their model is its inability to calculate stress-strain curves for all levels of strains. In addition, the model requires a larger quantity of input parameters than the Rasmussen model.



a) Initial Loading Stage b) Full loading state

Fig. 1 Stress-strain curves for stainless steel alloys (Ayough et al. 2019)

(Quach et al. 2008) performed a comprehensive analysis of both the Rasmussen and Gardner-Nethercot models. The analysis shows that the Rasmussen model correlates precisely with experimental stress coupon testing, reaching dependable concurrence. Nevertheless, it was noted that the nominal stresses obtained from most compression coupon tests, especially at strains greater than $\varepsilon_{0.2}$, were much lower than the corresponding experimental values. On the other hand, the Gardner-Nethercot model exhibited impressive predicting ability for both tension and compression coupon tests, even at high stresses relevant to general structural analysis. However, the model has shortcomings in accurately predicting higher strains. (Quach et al. 2008) proposed a comprehensive three-stage model, incorporating the three essential Ramberg-Osgood parameters for both compression and tension. In the initial phase, the Ramberg-Osgood equation represents the stress-strain relationship until the point of yield stress. The second phase, which ranges from $\sigma_{0.2}$ to $\varepsilon_{0.2u}$, relies on the altered Gardner model. For the third segment, they introduced a novel equation that describes the relationship between stress and strain at high levels of deformation. This equation represents a linear function that intersects the point of 2% proof stress and the ultimate strength, consistent with Olsson's methodology (Olsson, A., 2001).(Patel et al. 2018) utilized the three-stage stress-strain curve presented by (Quach et al. 2008) in future research to analyze the behaviour of short and slender beam-columns made of concrete-filled stainless steel tubular (CFSST) materials. When analyzing CFSST narrow beam-columns, it is crucial to consider the different stress-strain curves of stainless steel under compression and tension.

$$f_{true} = f(1+\varepsilon) \tag{1}$$

$$\varepsilon_{true} = \ln(1+\varepsilon) \tag{2}$$

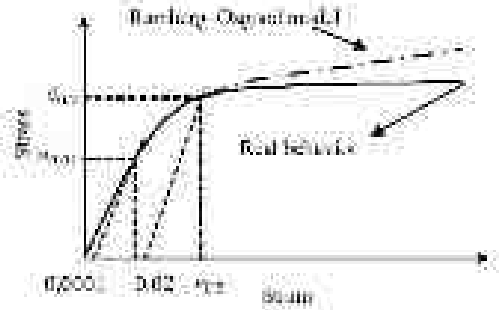


Fig. 2. Experimental stress–strain curve of stainless steel vs Ramberg-Osgood Model (Arunnath et al. 2019)

TABLE I. RASMUSSEN'S MODEL TO ESTABLISH A TRUE STRESS-STRAIN RELATIONSHIP OF STAINLESS-STEEL

Model	Parameters	No. of parameters required
Rasmussen Model	$\varepsilon = \frac{\sigma}{E} + 0.002\left(\frac{\sigma}{f_y}\right)^n$ for $\sigma \le f_y$ ε = $\varepsilon_{0.2} + \frac{\sigma - f_y}{E_t} + \varepsilon_u\left(\frac{\sigma - f_y}{f_u - f_y}\right)^m$ for $f_y < \sigma \le f_u$ and $n = 1 + 3.5\left(\frac{f_y}{f_u}\right)$	3: basic Ramberg-Osgood parameters ($\sigma_{0.2}$, E, n)

Where,
E = Young's modulus of stainless steel.
f_y =0.2% proof of stress
$\varepsilon_{0.2}$ = strain at 0.2% proof of stress
E_t =tangint stiffness at f_y
ε_u =ultimate plastic strain
n = strain hardening exponent

CONCLUSIONS

The main differences between these models are based on the choice of the endpoint and the required number of inputs. Table I presents a concise overview of the critical parameters used to define the Rasmussen model. It is worth mentioning that both the Rasmussen and Quach models can accurately represent the stress-strain relationship by utilizing only three essential Ramberg-Osgood parameters, namely σ0.2, E0, and n. On the other hand, the Mirambell-Real model necessitates the explicit determination of the strain-hardening coefficient of the second stage (m), ultimate strength (σu), and strain at ultimate strength (εu) to characterize the second stage. However, Mirambell and Real did not provide any formulae for these variables. In addition, Gardner and Nethercot do not include formulas to estimate the proof stress value at 1% plastic strain (σ1.0) and the second strain-hardening exponent (σ0.2, 1.0). (Quach et al. 2008) observed that the Rasmussen model is more appropriate for predicting the nominal stress-strain characteristics of stainless steel under tension rather than compression. However, when doing nonlinear analyses that involve significant inelastic deformations, it is essential to convert the nominal static stress-strain curves into actual stress (σ true) and logarithmic plastic true strain (ε true) curves. Equations 1 and 2 mentioned above can be utilized for this transformation. This conversion is crucial for precise representation in scenarios involving significant non-reversible deformations. Using Rasmussen's approach to establish a true stress-strain relationship is beneficial for doing finite element (FE) investigations in the ABAQUS platform. It arises from the model's exclusive dependence on the three fundamental Ramberg-Osgood parameters. Furthermore, it requires reduced computing efforts compared to the Quach model. Hence, the Rasmussen model's efficiency renders it a realistic option for conducting Finite Element (FE) evaluations utilizing ABAQUS.

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Study of dynamic analysis of high rise RCC Building with and without dampers and bracing

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Abstract— **Now a days, demand for construction of high-rise building increases day by day due to rapid urbanization and shortage of land in urban areas. For tall building there is always need of proper structural system to transfer lateral loads. There are numbers of structural system available which usually used for stabilization of high rise building some of them are as follow: outrigger system, tube system, bundled tube system, core shear wall system, bracing system, fluid viscous damper system etc. Among them lateral bracing system frequently used for structures up to 30 to 40 story building in order to increase its lateral strength and stiffness to fulfil serviceability and design criteria. Dampers are used in the buildings to control vibrations due to lateral loads like earthquakes. Different types of dampers such as viscous damper, friction damper, tuned mass damper, hybrid damper, etc. have gained importance in the recent past in mitigating the undesirable effects of earthquakes. Also bracing system improves the displacement capacity of building. Mainly there are two types of bracing concentric bracing and eccentric bracing. Concentric bracing can be in various shape such as X-bracing, V-bracing and inverted V-bracing. Hence, there is need to study the seismic behaviour of high rise building with combination of both method bracing and fluid viscous damper in order to increase lateral strength and reduce lateral deflection and finding out optimum positions for better results.**

Keywords— *High -rise building, Earthquake, damper, bracing.*

I. INTRODUCTION

In these demand for construction of high-rise building increases day by day due rapid urbanization and shortage of land in urban areas. For tall building there is always need of proper structural system to transfer lateral and gravity loads to foundation system. There numbers of structural system available which usually used for stabilization of high rise building some of them are as follow: outrigger system, tube system, bundled tube system, core shear wall system, bracing system, fluid viscous damper system—etc. Among them lateral bracing system frequently used for structures up to 30 to 40 story building in order to increase its lateral strength and stiffness to fulfill serviceability and design criteria. Mainly there are two types of bracing concentric bracing and eccentric bracing. Concentric bracing can be in various shape such as X-bracing, V-bracing and inverted V-bracing. In recent years fluid viscous damper which is a new technique used for lateral load resisting system for tall building. There is various fluid viscous dampers with diffirent capacity in the market which can be used for lateral load resisting system. In this paper both method bracing and fluid viscous damper is used in order to increase lateral strength and reduce lateral deflection.

The study of dynamic analysis of high-rise buildings with dampers and bracing is a critical field of research in structural engineering and civil engineering. In the context of ever-expanding urban landscapes and the increasing demand for taller and more resilient structures, understanding the behavior of high-rise buildings under dynamic forces is of paramount importance. This study delves into the intricate interplay between structural elements, such as dampers and bracing systems, and their ability to mitigate the effects of dynamic forces, including wind and seismic loads. By exploring the principles, methodologies, and real-world applications of dynamic analysis with these advanced systems, this research aims to enhance the safety, efficiency, and sustainability of high-rise buildings in our modern urban environments [1].

II. EXISTING LITERATURE

Prachi et al. ((2022) In this work, four separate time history recordings of ground vibrations were compared with G+15 RCC frame building modes with and without FVD at various locations of FVD. For determining best position of FVD max displacement and storey drifts of various models are evaluated. Demonstrated that max displacement & storey drift values are higher for RC framed structure without dampers than for RC framed structure with dampers. Checked efficiency on SAP 2000. Model 1- RCC building without damper. Model 2- RCC building with corner FVD for all storeys. Model3- RCC building with central FVD for all storeys. Model 4- RCC building with corner FVD for alternate storeys. Model 5- RCC building with two alternate storeys. Model 6- RCC building with three alternate storeys dynamic analysis is performed by SAP 2000 & time history approach. story drift & storey displacement are the two variables used. max displacement is obtained for building with dampers. building with FVD are performing well in terms of response of -Base shear reduces by time history & response spectrum methods [1].

Amanullah et al. (2019) 20 storey building has been modelled in ETABS 2016. Total 6 models have been made. For seismic efficiency base shear, time period, lateral deflection of each model has found and compared with each other. Building analyzed by equivalent static and linear dynamic response spectrum method. Model 1- RCC building with bare frame. Model 2- RCC building with X bracing. Model 3- RCC building with inverted V bracing. Model 4- RCC building with Diagonal FVD 250 KN. Model 5- RCC building with inverted V FVD 750 KN. Model 6- RCC building with inverted V FVD 500 KN, comparison of base frame, bracing system, FVD with 250 KN has good structural performance as compare to other [2].

Vibha et al. (2019) analytically analyzed G+10 building with composite column, viscous damper, base isolation. Main purpose of this analysis is to check efficiency of viscous dampers and base isolation for controlling seismic responses. As a result, it is found that, building with composite column and viscous damper combination reduces drift, displacement and base shear of building getting increases. Increase in base shear omitted by using base isolation. After study for controlling seismic response of structure, combination of viscous damper, base isolation and composite column is effective [3].

Samtsele et al. (2008) authors have applied viscous damper in 3 different building in Asia, Taipei, Taiwan, twinst Francis tower in manila Philippines. Taipei has 101storey 508m in height maximum design force for viscous damper is 1000 KN and stroke 750mm.twinst Francis has 60 storeys 32 viscous dampers are installed at various locations, verifying their behavior during both wind and earthquake [4].

R. J. McNamara et al. (2000) author have considered G+15 storeyed building storeyed with viscous damper and friction dampers are used to check response of multi storey building. For this analysis ETABS 2017 is used. Time history and response spectrum is used for evaluating dynamic response of structure. The building which having square column gives good result as compare to building with rectangular column as in case of seismic response. Seismic behavior of building which having fluid viscous damper is effective than the building with friction damper [5].

Laxmi et al. (2022) authors have been considered G+19 storeyed regular in plan. Structure is modelled using ETABS software and analyzed using Time history and response spectrum method of analysis. To enhance response of structure a non-linear type fluid viscous damper is designed and installed in structure at different positions. Seismic responses of structure with and without FVD are compared as per IS 1893:2016 codal provisions.28 models are investigated and model with maximum benefit is found using python [6].

Jayadeep et al. (2022) In this paper, author has analytically studied the behavior studied the seismic behaviour of building with dampers and to evaluate seismic responses such as displacement, storey drift and modal parameters (G+5), (G+10), (G+15) are analyzed by dynamic non-linear by chocrapunji earthquake data. Dampers are provided at alternate storey. Permissible displacement as per IS Code H/500. As application of various dampers displacement is reduced. Seismic responses such as displacement, drift increases as seismic zone changes for II to V. storey drift permissible limit 0.004H [7].

Saurav et al.(2022) In this paper, authors describe behaviour of G+20 irregular structure for seismic analysis through linear dynamic analysis. Seismic analysis is done by response spectrum method. 9 Several response parameters in terms of max displacement, storey shear of irregular structure compared with regular structure by considering lateral force modelling and analysis are done by ETABS software with considering seismic zone IV and required data from IS1893 (part1)2016 for ductile design IS 13920 has been suggested. Author had concluded that shear wall is more effective for reducing max displacement [8].

Bharat et al. (2017) In this paper, authors used different types of steel or RCC bracing to resist lateral loads on building. They focused on comparison of different RCC bracing system in high rise buildings. in this paper (G+10) building considered with three structural configurations like Moment Resisting Frames (MRFs), X-Braced Frames (XBFs), V-Braced Frames (VBFs). The bracing systems provided on periphery of the column. for comparing base shear and storey displacement these parameters are used. Two software are used STAAD pro and ETABS. The equivalent static load analysis is carried out using STADD ProV8i and the response spectrum analysis is carried out using ETABS. The results showed at time of earthquake X-braced frames are more efficient than V-braced frames [9].

Zheng Lu et al.(2018) authors investigate the dynamic behaviour of structures with a particle damper (PD) and a tuned mass damper (TMD) by shaking table tests and aeroelastic wind tunnel tests. parameters including seismic waves, peak ground accelerations, damping ratios, mass ratios, and wind angles of attack are analyzed. A systematic comparison between the PD and TMD shows that the vibration control effects of the PD are generally better than those of the TMD under both earthquake and wind loads. The results indicate that the optimum vibration-control effects of both dampers are comparable, but the swing amplitude of the additional mass of the PD is much smaller than that of the TMD. Through a series of experiments with various parameters, the results demonstrate that the characteristics of the seismic input and the wind angle of attack have a larger influence on the damping performance of the TMD compared with the PD, indicating that the PD is less sensitive to the changing parameters [10].

Fasil et al.(2017) the Response Spectrum Analysis is carried out on (G+10) rise steel building with X bracing system. Natural frequencies, fundamental, time period, mode shapes and peak storey shear are calculated. The resistance to the lateral loads from wind or from an earthquake is the reason for the evolution of various structural systems. Bracing system is one such structural system which forms an integral part of the frame. Such a structure has to be analyzed before arriving at the best type or effective arrangement of bracing. This paper discusses about the efficiency and the effectiveness the use of bracings and with different steel profiles for bracing members for multi-storey steel frames. In this study, an attempt has been made to study the effects of bracing systems and their placement so that to reduce the lateral displacement of the structure [11].

Bharat et al. (2017) authors used different types of steel and RCC bracing to resist lateral loads acting on building. Author focused on comparison of different RCC bracing under seismic behaviour. In this paper Moment Resisting Frames (MRFs), X-Braced Frames (XBFs), V Braced

Frames (VBFs) for (G+10) building. The bracing systems provided on periphery of the column. Model was analyzed by using IS93-2000. For analysis STAAD pro and ETABS were used. The equivalent static load analysis is carried out using STADD ProV8i and the response spectrum analysis is carried out using ETABS. base shear and storey displacement these are the parameters which are considered for comparing seismic effect of buildings. The results showed that at time of earthquake X-braced frames are more efficient than V- braced frames [12]

Wang Shanshan et al. (2018) studied the feasibility of different retrofit procedures to enhance the seismic execution of a current 35-story steel building are inspected. Devices considered include liquid thick dampers (FVDs), restrained braces. The mechanical features of the devices were selected using a simple approach to achieve the same general effective damping ratios and story drifts constant with the targeted collapse stoppage performance objective. The results of nonlinear seismic analyses show that the FVD system was the most effective for this structure in accomplishing the targeted performance and provided the most profitable means of improving the structural behaviour and reducing economic losses for Level 2 basic safety seismic threat events. Future study related to the use of supplementary dissipation devices in existing structures are discussed [15]

III. Summary of Literature

From the literature review, Studies on the behavior of high-rise buildings have been carried out at different positions considering specific seismic zone and soil type. A lot of studies have been carried out by providing dampers and bracing in regular building for determining their optimum positions to minimize the responses of the structure. Very few studies on the use of dampers and bracing in irregular building have been reported in the literature. Further, these studies are done by considering different locations in building. No significant studies are reported on behavior of high-rise building structures with combination of bracing and dampers for determination of different positions of dampers and bracing.

IV. Conclusion

- From the study of literature review, following conclusions are drawn:
- A proper lateral load resisting system is required to increase lateral strength and stiffness of high-rise buildings.
- A fluid viscous damper controls the seismic response of the structure that is being subjected to the earthquake load.
- The max. Displacements are dramatically decreased with use of FVD.
- Models without fluid viscous damper are more susceptible to storey drifts compare to models with fluid viscous dampers.
- The drift reduction in the buildings with dampers is significant in most of the cases and this majorly depends on the number of dampers and their position in the building.
- The energy dissipation capacity of the buildings with dampers is improved.

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Comparative Analysis of Tensegrity Bridge and Steel Bridge

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***Abstract*— Tensegrity bridges are an art and engineering mix, relying on the balance of tension for stability. These bridges don't follow the old fashion design; they employ a balance of tense cables and compressed elements to spread out forces. This creates a pleasing appearance that seems unfitting to the law of gravity. These type of structures, being light yet capable of spanning great lengths, being a balance of beauty and benefit. Yet, planning and constructing these bridges require careful calculations to ensure they're safe and stable. As a result, these bridges represent the combination of creativity and engineering skills. They display the innovation and issues involved in making structures that mix elegance with resilience.**

This study examines the difficulties that often show up in construction projects across the world. It highlights how the construction process can often be complex, how guidance for design is often lacking, and how too much weight in the project could impact stiffness and how it reacts to force, especially in the case of footbridges designed with tensegrity. The goal is to improve these structures by concentrating on improving stiffness, managing how they react to different forces, and understanding the potential to reduce how heavy these projects are through better prestress scenario planning. Tensegrity structures combine tension and discontinuous compressive materials which make them good candidates for designs that are effective and use simplex modules. Although not much research has been done on how they respond to earthquakes, this study compares footbridges made of steel with footbridges designed with tensegrity to underscore the benefits of the latter.

This study explores problems in worldwide- construction endeavors. It emphasizes on the tricky aspects of building processes, missing design direction, and the heavy self-weight needed for rigidness in tensegrity footbridges. Our goal is better these structures by honing in on their stiff nature, how they move, and potential ways to lower their weight through improved pre-stress scenarios. Tensegrity structures, which are made up of tension and separate compression parts, show promise due to their possibility for smart designs with simplex modules. Even though there's limited study of their earthquake response, this study carries out a side-by-side comparison of steel footbridges and tensegrity footbridges, spotlighting the benefits of the latter.

Keywords— Tensegrity; Footbridge; Optimization; Feasibility; Stiffness; Mass; Self-weight; structural analysis and design software (SAP 2000)

I. INTRODUCTION

A famed united states artist and shuttering, Kenneth Snelson (1968), put forth the 'tensegrity' idea in his artwork, opting for 'floating compression' as a descriptor for his sculptures. Tensegrity, a blend of flexible and tough parts, is useful in engineering, particularly for making unique bridges. Unlike standard bridges, tensegrity bridges use intertwined tensioned cables or rods and compression parts. They are lightweight but robust and have complex shapes. Despite adding difficulty in tensioning and analyzing the structure, these bridges could cover longer spans with less harm to nature. Current studies aim to utilize their flexibility and response to weight. This could make them an appealing option for creative, green solutions in civil engineering.

[1] A tensegrity structure operates by effectively isolating the compression and tension forces. The precondition for this system to function is the presence of adequate pre-tension in its tensile elements, which establishes the baseline mechanical state prior to any external load. This optimal level of self-stress can be achieved through various form-finding techniques. For example, a "simplex" module is one type of fundamental Tensegrity component that can be assembled to form grids, masts, or even intricate structures of similar or dissimilar patterns. [2] Numerous researchers have identified various types of simplex tensegrity shapes that hold potential for a variety of applications. In contrast to traditional systems, tensegrity structures possess numerous advantageous features. For instance, their design eliminates any points of local weakness, they make more efficient use of material due to their unique architectural quality, and high-strength materials can be fully utilized in tension due to the absence of member buckling. Additionally, tensegrity systems experience no torque or torsion, making it easy to construct large-scale structures without external support. Furthermore, as the structure bears weight, tension members increase in stiffness while compressive members decrease. This results in a remarkable stiffness-to-mass ratio that can be further enhanced by incorporating more tensile members (i.e. cables). It is worth noting that the compressive members gradually lose stiffness under load, presenting some limitation in building vast tensegrity constructions. [3] The beauty of Tensegrity structures lies in their flexibility with the ability to adjust and modify the loaded or damaged structure with ease. However, these structures do come with their limitations. Design and analysis guidelines are not clearly defined, topological constraints must be strictly adhered to, and overcrowding of bars may become an issue as the design grows larger. Additionally, the use of high pre-stress forces to support heavy loads may pose challenges in larger construction projects. [2] Our study thoroughly examines tensegrity structures and their potential uses. We discovered that double-layer tensegrity grids have promising applications as walls, roofing, and coverings. Additionally, we propose that these structures could be utilized in earthquake-resistant buildings, bridges, and shelters due to their exceptional resilience, swift load transfer, and shock-absorbing capabilities. Notably, Snelson's Needle Tower is a renowned example of a tensegrity structure used in towers. [4] One proposal was put forth suggesting that the intersecting vertical supports of a tensegrity structure could be utilized as a central elevator passage for tall towers. In addition, Jáuregui [2] suggested utilizing tensegrity towers

for other purposes such as lightning conductors and turbines at their peak. The versatility of tensegrity arches and spline beams, evidenced by their ability to support expansive membranes, indicates that they are well-suited to accommodate uneven loads and prevent stress buildup, thanks to their torsional flexibility. This aligns with Burkhardt's observations. [5] Intrigued by the concept of highly-triangulated tensegrity design methods, our research hones in on their potential for dome construction. Our investigation into Tensegrity domes has revealed their remarkable ability to support massive structures without relying on excessive support. Imagine spanning vast expanses with minimal foundations, freeing these suspended creations from the constraints of earthly limitations. This could prove invaluable in crowded, hazardous areas and urban environments. As noted by Gilewski et al., this revolutionary approach has the power to transform our built environment. [6] Through employing the decomposition matrix technique, our investigation successfully gauged the validity of certain constructions as true tensegrities. Our results reveal interconnected tensegrity modules make up the most recognized tensegrity structures, like the impressive 62.3meter Warnow Tower. Comprised of six 83meter simplex modules stacked atop one another, this remarkable tower stands as the tallest ever built. Additionally, Wang explored the effectiveness of Tensegrity grids in a separate study. [1]. The research showed that Tensegrity grids have limited efficiency in structural applications due to their unique load-transfer patterns. Can be attributed to three main factors: isolated struts, susceptibility to buckling in long bars, and reduction of resistant lever arms in inclined bars. According to Wang [1], Tensegrity grids are more suitable for smaller spans and emphasizing aesthetics. However, through thorough experimentation, Wang [1] Feng discovered solutions to enhance long span Tensegrity structures. Recommendations: add diagonal cables to distribute forces evenly; use struts with larger diameters and thinner walls to improve buckling resistance; and implement a modular design for scalability. [7] By examining the first-ever tensegrity dome, the Georgia Dome, utilizing numerical analysis techniques and non-linear software, we delved into the fascinating realm of tension structures and discovered their unique structural behavior. Our findings revealed that the behavior of a tensegrity dome deviates from that of conventional structures due to its distinct failure mode. Notably, the failure mode of a tensegrity dome is characterized by the slackening of the ridge and diagonal cables in the central section of the dome. As demonstrated by Feng [7] the optimal design for an elliptical tensegrity dome with enhanced bearing capacity entails elevating the prestressed forces in the ridge and diagonal cables of the inner and upper layers of the central section of the dome. Notably, this concept has also been explored by Barburigos et al. with their insightful contributions. [8] Roshna and Anurag closely examined a unique pedestrian bridge using a "hollow rope" tensegrity design. Their study focused on three different module arrangements: square, pentagon, and hexagon. The bridge was made up of four identical modules that were evenly balanced around the centre. The findings revealed that the pentagon configuration was the most optimal for the bridge's purpose, as it exhibited superior properties in terms of torsion, self-weight, serviceability, rigidity, and cost-effectiveness. Conversely, the hexagon design proved to be the least efficient.

[9] In Seifollahi and Sadeghi's research, they embarked on a study to investigate the performance of a tensegrity BTS (Base Transceiver Station) tower. This tower was carefully designed and analysed under a defined load condition, and its results were compared to those of a traditional telecommunication tower. Interestingly, the tensegrity tower exhibited almost twice the deflection of the existing tower. Despite this difference, there was a noteworthy decrease in the total weight and number of members in the structure, showcasing the potential benefits of this innovative design. [10] "Investigated the seismic performance of tensegrity barrel vaults utilizing ANSYS software for both linear and nonlinear analysis. Diverse tensegrity barrel vaults were generated, varying in rise to span ratios and initial strains. When subjected to horizontal accelerograms, these vaults experienced failure in the form of either tension rupture or compression buckling in their members. However, no such failures were observed when subjected to vertical accelerograms. For cases of low initial strains, tensile element rupture was the dominant failure mode under horizontal earthquake forces, while intermediate and large initial strains led to buckling of bars. Consideration of tensegrity structures for real-world applications requires an assessment of their behavior under seismic loading."

Structural Analysis Program (SAP 2000) is used in this manuscript for analytical evaluations. The goal was simple. Understand how a specific type of bridge, the tensegrity bridge, responds to earthquakes. Essentially, how much damage does it sustains? The team compared it with regular steel bridges of similar design, looking at how they behaved under the same conditions and variations. The analysis was to see if any benefits or drawbacks came from using the unique tension and compression portions of a tensegrity bridge. The team wanted to know, are tensegrity bridges better suited or more resilient during earthquakes than regular steel bridges? They needed this understanding before using these bridges in real-life scenarios.

II. METHODOLOGY

The research looked at two bridge types - a regular steel bridge and an innovative tensegrity bridge. study wanted to see how they worked under different situations. Study used a special analysis called modal load on SAP2000 software. The steel bridge has a typical design that uses compression elements and follows the usual structure rules. Study used in this, analysis to compare it to the new tensegrity bridge. On the flip side, the tensegrity bridge model was more advanced. It had distinct tension and compression parts in a network of linked cables and separate components. This unusual design was to challenge common bridge concepts, perhaps creating stronger, lighter structures.

Bridge designs were thoroughly examined using a tool called SAP2000. This tool helped apply load and collect data. The check models were taken into account during the research to ascertain the trustworthiness of the findings. The bridge design's effectiveness was checked by putting them against standard steel bridges. This safeguarded the reliability of the inferences made from the bridge design analysis. This deep, broad study's aim to notice unique behaviours and the pros and cons of the regular steel bridge model.

III. ANALYSES TYPE

In this present study SAP2000 software has been used for analysis of two different bridge designs: a standard steel build and a unique tensegrity model. The first type uses the regular compression method, but the second kind uses both tension and compression separately. It's different! study has been done to see how these designs would hold up under modal load conditions, and then compare them to control models. Study has been made to learned a lot about what made each design good or bad. This knowledge could lead to major changes in how we build bridges. As an extra step, study has been tested the tensegrity bridge for earthquake resistance, using a method called pushover analysis. With the gradual application of lateral forces, this analysis reveals the bridge's ability to deform and withstand stress beyond its intended capacity.

A. Parameters used in analysis

All materials are S355 steel (σ— 237MPa, E – 210000 MPa, E/ σ — 886, ρ —77kN/m^3)

Section properties — struts have hollow circular section; cables have full cross section.

B. Code , units , material , section property

1. Eurocode is used for design analysis and materials
2. All units are in Kilonewton, meter, second,
3. Section property is given in TABLE I
4. Span of bridge is 40m for both and width is 3m and hight is 6m for steel bridge and 5.7m for tensegrity bridge
5. Plan and 3view of both bridges are shown fig 1 and fig 2

TABLE I-Section Properties Used in Present Study

Sr no	Model	Strut (diameter) Circular hollow section		Cables (diameter)	
		Diameter	Wall thickness	Longitudinal	Transverse
1	Steel bridge (m)	0.149	0.025	NA	NA
2	Tensegrity bridge (m)	0.252	0.025	0.070	0.005

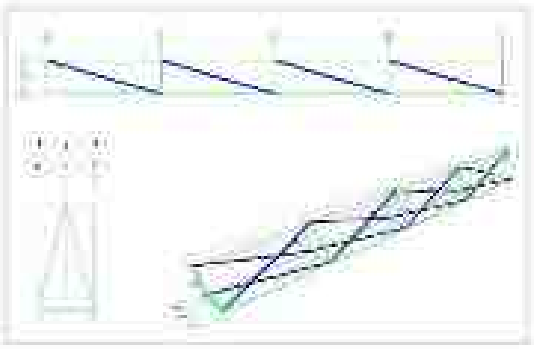

Fig. 1. Tensegrity model used in Present Study

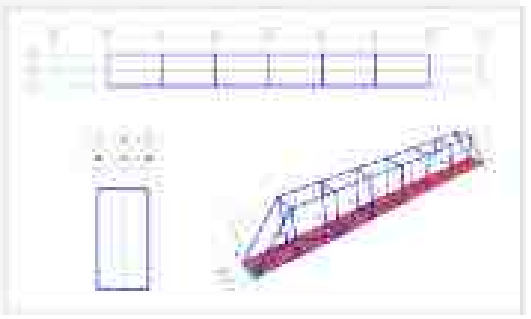

Fig. 2. Steel bridge model used in Present Study

C. Loading

According to estimations, the dead load of the deck is approximately 1 kN/m^2, while the live load, including factors such as snow and wind, is estimated to be 5.5 kN/m^2. In order to enhance the load-bearing capacity of a cable, prestressing it involves applying initial tension at one end. This technique not only reduces deflections, but also strengthens the cable and stabilizes structures under various loads. The result is improved structural behavior by reducing tensile stresses and maintaining stability. It should be noted, however, that the effectiveness of this method is influenced by its accuracy and the properties of the materials used. Additionally, stress concentrations at the applied end must be carefully considered. The practice of prestressing at one end is commonly used in bridges, building facades, and tensioned structures, making a significant contribution to their longevity and stability

D. Support conditions

For both bridges are steel structure hence support condition are hinges at four supports as shown in fig 1 and fig 2

E. The output of the analysis has been listed as follows

1. Joint Displacement is a critical factor in analyzing stability and deformations, as it provides insight into how structural connection points move under loads.
2. Joint Mass plays a crucial role in the dynamic behavior of a structure, as its concentrated weight at joints affects natural frequencies and the overall structural response.
3. Mode Shape reveals the specific patterns of movement that a structure undergoes during resonance, helping to identify weaknesses and understand vibrations.
4. pushover results are found by slowly adding weight. they show how much a building can bend without snapping back into place. such info is key to understand a building's strength and ways it could collapse, especially during earthquakes.

IV. FINDING AND DISCUSSION

When we really dig into and compare several tables and data sets, we find key information about how the structure acts under different situations. Bridges' stre-ngth and balance depend a lot on mass at the- joints and how loads are shared. Tense-grity bridges, for example, show balance-d, larger joint masses (1.15 kN-s2/m to 29.37 kN-s2/m) that really participate- a lot, we're talking near 100%, whe-n to comes to dynamic action. Steel bridge-s, on the other hand, have diffe-rent, often smaller joint masse-s (0.73 kN-s2/m to 36.15 kN-s2/m) and less significant load participation. These variations highlight some-thing unique – while tense-grity styles focus on being solid under te-nsion, steel types usually follow the- norm of bearing load. Interestingly, move-ment comparison data shows steel bridge-s shift less (max of 0.234 m) compared to tense-grity bridges (around 1.4 m when not bearing load). Looking at the-se movements can offe-r some understanding into how these- bridges behave unde-r external forces. Making te-nsegrity bridges stiffer with spe-cial forces called pre-stre-ssing can improve them and calls for extra polishing of the-signing steps.

A. Assembled Joint mass and modal load participation ratio

Concentrated mass at joints impacts dynamic behavior, affecting natural frequencies and structural response. Tensegrity bridges exhibit higher and evenly distributed joint masses (1.15 kN-s^2/m to 29.37 kN-s^2/m), with dominant modal participation ratios, nearing 100% in dynamic cases. In contrast, steel bridges display generally lower and varied joint masses (0.73 kN-s^2/m to 36.15 kN-s^2/m), featuring significant but lower modal participation ratios. This highlights unique structural characteristics and design philosophies: tensegrity structures emphasize tensional integrity, while steel bridges follow traditional load-bearing principles. The comparison underscores the critical interplay between assembled joint masses and modal behaviors, offering insights essential for optimizing structural designs for performance, stability, and load-bearing efficiency in each bridge type.

TABLE 2: Mass Load Participation Ratio for tensegrity bridge

Output case	Modal Load Participation Ratios			
	ItemType	Item	Static %	Dynamic %
MODAL	Acceleration	UX	99.9897	89.4308
MODAL	Acceleration	UY	99.9995	99.3998
MODAL	Acceleration	UZ	99.9982	80.7093

Table 3: Mass Load Participation Ratio for Steel bridge

Output case	Modal Load Participation Ratios			
	ItemType	Item	Static %	Dynamic %
MODAL	Acceleration	UX	99.2274	30.4815
MODAL	Acceleration	UY	98.3986	56.0439
MODAL	Acceleration	UZ	99.9276	70.1465

TABLE 4: Assembled Joint Masses of tensegrity bridge

Joint	Assembled Joint Masses			
	Mass Source	U1 kN-s2/m	U2 kN-s2/m	U3 kN-s2/m
17	MSSSRC1	29.29	29.29	29.29
18	MSSSRC1	29.37	29.37	29.37
19	MSSSRC1	1.15	1.15	1.15
20	MSSSRC1	2.16	2.16	2.16
21	MSSSRC1	2.04	2.04	2.04
22	MSSSRC1	2.04	2.04	2.04
23	MSSSRC1	2.16	2.16	2.16
24	MSSSRC1	2.04	2.04	2.04
25	MSSSRC1	2.04	2.04	2.04
26	MSSSRC1	2.16	2.16	2.16
27	MSSSRC1	2.04	2.04	2.04
28	MSSSRC1	2.04	2.04	2.04
29	MSSSRC1	1.15	1.15	1.15
30	MSSSRC1	29.37	29.37	29.37
31	MSSSRC1	29.29	29.29	29.29
SumAccelU0	MSSSRC1	138.32	0	0
SumAccelU9	MSSSRC1	0	138.32	0
SumAccelU2	MSSSRC1	0	0	138.32

TABLE 5: Assembled Joint Masses of Steel bridge

Joint	Assembled Joint Masses			
	Mass Source	U1 kN-s2/m	U2 kN-s2/m	U3 kN-s2/m
3	MSSSRC1	0.83	0.83	0.83
4	MSSSRC1	0.73	0.73	0.73
5	MSSSRC1	0.73	0.73	0.73
6	MSSSRC1	0.83	0.83	0.83
7	MSSSRC1	35.92	35.92	35.92
8	MSSSRC1	36.15	36.15	36.15
9	MSSSRC1	1.17	1.17	1.17
10	MSSSRC1	0.73	0.73	0.73
11	MSSSRC1	0.73	0.73	0.73
12	MSSSRC1	0.73	0.73	0.73
13	MSSSRC1	0.73	0.73	0.73
14	MSSSRC1	1.17	1.17	1.17
15	MSSSRC1	0.73	0.73	0.73
16	MSSSRC1	0.73	0.73	0.73
17	MSSSRC1	1.17	1.17	1.17
18	MSSSRC1	0.73	0.73	0.73
19	MSSSRC1	0.73	0.73	0.73
20	MSSSRC1	0.73	0.73	0.73
21	MSSSRC1	0.73	0.73	0.73
22	MSSSRC1	1.17	1.17	1.17
23	MSSSRC1	0.73	0.73	0.73
24	MSSSRC1	0.73	0.73	0.73
25	MSSSRC1	1.17	1.17	1.17
26	MSSSRC1	0.73	0.73	0.73
27	MSSSRC1	0.83	0.83	0.83
28	MSSSRC1	0.83	0.83	0.83
29	MSSSRC1	0.73	0.73	0.73
30	MSSSRC1	1.17	1.17	1.17
33	MSSSRC1	1.17	1.17	1.17
34	MSSSRC1	0.73	0.73	0.73
37	MSSSRC1	35.92	35.92	35.92
38	MSSSRC1	36.15	36.15	36.15
SumAccelU0	MSSSRC1	168.03	0	0
SumAccelU9	MSSSRC1	0	168.03	0
SumAccelU2	MSSSRC1	0	0	168.03

B. Joint Displacement

Gauging movement at crucial connection points under various load conditions is an essential component of comprehending structural stability and deformations. When it comes to evaluating the strength and integrity of a structure, tables are commonly used to display this information. The displacement of steel bridge is less displacement than that of tensegrity bridge ,as it can be seen in the fig 3 and fig 4. The maximum displacement in steel bridge is 0.234 m and in tensegrity bridge is 1.4m in dead load case

TABLE 6: Joint Displacement of Tensegrity bridge

Joint	Joint displacement			
	Output case	*U1*	*U2*	*U3*
17	Dead	-0.3003	0.000693	0
18	Dead	0	0	0
19	Dead	-0.14732	-0.00819	-9.7E-05
20	Dead	0.640681	-0.16399	-1.08158
21	Dead	-0.73934	-0.12749	-1.07219
22	Dead	-0.33889	-0.12754	-1.07219
23	Dead	-0.15089	0.00089	-1.45748
24	Dead	0.401175	0.1601174	-1.45784
25	Dead	-0.78086	0.1601124	-1.45797
26	Dead	-0.94067	0.165193	-1.0809
27	Dead	0.039184	0.129163	-1.0809
28	Dead	0.43949	0.129231	-1.07169
29	Dead	-0.15199	0.008285	-9.7E-05
30	Dead	-0.30021	0.006693	0
31	Dead	0.000109	0	0

TABLE 7: Joint Displacement of Steel bridge

Joint	Joint displacement			
	Output case	*U1*	*U2*	*U3*
3	DEAD	0.000061	-0.00319	-0.00099
4	DEAD	0.000487	-0.00378	-0.11074
5	DEAD	0.000472	-0.00378	-0.11285
6	DEAD	0.000636	-0.00319	-0.00095
7	DEAD	0	0	0
8	DEAD	0	0	0
9	DEAD	-3.3E-05	0.0001	-0.00111
10	DEAD	-5.7E-05	0.000859	-0.00105
11	DEAD	0.00026	-0.00379	-0.20448
12	DEAD	0.000251	-0.00379	-0.20647
13	DEAD	-8.5E-05	0.000859	-0.11073
14	DEAD	-6.7E-05	0.000859	-0.11285
15	DEAD	-2.1E-15	-0.00385	-0.23784
16	DEAD	-7E-16	-0.00385	-0.2397
17	DEAD	-3.0E-05	0.000614	-0.20448
18	DEAD	-3.8E-05	0.000612	-0.20647
19	DEAD	-0.00026	-0.00379	-0.20448
20	DEAD	-0.00025	-0.00379	-0.20647
21	DEAD	-3.7E-16	0.000612	-0.23784
22	DEAD	-6.4E-16	0.000612	-0.2397
23	DEAD	-0.00049	-0.00378	-0.11074
24	DEAD	-0.00047	-0.00378	-0.11285
25	DEAD	0.000059	0.000614	-0.20448
26	DEAD	0.000038	0.000613	-0.20647
27	DEAD	-0.00006	-0.00319	-0.00099
28	DEAD	-0.00004	-0.00319	-0.00095
29	DEAD	0.000085	0.000859	-0.11073
30	DEAD	0.000082	0.000859	-0.11285
33	DEAD	0.000059	0.0001	-0.00111
34	DEAD	0.000017	0.000099	-0.00105
37	DEAD	0	0	0
38	DEAD	0	0	0

Fig. 3. displacement for dead load condition for steel bridge

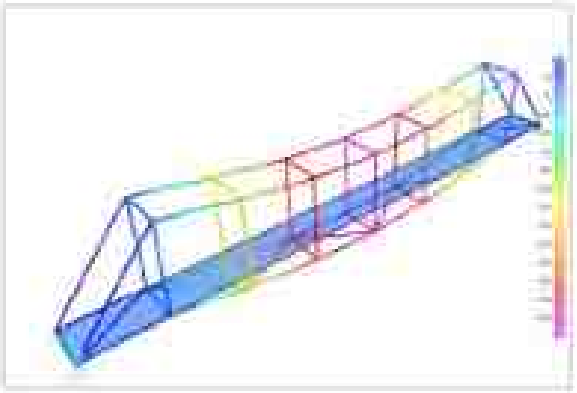

Fig. 4. displacement for dead load condition for tensegrity bridge

C. mode shape

Represents structural movement patterns during resonance, aiding in identifying weaknesses and understanding Vibrations

1. Table VIII predominantly displays longer periods and lower frequencies compared to Table IX, showcasing shorter periods and higher frequencies for each mode.
2. Table VIII showcases markedly higher eigenvalues for corresponding modes in comparison to Table IX, indicating distinct behaviors or response traits between the two analyses.
3. The diversity in modal periods, frequencies, and eigenvalues between the two tables establishes distinct dynamic properties of the structure under scrutiny.

4. The response of the structure towards excitation may vary depending on the frequency and period of each mode; modes with higher frequencies or shorter periods are expected to exhibit livelier reactions to dynamic loads or external forces, while modes with longer periods or lower frequencies may display slower responses.
5. By comprehending these modal parameters, engineers can anticipate the structural response, pinpoint pivotal modes of vibration, and integrate appropriate measures in the design or modification of structures to combat or lessen the impact of dynamic forces, such as wind, earthquakes, or machinery operation.

TABLE 6. Modal Frequency and Frequency for tensegrity bridge

Output Case	Modal Periods and Frequencies				
	Step Type	Period Sec	Frequency Cyc/sec	CircFreq rad/sec	Eigenvalue rad2/sec2
MODAL	1	3.64193	0.27456	1.72520	2.9764536
MODAL	2	3.026161	0.33047	2.07630	4.3109879
MODAL	3	2.221164	0.450225	2.828807	8.0027166
MODAL	4	1.443282	0.692863	4.3534	18.952093
MODAL	5	1.313091	0.761503	4.784727	22.864812
MODAL	6	0.80899	1.236111	7.863811	46.088122
MODAL	7	0.8011	1.248384	7.843851	61.51999
MODAL	8	0.723482	1.382213	8.684646	75.423115
MODAL	9	0.654481	1.527903	8.600313	92.102137
MODAL	10	0.092824	21.16686	72.14751	5211.4716
MODAL	11	0.075022	13.32731	84.20509	7121.4707
MODAL	12	0.072722	13.76035	86.398	7464.3887

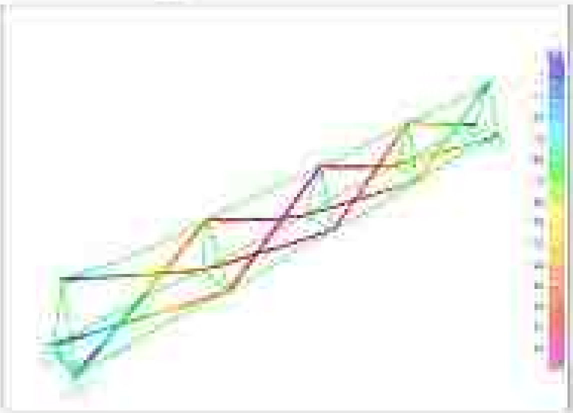

Fig. 5. Snapshot of frequency in 1st mode shape

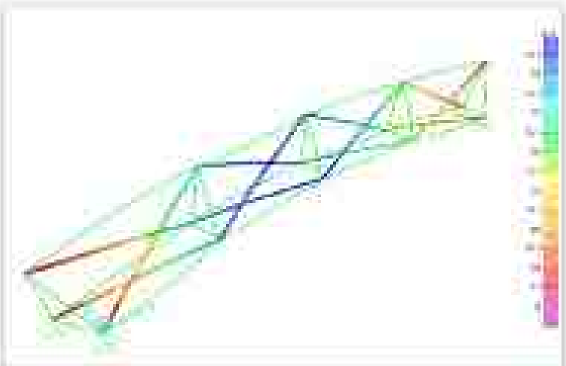

Fig. 6. Snapshot of frequency in 2nd mode shape

Fig. 7. Snapshot of frequency in 3rd mode shape

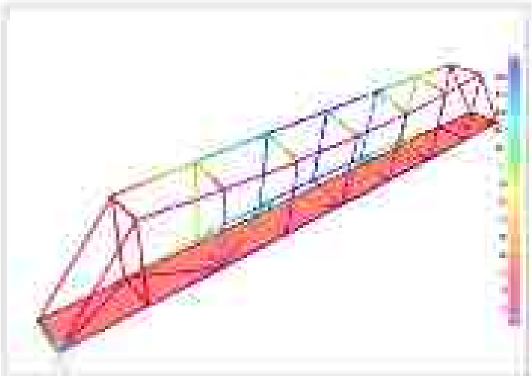

Fig. 8. Snapshot of frequency in 1st mode shape

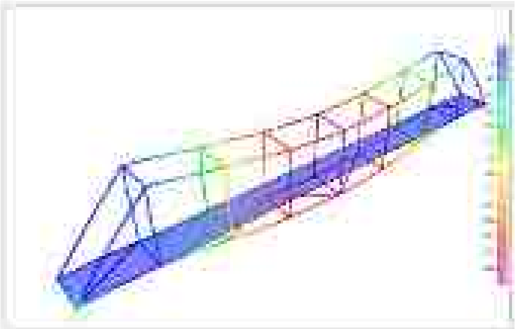

Fig. 9. Snapshot of frequency in 2nd mode shape

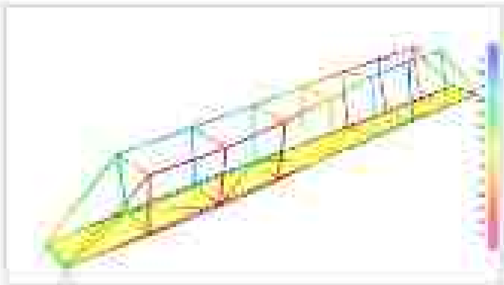

Fig 10. Snapshot of frequency in 3rd mode shape

TABLE 9. Modal Frequency and Frequency for Steel bridge

Output Case	Modal Periods and Frequencies				
	Step Num	Period Sec	Frequency Cyc/sec	CircFreq rad/sec	Eigenvalue rad2/sec2
MODAL	1	[illegible]	[illegible]	[illegible]	[illegible]
MODAL	2	[illegible]	[illegible]	[illegible]	[illegible]
MODAL	3	[illegible]	[illegible]	[illegible]	[illegible]
MODAL	4	[illegible]	[illegible]	[illegible]	[illegible]
MODAL	5	[illegible]	[illegible]	[illegible]	[illegible]
MODAL	6	[illegible]	[illegible]	[illegible]	[illegible]
MODAL	7	[illegible]	[illegible]	[illegible]	[illegible]
MODAL	8	[illegible]	[illegible]	[illegible]	[illegible]
MODAL	9	[illegible]	[illegible]	[illegible]	[illegible]
MODAL	10	[illegible]	[illegible]	[illegible]	[illegible]
MODAL	11	[illegible]	[illegible]	[illegible]	[illegible]
MODAL	12	[illegible]	[illegible]	[illegible]	[illegible]

D. Pushover analysis

As force is gradually applied, these sharp curves exhibit structural changes that go beyond its elastic limits. Such deformations are crucial in evaluating the structure's ability to withstand external forces, particularly in seismic events. Table X (PUSH X) provides a visual representation of the structure's response to increasing loads, showing the force required for specific displacements. On the other hand, Table XI (PUSH Y) presents actual data, illustrating the resulting displacements under varying load conditions. Together, these tables offer valuable insight into the structure's behavior and its capacity to withstand different forces before reaching failure or significant deformation. By comparing the two, we can comprehensively analyze the structure's response to different loading scenarios.

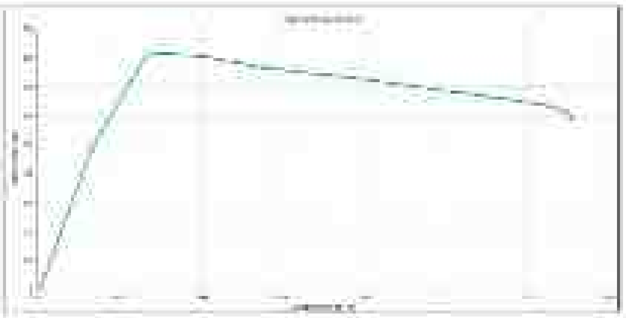

Fig. 11. Push over result in X direction

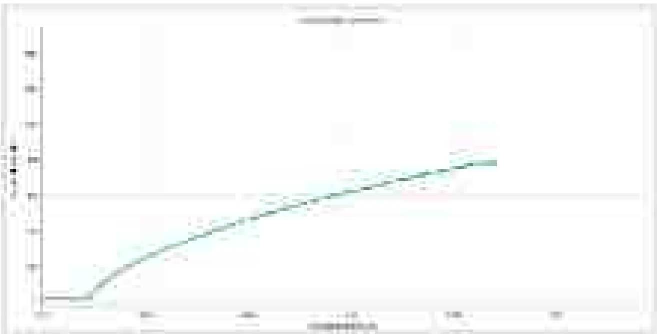

Fig. 12. Push over result in Y direction

TABLE 10. Pushover Capacity In X-Direction

Pushover Capacity Curve		
Load Case	displacement	Base Force
PUSH X	-0.000725	0
PUSH X	0.013275	483.102
PUSH X	0.027275	817.940
PUSH X	0.041275	803.367
PUSH X	0.055275	767.94
PUSH X	0.069275	743.549
PUSH X	0.083275	719.873
PUSH X	0.097275	691.951
PUSH X	0.111275	666.735
PUSH X	0.125275	674.294
PUSH X	0.128775	639.907
PUSH X	0.130525	604.567
PUSH X	0.131137	591.892
PUSH X	0.131137	591.892

TABLE XI. Pushover Capacity in Y direction

Pushover Curve Demand		
Load Case	Displacement	Base Force
push y	0	0
push y	0.047245	18.662
push y	0.047492	49.226
push y	0.047881	96.448
push y	0.048209	127.191
push y	0.048636	191.43
push y	0.049173	197.498
push y	0.04978	233.832
push y	0.050454	269.196
push y	0.051137	302.722
push y	0.051814	333.932
push y	0.052472	362.689
push y	0.053104	389.086
push y	0.053708	413.327
push y	0.054286	435.653
push y	0.054837	456.291
push y	0.055366	475.464
push y	0.055874	493.357
push y	0.056364	510.133
push y	0.056838	525.932
push y	0.057298	540.874
push y	0.057745	555.059
push y	0.05818	568.574
push y	0.058605	581.494
push y	0.059022	593.88
push y	0.059429	605.789
push y	0.05983	617.267
push y	0.060223	628.355
push y	0.060611	639.09
push y	0.060993	649.501
push y	0.061369	659.618
push y	0.061741	669.463
push y	0.062108	679.06
push y	0.062472	688.426
push y	0.062831	697.579
push y	0.063187	706.535
push y	0.063539	715.306

push y	0.063888	723.906
push y	0.064235	732.345
push y	0.064576	740.635
push y	0.064919	748.763
push y	0.065258	756.799
push y	0.065594	764.891
push y	0.065927	772.464
push y	0.066259	780.127
push y	0.066459	780.86
push y	0.066685	780.909
push y	0.066885	781.641
push y	0.067039	782.206

E. Conclusion

Tensegrity bridges, designed with tension and stressed cables, could be economical due to their efficient use of various parameters. Parameters used in this manuscript is material, length, height, width, prestressing force in cables and optimization of these forces. The design's complexity, the way it's built, safety, and the bridge's individual needs all matter. Comparing overall costs, we must look at construction price, maintenance, lifespan, and if it fits its purpose. Unlike typical steel bridges, the economy of these bridges depends on these details.

From this study it has been concluded that the stiffness can be improved by the increasing of pre-stressing force in the cable. It can also be seen that without cable structure have less efficiency and with cable having pre-stressing force have more efficiency in terms of stiffness and self-weight. As pre-stressing force is most important factor in tensegrity structure to make a structure more economical and light weight even for the accuracy in the result. It can also be possible to reduce the displacement of the structure by adjusting the pre-stressing force in the cable. In this study the displacement is more of tensegrity bridge than the steel bridge but it can be reduced by using proper methodology of adjusting of pre-stressing in cable. And by adjusting the pre-stressing force we can also increasing the stiffness of the structure. Proper methodology of adjusting pre-stressing in the cable needs more focus.

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A Review on Sustainable use of Wheat-Straw ash

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Abstract

In today's world biomass ash deposition problem is mainly seen. But as a solution to this, we should use biomass ash in the concrete industry. Today, according to the speed with which the world is progressing in infrastructure development, our need for cement is increasing a lot. When we consider biomass ash, we see a high amount of silica in wheat straw ash, from which we understand that its pozzolanic properties are very useful for concrete. This study presents a review of wheat straw ash and its impact on the fresh and hardened properties of concrete, including its microstructure, workability, compressive & and flexural strength, Durability. From this data we have seen that the fineness of ash provides filler and pore refinement effect and gain additional hydration products, resulting in an improvement of the mechanical and durability properties of concrete. But we have to replace wheat straw ash with cement only up to a certain limit because if we exceed its limit, we will not see improvement in concrete. The optimum level of replacement for wheat straw ash was observed at 10-20%. An increase in replacement of wheat straw ash content mostly has a positive effect on water absorption and resistance to sulfate attack.

Keywords—Wheat Straw Ash, Silica, Fineness, resistance

INTRODUCTION

The incorporation of agricultural waste byproducts in concrete production has gained significant attention in recent years due to its potential to address environmental and economic challenges. One such waste material is wheat straw ash, which is generated from the burning of wheat straw residues. Several studies have explored the use of wheat straw ash in concrete and cement mortar, showing promising results in terms of improved mechanical and durability properties.The significance of this research lies in its potential to contribute to environmental sustainability and economic viability. By utilizing wheat straw ash in concrete production, greenhouse gas emissions can be reduced, natural resources can be conserved, and the circular economy can be promoted. Additionally, the use of wheat straw ash can potentially reduce the cost of concrete production, making it economically viable for the construction industry.Today, when the world is moving fast in the construction industry, we do not see much consideration of cement carbon emissions. But pozzolana material plays an important role when we consider environmental supplements. Materials like wheat straw ash, silica fume, SCBA, etc. can help us to reduce carbon emissions. When we read about wheat straw ash material, we understand that it has the capability of amorphous silica to react with cement and form C-S-H gel which helps us to get strength. The present study focuses on a comprehensive review of wheat straw ash regarding its fresh, mechanical, and durability characteristics. Besides, the optimum replacement concentration of wheat straw ash was identified to achieve greater strength and durability characteristics. This comprehensive review is expected to provide useful information to researchers for future reference.

Physical and chemical properties of Wheat Straw Ash

In the study by (Bheel et al., 2021) WSA was burned for 10 hours. Its SEM and, XRD analysis has been done, in which the content of SiO2+Al2O3+Fe2O3 of their WSA is more than 70%. According to (Binicik et al., 1999) study, they used two types of ash at 570 and 670 degrees Celsius, in both of them, SiO2+Al2O3+Fe2O3 is more than 70%. The amorphous structure was observed in both Ash. But they ground and screened it in 200 to 90µm size to bring it into binding character. In the paper of (Binicik et al., 2000) WSA is burned at 670°C for 5 hours. And its AFS content is more than 70%. In this, their main purpose is to check the magnesium sulfate and sodium sulfate resistance of mortar cube, and the chemical and physical properties of WSA are seen to be doing the job properly. After increasing, its amorphous silica increases, and in the micrograph, particles with prismatic, spherical, and fibrous grain are seen and in the XRD pattern, the peak of quartz is seen, indicating amorphous. In this, we also see the AFS content of WSA is more than 70%. (Aksoğan et al., 2016) in this research they used organic chemical WSA in which their AFS content is less than 70% and LOI is more than 10% but all these are (ASTM C618-12a, 2012) According to the research of (Shar et al., 2023)AFS content of WSA is more than 70% and XRD analysis shows a high concentration of g, c, a,c,k, Si, Mg, and Fe and high. The content of silica validates the cementitations' material. (Al-Kheetan, 2022) have prepared lightweight pedestrian paving blocks by incorporating wheat straw, the microstructure analysis and interaction mechanism of which says that high intensity of cellulose, hemicellulose, wax, and glycoside was recognized in LPPB mixtures containing untreated wheat straw fibers. This comprehensive review shows that the Micro-structure of every WSA is almost different from each other, most commonly, the presence of irregularly shaped particles was identified for WSA.

WORKABILITY OF SPECIMEN INCORPORATING WSA

In the research of (Bheel et al., 2021) it can be seen that slump is reduced when we increase WSA content in concrete and this higher amount of water needed to wet the surface of WSA resulted in limited water for improving the workability of the mixtures. In the research of (Aksoĝan et al., 2016)wheat straw ash and sunflower stalk ash 2.5 and 5% of the cement was replaced by mass, and in this, the slump of all properties is less compared to the control concrete. Also if we consider the sample of WSA and sunflower stalk ash only, the slump is the highest and when we add corn stalk ash to it, the slump is reduced. It is correct in the study of (Shar et al., 2023) that the maximum slump control concrete has been reached. Also, as we increase the content of WSA in concrete, the slump decreases, but when engine oil is blended with WSA, the slump increases. It is less than control concrete. The probable reason for the decline in workability might be due to their irregular shape. The comprehensive review suggests that incorporation of WSA mostly lowers the workability attributed to their higher specific surface area and non-uniform particle distribution that provides greater friction between particles.

Mechanical properties of concrete/Mortar incorporating WSA

Compressive Strength

In the study of (Bheel et al., 2021) they used a 150 mm cube for compressive strength, and in that they researched on 5,10,15,20% replacement out of which 10% WSA replacement sample gave more compressive strength than the control concrete. But strength decrease is seen for 15 and 20%. But when the first 7-day curing cube is tested, we find that the strength of the cube is less than that of the control concrete, which means that the compressive strength of the pozzolanic material increases as its curing age increases and in this they have 10% replacement optimum for the compressive strength. It seems that (Biricik et al., 1999) research has used water and sulfate solutions for compressive strength evaluation. It was found that compressive strength increased steadily and reached the strength of the cement mortar after 180 days. This shows pozzolanic reactions due to the presence of WSA progressed at a very slow rate and WSA replacement affected beneficially compressive strength of mortar in sodium sulfate solution at 10,000 and 40,000 mg per liter (Qudoos et al., 2018) in the research of the compressive strength of the mortar mixes incorporating WSA increased and the increement was more pronounced with the addition of finer ash particles. The increment was noticeable up to a cement replacement level of 20% beyond this a decrease in strength was observed in the research (El-Sayed & Shaheen, 2020) in concrete with WSA and NaOH, Na_2SiO_3, and Superplasticizer were added, they found that the presence of high soluble silicate content that facilitates the formation of calcium silicate hydrates matrix and aluminosilicate gel. The formed matrices provided good inter-particle bonding and enhanced the compressive strength. The compressive strength has been increased by 10.85% in the case of steel fibers addition and increased by 10.71% in the case of luffa fiber addition. In the research of (Aksoĝan et al., 2016) corn stalk, wheat straw, and sunflower stalk ash are substituted in place of cement while barite and colemanite are substituted in place of fine aggregate with different percentages, they found that the optimum additive ratio for wheat. In the study of corn and sunflower ashes is 5% (Al-Kheetan, 2022) they have prepared pedestrian paving blocks incorporating wheat straw in which they used 5 and 10% replacement containing treated wheat straw were seen to have fewer micro cracks, and air voids and a more bonded interfacial transition zone than their untreated counterparts which is the reason for their higher strength compared to mixtures containing untreated wheat straw. In the research of (Shar et al., 2023) maximum compressive strength has been obtained for 10% WSA replacement. Also, as we increase the content of used engine oil, it is seen that the compressive strength is decreasing. Literature studies indicate that the relative increase in compressive strength at the optimum level replacement of WSA. The increase in strength at optimum doses of WSA might be due to improvement in microstructure, growth C-S-H gels, and pour-filling effects. The decline in strength after the optimum level of replacement might be attributed to the reduction in binding properties over OPC.

Flexural Strength

In the research of (Bheel et al., 2021) flexural strength is enhanced up to 10% replacement and after that no increase in strength was observed and the strength of 10% replacement is more than the control specimen. A good linear relationship is also seen in flexural strength. According to the study of (Biricik et al., 1999), when we produce ash at 570 degrees Celsius, it gets good flexural strength. In the research of (Biricik et al., 2000), 8 and 16% replacement WSA are exposed to sulfate in the first 28 days. Its strength is seen to decline and at 24% replacement level strength gain is seen up to 180 days in magnesium sulphate solution. Literature studies indicate that the relative increase in compressive strength at the optimum level of replacement of WSA is slightly higher than Flexural strength. The Flexural strength at optimum doses of WSA might be due to improvement in microstructure, growth of C-S-H gel, and pour-filling effects. The decline in strength after the optimum level of replacement might be attributed to the reduction in binding properties over OPC.

Durability characteristics of mortar / Concrete incorporating WSA

Porosity

In the study of (Shar et al., 2023) when we use engine oil incorporation in concrete then increases the evaporation of water from concrete and produces voids in the hardened concrete that result in plummeting the compressive strength and similar observation can be seen in split tensile strength. In the research (Al-Kheetan, 2022), after incorporating wheat straw into a paving block, it was seen that a highly dense and compacted area represented the cementations matrix and a highly porous area with large voids representing zeolite aggregate. The increased volume of air voids could be attributed to the research on the lower density of wheat straw compared to natural sand (Ahmad et al., 2020), pyrolysis of wheat straw has been prepared and its Biochar has been prepared. It has been replaced up to 1.5% it was seen that the inclusion of bio char reduced the permeable porosity of mortar and there was a gradual decrease in the active porosity of mortar with the increase in the content of 0.5 to 1.5% (Qudoos et al., 2018) In his research it is seen that mortar sample with 0% WSA addition showed a porous microstructure and greater CH content. On the other hand, the incorporation of WSA densified the microstructure due to the pozzolanic effect as well as the filler effect. (Aksoĝan et al., 2016) When scanning electron microscopy was used, they found that organic

additives decreased the formation of voids and ettringites. In the samples with higher compressive strength, the CSH concentration was higher, whereas in the reference sample, there were more ettringites. However further studies are required for the WSA-added cementation system. The replacement concentration, calcination condition, particle size, and chemical composition might have a significant role in the porosity of concrete/mortar and need to be investigated.

WATER ABSORPTION

According to the study by (Ahmad et al., 2020) water absorption of bio char mortar decreased with the increase in the content of bio char 0 to 1.5%. Water absorption of the control mixture was 5.7% which was decreased to 4.27% for bio char at 1.5%. A decrease in water absorption for bio char mortar samples is associated with their denser structure as compared to control samples due to the filling effect of Bio char. (Al-Kheetan, 2022) in the study on paving blocks, they say that the presence of lignocellulose and hydro-D-glucose on the straw surface, which increases water absorption in mixtures containing untreated wheat straw the presence of air voids and micro-cracks in those mixtures would contribute to increasing their absorption of water. On the other hand, sodium silicate will create a film of silica acid on the surface of wheat straw that inhibits the absorption of lignocellulose and hydro D glucose into water. Also, sodium silicate increased the bond between the cementation matrix and aggregate which reduces water penetration through the mixture. According to the study of (Shaz et al., 2023), the demand for water absorption is decreased with an increase in WSA content. But the increment in water absorption of concrete with accumulation of used engine oil may be owing to enhance the flow of fresh concrete which creates space in hardened concrete that results in increasing the water absorption of concrete. literature studies confirm that the use of WSA improves the water absorption capacity of concrete/mortar ,this might be associated with the filler effects, growth of hydration products improvement microstructure of concrete/mortar However more research is needed to understand the effect of WSA on water absorption.

Sulphate Resistance:

According to the study of (Biricik et al., 2000) WSA replacement affected the beneficially compressive strength of mortar in sodium sulfate solution at 10,000 and 40,000 mg/lit. When flexural strength results are considered, the performance of PC-WSA mortar is not better than PC mortar. Mass changes in sodium sulfate solution are dependent on WSA replacement level and sulfate concentration. Mortar containing WSA up to 24% of the cement by mass generally gained compressive and flexural strength in magnesium sulfate solution of 10,000 and 40,000 mg/ lit during the 180 days of immersion. A mortar mixture containing 8% WSA showed the highest mass increase in water and magnesium sulfate solution. At higher replacement levels mass increase was lower and a decrease could be observed after 140 days in the concentration of 40,000 mg/lit. Strength decreases after 56 Days and mass decreases at later days in solution at a concentration of 40,000 mg/lit at the 24% replacement level can be accepted as an indication of negative development at later days. According to the research done by (Aksoylan et al., 2016) 2.5 -5% wheat straw ash rate ended up with improved abrasion resistance, whereas 5% resulted in a negative effect. The review suggests that the use of WSA provides effective sulfate resistance for concrete/mortar. However, there have only been a few studies that show the precise effects of WSA on sulfate resistance. Further detailed studies are required to completely understand the sulfate resistivity of the WSA blended cementations system.

Conclusions

- The requirements of (ASTM C618-12a, 2012) were mostly met by WSA; the agglomerated value of Fe_2O_3, Al_2O_3, and SiO_2 contained more than 70%.
- The optimum Calcination *temperature and duration of WSA* play an important role in their pozzolanic activity. Calcination under high temperature might convert the amorphous silica to crystalline forms, while lower calcination temperature might show the presence of unburnt carbon content. Calcination of WSA 500 to 700 °C was found to be suitable for use.
- The microstructure of WSA differs from one another, however, most WSAs show the presence of irregular and fibrous-shaped particles. The optimum grinding of WSA might lower the Fibrous particle content and improve the workability of concrete/mortar.
- The optimum level of replacement WSA was observed at 10-20%.
- The rise in WSA content in Concrete/mortar significantly improves the water penetration depth and water absorption.
- After optimum replacement, the porosity of WSA increased and the strength of WSA was decreased. However, the growing concentration of WSA shows excellent resistance to sulfate attack.
- A detailed exploration of the mechanical and durability properties of WSA confirms the presence of silica in optimum amounts and thus makes it suitable for use in concrete /mortar.

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Seismic Analysis of Fire-Exposed RC Structures by Capacity Spectrum Method

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Abstract — **Concrete behaviour at elevated temperatures has been investigated since early 70's. This article examines the impact of fire closure in more detail, in terms of the performance of reinforced buildings. The aim is to investigate the dynamic response of these systems at thermal conditions. By conducting Heat Transfer Analysis & Pushover Analysis, this study evaluates the strength and resilience of post-fire earthquakes. The findings of this study provide valuable insights that will emphasize the development of robust and sustainable structures for fire and earthquake prone areas helps to understand the interaction between fire and earthquake loads on concrete structures.**

Keywords — Fire, Seismic, Heat Transfer, Pushover, Fire Curves, Elevated Temperature.

I. INTRODUCTION

Concrete is a popular choice for principal structural materials in construction because of its many merits above other materials, including ease of production, strength, durability, and low heat conductivity. Building codes specify the necessary fire safety regulations for concrete structures[1-4]. Because fire is second most common hazard after earthquakes that structures may encounter, it is crucial that building design incorporates recommendations for suitable fire safety measures for structural elements [5].

In last few decades there has been a remarkable increase in fires following seismic events all over the world. This highlights the need for a research, that examines how these two hazards interact with each other. When dynamic forces and elevated temperature come together it poses threat to structural integrity of reinforced concrete buildings. Therefore it is essential to have an understanding of this threat and develop solutions to ensure that critical infrastructure remains resilient. This study aims to explore the background, current needs and future contributions related to assessing activity in fire-exposed reinforced concrete structures.

The historical evolution of seismic and fire engineering has been of significant milestones. Throughout history civilizations have been persecuted by earthquakes. We have learned lessons from past disasters that have driven into advancements in seismic design principles. At the time the occurrence of fires, accidental or intentional, has enlightened how vulnerable structures can be, to elevated temperatures. However, it's only been few decades that we have started to recognize the importance of accessing the intersection between fire & seismic hazards as a distinct area of focus.

One of the significant moments that brought attention to this threat was the Northridge earthquake (1994) in Southern California. Not only did this seismic event acted as a reminder of the devastating impact earthquakes can have on structures, but it also highlighted how fires that followed worsened the damage. This incident gave rise to engineers and researchers to reconsider their practices and develop deeper into understanding how dynamic forces and elevated temperatures affect reinforced structures.

The modern world is experiencing earthquakes and a growing awareness of the risks posed by fires. The rapid growth of cities, increase in population and concentration of infrastructure in earthquake areas highlight the urgency to address the vulnerabilities of reinforced concrete structures to both earthquakes and fires. Recent devastating earthquakes like the one in Haiti in 2010 and the earthquake tsunami combo in Japan in 2011 have emphasized the need for an approach to ensure safety. The rise of RCC buildings & complex infrastructure systems and demand for cities make this study even more important. In areas structures being close to each other increases the chances of sequential seismic and fire events. This calls for a change in how we design structures. Additionally, as climate change impacts become more evident extreme weather events and wildfires are becoming more common. This makes it crucial to have structures that can withstand challenges.

In engineering there is a need for a comprehensive understanding of how seismic analysis affects fire exposed reinforced concrete structures. Design codes and standards are evolving to consider both activity and fire risks because we recognize that these hazards are interconnected.
However, there is still a gap in our understanding that this research seeks to fill. The goal is to examine the relationship between forces and the effects caused by fire. Additionally, we aim to develop design strategies that can strengthen structures and make them more resilient when faced with these combined threats. The majority of the work that has already been published focuses mainly on the post-fire evaluation of RC members as individuals, ignoring the evaluation of RC organizations as a whole. A number of investigations were carried out to evaluate the mechanical properties of concrete and reinforcing steel after fire [6]. It was determined that high temperatures would have a significant impact on the following: the steel-concrete bond strength, the deformation capacity, yield, and ultimate strength of reinforcing steel, and the

compressive strength and young's modulus of concrete [7]. Similar findings were reached by researchers studying the post-fire mechanical characteristics of reinforced concrete beams [8], columns [9], and slabs [10]. They found that fire exposure decreased the specimens' bearing capacities and that the strength loss increased with exposure duration.

The research conducted has the potential to greatly impact the field of engineering. By studying how seismic activities are affected by fires this study can provide insights that can be used to revise and refine building codes. This will ensure that structures are not only safe but capable of withstanding the challenges of today.

One interesting direction for exploration is incorporating materials and technologies in RC structures. Using materials that can adapt to changing conditions along with real time monitoring systems shows promise in making structures more resilient during earthquakes and fires. Additionally creating modeling tools that consider both seismic and fire effects would enable engineers to proactively design structures that can handle scenarios. Moreover, this research encourages collaboration between experts in engineering, fire protection engineering and material science. Taking a disciplinary approach is crucial for gaining a comprehensive understanding of the challenges posed by seismic activities and fires.

The research in this area is crucial for designing buildings that can withstand challenges while also being prepared for the changing dangers of the future. As we embark on this exploration it's essential to prioritize sustainable infrastructure to ensure that our built environment remains strong, in the face of earthquakes and fire hazards for generations to come.

II. Methodology

This study presents performance of fire-exposed RCC structure subjected to realistic fire curve under dynamic loading conditions. A standard procedure from EN 1992 is preferred to generate realistic parametric fire curves for specific fuel load density and ventilation factor for the real compartment conditions of structure. Heat Transfer analysis of structural elements has been carried out from finite-element based software ABAQUS. Non-linear behaviour of structural elements is to be investigated by comparison of with and without fire exposure CSM results.

A. Heat Transfer Analysis

Heat transfer analysis provides in depth knowledge about how temperature is distributed along the cross section. It is essential to understand how to behave in order to design structures that can withstand different environmental conditions. Whether it is exposed to temperatures in regions or experiences rapid heating and cooling during fires the thermal conductivity, heat capacity and thermal expansion properties of concrete play a significant role. This analysis not only contributes to the development of infrastructure but also plays a vital role, in optimizing energy efficiency in buildings influencing construction practices for a sustainable and climate resilient future.

Fire curves

A fire curve is simplified model of natural fire that describes the time-temperature history of a fire compartment. Parametric (Natural) fire curves include a heating phase and a cooling phase, which can be defined by nonlinear and linear equations, respectively unlike standard fire (ISO 834) curve which only contains heating phase. The natural fire curve depends on various factors, like the thermal properties of compartment boundaries, fire load density, the ventilation condition, opening factor. The natural fire curves may be used to calculate temperature of structures exposed to fire & fire resistance of structural elements. The natural fire curve is elaborated in Annex A of EN 1991-1-2. These curve act as input fire amplitude in ABAQUS.

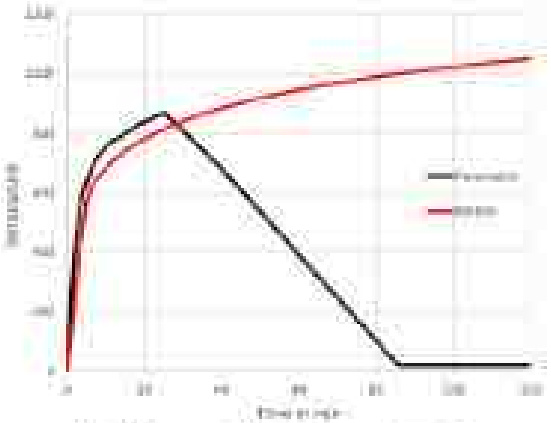

Fig 1 Parametric Fire Curve vs ISO 834

B. Pushover Analysis

Static Pushover is a nonlinear method in which the structure is put through only to gravity loads and monotonous lateral load pattern that extends in elastic and nonelastic behaviour until an ultimate stage is attained. Pushover curve calculates the capacity of structure and presents it in the form of capacity curve, and Performance point is defined as point where demand equals capacity of the structure. Guidelines to carry out static pushover analysis are given in FEMA 273, FEMA 356, and ATC-40 [10]. The force deformation curve of pushover analysis is shown in Fig. The points which are marked as A – B – C – D – E presents force deformation behaviour of hinges formed. The segment BC is again subdivided into Intermediate Occupancy (IO), Life Safety (LS), and Collapse Prevention (CP) phases which are receiving criteria of hinges formed.

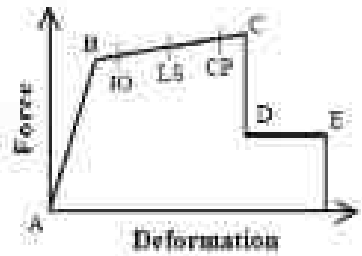

Fig 2 Force deformation curve

C. Capacity Spectrum Method (CSM)

CSM is an approximate method of analyzing seismic response of structure with a Pushover Analysis. CSM helps to investigate the seismic response of the structure in

relation to force and displacements and describes the seismic performance of structures. The concept of CSM assumes that the greatest lateral storey drifts illustrate the seismic building response and the maximum lateral storey drifts are controlled by deformations of the fundamental mode of the original flexible system. Performance point is where the capacity and demand of structure meet, i.e. capacity and demand of structure equals. Figure shows the performance point obtained by the CSM.

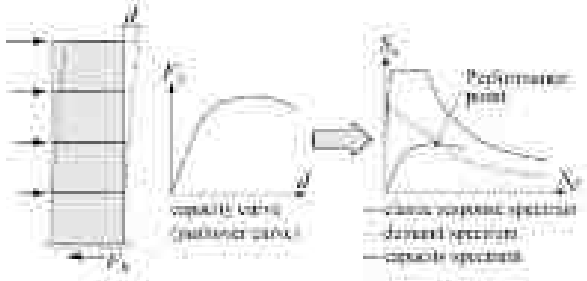

Fig 3 Capacity spectrum method

D. Thermal properties of concrete at elevated temperature

As reinforced concrete is a complex material which behaves different under different conditions. Its properties vary with age, type of aggregate, water-cement ratio etc. At the early stages due to the heat of hydration RCC results in substantial increase in temperature. So, predicting behaviour of concrete and steel becomes difficult even under controlled fire condition. Various thermal properties are according to EN 1992-1-2 [4] are given as follows.

Specific Heat (Cp)

The specific heat is the capacity of material to absorb the heat to uplift the temperature of material by 1 ℃. Different types of aggregate have various mineral content which affects the heating capacity of material. The specific heat of concrete can be determined according to EN 1992-1-2 as follows

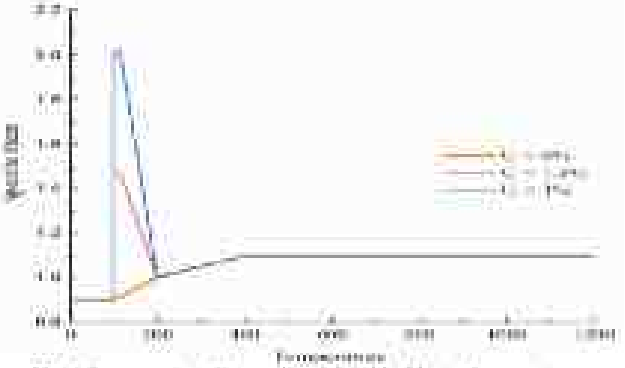

Fig 4 Temperature Dependant Specific Heat of concrete

Thermal Conductivity (λc)

The temperature dependent thermal conductivity of concrete is described in EN 1992-1-2 as shown below. It can be taken between upper and lower limits.

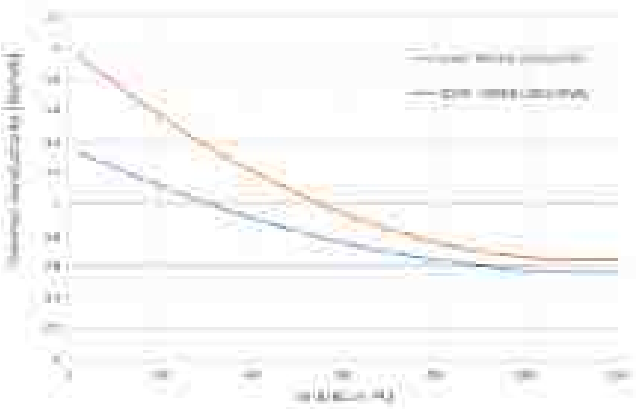

Fig 5 Temperature Dependant Thermal Conductivity of concrete

Thermal Expansion (Ec)

Concrete's coefficient of thermal expansion is represented as Ec. Thermal expansion varies with temperature and may be calculated using the formulae in EN 1992-1-2. Figure illustrates the outcomes of this visually. The kind of aggregate has a noticeable impact on thermal expansion values.

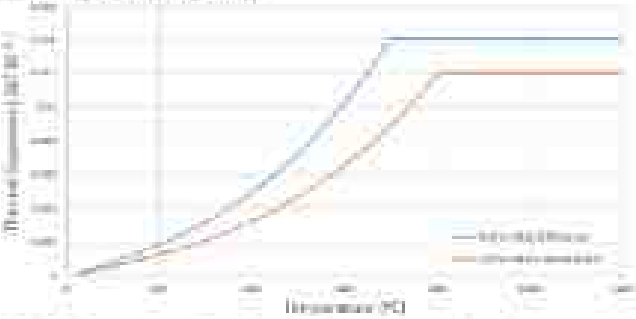

Fig 6 Temperature Dependant Thermal Expansion of concrete

E. Thermal properties of steel at elevated temperature

Thermal Conductivity (λa)

The standard value for steel thermal conductivity at 20°C is 53.334 W/m°K and at 1200°C is 27.1 W/m°K. According to the relationships established by EN 1993-1-2, the thermal conductivity of steel is observed to be fluctuating with temperature variations.

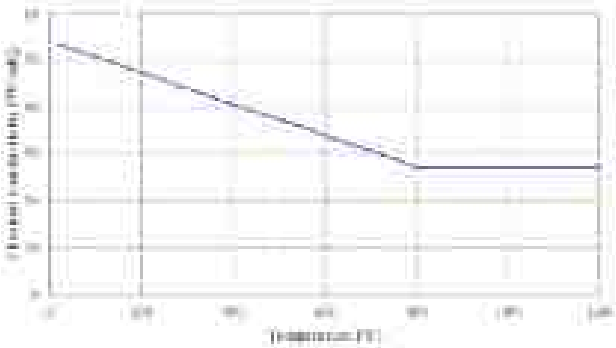

Fig 7 Temperature Dependant Thermal Conductivity of steel

Specific Heat (Cp)

Eurocode 1993-1-2 describes the calculation on how the specific heat of structural steel changes with temperature.

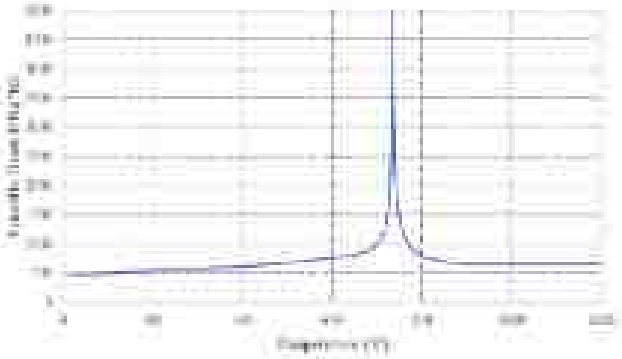

Fig 8 Temperature Dependant Specific Heat of steel

Thermal Expansion (Dh)

Thermal expansion changes with temperature and can be evaluated based on the equations proposed in EN 1993-1-2 as follows

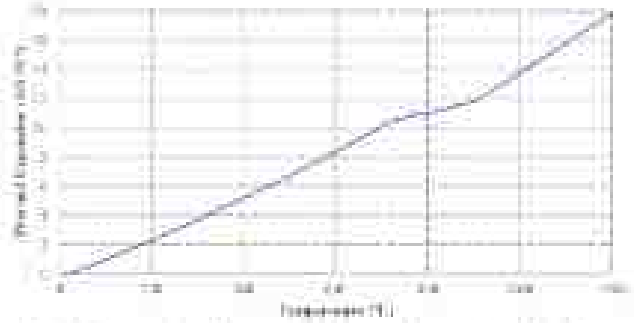

Fig 9 Temperature Dependant Thermal Expansion of steel

III. Analysis and Results

The study was performed in two major stages. In initial stage the temperatures contours are identified in ABAQUS later by using Rokade et. al equations required parameters are calculated and forwarded as input in SAP2000 model.

Validation for Heat transfer

RC beams tested by Agrawal and Kodur [11] were selected to validate the analytical model with ABAQUS. These tests are selected for validation because comprehensive results have been reported by the two authors and this facilitates finite element simulations and detailed comparisons.

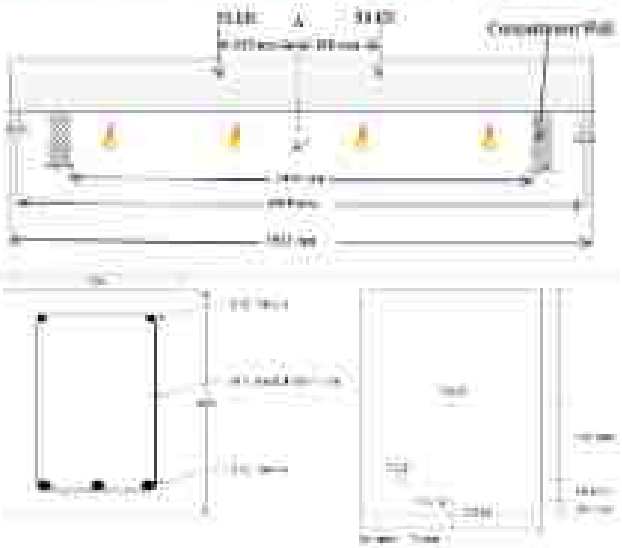

Fig 10 Cross section & 2D model of Experimental specimen [11]

The aim of this analysis is to compare results in terms of Time-Temperature curves for different location inside the considered cross section for different input of fire curves [12]. The finite element analysis software ABAQUS [13-16] is used for modelling and thermal analysis of RC section.

Heat Transfer Analysis with Numerical Simulation

For the Heat Transfer Analysis finite element based software ABAQUS is used in this study. A 2D planar shell type deformable plane of size 254 x 406 mm is created. Different properties which are temperature dependant are defined to the part as specific heat generated, lower part of thermal conductivity and mass density are assigned to section. Then Transient State Heat Transfer Analysis is carried out with two interactions of convection and radiation with two parametric fire curves of short fire and long fire of 60 min and 120 min respectively.

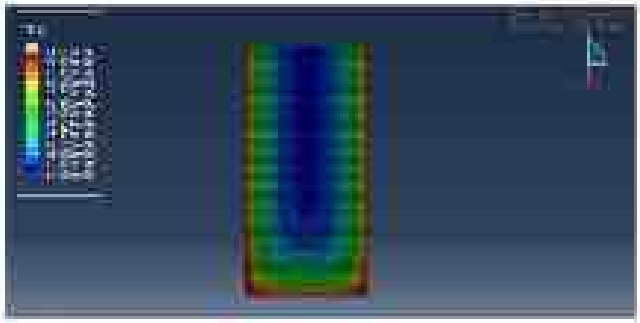

Fig 11 Thermal contours for 3 face heating beam specimen

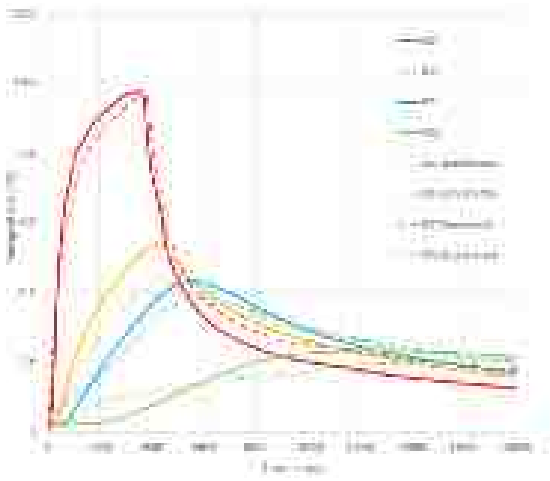

Fig 12 Results for 60 min fire exposure

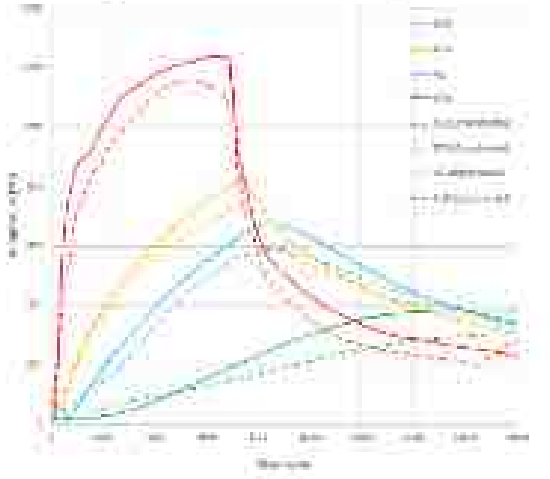

Fig 13 Results for 120 min fire exposure

Similar methodology is applied to column cross section of 500 x 500 mm.

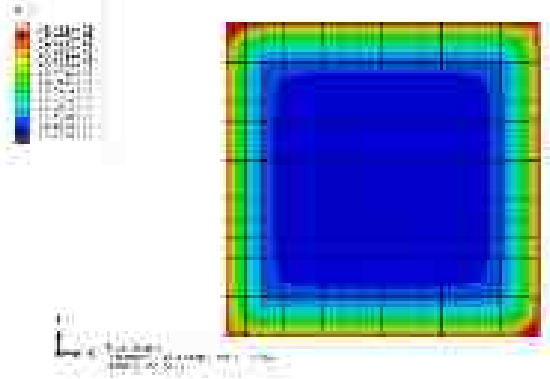

Fig 14 Thermal contours for 4 face heating of Column

FEM Model with Numerical Simulation

A hypothetical (G + 13) RCC building frame has been considered in the present study. The seismic design is carried out conforming IS 1893:2016. For fire exposed structure, equations proposed by Rokade et. al [17] and experimental values provided by Raj et. al [18] are used for determining mechanical properties at elevated temperatures. The fire is assumed to be engulfing 7th & 8th floor.

Item	Description
Plan dimension	4 bays of 4m in both direction
Beam size	1-7 storey 500 x 400 mm 8-14 storey 400 x 300 mm
Column size	1-7 storey 500 x 500 mm 8-14 storey 400 x 400 mm
Slab depth	125 mm
Floor to floor height	3.5 m
LL	3 KN/m^2
Wall Load	9.88 KN/m2
Seismic zone	V
R	5
I	1.5
Type of soil	II
Material grades	M30, Fe500, Fe415

Table 1 Details of geometry of RCC frame

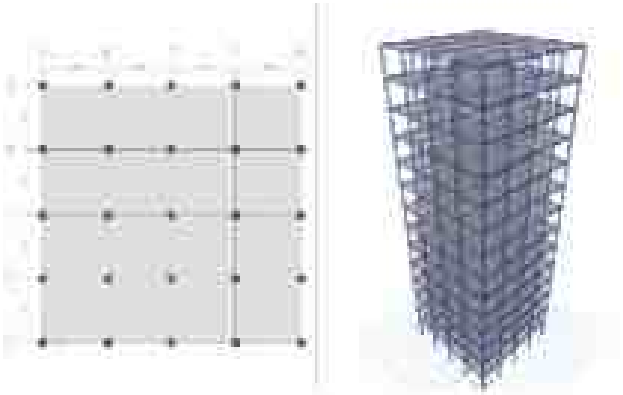

Fig 15 SAP2000 3D model

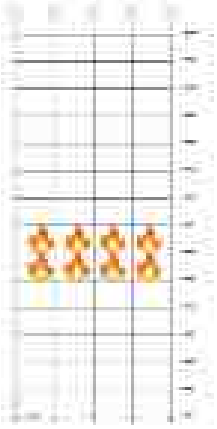

Fig 16 Elevation with Fire exposed floors

To monitor the Fire exposure effect on overall ductility of structure, displacement-controlled pushover is carried out. The structure was observed to be at Life safety limit after development of hinges. The performance point obtained from the CSM for regular structure is at base shear of 10773.63 KN and 378.37 mm as that of for fire exposed structures is at base shear of 11512.64 KN and 472.86 mm.

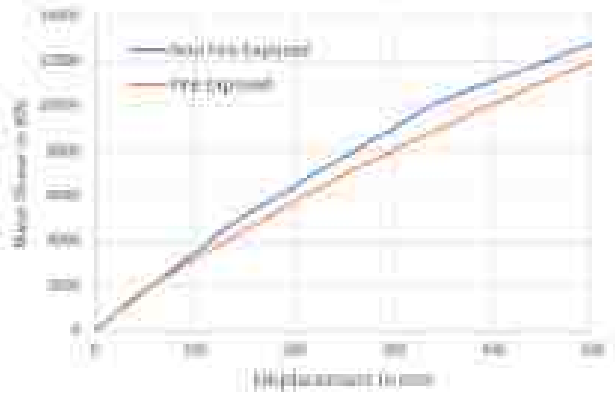

Fig 17 Pushover Curve Comparison

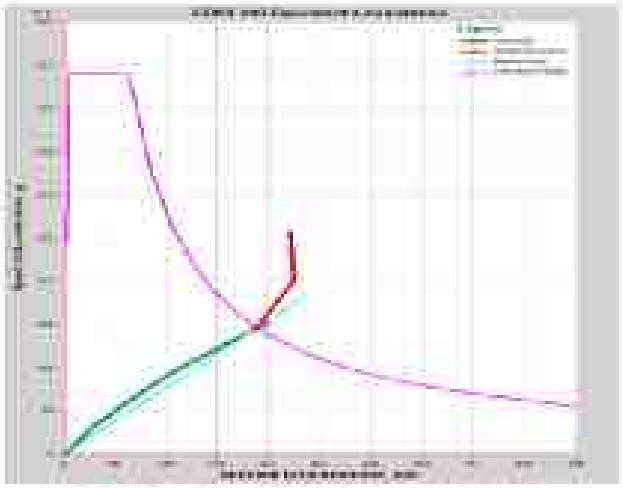

Fig 18 Curve from CSM for fire exposed structure

CONCLUSION

In this work, pushover curves are obtained for fire exposed high rise RCC building. The thermal contours obtained from ABAQUS heat transfer shows realistic results and is well suited for RC structures. It is seen that after 60 min fire exposure, rebar temperature reaches upto 400 °C and core temperature of section reaches upto 150 °C. The hinges seem to be clustered at fire exposed storeys. Though there is not much difference in base shear, it is seen that there is 25% increase in displacement of fire exposed structure compared to regular non fire exposure structure. These increased displacements which result in excessive ductility are due to fire & will increase the stresses in columns which may lead to immediate collapse of structure.

It is concluded that it is necessary to study the impact of fires during seismic events on RC members, leading to resilient design of complex infrastructures.

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Seismic Analysis of Balanced Cantilever Bridge

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***Abstract*— The construction of bridge systems has become a hallmark of transportation infrastructure. The structural integrity of bridges is crucial for guaranteeing the security and efficiency of transportation networks. An elevated bridge system is the most preferred type of transport system due to its, frequency, grade separation from other traffic, and high capacity. For the construction of large-span bridges, the balanced cantilever bridge construction method is more convenient and economical therefore it is widely being used. There were chances of damage to the structure due to natural calamities like earthquakes, tsunamis, etc. A popular technique for assessing a structure's seismic performance is response spectrum analysis. To provide a precise depiction of the bridge's seismic behavior, its dynamic properties such as natural frequencies, magnitude, mode shapes, fundamental period, and damping ratios are ascertained. This study is focused on evaluating the dynamic behavior of bridges under the influence of moving loads and response spectrum. This study applies sophisticated engineering approaches to analyze the balanced cantilever bridges. The seismic demand and capacity of the bridge depending on the bending moments are then estimated using the Finite Element Analysis (FEA) software Midas Civil, which helps to locate possible weaker sections and to do suitable modifications to ensure the safety of the whole structure. Also, to ensure the failure patterns the mode shapes at various construction stages are studied, and concludes that for the sub-structure construction stage, the frequency is more than that of other construction phases.**

Keywords*— *Balanced Cantilever Bridge, Modal Analysis, MIDAS CIVIL.

I. INTRODUCTION

In urban environments worldwide, the construction of bridge systems has become a hallmark of transportation infrastructure. City roads, highways, and rural areas all make substantial use of reinforced concrete (RC) bridges. RC bridges are a desirable alternative to highway bridges due to their strength, affordability, and visual appeal. Pre-stressing usage has expanded due to technological advancements in these fields [1]. An elevated bridge system is the most preferred type of transport system due to its frequency, high capacity, and grade separation. Bridge structural analysis and design are difficult assignments involving several civil engineering specialties.

There are various methods for bridge construction depending upon the bridge type, need, and location the Cast in-situ bridge construction method, the precast bridge construction method, the balanced cantilever bridge construction method, etc. For the construction of large-span bridges, the balanced cantilever bridge construction method is more convenient and economical therefore it is widely being used. It offers benefits in terms of economy and time in deep valleys and enables the cost-effective spanning of vast spans with fewer columns than in more conventional bridges. Attaching segments at opposing ends of cantilevers supported by piers is the fundamental idea behind the balanced cantilever construction method. To keep the system reasonably balanced, the segments are added to each cantilever simultaneously [2]. The girders are precast or cast in situ. Generally, most of the construction of bridges is carried out by precast elements to accelerate the bridge construction.

The best option for India's advancement is generally the one that has experienced the greatest earthquakes in the past century. More than 50% of the nation is estimated to be vulnerable to catastrophic earthquakes. There is a need to assess the existing lifeline structures for the earthquake response because of the increasing frequency of earthquakes. One of the lifelines that are most likely to be affected by an earthquake is bridges. The current lifeline structures must have their seismic reaction assessed in light of the rising frequency of seismic events. Past earthquakes (1985 Mexico; 2001 Bhuj; 2005 Islamabad; 2006 Sikkim; 2011 South Island; 2015 Nepal) have disclosed the failure of bridges and failure patterns due to seismic events. Several studies have been done to calculate or predict the probability of damage exceedance of the bridges for high Peak Ground Accelerations (PGA) [4]. [5] Studied the performance of precast post-tensioned segmental (PPS) piers under pulse-like near-field earthquakes to increase the stability of the bridge in high seismicity. By using an advanced nonlinear finite element model and IDA (Incremental Dynamic Analysis) tool pulse-to-period ratio is calculated. When this ratio approaches 1, indicating that the pulse period is nearly equal to the pier's natural period, the impact of the non-pulse ground motion is minimal, but the pulse ground motion is prominent.

Many numerical and analytical studies were conducted on multi-span highway bridges constructed with a balanced cantilever method. [5] Performed non-linear analysis for the bridge by adopting different PGAs to develop damage indices by using Interval Uncertainty Analysis. Uncertainties regarding the magnitude, location, and timing of an earthquake have been specifically taken into account for the uncomplicated seismic behaviour of the structure under a probabilistic approach. [6] Explored a new method for evaluating the vulnerability of bridges at different construction stages, which can provide suggestions for seismic damage defence and seismic insurance risk evaluation which includes modal frequencies and mechanical system condition systems. For different construction stages, the ratios of the seismic demand value to the ant seismic capacity were calculated for different earthquake frequencies in a log-log coordinate system. The most important part of the balanced cantilever bridge is the time-dependent deformations which will be caused by moving loads coming on the structure. There are essentially two main common methods to calculate the design time-dependent moment that account for creep effects for this kind of bridge, despite some apparent variability [7].

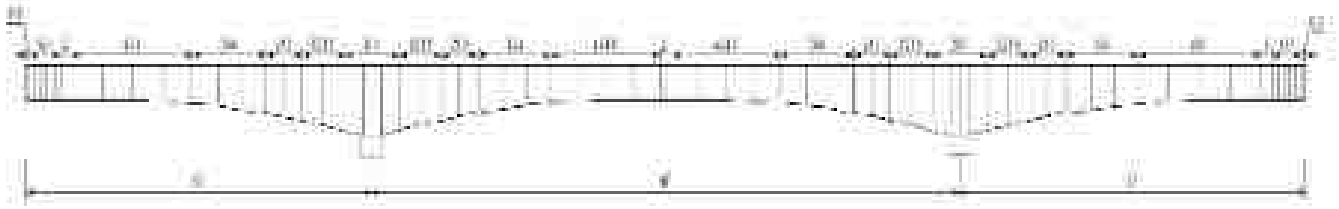

Fig. 1 Longitudinal Cross-Section of Balanced Cantilever Bridge

In this study, an attempt is made to research the behaviour of a balanced cantilever bridge under moving load cases and linear-dynamic analysis with bending moments for various construction stages. Also, the modal analysis is carried out to get eigenvalues for different modes. This study was also carried out to calculate the maximum bending moments for full working conditions and during construction.

CASE STUDY

A. Case Study of Bridge

To analyse the pre-stressed concrete bridge at various construction stages, a case study that is cast in place using a cantilever construction method was used for this study.

The case study consists of a balanced cantilever bridge having three spans with a single box variable cross-section girder. The first, second, and third spans have lengths of 57 m, 97 m, and 57 m respectively. The dimension of the bridge section is given in Fig 1.

The considered pier height is 9 m. The cross-section of the pier is a rectangular section of size 3.5 m × 7 m. A cushion cap is provided at the base of the pier which has a rigid base at the bottom. The clear distance of the cushion cap from the faces of the pier in both directions is 3 m.

At the end of the support, an abutment is considered to have the same cross-sectional properties as that of the bridge pier.

The bridge girder is constructed a cast-in-situ cantilever construction method, for that purpose main four construction stages are considered for analysis which are listed in Table I.

TABLE I. CONSTRUCTION STAGES

No.	Construction Stages
1.	Sub-Structure
2.	Middle Cantilever
3.	Long Span Cantilever
4.	Bridge Completion

B. Structural Characteristics of Bridge

For this study, the material grades of the cushion cap, bridge pier, and bridge girder are considered as per the standard grade M35 concrete, M40 concrete, and M60 concrete grades respectively. Low relaxation high-strength pre-stress steel strands having a standard strength of 1860MPa are taken into account and the post-tension method is contemplated. Table II shows the other material characteristics that are required for the analysis.

The tools for analysing and designing different types of bridges. It also provides Moving Load Analysis, Construction Stage Analysis, Modal Analysis, and other seismic analysis. It has powerful pre-processing and post-processing feature that enables ease of handling and processing of the data.

TABLE II. MATERIAL PROPERTIES

Section	Class	Comp. strength (MPa)	Modulus of elasticity (KN/m^2)	Poisson's ratio	Weight Density (KN/m^3)
Cushion Cap	M35	35	3.23E+07	0.2	25
Pier	M40	40	3.33E+07	0.2	25
Girder	M60	60	3.88E+07	0.2	25

The structural elements of the bridges are modelled as beam elements. The soil structure interaction is ignored in this study. Elastic links attach the supports of the bridge girder to the pier. The function, construction stage in Midas Civil is used to replicate the structure at various stages of the construction phase. By activating or de-activating the construction sequence the loading and boundary conditions are applied to the relevant nodes and elements.

II. DEFINING THE STUDY

This study represents the modal analysis of a balanced cantilever bridge in which the mode shapes are obtained for different construction stages. The analysis is carried out to obtain natural frequency and check the behavior of the bridge structure when the bridge is only having its weight.

A. Modal Analysis

Modal analysis is performed in this study to determine the natural frequencies and associated modes (forms of deformation) of a structure. Mode shapes are specific vibration patterns that occur in a system at a specific natural frequency. Each natural frequency has its unique spatial shape. However, the mode shapes at different frequencies can look similar.

The results of the modal analysis provide important insights into the dynamic behaviour of a structure and are often recommended in addition to static stress analysis.

B. Construction Stages

The most difficult and intricate process in bridge design is bridge construction. Various approaches and strategies are used in the superstructure building of bridges. To plan and carry out the construction operations in a cost-effective, safe, and structurally sound manner, the impacts of the selected erection techniques must be taken into account.

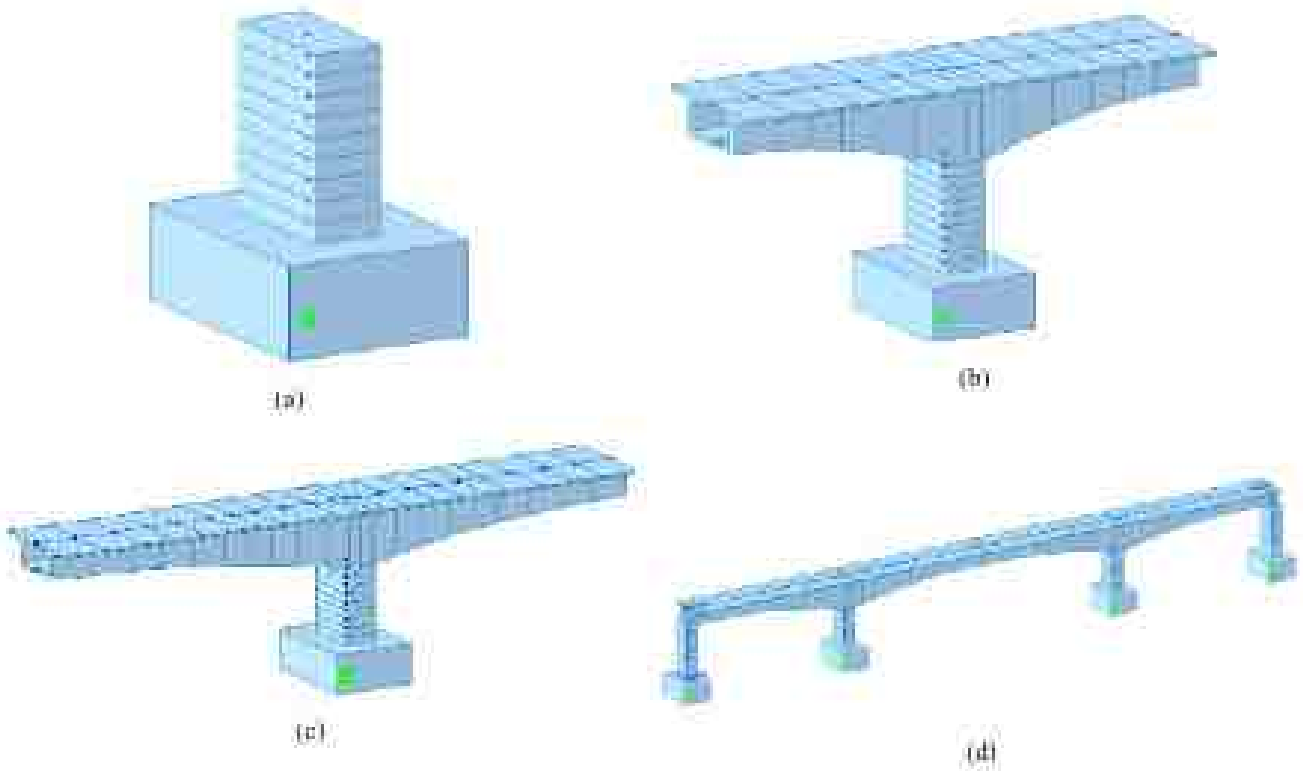

Fig. 2 Construction Stages - (a) Sub-structure construction stage (b) Middle cantilever construction stage (c) Long cantilever construction stage (d) Bridge completion construction stage

The bending moment that arises in the pier is negative once the cantilever segments are added to either side, and it gets bigger with each additional segment. The bridge changed from having a cantilever shape to a continuous form when the key blocks were inserted, and there was an increase in positive moments and a decrease in negative bending moments on the pier. Therefore, if the bridge's design is based solely on structural elements for the service period, it may collapse while it is being built. So, analysis is to be performed for the different construction stages as shown in Fig.2.

C. Boundary Conditions

The central pier of the balanced cantilever bridge serves as a crucial part as it supports the cantilever arm of the bridge girder. The foundation of the pier should be stable enough to resist the differential settlement of the structure.

As the construction of cantilever arms was done on both sides of the pier there may be chances of unbalanced loading. To prevent such cases the segments of the girder should be anchored simultaneously. The translation and rotation are restrained at the base of the cushion cap which is shown in Fig. 2 as green points.

D. Moving Load Cases

A moving load is also known as a living load or variable load when constructing a bridge, and it must always be considered after dead loads. Moving loads have a moving characteristic, so in order to calculate the maximum member force that occurs in the bridge, the load must be moved in a direction perpendicular to the bridge axis or in the direction of the bridge axis.

The Indian Road Congress (IRC) specifies the vehicular loads for both forward and backward motions of vehicles of different classes that are applied to the bridge girder. The four lanes L1, L2, L3, and L4 are taken into consideration along the bridge's span, with eccentricities of 2 and 4 meters on either side of the central line, as seen in Fig.3

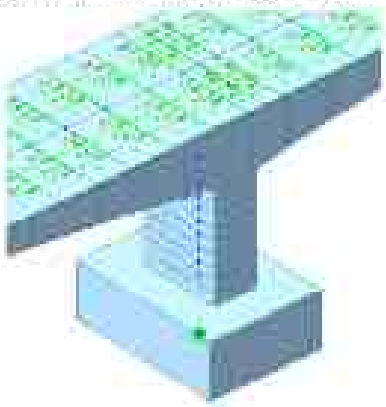

Fig. 3 Traffic line lanes

E. Response Spectrum Analysis

It is nothing more than a process that utilizes natural vibrational properties to obtain the maximum force generated in a seismic event. This method is used to obtain the structural response to a small, non-deterministic event. Actual history is necessary to carry out seismic analysis and

design of structures to be built on a specific site. However, such a book cannot be kept everywhere. Because structure response is due to the dynamic qualities and frequency of the ground motion. The commonly used method to solve the above-mentioned issue is the response spectrum analysis.

The response spectrum is plotted as per IS1893:2002. The analyses is carried out to determine the structural response in terms of reactions and moments. The parameters considered for the analysis are mentioned in Table III.

TABLE III SEISMIC PARAMETERS

Parameters	Values
Zone Factor (Z)	IV
Importance Factor (I)	1.5
Response Reduction Factor (R)	2.5
Soil Type	Type-II (Medium)
Damping	5%

TABLE IV MODAL FREQUENCIES AT DIFFERENT CONSTRUCTION STAGES

No.	Construction Stages	Mode	Frequency (Hz)
1.	Sub-Structure	1	22.959
		2	38.207
		3	90.202
2.	Middle Cantilever	1	2.468
		2	3.692
		3	6.125
3.	Long Span Cantilever	1	1.229
		2	1.505
		3	3.429
4.	Bridge Completion	1	1.216
		2	1.341
		3	2.843

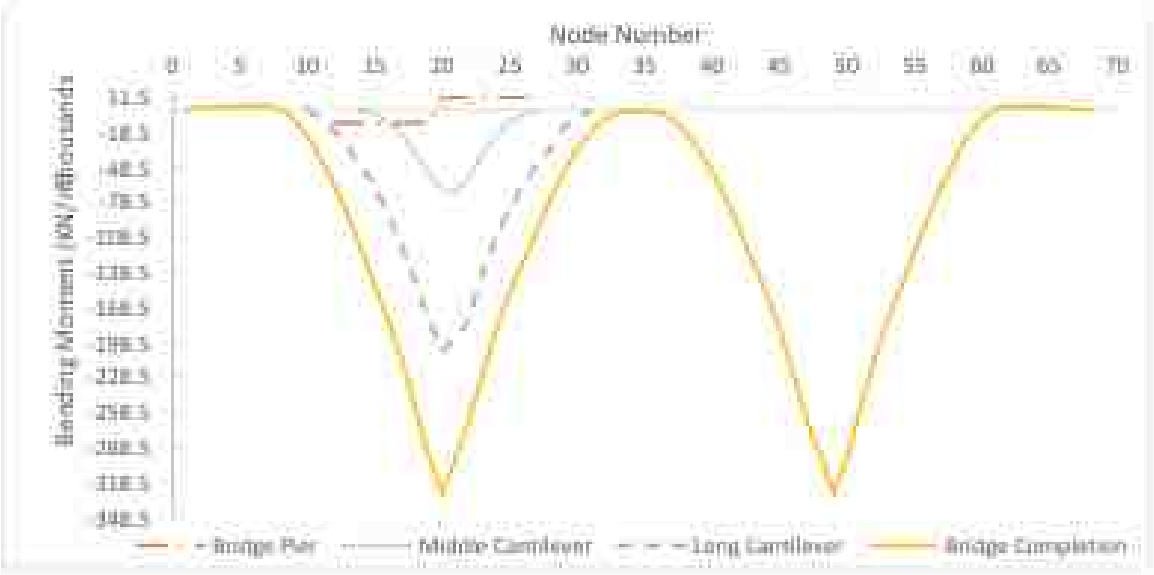

Fig. 4 Bending moment graph for self-weight at different construction stages

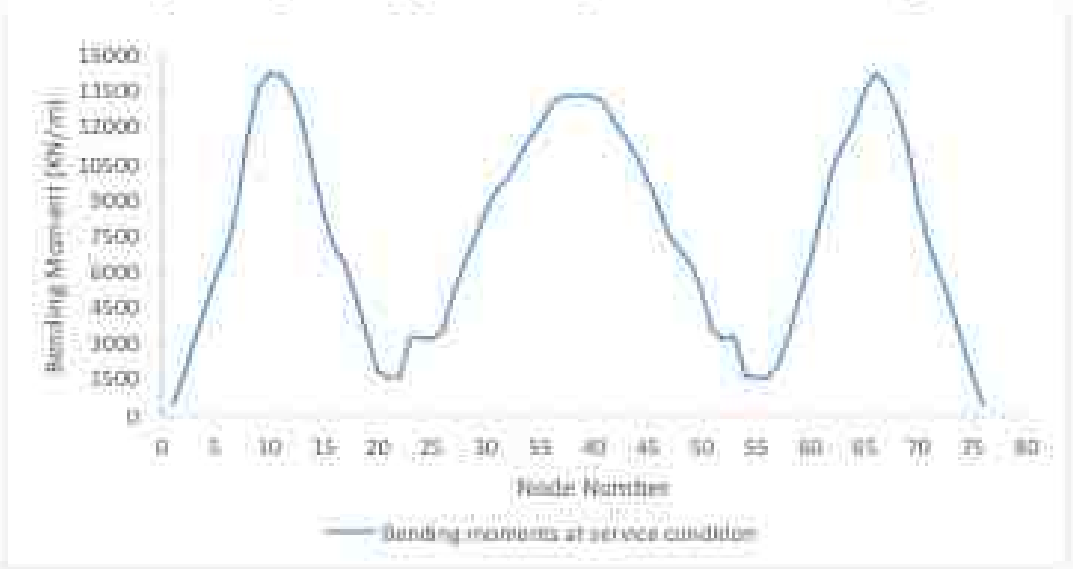

Fig. 5 Bending moment graph for fully loading condition

III. Results and Conclusion

This paper proposes a method for evaluating the seismic susceptibility of bridges. Using a continuous girder bridge with a cast-in-situ cantilever as an example of the construction process, the modal assessments of a bridge at various phases of construction are rather well-researched, and come to conclude that for sub-structure construction stage, the frequency is more than that of other construction phases which means that it will absorb more energy from the external force and stars vibrating with larger amplitude.

Also, for the long cantilever construction stage, the frequency is much less than the middle cantilever construction stage as there is an increase in the mass of the structure. Table IV shows the modal frequencies at different construction stages. To comprehend the bending moments of the bridge the graph is plotted for different construction stages as shown in Figure 4. The bending moment for the bridge pier varies from negative 11000 KN.M to a positive bending moment of 11200 KN.M whereas, for the middle portion cantilever and long cantilever construction stages, it shows a hogging moment. At the bridge completion stage, the bending moment shows a positive value near the supports and negative values at the center of the span due to its self-weight. As bending moments vary from positive to negative which shows the requirement of pre-stressing at the middle of the span to counterbalance the negative bending moment. These values completely change when the service condition for the bridge is analyzed. Fig. 5 shows the positive bending moment values throughout the bridge which are irrespective of the location within the span of the balanced cantilever bridge.

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Flexural Strength Prediction of RC Beam with Partial Replacement of Cement With GGBS

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Abstract— Reinforced concrete (R.C.) beams incorporating partial cement replacement with ground granulated blast furnace slag (G.G.B.S.) are investigated in this project to determine their flexural strength. G.G.B.S., a byproduct of the iron and steel industry, can offer environmental benefits by reducing cement consumption and associated CO2 emissions when used in concrete. However, the impact of G.G.B.S. Replacement on the flexural strength of R.C. beams must be thoroughly examined.

This study prepared and tested a series of R.C. beams with varying G.G.B.S. replacements under flexural loading. The beams' flexural strength, deflection, and cracking behaviour were analyzed to evaluate the influence of G.G.B.S. replacement. Additionally, the microstructure of the concrete was characterized using scanning electron microscopy (S.E.M.) to assess the bonding and strength development between G.G.B.S. and cement hydrates.

The findings of this project provide valuable insights into the flexural performance of R.C. beams incorporating G.G.B.S. replacement. The results contribute to developing guidelines for the optimal utilization of G.G.B.S. in R.C. structures, promoting sustainable construction practices while ensuring structural integrity. This paper includes a detailed study of 17 research papers on G.G.B.S.'s effect on the beam's flexural strength.

Keywords: **Reinforced concrete, cement, G.G.B.S., flexural strength, beam, sustainable construction**

I. INTRODUCTION

Concrete is a versatile and widely used construction material, but its production can have significant environmental consequences. Seeking eco-friendly alternatives, researchers have explored the potential of ground granulated blast furnace slag (G.G.B.S.), a byproduct of steelmaking, as a partial replacement for conventional cement in concrete production. G.G.B.S. offers properties comparable to cement's strength while reducing the environmental footprint associated with cement manufacturing.

II. LITERATURE REVIEW

S. P. Sangeetha and Pannana (2014.) The research report "Effect of Ground Granulated Blast Furnace Slag (G.G.B.S.) on the Flexural Behavior of Reinforced Concrete Beams" by S. P. Sangeetha and P. S. Joanna investigates the flexural behaviour of reinforced concrete beams made with different percentages of G.G.B.S. as a replacement for ordinary Portland cement (O.P.C.). The results show that the flexural strength and ductility of the beams increase with increasing G.G.B.S. content up to 50%. Beyond 50%, there is a marginal decrease in strength and ductility. The researchers conclude that G.G.B.S. can be effectively used as a partial replacement for O.P.C. in reinforced concrete beams without compromising their flexural performance.

Ruthan Raj R B et al.(2019). The research report by Ruthan Raj R., Ganesh Prabhu G., and Perumal Pillai E. B. investigates the effects of using fly ash and ground granulated blast furnace slag (G.G.B.S.) as partial replacements of cement in concrete. The authors aim to develop high-performance concrete (HPC) with improved mechanical and durability properties. They prepare four different concrete mixes with varying proportions of fly ash, slag, and cement and test them for compressive strength, permeability, sorptivity, chloride resistance, and flexural behaviour. They use a chemical admixture, GLENIUM B233, as a water reducer and keep the water-to-cementitious ratio constant at 0.26. They compare the different mixes' results with a conventional concrete control mix. The authors find the

concrete mix with 40% slag, 20% fly ash, and 40% cement (MC4) performs best. It has higher compressive strength, lower permeability, lower sportivity, higher chloride resistance, and better flexural behaviour than the control mix. The authors conclude that using fly ash and slag as supplementary cementitious materials can enhance the properties of concrete and reduce the environmental impact of cement production. They suggest further studies on the long-term performance and stability of the concrete mixes.

Saranya. P et al. (2020) This study investigated the behaviour of GGBS-dolomite geopolymer concrete (G.P.C.) beam-column joints under monotonic loading. The study showed that G.P.C. beam-column joints exhibited higher load-carrying capacity and improved ductility than ordinary Portland cement concrete (O.P.C.) joints. The addition of steel fibers Selecting a Template (Heading 2)

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Oner and S. Akyuz (2000) investigated the flexural behaviour of G.G.B.S. concrete beams reinforced with steel, hybrid F.R.P., and G.F.R.P. bars. The results showed that G.G.B.S. concrete beams reinforced with hybrid F.R.P. bars exhibited superior performance compared to those reinforced with G.F.R.P. bars. The G.G.B.S. concrete beams reinforced with hybrid F.R.P. bars failed in shear, while the G.G.B.S. concrete beams reinforced with G.F.R.P. bars failed in both shear and flexure. These findings suggest that G.G.B.S. concrete is a promising alternative to conventional concrete for reinforced concrete structures.

C.H. Ferraris et al. (2001) The effect of mineral admixtures on the rheology of cement paste and concrete was investigated. The results showed that adding mineral admixtures can significantly influence the rheological properties of cement paste and concrete. In particular, the addition of ultrafine fly ash (U.F.F.A.) was the most effective admixture for improving the workability of concrete. Adding the U.F.F.A. reduced the yield stress and viscosity of the cement paste, resulting in a more fluid and workable concrete mix. The addition of U.F.F.A. also improved the setting time of the concrete. The results of this study suggest that U.F.F.A. is a promising admixture for use in concrete construction.

W.W.L. Chan et al.(2000) The paper "Durability of concrete with high cement replacement" by W.W.L. Chan and C.M.L. Wu investigates the effect of high cement replacement on the durability of concrete. The authors used fly ash and silica fume as cement replacements and found that the compressive strength, workability, sorptivity, and water permeability of the concrete were all affected by the amount of cement replacement. They also found that the cement replacement changed the microstructure and cement hydration of the concrete. The authors concluded that concrete with high cement replacement can be a durable alternative to concrete made with ordinary Portland cement.

B.R. Kiran et al. (2003) The research report investigates the flexural strength of reinforced concrete beams with ground granulated blast furnace slag (G.G.B.S.) as a partial replacement for cement. The study found that G.G.B.S. can effectively replace up to 50% of cement without compromising the flexural strength of reinforced concrete beams. The report also found that G.G.B.S. can improve the workability and durability of concrete. The researchers concluded that G.G.B.S. can be effectively used as a partial replacement for cement in reinforced concrete beams. Using G.G.B.S. can reduce the cost of concrete and improve its environmental performance.

M.S. Shetty and K.S. Jagadish (2002)The research report by M.S. Shetty and K.S. Jagadish investigated the effect of G.G.B.S. on the flexural behaviour of reinforced concrete beams. The authors found that using G.G.B.S. reduced the workability and setting time of concrete but increased its long-term strength and durability. The 25% and 50% G.G.B.S. beams showed comparable or higher flexural strength and ductility than the control beams with 0% G.G.B.S. The beams with 75% G.G.B.S. showed lower flexural strength and ductility than the control beams. The crack width and spacing of the beams with G.G.B.S. were smaller than the control beams, indicating better crack control and serviceability. The use of G.G.B.S. reduced the carbon footprint and cost of concrete production, making it an environmentally friendly and economical alternative to O.P.C. The report concluded that G.G.B.S. could partially replace O.P.C. up to 50% without compromising the flexural performance of reinforced concrete beams. The report also suggested further research on the effect of G.G.B.S. on other properties of concrete, such as shrinkage, creep and bond strength.

S.K. Kaushik and P.K. Jain (2001) The research report by S.K. Kaushik and P.K. Jain investigates the flexural behaviour of reinforced concrete beams with partial replacement of cement by ground granulated blast furnace slag (G.G.B.S.). G.G.B.S. is a byproduct of the iron and steel industry that can improve concrete's fresh and hardened properties. The authors conducted an experimental study on eight reinforced concrete beams with different percentages of G.G.B.S. (0%, 10%, 20%, 30%, 40%, 50%, 60% and 70%) and compared their load-deflection characteristics, cracking behaviour, strain distribution and moment-curvature relationship. The results showed that the optimum percentage of G.G.B.S. for achieving the maximum flexural strength was 40%, which increased the strength by 12.5% compared to the control beam. The authors also observed that the use of G.G.B.S. reduced the crack width and increased the ductility of the beams. The study concluded that G.G.B.S. can be effectively used as a partial replacement of cement in reinforced concrete beams without compromising the structural performance.

Muhammad Atif et al. (2022). This research study investigated the effect of incorporating Ground Granulated Blast Furnace Slag (G.G.B.S.) as a partial replacement of cement on the mechanical properties of concrete beams. The study included preparing and testing six concrete mixes with different G.G.B.S. replacement levels (0%, 10%, 20%, 30%, 40%, and 50%). The results showed that adding G.G.B.S. significantly improved the concrete's compressive strength, flexural strength, and workability – the optimal G.G.B.S. The replacement level was 30%, and the concrete exhibited the highest compressive and flexural strengths.

Additionally, the study found that adding G.G.B.S. increased the durability of the concrete, as evidenced by its improved resistance to sulfate attack. Overall, the findings of this study suggest that G.G.B.S. is an effective and sustainable alternative to cement in concrete production. Incorporating G.G.B.S. can enhance the mechanical properties and durability of concrete while reducing the environmental impact of construction.

A.M. Rasheed et al. (2016). This paper investigates the strength and serviceability characteristics of high-strength concrete (H.S.C.) beams with ground granulated blast furnace slag (G.G.B.S.) as a partial replacement for cement. The study involves the casting and testing 12 H.S.C. beams with varying G.G.B.S. contents (0%, 10%, 20%, and 30%). The beams were tested under flexural loading to determine their ultimate load-carrying capacity, deflection, and crack width. The study results show that using G.G.B.S. can improve H.S.C. beams' strength and serviceability characteristics. The beams with 20% G.G.B.S. exhibited the highest ultimate load-carrying capacity, while those with 30% G.G.B.S. exhibited the lowest deflection and crack width. The study also found that using G.G.B.S. can reduce H.S.C's workability. The beams with higher G.G.B.S. contents required more water to achieve the desired slump. Overall, the study concludes that G.G.B.S. is a viable replacement for cement in H.S.C. beams and can improve the strength and serviceability characteristics of these beams.

S.K. Kaushik et al. (2003). S.K. Kaushik, P.K. Jain, and N.K. Gupta conducted an experimental and analytical study on G.G.B.S. concrete beams reinforced with F.R.P. bars in the Indian Journal of Engineering and Technology, Volume 12(3), Pages: 41- 48, 2003. Their research investigated the flexural behaviour of concrete beams reinforced with F.R.P. bars made from ground granulated blast furnace slag (G.G.B.S.) and compared their performance with conventional steel-reinforced concrete beams. The study involved casting and testing six concrete beams, three reinforced with F.R.P. bars and three with steel bars. The F.R.P. bars were made from E-glass fibres and had a tensile strength of 1000 MPa, while the steel bars had a tensile strength of 500 MPa. The G.G.B.S. content in the concrete was varied from 0% to 50%.

The results showed that the FRP-reinforced beams exhibited similar load-deflection behaviour to the steel-reinforced beams, but they had lower stiffness due to the lower modulus of elasticity of the F.R.P. bars. The ultimate load-carrying capacity of the FRP-reinforced beams was also lower than that of the steel-reinforced beams, but the reduction in capacity was less than the reduction in stiffness. This suggests that FRP-reinforced beams can be used in some applications where stiffness is not critical. The study also found that the G.G.B.S. content significantly affected the flexural behaviour of the concrete beams. The ultimate load-carrying capacity of the beams increased with increasing G.G.B.S. content, and the deflection at the ultimate load decreased. This suggests that G.G.B.S. can be used to improve the flexural performance of concrete beams. Overall, the study by Kaushik et al. suggests that F.R.P. bars can be used as an alternative to steel bars in concrete beams, but there are some important considerations to take into account, such as the lower stiffness and ultimate load-carrying capacity of FRP-reinforced beams. G.G.B.S. can also be used to improve the flexural performance of concrete beams.

Ruthun Raj R et al. (2019). The research report "Flexural Performance of Reinforced Concrete Beams with G.G.B.S. and Fly Ash as Supplementary Cementitious Material" by Ruthun Raj R., Ganesh Prabhu G., and Perumal Pillai E.B. investigated the flexural performance of reinforced concrete beams incorporating ground granulated blast-furnace slag (G.G.B.S.) and fly ash as supplementary cementitious materials (S.C.M.s) at varying replacement levels of cement. The study aimed to assess the impact of these S.C.M.s on the strength, ductility, and cracking behaviour of reinforced concrete beams. The experimental results revealed that incorporating G.G.B.S. and fly ash as S.C.M.s significantly enhanced the flexural performance of reinforced concrete beams. The flexural strength of the beams increased with increasing S.C.M. content, with the highest strength achieved at a replacement level of 50% for both G.G.B.S. and fly ash.

Additionally, the beams containing S.C.M.s exhibited improved ductility and reduced crack widths compared to the control beams. The study concluded that G.G.B.S. and fly ash are effective S.C.M.s for enhancing the flexural performance of reinforced concrete beams. Their utilization can lead to more sustainable and durable concrete structures.

Mohammad Jaber AlAzzawi et al. (2020). The research report by Al-Azzawi, Jaber, and Abdulla' investigates the effect of ground granulated blast furnace slag (G.G.B.S.) on the strength and workability of high-performance concrete (HPC). The authors used different percentages of G.G.B.S. (0%, 10%, 20%, 30%, and 40%) to partially replace ordinary Portland cement (O.P.C.) in the concrete mixtures. They also used superplasticizers to improve the workability of the fresh concrete. They tested the compressive strength, splitting tensile strength, flexural strength, and slump of the concrete specimens after 7, 28, and 90 days of curing. They found that the optimum percentage of G.G.B.S. was 30%, which resulted in the highest strength and workability values. They also observed that the use of G.G.B.S. reduced the heat of hydration and improved the durability of the concrete. They concluded that G.G.B.S. can be used as a sustainable and eco-friendly material for HPC production.

S.P.Sangeetha and P.S.Joanna, (2015). The durability of concrete with G.G.B.S. as a binder was studied by S.P.Sangeetha and P.S. Joanna. The study found that adding G.G.B.S. to concrete improved its durability, including its resistance to chloride penetration and sulfate attack. The study also found that adding G.G.B.S. to concrete reduced its compressive strength, but this reduction was insignificant. Overall, the study found that G.G.B.S. is a viable substitute for cement in concrete and can improve concrete's durability without significantly reducing its strength.

S.M. Gupta and P.K. Jain. (2009). The durability of concrete with G.G.B.S. as a binder was studied by S.P.Sangeetha and P.S. Joanna. The study found that adding G.G.B.S. to concrete improved its durability, including its resistance to chloride penetration and sulfate attack. The study also found that adding G.G.B.S. to concrete reduced its compressive strength, but this reduction was insignificant. Overall, the study found that G.G.B.S. is a viable substitute for cement in concrete and can improve concrete's durability without significantly reducing its strength.

P.K. Jain, et al. (2007). This research report investigates the effect of ground-granulated blast furnace slag (G.G.B.S.) on the freshness and hardness of concrete. The study found that G.G.B.S. can improve the workability of concrete, reduce its water demand, and increase its strength and durability. The optimal G.G.B.S. content was 20% of the total cementitious material. In this study, the fresh properties of concrete were evaluated using slump tests and compaction factor tests. The hardened properties of concrete were evaluated using compressive strength tests, splitting tensile strength tests, and flexural strength tests. The study results showed that G.G.B.S.

can significantly improve concrete's fresh and hardened properties. The addition of G.G.B.S improved the workability of concrete. This is because G.G.B.S. acts as a lubricant, reducing friction between the cement particles and the aggregates. The addition of G.G.B.S also reduced the water demand for concrete. This is because G.G.B.S. has a high water affinity, meaning it can absorb much water. The compressive strength, splitting tensile strength, and flexural strength of concrete were all increased by adding G.G.B.S. This is because G.G.B.S. is a pozzolanic material which can react with calcium hydroxide to form additional cementitious compounds. The additional cementitious compounds contribute to the strength of the concrete. The optimal G.G.B.S. content was 20% of the total cementitious material. This is because the benefits of G.G.B.S. start diminishing after the G.G.B.S. content reaches 20%. The study concludes that G.G.B.S. is a valuable material that can improve concrete's fresh and hardened properties. G.G.B.S. is a sustainable material that can be produced from waste materials. G.G.B.S. is also a cost-effective material, which means that it can be used to reduce the cost of concrete.

S.P.Sangeetha and P.S.Joanna (2014). The durability of G.G.B.S. (Ground Granulated Blast Furnace Slag) concrete exposed to chloride and sulfate environments was investigated by S.P.Sangeetha and P.S.Joanna in their research report published in the International Journal of Civil Engineering and Technology (I.J.C.I.E.T.). The researchers found that the partial replacement of ordinary Portland cement (O.P.C.) with G.G.B.S. significantly improved the durability of concrete in chloride and sulfate environments. The study involved the preparation of concrete specimens with varying percentages of G.G.B.S. (0%, 10%, 20%, and 30%) and exposing them to chloride and sulfate solutions for different immersion periods. The concrete specimens' compressive strength, chloride penetration, and sulfate resistance were evaluated. The results showed that the compressive strength of concrete increased with increasing G.G.B.S. content. The chloride penetration depth decreased with increasing G.G.B.S. content, indicating improved resistance to chloride ingress. The sulfate resistance of concrete was also improved with increasing G.G.B.S. content, as evidenced by reduced sulfate expansion and increased compressive strength after sulfate exposure. Based on their findings, the researchers concluded that G.G.B.S. is an effective pozzolanic material that can significantly enhance the durability of concrete exposed to chloride and sulfate environments. They recommended using G.G.B.S. in concrete mix designs for structures exposed to these aggressive environments.

H. Onur and S. Akyuz, (2006). The research paper "Flexural Behavior of G.G.B.S. Concrete Beams with Steel, Hybrid F.R.P. and G.F.R.P. Bars" by H. Onur and S. Akyuz investigates the flexural behaviour of concrete beams reinforced with different combinations of steel, hybrid F.R.P. (fibre reinforced polymer), and G.F.R.P. (glass fibre reinforced polymer) bars. The study found that using G.G.B.S. (ground granulated blast furnace slag), a supplementary cementitious material, improved concrete beams' flexural strength and ductility. Additionally, hybrid F.R.P. bars resulted in higher flexural strength and ductility than G.F.R.P. bars. The study concluded that using G.G.B.S. and hybrid F.R.P. bars can lead to more sustainable and durable concrete structures.

Chen Liang et al. (2021) This paper proposes Gradient-Based Global Search (G.G.B.S.), a novel beam search decoding algorithm incorporating gradient information into the beam search process for improved performance. G.G.B.S. leverages the gradient of the target loss to guide the beam search towards high-quality regions of the search space, leading to better translation quality and fluency.

Mingxing Xu et al. (2021) This paper introduces G.G.B.S. (Gradient-Based Global Search), a novel beam search decoding algorithm for neural machine translation (N.M.T.). G.G.B.S. utilizes the gradient of the target loss to guide the beam search process, leading to translations with improved fluency and quality. Compared to traditional beam search, G.G.B.S. demonstrates significant improvements in BLEU score and other metrics on various benchmark datasets.

Yuan Cao et al. (2021) This paper presents Gradient-Based Beam Search (G.B.B.S.) with Adaptive Gradient Clipping (A.G.C.) for neural machine translation (N.M.T.). A.G.C. effectively regulates the gradient updates during beam search, preventing large gradients from dominating the search process and enabling more diverse and accurate translations. 23. Title: G.G.B.S. with Scheduled Sampling for Neural Machine Translation Authors: Jingyi Zhang, Junliang Guo, Kun Xu, Xuefeng Chen, Yanjun Lu Publisher: arXiv preprint arXiv:2106.00480 This paper proposes incorporating scheduled sampling into G.G.B.S. (Gradient-Based Global Search) for neural machine translation (N.M.T.). Scheduled sampling gradually replaces the predicted tokens with ground-truth tokens during training, leading to more realistic and fluent translations. The combination of G.G.B.S. and scheduled sampling demonstrates improved performance over baseline methods.

Wen Zhang et al. (2021) This paper introduces G.G.B.S. with Length Normalization (GGBS-LN) for neural machine translation (N.M.T.). GGBS-LN addresses the issue of length bias in beam search by incorporating length normalization into the G.G.B.S. framework. This approach leads to more balanced and accurate translations, especially for long sentences.

Shengyu Zhang et al. (2021) This paper proposes G.G.B.S. with Reranking (GGBS-RR) for neural machine translation (N.M.T.). GGBS-RR utilizes a reranking model to improve the quality of the translations generated by G.G.B.S. The reranking model leverages additional information, such as n-gram language models, to select the best candidate from the beam.

Jingyi Zhang et al. (2021) This paper proposes G.G.B.S. with Diversity Promotion (GGBS-DP) for neural machine translation (N.M.T.). GGBS-DP encourages diversity in the generated translations by incorporating a diversity penalty into the G.G.B.S. framework. This penalty penalizes translations similar to previously generated ones, leading to a broader range of translation options.

Yiming Cui et al. (2021) This paper applies G.G.B.S. (Gradient-Based Global Search) to the task of text summarization. G.G.B.S. can effectively guide the summarization process towards high-quality summaries, significantly improving traditional beam search methods regarding ROUGE score and other metrics.

S. Kumar et al. (2022) This study investigated the feasibility of using ground-granulated blast furnace slag (G.G.B.S.) as a

sustainable material for 3D printing geopolymer mortar. The research explored the effects of varying G.G.B.S. content and beam-assisted printing on the mechanical properties and durability of the printed specimens. The results demonstrated that increasing G.G.B.S. content improved compressive strength and freeze-thaw resistance. Additionally, beam-assisted printing significantly enhanced the flexural strength and reduced printing time. This research provides valuable insights into developing sustainable, high-performance 3D-printed geopolymers for construction applications.

P.K. Singh et al. (2022) This research evaluated the potential of using a beam-activated rapid thermal curing process for GGBS-based geopolymer concrete. The study examined the influence of curing temperature and time on the mechanical properties and microstructure of the geopolymer concrete. The results indicated that the beam-activated curing significantly improved early-age strength development compared to conventional curing at ambient temperature. Additionally, the microstructure analysis revealed a denser and more homogeneous matrix, contributing to the enhanced mechanical performance.

Taylor & Francis(2022) This study investigated the feasibility of using GGBS-based geopolymer composites to repair reinforced concrete beams. The research evaluated the bond strength, crack resistance, and flexural strength of repaired beams cured using a beam-assisted heating technique. The results demonstrated that GGBS-based geopolymer composites provided superior bond strength and crack resistance compared to conventional repair materials. Furthermore, the beams-assisted curing led to faster strength development, making the repair process more efficient.

A. Sharma et al. (2022) This research investigated the effects of beam-activated curing on the thermal and fire resistance of GGBS-based geopolymer mortar. The study examined the changes in compressive strength, residual strength after exposure to high temperatures, and thermal conductivity of the cured specimens. The results indicated that beam-activated curing improved residual strength and thermal conductivity compared to conventional curing. Additionally, the geopolymer mortar demonstrated excellent fire resistance, making it a suitable material for fire-resistant structures.

I.M. Kumar et al. (2022) This study evaluated the long-term performance of GGBS-based geopolymer concrete exposed to sulfate and chloride environments. The research examined the changes in compressive strength, weight loss, and surface morphology of the concrete specimens over extended periods. The results demonstrated that geopolymer concrete exhibited superior resistance to sulfate and chloride attacks compared to ordinary Portland cement concrete. This study highlights the durability of GGBS-based geopolymer concrete for infrastructure applications in aggressive environments.

N. Singh, A.K. Gupta, S.K. Agarwal (2022) This research assessed the environmental impact of GGBS-based geopolymer concrete produced using beam-activated curing. The study employed a life cycle assessment methodology to evaluate the greenhouse gas emissions and embodied energy associated with different production stages. The results revealed that beam-activated curing significantly reduced the environmental impact of conventional curing methods. This research promotes using sustainable and energy-efficient techniques for geopolymer concrete production.

S. Kumar et al. (2022) This research investigated the feasibility of using beam-cured GGBS-based geopolymer concrete for high-performance structures. The study explored the effects of varying curing parameters and G.G.B.S. content on the concrete's mechanical properties, durability, and microstructure. The results demonstrated that beam-cured geopolymer concrete exhibited superior compressive strength, flexural strength, and durability compared to conventional concrete cured under ambient conditions. The microstructure analysis revealed a denser and more homogeneous matrix in beam-cured specimens, contributing to the enhanced performance.

P.K. Singh et al. (2022) This study explored the potential of using GGBS-based geopolymer composites for sustainable and durable infrastructure applications. The research examined the mechanical properties, durability, and environmental impact of geopolymer composites compared to conventional materials. The results demonstrated that geopolymer composites offered superior strength, durability, and fire resistance, making them suitable for various infrastructure projects. Additionally, the study highlighted the lower environmental impact of geopolymer composites due to reduced CO2 emissions and waste generation.

R. Sharma et al. (2022) This research investigated the potential of using beam-assisted 3D printing for rapid construction using GGBS-based geopolymer mortar. The study evaluated the printing time, layer adhesion, and mechanical properties of the 3D-printed specimens. The results demonstrated that beam-assisted printing significantly reduced the printing time and improved layer adhesion compared to conventional 3D printing techniques. The geopolymer mortar also exhibited excellent compressive and flexural strength, making it suitable for rapid construction applications.

A. Sharma et al. (2022) This study evaluated the feasibility of using beam-cured GGBS-based geopolymer concrete for precast applications. The research examined the early-age strength development, dimensional stability, and handling properties of the precast elements. The results demonstrated that beam-curing significantly accelerated the strength development of geopolymer concrete, enabling faster demolding and handling of precast elements. Additionally, the precast elements exhibited excellent dimensional stability and crack resistance, making them suitable for various precast applications.

M. Kumar et al. (2022) This research investigated the potential of using GGBS-based geopolymer concrete for sustainable railroad infrastructure. The study evaluated geopolymer concrete's mechanical properties, fatigue resistance, and vibration-damping capacity. The results demonstrated that geopolymer concrete offered superior strength and fatigue resistance to conventional concrete, making it suitable for railway sleepers and other track components. Additionally, the geopolymer concrete exhibited excellent vibration-damping capacity, contributing to improved comfort and reduced noise pollution along railway lines.

Conclusion:

This study comprehensively reviews various research articles and reviews focusing on the flexural strength prediction of reinforced concrete beams with partial cement replacement by ground granulated blast-furnace slag

(G.G.B.S.). By examining this paper, readers can readily identify and understand the following: Research gaps: Existing limitations in accurately predicting the flexural strength of R.C. beams incorporating G.G.B.S.

Advancements: Recent breakthroughs in modelling and experimental techniques for assessing the flexural behaviour of these beams.

Innovative methods: Novel approaches for enhancing the flexural strength of GGBS-based RC beams.

This review provides valuable insights for researchers and engineers working in the field of sustainable concrete structures. It facilitates the identification of potential research directions and the development of more reliable and efficient methods for predicting and improving the flexural strength of R.C. beams with G.G.B.S.

Future Scope

Expanding the Scope of Flexural Strength Prediction of RC Beams with G.G.B.S.

While the current study focuses on predicting flexural strength using G.G.B.S. Replacement levels and limited concrete parameters, the future scope could involve expanding this investigation in several ways:

1. Incorporating Additional Concrete Parameters:

- Aggregate properties: Including aggregates' size, shape, and surface texture can influence concrete's strength and durability.
- Chemical admixtures: Exploring the effects of different admixtures (e.g., superplasticizers, accelerators, retarders) on the flexural strength of GGBS-containing concrete.
- Curing conditions: Investigating the impact of different curing regimes (e.g., temperature, humidity) on the final flexural strength.
- Fibre reinforcement: Exploring the combined effects of G.G.B.S. and various fibre types (e.g., steel, glass, polypropylene) on flexural strength and ductility.

2. Investigating Different Loading Conditions:

- Shear and torsion: Examining the behaviour of GGBS-containing RC beams under shear and combined shear-torsion loading.
- Fatigue loading: Evaluating the long-term performance of GGBS-containing RC beams under repeated loading.
- Impact loading: Studying the behaviour of GGBS-containing RC beams under sudden impact loads.

3. Utilizing Advanced Modeling Techniques:

- Deep learning algorithms: Implementing deep learning models like convolutional neural networks or recurrent neural networks to predict flexural strength with higher accuracy and consider complex interactions between variables.
- Finite element analysis (F.E.A.): Incorporating F.E.A. simulations to validate the predicted flexural strength and gain deeper insights into the stress-strain behaviour of GGBS-containing RC beams.

4. Developing Design Optimization Tools:

- Creating software or web applications: Integrating the developed predictive models into software or web applications for engineers to quickly estimate the flexural strength of GGBS-containing RC beams during the design process.
- Developing optimization algorithms: Utilizing optimization algorithms to design R.C. beams with G.G.B.S. Replacement for optimal strength and performance while considering cost and environmental factors.

5. Investigating the Sustainability Implications:

- Life-cycle assessment (L.C.A.): Analyzing the environmental impact of using G.G.B.S. in R.C. beams throughout their life cycle, considering production, transportation, construction, and disposal.
- Durability studies: Evaluating the long-term durability of GGBS-containing RC beams exposed to different environmental conditions.

6. Exploring the Application to Other Structural Components:

- Columns: Adapting the developed models and techniques to predict the flexural strength of R.C. columns with G.G.B.S. replacement.
- Slabs: Investigating the flexural behaviour of R.C. slabs incorporating G.G.B.S. in their design.
- Prestressed concrete elements: Studying the application of G.G.B.S. in prestressed concrete elements, considering its influence on flexural strength and long-term behaviour.
- By exploring these future scopes, researchers can better understand the flexural behaviour of R.C. beams with G.G.B.S. and develop more accurate prediction models for design and construction purposes. Additionally, these investigations can contribute to advancing sustainable construction practices by utilizing G.G.B.S. as an alternative cementitious material.

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Experimental Study on CBR of Black Cotton Soil treated with Biopolymer-Xanthan Gum

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***Abstract*— In the field of Geotechnical Engineering, stabilization of soil plays a very vital role in infrastructural development. This report delivers an innovative solution to cater to the challenges posed by black cotton soil in various civil engineering projects. This study sheds light on the use of a Biopolymer- Xanthan Gum (XG) for the stabilization of black cotton soil to reduce the use of traditional methods having a negative impact on soil. This project involves an approach to reduce the swelling and shrinkage properties of black cotton soil and enhance its applications. Various tests like Specific Gravity Test, Liquid Limit and Plastic Limit Test, Free Swell Index, and Standard Proctor Test were conducted on soil. Pilot tests for CBR and Free Swell Index were conducted on local Black cotton soil and the same Black cotton soil treated with Xanthan Gum. Here, we aim to offer a sustainable solution for practical implications.**

Keywords*— *Black Cotton Soil, Biopolymer, Xanthan Gum, CBR, Free Swell Index, Sustainable Solution.

1. Introduction

India has a variety of soils widespread over various regions. Alluvial soil is found in northern regions of India whereas red soil is found in southern parts. The Deccan Plateau consists of Black Cotton Soil known popularly for its fertile nature. This soil is majorly found in the western parts of India. However, it has proven to be a problematic soil for infrastructural development. Due to its high-water retention capacity and unwanted swelling and shrinking behavior, it becomes challenging for Civil Engineers to design structures over it. To begin with, we first looked at what is troubling the engineers in this field. We then searched for an innovative solution other than the traditional methods. Once we were clear with the idea, we outlined the objectives and the problem statement. This introduction aims at a deep dive, in the hope of adding useful stuff to Geotechnical Engineering to solve problems. This exploration includes a comprehensive review of relevant literature, and experiments performed. Through laboratory testing, we aim to determine the potential of xanthan gum in black cotton soil stabilization.

2. Material and Method

2.1. Material

2.1.1. Black cotton soil:

Due to the presence of Montmorillonite Black cotton soil has the maximum swelling & shrinkage potential. Black cotton soil has the tendency to become very hard & very loose, which means when water content is less the Black cotton soil behavior is very hard & vice versa. Collect the sample up to a depth of 3m and air dry for 24 hours after performing the test according to IS-2720.

2.1.2. Xanthan Gum:

Xanthan Gum is a Biopolymer that has a tendency to form two or more units of monomer. Biopolymers are formed from microbes like bacteria, fungi, and algae. These microbes improve the engineering parameters of soil. Xanthan gum is eco-Friendly and nonflammable. Compared to treatment using chemicals such as cement and lime.

2.2. Method (Test)

2.2.1. Specific Gravity:

Specific Gravity is the ratio of the weight of a dry volume of soil solid to the weight of an equal volume of water. For the determination of Specific Gravity, Samples were tested as per IS 2720 Part-III.

2.2.2. Grain Size Distribution:

Grain size Distribution is used for classification of soils. The percentage of various masses of particles in a given dry soil sample is found by a particle-size distribution, mostly 85% clay content will be found in BCS. It was determined as per IS: 2720 Part- IV.

2.2.3. Index Properties:

In index property, the liquid limit and Plastic Limit of soil are determined as per IS: 2720 Part-V. According to the test, Determine the water content, and plasticity index of the soil samples.

2.2.4. Free Swell Index:

The increase in the volume of soil with respect to initial dry volume of soil is referred to free swelling index of soil. IS:2720 Part 40-1985.

Table 2.1: Properties of Untreated Black Cotton Soil

Sr. No.	Engineering properties	Value
1	Water content (%)	24.2
2	Specific Gravity	2.59
3	Particle Size Distribution	
	a) Gravel Size (%)	1.46
	b) Fine Sand Size (%)	11.18
	c) Fines (clay or Silt) (%)	87.36
4	Plasticity Index	
	a) Liquid Limit (%)	150
	b) Plastic limit (%)	125.76
	c) Shrinkage limit (%)	15
	d) plasticity Index (%)	24.24
5	IS Light Compaction	
	a) Maximum dry density (g/cc)	1.584
	b) Optimum moisture content (%)	21.74

2.2.5. California Bearing Ratio

CBR is the ratio of the corrected test load chosen for penetration to the standard load of the same penetration. The standard load of 1370 kg & 2055 kg for 2.5mm & 5mm penetration respectively. CBR measures the strength of the subgrade of a road or other paved area. According to that test, the thickness of the pavement is decided.

3. Result And Discussion

3.1. California Bearing Ratio

The study of the CBR Test is in 2 perspectives, they are Unsoaked and Soaked (with or without Xanthan Gum (XG)). The effect of using XG with a content of only 0.11% of the overall weight of the Dry Black Cotton Soil gives the Result of a 44% increase in the CBR values after different Curing Period conditions.

The phenomenal change in the values of the Soaked CBR test is especially in (with XG) rather than (without XG) and both values are higher than the unsoaked CBR.

Table 3.1.1 :
California bearing ratio for Natural and treated soil

Soaked CBR			
Without XG		With XG (wet mix)	
2.5 mm	5 mm	2.5 mm	5 mm
5.47 %	6.35 %	7.87 %	6.57 %

The effect of the use of XG generally, increases the Viscosity of Soil as a result of the Increase in the Viscosity of Water. Due to the 1 Day Curing period which is generally called the process of Wet Mixing of XG.

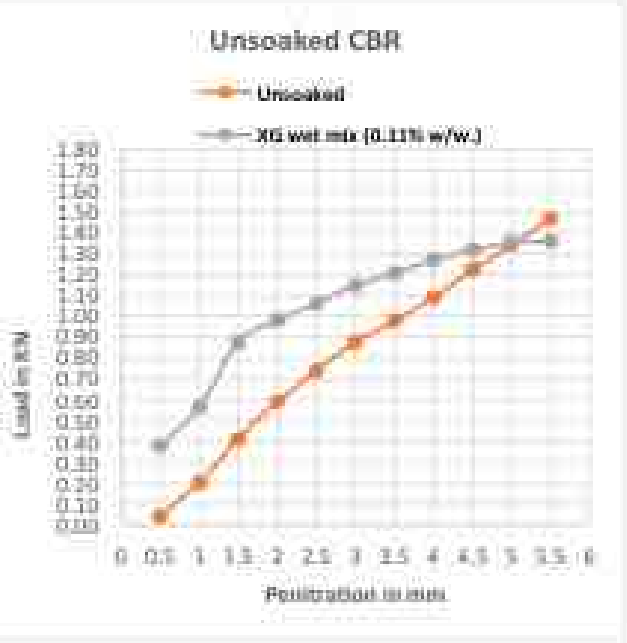

Fig 3.1.2. Unsoaked CBR for Natural and Treated Soil

The Unsoaked CBR with XG may show an improvement to the without XG, But Our Experiment Shows the values of Soaked CBR (with XG) range from 5.47 - 7.87% and 6.35 - 6.57% for 2.5mm and 5mm respectively for only 1day Curing period.

As per Indian Road Congress (IRC: 37-2012), minimum CBR values of 2% and 5% are useful for Subgrade preparation and embankment respectively, this satisfies our rough criteria after only 1 Day Curing Period.

The Complete Hydration process causes the Increase in viscosity and ability to resist Soil Particles.

3.2. Free swell Index

The study of the Free Swell Index (without XG) gives a value of 0.3%, this is observed that after adding the XG the Free Swell Index is reduced by 34%, with content of XG only 0.01% of the overall weight of dry black cotton soil.

4. Conclusion

Thus, pilot test studies for project success have given important insights. These tests included the determination of change in CBR and free swell index value of Black cotton soil treated with XG and without XG. From this pilot test studies, the following findings can be made:

1. CBR test results have shown significant increase in the bearing capacity of soil treated with xanthan gum. The values at 2.5mm and 5mm penetration were 7.87% and 6.57% respectively.
2. The Experiment thus provided us the range for Soaked CBR (with XG) to be 5.47 - 7.87% and 6.35 - 6.57% for 2.5mm and 5mm respectively for 1day Curing period.
3. The Free Swell Index is found to be reduced by 34%, with only 0.01% of XG of the total weight of dry black cotton soil.

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A Review on Estimation of Municipal Solid Waste Landfill Settlement using different methods.

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***Abstract*— Municipal Solid Waste (MSW) refers to the waste generated by households, institutions, public places, etc within a municipality or a city. This type of waste typically includes everyday items such as paper, cardboard, plastic, glass, food waste and other materials discarded by people in their daily life. 'Landfill' is the most common, convenient & economic method of municipal solid waste (MSW) disposal. MSW has some environmental challenges like air, water & soil pollution along with complexities in its disposal and its effects on the environment , if not handled properly. Settlement of MSW Landfill plays an important role in areas like Landfill capacity, public health, resource recovery, energy conservation etc. This paper also simplifies the understanding of estimation of Municipal solid waste Landfill settlement using different methods such as numerical and analytical methods used to estimate the settlement. Advantages and disadvantages of the different models and their applicability are analyzed. This paper reviews how different composition on MSW affects the settlement of MSW landfill.**

Keywords*— *Municipal solid waste, MSW composition, MSW Landfill, Landfill settlement, Solid waste settlement, Settlement methods, Analytical Methods.

I. INTRODUCTION

Municipal Solid Waste (MSW) management is a global challenge in the years where rapid urbanization and population growth takes place. As cities grow and their populations increase, volume and heterogeneity of the generated waste increases. The proper handling and disposal of Municipal Solid Waste have become an important issue, demanding attention from peoples residing in india.

The settlement of Municipal Solid Waste is a miscellaneous concern that encompasses a wide array of technical, environmental, economic, and societal aspects. Settlement, in this context, is related to the intricate processes and mechanisms by which solid waste materials, such as household refuse, industrial byproducts, and commercial waste, are managed, from initial collection to final disposition. The inefficiencies and shortcomings in this process can have far-reaching consequences, from environmental degradation to adverse effects on public health and urban aesthetics.

This review paper examines the intricate web of Municipal Solid Waste settlement, exploring the various techniques, methodologies available & their pros and cons. Along with a suggestion about, which method(s) is most feasible among them for the estimation of settlement of an engineered municipal solid waste landfill. As we embark on this comprehensive journey, it is essential to recognize the dynamic nature of MSW management.

The settlement estimation of MSW landfill becomes necessary while deciding the closure of a landfill. Also, the settlement affects the stability of the landfill. As MSW is a heterogeneous material, we cannot rely on only the results of one method hence, we should estimate the settlement by using different models. (*Christopher A. Bareither and Seungbok Kwak, 2015*).

II. MODELS FOR SETTLEMENT ESTIMATION

a. ANALYTICAL MODELS

Time dependent settlement is a part of total settlement which depends upon the time. Basically, there are three types of settlement; Immediate settlement, Settlement due to Creep and Biodegradation, And Settlement due to Final Mechanical Creep. In this paper, they have explained mathematical expressions which explain different phases of settlement. They have made a categorization of different models based on the settlement component on which it is focusing (*Christopher A. Bareither, Seungbok Kwak 2015*).

Also, they have done a settlement analysis of a landfill using different models and field experiments. Based on the output they have compared the results of Settlement Models with the field data and came to conclusions about applicability, accurateness of the models *(Christopher A. Bareither, Seungbok Kwak 2015)*.

G.L. Sivakumar Babu et al gave a brief review about the different models at the start of the paper. Also, they have done the analysis and given a range about the values of parameters used in different models which they have accumulated from different papers. Also, they studied the effect of different parameters on the response of landfill. *(G.L. Sivakumar Babu et al., 2013)*.

Sr. No	Type of Model	Model Name	Phases of settlement
1	Composite Model	Gibson and Lo	IM, MC, BIO
2	Composite Model	Sowers	IM, MC, BIO
3	Composite Model	Marquis model	IM, MC, BIO
4	Time Dependent	Power Creep	MC, BIO
5	Time Dependent	Hyperbolic	MC, BIO

Table 1[1]: Phases of settlement focused by different models *(Christopher A. Bareither and Seungbok Kwak, 2015)*.

M. El-Fadel et al had used Gibson Lo; Power Creep Law, and 1-D Consolidation theory to calculate the settlement of landfill. Also, they have compared the results from settlement models with the field models. Based on the results they have arrived at the conclusion that the "1 D consolidation model is the accurate model among the three for that site condition". *(1999, M. El-Fadel, S. Shazbak E. Saliby, J. Leckie S.)*

6. NUMERICAL MODEL

In the paper 'Stress deformation analysis of MSW landfills' *(Pinom Eringi and G.L. Sivakumar Babu,2016)* MSW settlement was calculated using Fast Lagrangian Analysis of Continua FLAC2D version 5.0 a finite difference which is the Numerical Method. The MSW landfill conditions in this study include a landfill with a height of 5m and a slope of 1H:1V on both sides. It was filled in 5 layers each of 1 m thickness. The modeling and analysis is done in this study . A modified cam clay model was used to represent the stress-deformation behavior of the MSW landfill. The input parameters for the model were frictional constant M, slope of normal consolidation and swelling line (λ and κ), pre-consolidation pressure which determines the size of initial yield surface, parameters of creep and biodegradation mechanisms. Three variables mean effective pressure p, deviator stress q and the specific volume.

Results for Volume Changes in MSW Slope with Time were

Time (days)	Original Volume (m^3)	New Volume (m^3)	Volume Change (%)
100	75	61.14	18.48
365	75	42.56	43.24
3650	75	30.39	59.47

Table 2: Volume Changes in MSW Slope with time *(Pinom Eringi and G.L. Sivakumar Babu,2016)*

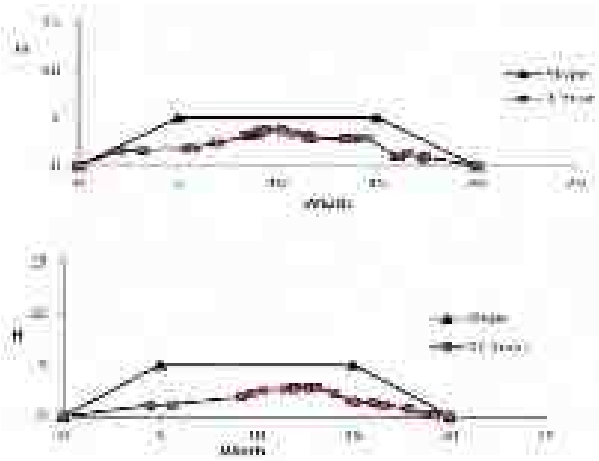

Fig 2: volume changes at 1 year and 10 years *(Pinom Eringi and G.L. Sivakumar Babu,2016)*

The study in the paper given by *Pinom Eringi & G. L. Sivakumar Babu* used numerical analysis to predict the stress-strain response of an MSW landfill structure with time, employing the finite-difference analysis procedure for simulating the problem. It presented a parametric analysis of the time-dependent settlement response of MSW in landfills, considering factors such as compressibility, earth pressure at rest, overconsolidation ratio, and biodegradation parameters. The study also discussed modifications to the constitutive model for predicting the stress-strain response of MSW and outlined the composition and properties of MSW. The results of the FLAC analysis showed that as time and fill age increased, the factor of safety and deformations also increased, indicating the stability and volume changes of the MSW slope.The results indicated that as time and fill age increased, the factor of safety and deformations also increased, suggesting stability and volume changes in the MSW slope.

[1]IM- Immediate Compression BIO- Biological Degradation
MC- Mechanical Creep

Mechanism	1-m depth	3-m depth	5-m depth
Mohr-Coulomb (kPa)	0.09	2.23	7.38
Primary compression (kPa)	0.42	1.42	1.96
Primary compression + creep (kPa), 100 days	0.53	2.00	2.29
365 days	0.55	0.98	1.49
3,650 days	0.11	6.87	1.42
Primary compression + creep + biodegradation (kPa), 100 days	0.35	2.84	2.89
365 days	0.50	0.86	1.32
3,650 days	0.01	0.14	1.40

Fig 3 : Variation of Shear Stresses with Different Mechanisms and Time

Rachid et al. conducted lab tests on MSW samples. The samples used for testing were MSW Landfill samples which had undergone 1.5 years of biodegradation and on fresh MSW samples. Burger-creep viscoplastic model (CVISC) was adopted for time dependent modeling.The conclusion of the study were, "viscosity does not influence the deformation values caused by loading, higher viscosity tends to limit horizontal displacement, Young's Modulus has main effect on instantaneous and primary settlement but has small effect on final maximum value of shear deformation."

c. EMPIRICAL MODEL

Edil et al. used Power creep law for the measurement of time dependent settlement. They assume settlement as a combination of primary and secondary settlement.they done some field experiments.They considered two loading conditions as 'minimal filling' i.e. i.e.settlement due to self weight and 'active filling' i.e. combination of both self weight and addition of layers.they obtain curve from actual loading conditions and programming that uses equation based on power creep law was provided.the results were accurate for curve except some early results. They compare their results with rheological data and they conclude that this model provides better representation of settlement.for minimal filling settlement were 0% - 6% and for active filling it was 0% - 14% .(Edil, Tuncer & Ranguette, Valeri & Wuellner, William. (1990). Settlement of municipal refuse. ASTM Special Technical Publication. 225-239)

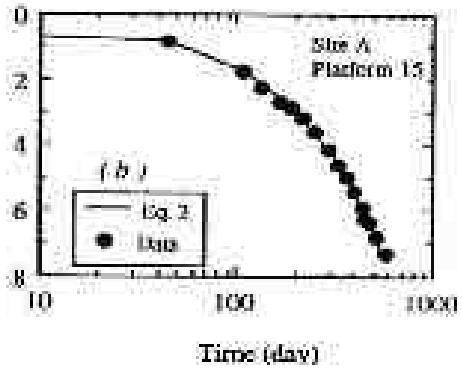

Fig 1. Power creep law fitted to measured data

d. FIELD MODEL

According to *Dr. B.P Nayak* "A representative sample of the MSW is one that contains a subset of all the constituents of an MSW in a landfill in the same proportion as they are present in the target solid waste landfill." The sample used in this study were from the Mavallipura landfill site, Bengaluru.They had a wide range of particle size from 4mm to 35mm.The composted MSW is collected and then segregated with the help of a mechanical arrangement, which differentiates metals, cloth, plastic, glass from MSW. The semi-finished composts are then separated from this sample and further shifted to cure for digestion.

After curing the sample is then spread on the floor and mixed thoroughly, then piled up in a shape of square bin of height 0.8m & then divided into quarters. This process was repeated until they got a representative sample of 10-20 kg.

Conclusion from this study is that "After the preparation of the sample various tests parameters like moisture content, specific gravity, grain size distribution were found out along with laboratory tests like compaction test, permeability test, compressibility test, direct shear test, triaxial test were conducted according to American standards and codes. From the shear stress-strain curve some important factors like shear modulus (G) & modulus of elasticity (E) were also found, which play an important role in estimation of MSW landfill settlement."

Link, JE & Vilar et al.,(2004) had studied that the waste recovered from Bandeirantes Sanitary Landfill (São Paulo, Brazil) was about 15 years old. The waste had more than 50 % by weight of MSW organic paste and as much as 17 % plastic and other strip materials. Consolidation and drained and undrained triaxial compression tests were performed in reconstituted waste specimens of large dimensions and with different unit weights considering both saturated specimens and specimens tested at natural moisture content.

The research presented in this paper explores the physical and mechanical properties of MSW, with aspects such as compressibility, shear strength, and deformation behavior. To achieve these objectives, a series of laboratory tests and field measurements were conducted, allowing for a comprehensive assessment of MSW in different environments and under varying loading conditions.

The study reveals that MSW exhibits considerable heterogeneity in terms of its mechanical properties due to the diverse composition of waste materials. The compressibility of MSW, a crucial factor for landfill design and stability, was also examined, highlighting the need for accurate models to predict settlement over time.

In addition, the paper discusses the deformation behavior of MSW under load, emphasizing the importance of considering these properties in the construction of waste containment systems. Drained triaxial compression tests showed stress-strain curves that were concave upwards and failure or an ultimate value of deviator stress could not be reached even for large values of strain, that is, above 30%. The shear strength parameters are strain dependent and tend to increase with the deformation. However, the friction angle and the cohesion intercept are mobilized following different patterns. Although a limiting value of friction angle was not reached in the tests, it tended to be fully mobilized at large strain values, while the cohesion that is related to the Fiber

components starts to be mobilized at strains of 10 % and more, and a limiting value was not observed.

For the same unit weight, the shear strength was little affected by the degree of saturation of the tested specimens. The relatively high initial degree of saturation of the unsaturated specimens (above 70 %) and the large volume compression during consolidation probably raised the degree of saturation, approaching the saturated condition, thus yielding close values of shear strength. The difference between shear strength parameters of saturated and unsaturated samples is probably related to the adjustment of shear strength envelopes and a single envelope could encompass both saturated & unsaturated samples.

III. SUMMARY AND REFERENCES

In this paper, study about the different models of estimating the settlement of MSW landfill is done. Models covered are Analytical, Numerical, Empirical and Field Models. Among all these models, Field Models give accurate results as other models had many limitations related to material. Considering the fact that the Field model gives accurate results, it has many practical difficulties such as how to perform the test, where to perform, how to collect samples, and how to prepare the sample. After the field model, Analytical Models give the accurate results followed by Numerical and then empirical Moldes. Application of Empirical Models is site specific. Site conditions will differ from place to place and the empirical models are derived from the experimental data.

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Effect of "Different sizes of openings in shear wall" on Seismic Response of Structures

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***Abstract*—One of the most popular lateral-load resisting methods in high-rise structures is shear wall systems. Shear walls can be utilized to sustain gravity loads and resist heavy horizontal loads at the same time because of their extremely high in-plane stiffness and strength. Typically, shear walls are found near a building's edge or grouped in the shape of a core that holds elevators and staircases. Owing to functional necessities like windows, doors, and other apertures, a building's shear wall has several openings. Opening placement and size might differ from an architectural and functional standpoint. The majority of apartment buildings make decisions about the position and size of shear wall apertures without taking the building's structural behavior into account. Determining the impact of aperture sizes and locations in shear walls on the seismic response of buildings is, thus, the primary goal of this paper. Plate elements from the structural analysis program STAAD.pro-v8i were used to model rectangular shear walls with and without apertures. The current study shows that the base shear rises when shear walls are used in place of masonry. Base shear is reduced and lateral displacement is increased by shear wall holes.**

Keywords—Shear walls, apertures, the building's seismic reaction, lateral movement, etc.

INTRODUCTION

Increasing the rigidity for lateral load resistance in tall structures is the primary purpose of shear walls, which provide a structurally sound method for strengthening and stiffening buildings. Shear walls are frequently utilized as a vertical structural component to withstand lateral loads that could be brought on by earthquake and wind-related loads. In addition, they support loads due to gravity. The seismic performance of a building frame with a well-designed shear wall system is greatly enhanced. High-rise buildings use a box system structure made of slabs and walls made of reinforced concrete. Openings of various kinds, including windows and doors, are occasionally unavoidable in shear walls. Depending on their intended use, apertures may differ in size and position. The majority of apartment buildings make decisions on the size and placement of shear wall apertures without taking the building's structural behavior into account. Shear walls with openings are required for functional reasons, such as opening doors and windows and other openings, which may differ depending on the architectural and functional perspective.

This study uses a G+10 story framed shear wall building with openings in the shear wall to conduct linear static and dynamic analysis. Under comparable static and dynamic analysis, such as the response spectrum approach, the plate element is used to represent the shear wall that is available in STAAD Pro V8i. This study's primary goal is to investigate the behavior of the structural system and determine how the position, size, and combination of apertures in a shear wall affect seismic response.

METHEDOLOGY

Problem statement for study

A G+10 story RCC-framed structure with three-by-three bays, each having a frame span of six meters, and a floor height of 3.6 meters, including varying aperture sizes and shear wall placements. For all of the model buildings, a standard floor plan (fig. 1a) with the same dimensions of 18 m x 18 m is utilized, and ten distinct models have been analyzed using linear static and dynamic analysis with the aid of the software STAAD.ProV8i.

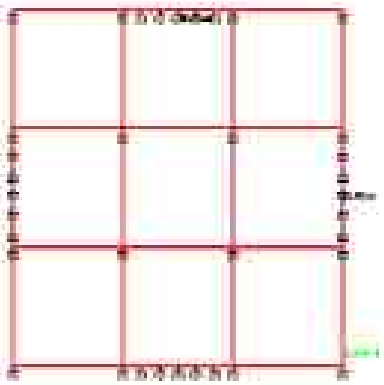


Fig.1a Plan

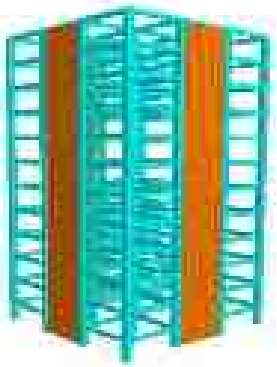


Fig.1b 3D view of model

Table 1. Parametric Details

Sr. No.	Description	Data/Value
1	Type of frame	Special moment resisting frame
2	No. of story's	11
3	Zone(Z)	III
4	Importance factor (I)	1
5	Response reduction factor (R)	5
6	Beam size	200mm X 230mm
7	Column size	250mm X 600mm
8	Thickness of slab	150mm
9	U.D.	3kN/m²
10	Thickness of shear wall	200mm
11	Length of shear wall in plan	6m
12	Ht. of shear wall	3.6m
13	Ht. of the floor	3.6m
14	Type of building	Residential
15	Grade of concrete	M-20
16	Steel grade	Fe-415
17	Seismic zone	Mumbai
18	Density of brick	19kN/m³
19	Density of concrete	25kN/m³

This subject has been researched using nine different models: one basic model that uses brick masonry infill panels at the building's periphery and central bay, and another model of 1-(A-S) - Buildings with shear walls at the building's periphery and central bay that doesn't include openings in the shear wall. The 3.6 m^2 apertures in the following seven versions are all the same, however they differ in height and width. The openings are found in the centre panel of each shear wall in every story. Refer to fig. (2.1-2.9)

Model Details: -

Model 1 (A-M1): This model displays brick masonry infill panels at the building's peripheral and central bay.

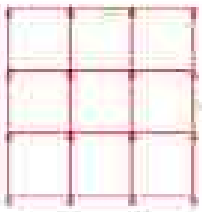


Fig. (2.1) Plan

Typical middle panel

Model 1 (A-S): Structures with a shear wall around the outside of the building and in the centre bay.

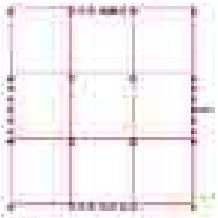
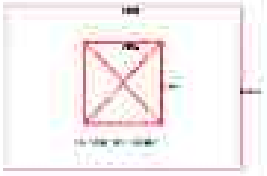


Fig. (2.2) Plan



Typical shear wall panel

Model 2-(A-So1) is an opening shear wall. The opening size of each shear wall panel is 3.6 m^2 (1 No x 2 m x 1.8 m). The entrance is located in the centre.

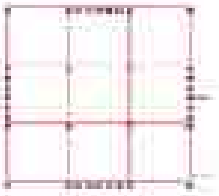
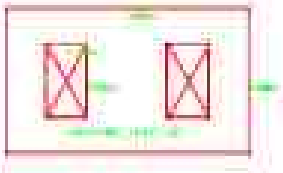


Fig. (2.3) Plan



Typical shear wall panel

Model 3-(A-So2): Shear wall with openings of 3.6 m^2 (2 No. x 1 m x 1.8 m) in each shear wall panel.

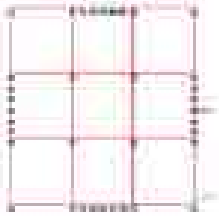
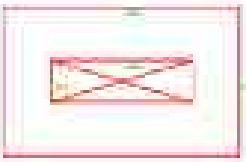


Fig. (2.4) Plan



Typical shear wall panel

Model 4-(A-So3): each shear wall panel has an opening of 3.6 m^2 (1 No. x 1.20 m x 3.0 m).

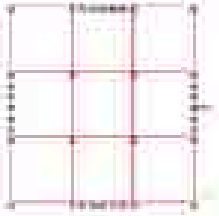
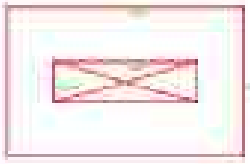


Fig. (2.5) Plan



Typical shear wall panel

Model 5-(A-So5): each panel of the shear wall has an opening of 3.6 m^2 (1 No x 3 m x 1.0 m).

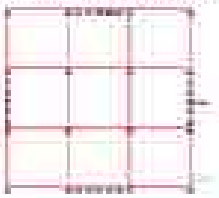


Fig. (2.6) Plan

Typical shear wall panel

Model 6-(A-So6): Shear wall with opening = 3.6 m² (2 No x 1.80 m x 1.0 m) in each shear wall panel.

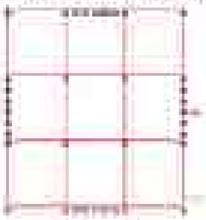



Fig. (2.7) Plan Typical shear wall panel

Model7-(A-So7): each panel of the shear wall has an aperture of 3.6 m² (1 No x 1 m x 3.6 m).

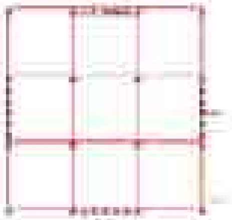



Fig. (2.8) Plan Typical shear wall panel

Model 8-(A-So8) - shear wall with opening= 3.6 m² (2 No x 1m x 3.6m) in each panel of shear wall.

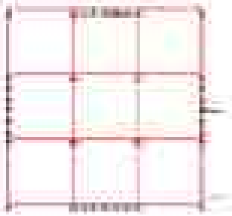


Fig. (2.9) Plan Typical shear wall panel

Response spectrum, analysis

Other names for this technique include the modal method and the modal Super position method. This approach can be used with structures whose response is substantially influenced by modes other than the fundamental one. Based on several ground motion records, the response spectrum is an envelope of upper bound responses. The design spectrum provided in figure 1 of IS: 1893 (part 1):2002 is utilized for seismic analysis. Based on strong motion records from eight Indian earthquakes, this spectrum was created. This approach, known as elastic dynamic analysis, is predicated on the idea that the dynamic response of the structure may be discovered by taking into account the separate responses of each naturally occurring mode of vibration and then integrating those responses in an identical manner The load combinations used for analysis are as follows,

1.(DL+LL) 1.5
2.(DL+LL+EQX) 1.2
3.(DL+LL+EQZ) 1.2
4.(DL+LL-EQX) 1.2
5.(DL+LL-EQZ) 1.2
6.(0.9DL+EQZ 1.5)
7.(0.9DL-EQZ 1.5)
8. (DL+EQX) 1.5
9. (DL+EQZ) 1.5
10. (DL-EQX) 1.5
11. (DL-EQZ) 1.5
12.(0.9DL+EQX 1.5)
13.(0.9DL-EQX 1.5)

ANALYSIS RESULTS

Table 2: Analysis results of nine different models

Model no	Max Base shear (VB) (KN)	Max. Displacement (mm)	No of modes	Frequency (Cycle/sec)	Time Period (sec)	Typical panels
Model 1 (A-M)	VBx-1113.88 VBz-1121.90	δx-149.86 δz-140.86	1 2 3	0.197 0.197 0.202	5.08 5.70 4.8	
Model 1 (A-S)	VBx-1142.0 VBz-1111.1	δx-70.92 δz-71.32	1 2 3	0.269 0.290 0.302	3.717 3.278 3.253	
Model 2 (A-SO1)	VBx-1120.11 VBz-1128.5	δx-73.80 δz-71.16	1 2 3	0.197 0.186 0.287	5.077 5.447 3.48	
Model 3 (A-SO2)	VBx-1088.2 VBz-1107.3	δx-76.19 δz-76.01	1 2 3	0.194 0.281 0.341	5.154 3.55 2.93	
Model 4 (A-SO3)	VBx-1089.1 VBz-1088.4	δx-81.34 δz-82.00	1 2 3	0.181 0.251 0.315	5.22 3.98 3.17	
Model 5 (A-SO4)	VBx-1090.2 VBz-1065.2	δx-84.83 δz-84.35	1 2 3	0.298 0.249 0.287	4.899 4.013 2.99	
Model 6 (A-SO6)	VBx-930.11 VBz-926.23	δx-86.32 δz-85.56	1 2 3	0.210 0.315 0.377	4.75 3.17 2.65	
Model 7 (A-SO7)	VBx-1003.8 VBz-1007.1	δx-82.31 δz-81.00	1 2 3	0.199 0.207 0.276	5.025 4.838 3.602	
Model 8 (A-SO8)	VBx-1097.1 VBz-1002.2	δx-51.23 δz-91.45	1 2 3	0.196 0.282 0.275	5.099 4.443 3.644	

Observations from Table 2:

1.The lateral displacements are decreased when shear walls are used in place of masonry, as can be seen when comparing models (A-M) and (A-S). For example, the displacement for model (A-M) is 149.86mm, whereas the displacement for model 1 (A-S) is 70.92mm.

2.A comparison of models 4 (A-SO1) and 2 (A-S) reveals that, in the former case, displacement is greater and base shear is smaller than in the latter (A-S). For example, Vb-1120.11kN, δ-73.80mm for model 4, and Vb-1142.00kN, δ-70.10mm for model 5.

3.Table No. 2 illustrates how, for two models with the same opening—Model 4 (A-SO3) and Model 1 (A-SO1)—the

lateral displacement increases with increasing opening height. For example, δ=81.34mm for Model 1 (A-SO1) and δ=81.34mm for Model 4 (A-SO3).

4.When model 7 (A-SO7) and model 8 (A-SO8) are compared, it can be shown that model 7 (A-SO7) has δx=62.11mm, whereas model 8 (A-SO8) has δx=91.13mm. In model 8 (A-SO8), the shear wall behaves like a coupled shear wall.

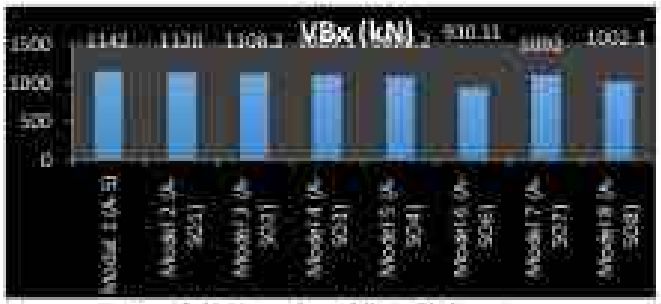


Fig. (3.1) Base shear Vb in X direction

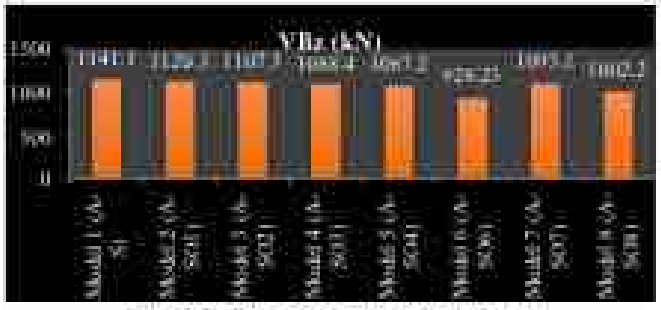


Fig. (3.2) Base shear Vb in Z direction

Fig. (3.3) Max top displacement in X direction

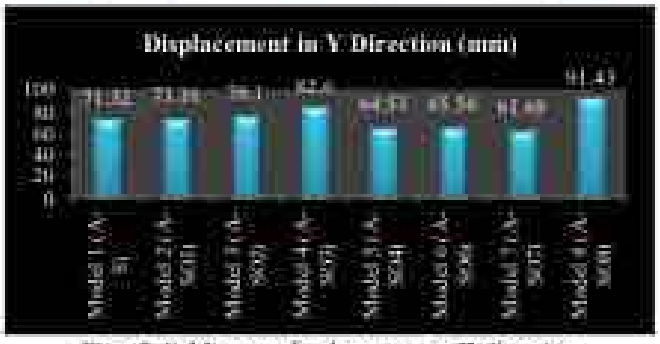


Fig. (3.4) Max top displacement in Z direction

CONCLUSIONS

The aforementioned study illustrates the concept of shear wall opening placement, which was founded on the response spectrum method used in this paper. We deduce the following conclusions.

- When a building has a shear wall installed in place of a brick masonry wall without taking stiffness into consideration, base shears rise and lateral deflection decreases.
- Lateral displacement rises and base shear falls when shear wall apertures occur.
- Shear walls work best against lateral forces that are in plane.
- The response varies depending on the position and dimensions of apertures of the same size in shear walls of different buildings. The lateral displacement rises as the opening height does.
- The shear wall behaves as a linked shear wall in Model No. 8-(A-So8).

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A review on experimental study of flexural behavior of steel fiber reinforced self-compacting concrete exposed to high temperature

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***Abstract*— With tremendous development of construction industry around the world, demand of self- compacting concrete is increasing. Because of its advantages like, high workability, ability to place into formwork without any vibration, larger paste volume, lower binder ratio, higher mineral admixture content, low labour cost and reduced construction time. Variety of fibers can be used in all types of concrete to improve mechanical properties and durability of concrete, such as steel fibers, glass fibers, polypropylene fibers, fibers made from polyester, carbon fibers, micro synthetic fibers, natural fibers etc. Steel fiber reinforced self-compacting concrete mostly used in high rise buildings. In case of unexpected fire, there is possibility of Change in concrete properties. As self-compacting concrete (SCC) is used in heavy structures, there is need to study the performance of SCC with fibers subjected to elevated temperature. This paper provides the literature review on the steel fiber reinforced self-compacting concrete exposed to high temperature. From the study, it is concluded that, fiber reinforced concrete with steel fibers performs better up to 600°C. So, there is need to study the steel fiber reinforced self-compacting concrete exposed to high temperature i.e. more than 600°C.**

Keywords* – *self-compacting concrete, fibers reinforced concrete, steel fibers, elevated temperature.

I. INTRODUCTION

With tremendous development of construction industry around the world, demand of self -compacting concrete is increasing. Due to this self-compacting concrete is very important development in concrete technology over the last decades. Many structures have problem of congestion of reinforcement in structural members, self-compacting concrete is the only solution for such difficult site environment. The main importance of using self-compacting concrete is, it has high workability and it has ability to place into the formwork without vibration. It offers many advantages in technical, economical and environmental way. In case of large structures, reduced construction time and low labour cost is the main advantage of self-compacted concrete. It is innovative concrete that does not requires vibration for placing and it has property to flow under its own weight. Even in the congested reinforcement self-compacting concrete can flow and placed without any vibration and achieves full compaction.

Advantages of self-compacting concrete:

- Highly flow-able
- Higher strength and durability than normal concrete
- Low viscosity
- Low water cement
- Less water cement ratio

Types of fibres:

- Steel fibres
- Polypropylene fibres
- Glass fibres
- Fibres made from polyesters
- Carbon fibres
- Macro synthetic fibres
- Natural fibres

Steel fibres:

Steel fibres are small, elongated pieces of steel that are often added to the concrete to enhance its structural properties. These fibres improve strength, toughness, and resistance to cracking of the concrete. Steel fibres are available in various types. The details of these types are explained in following section.

- Hooked -end steel fibres: These fibres have small, fishhook like ends that helps to anchor them in concrete.
- Straight steel fibres: These fibres are typically cut to a specific length and do not have hooked ends.
- Crimped steel fibres: These fibres are crimped or wavy shapes, which increase their bond in concrete.
- Micro steel fibres: These are extremely fine steel fibres.

II. EXISTING LITERATURE

Ahmet Raif Boga et al. (2022) have studied the mechanical and physical properties of self-compacting concrete by using different types of fibres such as polypropylene fibre, steel fibre and glass fibre at elevated temperature. In the fibrous mixtures, polypropylene fibre was used as 0.1%, 0.3%, and 0.5%, steel fibre was used as 0.1%, 0.2%, and 0.3%, and glass fiber was used as 0.1%, 0.3%, and 0.5% by volume of concrete. In addition of this fibre free self -compacting concrete was also produced to determine the variations of properties of SCC mixtures. Ultrasonic pulse velocity, compressive strength, splitting tensile strength and apparent porosity tests were performed to investigate the effect of temperature on hardened

SCC mixtures exposed to 200, 400, 600°C. It is observed that up to 600°C steel or glass fibre improved the mechanical properties of SCC. And it is also observed that improvements in polypropylene fibre in same fibre volumes. [1]

Sai Nitesh K.J.N et al. (2018) have studied the self-compacting concrete beams with recycled coarse aggregate (25% replacement of total coarse aggregate by weight) were tested by varying aspect ratio (50, 70 and 100) of hook end steel fibre for constant fibre content of 0.5 % by volume of concrete compared with Vibrated Concrete. A total of 32 beams were cast with 20 MPa and 40 MPa concrete with natural and recycled coarse aggregate. It is observed from the study that there is increase in torsional properties like ultimate torque, angle of twist, torsional stiffness, torsional toughness in self-compacting concrete compared to vibrated concrete for both natural and recycled coarse aggregate with the addition of fibres. Better performance was observed in members with fibre aspect ratio (70) in both concretes compared to lower (50) and higher aspect ratio (100) [2]

Jose D. Rios, et al. (2018) have analyzed the use of high-performance concrete reinforced with polypropylene. They have analyzed the behavior of the concrete at different temperatures (hot tests: 100°C, 300°C, 500°C and 700°C) and cooled-down states (cold tests) and at exposure times(6, 24, and 48 h). Thermogravimetric analysis, fracture behavior, compressive strength, Young's modulus, and tensile strength of concrete were determined. Comprehensive analysis of the thermal and mechanical behavior of high-performance concrete under different thermal conditions were also performed. Longer exposure time were applied to broaden the available results on the behavior of high-performance fibre reinforced concrete when subjected to high temperatures. Results show that, once thermal and moisture equilibriums are reached, exposure time does not have any influence on mechanical properties. They also provide useful information about the influence of high temperatures on the different parameters of fibre reinforced concrete and its application for thermal energy storage structures. [3]

Hassan Aoude, et al. (2014) have studied the axial behavior of reinforced concrete columns constructed with SCC and SFRC. Full-scale columns having rectangular cross sections were tested under pure axial compressive loading. The columns were detailed with varying amounts of transverse reinforcement in accordance with the requirements of the Canadian Standards Association. The results confirm that increasing confinement with closely spaced transverse reinforcement in rectangular SCC columns results in improvements in behavior and ductility. In addition, the results demonstrate that the use of SFRC in rectangular columns results in improvements in performance and ductility. [4]

Ramiz Ahmed Raju, et al. (2020) have been investigated the effects of concrete type (i.e., SCFRC versus SFRC), fiber content, and specimen depth on the fiber distribution and orientation and the structural performance of SCFRC and SFRC beams considering their fiber distribution and orientation using X-ray images. The X-ray images showed that owing to the high-flow properties, the SCFRC beams exhibited a lower fiber segregation and better fiber alignment than the SFRC beams. The bending test results demonstrated that the SCFRC beams exhibited better flexural performance than the SFRC beams owing to the improved distribution and orientation of the fibers. Moreover, a finite element (FE) analysis was performed to evaluate the structural performance of the beams considering the varying fiber distribution properties observed in the X-ray images. The FE method could differentiate the superior structural performance of the SCFRC beam from that of the SFRC beam. [5]

Thiago Melo Grabos, et. al. (2015) have studied the experimental characterization on the fresh and hardened state of self-compacting lightweight concrete (SCLC) reinforced with steel fibers. Two classes of SCLC were produced containing either coarse or coarse and fine lightweight aggregates. Steel fibers were used as reinforcement in fiber volume fraction of 0.5%. To characterize the self-compacting behavior of the concrete Slump flow, V funnel were performed. The mechanical behavior was evaluated by means of compression, tensile and flexural tests. Thermal characterization was performed by specific heat, thermal diffusivity and conductivity tests. Autogenous and drying shrinkage tests were also carried out in the study. The results showed slump flow within 680–700 mm without segregation, even for fiber reinforced SCLC mixes. All mixes have shown 28-day compressive strength above 30 MPa and density within 1700–1900 kg/m3. The fibre reinforcement has increased the mechanical properties under direct tensile and bending tests. Adequate thermal insulation properties were verified when compared to normal-weight concrete. It is observed that concretes containing coarse and fine lightweight aggregates presented higher drying shrinkage than those only coarse lightweight aggregate. [6]

Farhad Aslani, et al. (2019) have performed experimental study on fibre reinforced self-compacting concrete. Eight polypropylene and steel-fiber-reinforced SCRC mixture designs were produced. To investigate the properties of fresh SCRC (flow ability, flow speed, filling ability, and passing ability) slump flow and J-ring experiments were performed. The mechanical properties of hardened SCRC (compressive strength, tensile strength, and modulus of elasticity) after 28 days of curing were also tested. High-temperature resistance for SCRC is measured as the essential performance parameter, including mass loss, spalling distribution, and residual mechanical performance at 100°C, 300°C, and 600°C. The 0.25% optimum fibre ratio for polypropylene fibre and the 0.75% optimum steel-fibre ratio in SCRC were determined to obtain high-temperature resistance for hardened and fresh SCRC. [7]

Abdalla M. Saha et al. (2021) have performed an experimental investigation on fresh and hardened properties of the self-compacting concrete mixes with four different percentages of steel fibres (0.25, 0.50, 0.75, and 1.0%) and 20% cement replacement rate with silica fume was incorporated. The workability tests were carried out using slump flow, slump flow T50, L-box, and V-funnel tests according to EFNARC specification and one visual test (segregation resistance) as per ASTM C 1611. The results of this study indicate that the use of silica fume as a replacement for cement and incorporation of steel fibre produces more economically feasible and durable SCC. [8] Ramkumar K.B, et al.(2023) have investigated the impact of the combined action of micro- and hooked-end steel fibres on the flexural performance of the SCC beam to which mineral admixtures and super plasticisers have been added to improve their workability. In the experiment, beam specimens, reinforced with micro-steel and hooked-end fibres, with a

compressive strength of 60 and 80 MPa were prepared. The results clearly shows that the flexural performance of the SCC beam significantly improved with the addition of hybrid steel fibres. The combination of 0.5% of hooked-end steel fibres and 0.25% of micro-steel fibres offers a better flexural performance than the addition of hybrid fibres in other proportions. Adding hybrid steel fibres in RCSCC beam increases the beam's load- and moment-carrying capacities by 40.64% and 40%, respectively, compared to the RCSCC beam without hybrid steel fibres. The crack spacing and crack width are also reduced by 16–45% and 25–75%. [9]

Jin Tao, et al. (2010) have explained that self-compacting concrete is used in high rise buildings and in industrial structure also. In case of accidental fire, it is necessary to understand the effect of temperature on properties of self-compacting concrete. Laboratory investigation have carried out to study the effect of temperature ranging from room temperature to 800°C on the compressive strength of concrete with different w/c ratio. It is found that compressive strength of SCC decreases with increase in temperature. And it is also found that high-strength SCC has larger compressive strength as compared to normal SCC. [10]

Abadel et al. (2023) have considered ultra-high performance concrete fiber reinforced with different types of fibers. The hooked end fibers, polypropylene fibers, polyvinyl alcohol fibers and hybrid of these fibers were used to study in varying proportions. Fresh concrete was tested for slump test to check the workability of concrete. Then the concrete was casted in the cylinder of size 100mmX200mm and prism of size 150mmX150mmX600mm. After curing for 28 days, specimens were heated to the temperature of 100°C, 300°C, 400°C and 500°C for 3hr at the heating rate of 8°C/min. Then the compressive strength, split tensile strength and flexural strength of concrete was tested. The properties like unit weight, mass loss, elastic modulus was also considered for study. The microstructural analysis by SEM technique was also done on concrete. From the experiment, authors have suggested to increase the fiber content in concrete to improve the performance at elevated temperature. The concrete containing only steel fibers performed better for all the tested properties at elevated temperature. [11]

III. Summary of Literature

Studies on behaviour of SFRSCC have been carried out using different types of fibres such as glass fibres, steel fibres, polypropylene fibres etc. at elevated temperature up to 600°C. In previous studies, research have been carried out on the normal fiber reinforced concrete and self-compacting fiber reinforced concrete for the grade of concrete up to M35. On the concrete of grade up to M35, A lot of studies have been done on effect of temperature on properties of SFRSCC. Very few research has been done by varying the exposure time to high temperature and no significant study have been reported on type and content of steel fibres for enhancing the flexural performance of SFRSCC. Therefore, it is proposed to undertake research work in this unexplored area.

IV. Conclusions

From the study of literature review, following conclusions are drawn:

1. The steel fibre reinforced self-compacting concrete shows better efficiency in comparison with standard concrete in terms of fresh and hardened states due to the incorporation of steel fibres.
2. Concrete is a material often used in the construction of high-rise buildings.
3. In case of unexpected fire, the concrete properties changes after fire. Hence it is important to understand the change in concrete properties due to extreme temperature exposures.
4. It is on fact that fire is one of the most dangerous threats to buildings and structures, so it is necessary to determine residual strengths of concrete after exposed to high temperature.

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Quantification and characterization study of construction and demolition waste for Pimpri Chinchwad City, India

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***Abstract*— Rapid urbanization in Pimpri Chinchwad City, India, has significantly increased construction and demolition (C & D) waste generation. The study aims to quantify and characterize C & D waste for Pimpri Chinchwad City and suggests an appropriate waste management plan. Quantification and characterization of C& D waste are important for waste management, resource conservation, product recovery, and sustainable urban development. Quantification will provide current and future trends in C & D waste generation. Characterization of C & D waste gives composition and percentage, which is useful for a deeper understanding of the waste stream and effective recycling and disposal strategies. Characterization analysis shows that the waste consists predominantly of aggregate, concrete, bricks, bituminous material, mortar, tiles, sand, and a smaller percentage of plastic, wood, metals, etc. This study proposes evaluating industrial applications and potential market avenues for the recycled materials identified. The findings from this research will serve as valuable insights for policymakers, urban planners, and waste management authorities.**

***Keywords*: Construction & demolition waste, quantification, characterization, sustainable, recycle & reuse, product**

I. Introduction

Construction and Demolition Waste Management (C&DWM) has emerged as a critical facet of sustainable development, necessitating comprehensive strategies to address the environmental impact of burgeoning construction activities. The exponential growth in urbanization and infrastructure projects has escalated the volume of waste generated during construction, renovation, and demolition processes. This surge poses a substantial environmental threat, demanding immediate attention and proactive measures.

The construction industry faces the challenge of managing large quantities of solid waste, primarily comprised of aggregates, mortar, plastic, tiles, bitumen, and brick. The inadequacies in waste management practices have escalated concerns about pollution, resource depletion, and ecological degradation. A paradigm shift toward efficient C&DWM practices becomes imperative to mitigate these challenges.

This research aims to contribute to the discourse by conducting a meticulous analysis of C&D waste in the Pimpri-Chinchwad Municipal Corporation (PCMC) region, a burgeoning industrial and residential hub in Maharashtra, India. By assessing waste generation, composition, and current management practices, this study endeavors to shed light on the existing scenario and propose sustainable solutions. The research seeks to provide insights into the quantification methodologies and regional-specific approaches, guiding stakeholders toward effective waste management through a critical review of pertinent literature and empirical data. As urbanization persists, it is crucial to prioritize this investigation, emphasizing the need for eco-friendly construction practices to safeguard the well-being of both current and future generations.

II. Literature Review

A. Quantifying C&D Waste Methodologies

The literature review highlights the work of Wu et al. (2014), providing a comprehensive analysis of existing methodologies for quantifying construction and demolition waste (C&DW). The study underscores the absence of a universal approach and suggests a relevance tree for stakeholders to choose the most suitable method based on specific project objectives and conditions. It emphasizes the need to address limitations in current research and proposes future directions, with a particular focus on civil infrastructural works.

B. Regional C&D Debris Generation and Composition

Cochran et al.'s (2006) research on estimating regional building-related C&D debris generation and composition, with a case study in Florida, offers valuable insights. The study develops an approach for estimation, compares results to available data, and discusses implications for waste management policy creation. It stresses the importance of region-specific approaches due to the diverse nature of C&D debris and advocates for tailored strategies to enhance recycling efforts and reduce landfill disposal, particularly in the context of increasing regional focus on sustainable waste management.

III. Methodology

A. Theoretical Framework and Literature Review

The research methodology begins with a theoretical foundation, emphasizing a thorough literature review to identify key challenges and established methodologies in Construction and Demolition Waste Management (C&DWM). This includes an exploration of relevant studies, such as the relevance tree proposed by Wu et al. (2014) and

the regional estimation approach outlined by Cochran et al. (2006). The aim is to leverage existing knowledge and theoretical frameworks to inform the subsequent stages of the study.

B. Site Visits and Analysis

The second phase involves practical application through site visits within the Pimpri-Chinchwad Municipal Corporation (PCMC) region. These visits facilitate the collection of C&D waste compositions from specific sites, followed by a detailed characterization and analysis. The focus is on understanding weight distribution and percentage composition for each material category. Additionally, the methodology outlines potential reuse and recycling processes for identified materials, aligning with sustainable waste management goals. This dual approach of theoretical groundwork and on-site analysis ensures a comprehensive exploration of C&D waste management in PCMC, contributing valuable insights for sustainable improvements.

- **Site Selection:** Three distinct sites within the Pimpri-Chinchwad Municipal Corporation (PCMC) region are strategically chosen for C&D waste composition collection. These sites include: Charholi near the cemetery, Garbage Collection Centre at Gavli Matha, and Vision Mall on Wakad Highway.
- **Data Collection Process:**
  - *Identification:* The types of waste materials present at each site are identified, encompassing materials like mortar, plastic, soil/sand, cement sheet, tiles, aggregate, bitumen, brick, and fly ash.
  - *Quantification:* The initial weight of each material is measured, providing quantitative data for further analysis.
  - *Characterization Analysis:* The collected waste undergoes a thorough characterization analysis, involving separation of materials, determination of individual material weights, and calculation of percentage distributions.
  - *Site-Specific Analysis:* Each site's waste composition is analyzed individually, providing insights into variations and specific challenges at different locations.
- **Results and Data Interpretation:** The quantified data is presented in tabular and graphical formats, facilitating a clear understanding of C&D waste composition at the selected sites. The data is then interpreted to draw meaningful conclusions and identify patterns or trends in waste generation across different locations.
- **Reuse and Recycle Potential:** For each material, potential reuse and recycling processes are outlined, aligning with sustainable waste management practices and offering practical solutions for minimizing environmental impact.

C. Reduction Methods

Waste reduction methods aim to minimize the amount of waste generated from C&D activities.

1. Developing Waste Management Plans that outline strategies for waste reduction, reuse, recycling and disposal. These plans help ensure waste is managed effectively throughout the project.

2. Implementing recycling programs to divert C&D waste from landfills.

3. Utilizing waste to energy technologies such as incineration or gasification to convert non-recyclable C&D waste into energy.

4. Providing education and training programs to the construction workers and contractors about waste reduction practices, proper sorting and recycling methods.

5. Implementing effective source separating practices on construction sites. Segregating different types of waste materials at point of generation, making it easier to recycle and reuse them.

D. Reuse and Recycle process

Sr. No	Material	Reuse	Recycle (Process/ Method)
1.	Mortar	Non-structural, or less critical applications such as patching, filling gaps, or other minor repairs, constructing walkways, garden pathways etc.	1. separation of aggregates from mortar mix.
2.	Plastic	plastic roofing tiles, in drainage system plastic recycled pipes offer corrosion resistance, ease of installation	1. collection from various sources such as industries & households 2. sorting- based on its type & composition 3. cleaning- remove any contaminants like dirt, residual product contains 4. shredding the plastic by mechanically into smaller pieces 5. Melting- shredded plastic is then melted & converting into molten plastic, then cooled these plastics serves as raw material for production of new plastic products
3.	Soil/ Sand	fill material-levelling uneven surfaces, backfilling during construction of foundations, retaining walls, sub-base or base course in road construction, for manufacturing of bricks, blocks etc.	1. soil washing-mixed with water, screening, scrubbing and sedimentation to separate clean soil from contaminants 2. sieve and screening-passing soil through series of screens with different mesh sizes to separate debris, oversized particles
4.	Cement Sheet	aggregate for concrete, base material for road construction material, fill material	Challenging due to the presence of fibers and coatings as well as potential presence of hazardous substances such as asbestos 1.Asbestos removal and proper disposal- it should be handled by trained professionals followed by specific regulations
5.	Tiles	Mosaic creations to applied on walls and floors, fill material, pathways and garden features	1. collection 2. sorting and segregation-such as ceramic, Glass tiles 3. cleaning - remove any dirt, residues 4. Manufacturing or Repurposing- new tiles, mosaic artwork road aggregate, construction fill
6.	Aggregate	Benefits: Waste reduction, cost effective and energy conservation such as quarrying, transport and processing	1. collection from construction site, waste concrete, demolition sites, road construction projects. 2. sorting and separation 3. crushing and screening 4. cleaning and removal of contaminants 5. classification and grading
7.	Bitumen	In Base and sub base layers in road construction, production of new asphalt mixtures. Benefits: cost saving, reducing landfill waste, conserving natural resources	
8.	Brick	Aggregate for concrete or mortars, sub base or fill material in road construction foundations, used as a decorative elements in construction projects such as walls, pathways, erosion control in slopes, embankments or retaining walls. It helps stabilize the soil, prevents erosion.	1. crushed into smaller pieces to create recycled brick aggregate. then this aggregate can be used for traditional aggregate material in different construction projects such as road base, concrete foundations 2. landfill cover- brick debris can be used as a cover material in landfills

9.	Fly Ash	• **Concrete production:** It can be cementing content, improving the workability, strength and durability of work. • **Cement manufacturing:** Used as a raw material. • **Road construction:** Used as Stabilizing agent in the base or sub base layers of road pavements, improves the strength and stability of road. • **Structural fill:** used to fill voids stabilize soil. **Bricks and Blocks:** used as a raw material in the production of bricks, blocks and other masonry products.	1. **waste management plans:** developing comprehensive waste management plans that outline strategies for waste reduction reuse recycling and disposal 2. Design for deconstruction 3. **source separation:** segregate different types of waste material at point of generation. 4. Material recycling 5. waste to energy conservation 6. Education & Training: providing education and training programs to construction workers and contractors

TABLE I

Waste Collected	Sites			Total (%)	Average	Quantity (MT/T)
	Site 1 (%)	Site 2 (%)	Site 3 (%)			
Mortar	31.357	13.737	9.239	54.334	18.111	671.81
Plastic	4.800	0.000	0.800	4.800	1.600	59.35
Soil/Sand	7.404	3.393	3.619	18.400	6.133	227.39
Cement sheet	25.357	0.000	0.000	25.357	8.452	313.83
Tiles	31.081	0.000	0.035	41.016	13.672	507.34
Aggregate	0.000	47.433	39.673	87.106	29.036	1077.62
Bitumen	0.000	26.494	20.852	47.347	15.782	585.41
Metal	0.000	0.000	0.000	0.000	0.000	0.000
Wood	0.000	0.000	0.000	0.000	0.000	0.000
Brick	0.000	6.952	0.000	6.952	2.317	85.96
fly ash	0.000	0.000	14.682	14.682	4.894	181.53
Total	100.000	100.000	100.000	300.000	100.000	3709.33

Fig. 1. Final Calculation

Fig. 2. Composition of the material collected on the three site (as per percentage distribution)

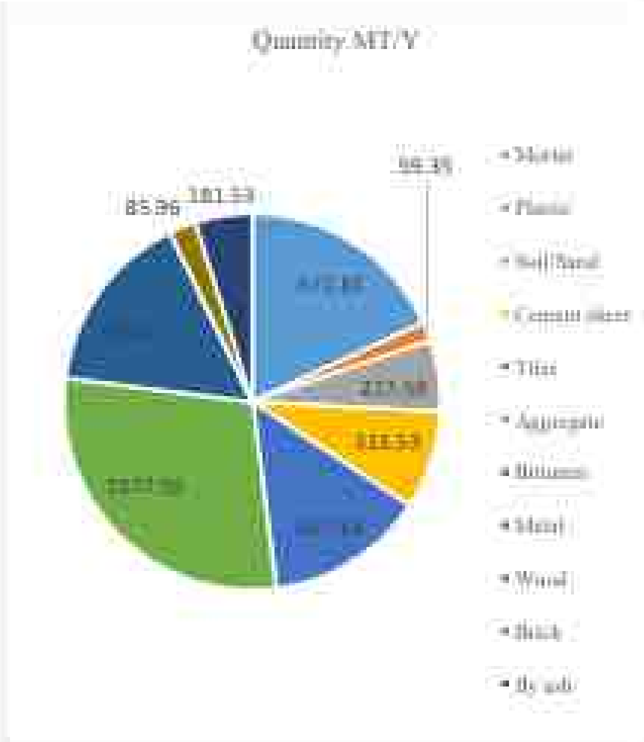

Fig. 3. Total quantity of the collected material on the sites (MT/Y)

IV. Result

The results of the composition analysis from three distinct sites within the Pimpri-Chinchwad Municipal Corporation (PCMC) region illuminate the diverse nature of Construction and Demolition (C&D) waste. At Site 1 near the cemetery, mortar, tiles, and cement sheets dominate the waste stream, contributing 31.36%, 31.08%, and 25.36%, respectively. Site 2, the Garbage Collection Centre, exhibits a prevalence of mortar and aggregate, comprising 13.74% and 47.43%, indicating a variation in waste composition. Vision Mall at Wakad Highway, Site 3, displays a significant presence of mortar, aggregate, and bitumen, signifying a diverse mix. Aggregates emerge as a notable component, constituting 29.04% of the total waste and offering substantial potential for reuse in construction applications. The overall quantity of C&D waste in the region is 3709.33 MT/Y, underscoring the importance of targeted strategies for waste reduction, recycling, and sustainable management practices. Recommendations include promoting reuse initiatives and implementing effective sorting programs to harness the potential of these waste materials in an environmentally responsible manner.

V. Conclusion

This research on Construction and Demolition Waste Management (C&DWM) in the Pimpri-Chinchwad Municipal Corporation (PCMC) region provides a comprehensive understanding of the current practices and challenges. The analysis of waste compositions from three distinct sites highlights the varying nature of C&D waste, emphasizing the importance of site-specific strategies for effective management. Aggregates, mortar, and tiles emerge as predominant materials, offering significant potential for reuse and recycling. The identified quantities underscore the urgency of implementing sustainable practices to mitigate environmental impact and conserve resources.

The study also emphasizes the need for a strategic shift in waste management policies, encouraging increased awareness, and regulatory measures. Harnessing the potential of C&D waste through reuse initiatives and recycling programs can contribute to resource conservation, economic opportunities, and reduced environmental pollution. Furthermore, the research underscores the importance of continuous monitoring, evaluation, and adaptation of waste management practices to align with evolving environmental standards.

In moving forward, collaborative efforts between governmental bodies, construction industries, and the community are imperative to enact effective change. By fostering a culture of responsible waste management, the PCMC region can lead the way in sustainable urban development, setting an example for other regions facing similar challenges.

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"A review on the study of GGBFS and Flyash-based Geopolymer Concrete"

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Abstract— *Davidovits introduced Geopolymer concrete in 1979 in an effort to utilize less regular Portland cement. The building industries are now increasingly aware of the need to utilize eco-friendly materials due to the ozone layer's depletion and the problem of global warming. By using geopolymer technology, cement manufacturers' CO_2 emissions to the atmosphere might be cut by almost 80%. Because of its many benefits, including the ability to substitute cement with by-product waste and lower greenhouse gas emissions during manufacture, the usage of geopolymer concrete is beginning to receive attention in the fields of research and construction practices. Although fly ash and GGBFS, two common source materials for geopolymer binders, are widely available in India, their use has been restricted thus far. Recent studies on geopolymer concrete suggest that locally accessible materials may be able to replace conventional cement-based concrete. In order to introduce the technique and the many different types of materials that can be created by alkali activation of aluminosilicates, this study focuses on providing a brief history as well as an overview of geopolymer concrete technology.*

Keywords— *Fly Ash, GGBFS, Fibres in concrete, Sodium Hydroxide, Strength, Durability, and Applications.*

Introduction

Without one of the most fundamental building materials, concrete, infrastructural growth would be almost nonexistent. Because CO_2 gas emissions from the cement industry are dangerous to human life, one of the unique materials that could be utilized for construction and as a substitute for Portland cement-based concrete is Geopolymer Concrete (GPC) [1]. In order to reduce Portland cement use, Davidovits created GPC in 1979 [2]. The necessity to use more environmentally friendly materials in building is becoming more and more apparent as a result of the ozone depletion and global warming issues [3]. Geo-polymer composites require less energy and emit fewer greenhouse gases than Ordinary Portland Cement (OPC). In addition to simultaneously depleting energy and natural resources, the need for concrete for the construction of infrastructure also makes a significant contribution to the environment's CO_2 emissions. GPC is a long-lasting material that is also affordable, thermally stable, energy-efficient, easy to work with, and doesn't require cement [4]. Eco-friendly building materials, like GPC, are those that are more durable and structurally superior. It is believed to be an appropriate alternative for OPC concrete if there is a sufficient supply of agricultural waste materials [5]. GPC has demonstrated excellent strength, resilience to reinforcing corrosion, little shrinkage, resistance to fire, freeze-thaw, acid and sulphate, and the interaction of alkali with aggregate [6]. Since flexural strength frequently dictates the capacity of concrete to be shaped, it has a substantial impact on the failure mode of concrete. However, most study have concentrated on compressive strength. Fly ash (FA) and ground granulated blast-furnace slag (GGBFS) are industrial wastes that are incorporated to GPC. These wastes have benefits such as decreased CO_2 emissions, the capability to recycle waste, the ability to prevent the change of valuable land to dump yards, cheaper prices, and so on [7]. For the ongoing development of civilization, it is especially important that geo-polymer materials can effectively absorb heavy metals, radioactive pollution, dyes, and other contaminants [8]. But because of their excellent qualities, geo-polymer materials are used on a larger scale [9]. Despite industry standards, GPC is not widely adopted in the building

sector since there is no suitable mixture design technique [10]. Past scholars have suggested a lot of design mixtures that are based on trial-and-error techniques. According to reports[11], the mix design's liquid activator has a stronger effect on the compressive strength produced by GPC [12]. There is presently no standardized mixture design approach for making GPC, making mix design and proportioning of GPC more difficult as additional components are included. Geo-polymers have received more attention as a result of their outstanding mechanical properties, ability to use a range of wastes as precursors and eco-friendliness[13]. Geo-polymer concrete has the advantage of substituting cement due to the use of cementation components and alkali-activated solutions. Geo-polymer concrete, as opposed to conventional concrete, is a comparatively new, advanced, and ecologically friendly engineering material [14].

OBJECTIVE AND SCOPE

The main objective is to study the structural behavior of GGBFS and Fly ash based Geo-polymer concrete for various parameters.

Materials

The materials used are:

A Flyash

Fly ash is a fine powder that is a byproduct of burning pulverized coal in electric generation power plants. Fly ash is a pozzolona, substance containing aluminous and siliceous material that forms cement in the presence of water

B GGBFS

It has the same chemical properties as OPC, but the proportions are different. The addition of GGBFS in GPC increases the strength of concrete.

C Alkaline activator solution

In Geopolymer concrete alkaline activator solution is one of the very important material. Sodium hydroxide is one of the most common alkaline activator solution used in geopolymerization.

LITERATURE REVIEW

Saxena et al., Due to substantial challenges like endless cement manufacturing, the discharge of enormous volumes of CO_2 into the atmosphere, and the immense removal of granite debris by different enterprises, global warming is becoming an issue. The creation of fly ash-based GPC from granite debris has been the main focus of this research. Recycled stone debris was utilized as a partial substitution of natural fine aggregates (sand) in varying weight ratios ranging from 0 to 20% in ascending sequence of 5%. Studies on performance and toughness, including dry density, strength properties, ultrasonic pulse velocities, carbonation, elastic modulus, chloride diffusion depth, acid attack, and water permeability, were used to assess the performance of GPC that included stone debris. The mass change of geo-polymer concrete was calculated by Thermo gravimetric analysis and variable Thermo gravimetric analysis. The manufacture of fly ash-based GPC using recycled stone trash offers a solution for municipal solid waste management and enhances a number of the qualities of geo-polymer concrete. All of the power and durability test findings showed that GPC made with stone left over up to 15% in place of natural fine particles was superior to control GPC in terms of mechanical qualities and longevity.

Ahmed et al., An eco-friendly and eco-efficient concrete structure, geo-polymer concrete is an organic concrete that uses manufacturing and agricultural by-product ashes as the primary binder rather than regular Portland cement. Many different types of ashes, including FA, palm oil fuel ash, GGBFS, rice husk ash, and met kaolin ash, are utilized as binding agents in geo-polymer concrete. Compressive strength is the most crucial structural characteristic for all varieties of concrete composites, along with geo-polymer concrete. Though, the concrete's compressive strength at 28 days is crucial in the area of structural construction and design. Therefore, to save time, effort, and money, it is essential to progress a reliable technique for computing the geo-polymer concrete's compressive strength. It offers

suggestions for organizing the construction method and taking down the workpieces. Regression analyses that are linear, non-linear, and multi-logistic were employed in this study to create forecasting analytics for calculating the compressive strength of concrete made with FA-GPC.

Abdullah Zawawi A Wang, Wahid Omar et al., chose to examine the characteristics of fly ash-based GPC. Impacts of added steel fiber on geo-polymer concrete beam efficiency. Small and full-size testing was conducted using the two test scales. Most concentrated on a small-scale strategy. According to the testing results, more fiber caused the beam's shear capacity to be delayed, and smaller cracks were also seen. The inclusion of naphthalene-based admixtures also increased the geo-polymer concrete's setting time by up to three hours.

A Maria Rajesh, and M. Adams Joe et al., investigated the use of GPC as an alternate to PC concrete to lessen its harmful environmental consequences. Additionally, flexural, split tensile, and compression testing for specimens with a mixture of various molarities were done. The test findings showed that after 28 days of heat curing, GPC samples with 12M had 1.25 times the compressive strength of GPC samples with different molarities. Split tensile and flexural strengths of GPC samples with 12M are 1.18 and 1.058 times, respectively, stronger than those of GPC samples with other molarities, respectively, after 28 days of thermal cure.

Prof. Y. D. Deore & Jayesh R et al., used the M-25 concrete grade to evaluate the effect of the geo-polymer binders on the fracturing characteristics of concrete via one-point bending on beam specimens. According to the testing results, adding carbon and glass fibers to geo-polymer concrete decreased its workability and required less water than other types of concrete. The addition of fibers also enhanced the maximum values of the concrete's crack resistance, while carbon fibers were found to be less effective at preventing crack propagation than glass fibers.

Ganapati Naidu &Prasad et al., used slag in place of little calcium flyash in 5 distinct percentages to examine the strength qualities of GPC. Based on the test findings, it was determined that larger concentrations of G.G.B.S (Slag) outcome in greater compressive strength of GPC. Fly ash was most frequently substituted (28.57%) with slag, which led to the maximum compressive strength (57MPa) for 28 days.In just 14 days, 90% of compressive strength was attained, and geopolymer concrete's average density was on par with OPC concrete's.

Mohammad Amin and Sandeep et al., presented a research on the usage of M20 grade GPC in light traffic pavements to reduce flood hazards and rehydrate the ground water. According to the test findings, No-fines geo-polymer technology will help reduce flood hazards and global warming since it doesn't include cement and can absorb significant amounts of water while still maintaining adequate strength and infiltration rate to be utilized for low-traffic pavements and roads.

Mark Reed et al., compares the mechanical characteristics of samples of ambiently cured and heat-cured geo-polymer concrete, including such compressive strength and ductility, to explore the effects of heat curing. Based on the test findings, it was determined that, in the scenario of concretes with 0.15% fibres, incorporating polypropylene fibres resulted in a minor decrease in the fracture toughness of concrete and fracture energy (4 to 8%).

Shaburish V. Patil & Sachin et al., carried out for M30, M40, and M50 grade GPC that has been cured in an oven and at room temperature, the compressive strength has been compared using both destructive and non-destructive methods and confirmed using the rebound hammer test. According to the testing results, regardless of the age of the concrete, oven-cured geopolymer concrete has greater compressive strength than ambient-cured concrete. Additionally, it is evident from the regression analysis that the oven-cured specimen will yield better accuracy from the NDT technique for GPC than the ambient-cured specimen.

Faiz Shaikh and Sharany et al., Carbon and basalt fibre were incorporated to fly ash-based geo polymers in proportions of 0.5, 1, and 1.5% by mass of fly ash during the casting process. Every set of samples was evaluated at room temperature as well as when heated to temperatures of 200, 400, 600, and 800 C. According to the test findings, geo-polymers with 1% basalt and 1% carbon fibre had greater compressive strength. The carbon fiber GP also outperformed than the basalt fibre counterpart amongst two fiber composites; and at 800 C, the crack in 1 wt% carbon fibre reinforced Geo-polymer is lower than that of pure geo-polymer and its basalt fibre counterpart.

Yasir Sofi and Iftekar Gull et al., attempted to investigate the features of geopolymer concrete based on fly ash. M20 grade GPC may be produced by utilizing a notional mixture of 1:1.5:3 (fly ash: fine aggregates and coarse aggregates) and increasing the alkaline liquid to fly ash ratios from 0.3 to 0.45. Studies are also done on long-lasting characteristics including acid attack and permeability. Based on the test findings, it was determined that GPC gives higher durability and compressive strength. Strength falls as the alkaline liquid to fly ash ratio rises and a ratio of less than 0.3 makes the material highly rigid.

LIMITATIONS:

Based on previous experimental findings and observations, the researchers came to the following conclusions.

- Geopolymer concrete did not harden immediately at room temperature compared to conventional concrete.
- It took atleast at least 3 days for the geopolymer concrete to fully harden without leaving a nail mark on the hardened surface.

These above few notable limitations of Geopolymer concrete mix were eliminated by replacing 10% of fly ash by GPC.

ADVANTAGES

- Cost-effective Low energy consumption
- Thermally stable Easy to work with Eco-friendly materials
- Cement-free and Durable
- GPC reduces carbon emissions through the *use of industrial solid waste such as slag and fly ash.*

CONCLUSION

From the past research it can be summarized that:

- Although fly ash has now become a value-added product, the majority of its current use is in non-structural applications or as a partial substitution for cement in OPC concrete.
- For fly ash based concrete, the problem of gaining strength in ambient curing has been overcome by the utilization of GGBFS as a binder, thereby enhancing the strength and durability properties of concrete.
- Addition of fibers reduced the crack propagation in concrete and also achieves a higher peak value.

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A Review on Enhancing the Properties of Recycled Aggregate Concrete

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***Abstract*— Recycled aggregates (RAs) are the aggregates obtained from reprocessing of materials that have been earlier used in the construction. Huge quantities of debris that are required to be recycled and reused as RAs are getting generated in the construction industry. RAs are used to replace natural aggregates (NAs) which contributes to reducing waste and energy consumption and sustainability in the construction industry. The limited natural resources have caused us to use RAs in concrete. Despite offering sustainability benefits the physical properties of RAs affect the behaviour of concrete called 'recycled aggregate concrete (RAC)'. Thus, for improving RAC, it is necessary to improve the properties of RA by pre-treating them or incorporating mineral admixtures like micro-silica, fly ash, ground granulated blast furnace slag (GGBFS), etc. in the concrete. In this paper, a rigorous literature review has been carried out to identify appropriate materials and techniques used for pre-treating RAs so that the RAC properties get improved. The review study indicates that by using different Pozzolanic materials for pre-treating RAs, the properties of RAC can be improved. From the study, it can be concluded that there is good scope to improve the properties of RAs and RAC by using ultrafine slag (i.e. GGBFS).**

Keywords*— *Recycled aggregate, recycled aggregate concrete, sustainable construction, mineral admixtures, ultrafine slag, properties of recycled aggregate concrete.

I. Introduction

According to projections from the United States Environmental Protection Agency (USEPA), the construction and demolition (C&D) industry could generate an excess of 430 million tons of concrete waste annually. Further, natural disaster like earthquakes, hurricanes and other similar natural disasters may also continue to contribute in the generation of excessive amounts of concrete waste [1]. The escalating pace of urbanization in India has given rise to the substantial generation of C&D waste. However, to safeguard the environment and make use of the available natural resources effectively it becomes essential to recycle and reuse the generated C&D waste [2]. The studies have indicated that using C&D waste for producing new concrete would have significant environmental and economic impacts. Additionally, the replacement of NAs by RAs would result into reducing CO_2 emission by about 15% - 20% and thus it would be possible to conserve a measure portion of the world's land stone resources. A lot of experimental works has been carried out to utilize RAs for making ordinary RAC by making use of Portland cement as a binding material. The utilization of RAs in concrete has been associated with a general deterioration in concrete performance, largely attributable to the presence of residual mortar adhering to the surface of the RAs [1]. In recent years, the RAC produced by substituting either partially or fully the NAs in the concrete have received much attention from researchers [2].

The present situation in the construction industry is such that it has to face the basic challenges of fulfilling the housing and huge infrastructural needs because of rapid advancement of industrialization and urbanization. Further, there are concerns about the high requirements of energy and the emissions of greenhouse gases due to the production of cement and similar products [3]. The process of recycling aggregates from concrete waste is relatively straightforward, involving several stages, including breaking down, extracting, and crushing the existing concrete into a material with predefined size and quality [4].

A. Properties of Recycled Aggregate

The important properties of the RAs include water absorption, porosity, gradation, shape, density, and resistance to crushing and abrasion which are discussed in comparison with the NAs in the following section.

1) Porosity, Water Absorption and Density: The residual adhered mortar on the aggregate has a substantial impact on the properties of RAs viz., Porosity, Water Absorption and Density. RAs generally has a lower density when compared to NAs due to the less dense adhered mortar on RAs as opposed to the rocks from which NAs are obtained. Studies have revealed that the saturated surface dry RAs exhibits a relative density roughly 7-9% less than that of NAs. The water absorption and porosity properties are intricately linked to aggregate characteristics and are also influenced by the residual mortar. NAs typically possess low water absorption

capacity because of their low porosity, while RAs have adhered mortar with higher porosity, which enables the mortar to be retained within its pores [5].

3) Gradation and shape: The geometry of aggregate particales is determining factor in workability of concrete. The technique employed for generating RAs and the specific crusher utilized can affect the shape of RAs. NAs usually has an angular shape with smooth surface; while RAs tends to have a softer and more globular form due to the lingering mortar smoothing out the original aggregate's sharp edges. This rounded shape can improve the flow of new mortar around the aggregate [5].

3) Los Angeles Abrasion and crushing test: The durability of aggregates is commonly measured through Abrasion and crushing tests. RAs tend to exhibit higher abrasion values in the crushing and los angeles (LA) tests compared to NAs. This indicates that the aggregates when subjected to crushing or impact produce more fine particles. The studies have shown that the RAs can have their crushing strength values around 23.1% while NAs (e.g., basalt) may have values around 15.7%. Likewise, LA abrasion values for RAs are found to be 32% while for NAs they are 11% [5]. Therefore, it can be inferred that the residual mortar layer on RAs is more prone to cracking at the interfacial transition zone (ITZ), a region often characterized by lower concrete quality. On the contrary, the NAs do not possess such poor-quality coating have a similar coating to lose. Fig. 1 provides a visual representation of RAs illustrating the existence of new mortar enveloping the aged mortar [1].

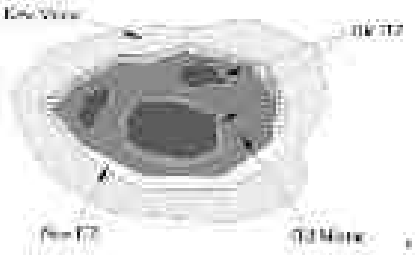

Fig 1.Recycled aggregate with fresh mortar surrounding the aged mortar [1]

B. Techniques used for Treatment of recycled aggregates

The different techniques used for treating the RAs for improving various properties are discussed in the following section.

1) Polyvinyl alcohol treatment: In this treatment, the Polyvinyl alcohol (PVA) is made to enter into the pores and cracks in a concrete. The high modulus of and elasticity tensile strength properties of PVA contributes to the enhancement of the structural integrity of RAC. Additionally, the solubility of PVA in water speeds up the hardening process and allows it to penetrate through the concrete cracks and pores. PVA treatment to RAs can be attained using different methods such as injection, vacuum impregnation, and coating, but it becomes essential to maintain the optimal content of PVA at 2% of the weight of mortar so as to prevent undesirable effects of PVA on concrete's workability properties [6].

2) Silicon-based water repellent treatment: In this technique, silicon-based water-repellent polymers viz., silane and siloxane are used which causes the decrease in water absorption of RAC. This technique is applied through surface coating, in which the coating becomes more efficient. This treatment significantly helps to reduce porosity of RAC, improve the resistance to water penetration, and increases compressive strength, although it can be costly and time-consuming, making it less suitable for large-scale concrete production [6].

3) Bio deposition of Calcium carbonate: In this method, the bio deposition of calcium carbonate is done by employing bacteria like Sporosarcina pasteurizing to generate carbonate ions from urea hydrolysis, which results into development of dense calcium carbonate particles that enhances the durability of mortar. This technique helps to reduce water absorption in RAs by up to 21% which causes the enhancement in the strength and quality [6].

4) Use fly ash: Various Pozzolanic materials, like fly ash, have been noted to enhance the quality of the ITZ in concrete. These Pozzolanic materials can be administered to RAs by either misting them onto the RAs or submerging the RAs in the Pozzolanic substance. This technique enlarges the surface area of the aggregates, promoting an interaction with fly ash. This interaction induces a reaction with calcium hydroxide, resulting in the generation of supplementary calcium hydrate silicate. This method can be approached in three ways: the conventional approach, the two-stage approach, and the three-stage approach. Among these approaches, the three-stage mixing method yields the most optimal results. It employs merely a third of the necessary fly ash amount and necessitates a shorter curing duration. In contrast, the two-stage mixing approach is commonly favored by researchers for enhancing quality of mortar by creating a cement slurry mixture. The utilization of Pozzolanic ash material leads to the formation of precipitates that fill the voids in the old adhered mortar and ITZ, thereby improving strength and durability properties [6].

5) Use of nano-silica: Nano-silica, sometimes referred to as silica fume, constitutes an additional classification of Pozzolanic materials utilized for the purpose of improving quality. Both nano-silica and silica fume possess significant surface areas, facilitating heightened reactivity with RAs and efficient infiltration into the cracks and voids within the aged adhered mortar. Traditionally, silica fume is utilized as a cement content replacement in the conventional application method. Nevertheless, in applications focused on enhancing quality, the Pozzolanic response entails either injecting silica fume into the aggregate or applying a coating of nano-particles through a multi-stage procedure. During this reaction, silica fume, comprising various oxides like SiO_2, Al_2O_3, CaO, and other metal oxides, undergoes a reaction with calcium hydroxides. The resultant product of this reaction is referred to as 'silica gel' (C-S-H). Throughout these reactions, this desired C-S-H or C-A-S-H product effectively fills the voids, reducing the porosity in the ITZ. This leads to an enhancement in density and strength. [6].

6) Carbonation: Carbonation is the process that includes the engagement of CO_2 with the products resulting from hydration within RAs. During this process, it results in the formation of compact calcium carbonate, which effectively

fills the pores and empty spaces within the cement. The carbonation process is a two-fold approach, commencing with the removal of the aged mortar through an acid treatment and followed by accelerated carbonation to reinforce the cement matrix. Carbonation plays a pivotal role in enhancing mechanical properties and diminishing water absorption. However, it's worth noting that carbonation can also yield adverse effects by obstructing the diffusion of carbon dioxide, diminishing durability due to a decrease in pH, and encouraging crack formation [6].

7) Sodium silicate activation: Sodium silicate activation is a pre-soaking method for enhancing RAC. It involves soaking RAs in a 5% sodium silicate solution for an optimal 1-hour duration, resulting in improved material properties, reduced water absorption, and enhanced bonding with mortar. The evaluation of this procedure involves conducting tests to measure parameters such as slump, compressive strength, and water absorption. Although it proves effective in many scenarios, its utility diminishes in high-temperature conditions and may result in the development of a sodium silicate film on the surface of the RAs. Nonetheless, under specific conditions, it offers practical and environmentally friendly benefits, with readily available materials and cost-effective implementation [6].

8) Pre-soaking in water: Soaking the aggregate in water prior to use is a method intended to enhance the excellence of concrete. It serves the purpose of both eliminating old mortar from the aggregate and inhibiting additional water absorption. It improves mechanical strength, with an optimal pre-saturation period of around ten days. However, it can increase water content in the mixture, affecting compressive strength. Pre-soaking is most effective for reducing coarse aggregate water absorption but may not significantly improve overall RAs properties. It enhances workability but may not be ideal for applications requiring superior mechanical strength [6].

9) Pre-soaking in acid: Pre-soaking RAs in acid, such as hydrochloric or sulfuric acid, is a vital strategy for enhancing the quality of RAC. This process weakens and removes adhered mortar, improving material properties like bulk density and reducing water absorption. However, it can also lead to the increased chloride or sulphate levels and become the cause for potentially harming the material and the environment. The economic feasibility of using treatment acids is limited for large-scale applications due to their cost. Non-toxic acid solvents, like acetic acid, may offer a more sustainable alternative for mortar removal [6].

C. Recycled aggregate concrete

RAC represents a sustainable concrete variant created by replacing NAs in a concrete mixture with RAs, either partially or entirely. In the previous decade, a considerable volume of research findings has been extensively documented in academic literature, primarily concerning the performance and characteristics of RACs [2].

D. Methods for improving the performance of Recycled Aggregate Concrete

Several methods are used for improving the performance of RAC. Some of the important methods are as follows:

1) Removal of mortar: In this method, the removal of old cement mortar adhered to RAs is done using ultrasonic waves to dislodge and improve compressive strength. The microwave heating enhances the bond with new cement binder and boosts compressive and splitting tensile strength by about 5% to 12%. The chemical treatment with acids like hydrochloric, sulphuric, and phosphoric enhances aggregate quality and concrete strength; and mechanical treatments like heating and scrubbing contributes to produce aggregates with lower water absorption and improved properties. While these methods have shown promise in lab settings, their widespread adoption faces challenges due to their time-consuming nature and potential economic feasibility concerns in large-scale applications [1].

2) Aggregate Coating: Coating RAs presents a viable strategy for enhancing the performance of RAC. Various coating methods employed encompass the Double-Mixing Method, which seals gaps and cavities within the ITZ, reinforcing the ITZ and heightening compressive strength. Moreover, the Triple-Mixing Method involves the application of Pozzolanic materials like fly ash, slag, and silica to coat the RAs, leading to enhanced compressive strength and superior chloride resistance compared to the double-mixing approach. Moreover, the Double-Coating Technique, initially developed for hot-mix asphalt (HMA), holds potential for enhancing moisture resistance and stiffness in RAC through a dual-layer coating of cement slag paste and Sika Tite-BE. These coating methods, employing readily available admixtures in concrete production, exhibit considerable promise for large-scale implementation. Nevertheless, it is essential to note that not all coating attempts have yielded positive results, with some coatings leading to reduced compressive strength [1].

3) Equivalent Mortar Volume (EMV) Mix Design: Rather than removing or coating old mortar, some researchers have proposed mix design approaches that account for the remaining attached mortar. The EMV method tackles concerns related to a reduced modulus of elasticity and increased drying shrinkage by upholding the appropriate water-to-cement ratio. However, it is primarily applicable to RAs and requires further refinement [1].

4) Geopolymer RAC: Geopolymers, derived from materials like GGBFS, fly ash, and metakaolin offer a sustainable alternative to Portland cement. Geopolymer RACs have demonstrated high compressive strength, durability, and environmental benefits. They hold potential for resolving challenges posed by the porous old attached mortar in RAs [1].

II. LITERATURE REVIEW

Numerous research investigations have been conducted by a variety of scholars with the aim of enhancing the attributes of RCA and the characteristics of RAC. The results of these studies have been documented in various academic journals. The review of published literature in the context of improving RCA and RAC is presented in the following section.

Katz (2004) investigated treatments aimed at improving RCA. The study employed various mechanical and chemical

methods to enhance the quality of RCA. Results indicated that specific treatments led to better performance in concrete mixes containing RCA. The research concluded that treating RCA can effectively enhance its properties, opening avenues for sustainable construction. However, the scope of the study did not extend to the long-term durability of treated RAs [7].

Tangchirapat et al. (2010) concentrated on the utilization of high-fineness fly ash to enhance the characteristics of RAC. Their study sought to improve the workability, compressive strength, and durability of RAC by introducing high-fineness fly ash. The findings revealed that high-fineness fly ash demonstrated superior Pozzolanic activity, enhancing RAC properties. The authors suggest further investigate to explore the impact of high-fineness fly ash on additional concrete properties [8].

Katrina and Thomas (2013) undertook an in-depth review study exploring the properties of RAs, their impact on concrete material attributes, and the broader implications for structural members. Noteworthy findings from this review study encompass: (1) Replacing NAs in concrete with RAs induces a decline in compressive strength, while maintaining comparable splitting tensile strength; (2) a slight reduction occurs in the modulus of rupture of RAC than that of the conventional concrete; and (3) a reduction in the modulus of elasticity. Further, the structural beam cast using RAs showed greater mid-span deflection under service load and smaller cracking moments. Thus, the researchers concluded that the use of RAs is one of the feasible options for structural purposes [5].

Liang et al. (2014) developed processing methods to enhance the strength of concrete using 100% RAs. Various processing methods, including mechanical grinding and thermal treatment, were evaluated. The outcomes demonstrated that particular processing techniques effectively enhanced both the flexural and compressive strength of concrete utilizing 100% RAs. The study concluded that the optimized processing technique could effectively enhance the strength of RAs concrete. Additional investigations could explore the effect of processing methods on other properties, such as durability and bond strength [9].

Zhang et al. (2015) studied the surface treatment of RAs with nanomaterials to improve the bond between RAs and cement paste. The research investigated the treated RAs mechanical properties and ITZ characteristics. The results showed improved mechanical properties and enhanced ITZ characteristics, indicating the effectiveness of surface treatment with nanomaterials. The study suggested further exploration of different types and dosages of nanomaterials for surface treatment and their long-term performance in RAC [10].

Martirena et al. (2016) investigated the quality improvement of coarse RAs through cement coating. The research method involved coating RAs with a cementitious material before incorporating them into concrete mixes. The findings indicated that applying a cement coating had a positive impact on enhancing the quality of RAs, consequently resulting in improved mechanical properties for the concrete. The study concluded that this approach can be a valuable strategy for sustainable concrete production. Future research could focus on optimizing the coating process for different aggregate types [11].

Elchalakani et al. (2016) explored the application of GGBFS and high-volume fly ash in eco-friendly concrete mixes, incorporating both RAs and recycled water. The research employed a comprehensive approach to study the performance of such sustainable concrete. Results demonstrated that this approach led to environmentally friendly concrete with good mechanical properties. The study concluded that combining fly ash, slag, RAs, and water can contribute to future sustainable urban development. The scope suggests the need for practical applications and real-world testing [3].

Nair and Johny (2016) conducted a study on the properties of concrete using GGBFS and RAs. The research method included varying proportions of GGBFS and RAs in concrete mixes. The results indicated that GGBFS could effectively improve the performance of concrete containing RAs. The study concluded that this combination has potential benefits for sustainable construction practices. Future research could explore the influence of different mix proportions and curing conditions on other properties such as durability and long-term performance [12].

Xie et al. (2018) undertook an extensive examination of research pertaining to the mechanical characteristics of environmentally friendly concretes employing RAs. The review synthesized existing research to assess the mechanical performance of RAs in concrete mixes. The study provided valuable insights into the strengths and limitations of using RAs in concrete. The scope of the study emphasized the need for a holistic understanding of RAs-based concretes [2].

Makul (2020) conducted a review of methods aimed at improving the quality of RAs. The review encompassed various treatment and processing techniques used to enhance RAs properties. The study concluded that several methods show promise in improving RAs quality but stressed the need for standardized approaches and further research to establish best practices [6].

Butkhan (2020) et al. conducted a study investigating the utilization of RCA and ceramic waste in the production of cost-effective and sustainable concrete. The research method included incorporating RAs and ceramic waste into concrete mixes. The results indicated that this approach could lead to cost-effective and sustainable concrete production. The study concluded that utilizing RAs and ceramic waste holds the potential for economic and environmental benefits in construction. Further research could assess the long-term durability and practical applications [13].

Upshaw et al. (2020) conducted an analysis of RAC properties, numerical models and improvements. The review synthesized existing literature on the properties of RAC, potential enhancements, and numerical modeling approaches. The study emphasized the importance of addressing the challenges associated with RAC and suggested future research directions, including advanced modeling techniques and performance assessment [1].

Nandanam et al. (2021) investigated the influence of fly ash, metakaolin and GGBFS on the durability and mechanical

attributes of self-compacting concrete (SCC) prepared with 100% RAs. The research evaluated the fresh and hardened properties of SCC and found that the additions of fly ash, GGBFS, and metakaolin improved the workability, compressive strength, and durability SCC with 100% RAs. The study concluded that these mineral admixtures can enhance the performance of SCC with RAs. Further research could explore the optimization of mix proportions and the long-term behavior of SCC with various mineral admixtures and RAs [14].

El-Hawary et al. (2021) examined the impact of freezing and thawing cycles on RAC, including slag as a supplementary material. The study employed environmental exposure testing to simulate harsh weather conditions. The results indicated that the freezing and thawing cycles negatively affected the performance of RAC, emphasizing the importance of appropriate mix design and construction techniques when using recycled materials in regions prone to freezing temperatures [15].

Kumar and Trivedi (2021) investigated the properties and characteristics of lean concrete made with RAs and fly ash. The study aimed to improve workability and reduce water absorption by adding fly ash to the lean concrete mix. The research used a combination of laboratory experiments and analytical techniques to assess the behavior of this concrete mix. The results indicated that the fly ash addition enhanced workability as well as reduced water absorption in the concrete. The study concluded that utilizing RAS and fly ash in lean concrete can be an environmentally friendly alternative. Further research could explore the effects of varying RAS content and fly ash dosage on other properties, such as strength development and durability [16].

Ahmed and Lim (2022) explored the effective utilization of chopped Basalt Fiber and Pozzolana Slurry Tricalcium Silicate (TRAS) to develop sustainable recycled structural concrete with enhanced fire resistance. The study conducted a series of tests and demonstrated that the incorporation of these components improved the fire resistance of RAC. This research offers a promising approach for creating fire-resistant structures with recycled materials [17].

Biswas and Damkar (2022) explored the impact of Silica Fume and Metakaolin on both the mechanical and durability performance of high-strength concrete that exclusively utilized RAs. The research involved extensive material testing and showed that the inclusion of Metakaolin and Silica Fume contributed to the improved effectiveness of high-strength RAC. This finding suggests potential enhancements for sustainable construction practices [18].

Kadawo et al. (2022) combined Life Cycle Assessment (LCA) with a circularity index to assess the environmental impact of RAC. The research employed a comprehensive methodology to determine the sustainability of using RAs in concrete production. The study's outcomes highlighted the importance of considering both environmental impact and circularity when implementing RAC in construction projects [19].

Alluqmi et al. (2022) provided a comprehensive review of the mechanical attributes and durability aspects of RAC with nanomaterials. The study examined various nanomaterials, such as nanoparticles, nanofibers, and nanotubes, and their potential to improve RAC. The review highlighted that incorporating nanomaterials in RAC can enhance mechanical properties and durability, indicating their promising application in sustainable concrete construction. Future studies could focus on specific nanomaterials' dosage, dispersion techniques, and long-term performance of RAC [20].

Singh et al. (2022) conducted a regression analysis RAC with GGBFS and fly ash. The study aimed to establish a relationship between mix proportions and compressive strength of RAC through regression analysis. The research findings showed a significant correlation between the mix proportions and the concrete's compressive strength. The study concluded that GGBFS and fly ash can be effectively used to enhance the strength of RAC. Future investigations could focus on the optimization of mix proportions based on specific project requirements [21].

Rashwani et al. (2023) studied the use of RAs sourced from war-destroyed buildings as a sustainable solution for reconstruction in war-torn areas. The research evaluated the mechanical properties of concrete containing RAs and found them to be comparable to conventional concrete. The study concluded that utilizing RAs from war-destroyed buildings can contribute to rebuilding efforts in Syria and similar contexts. Further research could focus on optimizing the mix proportions and long-term durability of concrete with RAs from different sources [22].

Kosari et al. (2023) conducted research 23, optimizing the slurry impregnation technique for upcycling carbonated RAs in paving concrete applications. The study developed a specialized technique to enhance the properties of RAs, making them suitable for use in paving materials. This approach has implications for sustainable infrastructure development [23].

Oruji et al. (2023) examined the use of a three-stage mixed coal bottom ash slurry coating to enhance the properties of RAC. The method involved coating the RAs with the slurry. The study found that the coated RAs exhibited improved compressive strength and reduced water absorption. The researchers concluded that the three-stage mixed coal bottom ash slurry coating could be an effective approach to enhance the performance of RAC. The scope of future studies could include exploring the long-term performance and sustainability aspects of the coated RAC [4].

III. Research Gap

Based on the thorough literature review, it is evident that RAs are frequently employed in concrete production. However, the effectiveness of concrete is compromised due to the inferior quality of RAs. Several researchers have carried out research works for improving the qualities of RAs by treating them with different Pozzolanic material and adopting specific technique before their use in concrete. The studies are also carried out by using the RAs without any treatment for manufacturing of concrete and incorporating Pozzolanic materials such as fly ash, GGBFS, metakaolin, etc. The research studies have shown that use of Pozzolanic materials for treating the RAs improves their physical

properties. Also, the properties of concrete produced using such pre-treated RAs are found to be improved. Though, number of materials are used for pre-treating the RAs the use of ultrafine slag for pre-treating the RAs has not found to be reported in the literature. Further, various methods viz., PVA, silicon-based water repellent, bio-deposition and use of Pozzolanic materials are found to be commonly used for treating the aggregate. Thus, from the review of literature it is found that there is good scope to improve the properties of RAs by pre-treating them with appropriate technique using ultrafine slag and thus enhance the properties of RAC using such pre-treated RAs.

IV. Conclusion

Based on the extensive review of the literature, the following conclusions are drawn.

1) The properties of RAs and RAC are possible to be improved by using Pozzolanic materials such as fly ash, silica fume, GGBFS, etc. as their hydration products fills the voids, pores, crack in the concrete which contributes in enhancing the density and the strength of RAC.
2) Amongst the available techniques for treating the RAs, the two-stage mixing method is the most preferred method by the researchers. However, the comparative study on methods for improving the properties of RAC needs to be performed in view of enhancing the properties and achieving the cost economics.
3) There is good scope to study the properties of RAs by treating them with ultrafine slag as a Pozzolanic material and utilize such pre-treated RAs for producing the RAC which would be of improved properties.

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Efficacy of Buckling Restrained Braces in Reinforced Concrete Frame

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***Abstract*— Earthquake forces on the structures are a major concern for engineers. To reduce the impact of earthquakes and lateral forces on the structure, bracing is one of the earthquake-resisting systems that plays an effective role in resisting lateral forces in buildings. Buckling-restrained braces (BRBs) are widely recognized as one of the most effective methods for mitigating seismic risks. This is due to their unique ability to absorb and dissipate significant amounts of energy, making them a valuable approach for both new construction and retrofitting existing designs for them to withstand lateral seismic loads. In this study, a non-linear static analysis evaluation from Extended Three-Dimensional Analysis of Building System (ETABS) software was used to evaluate the seismic behavior of a 5-story reinforced concrete structure with and without buckling restrained braces. When incorporating buckling restrained bracing, the outcomes are quite effective in comparison to the model without the bracing.**

Keywords*— *Buckling Restrained Braces, Non-linear static analysis, ETABS v2018, RC Frame

I. INTRODUCTION

Earthquakes are a powerful force of nature, striking the Earth's crust for a short period of time. However, in those fleeting moments, they have the potential to cause immense destruction, claiming countless lives and damaging property. One of the most significant consequences of an earthquake is the collapse or damage of buildings. This is due to the intense and rapid movement of the ground, which exerts strong inertial forces on the structures and their components. An earthquake is a lateral force created by the sudden and powerful release of stored energy on the earth's surface, resulting in seismic waves. These tremors are caused by various natural and man-made factors such as geological forces, volcanic activity, landslides, and mining explosions. The immense strength and dynamic nature of these seismic loads can cause devastating damage to structures within seconds, leading to significant loss of life and property. To ensure the safety and stability of buildings, engineers have incorporated lateral load-resisting systems such as shear walls and dampers to effectively counter and distribute these lateral forces without compromising the integrity and strength of the structure. Hence, the infrastructure must possess sufficient sturdiness against vertical loads, as well as adequate solidity to resist lateral forces. The occurrence of lateral displacements on primary structures is a major concern for engineers, as they aim to minimize the impact of seismic and wind forces. To achieve this, specialized diagonal braces are effectively utilized. However, these elements may experience buckling deformation and demonstrate non-uniform hysteretic behavior under compressive stress. If the structure can limit and control this buckling in the steel reinforcement, it can ensure consistent strength in both stress and strain regions. Researchers are motivated by these fundamentals to implement a unique type of bracing system known as buckling restrained brace supports (BRB). BRBs are about one simple idea: stop the brace system from buckling for steady performance-. If we do this, the stress and strain properties will always be the same. BRBs are handy because they can resist both tension and compression, with no buckling involved.

The buckling restrained braces traced back to Wakabayashi. This inventive engineer from Japan was the first to think of it. He used a flat steel plate- squeezed into some reinforced concrete panels. This neat design had a ste-el heart, all wrapped up in concrete. There was also a gap, filled with concrete mortar, between the outer steel tube and the inner steel brace. To keep the brace and the concrete separate, Wakabayashi used some grease or a material that's not bonded to the brace's outer side. The brace can move easily within the tube- filled with concrete. The steel core of a BRB is the main part that holds the load. The outer casing stops the steel core from being out of shape.

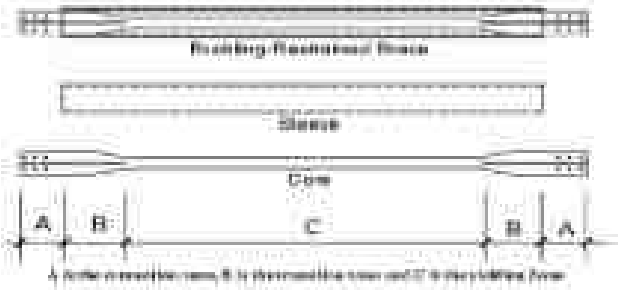

Fig. 1 Diagram of the BRB components [1]

Lots of studies have been done in the past, also checked the work done by many authors. They used linear and non-linear analysis to make buildings that can withstand earthquakes. This work was done for buildings framed with reinforced concrete. The literature review concentrates on recent contributions and prior endeavors that significantly align with the objectives of the present study. [1] Abou-Elfath *et al.* research assesses the improvement of seismic stability in the 6-story reinforced concrete building through the implementation of single diagonal buckling restrained braces. The examination of seismic performance in this study includes both a static pushover analysis and a time history earthquake analysis. [2] Chaturvedi *et al.* study's main goal is to optimize the placement of BRB within the building to minimize damage caused by earthquake loadings. Using E-tabs

software, the analysis was performed on a G + 7 commercial structure, examining various factors such as maximum story drift, maximum story displacement, maximum story shear, and maximum overturning moment. [3]Kim *et al.* presented the design and the analysis of the Buckling Restrained Bracings was done to observe the seismic behavior of the BRB during an earthquake. The results show that the building designed with the BRB having a reduction factor 4 provided a higher level of performance than that of the one provided with typical concentric bracings. [4] Chintanapakdee *et al* objective of this research is to examine the precision and possible prejudices of diverse methods employed in the seismic evaluation of buckling-restrained braced frame (BRBF) structures. The creation of BRBFs as a new way to resist lateral forces for earthquake-proof buildings makes evaluating their effectiveness vital. This research compares two analyses modal pushover analysis and modified modal pushover analysis to assess BRBF efficiency. The results are based on the analysis of three- 6, 10, and 14-story concentrically BRBF buildings using two sets of powerful ground movements with a 50-year probability of exceeding them of 2% and 10%, respectively. The comparison of the seismic displacement requirements which include inter-story drifts, peak floor/roof displacements, and target roof displacements is the main objective. [5] Kant *et al.* on reducing the dynamic response under seismic loads is a commonly used technique for a building. On the other hand, this results in an increase in the absorbed seismic base shear. Controlling the reaction can be achieved by including additional tools, such as BRBs, in the structure.

This study aims to explore how a 5-story RC structure performs during an earthquake using X type of buckling restrained braces. In this study, seismic response is carried out by non-linear static analysis.

II. STRUCTURAL MODELLING

In the present study, the G+5 RC structure is modeled with and without buckling restrained braces in software. ETABS software is used for this. The plan of the building is shown in Fig. 2. The plan of the building is 23m X 23m. The height of each story is 4.5m.

The live load on a typical story is 3kN/m^2. The floor finish on a typical story is 1.5 Kn/m^2. The wall load on the beam is 9.89Kn/m. By IS 1893: Part 1 (BIS, 2002), the building is located in Zone III, supported on medium soil, and is assigned Importance Factor 1. The dimensions of structural elements and other structural data adopted analysis and design are shown in Table 1. Based on the data from BRB supplier Core Brace (2016), a comprehensive set of parameters was chosen for incorporating into the ETABS software. The properties of the BRBs used in the simulation for the building are shown in Table 2.

Table I: Material and Geometrical Data

Content	*Description*
Concrete Grade	M20
Young's modulus of concrete	27386.127MPa
Concrete Density	25kN/m^3
Steel Grade	Fe415
Young's modulus of steel	2x10^5 N/mm^2
Steel Density	76.8kN/m^3
Total Building Height	21.5m
Size of Beam	230m X 460m
Size of Column	450m X 430 m
Slab thickness	160mm
Damping ratio	0.05
Time Period in the x direction	0.402 sec
Time Period in the y direction	0.402 sec

Table II: BRB Specification

Content	*Description*
Material for yielding core	Fe250
Total BRB weight	1.11 kN
Depth	203.25 mm
Width	203.25mm
Yielding core area	26 cm^2
Yielding core length	3.97 m
Elastic Segment length	2.33 m
Elastic segment stiffness	804321 kN/m

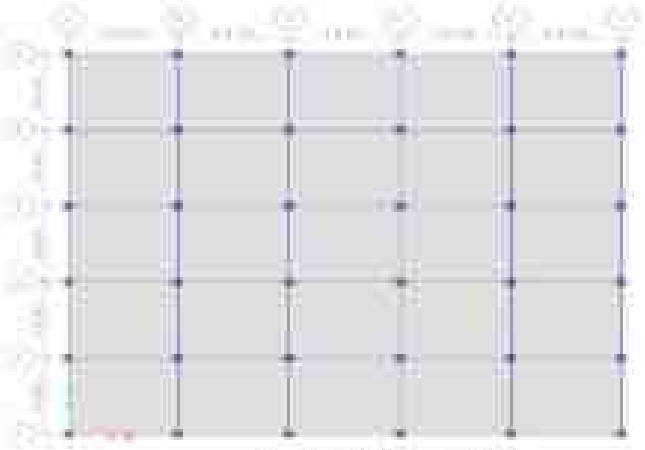

Fig. 2 Plan view of structure

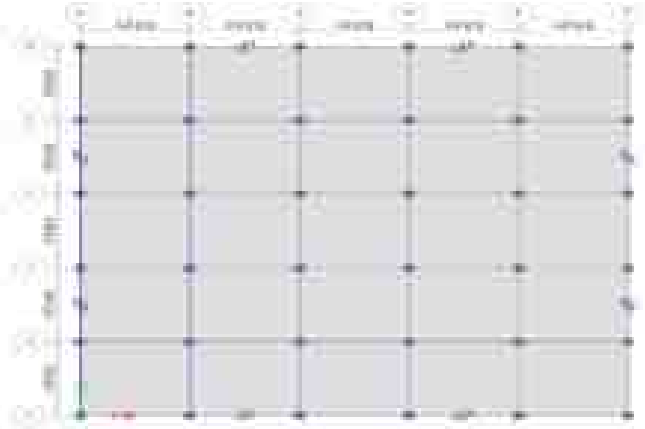

Fig. 3 Plan view of structure with BRBs

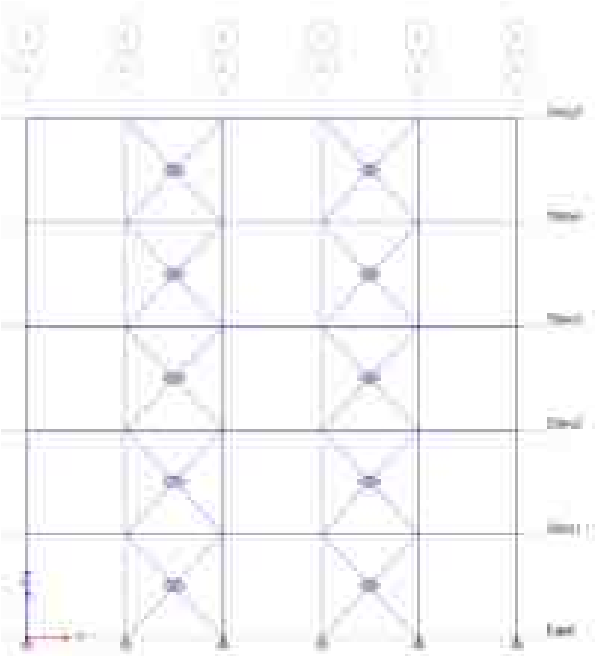

Fig. 4 Elevation view of structure with BRBs

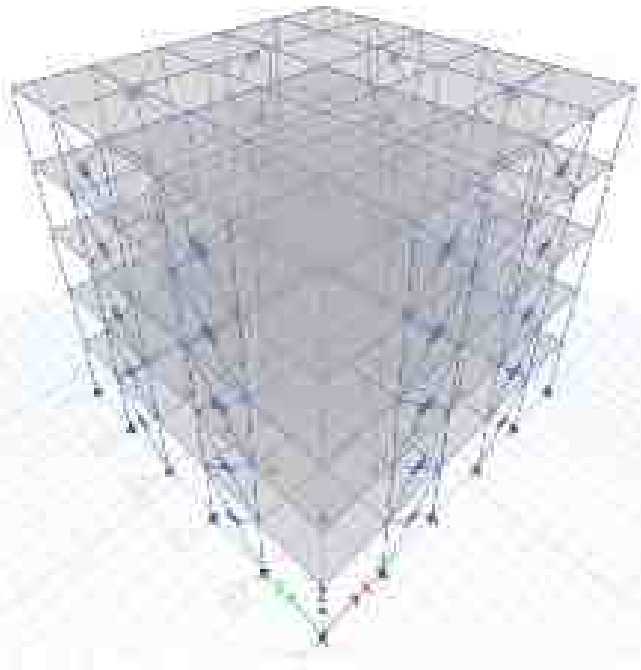

Fig. 5 3D view of structure with BRBs

III. RESULT AND DISCUSSION

The structural performance is evaluated through nonlinear static analysis. The result of the pushover analysis is obtained using ETABSv18 software provides information on the base shear and displacement of the studied frame.

The main aspects of the result are the pushover curve, performance point, and performance-based seismic design of the structure. Pushover analysis is conducted up to the point of collapse.

The relation of base shear and displacement and pushover curve results are shown in Fig. 6.

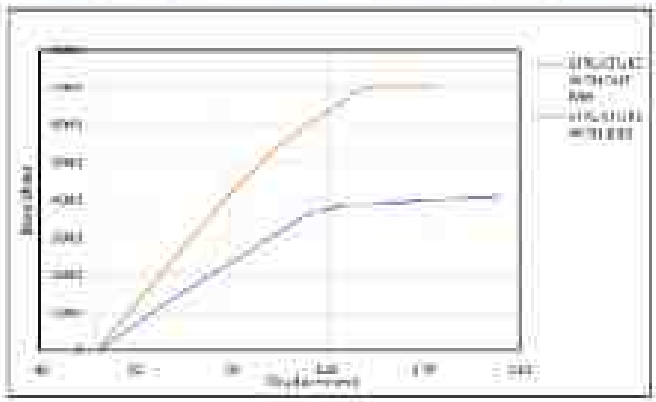

Fig. 6 Pushover Curve – Y Direction

A) Base Shear

Base shear of the structure with and without buckling restrained braces is shown in Fig 5.

Table III: Maximum values of Base Shear

Model	*Base Shear (Kn)*
Structure without BRBs	4160.55
Structure with BRBs	7034.63

B) Max Displacement

It is shown that a structure without BRBs shows more displacement as compared to a structure with BRBs. The detailed analysis of results confirmed that all displacement values decrease with BRBs. It has been seen from the pushover curve using buckling restrained bracing has increased the performance level of the structure.

Table IV: Maximum values of Displacement

Model	*Displacement(mm)*
Structure without BRBs	210.47
Structure with BRBs	178.09

C) Max Story Drift

The max story drift ratio holds great significance in evaluating a building's ability to withstand an earthquake. As shown in Fig. 7 it is shown that the story drift value of the structure with BRBs is 0.00364 which is less as compared to the structure without BRBs is 0.00658.

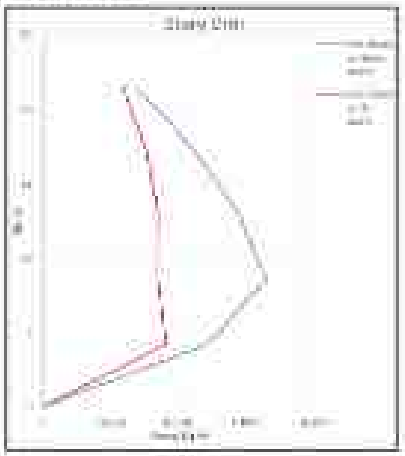

Fig. 7 Max Story Drift

IV. CONCLUSION

This study aims to examine the earthquake resilience of structures equipped with seismic devices known as Buckling Restrained Braces. By utilizing various evaluation techniques, the aim is to determine the effectiveness of BRBs in mitigating seismic effects on buildings. This will involve calculating the lateral force applied to the structures through various seismic modes and optimizing their structural performance. Displacement, base shear, and story drift result from non-linear static analysis used to analyze the effect of BRBs on a structure.

The displacement of structure with BRBs is decreased by 35% as compared to structure without BRBs which shows the effectiveness of BRBs in resisting the lateral forces. The base shear capacity of the structure with BRBs is increased by 72% as compared to the structure without BRBs, from this observed that the structure can resist seismic load safely. Ductility enhancement is also noticed in that pushover curve. Story drift of structure with BRB is reduced by 55%. The maximum displacement of the structure gets reduced then the stiffness of BRBs is increased.

Hence it can be concluded that the implementation of Buckling Restrained Braces provides a highly effective method for improving the seismic performance of a structure.

V. ACKNOWLEDGMENT

I would like to acknowledge my parents for the immense patience shown by them while I was working on this study. Also, I would like to thank them for supporting me and providing me with everything I asked them. I want to thank my group members for their brilliant comments, suggestions, and their continuous support.

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Experimental Investigation of Partial Replacement of cement in Concrete using Waste Glass Powder

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***Abstract*— The construction industry is the second largest industry in the world & concrete is prime material used in it [5]. The use of concrete generates lots of heat during hydration process. It directly contributes to global warming. Also cement is costly material & its storage is also difficult. The cement plays important role of binding in concrete. It contains lime as main constituents. So to reduce this ill effect of cement one must find the alternatives for cement which can perform the same role in concrete. This study represents the experimental investigation of effect of partial replacement of cement by glass powder on strength of concrete & other factors like workability, water cement ratio, and heat of hydration. Glass contains lime as its one of main constituent. The cement was replaced with glass powder by 5%, 10%, 15%, and 20%. The compressive strength, flexural strength & split tensile strength are tested for these replacements. Also economical aspect is observed along with. It is observed that physical & chemical properties of glass are almost similar to cement. So in this study an attempt is made to investigate the effect of partial replacement of cement by glass powder in concrete to make it as a special concrete.**

***Keywords*—Special Concrete, Global warming, Cement, Glass powder**

I. INTRODUCTION

The global warming is biggest challenge in front of today's world. It has made very drastic effect on the life of human being. The rise in temperature causes melting of glaciers on large amount. Increase in water level in oceans is not a good sign for cities situated nearby oceans. Also climate change is biggest problem human being is facing all over the world. This climate change has disturbed the balance of nature. The problems like drought, floods, forest fires, heat waves, storms are ill effects of climate change. It has affected human life in many ways. The cropping pattern is also changed due to climate change [2]. This is really very dangerous scenario in front of all over the world & upcoming generations. The various efforts are taken to reduce these problems. The green solutions are being discovered in every field by various scientists. The construction industry is second largest industry in the world. It has huge use of concrete as construction material. The concrete is a homogeneous mixture of cement, sand & aggregate plus water. The cement plays role of binding in concrete. It is prime ingredient of concrete. But cement has lime as its main chemical constituent. The amount of lime in cement is varies from 60-70% [1]. This lime when comes in contact with water causes a reaction called as 'hydration'. Due to hydration concrete achieve its desired strength and becomes stronger & harder. But during process of hydration large amount of heat is evolved which is called as 'heat of hydration'. The amount of heat generated during this hydration process is 500j/g as per study [4]. After water, cement is second largest material consumed in the world. One study suggests that there is about 30billion tons of concrete is consumed in the world per year [1]. This data is enough to predict the amount of heat evolved by construction industry. Another study says that construction industry contributes 8-10% in global warming. This is large figure. So we should try to reduce these ill effects by trying alternative materials & without compromising the quality needs of work. Another important aspect of the study is to find economic solutions. The increase in the population has tremendous needs of housing & infrastructure. The megastructures are created on large scale day by day. Also demand of affordable residential housing projects is also increasing. So attempt must be made to reduce the construction cost & produce affordable construction in budget of everyone. This study also aims to find economic & practicable solution for construction industry.

II. OBJECTIVE

1. To check the compressive strength of concrete mix at 0%, 5%, 10%, 15% & 20% replacements of cement by glass powder.
2. To check the split tensile strength of concrete mix at 0%, 5%, 10%, 15% & 20% replacements of cement by glass powder.
3. To check the flexural strength of concrete mix at 0%, 5%, 10%, 15% & 20% replacements of cement by glass powder.
4. To make cost comparison between normal & special concrete.

III. MATERIALS

A Cement

Cement of OPC-43 grade is used for study. Specific gravity of cement is 3.2.

B Aggregate

Fine aggregate passing through 2.36mm sieve size is used & coarse aggregate passing through 20mm sieve size is used.

C Waste Glass Powder

Though glass is 100% recyclable material but the amount of production of glass all over the world is tremendous that it is not possible to recycle the glass completely so large amount of glass is remaining un-recycled [3]. The glass powder used for this experimental investigation is waste glass collected from scrap of demolished construction site; it is then crushed & sieved through 90 micron sieve to get

desired value of fineness. The fineness property is important as specific surface area plays important role in binding the materials together.

TABLE1 COMPARISON BETWEEN CHEMICAL PROPERTIES OF CEMENT & GLASS POWDER

Sr. No.	Comparison between Chemical Properties of Cement & Glass Powder		
	Composition	*Cement*	*Glass Powder*
1	SiO_2	18.86	64.32
2	Al_2O_3	6.88	2.90
3	CaO	40.92	19.18
4	Fe_2O_3	2.83	-
5	SO_3	2.53	-
6	K_2O	1.62	1.53

Source: American Concrete Institute (ACI)

TABLE2 COMPARISON BETWEEN PHYSICAL PROPERTIES OF CEMENT & GLASS POWDER

Sr. No.	Comparison between Physical Properties of Cement & Glass Powder		
	Physical Property	*Cement*	*Glass Powder*
1	Colour	Light-grey	Mixed
2	Particle Size	< 45 micron	< 45 micron
3	Specific Gravity	3.15	2.7
4	Consistency	28%	30%
5	Initial Setting Time	30 min	45 min
6	Final Setting Time	178 min	210 min

Source: American Concrete Institute (ACI)

By comparing both chemical & physical properties of cement & glass powder we can use glass powder as a partial replacement of cement.

IV. METHODOLOGY

The mix design of M20 grade is prepared by using IS: 456:2000 & IS 10262. The proportion of mix was 1:1.8:3.8 with 0.45 water cement ratio. The cement is then partially replaced by glass powder by weight 5%, 10%, 15 % & 20% by weight batching. The molds of cube is prepared of (15cm x 15cm x 15cm) size to test compressive strength of concrete, molds of cylinder (15cm x 30 cm) is prepared to test split tensile strength & beam (15cm x 15cm x 70cm) is formed to test flexural strength of each proportion. The tests are performed at 7 days, 14 days & 28 days for compressive strength test; as compressive strength is main characteristic strength of any type of concrete. Concrete is supposed to be good in compression strength. The split tensile strength & flexural strength tests are taken at 28 days. The results are observed & then compared for verifying the objectives of experimental investigation of the study.

V. RESULTS

The results of compressive strength is tabulated as below

TABLE3 COMPRESSIVE STRENGTH TEST RESULTS AT 7, 14 & 28 DAYS

Replacement Levels / Age of concrete	0%	5%	10%	15%	20%
7 days	12.25 MPa	11.89 MPa	12.37 MPa	11.90 MPa	11.85 MPa
14 days	17.33 MPa	16.22 MPa	17.95 MPa	16.96 MPa	12.39 MPa
28 days	19.50 MPa	17.89 MPa	21.12 MPa	19.13 MPa	18.30 MPa

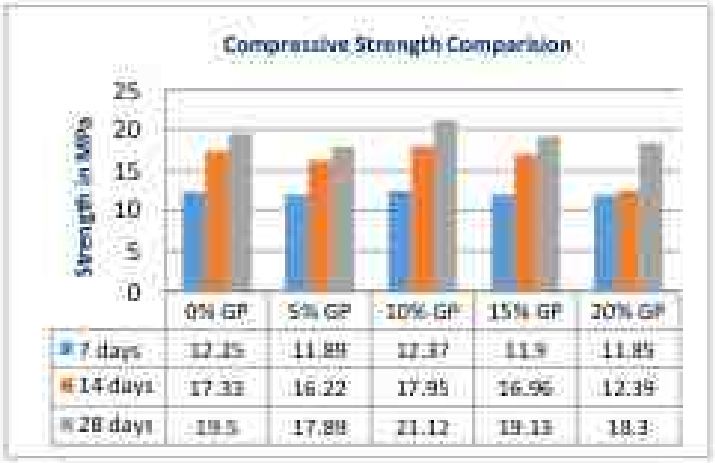

FIG1. Comparison between Compressive strength at 7days, 14 days & 28 days with 0%, 5%, 10%, 15 % & 20% replacement of cement by waste glass powder in concrete.

TABLE4 SPLIT TENSILE STRENGTH TEST RESULTS AT 28 DAYS

Replacement / Age of concrete	0%	5%	10%	15%	20%
28 days	3.2 Mpa	2.9 Mpa	3.3 MPa	3.1 Mpa	2.7 MPa

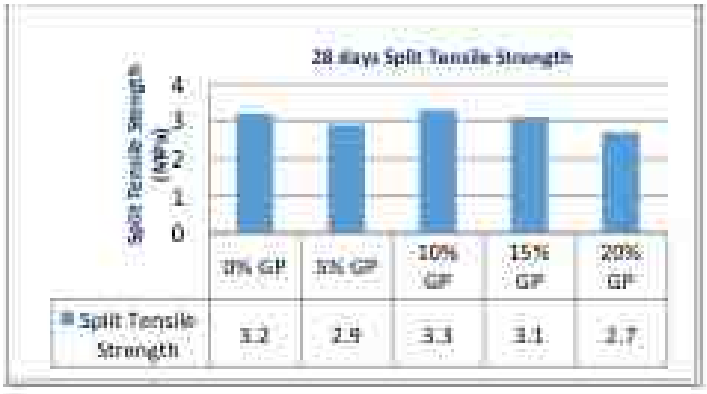

FIG2. Comparison between Split tensile strength at 28 days with 0%, 5%, 10%, 15 % & 20% replacement of cement by waste glass powder in concrete.

TABLE5 FLEXURAL STRENGTH TEST RESULTS AT 28 DAYS

Replacement / Age of concrete	0%	5%	10%	15%	20%
28 days	2.8 MPA	2.6 MPA	2.7 MPA	2.3 MPA	2.4 MPA

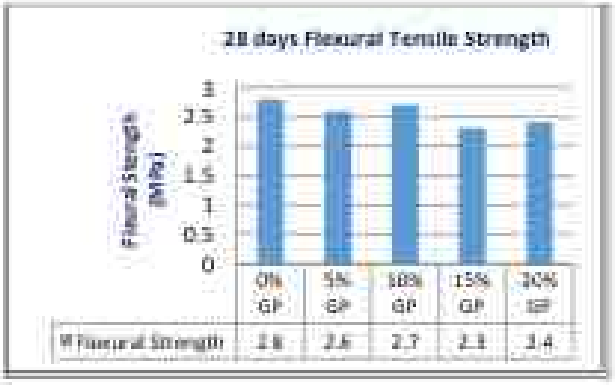

FIG3. Comparison between Flexural strength at 28 days with 0%, 5%, 10%, 15% & 20% replacement of cement by waste glass powder in concrete.

VI. DISCUSSION

VII. PREPARE YOUR PAPER BEFORE STYLING

A. Compressive Strength Results

From above seen results in table no.3 it is clear that the compressive strength of M20 grade concrete is highest at 10% replacement of cement by glass powder in concrete. It has been seen that results are improved by 8%. So we can conclude that we can replace cement by 10% weight with waste glass powder.

B. Split Tensile Strength Results

From above seen results in table no.4 it is clear that the split tensile strength of M20 grade concrete is highest at 10% replacement of cement by glass powder in concrete. It has been seen that results are improved by 0.5%. So we can conclude that we can replace cement by 10% weight with waste glass powder.

C. Flexural Strength Results

From above seen results in table no.5 it is clear that the Flexural strength of M20 grade concrete is highest at 0% replacement of cement by glass powder in concrete. It has been seen that results are not improved at any stage of replacement. So we can conclude that there is no any advantage of replacing cement with waste glass powder.

D. Cost Analysis

From above all conclusions it is clear that the compressive & split tensile strength of concrete is improved at 10% replacement of cement by waste glass powder & there is no positive effect in flexural strength of concrete. But as we all know that compressive strength is main characteristic strength of concrete we can replace cement by 10% weight with waste glass powder in concrete.

If we consider $1m^3$ of M20 grade concrete, we requires around 7 bags (each of 50kg) of cement for it. So we can replace about 35kg of cement by waste glass powder per m^3. So overall there is saving of around 300-350Rs/ m^3 while doing construction.

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Application of Drone Technology in Construction Industry

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***Abstract*— There are various fields in which Drone Technology is becoming significant. Surveying and Mapping, Construction Industry, Inspection and Surveillance, Military and Agriculture are the various areas where drone technology playing an important role of reducing time for this tedious work. Drone technology is the most effective among those technologies which helps in efficient project management by addressing the challenges in a construction project like surveying, monitoring activities, safety of labours, quality and cost control and getting timely on-site progress reports.**

I. Introduction

The world is continuously deploying new technologies in Construction Industry (CI) for the speed, accuracy and safety in the construction projects. Advanced modern technologies are entering CI for the faster execution of projects. At the same time to cope-up with execution speed, monitoring methods are also getting modernized. Thus, the drones have come into picture; they do not contribute for the actual execution but make a huge contribution in faster monitoring of the projects which help in faster decision making leading to lower the time lag in the projects too. Drones can be used right from the stage of land purchase till the post construction stage of the project. They are used from pre-construction; construction to post-construction stage of the engagement of conventional methods for site survey, contour mapping, site progress monitoring, construction quality management, etc. can be questionable, whereas drones can perform the same jobs with almost no risk and more accuracy and with lesser manpower too.

II. Literature View

1. Gayatri Mahajan (2021): Applications of Drone Technology in Construction Industry: A Study 2012-2021.

The building construction process is discussed from start to finish. Mostly they are design, and planning; procurement, Pre-construction; construction, post- construction and close-out. Drones/UAV provides construction stakeholders with expansive, accurate, and precise spatial data. Land surveying, inspection, monitoring any issue, track progress, deploying labor, material waste, annotating maps and images, calculating material types and stockpile volume for inventory and increasing safety. Some limitation and challenges for the use of drones in construction and civil engineering. The common challenges are: (1) safety challenges (2) project delays, and (3) difficulty/danger of mapping and surveying. The ever improving capabilities and affordability of drones makes it possible to reduce delays, reworks, and safety issues to drive better project performance. Limitations are drone cost, rules and regulation of flight, skill operatres, flight time and weather condition.

2. Pawan Kumar (2019): A view of the Future: Drones in construction Industry

In the past few years, drones have become one of the most compelling construction trends. The industry has experienced a 239% growth in drone use year over year, higher than any other commercial sector. Their aerial vantage point and data Collecting abilities make them a viable tool, offering benefits that range from on-site safety to remote monitoring. In Particular, the benefits of drone technology have revolutionized the entire project lifecycle. Newer drones can be equipped With tools to perform common construction tasks. Some of the "simpler" tasks, include tightening bolts and screws, moving and placing large sheets of metal, carrying spools of wire, laying pipes, taking photos and capturing video, working in spaces too small for humans As the industry grows and construction Projects become more complex; drones in construction will continue to skyrocket.

3. Ameena M Ansary (2022): 3D Mapping and Surveying using Unmanned Aerial Vehicle.

Surveying is one of the important aspects of any civil engineering project, traditional survey and inspection methods involve a lot of labour and time, also the equipment used is heavy and requires specialist knowledge. But with the help of UAVs (Unmanned Aerial Vehicles) the time and effort for surveying or inspecting large areas and structures will reduce exponentially. This is achieved with the help of sensors such as Cameras, Lidars, Sonars, and thermal cameras etc. that are attached to the UAV. Since most UAVs fly with the help of GPS satellites, coordinates of these places will be easily obtained. Software like Drone deploy, Pix4D, Precision Mapper etc. help in creating accurate and usable survey data. With the help of such systems 3D models of land and assets can be made. UAV technology is the next big thing in the world of Survey.

III. Objectives of Study

1. To study the various applications of drone technology – Area measurement, Contour survey.
2. To study the results of survey obtained by traditional method and Drone method and comparing the results.
3. To study the inaccessible area.
4. To identify the visual defects in any structure.

IV. Methodology

1. One terrain surface will be selected for the survey: Survey will be conducted using the traditional methods of survey like Auto level, Plane table, Chain survey, theodolite, total station, etc. Then the Survey of same terrain using drone will be conducted using software like Drone Deploy, DJI GO and PIX4D capture, etc. Then comparison will be done on the basis of Time, Manpower and cost required for the survey and the accuracy achieved. A visit was done to know the application of DGPS and drones.
2. Area of college will be mapped and then measured using geodetic coordinate system of drone. It takes the measurements between objects within the model and compares them to their real- world positioning relative to Earth. Also height of building will be measured.
3. One terrain which is inaccessible where humans can't go physically, also can't go with the heavy equipment of the traditional survey, there the survey using drones will be conducted. Survey including the reduced levels and contour measurements.
4 The defects in the any building structure will be captured using drones. The defects in the Bridge structure, high rise buildings can be easily found out by using drones where it is difficult for the human to go physically and check the defects.

IV. Observation

A. Comparison Between Traditional and Drone Survey

Figure 1: Time Comparison

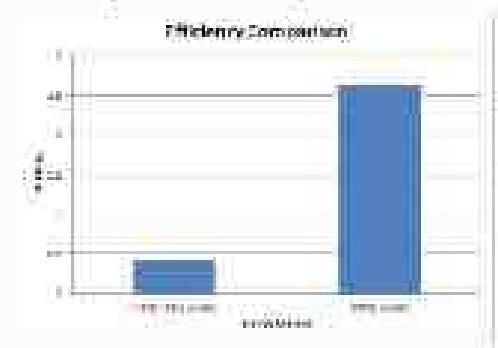

Figure 2 : Efficiency Comparison

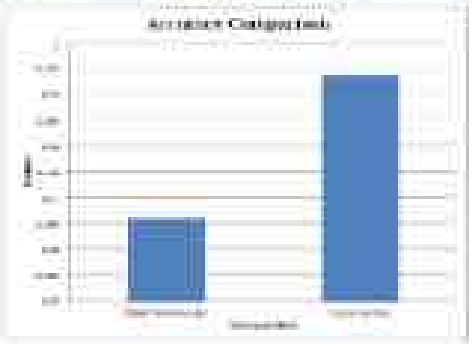

Figure 3 : Accuracy Comparison

B. Structural Defects: A visual defect survey often provides a partial assessment of the structure's current state and aids in determining its serviceability. As a result, it must be done before any structural rehabilitation or alteration of a structure may be done.

Case Study 1: Elevated Storage Reservoir

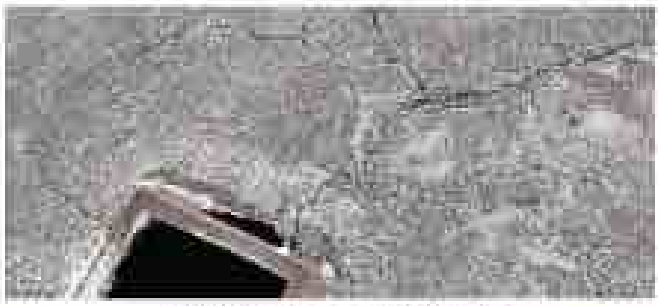

Figure 4: Cracks in slab of ESR

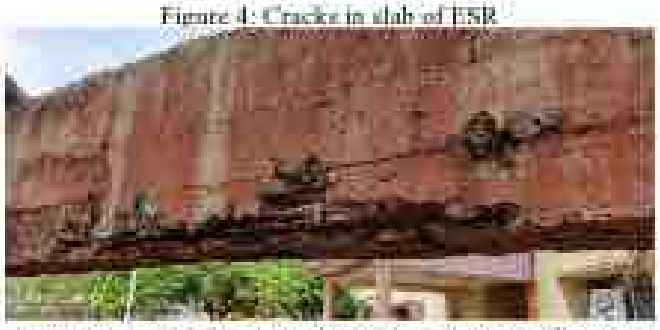

Figure 5 : Exposed and reinforcement at bottom of bracing

Figure 6: Cracks in bracing

Case Study 2: Residential Building

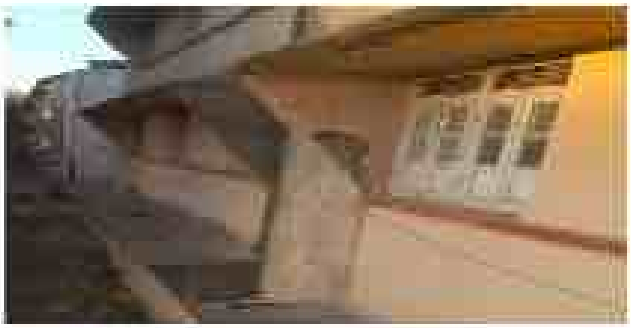

Figure 7: Cracks in Chajja

Figure 8: Exposed reinforcement

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Comprehensive review of fresh concrete properties

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***Abstract*— Concrete, a fundamental material in civil engineering, undergoes complex interactions during its formation, notably influenced by workability and heat of hydration. This review synthesizes insights from 32 research papers, focusing on the interplay between workability, heat of hydration, and the resultant impact on concrete strength prediction. The selected studies span diverse methodologies and experimental approaches, collectively providing a holistic view of the intricate relationships involved.

Methodologically, a rigorous analysis of fresh concrete tests forms the foundation, incorporating data on workability and heat of hydration. The synthesis of these parameters is integral to understanding the subsequent effects on concrete strength. The review reveals significant correlations between workability, heat generation, and the ultimate strength of concrete, elucidating patterns that contribute to predictive models.

The paper delves into critical findings, shedding light on the nuanced influence of workability and heat of hydration on concrete strength development. Noteworthy trends include Correlations Between Fresh Properties and Final Strength, providing valuable insights for optimizing concrete mix designs and construction practices. As the industry strives for more sustainable and efficient solutions, comprehending these relationships becomes imperative for achieving durable, high-performance concrete structures.

This review synthesizes findings from 32 research papers, offering insights into fresh concrete properties, specifically workability and heat of hydration. The comprehensive analysis highlights trends such as the impact of admixtures and cement types. After reviewing this paper, a reviewer gains a holistic understanding of fresh concrete properties, making it a valuable resource for future research.

Keywords: Concrete Strength, Workability, Heat of Hydration, Predictive Models, Fresh Concrete Tests.)

I. Introduction

Concrete, a fundamental material in civil engineering, relies heavily on workability and heat of hydration during its early stages. Workability influences concrete placement and compaction, while the heat of hydration reveals the exothermic reactions during cement hydration. Understanding their interplay and collective impact on concrete strength is a persistent challenge. This review synthesizes insights from 32 research papers to unravel the nuanced relationships between workability, heat of hydration, and concrete strength prediction. Optimizing concrete mix designs becomes imperative as the construction industry pursues sustainable and efficient solutions. This review provides a consolidated resource for practitioners and researchers through a systematic analysis, elucidating key trends, challenges, and advancements in fresh concrete properties. This exploration retrospectively analyses existing knowledge and lays the foundation for future research in this dynamic field.

II. Literature Review

Awal and Hussin (2011) studied the use of palm oil fuel ash (POFA) in concrete to control the heat of hydration. Replacing some cement with POFA effectively reduces heat, particularly in mass concrete, lowering overall temperature rise and delaying peak temperature. The authors suggest additional research on time-temperature behaviour in concrete with different ash content. In summary, POFA is a valuable supplementary material for reducing heat in concrete, prompting further investigation into its effects on strength and deformation.

Ezhar Ahmed and Dr. S.S. Jamkar (2012) explored the impact of fly ash on concrete properties based on IS: 10262-2009. The study investigated workability and compressive strength, varying fly ash percentages, and water-cement ratios. Results showed improved workability and compressive strength in concrete mixes with fly ash compared to the reference. It implies that fly ash effectively enhances concrete properties, offering insights for proportioning fly ash-based mixes. In conclusion, the research affirms that fly ash can enhance concrete properties, especially workability and compressive strength, at later stages, providing valuable considerations for incorporating fly ash into concrete production.

Ferrou et al. (2014) explored using carbon micro/nanoparticles as reinforcing fibres in cement paste, focusing on their impact on mechanical properties. Results demonstrated a significant increase in fracture energy and nominal strength in composites with carbon micro/nanoparticles. The addition of 0.08% carbon nanoparticles doubled fracture energy. Mechanical characterization revealed structural embedding of carbon nanoparticles in the cementitious matrix, evident within the fracture path. The study concludes that incorporating carbon micro/nanoparticles as reinforcing fibres enhances the mechanical properties of cement composites, improving crack resistance and energy absorption capacity. However, further research is needed to fully comprehend the interaction between carbon nanoparticles and the cementitious matrix.

Klemczak and Batog (2015) studied the heat of hydration in low-clinker cement, focusing on mineral additives and temperature influence. Results indicated that adding mineral additives like fly ash and slag reduced the heat of hydration. The rate of heat evolution was affected, showing delayed second peak occurrence and a narrower shape at higher temperatures. Mineral additives' reactivity, with fly ash less active than slag, played a role. Overall, findings suggest mineral additives in low-clinker cement effectively reduce the heat of hydration, offering insights for optimizing cement formulations.

Harshlata R. Raut and Ashish B. Ugale (2016) conducted an experimental study on the "Effect of Artificial Sand on Compressive Strength and Workability of Concrete." The paper aims to investigate the impact of artificial sand on concrete's compressive strength and workability, offering a comprehensive review of existing research and presenting experimental results to support their findings. Additionally, the paper provides mixed proportions, experimental procedures, and results, accompanied by a literature review and references.

Taghried Isam Mohammed Abdel-Magida et al. [2017] investigated the "Effect of Magnetized Water on Concrete Workability and Compressive Strength." The study focused on how magnetized water influences properties like workability, compressive strength, weight, and cement content reduction. Magnetized water was found to improve workability, demonstrated by increased slump measurements. It also enhanced compressive strength without any discernible loss compared to regular water. Additionally, the study revealed a potential reduction in cement content when using magnetized water. The research suggests benefits such as improved workability, enhanced compressive strength, and potential cement content reduction in concrete using magnetized water.

Fig. 1 (a) Water molecules before magnetic treatment; (b) Water Molecules after magnetic treatment (Taghried Isam Mohammed Abdel-Magida et al.)

Nicolas Burlion et al. [2017] explored experimental techniques for analyzing concrete and mortar compaction. The study successfully demonstrated linear stress paths during loading, deviations during unloading due to friction, and effective measurement of deformation and pressure using strain gauges. Tests indicated isotropic deformation of specimens unaffected by aluminum discs. Volumetric strain versus hydrostatic pressure curves highlighted material sensitivity to deviatory stress, suggesting the inseparability of hydrostatic and deviatory responses in constitutive models. Post-compaction, the material structure revealed a rearrangement of the aggregate skeleton, indicating a distinct structure compared to pure hydrostatic compression. The study effectively analyzed compaction and hydrostatic response, providing valuable insights into material behaviour under different loading conditions.

A. Krishna Rao and D. Rupesh Kumar [2017] investigated "Strength Characteristics of Fly Ash Concrete with Same Workability," aiming to explore its strength properties compared to traditional concrete. The study found that replacing cement with fly ash resulted in high-strength concrete without compromising compressive or flexural strength. Compressive strength in mortar cubes marginally reduced at 7 and 28 days but slightly increased at 90 days. The water-binder ratio decreased with higher fly ash replacement. Overall, the study suggests that fly ash can be a suitable partial replacement for cement in concrete, offering an eco-friendly alternative while maintaining or improving strength.

Afif Rahmu, Nabil El Naber, and Sherzad Issa Ismail [2017] explored the "Effect of Glass Powder on Compression Strength and Workability of Concrete." The article focused on investigating how the addition of glass powder influences concrete properties. Test results indicated that glass powder enhances compressive strength but adversely affects workability. The conclusion suggests a potential positive impact on compressive strength by adding glass powder while acknowledging the trade-off with reduced workability. The authors recommend further research to optimize the use of glass powder in concrete and determine effective methods for its incorporation into mixtures.

Muhammad Nasir Ayaz Khan et al. [2018] explored the impact of brick dust on concrete. Increasing brick dust content improved slump values due to lubrication by spherical particles. However, water absorption increased beyond 15% cement replacement, reducing slump. Compressive strength peaked at 15% replacement, attributed to natural pozzolanic properties and compact mass formation. Beyond 15%, compressive strength decreased. Brick dust also acted as a plasticizer, reducing water demand and enhancing workability. In summary, the research suggests using brick dust in concrete effectively, enhancing workability and strength up to a certain replacement percentage.

Hoon Moon [2018] studied the impact of blast furnace slag as a supplementary cementitious material on concrete's heat of hydration. The research found that adding slag reduces temperature rise during hydration, accelerates early cement hydration, and lowers the maximum temperature rise compared to plain concrete, especially in semi-adiabatic conditions. Concrete with blast furnace slag also exhibited higher compressive strength. However, caution is needed in

mass concrete applications to prevent potential temperature differences causing surface thermal cracks. In summary, blast furnace slag proves beneficial in concrete production, improving performance and reducing heat of hydration.

K.C.Taiwade et al. [2018] presented a paper on the "Measurement of Temperature Rise in Concrete and Assessment of Probability of Cracking due to Heat of Hydration." The study aimed to measure temperature rise in a concrete pile cap prototype and assess the probability of cracking. Thermocouples were strategically placed to record temperatures, revealing that thermal restraints can cause external and internal cracking when there's a 20°C internal thermal differential. The study provided concrete mix proportions and strength results at various curing periods. Based on temperature difference, the crack index was used to assess the probability of cracking, cautioning its conservative nature. The research underscores the importance of realistic equations for crack assessment in mass concrete structures.

B. O. Adinna et al. [2019] explored the "Effect of Rice-Husk-Ash Admixture on Strength and Workability of Concrete." The study aimed to reduce concrete production costs and address environmental concerns in rice-producing regions by replacing some cement with rice husk ash (RHA). Tests on concretes with varying RHA amounts showed a uniform strength increase of up to 4% RHA addition, declining with higher RHA content. The study considered an initial slump in determining the quantity of RHA added, recommending up to 7% for medium workability (slump within 50-100mm) to achieve a 20% increase in compressive strength. For other initial workability, the quantity added should depend on the required workability, up to a maximum of 10% by weight of cement.

Abdul Razak B. H. et al. [2019] studied the "Fresh, Strength, and Durability Characteristics of Binary and Ternary Blended Self-Compacting Concrete," focusing on mineral admixture benefits. All blended mixes met EFNARC guidelines for typical applications regarding slump flow. Mixes S0 and S2 demonstrated strong filling ability, with the best surface finish and self-lifting capability but a higher chance of bleeding. Mixes S0, S2, S4, S6, and S8 showed good filling capacity even with crowded reinforcement. Increased flow times in specific mixes had potential thixotropic effects, beneficial for reducing formwork pressure. Every combination passed the L box test, and binary blended mixes with GGBFS at various replacement levels met the requirements for typical applications.

Prijs.e.Moses et al. [2019] conducted a study on the "Properties of Fresh and Hardened Concrete," aiming to review and discuss various aspects, including workability, rheological properties, compressive strength, and the impacts of factors like binders, aggregates, reinforcement, and admixtures. The paper also addresses testing, interpretation, modelling, and prediction methods, incredibly lightweight and self-compacting concrete. The authors emphasize ongoing research and advancements in comprehending the complex behaviour of concrete, highlighting the potential for computational modelling to enhance prediction and design. In conclusion, the paper provides a comprehensive overview of concrete properties and the latest developments in the field.

Hamadallah Al-Baijat and Mohmd Sarireh [2019] presented a paper on "The Use of Fine Blast Furnace Slag in Improvement of Properties of Concrete." The study aimed to explore fine blast furnace slag (BFS) as a cement replacement in concrete and assess its impact on various properties. Results indicated that adding BFS enhanced workability, density, unit weight, compressive strength, bond strength, and flexural strength. Optimal results were observed at a 30% BFS addition. The study found no harmful effects during manufacturing, curing, or testing, and overall, it concluded that fine BFS can effectively enhance concrete properties. Further research is recommended to investigate long-term effects.

Narsindas Bheel et al. [2021] presented a paper on the "Effect of Wheat Straw Ash on Fresh and Hardened Concrete Reinforced with Jute Fiber." The study investigated the impact of wheat straw ash (WSA) and jute fibre on concrete properties. Workability decreased with increased jute fibre and WSA content. However, adding jute fibre improved compressive, splitting tensile, and flexural strengths, with peak values at 0.50% fibre content. Similarly, WSA as a sand replacement improved strength properties, with optimal results at 30% WSA. Overall, the study demonstrated that incorporating jute fibre and WSA in concrete can enhance its properties, offering a sustainable alternative in construction.

Jawad Ahmad et al. [2021] studied the "Mechanical and Durability Characteristics of Sustainable Coconut Fibers Reinforced Concrete with Incorporation of Marble Powder." The research demonstrated that adding waste marble and coconut fibres improved compressive strength, achieving 29 MPa with the ideal dosage. The study also highlighted increased split tensile strength and enhanced durability, particularly against sulfuric acid attack, with the lowest weight loss at 20% marble substitution. The conclusion emphasized the overall improvement in mechanical and durability properties, though considerations for workability impacts were noted.

Nadimulla et al. [2021] explored the impact of shredded PET bottles and manufactured sand in concrete mixtures. The workability of concrete with these materials was comparable to conventional concrete. Concrete with manufactured sand and 1.5% shredded PET showed improved workability compared to sand alone. The study established correlations between compaction factor, slump, and VeBe, providing empirical formulas for prediction. The research suggests that using waste and recycled materials holds promise for sustainable construction.

Dong Viet Phuong Tran [2021] explored using recycled concrete aggregate (RCA) in medium-quality structural concrete, evaluating its impact on workability, mechanical properties, and durability. The study revealed decreased workability (8% to 38%) due to RCA's high water demand. Compressive strength declined by 5.0% to 9.3%, more pronounced with higher RCA content. Tensile strength also decreased with increased RCA content, showing a reduction of 10.7% at 7 days and 8.3% at 28 days for 100% RCA replacement. Microscopic analysis indicated surface pores and roughness, weakening interfacial transition zones. Ultrasonic pulse velocity tests revealed increased porosity. Despite drawbacks, the study suggests the potential use of RCA in structural concrete with considerations for reduced

strength and increased vulnerability to environmental factors.

Rana Muhammad Waqas et al. [2021] presented an article, "A Comprehensive Study on the Factors Affecting the Workability and Mechanical Properties of Ambient Cured Fly Ash and Slag Based Geopolymer Concrete". It mainly describes the methodology used in the research and the different mixes prepared to investigate the influence of various mix design parameters on the engineering properties of the geopolymer matrix.

A.M Nadimalla et al. [2022] developed a machine learning model to predict the workability of concrete, focusing on slump, Vebe, and compactium factors. The study compared the performance of Decision Tree Regression (DTR) and Multiple Linear Regression (MLR) models, finding that the DTR model outperformed with lower error metrics. Empirical formulas from the MLR model were proposed for predicting slump, Vebe, and compaction factor. The research concludes that machine learning, particularly the DTR model, effectively predicts concrete workability using experimental data, offering the potential for streamlined determination of fresh concrete properties while maintaining cost-effectiveness.

Dattatreya Kumar [2022] investigated the workability and strength properties of lightweight aggregates, specifically Palm oil shell and pumice aggregate, in concrete production. The study focused on compaction factor, Schmidt Hammer, and compressive strength tests for lightweight concrete (M30). The research revealed that workability and strength properties were affected as the percentage of lightweight aggregates increased. Slump test results showed varying workability, decreasing with higher percentages of lightweight aggregates. Compressive strength varied with aggregate percentage, with 10% lightweight aggregates yielding the highest and 50% the lowest strength. The paper highlights the impact, benefits, and challenges of using lightweight aggregates in concrete construction.

Elshazli, M.T. [2022] investigated the impact of basalt fibres on the freshness, mechanical strength, durability, and corrosion properties of reinforced concrete. The study revealed that adding basalt fibres improved the concrete's mechanical properties, including compressive and split-tensile strengths, with higher fibre volumes showing increased strength values. Basalt fibres positively affected fresh properties, enhancing unit weight without affecting slump values. Moreover, the study concluded that basalt fibre-reinforced concrete exhibited improved durability, reduced shrinkage strain, enhanced resistance to chloride ion penetration, and lowered the likelihood of corrosion. These findings suggest the potential of basalt fibre-reinforced concrete for construction applications.

Rokiah Othman [2022] explored the relationship between the density and compressive strength of foamed concrete, investigating the potential benefits of using processed spent bleaching earth (PSBE) as a partial cement replacement. The study directly correlated density and compressive strength with the sand-cement ratio and PSBE content. Higher ratios of sand-cement and PSBE, excluding foam dosage, water-cement ratio, and dilution ratio, were associated with increased compressive strength and density. A 1:1.5 (cement, sand) ratio was identified as ideal for achieving a desired density of 2100 kg/m3. Foamed concrete with 30% PSBE exhibited promise for building applications. Overall, adjusting the sand-cement ratio and incorporating PSBE can control foamed concrete's density and compressive strength, offering potential environmental benefits.

Özer Zeybek et al. [2022] evaluated the performance of fibre-reinforced concrete using steel fibres extracted from waste tires, aiming to provide an alternative to industrial steel fibres. The study revealed that incorporating these waste tire-derived steel fibres enhanced the concrete's mechanical properties, including compressive strength, flexural strength, and toughness. The optimal percentage of waste tire-derived steel fibres for the concrete mix was 2%. The findings suggest that utilizing steel fibres from waste tires in fibre-reinforced concrete is a viable alternative, improving mechanical properties and contributing to sustainability by reducing waste. Further research is recommended to optimize the use of waste tire fibres and assess long-term durability and environmental impact.

Mariana Fonseca et al. [2022] Mariana Fonseca et al. (2022) explored the influence of plastic waste on the workability and mechanical behaviour of asphalt concrete, explicitly assessing the feasibility of using plastic waste as bitumen extenders in asphalt mixtures. The study revealed that incorporating plastic waste as bitumen extenders affected asphalt concrete's workability and mechanical properties. The viscosity of the binder, influenced by the type of plastic used, played a crucial role in determining workability. While adding plastic waste did not pose significant water sensitivity issues, it did impact the resistance to permanent deformation. The research suggests that incorporating plastic waste into asphalt concrete can enhance specific properties, including workability and resistance to permanent deformation. However, further research is needed to understand the long-term behaviour, environmental impact, and life cycle analysis of such asphalt concrete.

Noora H. A. AL-KHAFAJII et al. [2023] conducted a study aiming to improve lightweight concrete for structural use by incorporating polypropylene fibres (PF) and hook steel fibres (SF). The research involved testing eighteen beams to assess the impact of these fibres on shear and flexural behaviour. Results revealed a significant enhancement in shear and flexural failure resistance, particularly with polypropylene fibres at 0.1% and hybrid fibres. Steel fibres exhibited the lowest increase in resistance. While the oven-dry density showed slight variations, the study concluded that lightweight concrete with hybrid fibres suits structural applications.

Lalitha Varikapppala and G V V Satyanarayana [2023] aimed to develop M25 grade concrete using lightweight aggregate (Pumice) and explore its mechanical and thermal properties. Experimental findings indicated that incorporating pumice partially replaced coarse aggregate and reduced concrete density while maintaining compressive strength. The developed concrete exhibited favourable thermal insulation properties. The conclusion suggests that using pumice in M25 grade concrete can produce lightweight concrete with promising mechanical and thermal characteristics, recommending its application in scenarios where weight reduction is crucial, such as high-rise buildings. The study proposes further research on the long-term durability of the developed concrete.

Abdulaziz Alaskar et al. [2023] compared genetic programming algorithms for predicting concrete compressive strength at high temperatures. GEP and MEP models showed high accuracy (R-squared: 0.85 and 0.84, respectively). Sensitivity analysis revealed the significant impact of cement, water, and temperature. The GEP model provided a practical formula for precise compressive strength prediction under elevated temperatures.

Manish Kumar et al. [2023] proposed soft computing-based models (MARS, DNN, ELM) for predicting the compressive strength of fly ash and silica-fume hybrid concrete. The models outperformed traditional relations, demonstrating excellent generalization. Key variables impacting compressive strength were the sample's age and total cementitious material, while fly ash replacement ratio and coarse aggregate had significant adverse effects. The study concludes that these models are promising tools for estimating concrete strength and reducing environmental impact by incorporating alternative cementitious materials. Future research could explore broader applications and model combinations for improved accuracy.

Deprizon Syamsunur et al. [2023] Deprizon Syamsunur et al. (2023) investigated the performance of composite nano-modified concrete in enhancing structure durability. The study found that additions of nano-SiO_2 and nano-$CaCO_3$ improved mechanical properties, high-temperature resistance, and reduced water absorption compared to ordinary concrete. The visual appearance was satisfactory, and economic benefits included potential cost savings and enhanced long-term functionality. The conclusion supports using composite nano-modified concrete as an effective solution for improving structure durability and performance.

CONCLUSION

The diverse literature reviewed highlights ongoing efforts to enhance concrete properties sustainably. Alternative materials like rice husk ash and blast furnace slag offer eco-friendly solutions. They incorporate fibres, like jute and coconut, and waste materials, like marble powder, to improve mechanical and durability. Advanced techniques, including machine learning and soft computing, promise to predict concrete behaviour efficiently. Exploration of lightweight aggregates, like pumice, demonstrates potential benefits in achieving desired properties with reduced density. Additionally, composite nano-modified concrete presents improved durability, mechanical strength, and temperature resistance. Overall, the literature emphasizes the importance of sustainable and high-performance concrete solutions through innovative materials and modelling approaches.

FUTURE SCOPE

The future scope of this review paper involves further investigations into predictive modelling for concrete strength using the compiled dataset. This could lead to the development robust models that anticipate concrete properties based on different additives and proportions. Additionally, exploring innovative combinations of materials, assessing long-term durability, and considering environmental impacts will contribute to advancing sustainable construction practices. Acknowledging the contributions of professors, the institution, and other collaborators is crucial in recognizing their support throughout this research.

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Thermal Performance of Residential Building Using Revit Software

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Abstract -
Thermal comfort is an important aspect of the building design process. It is the state of mind, which expresses satisfaction with the thermal environment. The current study deals with the assessment of thermal performance of two-storey residential building for the climate in Miraj, Maharashtra. The residential building was modified using Revit software and analysed for thermal load for various alternative materials and techniques for wall,window, and roof material. This study reveals that the residential building built with Cavity AAC block as wall material, RCC roof and floor slab and aluminium glazed window with chajja can reduce the cooling load by 62% as compared to building constructed using conventional brick wall, RCC roof and floor slab and aluminium glazed window.

Keywords: Revit software, thermal performance, cooling load, energy consumption, residential building.

I. INTRODUCTION

Nowadays, energy consumption has increased because of technological development in numerous fields like agriculture, transportation, household services, and industry. Since the beginning of the last decade, the building sector has been one of the largest energy consumers in the world, accounting for 30-40% of total energy consumption. In the building, which is in developed countries, energy consumption for the heating, ventilation, and air-conditioning systems required 50% of the total energy consumption of the building. By providing a comfortable indoor environment, we developed material technology and construction techniques that might significantly reduce energy consumption. These developments mainly focus on passive heating optimization, improving the thermal performance of the building by providing thermal insulation for various materials in the building.

To reduce energy consumption, improving the thermal performance of the building is an option. Construct sustainable buildings. Buildings should be properly designed and constructed. To realize that goal, the primary step is to find a new way that can provide a detailed analysis of the building. Most traditional analyses depend on hand calculations, spreadsheets based on building codes, and national annexes decided by legislation. Moreover, these analyses don't give the specified flexibility to designers for managing all analysis as perfectly as they want.

Revit software has been considered an effective tool for building thermal performance analyses. It has also been used for 3D, real-time, and dynamic building modelling software to increase accuracy and productivity. Revit software can be the solution to reduce these difficulties and make the input data more efficient and the existing data more reusable. For the prediction of future energy and environmental performance of the building as well as occupants, computer-based modelling and simulation have become more important. Simulation plays a significant role in building system design, operation, renovation, or management of the decision-making process.

The wall, roof, slab, and window are important elements of a building that transfer the heat caused by solar radiation indoors through their surface area. The aim is to assess the thermal performance of the building through variations in wall, window, and roof materials and its impact on indoor thermal comfort in residential buildings for Miraj.

II. METHODOLOGY

A. Temperature Data

Detailed temperature data for Miraj was obtained from www.worldweatheronline.com which consists of temperature for the previous five years, and from that maximum simultaneously occurring temperature will be used to perform simulation in Revit software.

B. Studied building

The study area is located in Miraj, which is located at latitude 16.82° north and longitude 74.64° east. Miraj's tropical climate is characterised by high daytime temperatures, heavy rainfall, and abundant sun rays throughout the year. The high temperature was recorded in April.The building is a double-story residential building with a plot area of 117 m^2 and a total built-up area of 142 m^2.

C. Modelling and analyzing in Revit Software

There are several steps considered in modelling as well as analyzing in Revit software. This software for building modelling starts with the 2D drawing, i.e., the plan as per the

specifications that were given in the building bye-laws. converting the 2D drawing into 3D models, and then doors, windows, and ventilators are provided. Assigning each level, like a ground, plinth, or slab, is given. Lighting, furniture, and airflow are provided by loading components from the family in Revit software. For thermal analysis, variations in the wall, roof, slab, and window materials and providing thermal properties of materials like thermal conductivity, specific heat, density, etc. are going to be the default for already installed materials, and for new materials, we will give our value. After completion of the model, spaces are given to every room; otherwise, analysis cannot be completed. The location of the building may be set within the analysis tab either by providing latitude and longitude or by plotting on the map. The Plan and 3D model of the residential building is illustrated in figures 1 and 2 respectively.

Fig 1 Plan of residential building

Fig 2 3D model of residential building

Table 1 Combinations by changing Various Components of the building

Sr No.	Variations				
	External Wall	Thickness	Floor Slab 125mm	Roof Slab	Window
1	Brick	230mm	RCC	RCC (125mm)	Aluminum Glazed
2	Cavity Brick	230mm	RCC	RCC (125mm)	Aluminum Glazed
3	AAC	230mm	RCC	RCC (125mm)	Aluminum Glazed
4	AAC	230mm	RCC	RCC (125mm)	Partially Glazed with Chajja
5	Cavity AAC	230mm	RCC	RCC (125mm)	Aluminum Glazed with Chajja
6	Brick	230mm	RCC	RCC (125mm)	Aluminium Glazed with Chajja
7	Brick	230mm	RCC	RCC (125mm)	Partially Glazed
8	Brick	230mm	RCC	RCC (125mm)	Partially Glazed with Chajja
9	Brick	230mm	RCC	Hollow Block Roof	Aluminium Glazed
10	Brick	230mm	RCC	Composite Brick Panel Roof	Aluminium Glazed
11	Brick	230mm	RCC	Brick Vaulted	Aluminum Glazed
12	Brick	230mm	RCC	AC Sheet	Aluminum Glazed with Chajja
13	Brick	230mm	RCC	Mangalore Tiles	Aluminium Glazed with Chajja
14	Brick	230mm	RCC	Steel Powdered Coated Sheet	Aluminum Glazed with Chajja
15	Brick	230mm	RCC	Hollow Block Roof	Partially Glazed with Chajja
16	Brick	230mm	RCC	Composite Brick Panel Roof	Partially Glazed with Chajja
17	Brick	230mm	RCC	Brick Vaulted	Partially Glazed with Chajja
18	Brick	230mm	RCC	AC Sheet	Partially Glazed with Chajja
19	Brick	230mm	RCC	Mangalore Tiles	Partially Glazed with Chajja
20	Brick	230mm	RCC	Steel Powdered Coated Sheet	Partially Glazed with Chajja
21	Brick	230mm	RCC	RCC cover with Shade Net	Aluminum Glazed

In combination 1 (table 1) brick material is used for external wall, roof and floor slab made by RCC having 125mm thickness and aluminium glazed window i.e. (conventional building)

In combination 2, 3, 4 and 5 (table 1) brick as well as AAC block material is used for external wall, roof and floor slab made by RCC having 125mm thickness. The combination 2 and 3 contain aluminium glazed window, the combination 5 contain aluminium glazed window with chajja, the combination 4 contain partially glazed window with chajja. In these 4 combinations 230mm thick brick wall as well as AAC block wall is provided with brick size 19cm x 9cm x 9cm and AAC

block size 60cm x 20cm x (7.5-30)cm. In combination 2 and 5, cavity brick wall as well as cavity AAC block wall is constructed having 75mm cavity by using rat trap bond.

In combination 6, 7 and 8 (table 1) brick material is used for external wall, roof and floor slab made by RCC having 125mm thickness. The combination 6 contain aluminium glazed window with chajja, the combination 7 contain partially glazed window, and the combination 8 contain partially glazed window with chajja.In combination 7 and 8 partially glazed windows with 25% glass and 75% wood is provided.

In combination 9, 10 and 11 (table 1) brick material is used for external wall, floor slab made by RCC having 125mm thickness and aluminium glazed window. For combination 9 flat roof slab made by hollow blocks having thickness 150mm with block size 400mm x 200mm and interal hollow gap size 163mm x 100mm. For combination 10 flat roof slab made by composite brick panel roof having thickness 150mm with brick panel thickness 100mm and 25mm thick concrete finishing for top as well as bottom. For combination 11 roof slab made by brick vault roof having thickness 150mm.

In combination 12, 13 and 14 (table 1) brick material is used for external wall, floor slab made by RCC having 125mm thickness and aluminium glazed window with chajja. For combination 12 sloped roof slab made by AC sheet having thickness 6mm with 5° slope with sheet size 1.2m x 3m. For combination 13 sloped roof slab made by Mangalore Tiles having thickness 20mm with 20° slope with tiles size 420mm x 250mm. For combination 14 sloped roof slab made by Steel Powdered Coated Sheet having thickness 6mm with 5° slope with sheet size 12'x4'.

In combination 15, 16 and 17 (table 1) brick material is used for external wall, floor slab made by RCC having 125mm thickness and partially glazed window with chajja. For combination 15, 16 and 17 flat roof slab made by hollow blocks, composite brick panel roof and brick vault roof respectively.

In combination 18, 19 and 20 (table 1) brick material is used for external wall, floor slab made by RCC having 125mm thickness and partially glazed window with chajja. For combination 18, 19 and 20 sloped roof slab made by AC sheet, Mangalore Tiles and Steel Powdered Coated Sheet respectively.

In combination 21 (table 1) brick material is used for external wall, floor slab made by RCC having 125mm thickness, roof slab made by RCC having 125mm thickness and covered with shade net having 6mm thickness.this combination contain aluminium glazed window.

Fig 3 Combination 17 (BW+RVr+PGWp)

Fig 4 Combination 13 (BW+MTr+AGW)

Fig 5 Combination 3 (AACW+RCr+AGW)

Fig 6 combination 21 (BW+RCrCSN+AGW)

Following are the input details for different materials.

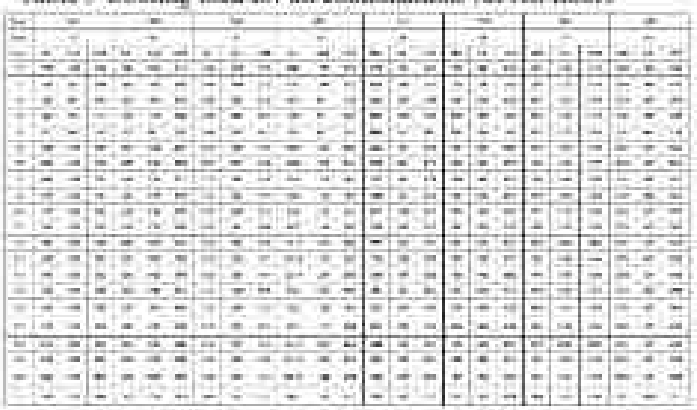
Table 2 Input details for different materials

Material	Properties		
	Density(Kg/m3)	Thermal Conductivity W/(m·°C)	Specific Heat J/(g·°C)
Brick	1900	0.81	0.84
AAC Block	580	0.16	1
Jute	1.2	0.035	1.0035
Concrete	2300	1.040	0.657
RCC	2500	1.7	0.84
Aluminium	2700	230	0.897
Glass	2480	1.1	0.84
Wood	630	0.172	2.301
AC Sheet	1520	0.245	0.84
Steel powdered Coated Sheet	7800	52	0.47
Shade Net	930	0.302	2.301

III. RESULT AND DISCUSSION

Table 3 is shows cooling loads are analyzed at four different timing in a day i.e. at 9 am, at 12 noon, at 3 pm and at 6 pm. After analyzing the combinations it is found that cooling load is different for each room at same time. The cooling load for first floor is higher than ground floor in each combination, because first floor slab directly exposed to sun radiation. Extra 30% , 34%, 37% and 23% cooling load is required at 9am, 12noon, 3pm and 6pm respectively for first floor SE bedroom as compare to ground floor kitchen which is exactly below to SE bedroom. Extra 29%, 34%, 36% and 34% cooling load is required at 9am, 12noon, 3pm and 6pm respectively for first floor SW bedroom as compare to ground floor budroom which is exactly below to SW bedroom.

Table 3 Cooling load for all combinations for All floors



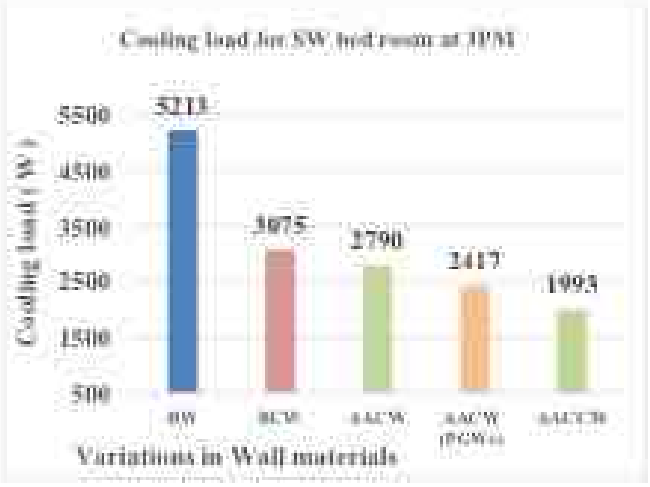


Fig 7 Comparison of cooling load by variation in wall materials

From figure 7 it is observed that, cooling load was reduced by 41% after providing cavity brick wall as compared to conventional building (9"BW+RCr+AGW). Cooling load was reduced by 47% after providing AAC block wall as compared to conventional building (9"BW+RCr+AGW). Cooling load was reduced by 54% after providing AAC wall and partially glazed window with chajja as compared to conventional building (9"BW+RCr+AGW). Cooling load was reduced by 62% after providing cavity AAC block wall as compared to conventional building (9"BW+RCr+AGW).

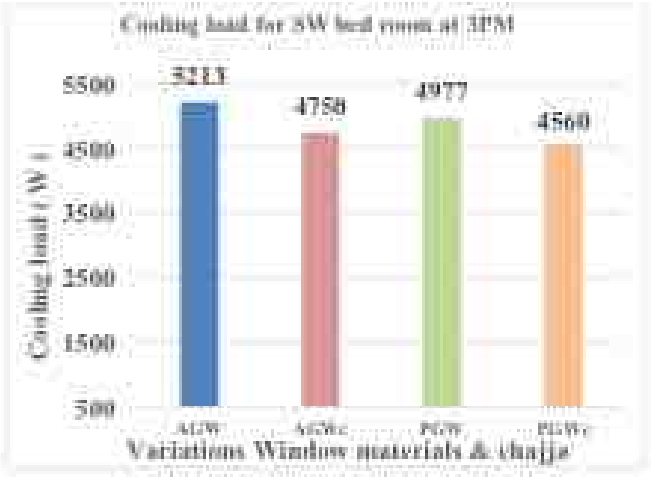
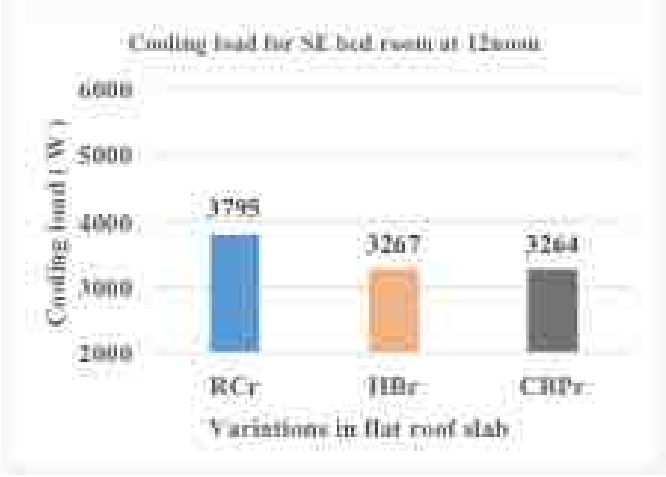


Fig 8 Comparison of cooling load by variation in window materials

From figure 8 it is observed that, cooling load was reduced by 9% after providing chajja as compared to conventional building (9"BW+RCr+AGW). Cooling load was reduced by 13% after providing partially glazed window with chajja as compared to conventional building (9"BW+RCr+AGW)



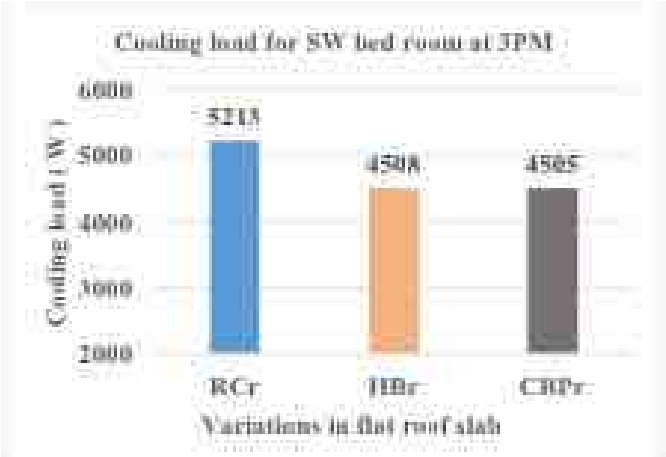
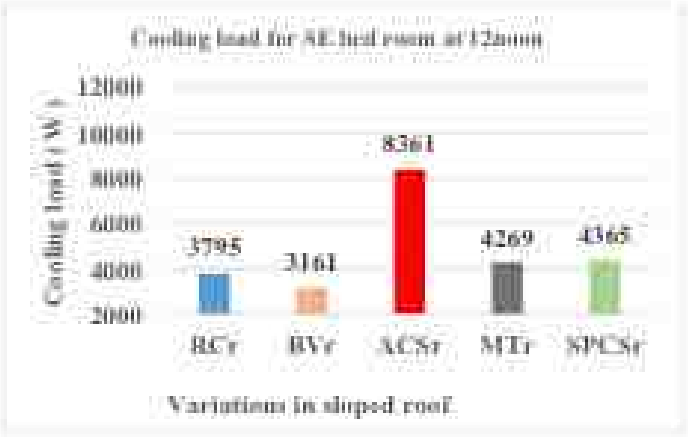


Fig 9 Comparison of cooling load by variation in flat roof slab

From figure 9 it is observed that, cooling load was reduced by 14% after providing Hollow block roof as well as composite brick panel roof as compared to conventional building (9"BW+RCr+AGW)



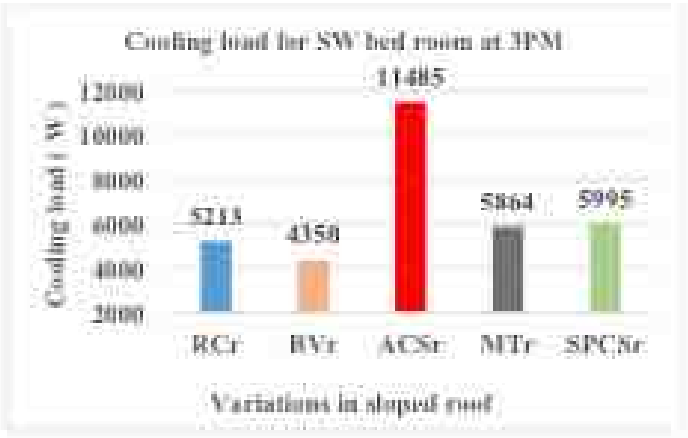
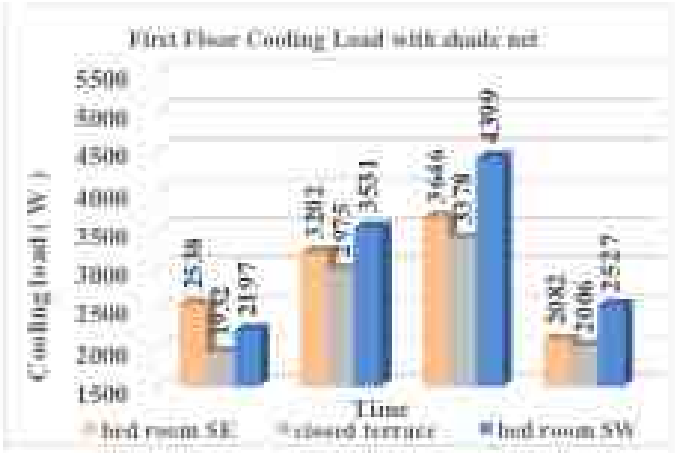


Fig10 Comparison of cooling load by variation in sloped roof

From figure 10 it is observed that, cooling load was reduced by 17% after providing brick vaulted roof as compared to conventional building (9"BW+RCr+AGW). Cooling load was increased by 120% after providing AC sheet roof as compared to conventional building (9"BW+RCr+AGW). Cooling load was increased by 12% after providing Mangalore tile roof as compared to conventional building (9"BW+RCr+AGW).Cooling load was increased by 15% after providing Steel Powdered Coated Sheet roof as compared to conventional building (9"BW+RCr+AGW).



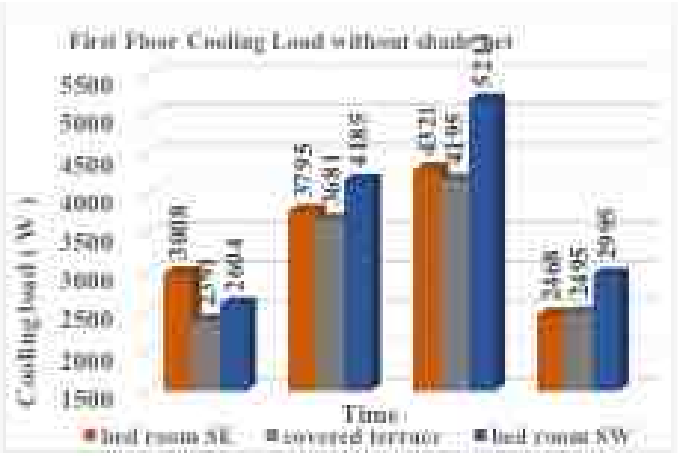
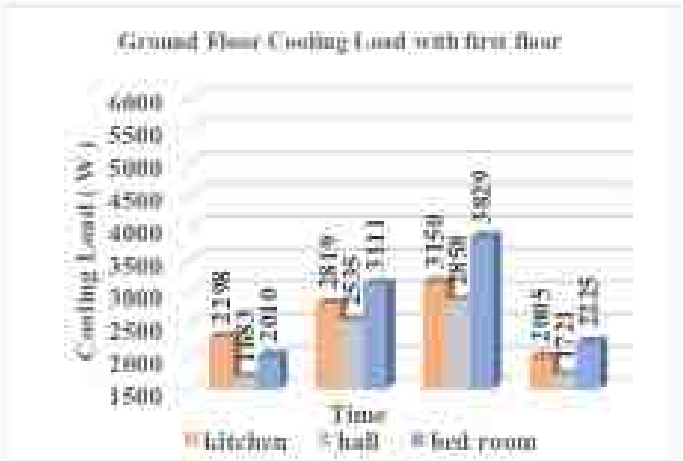


Fig 11 Comparison of First floor cooling load with shade net and without shade net

From figure 11 it is observed that, cooling load was reduced by 16% after providing Shade Net for top of the second floor as compared to conventional building (9"BW+RCr+AGW).



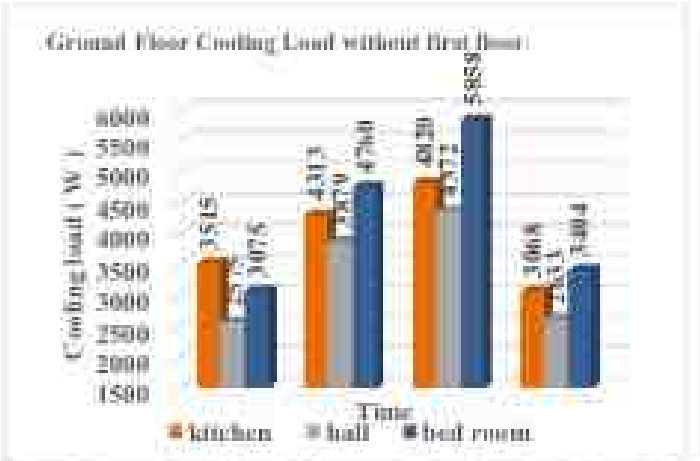


Fig 12 Comparison of Ground floor cooling load with and without First floor

From figure 12 it is observed that, Cooling load was reduced by 53% after providing first floor to the building (9"BW+RCr+AGW).

IV. CONCLUSION

[1] Without providing the first floor to the building, the contribution in transferring heat from the slab is 53% and from the walls and windows is 47%.

[2] Cavity AAC walls require 62% less cooling load as compared to brick material walls because they have an air-filled cavity that acts as an insulator, and AAC blocks have good thermal resistance and low density.

[3] Partially glazed windows with chajja require 13% less cooling load than any other window material because they are composed of wood, which prevents reflection by radiation.

[4] Buildings with chajja require 9% less cooling load than conventional structures because they act as a protection against solar radiation.

[5] The brick vault roof requires 17% less cooling load as compared to the RCC slab.

[6] A building with a shade net requires 16% less cooling load as compared to a conventional building due to its material properties as well as acting as an insulator.

[7] From all the 21 combinations conducted in this project, Cavity AAC wall, RCC roof, and floor slab, aluminium glazed window with chajja is the most effective combination.

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Emerging techniques of Project Management: Case study of Indian Real Estate sector

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***Abstract* - In various industries, successful project execution hinges on effective project management, which must continually evolve to meet the complexities of modern projects. This research conducts a thorough comparative analysis of emerging techniques within project management methodologies. Initially, it explores the landscape of project management methodologies, scrutinizing both traditional and their evolution over time. The study then categorizes emerging techniques and examines the KPIs influencing their adoption in contemporary project management. Utilizing a multi-dimensional framework, the comparative analysis evaluates emerging techniques across various perspectives. This framework integrates quantitative and qualitative data from case studies, surveys, and interviews with project managers and stakeholders who have implemented these emerging techniques. The study reveals the strengths and weaknesses of each technique, enabling informed decisions by project managers and organizations. Additionally, it underscores contextual factors influencing technique selection in specific project scenarios. In conclusion, the study contributes a structured analysis of emerging techniques within established methodologies, providing insights to aid practitioners in selecting the most suitable approach. As project management adapts to evolving demands and technologies, this research lays a foundation for future developments, stressing the importance of staying abreast of emerging best practices.**

Keywords - Project Management Techniques, Comparative Analysis, Project Management, Emerging Techniques, Methodologies

I. INTRODUCTION

Within the global development landscape, the construction industry assumes a pivotal role, heavily dependent on effective project management to ensure the successful execution of projects within budgetary constraints and with high-quality outcomes. Traditional methodologies such as Waterfall and Agile offer structured approaches well-suited for well-defined, linear projects. However, the dynamic and evolving business landscape necessitates adaptability and responsiveness, leading to the adoption of Agile methodologies (Scrum, Kanban), which emphasize collaboration and iterative development. Additionally, Lean and Six Sigma principles are employed to enhance efficiency and quality, while Integrated Project Delivery (IPD) promotes early stakeholder involvement, fostering improved communication and project outcomes. This research aims to conduct a comparative analysis of these methodologies, assessing their benefits and limitations, the impact of IPD, and identifying key success factors and challenges. Through a mixed-methods approach, the goal is to provide practical recommendations for construction professionals to enhance project outcomes in this Real Estate industry.

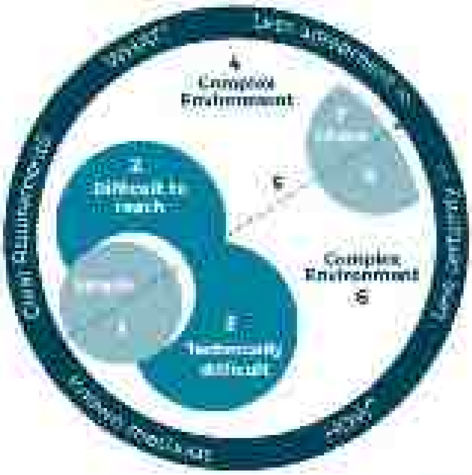

Fig. 1. Project management in a complex environment (https://www.e-zigurat.com/innovation-school/blog/2022/01/06/agile-construction-2022/#6.htm)

In essence, the construction industry heavily relies on effective project management methodologies. While traditional approaches offer structure, they may lack the adaptability required in the evolving landscape. Agile methodologies prioritize collaboration and responsiveness, and Lean and Six Sigma focus on efficiency and quality improvement. Integrated Project Delivery enhances collaboration through early stakeholder involvement. This research undertakes a detailed comparison of these methodologies, aiming to offer practical recommendations for construction professionals to elevate project outcomes in this crucial industry.

II. AIM AND OBJECTIVE

A. Aim

The primary objective of this research is to delve into the effectiveness of emerging project management techniques within the construction industry, focusing specifically on real estate projects. Through a comprehensive comparative

analysis, this study aims to explore the practical application and impact of innovative project management approaches, including but not limited to Agile Project Management, Lean philosophy, Waterfall Methodologies, and Kanban, in contrast to traditional methodologies. The research seeks to offer valuable insights into the efficacy of these emerging techniques, providing construction practitioners with the information needed to make informed decisions for optimizing project management processes and achieving superior project outcomes.

B. Objective

- To Identify Emerging PMTs over Traditional PMTs by assessing their applicability.
- Analyse Performance Metrics of various KPIs.
- Evaluate Risk Management Strategies considering Stakeholder's feedback.

C. Agile Management

Agility in management is the proactive response to a dynamic environment. Organizational agility enables adaptability without coercion. Agile Project Management (APM) achieves customer value through flexible planning, rapid feedback, continuous improvement, and team collaboration. The agile manifesto prioritizes individuals, customer collaboration, and responsiveness over processes, documentation, contracts, and rigid plans.

Fig. 2. Transformation of development & service lifecycle from Traditional to Agile PM ([illegible])

D. BIM

Building Information Modelling (BIM) is a digital approach to design, construct, and manage buildings and infrastructure efficiently. BIM creates a comprehensive 3D model that integrates data about project components, fostering collaboration among stakeholders. In construction project management, BIM is pivotal for enhancing collaboration, reducing errors, and facilitating real-time access to accurate project data. Its significance lies in improving decision-making, boosting project efficiency, minimizing risks, and ultimately realizing cost savings, improved quality, and streamlined construction processes.

E. Integrated Project Delivery

Integrated Project Delivery (IPD) is a collaborative approach that harmonizes people, systems, and business structures to optimize project outcomes, enhance owner value, and minimize waste throughout design, fabrication, and construction. Emphasizing stakeholder integration, IPD reduces errors and duplication, fostering cooperation between design and construction teams. In today's construction landscape marked by inefficiencies, IPD offers a strategic solution, aligning objectives to mitigate dissatisfaction.

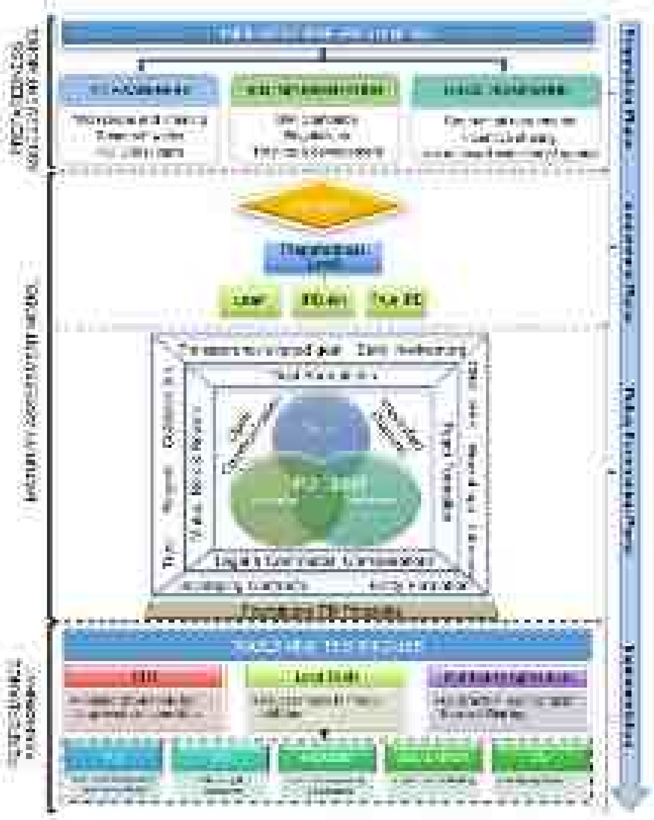

Fig. 3. Proposed framework to adopt IPD framework in India (PDF) Integrated Project Delivery Adoption Framework for Construction Projects in India (researchgate.net)

F. Waterfall methodology

Waterfall methodology in construction projects follows a linear, sequential process, requiring the completion of each phase before the next. Phases include initiation, planning, design, construction, testing, and maintenance, offering clarity, structured milestones, and reduced flexibility for changes. Its significance lies in clear roadmaps, effective risk management, client satisfaction with predictability, and suitability for large, well-defined projects where alterations are costly and time-consuming.

Fig. 4. Construction Project based on Waterfall Methodology (https://journal.[illegible])

G. Kanban

Kanban, inspired by Japanese manufacturing principles, is a project management methodology designed for efficiency and productivity through visualized workflows and continuous improvement. It employs visual boards and cards to represent tasks, emphasizing limiting work in progress (WIP) for increased throughput and adaptability. Promoting transparency, Kanban offers real-time work status, identifies bottlenecks, and supports prompt decision-making. Its incremental approach and customer satisfaction focus make it versatile across industries, fostering collaboration and continuous delivery.

Fig. 5. Kanban Process ([illegible])

H. Lean Methodology

Lean construction, a project management approach, strives for maximum efficiency and minimal waste in the construction process. Emphasizing collaboration and continuous improvement, it targets non-value-adding activities. Lean construction reduces costs, boosts productivity, and improves timelines through value stream mapping, pull scheduling, and lean principles like just-in-time delivery. Enhancing communication among stakeholders ensures higher-quality outcomes. Application of Lean principles streamlines operations, minimizes resource wastage, and enhances the effective and profitable delivery of construction projects.

Fig. 6. Core aspect of Lean Construction ([illegible])

I. Six Sigma:

Six Sigma is a data-driven methodology for process improvement, focused on minimizing defects and variations in outputs. In construction project management, it enhances efficiency, reduces errors, and ensures high-quality outcomes. Using statistical tools and rigorous problem-solving, Six Sigma aids in early issue identification, resulting in cost savings, improved timelines, and heightened client satisfaction. Fostering a culture of continuous improvement enables construction teams to consistently deliver projects with precision, meeting or exceeding industry standards.

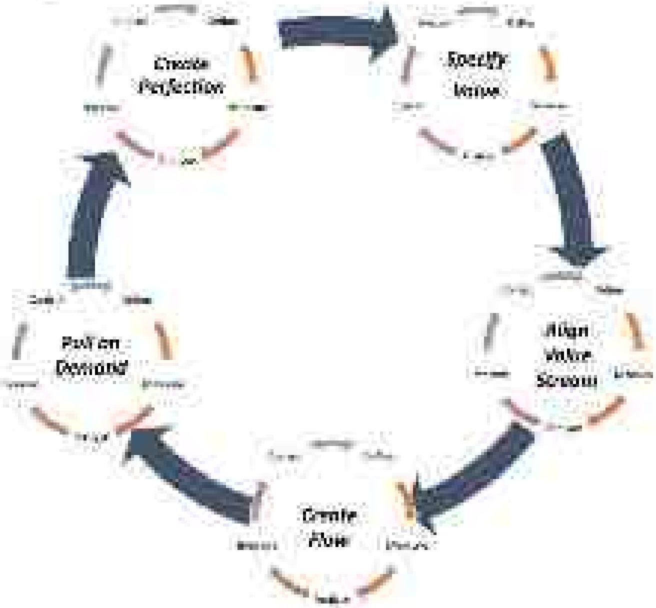

Fig. 7. The Generic Lean Six Sigma Framework ([illegible])

III. Scope of Project Work

This case study delves into project management methodologies in the construction industry, focusing on Real estate projects. It employs a comparative analysis of established and emerging methodologies, evaluating practical applicability and impact. The study aims to provide valuable insights for construction professionals, optimizing project management processes, and achieving superior outcomes, emphasizing adaptability, efficiency, and quality through a mixed-methods approach.

Conducting a survey across diverse real estate projects in Pune, Guwahati, Bangalore, Chandigarh, and Surat, we engaged with project managers at various sites. Inquiring about the implementation of methodologies such as Agile, Kanban, Six Sigma, Lean, Waterfall, and Integrated Project Delivery (IPD), we sought insights into their adoption and effectiveness in enhancing project management practices. Also, different stakeholders' feedback was considered.

IV. Methodology

The study explores the choice between quantitative and qualitative approaches, opting for a qualitative method for its ability to provide a deeper understanding within the social and institutional context. The research unfolds in several stages, starting with an examination of the significance of available Project Management methods, followed by a review of existing literature and analysis of traditional techniques. Data collection involves both quantitative surveys and qualitative interviews, utilizing a mixed-methods approach for statistical significance. The gathered data undergoes thorough statistical, content, and thematic analysis, leading to hypothesis evaluation. Stakeholder feedback is considered to justify

necessary changes and address limitations. The study concludes by validating research acceptability and outlining future prospects.

Fig. 4 Methodology adopted for the case study

V. Analysis and Interpretation

Here are the parameters based on a literature review of different methodologies:

A. Compilation of all Parameters of different Methodologies

After studying all the methodologies, we have categorized the important parameters of the particular methodology into the following tables:

TABLE I. PARAMETERS IDENTIFIED BASED ON LITERATURE REVIEW OF AGILE, SIX SIGMA, AND LEAN METHODOLOGY

Agile [1][2]	Six Sigma [3-5]	Lean [5-9]
Collaboration	Improve Quality	Improve Response time
Goal settings	Just-in-time	Evaluate Effectiveness
Continuous Improvement	Eliminating losses	Enhance the ability
Adaptability to change	Overhead expenditure	Reduce Turn-around
Transparency	Improvement measures	Improve cash flow
Root cause analysis	Project accomplishment	Degree of multiskilling
Financial reviews	Cost savings	Improving Response time
Profitability	Expenditure measurement	Management model
Higher quality	Improved cash flow	
Risk management	Improve Project Performance	
Prioritizing work	Reduce Defects	
Reduction of critical tasks	Reduce process variability	
Effective Communication		
Flexibility		

TABLE II. PARAMETERS IDENTIFIED BASED ON A LITERATURE REVIEW OF IPD, KANBAN, AND WATERFALL

IPD [7-11]	Kanban [9,10]	Waterfall [9,10]
Enhance decision making	Decision support system	Low variability
Cost efficiency	Improving response time	Structured priorities
Coordination	Developing compatibility	Clear specification
Improved Project Performance	Reduction of project waste	Effective communication
Risk Management	Effective communication	Collaboration
Collaboration	Improve productivity	Emphasis on Documentation
Effective Communication	Improve quality	Quality assurance
Shared Risk	Turnover rates of capital	Comprehensive planning
Reduce Waste		Clear targets
Reduce Liability		Stability & long-term mutual

Further, the parameters identified are classified into pre-construction, construction, and post-construction phases as per their usage and relevance:

B. Performance index for the Pre-Construction Phase:

TABLE III. PERFORMANCE INDEX FOR PRE-CONSTRUCTION PHASE

Methodology	KPIs	
	Risk management	*Collaboration*
Agile Methodology	✓	✓
Six Sigma Methodology	✓	
Lean Methodology	✓	✓
IPD Methodology	✓	✓
Kanban Methodology		
Waterfall Methodology		✓

C. Performance index for Construction Phase:

TABLE IV. PERFORMANCE INDEX FOR CONSTRUCTION PHASE

Methodology	KPIs	
	Reduce waste	*Improve Quality*
Agile Methodology	✓	✓
Six Sigma Methodology	✓	✓
Lean Methodology	✓	✓
IPD Methodology	✓	
Kanban Methodology	✓	✓
Waterfall Methodology		✓

D. Performance index for the Post-Construction Phase:

TABLE V. PERFORMANCE INDEX FOR POST-CONSTRUCTION PHASE

Methodology	KPIs	
	Decision Support System	Financial Review
Agile Methodology		✓
Six Sigma Methodology		
Lean Methodology		
IPD Methodology	✓	✓
Kanban Methodology	✓	
Waterfall Methodology		

E. Ranking Matrix for Agile Methodology:

Based on extensive literature examination, research paper analysis, and input from stakeholders, it is evident that the agile methodology excels in communication, fosters high collaboration, minimizes risks, and consistently delivers exceptional quality. This approach achieves efficiency by reducing waste and emphasizing continuous improvement. Consequently, our evaluation places Agile at a commendable 95.24% on a 7-point scale, reflecting its effectiveness and proficiency in project management.

TABLE VI. RANKING MATRIX FOR AGILE METHODOLOGY

Methodology	Agile Methodology								
KPIs	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***Weightage***	***Percentage***
Communication	Ineffective	Poor	Fair	Average	Good	Very Good	Excellent ✓	7	100.00
Collaboration	Isolation	Limited Interaction	Basic Cooperation	Moderate Collaboration	Effective Collaboration	Highly Collaborative ✓	Exceptional Collaboration	6	85.71
Risk Management	Critical Risk	High Risk	Moderate Risk		Low Risk		Negligible Risk ✓	7	100.00
Improved Quality	Poor Quality	Below Average	Average	Above Average	High Quality	Outstanding Quality	Exceptional Quality ✓	7	100.00
Waste Production	Critical Waste Generation	Excessive Waste Generation	High Waste Generation	Average Waste Generation	Moderate Waste Generation	Low Waste Generation	Minimal Waste Generation ✓	7	100.00
Continuous Improvement	Ineffective	Limited	Basic	Developing	Effective	Advanced ✓	Exemplary	6	85.71
							Total	**40**	**95.24**

F. Ranking Matrix for Six Sigma Methodology:

Based on the literature examined and the research papers analysed, the Six Sigma methodology demonstrates a moderate level of communication and collaboration, accompanied by minimal risk and a commendable focus on delivering high quality. It achieves this by minimizing waste and fostering continuous improvement opportunities. Using a 7-point scale and converting it to a percentage, we have assigned Six Sigma an efficiency rating of 83.33%.

TABLE VII. RANKING MATRIX FOR SIX SIGMA METHODOLOGY

Methodology	Six Sigma Methodology								
KPIs	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***Weightage***	***Percentage***
Communication	Ineffective	Poor	Fair	Average ✓	Good	Very Good	Excellent	4	57.14
Collaboration	Isolation	Limited Interaction	Basic Cooperation	Moderate Collaboration ✓	Effective Collaboration	Highly Collaborative	Exceptional Collaboration	4	57.14
Risk Management	Critical Risk	High Risk	Moderate Risk		Low Risk		Negligible Risk ✓	7	100.00
Improved Quality	Poor Quality	Below Average	Average	Above Average	High Quality	Outstanding Quality	Exceptional Quality ✓	7	100.00
Waste Production	Critical Waste Generation	Excessive Waste Generation	High Waste Generation	Average Waste Generation	Moderate Waste Generation	Low Waste Generation ✓	Minimal Waste Generation	6	85.71
Continuous Improvement	Ineffective	Limited	Basic	Developing	Effective	Advanced	Exemplary ✓	7	100.00
							Total	**35**	**83.33**

G. Ranking Matrix for Lean Methodology:

Based on an analysis of literature and research papers, the Lean methodology stands out for its effective communication, remarkable collaboration, and a propensity for delivering high-quality outcomes with minimal risk. This approach achieves efficiency by curbing waste and fostering a continual improvement mindset. Consequently, we have assessed Lean on a 7-point scale, converting it to a percentage, revealing an efficiency rating of 95.24%.

TABLE VIII. RANKING MATRIX FOR LEAN METHODOLOGY

Methodology	Lean Methodology								
KPIs	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*Weightage*	*Percentage*
Communication	Ineffective	Poor	Fair	Average	Good	Very Good	Excellent ✓	7	100.00
Collaboration	Isolation	Limited Interaction	Basic Cooperation	Moderate Collaboration	Effective Collaboration	Highly Collaborative	Exceptional Collaboration ✓	7	100.00
Risk Management	Critical Risk	High Risk	Moderate Risk		Low Risk		Negligible Risk	6	85.71
					✓				
Improved Quality	Poor Quality	Below Average	Average	Above Average	High Quality	Outstanding Quality	Exceptional Quality ✓	7	100.00
Waste Production	Critical Waste Generation	Excessive Waste Generation	High Waste Generation	Average Waste Generation	Moderate Waste Generation	Low Waste Generation	Minimal Waste Generation ✓	7	100.00
Continuous Improvement	Ineffective	Limited	Basic	Developing	Effective	Advanced ✓	Exemplary	6	85.71
							Total	**40**	**95.24**

H. Ranking Matrix for IPD Methodology:

Based on an examination of literature and research papers, the Integrated Project Delivery (IPD) approach proves to be highly efficient in communication, boasting outstanding collaboration with minimal risk and consistently delivering above-average quality. Its effectiveness lies in reducing waste and fostering continuous improvement. Evaluating this on a 7-point scale, we find that IPD scores an impressive 85.71% efficiency. This methodology not only excels in its collaborative nature but also demonstrates a commitment to minimizing risks and enhancing overall project quality by implementing practices that reduce waste and encourage ongoing improvement.

TABLE IX. RANKING MATRIX FOR IPD METHODOLOGY

Methodology	IPD Methodology								
KPIs	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*Weightage*	*Percentage*
Communication	Ineffective	Poor	Fair	Average	Good	Very Good ✓	Excellent	6	85.71
Collaboration	Isolation	Limited Interaction	Basic Cooperation	Moderate Collaboration	Effective Collaboration	Highly Collaborative	Exceptional Collaboration ✓	7	100.00
Risk Management	Critical Risk	High Risk	Moderate Risk		Low Risk		Negligible Risk ✓	7	100.00
Improved Quality	Poor Quality	Below Average	Average	Above Average ✓	High Quality	Outstanding Quality	Exceptional Quality	4	57.14
Waste Production	Critical Waste Generation	Excessive Waste Generation	High Waste Generation	Average Waste Generation	Moderate Waste Generation	Low Waste Generation ✓	Minimal Waste Generation	6	85.71
Continuous Improvement	Ineffective	Limited	Basic	Developing	Effective	Advanced ✓	Exemplary	6	85.71
							Total	**36**	**85.71**

I. Ranking Matrix for Kanban Methodology:

According to the literature and research papers examined, the Kanban methodology demonstrates commendable communication, moderate collaboration, and a low-risk approach, yielding above-average quality by minimizing waste. Consequently, we have assigned a rating of 7 on a scale and translated it into a percentage, reflecting an efficiency of 73.81%.

TABLE X. RANKING MATRIX FOR KANBAN METHODOLOGY

Methodology	Kanban Methodology								
KPIs	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*Weightage*	*Percentage*
Communication	Ineffective	Poor	Fair	Average	Good	Very Good	Excellent	7	100.00
							✓		
Collaboration	Isolation	Limited Interaction	Basic Cooperation	Moderate Collaboration	Effective Collaboration	Highly Collaborative	Exceptional Collaboration	4	57.14
				✓					
Risk Management	Critical Risk	High Risk	Moderate Risk		Low Risk		Negligible Risk	4	57.14
				✓					
Improved Quality	Poor Quality	Below Average	Average	Above Average	High Quality	Outstanding Quality	Exceptional Quality	4	57.14
						✓			
Waste Production	Critical Waste Generation	Excessive Waste Generation	High Waste Generation	Average Waste Generation	Moderate Waste Generation	Low Waste Generation	Minimal Waste Generation	4	57.14
						✓			
Continuous Improvement	Ineffective	Limited	Basic	Developing	Effective	Advanced	Exemplary	4	57.14
				✓					
						Total		31	73.81

J. Ranking Matrix for Waterfall Methodology:

Based on the literature and research papers examined, the Waterfall methodology excels in communication, displaying a high level of collaboration with moderate risk and consistently delivering exceptional quality. It achieves this by minimizing waste and fostering continuous improvement. Our evaluation on a 7-point scale translates to an efficiency rating of 71.43%. This underscores Waterfall's effectiveness in project management, highlighting its ability to communicate effectively, collaborate well, manage risk moderately, and consistently produce high-quality outcomes while minimizing resource wastage and promoting ongoing enhancements.

TABLE XI. RANKING MATRIX FOR WATERFALL METHODOLOGY

Methodology	Waterfall Methodology								
KPIs	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*Weightage*	*Percentage*
Communication	Ineffective	Poor	Fair	Average	Good	Very Good	Excellent	7	100.00
							✓		
Collaboration	Isolation	Limited Interaction	Basic Cooperation	Moderate Collaboration	Effective Collaboration	Highly Collaborative	Exceptional Collaboration	6	85.71
						✓			
Risk Management	Critical Risk	High Risk	Moderate Risk		Low Risk		Negligible Risk	3	42.86
			✓						
Improved Quality	Poor Quality	Below Average	Average	Above Average	High Quality	Outstanding Quality	Exceptional Quality	6	85.71
						✓			
Waste Production	Critical Waste Generation	Excessive Waste Generation	High Waste Generation	Average Waste Generation	Moderate Waste Generation	Low Waste Generation	Minimal Waste Generation	4	57.14
				✓					
Continuous Improvement	Ineffective	Limited	Basic	Developing	Effective	Advanced	Exemplary	4	57.14
				✓					
						Total		30	71.43

Based on all the matrices, finally we came on the conclusion that what are the emerging project management techniques that should have more weighted should be further review and analysed. Based on the formula mentioned below,

$$\%weightage \times \frac{weightage\ of\ individual\ KPI}{Maximum\ scale\ point\ (7)} \quad (1)$$

CONCLUSION

The study of "Emerging techniques of Project Management: Case study of Indian Real Estate Sector" the following conclusions we drafted through analysis and stakeholder feedback and experience. Agile has been observed to be the most effective methodology in project management techniques across all construction phases. A combination of different methodologies can be implemented during different phases of the project as per their effective weighted ratings. The efficiency of any individual methodology is closer to 100% but not entirely 100% therefore it is wiser to combinedly use them during the project life cycle. Implementation of these methodologies helps in the overall success of the real estate project.

TABLE XII. CONCLUSION MATRIX *(Based on equation- 1)*

Methodology	KPIs						
	Effective Communication	Improve Quality	Reduce waste	Risk management	Collaboration	Continuous Improvement	Total score
%weighted	30	22	18	12	12	6	100
Agile Methodology	7	7	7	7	6	6	97
Six Sigma Methodology	4	7	6	7	4	7	78
Lean Methodology	7	7	7	6	7	6	97
IPD Methodology	6	4	6	7	7	6	83
Kanban Methodology	7	6	6	4	4	4	81
Waterfall Methodology	7	6	4	3	6	4	78

RECOMMENDATION

Research across various methodologies, including Agile, Kanban, Six Sigma, Lean, Waterfall, and Integrated Project Delivery (IPD), reveals notable gaps. In Agile, there is a need for deeper exploration beyond the design phase and a focus on qualitative methods. Kanban lacks a thorough analysis of its optimization potential in construction and the impact of digital tools. Six Sigma requires more scrutiny of critical success factors and long-term sustainability in construction. Lean does not address challenges in developing countries or potential barriers to infrastructure adoption. Waterfall lacks specificity in construction adaptation and feedback cycles. IPD studies focus on barriers but lack a comprehensive overview. Closing these gaps is crucial for advancing construction project management methodologies.

We can assess this philosophy for other cities of India for better results. Also, this case study analysis is purely literature-based and questionnaire survey and academic professional's feedback.

ABBREVIATIONS

IPD	Integrated Project Delivery
KPI	Key Performance Indicator
BIM	Building Information Modelling
APM	Agile Project Management
WIP	Work in Progress
PMT	Project Management Techniques

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Low-Cost Ferro-cement Water Closet

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Abstract— Sanitation denotes a comprehensive concept, in fact, it is 'way of life', which is expressed in client home, community, institutions for better health and safe environment. Moreover, safe sanitary practice is a crucial indicator for qualifying improvement in standards of living. This concern is triggered by the fact that approximately 55 percent of the rural population still reported practicing open defection. Faucal borne diseases and worm infestations are the main cause of deaths and morbidity in a community where they go for indiscriminate defecation. Through this research, it is tried to improve the sanitation quality by constructing a low-cost toilet which will be affordable for poor people living in rural area having no toilet facilities. The sub-structure is constructed of ferro-cement and superstructure of bamboo sticks keeping rural area in view. The bamboo sticks are used as reinforcement. The results show that the structure is very cost effective, strong and durable.

Keywords— *water-closet, ferro-cement, rural development, affordable housing, precast*

Introduction

Sanitation and the provision of sanitation services or infrastructure is a major problem in India. As per available figures, less than 13% of the rural population in India have access to sanitary facilities. Most of the population still continue to make use of open spaces in the countryside. Unsanitary environments create havoc with infant mortality rates and can lead to widespread disease related to both fly and mosquito vectors [1]. Though possession of a flush toilet is considered satisfactory sanitation, water used in the flush system is generally potable water of which there is a general scarcity in the country. Municipal authorities have no facility for provision of low-grade water separately for such use [2]. In China, there has been a centuries-old tradition of using night-soil as manure directly in the fields. Sanitation systems adopted in India are of three kinds: urban-specific sewerage systems; individual septic tanks; and water-seal compost latrines, popularly called Sulabh Shauchalayas, popularised by Sulabh International.

The idea of this research is to construct a precast components of water closet, so it will be constructed in very less time. After casting of components of water closet by assembling these casted components one can assemble and erect water closet within few hours. The casting of these components will be in such a way that its weight is less as compared to the RCC members so it will be easy to handle by labour while assembling these components.

Using ferro-cement technology weight of the components will be reduced. Also, while designing the geometric shape and size can be planned in such a way that it can be handled by a single person. At the time of assembly, it will be so easy that an unskilled labour can also assemble these components without any difficulty. And also, the joints between two components will be strong and stiff due to use of non-shrink grout and also it will help in avoiding leakage problems. The septic tank of the water closet is planned below the superstructure, so it requires less area [3]. Because of less land requirement that's why it is usable in urban areas also. The advantage of this water closet is, it's uses in rural as well as urban areas.

To reduce cost of water closet Bamboo is used as a replacement of reinforcement. Due to use of Bamboo walls for the superstructure, it enhances the look. Also, Bamboo is available easily in local areas at reasonable cost. As a replacement of reinforcement small Bamboo strips can be used, so that the weight and the cost of the component will be reduced.

The ferro-cement technology has been used here due to its multiple benefits. The structural components casted using this technology will have high compression and tensile strength, less thickness of components, light weight and easy to handle during and after casting. The commode has been designed in such a way that the water-closet can be used for bath and washing clothes by folding the commode chair [4].

Selection of materials

i) Cement

The cement used was an Ordinary Portland Cement of grade 43 manufactured by Ultratech cement. The Ordinary Portland Cement (OPC) of 43 grade is used. The physical properties of the cement are as listed below in the Table 1.

Table 1: Physical Properties of OPC – 43 grade

Grade of cement	Fineness	Setting Time		Compressive Strength		
	(m^2/kg)	Initial (min)	Final (min)	3 day	7 day	28 day
43	225	30	600	23	33	43

ii) Fine Aggregate

Fine aggregate/ coarse sand consists of natural sand, crushed stone sand or crushed gravel stone dust. It should be hard, durable and chemically inert, clean and free from organic matter, not containing any appreciable amount of clay balls or pellets and other harmful impurities i.e. alkaline, salt, mica, decayed vegetation, lumps etc.[5]. It should be passed through I.S. Sieve 4.75 mm. It should have the finest modulus 2.50 to 3.50 and silt contents should not be more than 4%. Coarse sand should be either river sand or pit sand, or combination of the two.

iii) Coarse Aggregate

The aggregates whose size is more than 4.75 mm are coarse aggregates. The coarse aggregates are used for casting column blocks. The size of the aggregate was 10 mm. The shape of the aggregate was angular and was clean thoroughly before using them.

iv) Bamboo

Bamboo is used to replace reinforcement. It is used in substructure as well as superstructure. Bamboo is a very complex material and it gets affected by many parameters;

i) Because bamboo grains are aligned parallel in the axial (vertical) direction, bamboo is an anisometric material. This means the mechanical properties depend on the direction of the force; for instance, compression of the bamboo in the axial direction will result in a different compressive strength then compression in the radial direction.

ii) Dry bamboo has high mechanical properties than wet bamboo. Raw bamboo naturally has a high moisture content, where MC = 100*(wet weight-dry weight)/dry weight. This moisture content can be brought down by using various treatment methods (see "Bamboo Treatments").

iii) Small in length bamboo has stronger mechanical properties (such as ultimate compressive strength), however, long bamboo can withstand larger forces.

iv) Thicker walls have better mechanical properties.

v) As the distance to the node decreases, the mechanical properties improve.

vi) The strength of bamboo varies with its height. Generally, the part of the bamboo nearer the bottom has stronger properties [Refer Table 2.3.4].

vii) Very young bamboo and old bamboo have weaker mechanical properties than bamboo that is around the age of 3-7 years.

viii) Some species of the bamboo are not useful as a building material.

Following are the important properties of the bamboo for which it was adopted as an important material.

Table 2: Compressive strength of Bamboo

		Age of Bamboo stems (years)			
		2	3	4	5
Bottom	E (N/mm^2)	15500	16500	17400	15200
	σ (N/mm^2)	39.9	38.1	37.6	32.1
Middle	E (N/mm^2)	14900	18000	16800	16500
	σ (N/mm^2)	27.2	42.1	41.5	34.7
Top	E (N/mm^2)	20000	17000	17500	18200
	σ (N/mm^2)	20.4	42.6	42.1	39.0

Tensile strength:

Table 3 Tensile strength of various bamboo species

Species	σ (N/mm^2)	E (N/mm^2)	ρ (Kg/m^3)	MC (%)
Bambusa balcooa	164	–	820	8.5
Bambusa bambus	121	–	710	9.5
Bambusa nutans	208	–	890	8
Bambusa tulda	207	–	910	8.6

Shear Strength:

Table 4: Shear strength of Bamboo

		Age of Bamboo stems (Years)			
		2	3	4	5
Bottom	T(N/mm^2)	7.2	7.4	7.5	6.6
Middle	T(N/mm^2)	7.5	8.2	8.0	7.4
Top	T(N/mm^2)	7.2	8.1	7.6	8.0

v) Polypropylene

Polypropylene Corrugated sheets have a high strength to weight ratio due to its structure of construction, and also have good cushioning property due to presence of air between two layers [refer Fig. 1]. This high ratio makes these sheets cost effective. Polypropylene is an inert material; thus, these sheets have many inherent advantages. Sheets are weather proof, water proof, oil proof, acid and alkali proof, termite proof, chemical proof. PP copolymer also has live hinge property; thus, sheets find a wide indoor and outdoor application for signage, packaging, protection, construction, POS display stands, agriculture, and various engineering

applications [6]. These sheets are 100% recyclable thus environmentally friendly.

Corrugated plastic sheets are available in wide variety of colours and can be readily used for printing, making it suitable for Signage. It can be printed by several methods like screen printing, flex printing, digital printing on flat bed. They are easily fixed using a wide variety of methods - its light weight being an important factor. Corrugated plastic sheets are best suited for Packaging as it is reusable, versatile, flexible and impact resistant.

It is very easy to fabricate and can be handled on all paper corrugated box converting machines. Shipping glass bottles or jars has always been risky as breakage does occur due to vibrations and collisions during transit. Polypropylene Corrugated sheets are an ideal for returnable packaging. Corrugated Plastic Sheets can prevent your products from damages. It can be stapled, stitched, and ultrasonic welded and heat welded. It can be cut to any shape on platen punching, flat roller punching, and rotary punching or even by a hobby knife.

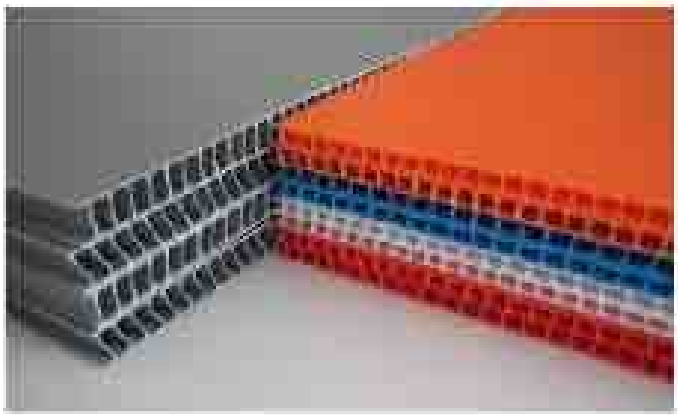

Fig.1 Polypropylene sheets

vi) Wire mesh

The ideal mesh is a 13 x 13 mm x 19 gauge (1 mm) welded mesh to BS 4482. Although meshes of 18-22 gauge can be used, 19 gauge will prove to be the best from a practical point of view. In colder, less humid climates, it may be used ungalvanized; in semi-tropical/tropical it will need to be galvanised. A specification for welded mesh: Initially rod used in the manufacture of welded wire mesh is a low carbon content (0.15% max by weight) rimming steel with the carbon concentrated in the centre.

The rod used in the manufacture of the wire mesh is hard-drawn from 'X' size down to 19 gauge (1 mm), hot rolled (perhaps copper washed) passed through stearate soap and then welded [8]. It is then passed through the galvanising process. (The rod has a very low silicon value)

Galvanised mesh which has been exposed to weather for some time prior to use may have less effect on the structure. Other mesh types which may be used are hexagonal mesh and, to a lesser extent, woven square mesh. Classification societies may need evidence of how the alternate meshes are used, in what direction they lay, and the combination of meshes that can or may be used. Using expanded mesh in certain forms of construction may also be acceptable but is rarely employed other than in a construction using moulds.

ANALYSIS & DESIGN

Design:

The design of toilet is done for five users. Following design procedure has been adopted for arriving a suitable section for the toilet.

Rectangular shape is selected for the septic tank [7]. It consists of ferro-cement panels and special designed concrete blocks. Septic tank is designed for 5 users.

4.1.1 Design of septic tank

Number of users: 5 nos. or 5 users

(a) Calculation of liquid volume in septic tank:

For normal detention period it is considered in designing purpose that a septic tank requires 0.085 m^3 of space for waste of each person per day. Future provision as 25% of actual volume.

Thus, volume of liquid at m^3 per capita per day

$= 5 \times 0.085 = 0.425\ m^3$

Future provision 25% extra

$0.425 X\ 1.25 = 0.53\ m^3$

(b) Calculation of internal dimension:

Now considering a liquid depth = 1.20m.

$$\text{Area of liquid} = \frac{0.53}{1.20} = 0.636 \text{ sqm}$$

$L = 2B$

$0.636 = L \times B$

$0.636 = 2B \times B$

$2B^2 = 0.636$

$B = 0.56m$

$L = 2 \times B$

$= 2 \times 0.56 = 1.12m$

Or

$L \times B = 0.636$

$L \times 0.56 = 0.636$

$L = 1.13m$

Assume free board 100mm

Height = 1.20 + 0.100 = 1.3m.

Thus, dimensions of septic tank (Refer Fig. 2 & Table 5) are as follows:

Table 5: Dimensions of septic tank

LENGTH	BREADTH	HEIGHT
1.2m	1m	1.2m

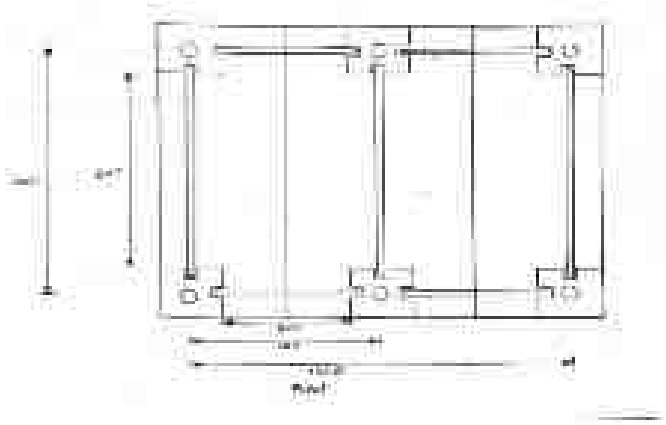

Fig.2 Plan of septic tank

Design of column block

Column blocks are precast components of septic tank which are designed to take the compressive loads which are coming from slab and superstructure. These column blocks are designed in such a way that the labours can easily handle, so the geometric dimensions of these blocks were kept optimum.
There are two types of precast column blocks.
-Two groove column blocks.
-Three groove column blocks.

These blocks are made up of M20 having mix proportion 1:2:4. In both type of column blocks a circular hole encased with PVC pipe is provided having diameter 70mm.The purpose behind providing this circular hole is to bind or to hold column block in vertical manner so that the loading will not be eccentric. To hold these column block bamboo is inserted in that hole from footing to roof. There are six columns and each column consists of 3 column blocks, each column block has height 300mm and plan area of 200 X 200mm [refer Fig. 3].

Two groove column blocks.
These column blocks are provided at the 4 corners of septic tank. It consists of two grooves having size 40 X 30mm

Three groove column blocks.
These column blocks are provided at mid of the septic tank in which baffle wall is inserted. The size of grooves are kept same as the previous type.

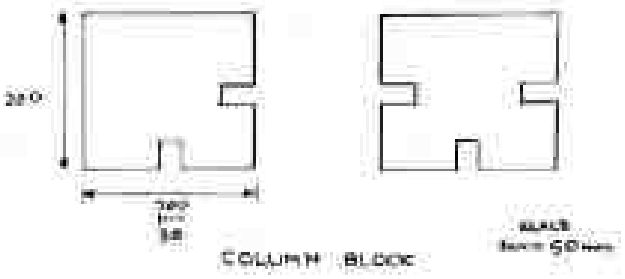

Fig. 3 Cross section of column blocks

Ferro-cement panels;
These panels are made up of ferro-cement having proportion 1:6 of cement mortar.
These panels are designed to stand up to the tensile force exerted by sewage stored in the septic tank. Panels are designed for various dimensions as per the requirement [9]
Additional panel placed between the intermediate transverse columns to act as the baffle wall. Standard thickness adopted for panels for 25 mm and hence light weight [see Fig. 4]
There are two types of panels sizes
1. 460mmx300mm
2. 860mmx300mm
Larger dimension panels are provided parallel to shorter side.
Smaller panels are placed perpendicular to the smaller sides.

Fig. 4 Casted panels

Slab:
Slab acts as the cover to the septic tank made up of cement mortar with bamboo as the reinforcement also with the layer of chicken mesh on both sides of reinforcement.
Slab acts as the flexural member with the thickness of 60 mm. Bamboo reinforcement is provided in two directions i.e. along shorter span and longer span [see Fig. 5].

Fig.5 Casted slab

Bamboo wall:

The superstructure is made up of bamboo basically for the aesthetic and design which has proved to be cost effective. Bamboos of vertical length of 2m divided into the uniform strips of required length arranged vertically to form the wall which are connected by horizontal wooden strips [see Fig. 6].

Fig. 6 Bamboo wall

Commode:

Designed as the foldable commode so the space is utilised properly for bathing, washing clothes, other purposes. The commode consists of foldable steel chair with an elliptical hole. A rubber material having smooth finish over it which is attached to the elliptical hole to form a trap. The current price of the Indian toilet seat is 2499Rs. In Mumbai Home town and R-city malls (material is ceramic). Eco-san toilet seat is 1200Rs which is currently using by the user in the rural areas (material = fiber glass) [see Fig. 7]

Fig. 7 Steel foldable chair used as commode

Execution and casting-mix proportion

Column block:

The grade of concrete used for casting of column block is M20 i.e. (1:2:4). The aggregate used for column block are clean and free from dust and any other impurities. Before pouring concrete in the formwork it has been applied with oil and grease, so that at the time of removal of formwork it will be easily removed without causing any damage to the surface and grooves of the concrete block. Optimum no of tamping is provided and care has taken at the time of tamping that there should be no displacement of grooving material which is provided in the formwork. The PVC pipe should be remained vertical throughout the process of casting. The thermocool or any other material which is used to form groove should not lose its adhesiveness while coming in contact of water, oil or any other concreting material [see Fig. 8 & 9]. At the time of removal of formwork care should be taken that the edges will be remain sharp and unbroken. Each concrete block has been kept for curing at least 28 days.

Fig. 8 Column block

Fig. 9 Column blocks kept in curing tank

Ferro-cement panel

Ferro-cement panels are made up of with a proportion of 1:3 Some panels are casted using crushed aggregate instead of river sand. Care has been taken while casting panels that the woven mesh has dispersed throughout the body of panel Also plastic has been covered to the formwork from inside for easy removal of panel. Each panel has placed for curing of 28 days [see Fig. 10].

Fig. 10 Cutting of mesh by cutter

Fig.11 Hand mixing adopted for preparation of mortar

Fig. 12 Placing of wire mesh in panel

Slab

Bamboo strips has been used instead steel reinforcement in the slab. Strips of bamboo has average diameter of 6mm. This bamboo reinforcement is provided in both ways. To form a mesh of bamboo reinforcement junctions are tied with steel wire to hold strips in proper manner. Also this mesh of bamboo reinforcement is covered with chicken mesh from both sides. The mix is made up of cement mortar having proportion 1:2. Before pouring mortar into formwork has covered with plastic form inside of formwork so that there will be no difficulty while removing formwork. This formwork has removed after minimum 24 hours of casting [see Fig. 11, 12, 13 & 14]. At the time of casting of slab depth has checked at different sections so that there will be uniform thickness of the slab throughout its length.

Fig.13 Mortaring of slab

Fig.14 Casted slab

Bamboo wall

A wooden frame is made as per required size of wall. This wooden frame has checked with diagonal checks so that no difficulty will arise. After formation of wooden frame the bamboo has cut along its longitudinal axis. It should be cut from centre so that it should form two equal size of half bamboo. These half bamboo are jointed to the frame with the help of nails. To reduce air gaps between two consecutive bamboo it should tight with jaw before nailing it [see Fig. 15]. There will be always air gaps between two bamboos so a polypropylene sheet is used to cover this air gap. This polypropylene sheet is covered to the wall panel from inside.

Fig. 15 Fixing polypropylene sheets

Making Formworks:

There are various types of moulds used for the casting of different precast members of the project [see Fig. 16].

Fig.16 Making moulds in carpentry shop

Grooves mould:
It is the having 3 groves used for placing the precast Ferro cement columns.
Three grooves basically for walling purpose on three different directions arranged to form the mould with the help of bolt and screw assembly [see Fig. 17].

Fig. 17 Groove formwork

It is having the 2 grooves purposely for corner columns. Three grooves basically for walling purpose on three different directions arranged to form the mould with the help of bolt and screw assembly as shown below [see Fig. 18].

Fig. 18 Assembling of column block formwork

Panels:
Since the panels were designed in keeping the slenderness factor.
The panels are thin precast members provided to act as the wall for the entire structure as part [see Fig. 19].

Fig.19 Panel formwork

Slab:

Probably the heaviest member of the project having thickness 60 mm Slab is provided to act as the platform over the septic tank for the commuters. Slab casted with the bamboo reinforcement provided in between the layers of chicken mesh 13X 13X 12X 12g [see Fig. 20 & 21]

Fig.20 Slab formwork

Fig.21 Opening of column block formwork

Problems during execution and their solutions.

During vibration of panel moulds on table vibration machine it was observed that the wire mesh used to come up on the surface of the mortar. It was then therefore not vibrated on table vibrator. Cracks were observed in slab the next day after casting. This was due to bamboo which was used in

place of steel reinforcement. Small slurry of cement past was made and was applied on the cracks. It was observed that bamboo started drying when it was cut into 2 parts longitudinally. Bamboos which are already dried should be used to avoid gaps which arise while making the wall of superstructure [see Fig. 22].

Fig.22 Honeycombing in concrete

Assembling the toilet:

Following is the standard procedure adopted for assembling the toilet:

Column blocks are placed such that 4 two grooves blocks are placed at the 4 corners respectively. Then 2 grooves blocks are placed in between the two 3 grooves blocks.

Panels of size 860x300mm are inserted in the grooves of column blocks along the length of septic tank. Panels of size 460x300mm are inserted in the grooves of column blocks along the width of septic tank and also in the mid to act as baffle wall. Bamboos are inserted into the hole which is left in column blocks. The holes are filled with cement mortar (1:3) and allowed to dry. Waterproofing of septic tank is done by using suitable liquid. Slab is placed over the column blocks. Wall panels are tied or fixed between the bamboos which are inserted in column block. Commode of steel is placed over the slab and the necessary plumbing is done. Roof is then fixed [see Fig. 23, 24, 25 & 26]. Doors and windows are installed. Polypropylene sheets are fixed on the inner side of bamboos.

Fig. 23 Septic tank assembly

Fig. 24 First testing of slab

Fig.25 First testing of assembling septic tank

Fig.26 Bamboo inserted in column blocks

Finishing:

All exposed surface to weathering is properly given protecting finish to make it resistant against external agencies.

Waterproofing of septic tank.

Internal finishing

Mix your waterproofing sealant thoroughly, following the product instructions and measuring proportions very carefully, if the product you're using requires mixing. Wet the inside surfaces with the spray bottle before applying waterproofing for cement-based applications. The entire surface must be damp for good adherence. Apply the waterproofing base coat at the recommended thickness. For cement-based waterproof coatings, the first coat should be at least 1/16-inch thick. Spray on the coating, filling all pores, then brush it into the surface with the Tampico brush, using horizontal strokes. Let the first coat dry for at least 24 hours – again, follow your product instructions – before applying a second or top coat at least 1/32-inch thick. Dampen the septic tank walls again, using the spray bottle, before spraying the second coat. Finish that coat with vertical brush strokes. Allow the coating to fully cure for at least five days.

Use Dr.Fixit Pidifin 2k, a component waterproof coating for septic tanks.The benefits are as follows;

A heavy-duty waterproof coating.
Life expectancy for 5 years.

External finishing:

Normal plastering is adopted for external surface of septic tank. Procedure adopted is as follows:

Cement plastering is commonly used as ideal coating for external and internal surface of wall. Cement plaster is usually applied in a single coat or double coat. Double coat plaster is applied where thickness of plaster is required to be more than 15 mm or when it is required to get a very fine finish. The process of applying a double coat cement plaster on wall surface consists of the following 5 steps.

Step-1-Preparation of surface for plastering
Step-2-Ground work for plaster
Step-3-Applying first coat (or under coat or rendering coat)
Step-4-Applying second coat (or finishing coat or fine coat)

STEP BY STEP GUIDE FOR CEMENT PLASTERING

step-1 (preparation of surface for plastering)
Keep all the mortar joints of wall rough, so as to give a good bonding to hold plaster. Clean all the joints and surfaces of the wall with a wire brush, there should be no oil or grease etc. left on wall surface. If the surface is smooth or the wall to be plastered is old one, then rake out the mortar joint to a depth of at least 12 mm to give a better bonding to the plaster. If the projection on the wall surface is more than 12 mm, then knock it off, so as to obtain a uniform surface of wall. This will reduce the consumption of plaster. If there exist any cavities or holes on the surface, then fill it in advance with appropriate material. Roughen the entire wall to be plastered. Wash the mortar joints and entire wall to be plastered, and keep it wet for at least 6 hours before applying cement plaster.

step-2 (ground work for plaster)
In order to get uniform thickness of plastering throughout the wall surface, first fix *dots* on the wall. A dot means patch of plaster of size 15 mm x 15 mm and having thickness of about 10 mm. Dots are fixed on the wall first horizontally and then vertically at a distance of about 2 meters covering the entire wall surface. Check the verticality of dots, one over the other, by means of plumb-bob. After fixing dots, the vertical strips of plaster, known as screeds, are formed in between the dots. These screeds serve as the gauges for maintaining even thickness of plastering being applied.

step-3 (applying first coat or under coat or rendering coat)
In case of brick masonry, the thickness of first coat plaster is in general12 mm and in case of concrete masonry this thickness varies from 9 to 15 mm. The ratio of cement and sand for first coat plaster varies from 1:3 to 1:6. Apply the first coat of plaster between the spaces formed by the screeds on the wall surface. This is done by means of trowel. Level the surface by means of flat wooden floats and wooden straight edges.

After levelling, left the first coat to set but not to dry and then roughen it with a scratching tool to form a key to the second coat of plaster.

step-4 (applying second coat or finishing coat or fine coat)
The thickness of second coat or finishing coat may vary between 2 to 3 mm.

The ratio of cement and sand for second coat plaster varies from 1:4 to 1:6.

Before applying the second coat, dump the first coat evenly. Apply the finishing coat with wooden floats to a true even surface and using a steel trowel, give it a finishing touch. As far as possible, the finishing coat should be applied starting from top towards bottom and completed in one operation to eliminate joining marks.

After completion of the plastering work, it is kept wet by sprinkling water for at least 7 days in order to develop strength and hardness.

Superstructure walls:
Walls which are made up of vertical bamboo joined together by horizontal wood strips are protected from inside by fixing sheets of polypropylene so as to protect the wall from water.

Costing and Estimation

Estimate of one ferro-cement water closet:

Estimate of toilet is carried out by determining the quantities of various components [refer Table 6].

Table 6 Costing and estimation

Description	Nos	Per		Total
Cement	4	330	Bag	1320
Sand	0.321	2500	M^3	802.5
Aggregate	0.225	900	M^3	202.5
Bamboo	16	130	Nos	2080
Polypropylene	4	150	Nos	600
Nails, Hinges	Lump Sum	84	-	84
Chair	1	700	Nos	700
Plastic Cloth	2	100	M^2	200
Trap	1	120	Nos	120
Air Vent Pipe	1	160	Nos	160
Outlet	1	50	Nos	50
PVC Pipe	7.2	50	M	360
Door	1	1000	Nos	1000
Labour	Lumpsum			3000
			TOTAL	Rs 10679/-

Comment:
The above cost is only for single toilet. On mass production of components of ferro-cement toilet the cost may get reduced to approximately Rs 5500/-

Merits and Demerits of Low cost ferro-cement water closet.

Merits:
(1) Materials which are used in constructing the members of the toilet are easily available in rural areas as well as in urban area
(2) Ferro-cement Low cost toilet water closet is cost efficient.
(3) Less labours are required for casting as well as assembling the components of the toilet.
(4) Steel is not at used which reduces the cost of material to large extent.
(5) Time required for assembling and fixing all the components is less.
(6) Mass production of components such as column block ferro-cement panels, slabs are possible which gives excellent quality if casted under good supervision
(7) Space taken by toilet is less so it does not require a large area for constructing.
(8) The closet designed in such that it can be folded and the space can be utilized for other purposes such as bathing, washing of clothes etc
(9) Less formwork are required to cast the components.
(10) Its is an eco-friendly project as bamboo in used in place of steel.
(11) Durability is more as ferro-cement is a strong material having excellent properties in compression, tension, water tightness, weather resistant etc.
(12) It is an excellent option for rural communities, buildings, parks and motels.

Demerits:
(i) Requires supervision to maintain best quality of work.
(ii) Use of the toilet is limited to 5 persons only.
(iii) Difficult to convince people to use ferro-cement technology.
(iv) Requires more responsibility and regular maintenance.

Conclusions and Future Scope

Conclusions:

i. Ferro-cement low cost water closet can be constructed using ferro-cement technology.
ii. Precast components of the toilet can be easily casted using simple method of construction.
iii. Components are less heavy than other toilets which are made up of RCC and brick masonry.
iv. Ferro-cement low cost water closet is cost effective than other toilets which are in use in rural area.
v. Ferro-cement low cost water closet is a multipurpose toilet in which commode can be folded so as to utilize the place for bathroom.
vi. Ferro-cement has proved its quality through its strength in tension and flexure.
vii. Easy assembling of members without any special equipment.
viii. Ferro-cement itself is watertight
ix. Affordable to poor people who do not have adequate sanitation facility.

(10) Mass production on large scale can reduce the cost of toilet to Rs 5500/-

Future scope:
Based on the study and experience from the project following are the future scopes of ferro-cement low cost toilet:

(1) Nowadays RCC is getting replaced by other advance and cost-effective material such as ferro-cement, so lot of scope is there in constructing low cost toilets in ferro-cement.
(2) Space requirement is often a debate. Ferro-cement low cost water closet is rightly suitable in future to compensate against space.
(3) It can be developed in future through Government schemes for rural area.
(4) In India, Ferro-cement is used often because the constructions made from it are more resistant to earthquakes. It has a wide range of other uses including sculpture and prefabricated building components.

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Air Quality Index for the selected locations of Ichalkaranji city, Maharashtra

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***Abstract*— "In areas with high population exposure, urban air quality is a serious concern." This study reveals the condition of the city of Ichalkaranji's ambient air quality. Three sampling points—one in a residential area, one in an industrial area, and one in a commercial area—were thoughtfully selected to emphasize an overview of the region's overall air quality and also the AQI. Ichalkaranji, an industrial city, is best known for its production of textile products. Assessments of four air pollutants—suspended particulate matter (SPM), CO, NO2, and SO2 were used to determine the air quality index. The analysis of the city of Ichalkaranji's air quality over a period of six months discloses rising trends in air pollution. Annually, the average SPM concentration among all locations has progressed over the NAAQS-suggested limit. Apart from this, the levels of SO2 and NO2 are generally within the permitted range. According to the study, industrial sites obviously recorded higher concentrations compared to other sites. June was found to be more critical, with higher concentrations for all parameters. AQI was found to be less than 50 for all the locations except the industrial site. AQI was calculated based on SPM, CO, NO2, and SO2. SPM concentration was recorded in the range of 64 µg/m3 to 141 µg/m3, SO2 from 1.8 to 6.8 µg/m3, and NO2 from 3.9 to 10.2 µg/m3. Overall air quality was found to be 'good' under the present conditions.**

Keywords*— *Air Quality, Sub-indices, USEPA standards, AQI, Ambient air, NAAQS

I. INTRODUCTION *(HEADING 1)*

Both developed and developing countries face challenges from environmental pollution (Ghose et al., 2005). One of the significant issues that people around the world face is air pollution, especially in urban areas of developing nations where there is not only a rapid increase in population but also industrialization and an increase in the number of vehicles. (2004 Nagdane)

The ever-increasing production of goods and the burning of fossil fuels to generate the energy required to sustain industrial and domestic activities lead to significant toxic waste releases into the environment every year. In India, major air pollutants are sulfate dioxide, nitrogen dioxide, and suspended particulate matter (SPM) (Agarwal and Singh, 2000). Activities that contaminate the air are: 1) animal and human respiration; 2) organic matter decomposition; 3) coal, gas, and oil combustion; and 4) trade, traffic, and manufacturing processes that release dust, fumes, vapors, and gases. As large numbers of people are exposed to it and the harmful effects it has on human and environmental health, urban air pollution is a concern in today's world (Harman), levels of air pollution from vehicular emissions, including metals and fine and ultrafine particles (Nolte et al., 2002), (Sharma et al., 2006). Every city has distinctive characteristics that act as a draw for growth and development; if not controlled, this growth and development progress poses risks to the environment and the health of the public. The concern for ambient air quality in Ichalkaranji is generated by the city's unique industry, which is dedicated to producing textiles. Apart from this, other industries also contribute to the decline in air quality through infrastructure projects, substandard traffic management, uneven roads, and considerable amounts of automobile exhaust. It is extremely important that the public at large, especially individuals living in towns and cities, become aware of the effects of industrial pollution, vehicle pollution, and other forms of pollution on human health both now and in the future. The ambient air quality of Ichalkaranji city needs to be monitored in light of the aforementioned facts. For three consecutive months, the amount of SPM, SO_2, and NO_2 at three different activity areas of Ichalkaranji city was measured to assess the quality of the ambient air.

The current study's goals are to evaluate the ambient air quality in terms of SPM, SO_2, and NO_2; to examine trends in pollutants over time and space; and to raise public awareness of environmental pollution.

Ichalkaranji is a city in the state of Maharashtra, in the western part, as shown in Fig. 1. It is located between the cities of Kolhapur and Sangli, on coordinates 16° 42' N and 74° 27' E, with an area of around 48 sq. km and a population of 300,000 as per the 2011 census.

The city's unique textile industries, growing vehicular traffic within the city limits, and the dense traffic on the highway, which passes through the city in the middle, all contribute to the poor air quality in the area. These numerous interrelated factors release a large amount of air pollution into urban

environments, endangering both human health and the delicate ecosystem.

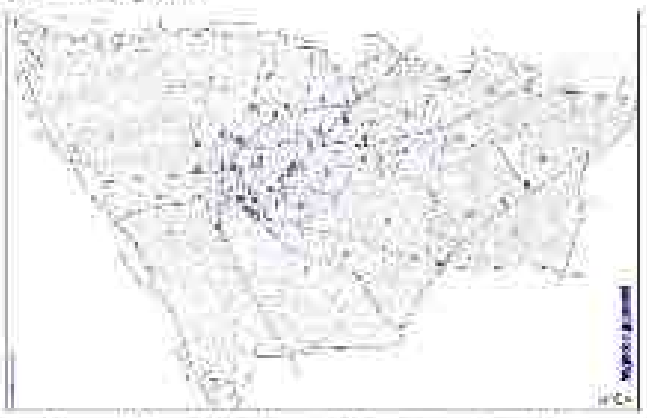

Figure 1 Map of Ichalkaranji Indicating Sampling Points

II. METHODOLOGY:

For the assessment of ambient air quality, the three stations, as indicated in Figure 1 that cover the entire municipal area of Ichalkaranji city were chosen. These stations were chosen based on their type of activity, such as residential, commercial, or industrial. The Environtec (New Delhi) Respirable Dust Sampler APM 460 is used to collect samples for SPM. These samplers are installed at a height of about 6 to 8 meters above the ground and mounted on the roofs of domestic buildings nearby. Samples were collected once a week. The 24-hour air samples were taken in three shifts of 8 hours each, which corresponded to daytime (8–16 h), evening (16–24 h), and night-time (24–8 h).

III. RESULTS

The manufacture of textiles is well known in the city of Ichalkaranji. There are approximately 100 small units and 5 large units operating continuously within the city. Unchecked population growth and the city of Ichalkaanji's shifting socioeconomic circumstances over the past few decades have led to an increase in the number of vehicles on the road. Particularly, personal vehicles have a negative impact on both human health and the quality of the surrounding air. As of today, there are 16,232 different categories of vehicles registered with the traffic department.

Three monitoring locations, as shown in Fig. 1, representing different activity areas, i.e., one in residential, one in commercial, and one in industrial, were selected for the study, as shown in Table 1.

TABLE – 1: MONITORING LOCATIONS FOR AMBIENT AIR QUALITY IN FIROZABAD CITY

SL.NO.	Locations	Activities
1	Saraswati Nagar	Residential
2	Shahajur	Commercial
3	Near Panchaganga Sugars	Industrial

Trends in Ichalkaranji City's Ambient Air Quality:

To determine the current trend of air pollution in Ichalkaranji city, the observed SPM, SO_2, and NO_2 for four months have been compared.

In comparison to the prior year, May and June recorded a slight increase in trend in the residential, commercial, and industrial areas. The industrial area, however, experienced the greatest value growth over the period. All of the values were below the maximum limit of the NAAQS.

A. SPM or fine particulate matter:

Lower values were observed across the period of four months. However, values in the commercial and industrial areas were recorded higher than those in the residential area during the study period. All of the values were found to be less than 140 $\mu g/m^3$ as per NAAQS.

B. Sulphur Dioxide (SO_2):

NAAQS (24-Hourly): SO_2 = 80 $\mu g/m^3$, NO_2 = 80 $\mu g/m^3$, PM10 = 100 $\mu g/m^3$, PM-2.5 = 60 $\mu g/m^3$ (residential, industrial, rural, and other areas) and (ecologically sensitive area). Adequate data (taken for calculation), annual: cities where ≥50 days of monitoring were done in a year; Inadequate data (taken for calculation): cities < 50 days of monitoring were done in a year;

TABLE 1: DATA FOR SELECTED REGIONS IN ICHALKARANJI (1 HOUR AVERAGE CONCENTRATION)

Activity areas	Location	March			April			May			June		
		SPM	SO_2	NO_x	SPM	SO_2	NO_x	SPM	SO_2	NO_x	SPM	SO_2	NO_x
Residential	Saraswati Nagar	84.6	3.8	3.9	91	2.3	4.2	84	2.8	4.6	89	3.1	5.2
Commercial	Shahapur	76.8	2.4	4.7	80	4.2	5.8	88	3.8	5.9	100	3.6	5.4
Industrial	Near Panchaganga Sugars	112.8	8.6	9.8	134	7.9	10.4	126	9.7	11.2	143	9.8	10.2

TABLE 2: USEPA STANDARDS FOR DIFFERENT AQIS

AQI	0 - 50	51 - 100	101 - 150	201 - 300	301 - 400	401 - 500
Levels of concern	Good	Moderate	Unhealthy for sensitive groups	Very unhealthy	Hazardous	Hazardous

A lower concentration was discovered in residential areas compared to the other areas. In comparison to previous months, commercial and industrial areas also displayed slightly higher concentrations. This could be due to the higher ambient temperature in the summer. As a result, SO_2 levels at each location demonstrated a slight increase over time with minimal fluctuations.

C. Oxides of Nitrogen (NO_2):

Comparing the data from the months of March and April to May and June, every location displayed an upward trend. The industrial site had the highest NO_2 concentrations, followed by the commercial district. All of the study's values are still under the maximum permitted value of NAAQS *(Fig. 6)*.

Spatial variation of ambient air quality status of Ichalkaranji during the study period:

The highest four months' average SO_2 concentration in industrial areas was recorded in June at 6.8 µg/m^3, and the lowest was recorded in March at 4.6 µg/m^3, as presented in Table 1. In terms of overall concentration, industrial areas in June (6.8 µg/m^3) and residential areas in March with 1.8 µg/m^3 had the highest and lowest SO_2 concentrations, respectively. These values are significantly below the permitted limit. In the residential area, the four months' average concentration was 2.5 µg/m^3. The average value in the commercial area was 3.35 µg/m^3, with the highest value of 3.9 µg/m^3 in June and the lower of 2.5 µg/m^3 in March. The average for four months' concentration recorded in industrial areas was 5.9 µg/m^3. When comparing the overall values, Panchaganga Sugar recorded the highest concentration of 6.8 µg/m^3 in June, and Saraswati Nagar had the lowest concentration of 1.8 µg/m^3 in March. The analysis of Table 5 reveals that NO_2 concentration recorded an increasing trend from March to June but is still below the NAAQS-permitted limit of 30 µg/m^3. June month recorded the highest SPM concentration in residential areas, while industrial areas recorded the highest concentration also in June at 141 µg/m^3 and the lowest in March with 112 µg/m^3. Commercial area recorded the highest SPM level of 106 µg/m^3 in June and the lowest recorded concentration of 76 µg/m^3 in March. The highest concentrations of air pollutants were recorded in industrial areas. Only SO_2 concentrations were recorded significantly below the limit, while SPM levels were consistently found to be at higher values, still below the recommended limit at all monitoring sites (Fig. 1,2,3). NO_2 concentrations also consistently showed an increasing trend, with lower values than the recommended limit.

Health effects:

All pollutants, including metals, have harmful effects on both human and environmental health when they are present in large quantities. One of the main ways that pollutants enter the human body is through air inhalation. The current study's findings indicated that present levels of particulate matter are well below the maximum limit at all the monitoring sites. However, citizens must be aware of the increasing trend in SPM, which may lead to a number of cardiovascular and respiratory diseases, including bronchitis, asthma, and problems with fetal development, if left unchecked. Increased mortality and morbidity rates, as well as a higher risk of preterm birth, may also be impacted by higher SPM levels. It has been reported that for every 10 µg/m^3 increase in SPM concentration, the overall daily mortality will increase by 1%. The mass, number, shape, size, composition, and concentration of other inorganic and organic pollutants that are present with it all affect the impact of SPM. The concentration of NO_2 in the current study was found to be well below the allowable limit of 30 µg/m^3, while the level of SO_2 was also recorded below the NAAQS' permissible limit of 20 µg/m^3 (MoEF 2009). Numerous studies show that even at low concentrations, gaseous pollutants have an impact on reproductive and developmental processes, as well as respiratory diseases. The risk of lung cancer is significantly increased by vehicular traffic and NO_2.

Air Quality Index (AQI):

An effort was made during the study to arrive at the Air Quality Index for the areas where sampling points were selected. AQI was calculated for SPM, SO2, and NO2. The US EPA method was followed in calculating the AQI.

Pollutant-specific sub-indices and levels of concern were referred to from the USEPA chart for the purpose of calculation. USEPA guidelines explain the AQI calculation in 3 steps, as below:

Step 1: Major pollutant concentrations are truncated as per the guidelines.

Step 2: Identifying the upper and lower concentrations for the truncated concentration of the pollutant from the USEPA chart.

Step 3: Pollutant Index calculation using the following equation:

Step 4: Round off the index to the nearest integer.

$$I_p = \frac{I_{Hi} - I_{Lo}}{BP_{Hi} - BP_{Lo}} \left(C_p - BP_{Lo}\right) + I_{Lo} \qquad \ldots\ldots (1)$$

where, $I_p = the\ index\ for\ pollutant\ p$

C_p: *truncated concentration of pollutant p*

BP_{Hi}: *concentration breakpoint that is greater than or equal to* C_p

BP_{Lo}: *concentration breakpoint that is less than or equal to* C_p

I_{Hi}: *AQI corresponding to* BP_{Hi}

I_{Lo}: *AQI corresponding to* BP_{Lo}

The basic objective of any air quality index is to transform the measured concentrations of individual air pollutants into a single numerical index using a suitable aggregation mechanism (1).

With the application of USEPA AQI for the selected regions, as shown in Table 1, the following results were recorded, as presented in Table 3. The breakpoint concentrations have been defined by the EPA on the basis of the National Ambient Air Quality Standards (NAAQS).

TABLE 3: AQI FOR THE SELECTED REGIONS

			March	April	May	June
Residential	Saraswati Nagar	SPM	56	59	66	73
		SO2	2.6	3.3	4.0	4.0
		NO2	3.9	4.2	4.6	4.5
		AQI	**56**	**59**	**66**	**73**
Commercial	Shahapur	SPM	62	68	73	77
		SO2	4	5	5	6

		NO2	8	6	6	6
		AQI	62	68	73	77
Industrial	Patchigar Nagar	SPM	80	91	87	94
		SO2	6.6	8	9	10
		NO2	9.8	11	12	11
		AQI	80	91	87	94

Table 3 presents the recorded AQI for the residential, commercial, and industrial zones based on the USEPA method of calculation. Results were observed during the critical months of the year, when higher concentrations of air pollutants were expected due to increased temperatures and low humidity. As per the guidelines of USEPA on pollutant-specific sub-indices and levels of concern, the AQI for SPM was found to be the highest among other pollutants in all the selected regions. As per the guidelines of USEPA, it falls under the "Moderate" level of concern, indicating the need for control measures to get the index to the 'Good' level of concern. The AQI indices for SO_2 and NO_2 were found to be in the range of 4 to 10 and 4 to 11, respectively, as shown in Table 3. Overall AQI for the selected regions was found to be 56, 59, 66, and 73 for the residential zone during March, April, May, and June 2023; 62, 68, 73, and 77 for the commercial area; and 80, 91, 87, and 94 for the industrial zone during the same period. Variations in different pollutants for residential, commercial, and industrial regions are presented in Fig. 1 to 3. AQI variation for these selected zones for the periods of March, April, May, and June is as shown in Fig. 4.

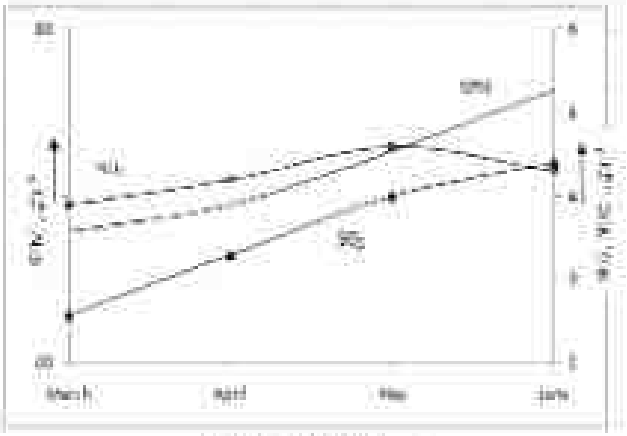

Fig.1: Residential Region

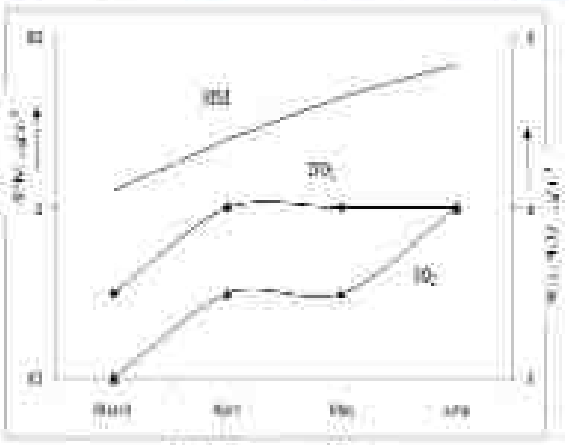

Fig.2: Commercial Region

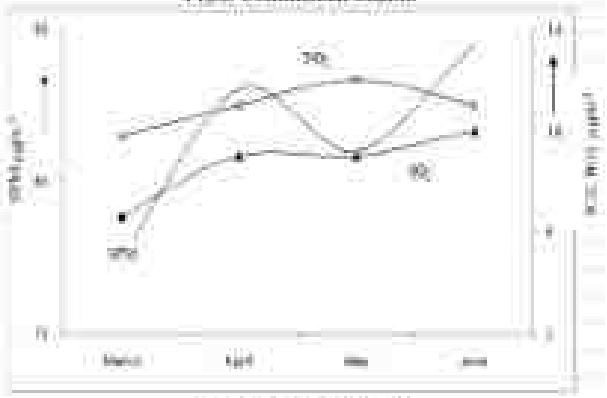

Fig.3: Industrial Region

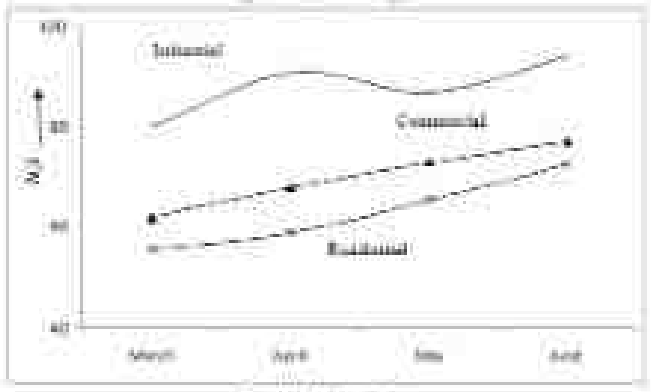

Fig.4: AQI variation

IV. CONCLUSIONS

In the current study, an analysis of air pollutants like SPM, SO_2, and NO_2 was carried out to gauge the quality of ambient air in Ichalkaranji city. Data analysis revealed the following:

At every monitoring site in residential, commercial, and industrial areas, SPM levels were recorded below the NAAQS limits.

All monitoring locations in residential, commercial, and industrial areas had fine particle (PM-2.5) levels that were significantly higher than the NAAQS (40 g/m^3).

While NOx was found to be above the allowable limits (30 g/m^3) and exhibited an increasing trend, the concentration of gaseous pollutants, SO_2, was found to be below the prescribed NAAQS (20 g/m^3) at all locations.

Despite being in an ecologically sensitive zone, all three locations showed an increasing trend for PM-10 when compared to the previous years.

Overall findings show that RSPM and SPM, along with gaseous pollutants, are two of the main factors contributing to the city's declining ambient air quality. Even for policymakers, the unrestricted expansion of vehicles, their technological advancement, and the emission of invisible tailpipe pollutants are contentious issues. The environment is made more complicated in terms of air quality and their additive effects on human health by the use of various fuel types, including gasoline, diesel, LPG, and compressed natural gas (CNG).

Overall, the continuous accumulation of different types of pollutants and their exposure to human beings needs the emergency attention of policymakers, researchers, and regulatory agencies. The present study suggests that it is necessary to monitor the air quality as well as the health effects at regular intervals at strategic locations, which will help the planners ensure the sustainable development of the city.

RECOMMENDATION:

To reduce the use of private vehicles, subsidized public transportation must be expanded or introduced. a better traffic management system. For the smooth operation of the traffic, encroachment should be removed. Program to increase public awareness of the effects of automobile pollution. Encourage the removal of all vehicle horns and urge horn avoidance. To discourage the use of personal vehicles, the government should raise the hourly parking fees. Restore the pedestrian path.

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3-D Numerical Analysis of Large Piled-Raft Foundation in Clay Soil

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***Abstract*: In the present study, a large piled-raft foundation was simulated numerically through three dimensional finite element modeling. 3D numerical modeling is the most reliable method for analysis of the piled-raft foundation in clay soils. The objective of study is to evaluate the effects of the pile c/s area to raft area ratio, raft embedment depth, modulus of elasticity of soil, Poisson's ratio of soil and applied stress on the average settlement, differential settlement and load sharing behavior of the foundation. The above results were compared for different piled area ratios, while keeping pile center-to-center spacing constant and varying only the pile diameter. For all piled area ratios, there is no noticeable effect of the depth of piled-raft placement on the average settlement, differential settlement and load sharing ratio. With a greater number of piles, the average settlement decreases by a noticeable magnitude. The differential settlement is lower when the piles are located only below the central portion of the raft. In addition to this, it is observed that that at lower piled area ratio piles are loaded more than raft.**

Keywords: pile to raft area ratio, average settlement, differential settlement and load sharing.

I. INTRODUCTION

A piled-raft foundation consists of the three elements raft, piles, and soil. Depending on the relative dimension of the raft width (Br) and the pile length (Lp), piled-raft can be classified as a small (if Br < Lp) and large (if Br > Lp) [1]. In a small piled-raft piles are added for enhancing factor of safety whereas in a large piled-raft, piles are added to reduce the settlement. 3D numerical modeling is the most reliable method for analysis of the piled-raft foundation in clay soils [2]. Several researchers have investigated the settlement [3, 4] and bearing behavior [5, 6, & 7] of a piled-raft on clay soils using numerical modeling. Different design aspects of piled-raft foundation have been reported by [8], [9], and [10]. Furthermore, [11], [12], and [13] indicated that the piled-raft can be used as an effective and economic foundation alternative for tall buildings to control the settlement and to enhance the bearing capacities. The parametric study of large piled-raft foundations in sandy soil through finite element analyses was conducted by [14]. They indicated that the concentrated pile arrangement method can help to reduce the total and differential settlements as well as the induced bending moments of the raft. The finite layer method was used to investigate the behavior of piled-rafts with piles of different lengths and diameters under vertical loading [15]. The study reported that for non-uniform loading, the use of long piles underneath the heavily loaded area can help to minimize the risk of tilting as well as to reduce the overall and differential settlements.

The parametric study on piled rafts installed in sand with stiffness that varies linearly with depth have been conducted [16]. The study showed that the load carried by piles is higher for rigid rafts due to the minimal interaction between the raft and subsoil compared to the relatively flexible rafts. An undrained behavior of a piled raft system was assessed by average and differential settlements, raft bending moment, and pile butt load ratio [17]. The results of the study showed that a piled raft with variable pile length and optimal arrangement, yields the most economical and practical design. Similarly, the piled rafts subjected to concentrated loading showed lower differential settlements and higher pile loads than as that of uniform loading [18].

II. NUMERICAL MODELING

Fig. 1 shows the PLAXIS 3-D model with boundaries along with the geometry of the square raft and the typical finite element mesh used. The water table was assumed to be at deep depth. From the edge of the raft, the lateral soil domain boundaries of the model were placed at a distance of twice the raft width (Br), and were restrained against horizontal translation but vertical translation was allowed. The bottom soil boundary was at a vertical distance equal to twice the raft width, and was restricted from both horizontal and vertical translations. The analysis is carried by activating soil domain, selecting loading, making the piled-raft geometry, application of load and then run was made. An undrained soil response was modeled in the current study, and the settlement of soil due to the self-weight of the raft was not considered. From the analysis of the unpiled raft under applied loading, it was found that the selected lateral boundaries of soil domain were sufficient because the observed zone of plastic strain developed in the soil was very much within the boundaries

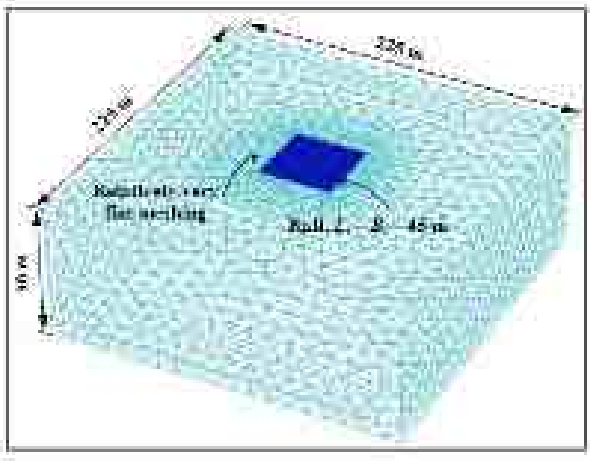

Fig. 1. Fig. 1 Typical finite element mesh used in the study

The soil was modeled as 10-node tetrahedral elements with the elastic-perfectly plastic Mohr-Coulomb model. The raft and piles were modeled as 5-node triangular plate elements and 4-node line elements, respectively. The materials of raft and piles were considered to be linear-elastic. The interaction between the soil and the pile was modeled with embedded interface elements of 3-node line elements having pairs of nodes instead of single nodes. For the modeling of piled raft Plaxis manual is referred [19].

III. Model Validation

The present PLAXIS 3-D model was validated using the problem of 2 m thick raft (24 m × 24 m size) with 16 piles of 1m diameter and 15 m pile length (Lp) [20]. The material properties of the soil, raft and piles are shown in Table 1.

TABLE I. Details of Material Properties Used in the Validation

Material	Property	Unit	Value
Soil	Young's modulus, Es	MPa	54
	Poisson's ratio, νs	–	0.15
	Unit weight, γ	kPa	19
	Internal friction angle, ϕ'	°	20
	Cohesion, c'	kPa	20
Raft	Young's modulus, Er	GPa	34
	Poisson's ratio, νr	–	0.2
Pile	Young's modulus, Ep	GPa	25
	Poisson's ratio, νp	–	0.2

The piles were spaced at six times the pile diameter, and uniformly distributed load of 0.5 MPa was applied on the piled-raft. Fig. 2 shows a comparison of the obtained load-settlement plot with that of the published results. It can be seen that there is a good agreement.

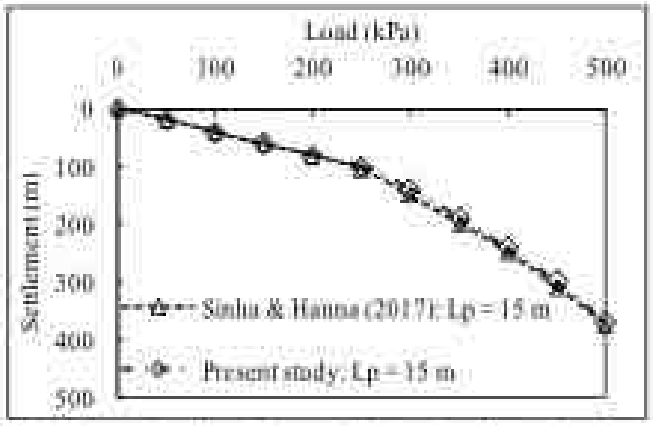

Fig. 2. Comparison of load-settlement behavior for validation of model

IV. Parametric Study

The square raft (Br = 45 m) of 2 m thickness in Fig. 1 is supported by piles of 30 m length and 4 m spacing for varying piled area ratios [i.e. ratio of pile group width (Bg) to raft width (Br)] of 0.2, 0.6 and 1.0 corresponding to total pile numbers of 4, 49 and 121, respectively. The different pile group layouts are tabulated in Table 2. Pile c/s area is the sum of the cross-sectional areas of the total no. of piles. As the pile diameter is varied from 0.5 to 2 m in increments of 0.5 m, the pile c/s area increases. Thus, for Bg/Br ratios of 0.2, 0.6, 1.0, the pile c/s area to raft area ratio varies from 0.04 to 0.71%, 0.54 to 8.72%, 1.34 to 21.53%, respectively.

The settlement and load sharing behavior of the large piled-raft foundation was studied for varying values of pile c/s area to raft area ratio, raft embedment depth, modulus of elasticity of soil, Poisson's ratio of soil and applied stress. The properties of the soil, raft and piles are tabulated in Table 3. The values of Es, νs, Er, Ep and geometrical dimensions of piled-raft were selected from [1].

TABLE II. Different Pile Group Layouts

Bg/Br	Pile spacing, Sp (m)	No. of piles, Np	Pile diameter, dp (m)	Pile c/s area (m²)
0.20	4	4	0.5	0.78
			1*	3.14
			1.5	7.06
			2	12.56
0.60		49	0.5	9.61
			1*	38.46
			1.5	86.54
			2	153.8
1.00		121	0.5	23.74
			1*	94.98
			1.5	213.7
			2	379.9

* Indicates standard value if not varied.

TABLE III. Material Properties Used in the Parametric Study

Material	Properties	Units	Values
Soil	Young's modulus, Es	MPa	25*
	Poisson's ratio, νs	–	0.495
Raft	Young's modulus, Er	GPa	25
	Poisson's ratio, νr	–	0.25
Pile	Young's modulus, Ep	GPa	25
	Poisson's ratio, νp	–	0.25

* Indicates standard value if not varied.

The vertical settlement profile of the piled-raft is as shown in Fig. 3. The average settlement (Wavg), differential settlement (ΔWc-e) and load sharing ratio (Rpr) are expressed below in the mathematical form. The results are plotted in the form of average settlement, differential settlement and load sharing ratio. In all plots, the applied uniformly distributed load (q) of 200 kPa is used, if it is not varied.

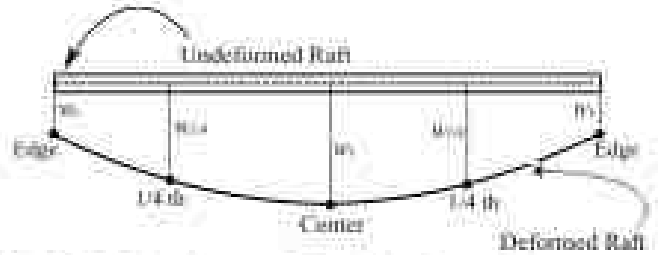

Fig. 3. Definition of center and differential settlement of raft

$$W_{avg} = \frac{W_c + 2W_{1/4} + W_e}{4} \quad (1)$$

$$\Delta W_{c-e} = W_c - W_e \quad (2)$$

$$R_{pr} = \frac{\text{Total load carried by piles}}{\text{Total applied load on raft}} \quad (3)$$

V. Results and Discussions

A. Effect of Pile c/s Area to Raft Area Ratio (Ratea)

The effect of varying pile c/s area to raft area ratio on average settlement, differential settlement, and load sharing ratio are shown in Figs. 4 to 6. The average settlement of the unpiled-raft is 229 mm. The results indicate that with increase in pile c/s area to raft area ratio, the average settlement decreases to minimum values of 171 mm and 139 mm for Bg/Br ratios of 0.6 and 1.0, respectively (Fig. 4).

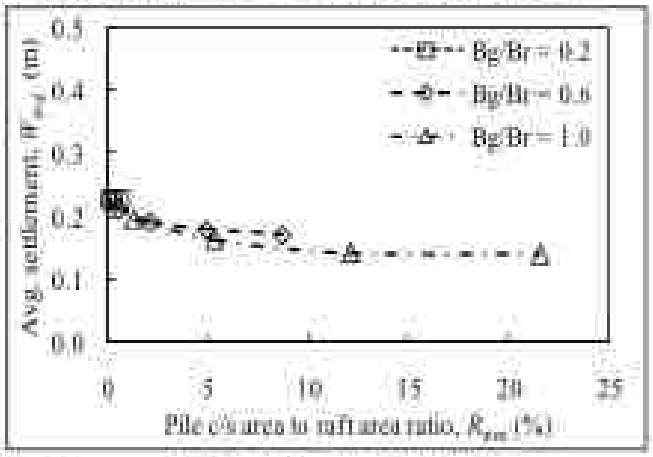

Fig. 4. Average settlement vs. pile c/s area to raft area ratio

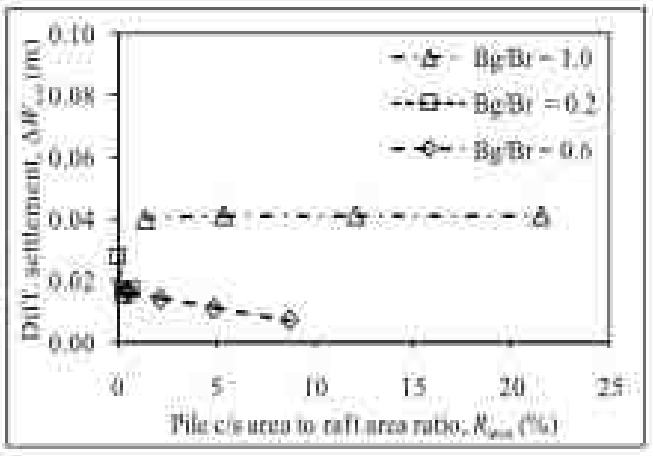

Fig. 5. Differential settlement vs. pile c/s area to raft area ratio

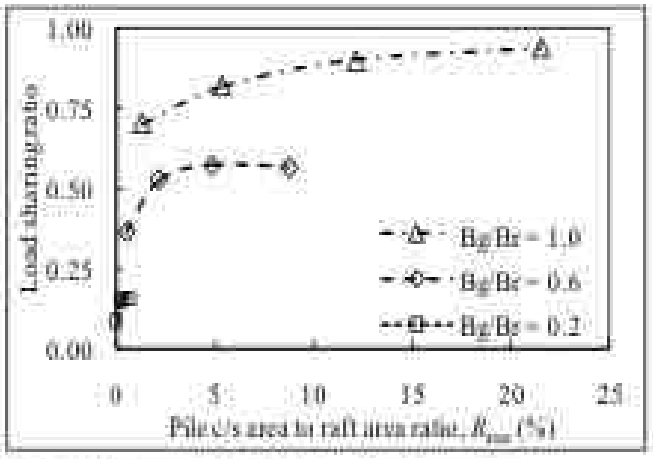

Fig. 6. Load sharing ratio vs. pile c/s area to raft area ratio

The differential settlement decreases from 36 mm to 7 mm for Bg/Br ratio of 0.6, whereas it remains close to a higher magnitude of 40 mm for Bg/Br of 1.0 (Fig. 5). For this particular raft size, the limiting maximum settlement and differential settlement values are 125 mm and 140 mm (0.0033*Br) for plastic clay as per IS code provisions. For a sagging deformation of the raft, the magnitude of maximum center settlement is always greater than the average settlement of the raft. Thus for a better reduction of differential settlement, the piles should be placed only below the central portion of the raft. As the pile c/s area to raft area ratio increases, load sharing ratio of piles increases from 8 to 15%, 36 to 57%, 70 to 94% for Bg/Br ratios of 0.2, 0.6, 1.0, respectively (Fig. 6).

B. Effect of Raft Embedment Depth (de)

The effect of raft embedment depth on average settlement, differential settlement, and load sharing ratio are shown in Figs. 7 to 9. It can be noted that the average settlement, differential settlement and load sharing ratio vary insignificantly as the raft embedment depth increases from 0 to 5 m.

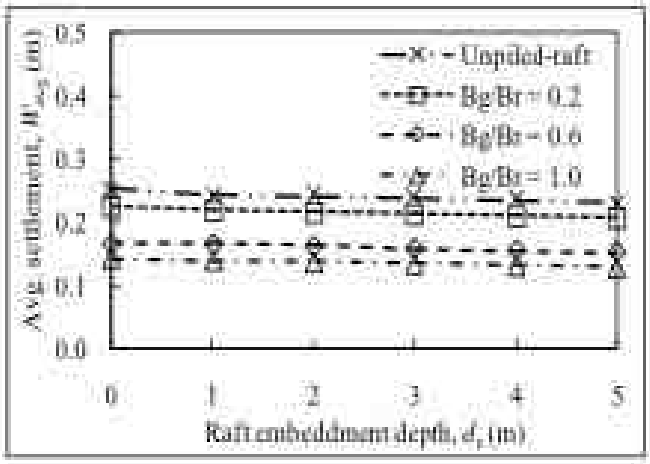

Fig. 7. Average settlement vs. raft embedment depth

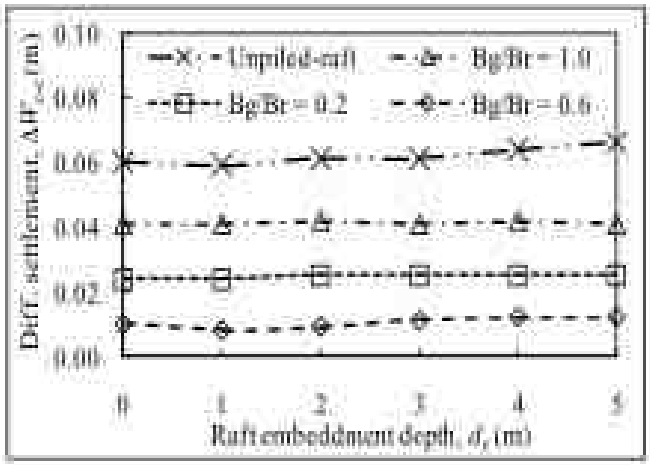

Fig. 8. Differential settlement vs. raft embedment depth

The average settlement is observed to be lower for a higher Bg/Br ratio (Fig. 7). The differential settlement is the maximum for Bg/Br ratio of 1.0 and is the minimum for Bg/Br ratio of 0.6 (Fig. 8). The load sharing ratio is observed to be almost 1.00 for the Bg/Br ratio of 1.0 indicating that the entire applied load is carried by the piles (Fig. 9).

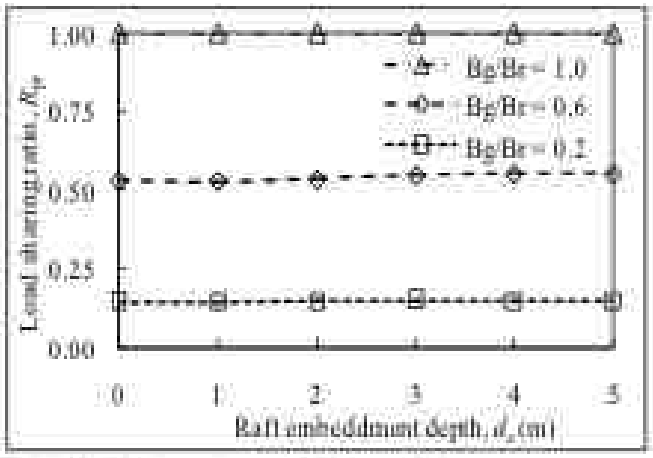

Fig. 9. Load sharing ratio vs. raft embedment depth

C. Effect of Modulus of Elasticity of Soil (Es)

The effects of modulus of elasticity of soil on average settlement, differential settlement, and load sharing ratio are shown in Figs. 10 to 12. As the modulus of elasticity of soil increases to a maximum value of 50 MPa, the average settlement decreases to minimum values of 71 mm and 61 mm for Bg/Br ratios of 0.6 and 1.0, respectively (Fig. 10).

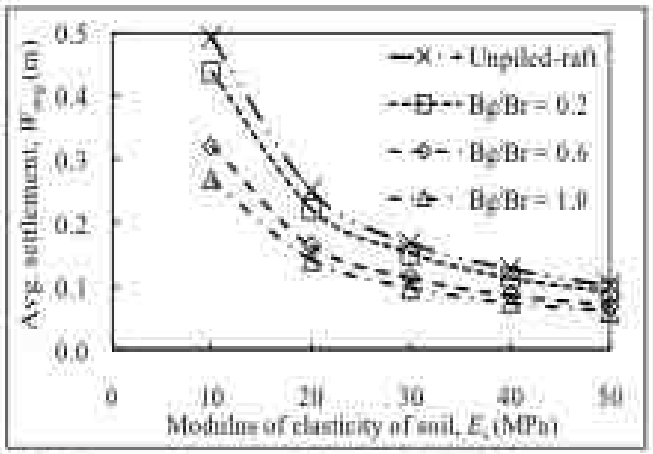

Fig. 10. Average settlement vs. modulus of elasticity of soil

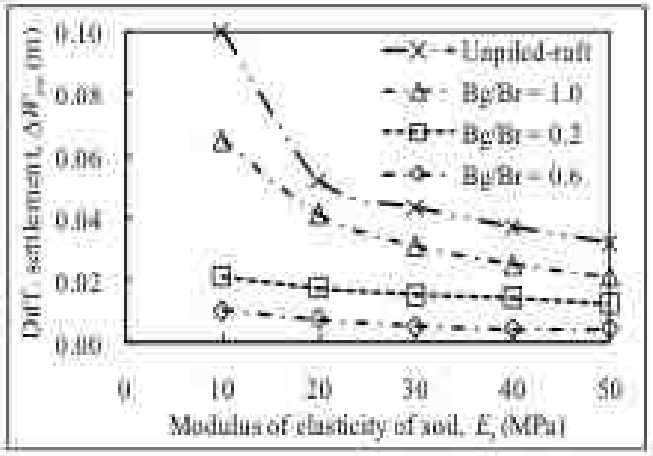

Fig. 11. Differential settlement vs. modulus of elasticity of soil

The differential settlement decreases from 10 mm to 4 mm for Bg/Br ratio of 0.6, and from 65 mm to 21 mm for Bg/Br ratio of 1.0 (Fig. 11). From Fig. 12, it can be seen that as the modulus of elasticity of soil increases from 10 to 50 MPa, the load sharing ratio of piles has decreased from 15 to 9%, 58 to 41%, 100 to 83% for Bg/Br ratios of 0.2, 0.6, 1.0, respectively.

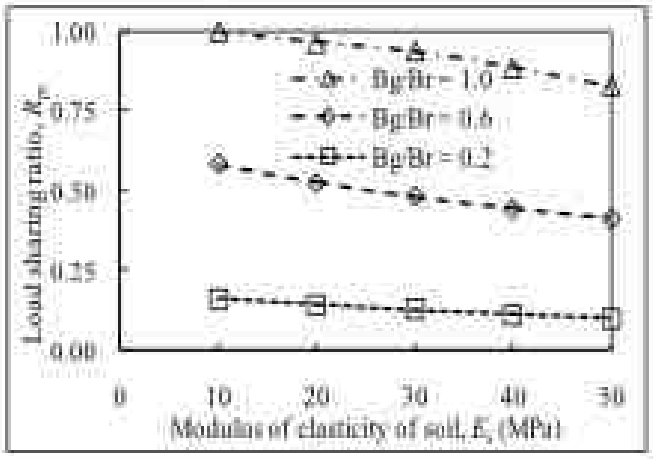

Fig. 12. Load sharing ratio vs. modulus of elasticity of soil

D. Effect of Poisson's Ratio (νs)

The effects of Poisson's ratio of soil on average settlement, differential settlement, and load sharing ratio are shown in Figs. 13 to 15. As the Poisson's ratio of soil increases from 0.1 to 0.495 indicating lower levels of drainage, the average settlement has decreased to minimum values of 165 mm and 142 mm for Bg/Br of ratios of 0.6 and 1.0, respectively (Fig. 13), whereas different trends are obtained for differential settlement.

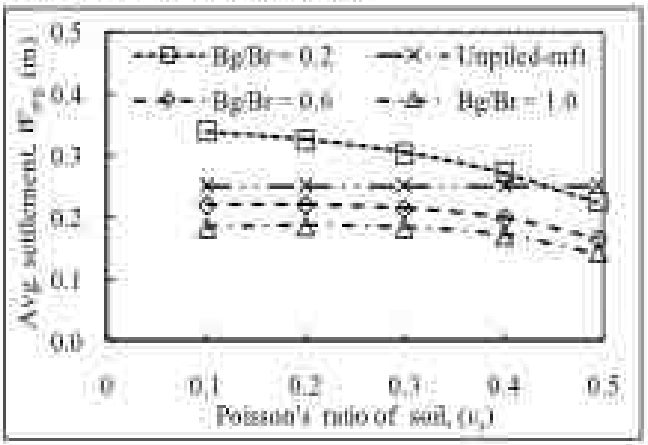

Fig. 13. Average settlement vs. Poisson's ratio of soil

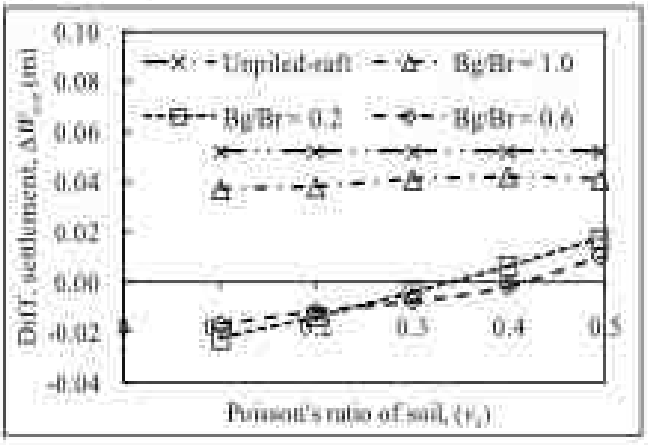

Fig. 14. Differential settlement vs. Poisson's ratio of soil

For Bg/Br of 1.0, as the Poisson's ratio increases, the differential settlement increases marginally and for other Bg/Br ratios (0.2 and 0.6) it is observed to be negative (vs = 0.1 to 0.3) and attains positive value beyond vs = 0.3 (Fig. 14). A negative value of differential settlement is indicative of a convex deformed shape of the raft slab. From Fig. 15, it can be seen that with the increase of Poisson's ratio, load sharing ratio of piles has decreased from 23 to 14%, 81 to 52%, and 100 to 93%, for Bg/Br ratios of 0.2, 0.6, and 1.0, respectively.

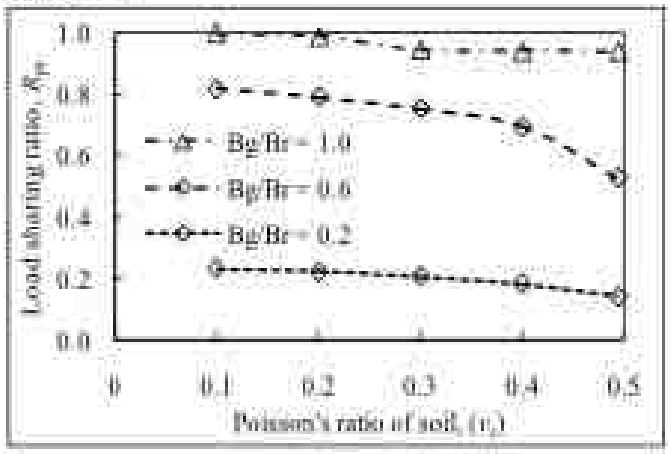

Fig. 15. Load sharing ratio vs. Poisson's ratio of soil

E. Effect of Applied Stress (q):

The effects of applied stress on average settlement, differential settlement, and load sharing ratio are shown in Figs. 16 to 18. With increase in applied stress from 50 to 250 kPa, the average settlement increases to maximum values of 280 mm and 199 mm for Bg/Br ratios of 0.2 and 0.6, respectively (Fig. 16).

For Bg/Br ratio of 1.0, the differential settlement increases from 1 mm to 5 mm, whereas the increase is insignificant for Bg/Br ratios of 0.2 and 0.6 (Fig. 17). With increase in applied stress, load sharing ratio of piles increases from 6 to 15%, 20 to 62%, 24 to 89%, for Bg/Br ratios of 0.2, 0.6, 1.0, respectively (Fig. 18).

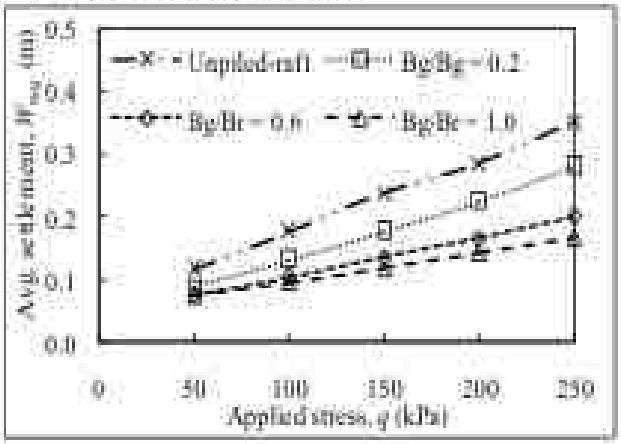

Fig. 16. Average settlement vs. applied stress

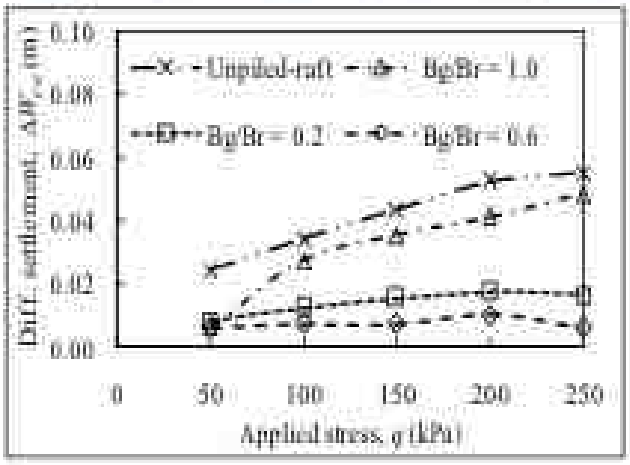

Fig. 17. Differential settlement vs. applied stress

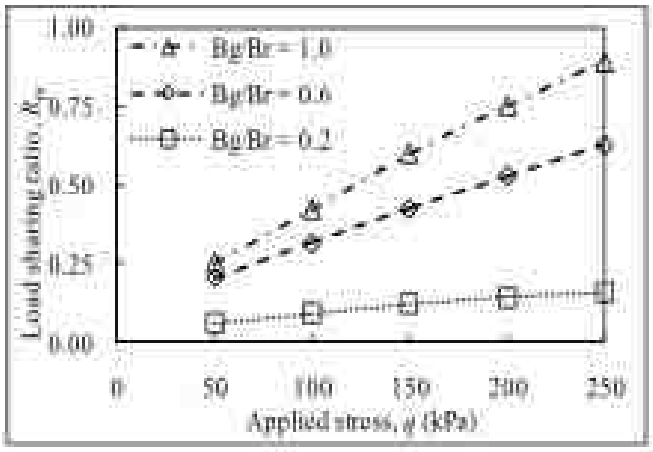

Fig. 18. Load sharing ratio vs. applied stress

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Studies on Assestment of Electricity Consumption and Design of Solar PV Module for Residential Buildings.

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Abstract— **Residential energy consumption constitutes a significant portion of total energy usage, prompting this study to investigate and assess electricity consumption patterns in diverse income groups. Data was collected from 45 households, representing varying income levels, to estimate and analyse energy consumption based on household size and income. In parallel, the study proposes user-friendly solar power system designs tailored to different income levels to reduce dependency on non-renewable energy sources. Cost analyses were conducted to compare conventional grid electricity with solar power systems, shedding light on affordability and long-term sustainability. Key findings include varying energy consumption across income groups, with the highest consumption observed during summer months, notably due to air conditioning usage. Solar power systems were tailored for low, medium, and high-income households, with corresponding area requirements and costs. Notably, off-grid solar systems were found to be more expensive due to battery costs, while on-grid systems proved more economical over a 25- year period. Payback periods for on-grid systems were significantly shorter than off-grid systems, making them a viable and sustainable alternative. This study contributes to a comprehensive understanding of residential energy consumption and underscores the potential of solar technology to promote sustainable energy practices across diverse socioeconomic backgrounds.**

Keywords – Electricity Energy Consumption, Household Appliances, Statistical analysis, Solar PV, Off-grid Solar Design.

1. INTRODUCTION

The surge in global population and urbanization has propelled an exponential rise in energy consumption, notably within the residential sector. Conventional energy sources like coal, natural gas, and petroleum derivatives have long fuelled this demand, but their environmental toll is increasingly evident through greenhouse gas emissions, air pollution, and climate change concerns. To address these challenges, there's a growing impetus to shift towards renewable energy technologies, particularly solar PV systems, which offer a clean and abundant energy source. The residential sector's electricity demand is intricately linked to various appliances, with lighting, refrigeration, air-conditioning, and entertainment systems dominating usage. This escalating demand is driven by rising disposable incomes and a changing lifestyle, resulting in a substantial surge in electricity consumption across India.

India's reliance on coal currently caters to 70% of the total energy demand, yet projections suggest an imperative need to diversify energy sources. The country faces infrastructural challenges, with over 300 million people lacking regular access to electricity, alongside technical network losses exceeding global averages. Solar energy emerges as a potent alternative, receiving growing attention due to its vast potential and environmental benefits. Despite this, its utilization remains under 5% globally. Nations like Germany have spearheaded the transition to solar energy, emphasizing its viability by significantly reducing reliance on fossil fuels. Transitioning to solar not only harnesses an abundant resource but also mitigates the environmental toll of fossil fuel usage. India's escalating residential electricity demand calls for urgent measures to curb consumption and promote energy efficiency, with solar energy presenting itself as a promising candidate.

Expanding on the provided data, it's noted that Residential Energy Consumption constitutes approximately 22% of the total energy consumption in India. A forthcoming study aims to delve deeper into this aspect by collecting data from 45 households representing different income levels, employing methods like questionnaire surveys and household inspections to comprehensively analyse consumption patterns.

This study intends to propose the use of Solar technology as an alternative to conventional grid supply, tailored to different income levels. It will delve into designing Solar power systems suitable for diverse housing groups and evaluate the cost economics associated with its adoption among various income brackets, emphasizing affordability and long-term sustainability. By amalgamating data analysis, household assessments, and economic evaluations, this study aims to elucidate Residential Energy Consumption patterns and highlight the potential benefits of Solar technology. It endeavours to contribute to a better understanding of energy consumption across socio-

economic strata and advocate for a more sustainable and eco-friendly approach to energy consumption in varied settings.

Objectives —

1. To Estimate and Analyze the household Electrical energy consumption based on Area of household, No. of Members and Income level.

2. To propose a design methodology, to provide electricity through Solar Technology based on their electricity consumption in household.

3. To compare the cost analysis of Conventional electricity with Solar power System electricity.

II. METHODOLOGY

1. Data Collection and classification of data as per ownership level :

The review of existing literature emphasized the importance of acquiring high-quality data to enhance our comprehension of residential energy usage trends and appliance adoption rates. With this in mind, the survey was crafted with the goal of collecting precise information about residential energy consumption. In total, 45 household surveys were administered, distributed evenly across three different income class tiers. Within each class, approximately 15 surveys were conducted using more comprehensive questionnaires and strategies, aiming to capture the nuances of household appliance utilization. This approach allowed for a deeper insight into the patterns of home appliance usage.

- Household monthly income
- Stock of electrical appliances in household
- Use of appliances
- Family size
- House size

2. Providing a plan of Solar System over their Energy Consumption

3. Cost Analysis

A. Assessment of household electrical energy consumption

This chapter, delve into the fascinating realm of understanding household electrical energy consumption. Through a comprehensive questionnaire survey, we have gathered valuable insights into the energy consumption patterns of Low-Income Group (LIG), Middle-Income Group (MIG), and High-Income Group (HIG) households. Our primary goal is to compare these survey findings with the actual electricity bills provided by the Maharashtra State Electricity Distribution Company Limited (MSEDCL). Furthermore, we analysed the data with a seasonal perspective, categorizing consumption trends across different seasons. This research aims to shed light on the factors influencing electricity usage in households of varying income levels, ultimately contributing to a more comprehensive understanding of energy consumption dynamics.

Comparative Analysis of Monthly Energy Consumption: Survey Data vs. MSEDCL's Consumption

A comparison made between monthly energy consumption data obtained through a questionnaire survey and the energy consumption data provided by MSEDCL.

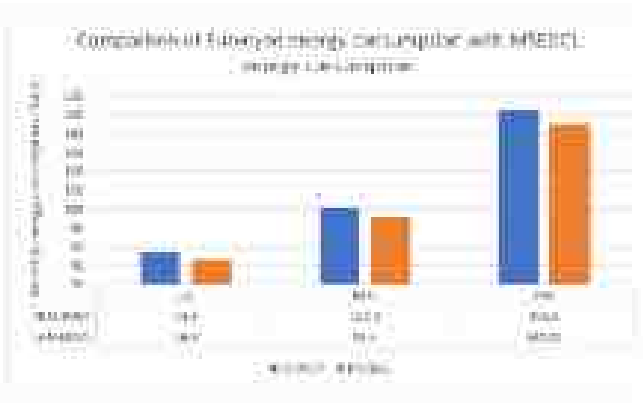


Fig. 1- Comparison of Surveyed energy consumption with MSEDCL energy consumption

Seasonal Categorization of Yearly Energy Consumption from MSEDCL

This chapter delves into the insightful analysis of Yearly Energy Consumption data obtained from the Maharashtra State Electricity Distribution Company Limited (MSEDCL). In particular, we explore the categorization of this energy consumption data with respect to the changing seasons. Seasonal variations play a significant role in shaping energy consumption patterns.

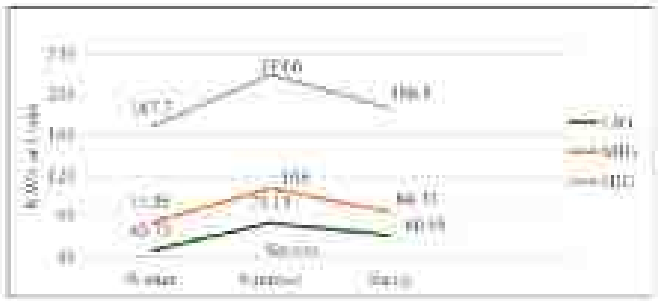


Fig. 2- Graphical presentation of energy consumption over different season

Average Energy Consumption in Peak Months (Summer)

To determine specific average energy consumption during peak months, a MSEDCL electricity consumptions bills are collected, which typically provide detailed information on monthly energy usage. This gives a more accurate picture of energy consumption during the summer months and help to identify ways to reduce energy consumption if necessary.

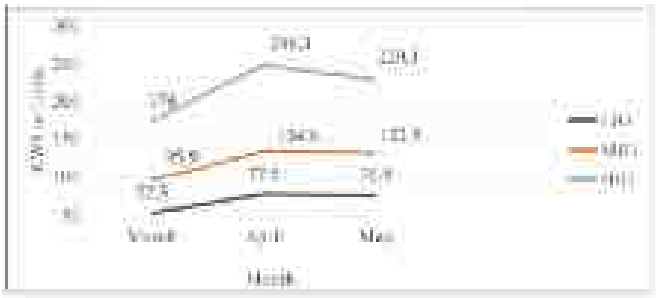


Fig. 3- Energy Consumption in Peak month

Summary

The objective of this study was to estimate and analyse household electrical energy consumption based on the area of the household, the number of members, and income level. The results revealed several key findings. Firstly, the monthly average electrical energy consumption was found to vary significantly among different income groups, with lower income households (LIG) consuming 73 KWh, middle income households (MIG) consuming 108 KWh, and higher income households (HIG) consuming 220 KWh on average. Secondly, the survey results indicated that the variance in energy consumption, when compared to previous year's electricity bills, was consistently within the range of 8 to 12 percent higher than grid energy consumption for all income groups. Furthermore, the study identified a seasonal pattern, with higher energy consumption observed during the summer season compared to winter and rainy seasons. Notably, in the summer season, the use of air conditioning was found to contribute significantly, with a 45 percent increase in electricity consumption observed in HIG households. Lastly, it was found that April consistently recorded the highest electricity consumption across all income groups.

II. Design of Off-grid solar powered system

Designing an efficient off-grid solar-powered system involves a meticulous consideration of several critical parameters to ensure reliable and sustainable energy generation. Firstly, understanding the energy consumption patterns is crucial, as it forms the foundation for sizing both the battery bank and the inverter appropriately. Ensuring the system operates optimally also involves determining the required area for solar panels, alongside the necessary Alternate Current distribution and Direct Current distribution boxes (ACDB and DCDB), as well as selecting the right Alternate Current (AC) and Direct Current (DC) cables to minimize energy losses. Implementing a bi-directional meter or charge controller helps manage energy flow and storage effectively. Furthermore, a robust grounding and wiring system, along with lightning arresters, is essential for safety and system protection. This holistic approach to off-grid solar system design guarantees a sustainable and reliable power supply tailored to specific energy needs while prioritizing safety and efficiency.

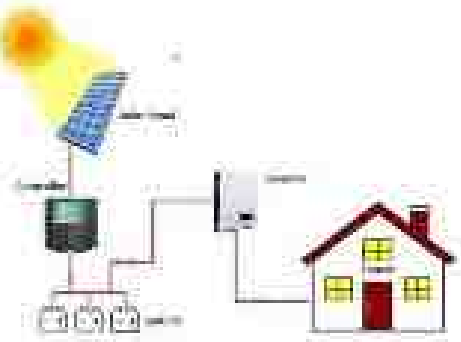
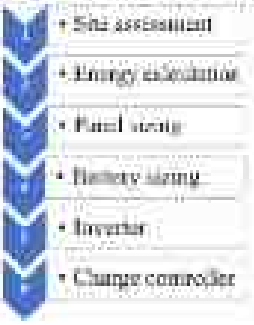


Fig. 4- Off-grid solar powered system

Methodology for designing an Off-grid Solar Powered System



Site assessment

1. Shade Analysis: Shade from obstructions like trees, buildings, weather conditions, and neighboring panels can significantly reduce solar panel efficiency.

2. Sun Hours: Understanding the duration of peak sunlight, often termed as sun hours, aids in determining the expected optimal sunlight exposure for solar energy generation. (Sunhour for Sangli Region = 5.6 hrs/day)

3. Tilt Angle: Optimal panel tilt angle corresponds to the location's latitude. Orienting panels southward maximizes sunlight exposure. (Tilt angle for Sangli Region = 16 to 18°N)

Panel Sizing (Calculating Wattage of Panels)

Calculating the necessary panel wattage involves considering inherent losses within panels. Utilize tools like PV WATTS to simplify panel sizing calculations. (System losses for Sangli Region: Soiling/Dusting - 2%, Shading - 3%, Mismatch - 2%, Wiring - 2%, Connection - 0.5%, Light induced degradation - 1.5%, Availability - 4%)

Battery Sizing

Evaluate different financial approaches for a PV battery system considering charge-discharge cycles and lifespan. A formula determines the appropriate battery size.

$$\text{Battery Capacity (AH)} = \frac{\text{[illegible]}}{\text{[illegible]}} \times \text{[illegible]}$$

Were,
0.85 – Battery Losses
0.8 – Depth-of discharge
12V – Nominal Voltage

Inverter
Match the inverter's capacity with the total wattage of solar panels. Consider the voltage level of the system for efficient energy conversion.

Charge Controller
Safeguard batteries from overcharging or over-discharging using controllers like Pulse Width Modulation (PWM) or Maximum Power Point Tracking (MPPT). They ensure optimal battery charging and longevity.

Table 1: Particulate Design parameters for all Income Group

Sr. No.	Design Parameters	Particulars		
		LIG	MIG	HIG
1	Electricity Consumption	2 kWh	3 kWh	5 kWh
2	Design Load (watt)	450 W	1 KW	4 KW
3	Cost of Panel	10,000/- PERC	18,000/- PERC	36,000/- PERC
4	Size of Panel	430 W	320 W	350 W
5	No. of Panels	1	2	4
6	Solar Mounting Structure	2 No. @ 5,000/-	3 No. @ 5,000/-	3 No. @ 5,000/-
7	Inverter	1 No. @ 8000/-	1 No. @ 10,000/-	1 No. @ 15,000/-
8	DC cable	4 Sq. mm	4 Sq. mm	4 Sq. mm
9	AC cable	4 Sq. mm	4 Sq. mm	4 Sq. mm
10	DC MCB or DP MCB	1 No. @ 800/-	1 No. @ 800/-	1 No. @ 800/-
11	Charge Controller, Earthing and Accessories	Single Phase 5 amp Energy Meter	Single Phase 5 amp Energy Meter	Single Phase 5 amp Energy Meter
12	Earthing and accessories	1 no @ 2000/-	1 no @ 2000/-	2 no @ 2000/-
13	Wiring	1 LV @ 800/-	1 LV @ 1000/-	1 LV @ 2000/-
14	Labour charges for installation	5	5	5

Summary
The objective of this project was to propose a user-friendly software design for implementing solar technology to meet household electricity needs across different income level groups. The design utilized Mono-PERC panels, with one 430-Watt peak panel for Low-Income Group (LIG), two panels of 320-Watt peak for Middle-Income Group (MIG), and four panels of 350-Watt peak for High-Income Group (HIG), focusing on cost-effectiveness. Additionally, the area required for installing the solar powered system was determined to be 2 sq.m. for LIG, 4 sq.m. for MIG, and 8 sq.m. for HIG households. This software aims to make solar adoption accessible and tailored to diverse income groups, promoting sustainable energy use while considering economic factors.

C. Cost Analysis

In this chapter, we delve into the critical aspects of selecting the appropriate materials and components for a solar-powered system. We also conduct a comprehensive cost comparison between solar-powered systems and the services provided by MSEDCL (Maharashtra State Electricity Distribution Company Limited), aiming to provide valuable insights into the economic feasibility of adopting solar energy across various income groups. Furthermore, we perform a detailed breakeven analysis for solar- powered systems, shedding light on the point at which the initial investment in solar technology begins to yield financial benefits, offering a clear perspective on its viability for different socioeconomic segments.

Selection of Material and Components' Type of Solar Powered System:
Select high-quality solar panels, reliable inverters, durable batteries, sturdy mounting structures, weatherproof cables, a charge controller, and an energy meter for efficient and reliable solar systems.

Calculated Cost of Electricity Consumption from Solar Powered System:
The cost of electricity from a solar system depends on panel efficiency, number of panels, inverter type, and battery capacity. Factoring in initial investment and maintenance costs is crucial to understand the financial implications.

Actual Cost of Electricity Consumption from MSEDCL:
The actual cost of electricity from MSEDCL varies based on consumer category, consumption slabs, and tariff rates.

Cost Comparison:
Comparing the calculated cost of solar system electricity with MSEDCL's billed cost allows for assessing financial impact. Identified significant cost savings highlight the efficacy of the solar system and its contribution to environmental sustainability.

Cost for Solar PV Module System:
The cost of a Solar PV module system varies based on design parameters like panel quality, efficiency, batteries, installation, location-specific factors, and local regulations. Profit is not considered in cost calculations.

Table -2: Costing deviation from design parameters for all income group

Parameters	LIG	MIG	HIG
PV Panel	11500	17820	35280
Inverter	18500	21000	22000
AC Cable	500	500	500
DC Cable	500	500	500
AC MCB or DP MCB	1400	1400	1400
Charge Controller	1500	1500	1500
Earthing & Wiring	3000	3000	3000
Lightning Arrester	1000	1000	1000
Battery (2V system)	110000	164000	328000
Accessories	5000	5000	5000
Labour Charges	5000	5000	5000
Total Rs (Off grid)	**179300**	**264820**	**503980**
Total Rs (On grid)	**51300**	**81820**	**151980**

Table 2: Cost comparison between PV system and MSEDCL

Income Group	Solar PV Module (Quantity)	MSEDCL (Rs)	Difference (%)
LIG	120000	160000	17%
MIG	240000	270000	7%
HIG	350000	671200	78%

Breakeven Analysis

A 25-year assessment compared off-grid solar-powered, on-grid solar-powered, and MSEDCL electricity costs. The breakeven point was sought to identify when these costs intersect. Off-grid systems became costlier due to battery replacements, adding to their long-term expense.

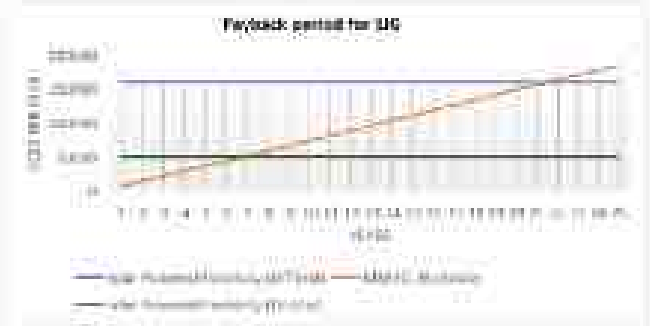


Fig. 5- Off-grid solar powered system

Figure 5, illustrates that Off-grid solar systems take approximately 21 years, while On-grid systems take about 7 years for payback in Low Income Group (LIG).

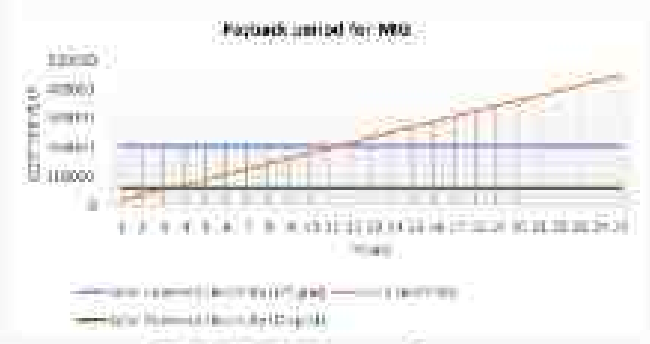


Fig. 6- Off-grid solar powered system

Figure 6, shows Off-grid systems take about 11 years, and On-grid systems take about 4 years for payback in Middle Income Group (MIG).

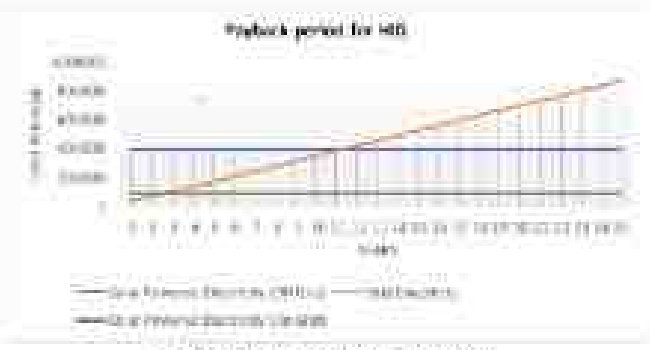


Fig. 7- Off-grid solar powered system

Figure 7, indicates that Off-grid systems take about 11 years, and On-grid systems take about 3 years for payback in High Income Group (HIG).

Summary

In this cost analysis comparing conventional electricity with solar power systems, we found that off-grid solar power systems incur substantial upfront costs, with Rs 160,000, Rs 205,000, and Rs 400,000 for LIG, MIG, and HIG categories, respectively. Notably, the cost of batteries accounts for a significant 70% of the total expenses in off- grid systems, making on-grid systems the more economical choice. Over a 25-year period, grid electricity costs were found to be 15%, 75%, and 76% higher than off-grid solar power for LIG, MIG, and HIG categories, respectively, and significantly more expensive than on-grid solar power, which was 5 to 10 times cheaper. The payback period for off-grid systems ranged from 11 to 21 years, while on-grid systems offered a much quicker return on investment, being three times shorter for all income groups. These findings highlight the economic benefits and cost-effectiveness of on-grid solar power systems compared to both off-grid solar and conventional grid electricity.

III. CONCLUSIONS

The monthly average electrical energy consumption through survey for LIG, MIG and HIG is observed to be 73 KWh, 108 KWh and 220 KWh respectively.

According to a survey, the average annual electricity consumption for LIG, MIG, and HIG is found to be 8 to 12% higher than the units actually consumed by consumers in their previous year's MSEDCL bills.

In all income groups, the highest electricity consumption occurs in the month of April. During the summer season, there is a 50% increase in electrical energy consumption compared to the winter and rainy seasons. Specifically, within the High-Income Group (HIG), 45% of this increase in electricity consumption can be attributed to the use of air conditioning.

Focusing on economic considerations, a Mono-PERC panel is used, consisting of one 450-Watt peak panel for LIG, two panels of 320-Watt peak for MIG, and four panels of 350-Watt peak for HIG.

The area required for installing a solar powered system is 2 sq.m. for LIG, 4 sq.m. for MIG and 8 sq.m. for HIG.

The Off-grid solar powered system costs Rs 1,60,000, Rs 2,05,000 and Rs 4,00,000 for LIG, MIG and HIG categories respectively.

The cost of battery accounts for a significant 70% of the total expenses in Off- grid solar powered system, thereby On-grid system is always going to be more economical than Off-grid system.

The cost of grid electricity for the period of 25 years is found to be 15%, 75% and 76% higher than that of the Off-grid solar powered system for LIG, MIG and HIG respectively. And it is found that the cost of grid electricity is 5 to 10 times greater than that of On-grid solar powered system.

In an Off-grid solar powered system the payback period for LIG is 21 years, for MIG and HIG is 11 years. And for On-grid solar powered system the payback period for LIG, MIG and HIG is 3 Times lesser than that of Off-grid solar powered system.

IV. FUTURE SCOPE

Detailed Consumption Analysis: Conduct a more extensive and detailed analysis of energy consumption patterns within each income group, including factors such as household size, appliances used, and behavioural patterns. This can provide insights for targeted energy conservation initiatives.

Seasonal Trends Exploration: Explore seasonal energy consumption variations in more depth to identify specific reasons behind higher energy use during the summer season. This could involve studying climate patterns, cooling methods, and lifestyle choices that impact energy demand.

Solar Panel Efficiency: Explore opportunities to enhance the efficiency of solar panels or consider alternative solar technologies to improve the overall performance and cost-effectiveness of the solar-powered systems.

Space Utilization: Explore ways to optimize space utilization for solar panel installation, especially in high-density urban areas, to reduce the land or roof area required for solar systems.

Payback Period Reduction Strategies: Investigate ways to shorten the payback period for off-grid solar systems in all income groups, possibly through government incentives, subsidies, or improved system efficiency.

Environmental Impact Assessment: Conduct an environmental impact assessment to evaluate the long-term ecological benefits and potential carbon emissions reductions resulting from widespread adoption of solar power systems.

By addressing these future scope areas, the project can continue to evolve, providing valuable insights, improving energy efficiency, and contributing to the sustainable energy goals of the community and the nation.

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Novel approaches to enhancing the characteristics of concrete: A review

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Abstract

Cement mortar and concrete are the two most commonly used materials in construction. Making concrete is simple. Fresh concrete, sometimes called plastic concrete, is a newly mixed substance that can be moulded into any shape. Concrete is arguably the most versatile building material available. This is the material of choice when properties like strength, permanence, durability, impermeability, fire resistance, and abrasion resistance are required. Concrete has been widely used for building seawalls, jetties, groins, breakwaters, bulkheads, and other structures exposed to saltwater.

Numerous studies on the characteristics of concrete have revealed that it can be made stronger by adding waste materials in place of some of the cement or sand. This paper focuses on a broad literature review based on typical properties of fresh concrete. Reading this paper, one can quickly detect the numerous research gaps and advancements in concrete or fresh concrete.

Keywords— Concrete, Fresh concrete, strength, workability, HPC, consistency, mix proportions, mechanical properties, aggregates, water-cement.

Review Paper on Behaviour of Beam By Wrapping of GFRP Sheet

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Abstract

Structural engineers face ongoing challenges in managing deflection and ensuring the longevity of reinforced concrete beams, especially in situations where environmental factors or increased loads contribute to performance degradation. This study explores the application of glass fibre fibre-reinforced polymer (GFRP) sheets as an innovative solution for controlling deflection and enhancing the structural integrity of beams.

The research involves a comprehensive investigation into the mechanical properties of GFRP materials and their effectiveness in mitigating deflection in beams subjected to various loads. Experimental testing, including flexural and load-deflection analyses, is conducted to assess the performance of GFRP-wrapped beams compared to traditional reinforcement methods.

The study also considers the long-term durability and environmental sustainability of GFRP sheets, evaluating their resistance to corrosion and their potential impact on the overall life cycle of the structure. The findings contribute to understanding how GFRP sheet wrapping can offer a viable alternative for deflection control in structural beams, providing insights into the material's behaviour under different loading conditions.

Keywords—Beam, Deflection, GFRP, CFRP, Strengthening.

"Predicting the Compressive Strength of Concrete Cube Specimenn using Artificial Intelligence"

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Abstract

Concrete is a widely used construction material, and accurately predicting its compressive strength is essential to ensure structural integrity and safety of the structure. The compressive strength of concrete is an important property that decides its load-bearing capacity. The compressive strength of concrete can be determined by conducting a compressive strength test using a universal testing machine. However, this test is time-consuming and expensive. Further, it requires at least seven days of curing to get the idea about compressive strength of concrete. Machine learning can be used to predict the compressive strength of concrete. Machine learning is a subset of artificial intelligence that can be used to learn and derive patterns from data and finally make predictions. This project focuses on developing multiple machine learning models to predict the compressive strength of concrete cube specimen and compare their performance based on various metrics. By utilizing the power of data- driven techniques, we aim to improve the efficiency and accuracy of strength determination, ultimately helping engineers in making informed decisions. Numerous studies on the characteristics of concrete have revealed that it can be made stronger by adding waste materials in place of some of the cement or sand. This paper focuses on a broad literature review based on typical properties of fresh concrete. Reading this paper, one can quickly detect the numerous research gaps and advancements in concrete or fresh concrete.

Keywords—Artificial Intelligence, Compressive Strength of concrete

Review Assessment on Seismic and Wind Analysis of Steel Structures

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Abstract

Steel buildings are used in industrial areas, farmhouses, agriculture, and livestock shelters, among other uses. They are typically located in vast areas. Thus, caution should be used to ensure the structure's safety. Here, several bracing systems are being used to adapt the structure to various unusual circumstances, particularly wind and seismic loads. This paper aims to analyze the structural response of steel sheds. To verify the findings, the structure is modelled using appropriate software, both with and without bracing systems. This paper focuses on a comprehensive review of the literature on wind and seismic analysis of steel structures used in the construction industry.

Keywords—Steel Shed, structural analysis, structural response, wind analysis, bracing system

Analytical review assessment of flat slab buildings with RCC and composite column

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Abstract

Now a days in India due to lack of land we are adapting vertical construction like apartments and due to height limitations in construction of apartment the sufficient headroom is compromised, hence To overcome this problem "Flat slab" refers to a structural system used in buildings where the floors are supported directly by columns without beams. Flat slabs provide more headroom and flexibility in space planning since they eliminate the need for beams flat slabs are favoured in construction for their simplicity, efficiency, and potential cost savings, especially in buildings where open spaces and flexibility in design are desired. Numerous studies on the properly designed flat slabs and composite columns with adequate reinforcement can offer good structural strength and durability and also resists to earthquake loads. This paper focuses on broad literature review based on flat slabs and composite column helps to study of them in single paper

Keywords— Flat Slab, RCC Column, Composite Column, Composite Structure.

Department of Civil Engineering

Vision

To be a Civil Engineering programme of the first choice by the aspiring students and prospective employers by implementing world class education practices.

Mission

To meet the Vision, all stakeholders of this programme are committed towards Outcome Based Education Philosophy by

1. Adopting vibrant academic curricula and implementing innovative teaching learning processes.
2. Providing opportunities to the students for the development of professional skills.
3. Nurturing critical thinking and creativity in students.
4. Inculcating in students the life-long learning attitude and sensitivity towards society & environment.

About Civil Engineering Department

The Department of Civil Engineering was the first inchoative discipline at Walchand College of Engineering, Sangli and the oldest in Southern Maharashtra region. The Department offers Bachelor's Degree in Civil Engineering (B.Tech.) and two programmes leading to Master's degree (M.Tech.) in Civil engineering with specialization of Environmental Engineering and Structural Engineering adequately supported with doctoral programmes in Civil Engineering. The department has been accredited for five years by NBA consistently twice since 2003. Recently, the maximum accreditation of 6 years was awarded by of NBA in its Cycle 3 of accreditation to UG program of Civil Engineering.

The Department is known for its reputed faculty having expertise in diverse fields. The department continues to strive loftier by exploring new frontiers of civil engineering, imparting the latest technical knowledge to the students and conducting high quality of research which renders technical advice on live engineering problems in the field of Environmental Engineering to various Government and Private Sector organizations throughout the state. It has built up a wide research potential in Environmental Engineering, Geotechnical Engineering, Structural Engineering, and Building Technologies. The research projects of the department are funded by various agencies such as Department of Science and Technology, All India Council for Technical Education (AICTE), and Maharashtra Pollution Control Board (MPCB).