

Volume 3, Book 4, 2024, IIP Series

Futuristic Trends in **Construction Materials & Civil Engineering**



Futuristic Trends in

CONSTRUCTION MATERIALS & CIVIL ENGINEERING

Volume 3, Book 4, 2024, IIP Series



Title of the Book: Futuristic Trends in Construction Materials & Civil Engineering

Edition: Volume 3, Book 4, 2024, IIP Series

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E- ISBN: 978-93-5747-676-8

Publisher, Printed at & Distribution by:

Selfypage Developers Pvt. Ltd.,
Pushpagiri Complex,
Beside SBI Housing Board,
K.M. Road Chikkamagaluru, Karnataka.
Tel.: +91-8861518868
E-mail: info@iipseries.org

IMPRINT: I I P Iterative International Publishers

PREFACE

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PART 1

Futuristic Trends in Construction Materials & Civil Engineering

Series Id: IIPV3EBS05_G21

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AN OVERVIEW OF WASTE MATERIALS USED AS SOIL STABILIZERS FOR SUSTAINABLE DEVELOPMENT

Abstract

Soil is the base of any construction, so for any construction activity engineers cannot construct their structure on soil of less strength. It becomes very important to stabilize soil so that it can bear the load of the structure and keep the structure safe and sound. There are various waste materials, and rather than disposing of them, they can be used to improve soil strength like CBR, Tri axial, and UCS. This study investigates and analyze, upon mixing that material what are the change in the properties of soil. Various waste materials like Processed E-waste, Fly ash, Plastic Strips, Stone dust, Slag, Rise Husk, Bottom ash, Bagasse Ash, Coir fiber, Waste Tyre chips, Waste Glass, Sewage Sludge, Foundry Sand, Ash. These materials are readily available and easy to handle. These materials could be used as an alternative to various stabilizers. It can be used in multiple fields like soil stabilization, concrete production, brick manufacturing, improving soil quality, and manufacturing of cement. On comparing it was concluded that these materials are economically, efficient and eco-friendly compared to traditional methods.

Keywords: Stabilization, Sustainability, Waste utilization, Environment

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I. INTRODUCTION

United Nations has given various aspects of Sustainability which mainly focuses on the Economy, Environment, and Society. To measure sustainability there are some Targets and Indicators. In our environment, due to human activity, there is a continuous generation of waste material in the name of development. Development is good but not at the cost of the degradation of resources and humans. So, there is a need for sustainable growth. As far as waste generation is concerned, waste materials are somehow useful in one or another field of application. There is a need for more research on the utilization of waste to a large extent. There are many waste materials applied in construction activities and their performance is measured with respect to traditional materials used.

Due to the increasing standards of living, people rapidly generate waste products in humungous amounts. This rapid generation of waste attracts researchers from all over the world to the various methods for utilization of the different wastes such as bagasse ash, bagasse fibres, fly ash, bottom ash coir fiber, rice husk ash, bamboo fiber, E-waste, rubber tyres chips, plastics waste, etc, generated from industries such as sugarcane, agricultural, thermal power plants, electronics etc.

For the sustainable development of the world, these wastes should be handled in a scientific manner so that they do not cause problems for nature and human beings. This is the main challenge for our society, due to rapid population growth natural resources are being used blindly. This imposes the problem of deficient natural resources for the need of the construction industry. This causes the researchers to pay attention to the use of alternate sources, which are not harmful to environmental sustainability. These wastes are used as a replacement in Highway construction, Railways, Skyscrapers, landfills, etc. In highway construction, these wastes are used as a soil replacement in some amount so that it reduces the cost of construction and it also diminishes environmental degradation. This also enhances the desirable properties such as CBR, Shear Strength, and Bearing capacity of the parent soil. The use of these wastes also reduces affinity towards the moisture content of the soil which results in less volumetric changes.

The waste generated from different sources and their sustainability encourages multi-disciplinary research and development and formulation relating to various technological developments and the challenges related to sustainability. Investigations were conducted on various fields such as civil engineering, environmental engineering, environmental science, Sustainable development, etc. It is to be noted here that the value of various waste used as a replacement for the parent material leads to the preservation of environment and natural resources, decreasing the accumulation of waste, diminishing air water, and soil pollution along with promoting environmental and socio-economic sustainability aspects.

As people are interested in the effects of climate change and the degradation of the environment consciously, many researchers put their interest towards the utilization of these wastes in various development projects and there are still many more waste materials remains that need proper attention.

Waste generated from different sources is accumulated at such a large amount in the current developing world. These wastes are generated from various industries such as

sugarcane, thermal power plant, plastic, electronics and agricultural industry. Firstly, the discarded material from various industries is gathered at specified locations. After sorting the various metals and non-metals from the discarded materials the non-metals part is utilised in various soil as a stabilizers. Disposal of these discarded waste materials is not easy with the old method of dumping in low-lying areas on the outskirts of the city. Different scientific methods should be adopted such as scientifically designed landfill with different covers on top layers after dumping. Disposal of medical waste is not easy as it may contain hazardous ingredients in it. If medical waste generated is dumped without scientific approaches it becomes very hazardous for the local environment. So, for sustainable development growth, scientifically describe approaches such as one adopted in Madhya Pradesh capital Bhopal City Municipal Solid Waste Management techniques can be adopted. Various waste materials which are used in this study E-waste Bottom Ash, Fly ash, Plastic Strips, Stone Dust, Slag, Rice Husk/coffee husk, Bagasse Ash, Coir Fibres, Waste tyre chips, Waste Glass, Sewage Sludge, Foundry sand etc. These wastes are used in different types of soil in various proportions for soil stabilizers. The characteristics of different discarded materials as waste resembles in such a way that it can be used as a soil stabilizer in different types of soil such as clay, silt and sand. Studying the various materials properties identified such as tensile strength, compressive strength, flexural strength, shear strength, and bearing capacity is being used to enhance the desirable properties of soil. Clayey Soil shows variation in moisture content as swelling and shrinkage. This causes many problems for the structures built on these types of soils. With the blending of these wastes in the soil these problems reduce to a great extent. Different experiments should be performed on soil in order to determine the various properties such as Atterberg limits, specific gravity, permeability, compaction characteristics, shear strength parameters, CBR value etc.

II. LITERATURE REVIEW

For this study, various research results were considered. Many experimental works were analysed and conclusions were drawn out from them. (Venkatesan and Vasudevan, 2022) analysed when cement is replaced with bagasse ash in different ratios as 10 to 20 % of bagasse ash with the blending of 1 & 2 % of bagasse fibre engineering properties are improved and also analysed application in agricultural waste utilization. (Kabari1 et al., 2018) defined stabilization of black cotton lateritic soils, fibre ash, and cement in combined actions, in Niger. Concluded that the swelling potential of treated soil decreased with the inclusion of fibre ash up to 7.5% + 7.5% for both soils. (Nnaji et al., 2020) in the country of Niger, black soil, lime, and bagasse fibre were used to stabilize clayey soils. This concluded that CBR increased with increase in additives inclusion with optimum mix of 0.75% + 7.5%. Cracks noticed occurred beyond the optimum level mix. (Naresh et al., 2022) This research emphasizes on improving the properties of laterite soil by blending coconut coir's fibres at different ratios viz., 0.25%, 0.5%, 0.75%, and 1%, which are obtained from coconuts serving as natural fibre for improving the strength properties of soil. It was found that at 0% blending of coconut coir fibre maximum liquid and plastic limits were determined and with every enhancement in the coir content the desirable properties such as plasticity index, unconfined compressive strength and California Bearing Ratio strengths were enhanced. (Pachauri et al., 2016) Improvement in ground with the blending of fibre-reinforced soil has been utilized in recently. However, with increasing concerns for sustainable development, researchers are encouraged to determine alternative forms of reinforcement than the main material which is in use. The fibre ratio blended with the soil at 0.5%, 0.75% and 1% of the dry weight of the

soil. Many tests of unconfined compressive strength (UCS) were performed to obtain the strength characteristics of the soil. The reinforcement results in an enhancement in the strength of the soil-coir fibre composite. Researchers (Kannan and Kumar, 2017) worked on bottom ash and studied for its suitability as the replacement for fine aggregate up to (0% to 50%). So far only a few researchers determined its suitability as FA by determining the compressive strength of concrete. Along with compressive strength, the split tensile strength of concrete and flexural strength of concrete was identified by replacing bottom ash with fine aggregate. The main aim of (Meh et al., 2022) is to identify the alternate solutions to the environmental causes due to large amounts of coal bottom ash (CBA) industrial waste. The CBA utilized in this experiment was classified as Class C according to its total mixture of about 55.53%. It contains pozzolanic materials and has a more calcium content. Since bottom ash has a high calcium concentration, this helps in the enhancement of C-S-H gels with large cementitious characteristics, resulting in improved strength performance.

There are tonnes of waste material that are produced on a daily basis. Reutilizing them is a demand of the near future. With present technology various materials are utilized in construction works, soil stabilization and production of bricks but their proportion is very low. So, there is a requirement for more research and technological advance in using these materials on a larger scale and exploring other fields for waste utilization.

III. MATERIALS

- 1. E-Waste:** E-waste, or electronic waste, refers to discarded electronic devices and equipment which is generated either from household devices or from industries. This is due to either they are out of service or outdated in terms of technology. The amount of e-waste generated worldwide is increasing rapidly (Doan et al., 2019). According to a report by the United Nations University, approximately 53.6 million metric tons of e-waste were generated worldwide in 2019, with an expected increase to 74.7 million metric tons by 2030. This shows a significant problem in the environment, e-waste when left on an open field over time, contaminates the surface and groundwater with heavy metals like lead, mercury, and cadmium (Mishra et al., 2023). To address this issue, various disposal and recycling methods have been developed to reduce the negative impact of e-waste on the environment (Ardi and Handafiah, 2019).



Figure 1: Processed E-Waste

E-waste can be recycled to recover valuable metals, gold, silver, copper, palladium, plastics, and glass reducing the need for raw materials in industries and providing a sustainable source of raw materials. Refurbishment and reuse: Functional electronic devices can be refurbished and reused, extending their useful life and reducing the need for new devices (Kahhat et al., 2022; Mishra et al. 2023). E-waste can be disposed of in a landfill, but this is not a sustainable solution as it can lead to the release of hazardous materials into the environment.

2. Bottom Ash: Bottom ash is produced from the incineration of solid waste which is formed from municipal solid waste (MSW) incinerators. It is leftover of the combusted waste. As urbanization is on rapid growth so is the production of Bottom ash. According to a report by the Central Pollution Control Board (CPCB), the total generation of municipal solid waste (MSW) in India in 2019-2020 was estimated to be around 1,50,000 tonnes per day. Bottom ash is a byproduct of coal combustion that can be beneficially reused in various applications and disposed of in several ways (Kannan and Kumar, 2017; Ganesan et al. 2023; Plan et al., 2018). Bottom ash has a similar structure to sand which is porous (Meh et al., 2022). The use of bottom ash in road construction, landscaping, and manufacturing provides environmental and economic benefits while landfilling and other disposal methods should be minimized to reduce their environmental impact. (Kannan and Kumar, 2017) upon experimental investigation explained as the percentage of bottom ash increases in concrete density decreases so as the split strength of concrete. (Ganesan et al., 2023). Bottom ash upon mixing with soil (Phoak et al, 2018; Zhang, 2022) improves soil condition in terms that include a high plastic index, high free swell index, low UCS, and low CBR of pure soil with the addition of different percentages like 10%, 15%, 20%, 25%, and 30% by dry weight of soil. (Petrov and Stefanova, 2022; Hauashdh et al., 2011) concluded that bottom ash could be used in road filling.

3. Fly Ash: Fly ash is a by-product of burning coal in thermal power plants. It is a fine powder that is carried away by the flue gases and collected by electrostatic precipitators or bag filters. Fly ash contains various components such as silica, alumina, iron, and calcium, which make it useful in various applications. However, fly ash can also be harmful to the environment and human health if not managed properly.

According to the World Bank, global fly ash production was estimated to be around 780 million tonnes in 2016. China is the largest producer of fly ash, followed by India and the United States. India with its high population required abundant of electricity. Coal is one of the major sources of generation of electricity, by burning of coal it produces fly ash.



Figure 2: Fly Ash

The main properties which fly ash possess is high water retention, no shrinkage, low permeability, low thermal conductivity. It can be used beneficially in various applications, such as cement and concrete production, road construction, bricks, agriculture, and landfill cover. If not used beneficially, it can be disposed of in landfills, surface impoundments, or ash ponds, which must be managed carefully to prevent environmental contamination

- 4. Plastic Strips:** Plastic bottles are widely used for packaging beverages. The production, use, and disposal of plastic bottles have significant environmental impacts. According to a report by the Ellen MacArthur Foundation, the world produced over 480 billion plastic bottles, and this number is projected to reach 583.3 billion by 2021. Recycling and reuse are the most sustainable options for managing plastic bottle waste, while landfill and incineration should be used as a last resort.



Figure 3: Waste Plastic Strip from PET Bottle

A report published by the World Wildlife Fund (WWF), It is estimated that by 2050, the production of plastic will increase to 1,124 million tonnes. Plastic waste is a significant environmental issue that requires urgent attention to reduce its impact on the environment and human health. Plastic has various uses, but it is crucial to manage

plastic waste properly through recycling, landfilling, or incineration to minimize its negative impact on the environment.

5. **Stone Dust:** Stone dust, also known as quarry dust or rock dust, is a byproduct of the crushing of stones, according to a study by Kandhal et al. (2005), the generation of stone dust during the crushing process can range from 5% to 25% of the total weight of the rock being crushed. It is a fine-grained and low-strength material. Stone dust has several applications in the construction industry, including Concrete production: Stone dust can be used as a partial replacement for sand in the production of concrete. Road construction: Stone dust can be used as a filling material in road construction projects, especially for the sub-base and base layers. Landscaping: Stone dust can be used as a decorative material for landscaping and garden pathways.
6. **Slag:** Slag is a byproduct of the metallurgical and smelting industries, generated during the extraction and refining of metal ores. It is a glass-like material that can be granulated or crystallized, depending on the cooling process used. Slag has various applications in construction and engineering, and its utilization helps to reduce waste generation and the environmental impact of the metallurgical industry. According to a report by the International Energy Agency (IEA), the global production of steel increased from 851 million tonnes in 2000 to 1.87 billion tonnes in 2019, and it can be disposed of through recycling, landfilling, or reuse.
7. **Rice Husk/Coffee Husk Ash:** Rice husk and coffee husk are agricultural byproducts generated during the processing of rice and coffee, respectively. These husks are usually considered waste materials and are often burned, which leads to environmental pollution. The main properties of Rice husk ash are low thermal conductivity, high melting point, low bulk density, and high porosity. However, research has shown that these byproducts have various applications in agriculture, energy production, and other industries. A study by Demirbas (2005), the global production of rice husk was estimated at 130 million tonnes per year, while the global production of coffee husk was estimated at 7.5 million tonnes per year. They have various applications in agriculture, energy production, and construction. They can be disposed of through recycling, land application, or incineration.
8. **Bagasse Ash:** Bagasse ash is a byproduct of the sugarcane industry generated during the combustion of bagasse, which is the fibrous residue left after sugarcane juice extraction. It is Black in color, powder form material with irregular and rough texture. Generation of bagasse ash: According to a study by Kuo and Wu (2009), the global production of bagasse was estimated at 190 million tonnes per year, and the combustion of bagasse can generate approximately 25% of its weight as ash. It has several applications in agriculture, construction, and wastewater treatment. Its generation depends on the amount of bagasse burned and the combustion process used, and it can be disposed of through recycling, land application, or landfilling.
9. **Coir Fibres:** Coir fiber is a natural fiber extracted from the outer husk of coconut. It is a byproduct of the coconut industry. Coir fiber has several applications in various industries, including agriculture, construction, and textile manufacturing. However, improper disposal of coir fiber can lead to environmental pollution. According to a study

by Babu et al. (2016), the global production of coir fiber was estimated at 550,000 tonnes per year. it can be disposed of through recycling, land application, or composting.

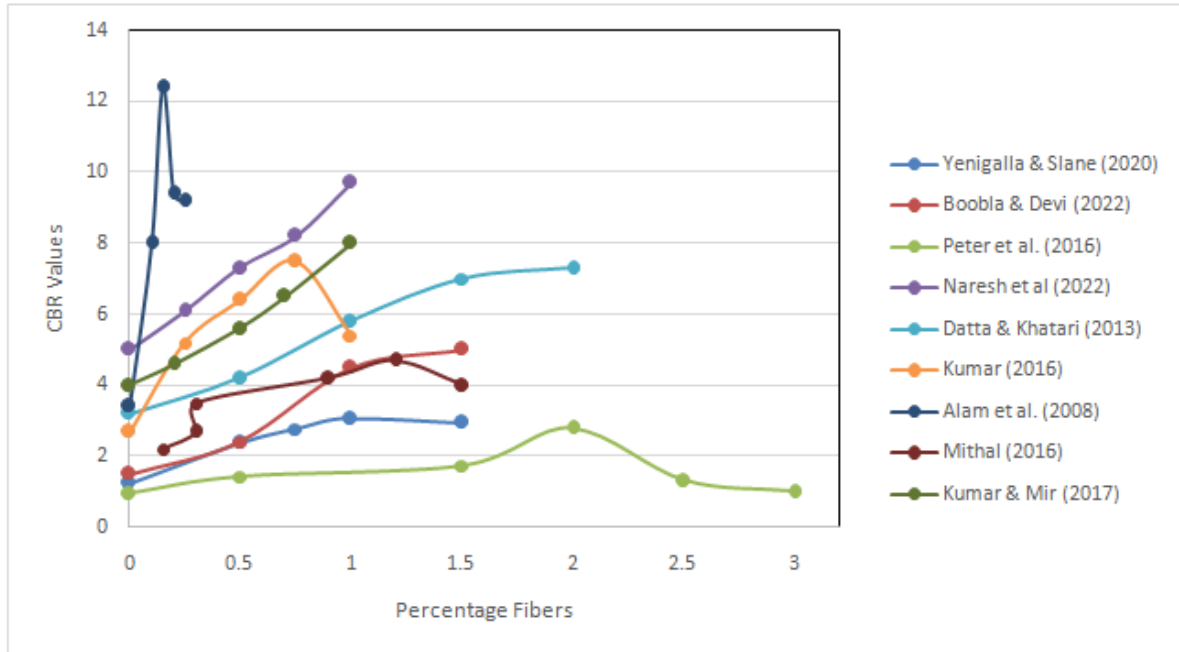


Figure 4: Effect of Fibers on CBR Values

The above graph shows the finding of various research on the effect of CBR values of soil when added with different proportions of fibers. It is also concluded that with the addition of fibers CBR value increases with long fibers permeability of soil decreases partially.

- 10. Waste Tyre Chips:** Waste tyre chips, also known as tyre-derived fuel, are small pieces of shredded tires used as fuel in various industries. The generation of waste tyre chips is a significant environmental challenge due to the large volume of tires discarded worldwide every year. Tyre chips are non-bio degradable, it has a low density and high shear strength. Proper disposal of waste tyre chips is crucial to prevent environmental pollution and promote sustainable development. According to a study by Kumar and Singh (2019), the global production of waste tires was estimated at 2.5 billion units per year, with approximately 75% of the discarded tires being either incinerated or landfilled.

- 11. Waste Glass:** Waste glass, also known as a cullet, is a byproduct of glass production and the disposal of glass containers. The generation of waste glass is a significant environmental challenge due to the large volume of glass discarded worldwide every year. Proper disposal of waste glass is crucial to prevent environmental pollution and promote sustainable development. a study by Soares et al. (2020), the global production of glass containers was estimated at 130 million tonnes per year, with approximately 30% of the discarded glass being recycled.

- 12. Sewage Sludge:** Sewage sludge is a semi-solid material that is generated during the treatment of wastewater. It is composed of organic and inorganic materials, including nutrients, pathogens, and heavy metals. The management and disposal of sewage sludge is an important environmental issue due to the potential health and environmental risks associated with its improper disposal. According to a report by the European Environment Agency (EEA) in 2021, around 12 million tonnes of dry sewage sludge are generated annually in the European Union. Sewage sludge can be used in various applications, including agriculture and energy recovery, and can be disposed of through land application, incineration, or landfilling.
- 13. Foundry Sand:** Foundry sand also known as green sand/ casting sand is high-quality silica sand that is used in the manufacturing of metal castings. American Foundry Society (AFS), predicts approximately 9 to 10 million tons of foundry sand are generated annually in the United States. India is the 4th largest casting producer with nearly 5000 foundry units. The management and disposal of foundry sand is an important environmental issue due to its potential impact on the environment and public health. It has the same properties as sand and it can be used as an alternate to river or sea sand in construction activities. Foundry sand can be used in various applications, road construction, landscaping and alternate construction material.

IV. METHODOLOGY

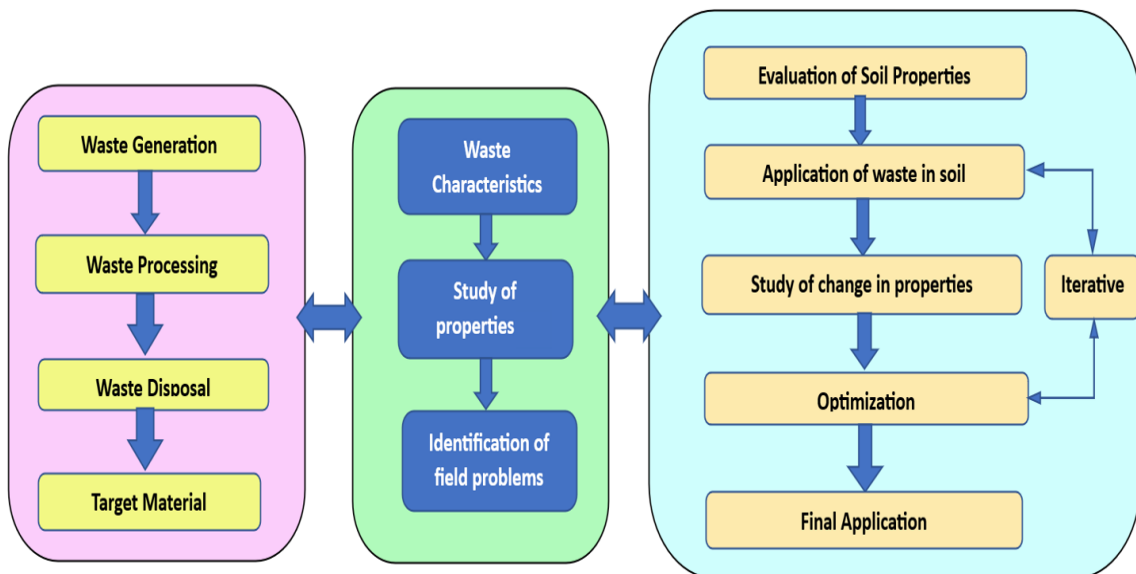


Figure 5: Methodology

The above methodology shows the process involved in this study. The whole process is defined in three blocks first is the generation of waste second is the technical analysis of waste material and last is the application of waste into the field, it can be soil stabilization, concrete manufacturing, agricultural application and many more.

First is the identification of waste material, the waste material that is generated from industries, factories or household waste. After the generation of the waste, the waste is

processed and then the most suitable way of disposal is selected. So, in the current study, those waste materials are selected which have engineering properties, which are identified by the researchers and are particularly targeted so that we can utilize them in solving engineering problems. The second block is the characterization of waste materials according to their properties, which could be grain size, shape, cohesion, porosity, activity and many more.

With the identification of field problems and selectively studying properties of waste material, they could be clubbed together to give possible solutions. As far as the geotechnical field is concerned there are many types of failures in soil due to lack of engineering properties in soil. So, to apply this waste material in soil stabilisation, the properties of waste material are important. When waste material and soil are blended the change in engineering properties of soil are noted and evaluated and continuous sampling and optimization techniques are applied to find the optimum dosage of waste material which will lead to the maximum improvement in engineering qualities. This is an iterative process, after various iterative processes the optimum dosage is determined. Once the lab results are evident, it is further applied to real-time field situations.

V. MATERIAL APPLICATION

This is the process of applying various materials in enhancing the required soil properties such as shear strength, bearing capacity, and reducing the chances of volumetric shrinkage. The properties of the materials used for this process should resemble the parent soil. The replacement of these wastes in different proportions reduces the cost of construction and it also helps in sustainable development. Various waste materials such as E-waste Bottom Ash, Fly ash, Plastic Strips, Stone Dust, Slag, Rice Husk/coffee husk, Bagasse Ash, Coir Fibres, Waste tyre chips, Waste Glass, Sewage Sludge, Foundry sand etc. are used in the different ratio in parent soil. The use of these wastes enhances the strength properties of soil.

The waste used in soil stabilization reacts chemically with the soil minerals and forms a bond, thus enhancing the engineering properties of different soil. Fly ash used with clay soil forms a stable compound that doesn't show its affinity towards moisture and thus reducing the chances of differential swell. Slag is effective in stabilizing sandy soils by improving their strength and reducing their compressibility. It is less effective in stabilizing clay soils. Recycled plastic is a waste material that is used for soil stabilization. It is effective in stabilizing sandy soils and reducing their permeability. It can also be used to prevent soil erosion.

Due to rapid development, the waste generated from various industries is quite high. That causes challenges in handling and disposal of these materials. So, for the proper disposal of these wastes government bodies made different sets of rules. Despite these rules, the handling and disposal of these waste is not easy. So, for that, scientific community gives the idea of using these materials as a replacement for soil stabilization and it also helps in environmental sustainability.

Table 1: List of Waste Material Applications

Waste	Source	Applications
1. E-waste	Electronic Devices consist of metals, plastics, glass, ceramics, and various hazardous substances	<ol style="list-style-type: none"> 1. Mining of precious metals 2. Reuse of plastic in manufacturing 3. Manufacturing of bricks 4. Stabilization of soil 5. Used in concrete 6. Bitumen mix design 7. Improving CBR value of Soil
2. Bottom Ash	Waste-to-Energy Facilities, Power plants, coal furnace	<ol style="list-style-type: none"> 1. Constructions of roads 2. Landfill cover 3. Landfill liner 4. Manufacturing of Blocks 5. Concrete mix design
3. Fly ash	Thermal power plants	<ol style="list-style-type: none"> 1. Manufacturing of cement 2. Construction of roads 3. Manufacturing of masonry blocks 4. Concrete production 5. Agricultural sector 6. Synthesis of Zeolites 7. Absorbent in water treatment 8. Black cotton soil stabilization
4. Stone Dust	Marble Industries	<ol style="list-style-type: none"> 1. Production of concrete 2. Base layer in stone pavement 3. Mortar preparation 4. Agriculture 5. plastering work 6. Soil stabilization
5. Plastic Strips	Plastic carry bags, disposable cups, PET bottles	<ol style="list-style-type: none"> 1. Bricks 2. Concrete production 3. Soil stabilization 4. Road construction
6. Slag	Blast furnace	<ol style="list-style-type: none"> 1. Road construction 2. Concrete 3. Cement production

		4. Water and Wastewater Treatment
7. Rice Husk	Agricultural activities	<ol style="list-style-type: none"> 1. Fertilizers 2. Concrete 3. produce refractory bricks 4. Soil Improvement 5. Preparation of activated carbon 6. fillers of rubber 7. water purification
8. Coir Fibres	Coconut fibers	<ol style="list-style-type: none"> 1. Insulation panels 2. Packaging 3. Soil Stabilization 4. Household items 5. Landscaping and Gardening 6. Ropes and Netting
9. Waste tyre chips	Scrap tyre	<ol style="list-style-type: none"> 1. Soil reinforcement 2. Replacement of aggregates in concrete 3. Pavement constructions 4. Asphalt Mixtures 5. backfill against retaining walls
10. Waste Glass	Glass bottles	<ol style="list-style-type: none"> 1. Aggregates in concrete
11. Sewage Sludge	Sewage treatment plant	<ol style="list-style-type: none"> 1. Improve fertility of soil 2. Sustainable agriculture
12. Foundry sand	Foundry industries	<ol style="list-style-type: none"> 1. Concrete manufacturing
13. Bagasse Ash	sugar manufacturing industry	<ol style="list-style-type: none"> 1. Fertilizers 2. A Filler in Concrete 3. Glass-ceramic material 4. Geopolymers 5. Phillipsite zeolite synthesis

VI. CONCLUSIONS AND RECOMMENDATIONS

There are many waste materials applied in construction activities and their performance is measured with traditional materials. The use of waste material in suitable proportions enhances the desirable properties in soil and other building materials resulting in a decrease in environmental degradation and hence promoting sustainable development.

Waste material can be used in other fields fly ash is used in improving soil quality for agriculture, backfill, replacement in concrete, construction of embankments, and making bricks with all these rather than polluting and occupying space in landfill, it can be used in many efficient ways. All other materials analyzed E-waste, Fly ash, Plastic Strips, Stone dust, Slag, Rice Husk, Bottom ash, Bagasse Ash, Coir fibre, Waste tyre chips, Waste Glass, and Sewage Sludge Ash have the same condition rather than disposing of it can be used for manufacturing of bricks, stabilization of soil, production of concrete, improving CBR value of soil, manufacturing of cement, improving the fertility of soil, absorbent in water treatment and many more.

Now a day, the world is looking towards sustainable development the use of these waste materials gives desired results without causing any serious harm to the environment. It was proven that waste materials with advanced applications are more efficient than traditional materials in terms of economy and eco-friendly. Also, there are many other waste materials available that can be utilized by blending different wastes together with soil in various proportions.

With this study, many research gaps are encountered, and many future research work scopes are there. Further micro-level examination of the changes in soil, XRD, and SEM can be performed. For the large-scale application of waste materials, further research is needed on technical standardization and guidance by government bodies. For a larger application, supply chain management will be required between production and application. Long-term analysis is required for the impact of engineering properties in soil.

REFERENCES

- [1] American Foundry Society (AFS). (2017). Foundry sand facts for civil engineers. Retrieved from https://www.afsinc.org/files/Facts_for_Civil_Engineers.pdf
- [2] Ardi, R., Handafiah, F.: Mapping Electronic Waste Flows in Depok, West Java. IOP Conference Series: Earth and Environmental Science, 401(1). (2019). <https://doi.org/10.1088/1755-1315/401/1/012005>
- [3] Babu, S., Aravindan, S., & Ravindran, K. Coconut coir pith and fiber as potential resources for sustainable agriculture, environmental, and industrial applications: A review. *Journal of Cleaner Production*, 123, 1-18. (2016). doi: 10.1016/j.jclepro.2015.12.057
- [4] Blessing, E., Kennedy, C., Amgbara, T. O.: Effectual Use of Costaceae Lacerus Bagasse Fibre and Lime as Expansive Soil Stabilizer. *International Journal of Advances in Scientific Research and Engineering*, 4(11), 06–16. (2018), <https://doi.org/10.31695/ijasre.2018.32937>
- [5] Boobalan, S. C., Sivakami Devi, M.: Investigational study on the influence of lime and coir fiber in the stabilization of expansive soil. *Materials Today: Proceedings*, 60, 311–314. (2022). <https://doi.org/10.1016/j.matpr.2022.01.230>
- [6] Carvalho, L. M. C., Monteiro, F. F., Casagrande, M. D. T. : Large-scale direct shear testing in coir fibers reinforced sand. *Soils and Rocks*, 46(1). (2023). <https://doi.org/10.28927/SR.2023.002822>
- [7] Chatrabhuj, Maheshwari, UK.: Experimental Investigation of Different Type of Soils with Addition of Geofibers. *Journal of Geotechnical Engineering STM Journals*. 8(2), 13–20 (2021).
- [8] Demirbas, A. Potential applications of renewable energy sources, biomass combustion problems in boiler power systems and combustion related environmental issues. *Progress in Energy and Combustion Science*, 31(2-3), 171-192. (2005). doi: 10.1016/j.peccs.2005.02.002
- [9] Dixit, A., Nigam, M., Mishra, R. Effect Of Fly Ash On Geotechnical Properties Of Soil. *International Journal of Engineering Technologies and Management Research*, 3(5), 7–14. (2020). <https://doi.org/10.29121/ijetmr.v3.i5.2016.62>
- [10] Dutta R K, Khatri V.: Compaction and CBR behaviour of clay reinforced with NaOH treated coir fibres. 2013. Pg 430-438.

- [11] European Environment Agency (EEA). (2021). Waste statistics — sewage sludge statistics. Retrieved from <https://www.eea.europa.eu/data-and-maps/daviz/waste-statistics-sewage-sludge-statistics-4.1/waste-statistics-sewage-sludge-statistics-4.1-2>
- [12] Ganesan, H., Sachdeva, A., Petrounias, P., Lampropoulou, P., Sharma, P. K., Kumar, A.: Impact of Fine Slag Aggregates on the Final Durability of Coal Bottom Ash to Produce Sustainable Concrete. *Sustainability (Switzerland)*, 15(7). (2023). <https://doi.org/10.3390/su15076076>
- [13] Hamanaka, A., Sasaoka, T., Shimada, H., Matsumoto, S.: Amelioration of acidic soil using fly Ash for Mine Revegetation in Post-Mining Land. *International Journal of Coal Science and Technology*, 9(1). (2022). <https://doi.org/10.1007/s40789-022-00499-9>
- [14] Hauashdh, A., Radin Mohamed, R. M. S., Jailani, J., Abd Rahman, J.: Stabilization of Peat Soil Using Fly Ash, Bottom Ash and Portland Cement: Soil Improvement and Coal Ash Waste Reduction Approach. *IOP Conference Series: Earth and Environmental Science*, 498(1). (2020). <https://doi.org/10.1088/1755-1315/498/1/012011>
- [15] <https://www.aaaa-usa.org/What-is-Coal-Ash>
- [16] https://www.itu.int/en/ITU/Environment/Documents/Events/WGES_2020/Session_2/Global_E-waste_Monitor_2020.pdf
- [17] International Energy Agency. (2021). <https://www.iea.org/reports/steel>
- [18] Kahhat, R., Miller, T. R., Ojeda-Benitez, S., Cruz-Sotelo, S. E., Jauregui-Sesma, J., Gusukuma, M.: Proposal for used electronic products management in Mexicali. *Resources, Conservation and Recycling Advances*, 13. (2022). <https://doi.org/10.1016/j.rcradv.2022.200065>
- [19] Kai, K., Kannan, K., Vijaya Kumar, R.: An Experimental Study On Effective Utilization Of Bottom Ash, 5(6), 152. (2017). <https://doi.org/10.5281/zenodo.818491>
- [20] Kandhal, P. S., Parker, F., & Garcia, R. Stone Dust in Concrete: Effect on Compressive Strength. *Highway Research Record*, (193), 65-78. (2005). doi:10.3141/193-08
- [21] Katman, H. Y. B., Khai, W. J., Bheel, N., Kirgiz, M. S., Kumar, A., Benjeddou, O.: Fabrication and Characterization of Cement-Based Hybrid Concrete Containing Coir Fiber for Advancing Concrete Construction. *Buildings*, 12(9). (2022). <https://doi.org/10.3390/buildings12091450>
- [22] Kennedy, C., Paulinus, A. P., Amgbara, T. O.: Hybridized Composite Materials Effect on Stabilization of Soft Clay Soils in Niger Delta Stabilization of Deltaic Soils using Costus Afer Bagasse Fiber. *The Journal of Scientific and Engineering Research*, 5(10), 97–103. (2018).
- [23] Kumar P.S.: Investigation of glass fiber reinforcement effect on the CBR strength of cohesive soil a study on behaviour of suction caisson foundations. *Indian Geotechnical Conference*. 15-17 December 2016, IIT Madras.
- [24] Kumar P, Mir F A. Improvement in Subgrade Characteristics of Soil Reinforced with Jute Fiber. *International Journal of Innovative Research in Science, Engineering and Technology* 2017, Vol. 6, Issue 2, doi: 10.15680/IJRSET.2017.0602133.
- [25] Kumar, S., Singh, P.: Waste tire management and challenges: A review. *Journal of Cleaner Production*, 236, 117599. (2019). doi: 10.1016/j.jclepro.2019.117599
- [26] Kuo, W.-T., Wu, J.-H. Characterization and use of sugarcane bagasse ash as an agricultural soil amendment. *Journal of Environmental Management*, 90(8), 3013-3018. (2009). doi: 10.1016/j.jenvman.2009.04.018
- [27] Meh, K. M. F. K., Shahidan, S., Shamsuddin, S. M., Zuki, S. S. M., Senin, M. S.: An Experimental Investigation Of Coal Bottom Ash As Sand Replacement. *International Journal of GEOMATE*, 23(99), 17–24. (2022). <https://doi.org/10.21660/2022.99.3515>
- [28] Mishra, ON., Chatrabhuj, Prajapati, B.: Experimental Analysis of Bearing Capacity of Soil with Addition of Processed E-Waste. In: *2nd International Conference on sustainable materials and practices for built environment (SMPBE-2023)*, Jaipur. 19-20 Jan. (2023).
- [29] Mittal A. Effect of coir fibres on strength, thickness and cost of PMGSY roads. *IOP Conf Ser Mater Sci Eng*, vol. 1136, no. 1, p. 012042, Jun. 2021, doi: 10.1088/1757-899x/1136/1/012042
- [30] Munirwan, R. P., Munirwansyah, Marwan, Ramadhansyah, P. J., Kamchoom, V. :Performance of Coir Fiber Addition for Clay as a Sub-Grade for Pavement Design. *IOP Conference Series: Materials Science and Engineering*, 712(1). (2020). <https://doi.org/10.1088/1757-899X/712/1/012009>
- [31] Naresh, J., Kastro Kiran, V., Karthik Chary, T., Jayaram, M.: An investigation on stabilization of laterite soil using coconut coir fibres. *IOP Conference Series: Earth and Environmental Science*, 982(1). (2022). <https://doi.org/10.1088/1755-1315/982/1/012041>
- [32] Nik Daud, N. N., Aliff Rusdi, M.: Fly Ash Stabilized Lateritic Soil as Subbase Material: A Review. *Earth Science Malaysia*, 6(1), 15–23. (2022). <https://doi.org/10.26480/esmy.01.2022.15.23>

- [33] Nitish, S. S. S., De, S., Ramya, A. V. S. L., Kumar, G. S.: Comparative study on soil stabilization using industrial by products and coconut coir. *Journal of Physics: Conference Series*, 2040(1). (2021). <https://doi.org/10.1088/1742-6596/2040/1/012014>
- [34] Noaman, M. F., Khan, M. A., Ali, K., Hassan, A.: A review on the effect of fly ash on the geotechnical properties and stability of soil. In *Cleaner Materials* (Vol. 6). Elsevier Ltd. (2022). <https://doi.org/10.1016/j.clema.2022.100151>
- [35] Paulinus, A. P., Kennedy, C., Biamene Barine, N.: Performance of Expansive Soils Stabilized with Costaceae Lacerus Bagasse Fibre Ash and Cement Composition. *The Journal of Scientific and Engineering Research*, 5(10), 119–127. (2018).
- [36] Pederneiras, C. M., Veiga, R., de Brito, J.: Physical and mechanical performance of coir fiber-reinforced rendering mortars. *Materials*, 14(4), 1–15. (2021). <https://doi.org/10.3390/ma14040823>
- [37] Peter, L., Jayasree, P. K., Balan, K., Raj, S. A.: Laboratory Investigation in the Improvement of Subgrade Characteristics of Expansive Soil Stabilised with Coir Waste. *Transportation Research Procedia*, 17, 558–566. (2016). <https://doi.org/10.1016/j.trpro.2016.11.110>
- [38] Rusănescu, C. O., Rusănescu, M.: Application of Fly Ash Obtained from the Incineration of Municipal Solid Waste in Agriculture. In *Applied Sciences* (Switzerland) (Vol. 13, Issue 5). MDPI. (2023). <https://doi.org/10.3390/app13053246>
- [39] Salim, A. A., Bahaa, Z., Fattah, M. Y., Mohammed, Z. B., Fattah, M. Y.: Influence of Adding Plant Fly Ash on The Geotechnical Properties and Pollution of Sanitary Landfill Soil Finite element. *Engineering and Technology Journal*, 40(11). (2022). <https://doi.org/10.30684/etj.v40i11.1136>
- [40] Sivakumar Babu, G. L., Vasudevan, A. K.: Seepage Velocity and Piping Resistance of Coir Fiber Mixed Soils. *Journal of Irrigation and Drainage Engineering*, 134(4), 485–492. (2008). [https://doi.org/10.1061/\(asce\)0733-9437\(2008\)134:4\(485\)](https://doi.org/10.1061/(asce)0733-9437(2008)134:4(485))
- [41] Soares, D., Ferreira, V. M., Baptista, J. D. C., Lapa, N.: Glass cullet from municipal solid waste: A review on generation, characterization, and applications. *Waste Management*, 102, 475–491. (2020). doi: 10.1016/j.wasman.2019.11.014
- [42] Taiyab, A., Islam, N. N., Rahman, M.: Desiccation characteristics and direct tension attributes of thin clayey soil containing discrete natural fibers. *Soils and Rocks*, 45(4). (2022). <https://doi.org/10.28927/SR.2022.074421>
- [43] Tariq, K. A., Ahmad, J., Husnain, S. A., Ijaz, M. S.: Influence on compressive and tensile strength properties of fiber-reinforced concrete using polypropylene, jute, and coir fiber. *Journal of the Mechanical Behavior of Materials*, 32(1). (2023). <https://doi.org/10.1515/jmbm-2022-0263>
- [44] Trung Phan, N., Sengsingkham, T., Tiyyayon, P., Maneeintr, K.: Utilization of bottom ash for degraded soil improvement for sustainable technology. *IOP Conference Series: Earth and Environmental Science*, 268(1). (2019). <https://doi.org/10.1088/1755-1315/268/1/012043>
- [45] United Nations Environment Programme. (2018). Single-use Plastics: A roadmap for sustainability.
- [46] https://wedocs.unep.org/bitstream/handle/20.500.11822/25496/singleUsePlastic_sustainability.pdf?sequence=1&isAllowed=y
- [47] Venkatesan, P., Vasudevan, R.: Behaviour of Bagasse Ash and Bagasse Fibre in Concrete. *YMER Digital*, 21(02), 409–417. (2022). <https://doi.org/10.37896/YMER21.02/40>
- [48] Vikas Kumar, Pankaj Kumar.: Effect of partial cement replacement with sugarcane bagasse ash. *International Journal of Science and Research Archive*, 8(1), 781–787. (2023). <https://doi.org/10.30574/ijrsra.2023.8.1.0128>
- [49] World Coal Association. (2018). <https://www.worldcoal.org/resources/coal-and-fly-ash>
- [50] World Wildlife Fund. (2021). Plastic waste: facts & figures. <https://www.worldwildlife.org/stories/plastic-waste-facts-figures>
- [51] Yenigalla, R. V., Slaney, G. V.: Effect of Epoxy Resin on CBR Improvement of Soft Clayey Subgrade Mixed with Coconut Coir Fibres. *IOP Conference Series: Materials Science and Engineering*, 1112(1), 012020. (2021). <https://doi.org/10.1088/1757-899x/1112/1/012020>

PART 2

Futuristic Trends in Construction Materials & Civil Engineering

Series Id: IIPV3EBS05_G22

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VARIOUS ARTIFICIAL INTELLIGENCE TECHNIQUES IN CONCRETE FOR DETERMINING CRACKING IN CONCRETE

Abstract

Plastic shrinkage cracking is a common issue that can occur in concrete during the early stages of curing. It happens when the rate of evaporation from the surface of the concrete exceeds the rate at which moisture is being supplied to the concrete, resulting in a rapid loss of moisture and volume reduction. This, in turn, leads to the formation of cracks on the surface of the concrete. In the growing world of various technologies using the AI methods latest techniques are found for analyzing the cracking in concrete. Various parameters of cracking is determined by various techniques using the software tools and AI parameters. Researchers have found different methods. This study aims to create knowledge about few methods that are suggested to found the parameters of concrete cracking.

Keywords: AI Techniques, Plastic Shrinkage Cracking, Image analysis, Machine learning, Concrete.

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I. INTRODUCTION

Plastic shrinkage cracking is a problem encountered in the early stages of concrete curing. When freshly poured concrete is exposed to environmental factors such as high temperature, low humidity and wind, it undergoes a process called "plastic shrinkage". During this stage, the water on the surface of the concrete evaporates faster than it can be replaced by water coming out of the mix[1]. This causes the concrete surface to lose moisture rapidly, resulting in volume loss and the formation of cracks in the concrete surface. These cracks can be superficial or deep and can affect the integrity, aesthetics and long-term durability of the concrete. Plastic shrinkage cracks are usually shallow and can extend in different directions on the surface[2]. While they do not directly affect structural integrity, they can act as conduits for harmful substances such as water, chloride and other chemicals to enter the concrete, which can lead to many problems get worse over time.

1. AI in Plastic Shrinkage Cracking: The use of artificial intelligence (AI) in construction and civil engineering is gaining momentum to address a variety of challenges, including concrete problems such as plastic shrinkage cracking. AI can be used to analyze and predict the occurrence of cracks caused by plastic shrinkage, helping to better understand and mitigate this problem.

2. Causes of Plastic Shrinkage Cracking in Concrete

- **High Temperature and Low Humidity:** Hot and dry weather conditions increase the evaporation rate of water from the concrete surface, leading to rapid drying and shrinkage.[4]
- **Wind:** Wind exacerbates the evaporation rate, particularly in exposed areas, accelerating the onset of cracking.
- **Lack of Proper Curing:** Inadequate or improper curing methods, such as not covering the concrete or keeping it moist during the early stages, can increase the risk of plastic shrinkage cracking.
- **High Cement Content:** High cement content in the mix leads to higher shrinkage potential as it requires more water for hydration.
- **Low Water-to-Cement Ratio:** A low water-to-cement ratio results in less bleed water to offset evaporation, increasing the likelihood of cracking.

II. MEASURING TECHNIQUES USING AI

Civil engineering plays a crucial role in designing, constructing, and maintaining the infrastructure that shapes our modern world. With the advancements in Artificial Intelligence (AI), civil engineers are increasingly incorporating AI-based measuring techniques to enhance the efficiency, accuracy, and safety of their projects.[6] These techniques leverage AI algorithms and data analysis to process vast amounts of information, enabling engineers to make better-informed decisions and optimize various aspects of civil engineering projects. Artificial Intelligence (AI) can be employed to assist in monitoring and predicting plastic shrinkage cracking in concrete.[7] As per previous studies, few analysis techniques are as follows:

1. **Image Analysis:** AI algorithms can analyze images or videos of concrete surfaces to detect cracks automatically. By training AI models on large datasets of cracked and uncracked concrete surfaces, the system can learn to identify and quantify the extent of cracking accurately.
2. **Weather and Environmental Data Integration:** AI can be used to analyze weather forecasts and environmental conditions to predict the likelihood of plastic shrinkage cracking. By considering factors like temperature, humidity, wind speed, and solar radiation, AI models can provide early warnings for potential cracking events.
3. **Concrete Mix Design Optimization:** AI can assist in optimizing the concrete mix design to minimize shrinkage potential. By analyzing historical data and experimental results, AI algorithms can suggest the most suitable combination of materials to reduce cracking risks.
4. **Sensor Data Analysis:** AI can process data from embedded sensors in concrete structures. These sensors can measure parameters like moisture content, temperature, and strain. By analyzing this real-time data, AI models can detect trends and patterns indicative of plastic shrinkage cracking.
5. **Early Warning Systems:** Integrating AI with monitoring devices can create early warning systems. These systems can alert construction personnel or engineers when conditions are conducive to plastic shrinkage cracking, allowing them to take preventive measures promptly.
6. **Predictive Models:** AI algorithms, particularly machine learning, can be trained on large datasets of concrete mixes, environmental conditions, and past instances of plastic shrinkage cracking. By identifying patterns and correlations in the data, these models can predict the likelihood of plastic shrinkage cracking under specific conditions, enabling engineers to take preventive measures.

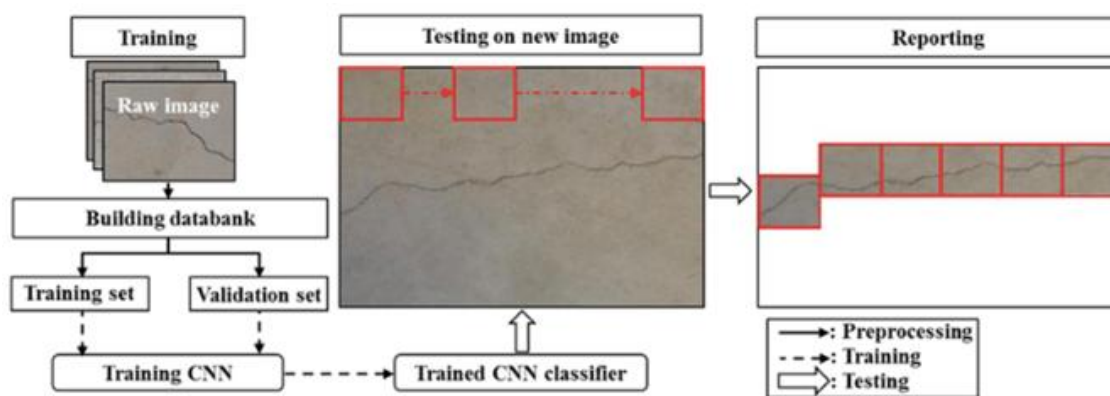


Figure 1

III. AI TECHNIQUES FOR CONCRETE DESIGN AND ANALYSIS

AI-powered sensors and monitoring systems can continuously collect data on concrete temperature, humidity, wind speed, and other relevant environmental factors. By analyzing

this real-time data, AI can alert construction teams about potential conditions that might lead to plastic shrinkage cracking, allowing for timely interventions. Researchers have worked on different forms of AI such as Machine learning, image processing, deep learning approach, IoT Real time monitoring etc. Overall, AI's ability to analyze vast amounts of data and recognize complex patterns makes it a valuable tool in predicting and mitigating plastic shrinkage cracking in concrete, improving the durability and longevity of concrete structures. AI can play a significant role in dealing with concrete cracking, including both plastic shrinkage cracking during the early stages and other forms of cracking that may occur later in the concrete's service life. Here are several ways AI can be utilized to address concrete cracking:

- 1. Optimization of Mix Designs:** AI algorithms can assist in optimizing concrete mix designs to make them more resistant to plastic shrinkage cracking. By considering various parameters like cement content, water-cement ratio, aggregate type, and chemical admixtures, AI can suggest mix proportions that are less susceptible to cracking.
- 2. Climate and Weather Analysis:** AI can analyze historical weather data and climate patterns to identify periods when plastic shrinkage cracking is more likely to occur. This information can be used to plan concrete placements during more favorable weather conditions, reducing the risk of cracking.
- 3. Guidance for Construction Practices:** AI systems can provide construction crews with real-time guidance on specific curing techniques and surface treatments that can minimize the risk of plastic shrinkage cracking.
- 4. Predictive Modeling:** AI can be used to develop predictive models that take into account various factors such as mix design, environmental conditions, curing methods, and construction practices. These models can assess the risk of concrete cracking and provide early warnings, enabling engineers and construction teams to take preventive measures.
- 5. Crack Detection Using Image Analysis:** AI-powered image analysis techniques can automatically detect and quantify cracks in concrete structures from photographs or videos. This can help in the early identification of cracks, allowing for timely repairs and maintenance.
- 6. Structural Health Monitoring:** By integrating AI with sensors embedded in concrete structures, continuous monitoring of the health of the concrete can be achieved. AI algorithms can process data from these sensors, detecting changes in strain, temperature, and other parameters that may indicate the onset of cracking or other structural issues.
- 7. Optimizing Mix Design:** AI can assist in optimizing concrete mix designs to minimize the risk of cracking. By analyzing data from previous projects and material properties, AI algorithms can suggest the best mix proportions and additives to improve concrete's durability and reduce cracking potential.
- 8. Automated Quality Control:** AI can be utilized for automated quality control during the concrete pouring process. By monitoring factors such as temperature, humidity, and

curing conditions, AI systems can ensure that the concrete is placed and cured optimally to minimize cracking risks.

- 9. Reinforcement Design:** AI algorithms can analyze complex data related to structural design and loading conditions to optimize the placement and configuration of reinforcements, reducing the likelihood of cracking due to excessive loads or structural inadequacies.
- 10. Learning from Historical Data:** AI can learn from historical data on concrete cracking incidents, identifying patterns and trends that might have contributed to the occurrence of cracks. This knowledge can be used to inform better construction practices and reduce the occurrence of similar issues in the future.
- 11. Decision Support Systems:** AI-based decision support systems can provide guidance to engineers and construction teams in selecting appropriate construction methods, materials, and maintenance strategies to prevent or mitigate cracking in concrete structures.

IV. CONCLUSION

In summary, AI's capabilities in data analysis, predictive modeling, image recognition, and learning from historical data make it a valuable tool in understanding and addressing concrete cracking issues. By leveraging AI technologies, engineers and construction professionals can enhance the durability and performance of concrete structures, leading to safer and longer-lasting infrastructure. AI technologies have significantly improved the accuracy, efficiency, and safety of concrete-related processes, leading to enhanced project outcomes and reduced costs. The benefits of AI in concrete works extend beyond calculation accuracy. AI-driven systems can continuously learn from past projects, leading to continuous improvement and refinement of concrete mix designs and construction practices. Moreover, AI-enabled solutions provide real-time monitoring and analysis of concrete curing and setting processes, allowing for immediate adjustments and minimizing the risk of defects or structural weaknesses. However, despite the significant advantages, the successful implementation of AI in concrete works relies on addressing some challenges. Data privacy and security concerns, the need for skilled AI professionals, and the cost of adopting AI technologies are some of the hurdles that the industry must navigate.

In conclusion, AI's integration in concrete works has revolutionized the construction sector, offering remarkable improvements in efficiency, accuracy, and overall project quality. As the technology continues to evolve, we can expect AI to play an increasingly crucial role in shaping the future of concrete construction, making it more sustainable, cost-effective, and resilient. Embracing AI in this field presents a promising path towards a smarter and more innovative construction industry.

REFERENCES

- [1] R. Chatterjee, A. Chatterjee, S. Roy and M. K. Gourisaria, "A Fast and Effective Machine Learning Approach for Road Cracks Classification," 2022 IEEE 19th India Council International Conference (INDICON), Kochi, India, 2022, pp. 1-6, doi: 10.1109/INDICON56171.2022.10039911.

- [2] Shouxing Wang, Yao Tang, Xusi Liao, Jiang He, Haoliang Feng, Hongzan Jiao, Xin Su, Qiangqiang Yuan, "An Ensemble Learning Approach with Multi-depth Attention Mechanism for Road Damage Detection", 2022 IEEE International Conference on Big Data (Big Data), pp.6439-6444, 2022.
- [3] R. Fan et al., "Road Crack Detection Using Deep Convolutional Neural Network and Adaptive Thresholding," 2019 IEEE Intelligent Vehicles Symposium (IV), Paris, France, 2019, pp. 474-479, doi: 10.1109/IVS.2019.8814000.
- [4] Faisal Javed, Mohanad Muayad Sabri Sabri, Raid Alrowais, Ahmed M. Maglad, Machine learning based computational approach for crack width detection of self-healing concrete, *Case Studies in Construction Materials*, Volume 17, 2022, e01610, ISSN 2214-5095.
- [5] Abdel-Jaber, H., and B. Glisic. 2015. "Analysis of the status of pre-release cracks in prestressed concrete structures using long-gauge sensors." *Smart Mater. Struct.* 24 (2): 025038. <https://doi.org/10.1088/0964-1726/24/2/025038>
- [6] Alshammari TO, Pilakoutas K, Guadagnini M. Effect of Curing Methods on Plastic Shrinkage Cracking. *Construction Materials*. 2023; 3(2):244-258. <https://doi.org/10.3390/constrmater3020016>
- [7] Bertelsen, Ida & kragh, christian & Cardinaud, Guillemette & Ottosen, Lisbeth & Fischer, Gregor. (2019). Quantification of plastic shrinkage cracking in mortars using digital image correlation. *Cement and Concrete Research*. Volume 123. 10.1016/j.cemconres.2019.05.006.
- [8] A. Gh eitasi, D.K. Harris, M. Hansen, An experimental-computational correlated study for describing the failure characteristics of concrete across two scale levels : Mixture and structural component, *Exp. Mech.* (2018) 11-32. doi:10.1007/s11340-017-0319-6
- [9] Boshoff, W.P., Altmann, F., Adendorff, C.J. et al. A new approach for modelling the ingress of deleterious materials in cracked strain hardening cement-based composites. *Mater Struct* 49, 2285–2295 (2016). <https://doi.org/10.1617/s11527-015-0649-8>.
- [10] Liu Jiaping, 2021, "Evaluation Method and Mitigation Strategies for Shrinkage Cracking of Modern Concrete" Elsevier Journal for Civil Engineering Materials Engineering 7 pp 348–357.
- [11] Nishane Utkarsh, 2017 "Experimental Studies On Fiber Reinforced Concrete" *Int. Journal of Engineering Research and Application*, Vol. 7, Issue 5, part-2 , pp. 40-44.
- [12] Nguyen Cong Thang 2020 "Effect of Zeolite on Shrinkage and Crack Resistance of High-Performance Cement-Based Concrete" *Modeling of Cementitious Materials and Structures*, Aug 2020. pp
- [13] Sinha Deepa, 2014, "Comparison of Normal Concrete Pavement with Steel Fiber Reinforced Concrete Pavement", *Indian Journal of Applied Research*, Vol. 4 issue 8 ISSN-2249-555X.
- [14] Wang Jun-Yan, 2012, "Effect of shrinkage reducing admixture on flexural behaviours of fibre-reinforced cementitious composites", *Elsevier Journal Cement & Concrete Composites* 34 pp 443–450.
- [15] Bayasi, Z. 2002 "Application of Fibrillated Polypropylene Fibres for Restraints of Plastic Shrinkage Cracking in Silica Fume Concrete", *ACI Materials Journal*, Vol. 99, No. 4.
- [16] Mark G. Alexander, "Concrete Repair, Rehabilitation and Retrofitting III" 3rd International Conference on Concrete Repair, Rehabilitation and Retrofitting, ICCRRR-3, 3-5 September 2012, Cape Town, South Africa.
- [17] Abdel-Jaber, H., and B. Glisic. 2015. "Analysis of the status of pre-release cracks in prestressed concrete structures using long-gauge sensors." *Smart Mater. Struct.* 24 (2): 025038. <https://doi.org/10.1088/0964-1726/24/2/025038>. Google Scholar
- [18] ACI (American Concrete Institute). 2010. Guide to hot weather concreting. ACI 305R. Farmington Hills, MI: ACI. Google Scholar
- [19] ACI (American Concrete Institute). 2014. Specification for hot weather concreting. ACI 305.1. Farmington Hills, MI: ACI. Google Scholar
- [20] ACI (American Concrete Institute). 2016. Guide to external curing of concrete. ACI 308R. Farmington Hills, MI: ACI. Google Scholar
- [21] ACI (American Concrete Institute). 2019. Building code requirements for structural concrete. ACI 318R. Farmington Hills, MI: ACI.
- [22] ADAFRUIT. 2021. "Anemometer wind speed sensor." ADAFRUIT 1733. Accessed March 18, 2021. <https://cdn-shop.adafruit.com/product-files/1733/C2192+datasheet.pdf>. Google Scholar
- [23] Al-Fadhala, M., and K. C. Hover. 2001. "Rapid evaporation from freshly cast concrete and the Gulf environment." *Constr. Build. Mater.* 15 (1): 1–7. [https://doi.org/10.1016/S0950-0618\(00\)00064-7](https://doi.org/10.1016/S0950-0618(00)00064-7).
- [24] Banthia, N., and R. Gupta. 2006. "Influence of polypropylene fiber geometry on plastic shrinkage cracking in concrete." *Cem. Concr. Res.* 36 (7): 1263–1267. <https://doi.org/10.1016/j.cemconres.2006.01.010>. Google Scholar

- [25] Bendimerad, A. Z., E. Rozière, and A. Loukili. 2016. "Plastic shrinkage and cracking risk of recycled aggregates concrete." *Constr. Build. Mater.* 121 (6): 733–745. <https://doi.org/10.1016/j.conbuildmat.2016.06.056>. Google Scholar
- [26] Bertelsen, I. M. G., L. M. Ottosen, and G. Fischer. 2019. "Quantitative analysis of the influence of synthetic fibres on plastic shrinkage cracking using digital image correlation." *Constr. Build. Mater.* 199 (Apr): 124–137. <https://doi.org/10.1016/j.conbuildmat.2018.11.268>. Google Scholar
- [27] Bhalla, N., S. Sharma, S. Sharma, and R. Siddique. 2018. "Monitoring early-age setting of silica fume concrete using wave propagation techniques." *Constr. Build. Mater.* 162 (Dec): 802–815. <https://doi.org/10.1016/j.conbuildmat.2017.12.032>. Google Scholar
- [28] Boshoff, W. P. 2012. *Plastic shrinkage cracking of concrete, part 1: Guideline*. Stellenbosch, South Africa: Stellenbosch Univ. Google Scholar
- [29] BSI (British Standards Institution). 2000. *Concrete. Specification, performance, production and conformity. BS EN 206-1*. London: BSI. Google Scholar
- [30] Chao, A. 2011. "Investigation of portland cement concrete hydration behavior at its early age using embedded fiber optic temperature sensors." Doctoral dissertation, Dept. of Civil and Environmental Engineering, Univ. of Massachusetts Lowell. Google Scholar
- [31] Chen, Q., X. J. Zhang, W. L. Lim, Y. S. Kwok, and S. Sun. 2019. "High reliability, low latency and cost effective network planning for industrial wireless mesh networks." *IEEE/ACM Trans. Networking* 27 (6): 2354–2362. <https://doi.org/10.1109/TNET.2019.2947077>.
- [32] Junbiao Pang, Baocheng Xiong, Peiyu Li, Jiaqi Wu, "You Need Dilated Convolution for Pavement Crack Detection", 2022 China Automation Congress (CAC), pp.899-904, 2022.
- [33] Rajdeep Chatterjee, Ankita Chatterjee, Soham Roy, Mahendra Kumar Gourisaria, "A Fast and Effective Machine Learning Approach for Road Cracks Classification", 2022 IEEE 19th India Council International Conference (INDICON), pp.1-6, 2022.
- [34] Ting Cao, Lei Liu, Kan Wang, Junhuai Li, "A Fractional Integral and Fractal Dimension-Based Deep Learning Approach for Pavement Crack Detection in Transportation Service Management", *IEEE Transactions on Network and Service Management*, vol.19, no.4, pp.4201-4212, 2022.
- [35] Hui Yao, Yanhao Liu, Xin Li, Zhanping You, Yu Feng, Weiwei Lu, "A Detection Method for Pavement Cracks Combining Object Detection and Attention Mechanism", *IEEE Transactions on Intelligent Transportation Systems*, vol.23, no.11, pp.22179-22189, 2022.

TOWARDS SUSTAINABLE SOIL STABILIZATION: A REVIEW OF INNOVATIVE TECHNIQUES

Abstract

The innovative soil stabilization techniques, such as Portland cement, fly ash, and recycled tire rubber, are examined in this review research. Soil stabilization is an essential part of civil engineering, and this technique offers a lot of promise for enhancing soil quality for a variety of uses. While Portland cement is well known for improving load-bearing capacity and compressive strength, fly ash serves as a sustainable cementitious material that minimizes environmental impact. Additionally, adding scrap rubber from old tires makes soil more resilient and less brittle, especially under conditions of dynamic stress. The study addresses how various materials could cooperate to improve technical properties and promote environmentally friendly behavior. However, a number of challenges must be resolved, including figuring out the best dosage ratios and doing long-term performance assessments. Overall, this integrated approach offers a practical and long-term solution for effective soil stabilization, assisting in the development of stronger, more robust infrastructure.

Keywords: Soil Stabilization, Impact, Resilient, Fly Ash, Scrap rubber, Portland Cement, Stress.

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I. INTRODUCTION

Soil stabilization is important in civil engineering and construction because it comprises a wide variety of procedures targeted at improving the engineering qualities of soil. The major goals are to increase the soil's load-bearing capacity, minimize settlement, and enhance overall stability. Soil stability is critical because it directly affects the longevity and safety of critical engineering projects such as bridges, buildings, embankments, and dams. Weak or unstable soils offer considerable concerns such as settlement, subsidence, and potentially catastrophic collapses, putting lives in peril and generating significant financial losses. Engineers and builders face several challenges because of soil variability and unpredictability. Soil qualities, composition, and behavior are all influenced by geology, climate, and environmental factors. To solve these challenges and assure infrastructure projects' long-term efficacy and sustainability, efficient soil stabilizing solutions must be devised. The goal of soil stabilization is to transform ordinary soil into a robust and stable material that can endure external pressures including traffic loads, dynamic forces, and environmental impacts while safely holding high loads. Traditional techniques of soil stability include chemical and mechanical stabilization, as well as more new and ecologically friendly alternatives such as biological stabilization.

Chemical stabilization is the process of altering soil characteristics by injecting chemical substances such as lime, cement, fly ash, or other stabilizers into the soil to create a more stable matrix. Mechanical stabilization procedures, on the other hand, employ physical methods to compact or reinforce the soil, so improving its density and strength. Biological stabilization, on the other hand, is based on plant roots and vegetation binding and fortifying the soil, providing a natural and sustainable method of reducing and stabilizing soil erosion.

This study examination delves into the intricacies of soil stabilization, looking into the concepts, efficacy, benefits, and drawbacks of various approaches. Case studies of successful soil stabilization projects will be examined, with an emphasis on the practical applications and outcomes of these approaches. In consideration of the growing global concerns with building and environmental sustainability, understanding and creating soil stabilization technologies is becoming more and more crucial. Engineers and researchers may assist to build safer, more durable, and environmentally responsible infrastructure by understanding the complexities of soil behavior and the many stabilizing methods available.

The purpose of this research article is to provide light not only on the relevance of soil stabilization in current practices, but also on potential future developments in civil engineering. By integrating current knowledge and research, it strives to inspire new ideas and encourage the adoption of the most effective soil stabilization technologies, so promoting the expansion and sustainability of the built environment.

1. Positive Outcomes of Soil Stabilization: Numerous advantages of soil stabilization have a good effect on several facets of civil engineering, building, and environmental management. The following are some of the main advantages of soil stabilization:

- The strength and load-bearing capacity of the soil are improved by soil stabilization, enabling it to support larger loads with the least amount of settlement and distortion.

This benefit is especially important when building roads, highways, bridges, and other infrastructure under heavy traffic loads or dynamic pressures.

- **Reduced Settlement:** Because unstable soils frequently cause settlement problems, uneven and sometimes dangerous ground conditions result. Maintaining a level and stable surface is essential for ensuring the appropriate performance of buildings and pavements, and soil stabilization is an efficient way to accomplish this aim.
- **Effective soil erosion control** may be achieved by applying certain stabilizing techniques, such as biological stabilization utilizing plants. Because plant roots bind soil particles together to act as a natural erosion barrier, they may be employed to safeguard riverbanks, embankments, and coastal areas.
- **Soil stabilization improves the soil's general stability and toughness** by giving it resilience against a variety of factors such cyclic loading, weathering, and erosive impacts. Buildings may last longer and keep their structural integrity by maintaining stable soils, which eventually results in lower maintenance and repair expenditures over time.
- **Construction is completed more quickly** because soil stabilization increases the strength of the soil base. With faster project completion and less downtime during construction, efficiency has grown.

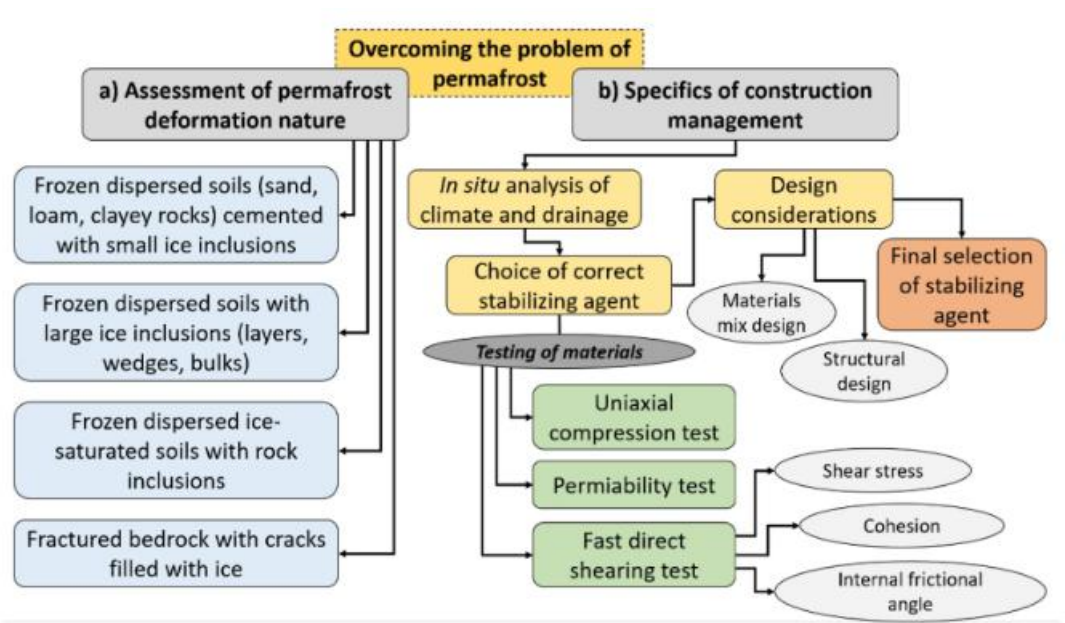


Figure 1: Permafrost Deformation Nature (a) and its Construction Management Specifics at Stabilization (b)

2. Possible Problems due to Stabilization: While soil stabilization has many advantages, it can also present certain obstacles and possible issues. These elements must be considered to guarantee successful implementation and to limit any negative consequences. Some potential issues with soil stabilization include:

- The stabilization procedure by itself could not totally reduce the dangers when dealing with contaminated soil that contains dangerous substances or contaminants. To successfully handle these pollutants, a complete site investigation and remediation may be necessary prior to stabilization.

- The permeability of the soil may be reduced by several soil stabilization techniques, particularly chemical stabilization. While this trait can be helpful in certain circumstances, it may also provide drainage issues in other circumstances.
- Prior to soil stabilization in the vicinity of existing structures or utilities, careful consideration is essential to avoid any negative impacts on their stability or proper functioning.
- When used to stabilize soil, cement, lime, and other chemical stabilizers can have a negative impact on the environment. When these materials are handled improperly, they may produce greenhouse gases during production or contaminate water.

II. MATERIALS USED FOR SOIL STABILIZATION

1. Soil Stabilization with Portland Cement: Portland cement is frequently used in civil engineering and building projects for soil stabilization. Portland cement may be used to strengthen and extend the life of soil by converting it into a cemented mass. It entails mixing Portland cement into the soil to improve its strength, durability, and load-bearing capability. According to the experimental findings, incorporating lime and cement in peat soil at mixing percentages ranging from 10% to 20% enhances its strength characteristics. Moreover, the peak shear stress is observed to rise, and the displacement also increases with the increment in normal stress.

2. Process of Soil Stabilization using Portland Cement:

- **Site Assessment:** It is the first step for soil stabilization. In this step we determine the type of the soil and its engineering behavior and the specific requirement of the project.
- **Soil Testing:** In this step we obtain the sample from the site and perform various laboratory and field for the determination of the Index and Engineering property of the soil.
- **Design mix:** Based on the result obtained from the various test performed on the soil we determine the appropriate mix of Portland cement to achieve the desired property of the soil. Design mix will specify the other additive (if required) to obtain desired property of the soil.
- **Spreading Portland Cement:** After the design mix, we spread the appropriate amount of Portland cement uniformly over the surface of the soil.
- **Mixing:** For the thoroughly mixing of the soil and the cement we use some methods such as (i). Mechanical mixing (ii). Pulverization. For deep soil stabilization the cement and the soil can be mixed by pulverizing the soil and adding cement simultaneously.
- **Water Addition:** For the activation of the cement's binding property, we use water in the mixture. Quantity of water need to carefully be controlled to achieve Optimum Moisture Content (OMC).
- **Compaction:** When the mixing is completed then we perform compaction on the soil using different compacting equipment (Vibratory Rollers, Sheepsfoot Rollers, Tamping Rollers, Pneumatic Rollers etc.) to achieve Desired property of the soil. Compaction improves the stability and strength of the soil.

- **Curing:** The purpose of the curing in soil stabilization to increase the formation of cementitious bonds, facilitate the proper hydration of cement particles and improving the strength of the soil. Curing also reduces the shrinkage and cracking in the soil.

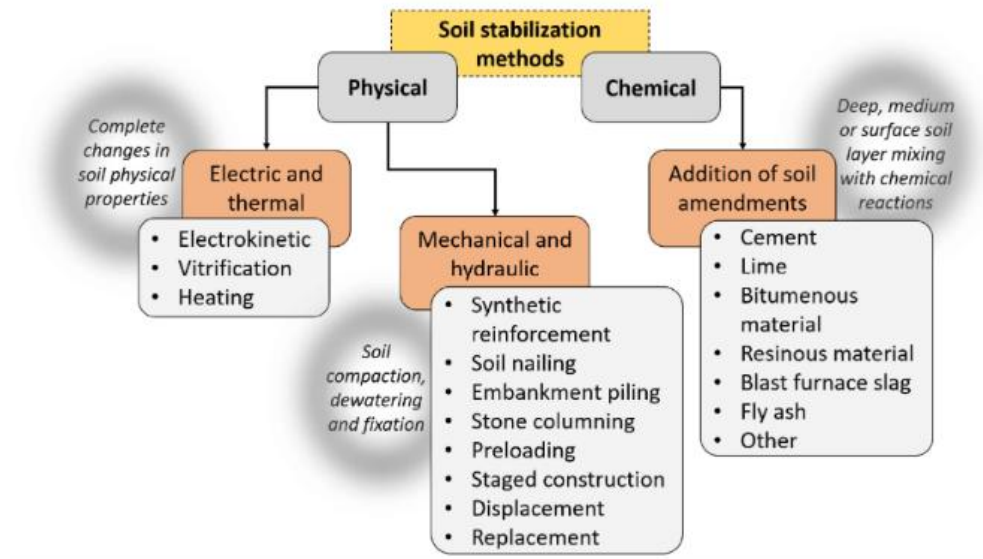


Figure 2: General Soil Stabilization Methods and their Impact on Soil

3. Soil Stabilization with Fly Ash: The powdery residue of burning coal in power plants, known as fly ash, is helpful for stabilizing soil. Pozzolanic properties make Class F, generated by burning anthracite or bituminous coal, and Class C, produced by burning sub-bituminous or lignite coal, both ideal for this usage. Class C, which contains a lot of calcium oxide, has better cementitious properties and needs less of it than Class F to be strong enough. The use of fly ash for soil stabilization aids in encouraging environmentally friendly waste recycling methods, sustainable construction, and environmental preservation by strengthening soil, reducing permeability, and strengthening soil.

4. Benefits of Incorporating Fly Ash for Soil Stabilization:

- The dry density and the moisture content of organic soil rise gradually when fly ash (classes C and F) is added.
- Unconfined compressive strength (UCS), pH values, liquid limit, plastic limit gradually increasing with the addition of the fly ash.
- The plasticity index decreases with the addition of the appropriate amount of fly ash in different organic soil.
- By the addition of the fly ash the Swelling and shrinkage properties of the various type of soil get reduced.
- The maximum dry unit weight and ideal moisture content both rise with the addition of fly ash.

5. Soil Stabilization with Scrap Tire: As a useful advancement for soil stabilization methods, rubber from old tires has shown a lot of potential. An innovative and eco-friendly solution to the issues concerning old tire disposal is to use them in construction projects. To enhance the engineering properties and general performance of soil, scrap tire rubber may be put into it in several ways. This article investigates the various applications and advantages of utilizing rubber from old tires to stabilize soil, emphasizing its potential to aid in the development of environmentally friendly infrastructure while solving waste management challenges.

6. Benefits of Incorporating Scrap Tire for Soil Stabilization:

- Issues with settling and failure of the bearing capacity of clayey soil exist. Rubber tire scraps from industrial trash may, up to a point, strengthen clayey soil.
- Rubber utilized in old tires has better compressive strength, compressibility, and swelling index properties.
- The use of 1 to 2 percent scrap tire rubber raises the maximum dry density (MDD) while reducing the ideal moisture level in clayey soil, reduces the void ratio, and minimizes compression and swelling.
- Through an addition of 2% scrap rubber tire, the compressive strength of the clayey soil increased thrice above the original soil.
- The incorporation of crumb rubber improves shear strength as when compared with dune sand alone. As the fraction of crumb rubber in the whole compound increases from 10% to 20%, the angle of internal friction increases from 31.3° to 32.75° .
- Rubber from discarded tires can increase CBR by up to 3%. CBR is reduced to less than 3% by increasing the rubber content in lateritic soil with a low plasticity index.

Therefore, the shear strength of dune sand is at its highest when there is a 20% crumb rubber content. The 10% crumb rubber powder increases the California bearing ratio of the black cotton soil. Nearly 10% of rubber powder is advised for black cotton soil.

III. RESULT AND DISCUSSION

1. Outcome of Soil Stabilization Using Portland Cement: The introduction of cement to the pore water of the soil leads to rapid hydration of the cement, resulting in the formation of hydrated calcium silicates (C_2SH_x , C_4AH_x) and hydrated lime $Ca(OH)_2$. Therefore, the soil's liquid limit is reduced [7]. According to the [9], incorporating lime and cement in peat soil at mixing percentages ranging from 10% to 20% enhances its strength characteristics. Moreover, the peak shear stress is observed to rise, and the displacement also increases with the increment in normal stress. Additionally, it has been shown that the displacement increases the normal stress and the peak shear stress.

In a study conducted by Oyediran and Kalejaiye (2011)[11], the impact of increasing cement content by weight on the strength and compaction parameters of lateritic soil was investigated. Three soil samples were collected from a pit and stabilized using cement at various percentages: 2%, 4%, 8%, 10%, and 20% by weight.

The results showed that as the cement content increased, the Maximum Dry Density (M.D.D), California Bearing Ratio (C.B.R), and Unconfined Compressive Strength (UCS) of the soil improved. Conversely, the Optimum Moisture Content

(O.M.C) decreased with increasing cement content. However, it was observed that adding more than 10% by weight of cement led to a decrease in M.D.D, UCS, and C.B.R, while causing an increase in O.M.C.

- 2. Outcomes of Soil Stabilization Using Fly Ash:** According to Bayshakhi Deb Nath , Md. Keramat Ali Molla, and Grytan Sarkar (Study on Strength Behavior of Organic Soil Stabilized with Fly Ash) [15] The pH values increase as fly ash concentration increases as a percentage, the dry density and moisture content increase with time, the liquid and plastic limits increase, and the plasticity index reduces the UCS. The strength of organic soil can be boosted by adding fly ash in the proper quantity. The amount of fly ash is influenced by the kind of soil classification.

According to Fusheng Zha , Songyu Liu Æ Yanjun Du Æ Kerui Cui (Behavior of expansive soils stabilized with fly ash) [16] The swelling and shrinking are lessened by treating the swelling black cotton soil with lime fly ash and fly ash. They assert that the maximum dry unit weight and ideal water content both fall when levels of fly ash and lime fly ash grow.

- 3. Outcomes of Soil Stabilization Using Scrap Tire:** According to A T Nazaruddin, M S Shakri, M A Ladin, M A Hafez, N F Abd Rahman, M Mohammad (Strength and consolidation index parameters of stabilise clay soil using scrap rubber tyre) [4] Clayey soil has issues with settling and losing its bearing ability. Rubber scrap tires (from industrial waste, etc.) may be used as a fix to solve the stabilizing problems only partially. These researchers claim that adopting this type of boosting technique improves compressibility, compressive strength, and swelling index properties. The maximum dry density is decreased while the optimal moisture content is increased, and the void ratio is decreased. Additionally, they reduce edema by 1% to 2%. The clayey soil's compressive strength quadrupled in comparison to the original soil when 2% recycled rubber tire was added. Nearly 2% is the recommended amount of old rubber tires as a stabilizer.

According to Ms. Deepti V. Zutting, Prof. (Dr.) P. L. Naktode (Soil Stabilization by using Scrap Tire Rubber)[17] Mixing recycled tire waste with poorly graded dune sand improves its engineering properties. Crumb rubber exhibits more shear strength in combination with sand than dune does on its alone. Crumb rubber is used to increase the internal friction angle. The internal friction angle steadily decreases from 30% to 100% crumb rubber content. Because of this, the shear strength of dune sand increases at 20% crumb rubber concentration but decreases at higher tire percentages. The addition of crumb rubber also lessens the mixture's weight, which lowers the lateral earth pressure.

According to Ms. Rajvinder Kaur, Er. Dalvir Singh (tyre rubber powder as a soil stabilizer)[18] Black cotton soil gains more shear strength when crumb rubber powder is added, around 10% more specifically. Crumb rubber powder increases the CBR value of the soil by 10%, making 10% the appropriate amount for soil stabilization in black cotton. When the powder content is increased over the ideal level, the soil's strength gradually decreases.

According to Ibrahim, M. T , Osinubi, K. J ,Umar, S. Y (Stabilization of Lateritic Soil with Scrap Tyre Crumb Rubber) [19] Scrap tire crumb rubber raises the

California bearing ratio by 3% when applied in lateritic soil with a low plasticity index, but after that point, CBR decreases because of an increase in rubber composition. Unsoaked CBR saw increases of 70.50%, 69.70%, and 78.40%, whereas wet CBR experienced increases of 71.00%, 67.90%, and 76.60%.

IV. CONCLUSION

Introduction of cement to soil pore water leads to rapid hydration and formation of hydrated calcium silicates and hydrated lime, reducing the soil's liquid limit.

- Incorporating lime and cement in peat soil at 10% to 20% mixing percentages enhances strength characteristics, with increased peak shear stress and displacement under higher normal stress.
- Increasing cement content in lateritic soil improves Maximum Dry Density (M.D.D), California Bearing Ratio (C.B.R), and Unconfined Compressive Strength (UCS), but adding more than 10% by weight of cement can lead to a decrease in M.D.D, UCS, and C.B.R while increasing Optimum Moisture Content (O.M.C).
- According to research on soil stabilization with fly ash, the parameters of the soil are improved, including pH values, dry density, moisture content, plasticity index, and Unconfined Compressive Strength (UCS). Fly ash can strengthen organic soil and lessen expansive soils' propensity to expand when added properly.
- The research highlights fly ash's potential as a workable and eco-friendly stabilizing agent, providing promising answers for enhancing soil stability and performance in construction applications.
- Scrap rubber tire stabilization improves clayey soil's compressibility, compressive strength, and swelling index properties.
- Adding crumb rubber to dune sand enhances shear strength and lowers lateral earth pressure.
- Crumb rubber powder increases black cotton soil's shear strength and CBR value, but excessive content can lead to reduced strength.
- In lateritic soil, scrap tire crumb rubber increases CBR up to a certain point, beyond which it starts to decrease.

Further study may look at the resilience and long-term effectiveness of soil stabilization using old rubber tires in a variety of climatic conditions. Insightful information for use in real-world civil engineering projects might also be gained by analyzing the cost-effectiveness and potential environmental implications of various stabilizing procedures.

REFERENCES

- [1] Nath, B. D., Molla, M. K. A., & Sarkar, G. (2017). Study on strength behavior of organic soil stabilized with fly ash. *International scholarly research notices*, 2017.
- [2] Zha, F., Liu, S., Du, Y., & Cui, K. (2008). Behavior of expansive soils stabilized with fly ash. *Natural hazards*, 47, 509-523. <https://doi.org/10.1007/s11069-008-9236-4>
- [3] Huat, B. B., Prasad, A., Asadi, A., & Kazemian, S. (2014). *Geotechnics of organic soils and peat*. CRC press.
- [4] Nazaruddin, A. T., Shakri, M. S., Ladin, M. A., Hafez, M. A., Abd Rahman, N. F., & Mohammad, M. (2023, June). Strength and consolidation index parameters of stabilise clay soil using scrap rubber tyre. In *IOP Conference Series: Earth and Environmental Science* (Vol. 1205, No. 1, p. 012056). IOP Publishing.

- [5] Zutting, D. V., &Naktode, P. L. (2020). Soil stabilization by using scrap tire rubber. *International Journal of Engineering Research And*, 9.
- [6] Kaur, M. R., & Singh, E. D. (2019). Tyre Rubber Powder as a Soil Stabilizer. *International Research Journal of Engineering and Technology*, 6(6), 1786-1791.
- [7] Ibrahim, M. T., Osinubi, K. J., Umar, S. Y., Joshua, A., Jagaba, A. H., & Soja, U. B. (2023). Stabilization of lateritic soil with scrap tyre crumb rubber. In *Sustainability Challenges and Delivering Practical Engineering Solutions: Resources, Materials, Energy, and Buildings* (pp. 185-193). Cham: Springer International Publishing.https://doi.org/10.1007/978-3-031-26580-8_28
- [8] Huat, B. B., Maail, S., & Mohamed, T. A. (2005). Effect of chemical admixtures on the engineering properties of tropical peat soils. *American journal of applied sciences*, 2(7), 1113-1120.
- [9] Bharti, M. K., Sharma, M., & Islam, N. (2020). Study on the Dam & Reservoir, and Analysis of Dam Failures: A Data Base Approach. *Int Res J Eng Technol*, 7(5), 1661-1669.
- [10] Zambri, N. M., &Ghazaly, Z. M. (2018). Peat soil stabilization using lime and cement. In *E3S Web of Conferences* (Vol. 34, p. 01034). EDP Sciences.
- [11] Rawat, S., Patel, P., Pal, S., Yadav, S. S., Krishna, S., & Sharma, M. Comparative Performance Evaluation of Fiber Reinforced Concrete & Conventional Concrete.
- [12] Oyediran, I. A., &Kalejaiye, M. (2011). Effect of increasing cement content on strength and compaction parameters of some lateritic soils from southwestern Nigeria. *Electronic Journal of Geotechnical Engineering*, 16(2), 1501-1514.
- [13] Sharma, M., Ansari, M. I., & Islam, N. (2022). Study of Concrete Filled Unplasticized Poly-Vinyl Chloride Tubes as Columns under Axial Loading. *Journal of Mechanical Materials and Mechanics Research*, 5(1), 10-17.
- [14] Sharma, M., Ansari, M. I., & Islam, N. (2023, September). Effect of strong ground motion on the dynamic response of concrete gravity dam based on linear correlation analysis. In *AIP Conference Proceedings* (Vol. 2888, No. 1). AIP Publishing.
- [15] Nath, B. D., Molla, M. K. A., & Sarkar, G. (2017). Study on strength behavior of organic soil stabilized with fly ash. *International scholarly research notices*, 2017.
- [16] Zha, F., Liu, S., Du, Y., & Cui, K. (2008). Behavior of expansive soils stabilized with fly ash. *Natural hazards*, 47, 509-523.
- [17] Ms. Deepti V. Zutting, Prof. (Dr.) P. L. Naktode Soil Stabilization by using Scrap Tire Rubber
- [18] Kaur, M. R., & Singh, E. D. (2019). Tyre Rubber Powder as a Soil Stabilizer. *International Research Journal of Engineering and Technology*, 6(6), 1786-1791.
- [19] Ibrahim, M. T., Osinubi, K. J., Umar, S. Y., Joshua, A., Jagaba, A. H., & Soja, U. B. (2023). Stabilization of lateritic soil with scrap tyre crumb rubber. In *Sustainability Challenges and Delivering Practical Engineering Solutions: Resources, Materials, Energy, and Buildings* (pp. 185-193). Cham: Springer International Publishing.https://doi.org/10.1007/978-3-031-26580-8_28
- [20] Vincevica-Gaile, Z., Teppand, T., Kriipsalu, M., Krievans, M., Jani, Y., Klavins, M., ... &Burlakovs, J. (2021). Towards sustainable soil stabilization in peatlands: Secondary raw materials as an alternative. *Sustainability*, 13(12), 6726.<https://doi.org/10.3390/su13126726>

PART 3

Futuristic Trends in Construction Materials & Civil Engineering

Series Id: IIPV3EBS05_23

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ANCIENT INDIAN ARCHITECTURE: A GLORIOUS TAPESTRY OF SPIRITUAL AND ARTISTIC MASTERY

Abstract

Ancient Indian architecture is evidence of the Indian subcontinent's rich cultural heritage and artistic prowess. This chapter delves into the fascinating realm of Indian architectural traditions, exploring the key characteristics, spiritual underpinnings, lasting influence of this extraordinary architectural legacy, and the significance they hold in contemporary times. Through a comprehensive analysis of ancient architectural features, including monumental structures, intricate ornamentation, and advanced construction techniques, this chapter shed light on the engineering prowess exhibited by ancient civilizations. It also underscores the harmonious fusion of art, science, and spirituality in the creation of awe-inspiring structures that have withstood the test of time.

Keywords: Architecture, Artistic Mastery

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I. INTRODUCTION

Ancient Indian architecture can be divided into two categories: religious monuments and non-religious monuments. Temples, Stupas, Chaityas, and Monasteries are examples of religious monuments, whereas forts, palaces, civic and urban planning structures are examples of non-religious architecture. The chapter would cover both styles of architecture that were built at comparable and notable times, giving the reader a thorough overview of ancient Indian architecture.

The chapter begins by examining the diverse architectural styles that flourished across different periods of Indian history, including the Indus Valley Civilization, Mauryan, Gupta, Post Gupta, Pallava, Chalukya and Chola eras. Each period brought forth unique architectural expressions, characterized by intricate detailing, elaborate ornamentation, and a deep reverence for religious and spiritual symbolism. The chapter further investigates the spiritual significance embedded within ancient Indian architecture. It explores the seamless integration of architecture and spirituality, where temples, stupas, and sacred spaces were designed as cosmic diagrams and symbols of divine presence. From the magnificent rock-cut caves of Ajanta and Ellora to the awe-inspiring temples of Khajuraho and the celestial architecture of Badami, Pattadakal and Aihole, ancient Indian architecture reveals a profound connection between the earthly and the divine.

II. INDUS VALLEY CIVILISATION

Discovery and Extent of the Civilisation: The Indus Valley Civilization, also known as the Harappan Civilization, was one of the world's oldest urban civilizations. It existed from approximately 2600 BCE to 1900 BCE in what is now modern-day Pakistan and northwestern India. The civilization was named after the Indus River, which flows through the region. Alexander Cunningham, an East India Company military engineer with an intense curiosity in archaeology, visited Harappa in the 1850s. He carried out a small excavation and discovered the remains of a number of structures. The civilization was largely forgotten until the 1920s when archaeologists under the directorship of John Marshall and excavators like Daya Ram Sahani and RD Banerji began excavating the ruins of Harappa and Mohenjo-daro. Since then, numerous sites have been discovered across the region, shedding light on the ancient civilization's existence and its remarkable achievements. The Harappan Civilization covered a vast region that stretched over 1.2 million square kilometres (about 463,000 square miles). This area included parts of present-day Pakistan, northwest India, and eastern Afghanistan. Its northernmost site is Manda near Chenab River in Jammu and southernmost site is Daimabad in Maharashtra covering a distance of 1600kms. Easternmost site is Alamgirpur near Hindan river in UP and westernmost site is Sutkagendor near Dashk river in Baluchistan covering a distance of 1400 kms. Till date there are more than 2800 sites which have been identified with this civilisation and many have been excavated like Mohenjo-Daro, Harappa, Kalibanga, Banawali, Ropar, Dholavira, Alamgirpur, Lothal, Rakhigarhi, Bhagwanpura etc. Many of these were urban centres and can be compared with modern day cities with some unique features like town planning, developed drainage system, standards in weight and measures and a complex society.

Features of Architecture: The Indus Valley Civilization was a remarkable ancient civilization with advanced urban planning, trade networks, and technological achievements

seen in the construction of public buildings like Great Bath (a swimming pool like structure whose water proofing was carried out using Bitumen some 3500 years ago). It remains a subject of fascination and study for archaeologists, providing valuable insights into the development of early human societies.

1. Town Planning was a remarkable aspect of the Indus Valley Civilization's urban development. The cities of Harappa and Mohenjo-Daro, in particular, demonstrate the civilization's sophisticated planning and organisation. Major centres like Harappa and Mohenjodaro were divided into two parts, upper town enclosed like a citadel, which was likely to be occupied by ruling class and a lower town inhabited by common people. Here are some key aspects of Indus Valley Civilization town planning:

- **Grid System:** The cities were laid out in a grid-like pattern, with streets oriented precisely north-south and east-west. Straight streets intersected at right angles, forming a well-organized network. This grid system made it easier to move around and navigate within cities
- **Well-Defined Structures:** Well-defined structures, such as houses, public buildings, granaries, and marketplaces, distinguished the cities. The houses were constructed of baked bricks and had multiple rooms, with an open courtyard in the centre. The streets were lined with houses, with wide lanes separating city blocks.
- **Advanced Drainage Systems:** The Indus Valley Civilization possessed an impressive drainage system, which reflected their understanding of urban sanitation. The streets had covered drains that collected wastewater and carried it away from the homes. These drains were sometimes covered with bricks, and other times with stone slabs. At Banawali, the remains of streets and gutters have also been discovered. The drains were linked to larger underground sewerage systems, ensuring waste disposal efficiency. Overall, the quality of the domestic bathrooms and drains is exceptional, and Harappa's drainage system is almost unique.
- **Water Supply:** The cities possessed a dependable water supply system. Many homes had private wells or had access to communal wells. The Great Bath at Mohenjo-Daro is a large water tank that was probably used for ritual bathing or other communal activities. The city is thought to have had a complex water management system that supplied water to various parts of the city.
- **Fortifications:** Some Indus Valley Civilization cities, including Harappa, had fortifications or defensive walls. The cities were protected by these walls, which were built with large bricks. Fortifications indicate a need for defence and protection against potential threats.
- **Public Spaces:** The cities had designated public spaces, such as marketplaces and open squares. The marketplaces were most likely economic hubs where goods were bought and sold. Open squares could have hosted social gatherings, religious ceremonies, or other communal activities.

Overall, the town planning in the Indus Valley Civilization demonstrated a high level of organization and engineering skill. The grid system, advanced drainage systems, well-defined structures, and provisions for water supply and defence all contributed to the efficient functioning of the cities. These well-planned urban centres were a testament to the civilization's advanced understanding of urban living and management.

2. Major Structures

- **Great Bath:** The great bath, which is a tank like structure, located in the citadel mound and is a fine example of beautiful brickwork, appears to have been the most important public place in Mohenjo-Daro. It is 11.88 X 7.01 metres with a depth of 2.43 metres. Steps at either end lead to the surface, and side rooms are available for changing clothes. The bath's floor was made of burnt bricks. Water was drawn from a large well in another room, and an outlet from the bath's corner led to a drain. It has been argued that the great bath was primarily intended for ritual bathing, which is so significant in Indian religious ceremonies.



Figure 1: Great Bath of Mohenjo-Daro

- **Granaries:** The largest structure in Mohenjo-Daro is a granary which was 45.71 metres long and 15.23 metres wide. However, there are as many as six granaries in Harappa's citadel. These were used for threshing grains and storing them for the use as famine relief.

III.MAURYAN AGE: CAVES, PILLARS AND STUPAS

The discoveries at Dholavira suggest that the development of monumental stone sculpture and architecture in the Indian subcontinent can be traced back to the Harappan civilization. However, there is a long gap following the decline of that civilization, and it is only during the Maurya period that monumental stone sculpture and architecture reappear on the scene. The Mauryan Empire was founded by Chandragupta Maurya and reached its zenith under the rule of Emperor Ashoka. Mauryan architecture refers to the architectural style that flourished during the Maurya Empire in ancient India, which existed from approximately 322

BCE to 185 BCE. The Mauryan contributed significantly to art and architecture and widely popularised stone masonry.

Features of Architecture: The Mauryan architecture was influenced by various regional architectural styles prevalent in different parts of the empire. Megasthenese, a contemporary Greek traveller claims that the Maurya palace at Pataliputra was as magnificent as the one in Iran's capital. At Kumrahar, on the outskirts of modern Patna, fragments of stone pillars and stumps indicating the existence of an 84-pillared hall have been discovered. Although these ruins do not recall the splendour mentioned by Megasthenese, they do attest to the high technical skill attained by Maurya artisans in polishing the stone pillars, which are as gleaming as the Northern Black Polished Ware. Transporting the massive blocks of stone from the quarries, as well as polishing and embellishing them when they were erected, was a difficult task. The entire process suggests a tremendous feat of engineering. Each pillar is made entirely of buff-colored sandstone. However, it also introduced some unique elements and innovations. Unfortunately, due to the passage of time and limited surviving structures, our knowledge about Mauryan architecture is somewhat limited, and most of our understanding is based on archaeological remains and historical accounts.

Here are some key features and examples of Mauryan architecture:

- 1. Pillars:** Mauryan pillars were made from a single piece of highly polished sandstone. The most commonly used stone was buff-coloured or reddish sandstone, although some pillars were made from other materials such as granite. The pillars were tall and slender, ranging from about 12 to 15 meters (39 to 49 feet) in height. They had a circular cross-section and tapered towards the top. The shafts of the pillars were often smooth and unadorned. The capital, or the topmost part of the pillar, was intricately carved and usually consisted of three distinct components: an abacus, a bell-shaped lotus, and an animal figure. The animal figure on the capital is most famous, featuring animals like lions, bulls, elephants, or horses. These animal capitals are often referred to as the "Mauryan lion capital" and are highly regarded for their artistic value. These pillars were often placed in important locations, such as palace complexes, religious sites, and city entrances. The most famous example is the Ashoka Pillar at Sarnath, which features a lion capital with four lions standing back-to-back.



Figure 2: Ashokan Pillar With Lion Capital

- 2. Stupas:** Stupas, or large hemispherical structures, were an integral part of Mauryan architecture. Stupas served as Buddhist religious monuments and contained relics of the Buddha or important Buddhist figures. As per the traditions it is believed that Ashoka built almost 84000 stupas all over the country which contains relics of Lord Buddha. The most notable example is the Great Stupa at Sanchi, commissioned by Emperor Ashoka. Others being at Sarnath, Bharhut, Takshashila and Amravati.



Figure 3: Sanchi Stupa near Bhopal

- 3. Fortifications:** The Mauryans constructed fortified cities and citadels to protect their territories. One prominent example is the city of Pataliputra (modern-day Patna), which served as the capital of the Mauryan Empire. The city was surrounded by timber palisades and had elaborate gates which was further reinforced with earthworks, moats, and guard towers.
- 4. Palaces and Buildings:** Although very few Mauryan palaces have been discovered, it is believed that they were constructed using wooden materials and have not survived. The remains of buildings in Mauryan cities are sparse, making it difficult to ascertain their architectural characteristics. Chandragupta Maurya constructed a palace in his capital city Patliputra (present day Patna) which was praised by Megasthenes, a contemporary Greek traveller. In the fifth century AD, during the time of Chandragupta II Vikramaditya, the Chinese traveller Fahiyen was astounded to see the unique beauty of the palace, decorated with bell-shaped roofs based on giant pillars and gleamed Polish.
- 5. Mauryan Rock-Cut Architecture:** The Mauryans also engaged in rock-cut architecture, carving out caves and structures from natural rock formations. One famous example is the Barabar Caves in Bihar, known for their polished interiors and intricately carved doorways and the famous Lomas Rishi Cave, which has an intricately carved facade. The Sudama Cave in Madhya Pradesh is another example of Mauryan cave architecture, featuring a simple cell with a rock-cut facade. However, it is important to note that the Mauryan caves are relatively fewer in number compared to later periods like the Gupta and Buddhist cave complexes. The Mauryan caves were primarily used as dwellings for monks or as places of worship. They were usually excavated in natural rock formations, particularly in hillsides, and consisted of simple cells or chambers carved into the rock.

Mauryan cave architecture is known for its simplicity and straightforward design. The caves typically consisted of small, rectangular chambers or cells with basic amenities for the monks. The cave entrances often featured carved rock-cut facades with ornamental motifs and decorative elements. **These facades** served as an architectural highlight of the caves. Some Mauryan caves also had chaitya windows, which were semi-circular or horseshoe-shaped windows resembling the apsidal windows seen in later Buddhist cave complexes. These windows provided natural light to the interior spaces.



Figure 4: The Horseshoe Shaped Entrance

Mauryan caves occasionally contained inscriptions, either carved on the walls or pillars, documenting the donations made by patrons or providing information about the cave's purpose. It's important to note that the development of cave architecture continued and evolved in subsequent periods, such as the Gupta and post-Gupta eras, with more elaborate cave complexes like Ajanta and Ellora Caves.

- 6. Public Works:** The Mauryans paid attention to urban planning and built cities with well-organized layouts, including well-laid-out streets, drainage systems, and public amenities. The Mauryan Empire was known for its ambitious public works projects, such as the construction of roads and canals for efficient transportation and irrigation purposes. These projects contributed to the overall development and prosperity of the cities. A rock in Junagadh, Gujarat, has been discovered with three inscriptions: a set of Ashokan edicts, an inscription of the Kardamaka ruler Rudradaman, and an inscription of the Gupta king Skandagupta. While Ashoka's inscriptions contain his dhamma discourses, the other two tell a unique story of the 1,000-year construction, maintenance, and repair of a water reservoir. The inscription's purpose is to commemorate the Rudradaman's restoration of a reservoir known as Sudarshana Lake. Vaishya Pushyagupta, the provincial governor of Chandragupta Maurya, initiated the construction of this reservoir. During Ashoka's reign, the Tushaspha, a Greek governor of the area, finished it.

Overall, Mauryan architecture exhibited a blend of indigenous traditions with influences from the Persian, Greek, and Hellenistic styles. However, it is important to note that much of the Mauryan architectural heritage has been lost over time, and our understanding of it is limited to a few surviving structures and historical records.

IV. GUPTA ERA: THE BEGINNING OF TEMPLE ARCHITECTURE

Gupta architecture refers to the architectural style and developments that emerged during the Gupta Empire in ancient India, which lasted from approximately 320 CE to 550 CE. The Gupta period is often considered a golden age in Indian history, marked by advancements in art, science, and architecture. Gupta cave architecture continued the tradition of rock-cut caves seen in earlier periods. The caves served as monastic retreats, prayer halls, or sanctuaries. The Ajanta Caves in Maharashtra, a UNESCO World Heritage site, exemplify the Gupta cave architecture style with their intricate sculptures and mural paintings. Stupas, Buddhist structures housing relics or serving as places of worship, continued to be constructed during the Gupta period. The Gupta stupas, such as the Dhamekh Stupa in Sarnath, displayed refined architectural features and intricate decorative elements.

Features of Architecture: The Gupta architects made significant advancements in structural engineering. They developed the arch and dome techniques, which allowed for more extensive and sophisticated construction. These innovations enabled the creation of larger temple complexes and more ambitious architectural designs. Gupta architecture emphasized artistic expression through intricate carvings and sculptural details. The temple walls, pillars, and doorways were adorned with sculptures depicting gods, goddesses, celestial beings, and various aspects of Hindu mythology. The artists displayed a high level of skill and craftsmanship in their creations. Gupta architecture showed regional variations across different parts of the empire. For example, the temples in northern India, such as the temples at Deogarh and Eran, displayed distinct features compared to those in central and southern India. The Gupta period witnessed the evolution of Hindu temple architecture. Temples were constructed using stone, and the structural elements of the temples became more elaborate and ornate compared to previous periods. The temples featured distinct shikhara (tower) and mandapa (hall) structures. Gupta architecture set the foundation for subsequent architectural styles in the Indian subcontinent and influenced the development of temple architecture in later periods.

V. AJANTA CAVES

Ajanta Caves, located in Maharashtra, India, are renowned for their exceptional Buddhist rock-cut architecture and exquisite mural paintings. The caves are purely dedicated to Buddhist religion only. These caves were carved into the rocky cliffs during the Gupta period and are considered a UNESCO World Heritage site. There are 30 caves in total at Ajanta. The Ajanta Caves consist of both monasteries (viharas) and prayer halls (chaityas). The viharas served as dwelling places for Buddhist monks, while the chaityas were used for communal worship.



Figure 5: Interior of A Chaitya Cave at Ajanta



Figure 6: Exterior Designs of Ajanta Caves

These caves were meticulously carved out of solid rock, resulting in impressive architectural structures within the natural surroundings. The entrance facades of the Ajanta Caves are intricately carved and adorned with sculptures and decorative elements. The doorways often have ornate motifs and relief sculptures depicting Buddhist themes and mythical figures. Many of the Ajanta Caves have large pillared halls, known as mandapas, where religious ceremonies and gatherings took place. These halls feature rows of beautifully carved pillars with elaborate capitals and sculptural reliefs. The chaitya caves at Ajanta are characterized by their horseshoe-shaped windows, also known as chaitya arches. These windows serve as apsidal windows, allowing natural light to filter into the prayer hall.



Figure 7: Mural Paintings of Buddhist Tales



Figure 8: Mural Paintings Seen on the Exterior of a Cave

One of the most remarkable features of Ajanta architecture is the extensive collection of mural paintings that adorn the walls and ceilings of the caves. These paintings depict various Buddhist stories, Jataka tales, and scenes from the life of the Buddha. The murals showcase exquisite artistry, vibrant colours, and intricate details. The sculptures and carvings in Ajanta caves exhibit a rich display of Buddhist iconography. They portray images of the Buddha, Bodhisattvas, deities, celestial beings, and various scenes from Buddhist mythology. The artists skilfully captured the spiritual and divine essence of Buddhism in their artwork.

VI. ELLORA CAVES

The Ellora Caves are a remarkable complex of rock-cut temples and monasteries in Maharashtra, India. The total number of caves in Ellora is 34. They encompass Buddhist caves (Caves 1 to 12), Hindu caves (Caves 13 to 29), and Jain caves (Caves 30 to 34). While Ajanta is purely Buddhist, Ellora is a synthesis of Hindu, Buddhist, and Jain architectural styles that dates from the 6th to the 10th century CE. The complex stands as a testament to the remarkable craftsmanship and architectural achievements of the time, showcasing the

synthesis of different religious traditions in a single location. The Ellora Caves comprise a series of structures carved into the basaltic rock of the Charanandri Hills.



Figure 9: Inner Wall Panel Depicting Ravana Seeking Kailash



Figure 10: Vishnu's Varaha Incarnation Saving Bhudevi

The caves are divided into three sections based on the religious affiliations of the structures: Hindu, Buddhist, and Jain. Each section contains a collection of temples and monasteries dedicated to their respective faiths. The Buddhist caves display architectural elements similar to those found in other prominent Buddhist sites, such as Ajanta. The Hindu caves at Ellora showcase a range of architectural styles and deities. Some of the notable cave temples are dedicated to Lord Shiva, Vishnu, and various manifestations of the Hindu pantheon. These caves exhibit elaborate carvings, sculptures, and intricate detailing, reflecting the artistic excellence of the time. The Jain caves at Ellora consist of monasteries,

temples, and prayer halls dedicated to Jainism. These caves feature sculptures and reliefs depicting Jain Tirthankaras (spiritual teachers) and intricate ornamentation, highlighting the Jain architectural style. Some caves at Ellora have multiple levels or stories, creating a multilevel architectural design. These structures have upper floors, balconies, and intricately carved columns, giving them a unique and dynamic appearance.



Figure 11: The Famous Monolithic Kailashnath Temple

Temple Architecture: Three types of temple architecture exist in India: Nagara, Dravida, and Vesar. The Dravida style flourished in South India, the Nagara style predominated in North India, and the Vesar style can be viewed as a hybrid of the two. Temples built during the Gupta era are of Nagara style with distinct Shikhar and Mandap. Some of the notable temples of this period include Dashavtar Temple at Deogarh near Jhansi and Bhitargaon Shiv temple near Kanpur. Jagati, Sanctum Sanctorum, Entrance Gateway, Mandap and Shikhara were the main parts of the temple in the Gupta period.

- 1. Jagati:** This is the platform on which the temple was built. It increased from two and a half feet to 25 feet, for example Kailashnath Temple of Ellora. The jagati serves several purposes and holds symbolic significance. Here are some key aspects related to the jagati in temple architecture. The jagati provides a solid and stable foundation for the temple structure. It raises the main temple above the ground level, protecting it from moisture, flooding, and other potential damages. The jagati represents the sacred cosmic mountain, Meru or Kailash, in Hindu mythology. It symbolizes the cosmic axis and the abode of gods. By constructing the temple on a raised platform, it is believed to bring the divine realm closer to the earthly realm. The jagati serves as an important space for various rituals and ceremonies conducted in and around the temple. Devotees and priests perform circumambulation (pradakshina) around the temple on the jagati, symbolizing their reverence and devotion. The raised platform of the jagati elevates the temple, enhancing its visual prominence and making it more visible from a distance. It creates a distinct architectural hierarchy, emphasizing the sacredness and significance of the temple. The jagati provides a transition zone between the outside world and the inner sanctum of the temple. It acts as a pathway for devotees to approach the temple and signifies the progression from the mundane to the sacred space.

- 2. Sanctum Sanctorum:** This was the temple's main room, where the deity idol was installed and therefore it is the holiest place in the temple. It is positioned in such a way that it represents the center of the universe or the cosmic axis, symbolizing the connection between the divine and the earthly realms. It may be smaller in size compared to the outer structures of the temple, emphasizing its sanctity and exclusivity. The architecture of the sanctum sanctorum may vary based on the regional and religious traditions. Access to the sanctum sanctorum is typically restricted to priests and authorized individuals involved in the worship rituals. Devotees usually offer their prayers and make offerings from the outer areas of the sanctum sanctorum. The sanctum sanctorum is believed to be charged with divine energy and spiritual power. It is considered the most potent and sacred space within the temple, where devotees can experience a closer connection with the divine. The sanctum sanctorum represents the divine abode and serves as a focal point for religious devotion. It symbolizes the ultimate reality, the center of spiritual energy, and the culmination of the temple's architectural and spiritual journey. The sanctum sanctorum was surrounded by walls on all three sides, with the main entrance remaining on one. The sanctum sanctorums were square in shape during the Gupta period. Originally, these walls were saris, but as time passed, the inner and outer walls were decorated with Apsaras, Kinnars, Gandharva animals, and birds as the main decorations. Many turns and folds were later added to the outer walls. Depending on the number of turns in the walls, the sanctum sanctorum or shikhara became known as Triratha, Pancharatha, or Saptratha.
- 3. Entrance Gateway:** The entrance gateway of an ancient temple, also known as the gopuram (in South India) or torana (in North India), serves as an important architectural element that marks the transition from the secular to the sacred space. It often represents the grandeur and significance of the temple complex. The entrance was simply marked in ancient times, but the idols of Ganga and Yamuna were installed in both wings. Giant Ganga and Yamuna idols found on Gupta temples built in Ahichhatra are now on display at the National Museum in Delhi. Many ancient temple gateways have multiple levels or tiers, each with its own set of carvings and decorative elements. These levels often rise in a pyramidal or stepped manner, leading to a central pinnacle or spire. The entrance gateway may serve as a ceremonial or ritualistic space. Devotees often pause or perform specific rituals or prayers at the gateway before entering the temple, symbolizing the crossing from the mundane world into the divine realm.
- 4. Mandap:** It is a pillared hall or pavilion within a temple complex that serves as an assembly or gathering space. The mandap is usually located in front of the main sanctum sanctorum (garbhagriha) and is used for religious rituals, ceremonies, and community gatherings. The mandap provides a covered space for devotees to gather, perform rituals, and participate in religious ceremonies. It acts as a transitional zone between the external world and the inner sanctum of the temple. Typically, the mandap is an open or semi-open structure supported by pillars. The number and configuration of pillars vary according to architectural style and regional traditions. Extensive carvings, ornamental details, and symbolic representations may be found on the pillars. The mandap is usually located in front of the main shrine, also known as the sanctum sanctorum. It functions as an antechamber or porch to the innermost sanctum. To give the mandap prominence within the temple complex, it may be raised on a platform or elevated level. Devotees gather in the mandap to participate in various rituals, prayers, and offerings. It serves as a

space for chanting hymns, reciting religious texts, and conducting ceremonial activities. Offerings such as flowers, lamps, and incense are often made in the mandap. The mandap is adorned with architectural and decorative features such as intricate carvings, sculptures, and reliefs. These elements depict gods, goddesses, mythical beings, and scenes from religious epics. The decorative embellishments enhance the aesthetic appeal and spiritual ambiance of the mandap.

- 5. Shikhar:** Shikhara, also known as "vimana," is a term used in Indian temple architecture to describe the towering spire or pinnacle that adorns a Hindu temple's sanctum sanctorum (garbhagriha). It is the tallest and most visible part of the temple's superstructure. The shikhar is typically built of stone or brick and rises above the main body of the temple. It represents Mount Meru, which is thought to be the abode of the gods in Hindu mythology. The shikhar's shape varies according to regional architectural style and period. The shikhar is typically curvilinear in North Indian temple architecture, with multiple horizontal sections, each smaller than the one beneath it, creating a pyramidal effect. This style is commonly found in Nagara temples found in Rajasthan, Madhya Pradesh, and Uttar Pradesh. Intricate carvings of gods, goddesses, celestial beings, and other mythological figures adorn the shikhar. The shikhar takes on a different appearance in South Indian temple architecture. The "gopuram" is a distinctive entrance tower that leads into the temple complex. The gopuram is taller and more elaborate than the shikhar found in North Indian temples. It is frequently adorned with intricate sculptures depicting scenes from Hindu mythology and religious stories. These towering gopurams are prominent in temples built in the Dravidian style in states such as Tamil Nadu, Karnataka, and Andhra Pradesh as seen in Chalukyan, Cholas and Pandyan architecture.

VII. RELEVANCE OF ANCIENT ARCHITECTURE

For several reasons, ancient Indian architecture remains relevant in modern architectural practises:

- 1. Cultural Heritage:** Ancient Indian architecture represents a rich cultural heritage that has influenced and shaped Indian society's identity. Many architectural elements, techniques, and design principles have been handed down from generation to generation. Architects today frequently draw inspiration from ancient Indian architecture to create modern designs that honour the country's historical and cultural context.
- 2. Innovative Construction Techniques:** Ancient Indian architecture demonstrates exceptional engineering and construction techniques. Structures such as the rock-cut caves of Ellora and Ajanta, or the intricately carved temples of Khajuraho, show the mastery of the time's craftsmen and architects. Knowledge of these ancient techniques can be useful in modern construction, inspiring new approaches and pushing the limits of architectural innovation.
- 3. Sustainable Design:** Traditional Indian architecture prioritised environmental sustainability and harmony. Passive cooling, natural ventilation, and the use of local materials were all part of ancient Indian architectural practises. In an era when there is a greater emphasis on sustainable design and environmental consciousness, architects are

revisiting and incorporating traditional techniques into modern buildings to reduce energy consumption and promote eco-friendly practises.

4. **Spiritual and Symbolic Significance:** Ancient Indian architecture was frequently imbued with profound spiritual and symbolic meanings. Temples were created as sacred spaces that embodied the divine and allowed for spiritual encounters. While modern architecture may not have the same religious connotations as traditional architecture, it can still benefit from the use of symbolism in order to create spaces that evoke emotions, tell stories, and foster a sense of connection and identity for the occupants.
5. **Aesthetic Inspiration:** Ancient Indian architecture's aesthetic beauty and complexity continue to captivate and inspire architects today. Exquisite carvings, ornate details, and balanced proportions can be found in structures such as the Taj Mahal and the Sun Temple at Konark, which serve as timeless examples of architectural excellence. Architects are frequently inspired by this aesthetics, incorporating elements of traditional Indian design into modern structures.

By acknowledging and studying ancient Indian architecture, architects can learn from the wisdom of the past and apply it to current design practices. This not only fosters a connection to cultural heritage but also enriches the architectural landscape by incorporating timeless principles, sustainable techniques, and a deeper understanding of human experiences. Its cultural heritage, sustainable design principles, innovative construction techniques, spiritual and symbolic significance, and aesthetic inspiration continue to inspire and shape modern architecture. Architects can create contemporary designs that honour tradition, promote sustainability, and foster a deeper connection between architecture and the human experience by drawing on the wisdom of the past. Ancient Indian architecture exemplifies the timeless principles of beauty, functionality, and natural harmony, reminding us of the enduring value of our architectural heritage.

PART 4

Futuristic Trends in Construction Materials & Civil Engineering

Series Id: IIPV3EBS05_G24

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INVESTIGATING THE INFLUENCE OF RIVER SAND AND CRUSHED SAND ON THE STRENGTH GAIN FOR M30 GRADE OF CONCRETE

Abstract

Concrete is a widely used construction material and the quality of its constituents significantly affects its overall strength and durability. Traditional concrete production involves the use of natural crushed sand as a fine aggregate. However, the availability of crushed sand has been diminishing due to environmental concerns and excessive mining. This has led to an increasing interest in using alternative materials, such as river sand in concrete production. This research provides a concise overview of a study focused on the compressive strength of concrete when crushed sand is replaced with river sand. The objective of this research was to investigate the impact of replacing crushed sand with river sand on the compressive strength of concrete, with the aim of addressing a current research gap in the field. The research gap identified in this study is the limited understanding of how replacing crushed sand with river sand affects the compressive strength of concrete. This knowledge gap necessitates the investigation of this relationship, as it has significant implications for the construction industry and the development of sustainable concrete production practices. The main aim of this project is to analyze the compressive strength characteristics of concrete by replacing crushed sand with river sand. A comprehensive experimental program was designed and executed, involving the preparation and testing of concrete specimens with varying proportions of river sand as a replacement for crushed sand. The compressive strength of these specimens was then evaluated using standardized testing methods. The results of the study

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INVESTIGATING THE INFLUENCE OF RIVER SAND AND CRUSHED SAND ON THE STRENGTH GAIN FOR M30 GRADE OF CONCRETE

revealed valuable insights into the effects of replacing crushed sand with river sand on the compressive strength of concrete. The findings provide a basis for optimizing concrete mix designs and improving the utilization of alternative materials in concrete production. In conclusion, this research project contributes to the existing knowledge by filling the research gap regarding the influence of replacing crushed sand with river sand on the compressive strength of concrete. The rate of gain of strength of river sand concrete is constant throughout between 7 days to the 21 days of curing. The findings offer valuable guidance for engineers, researchers and industry professionals involved in concrete production, enabling them to make informed decisions and promote sustainable practices in construction.

Keywords: Compressive Strength, Crushed Sand, River Sand and Replacement.

I. INTRODUCTION

Concrete, a widely used construction material, is composed of cement, aggregates, water, and other additives. Aggregates play a crucial role in determining the strength and durability of concrete. The two most commonly used types of aggregates are river sand and crushed sand. River sand is traditionally used as a fine aggregate in concrete production, while crushed sand, obtained by crushing rocks, has gained popularity as an alternative. The selection of appropriate aggregates is essential to ensure the desired properties and performance of concrete. The M30 grade of concrete refers to a mix design where the compressive strength of the concrete after 28 days of curing is targeted at 30 MPa. Achieving the desired strength requires careful consideration of the aggregate characteristics, as they significantly influence the overall quality of the concrete. This experimental investigation aims to analyze and compare the impact of river sand and crushed sand as fine aggregates in the production of M30 grade concrete. The study seeks to evaluate the mechanical properties, such as compressive strength, tensile strength, and flexural strength, as well as other relevant properties like workability and durability. By systematically studying the effects of using river sand and crushed sand in M30 grade concrete, this research aims to provide valuable insights into the performance and suitability of these two types of aggregates. The findings can aid engineers, architects, and construction professionals in making informed decisions regarding aggregate selection for specific construction projects. The aim of this project is to conduct an experimental investigation to evaluate and compare the impact of river sand and crushed sand as fine aggregates in the production of M30 grade concrete. The study aims to analyze the mechanical properties, workability, and durability characteristics of the concrete mixtures containing these two types of aggregates. By achieving this aim, the project aims to provide valuable insights and recommendations for the selection and optimization of fine aggregates in M30 grade concrete, benefiting the construction industry and facilitating informed decision-making in concrete construction projects.

The objectives adopted to achieve the aim of this project are as follows:

- 1 To investigate the influence of river sand and crushed sand on the compressive strength of M30 grade concrete.
- 2 To analyze the impact of different fine aggregates on the workability of concrete mixtures.
- 3 To provide recommendations and insights regarding the most suitable type of fine aggregates for M30 grade concrete based on the experimental findings.

II. METHODOLOGY

In the experimental investigation on the impact of river sand and crushed sand in M30 grade concrete, several tests are conducted to characterize the properties of the materials involved. These tests are crucial for understanding the behavior and suitability of the sands in concrete production. The following tests are typically performed:

- 1. Sieve Analysis of Coarse Aggregates:** This test determines the particle size distribution of the coarse aggregates. The aggregate is passed through a series of sieves with different mesh sizes, and the percentage of material retained on each sieve is determined.
- 2. Specific Gravity of Cement:** This test determines the specific gravity of cement, which

indicates its density compared to water. It is usually measured using a specific gravity bottle or a pycnometer.

3. **Specific Gravity of Coarse Aggregate:** The specific gravity of coarse aggregate is determined to understand its density in relation to water. This test helps in assessing the quality and suitability of the aggregate for concrete production.
4. **Water Absorption Test on Coarse Aggregate:** This test measures the amount of water absorbed by the coarse aggregate. It provides insights into the porosity and moisture content of the aggregate, which can influence the water-cement ratio and workability of concrete.
5. **Specific Gravity of Crushed Sand:** The specific gravity of crushed sand is determined to assess its density compared to water. This property helps in understanding the quality and characteristics of crushed sand as a fine aggregate in concrete.
6. **Water Absorption of Crushed Sand:** This test measures the water absorption capacity of crushed sand. It determines the amount of water absorbed by the fine aggregate, which can affect the overall water-cement ratio and workability of concrete mixtures.
7. **Specific Gravity of River Sand:** The specific gravity of river sand is determined to evaluate its density relative to water. This test provides insights into the quality and suitability of river sand as a fine aggregate in concrete production.
8. **Water Absorption of River Sand:** This test measures the water absorption capacity of river sand. It helps in understanding the amount of water that the fine aggregate can absorb, which can impact the water-cement ratio and workability of concrete.

These tests are essential in characterizing the physical properties of the coarse aggregate, crushed sand, and river sand, which are crucial components in concrete production. The results obtained from these tests contribute to a comprehensive understanding of the materials and facilitate the formulation of optimized concrete mix designs.

III. RESULTS & DISCUSSION

The compressive strength values obtained from the three-day, seven-day, fourteen-day, twenty-one day, and twenty-eight day compressive tests were recorded for both the river sand and crushed sand concrete cube samples simultaneously. The average compressive strength were calculated for each set of samples. The data were analyzed to compare the strength development and assess the influence of the different sands on the concrete's compressive strength. Based on the three-day compressive test results, the compressive strength performance of the river sand and crushed sand concrete samples can be evaluated. The findings will provide valuable insights into the early strength development and suitability of these sands in M30 grade concrete. The results will contribute to further discussions on the impact of the sand type on the concrete's overall strength characteristics and assist in making informed decisions regarding material selection in concrete production.

1. Results for Compressive Strength using River Sand:

- Three Day Compressive Strength:** In Table 1, the compressive strength of each individual concrete sample containing river sand is presented. The samples, labeled as Sample 1, Sample 2, Sample 3 were subjected to the three-day compressive test. The compressive strength values of each sample, expressed in megapascals (MPa), are listed in the corresponding column. To determine the average compressive strength of the river sand concrete samples, the values were summed and divided by the total number of samples tested. The tabulated data provides a quantitative representation of the compressive strength results for the river sand concrete samples. This information serves as a basis for comparing the performance of the concrete mix incorporating river sand and for further analysis and interpretation in the context of the experimental investigation

Table 1: Three Day Compressive Strength using River Sand

Sample	Weight (kg)	Load (N)	Area (mm ²)	Compressive Strength (N/mm ²)	Average Value (N/mm ²)
1	8.500	427	150 x 150	18.97	18.92
2	8.475	411	150 x 150	18.26	
3	8.500	440	150 x 150	19.55	

- Seven Day Compressive Strength:** In Table 2, the compressive strength of each individual concrete sample containing river sand is tabulated after seven days of testing. The samples, labeled as Sample 1, Sample 2, Sample 3 were subjected to the compressive strength test at the end of the seven-day curing period. The values of the compressive strength for each sample, measured in megapascals (MPa), are presented in the corresponding column. The tabulated data provides a quantitative representation of the compressive strength results for the river sand concrete samples at the seven-day mark. This information allows for a comparison of the strength development over time and provides insights into the performance of the concrete mix incorporating river sand. The average compressive strength value is essential for evaluating the overall strength characteristics and further analysis of the concrete samples in the context of the experimental investigation.

Table 2: Seven Day Compressive Strength using River Sand

Sample	Weight (kg)	Load (N)	Area (mm ²)	Compressive Strength (N/mm ²)	Average Value (N/mm ²)
1	8.750	689	150 x 150	30.62	29.73
2	8.480	678	150 x 150	30.13	
3	8.445	640	150 x 150	28.44	

- Fourteen Day Compressive Strength:** In Table 3, the compressive strength of each individual concrete sample containing river sand is tabulated after fourteen days of

testing. The samples, labeled as Sample 1, Sample 2, and Sample 3 were subjected to the compressive strength test at the end of the fourteen-day curing period. The values of the compressive strength for each sample, measured in megapascals (MPa), are presented in the corresponding column. The tabulated data provides a quantitative representation of the compressive strength results for the river sand concrete samples at the fourteen-day mark. This information allows for tracking the strength development over time and evaluating the performance of the concrete mix incorporating river sand. The average compressive strength value is essential for assessing the overall strength characteristics and further analysis of the concrete samples in the context of the experimental investigation.

Table 3: Fourteen Day Compressive Strength using River Sand

Sample	Weight (kg)	Load (N)	Area (mm ²)	Compressive Strength (N/mm ²)	Average Value (N/mm ²)
1	8.830	535	150 x 150	23.77	30.08
2	8.540	735	150 x 150	32.66	
3	8.405	761	150 x 150	33.82	

- Twenty-One Day Compressive Strength:** In Table 4, the compressive strength of each individual concrete sample containing river sand is tabulated after twenty-one days of testing. The samples, labeled as Sample 1, Sample 2, and Sample 3 were subjected to the compressive strength test at the end of the fourteen-day curing period. The values of the compressive strength for each sample, measured in megapascals (MPa), are presented in the corresponding column. The tabulated data provides a quantitative representation of the compressive strength results for the river sand concrete samples at the fourteen-day mark. This information allows for tracking the strength development over time and evaluating the performance of the concrete mix incorporating river sand. The average compressive strength value is essential for assessing the overall strength characteristics and further analysis of the concrete samples in the context of the experimental investigation.

Table 4: Twenty-One Day Compressive Strength using River Sand

Sample	Weight (kg)	Load (N)	Area (mm ²)	Compressive Strength (N/mm ²)	Average Value (N/mm ²)
1	8.835	700	150 x 150	31.11	30.54
2	8.550	675	150 x 150	30.00	
3	8.490	687	150 x 150	30.53	

- Twenty-Eight Day Compressive Strength:** In Table 5, the compressive strength of each individual concrete sample containing river sand is tabulated after twenty-eight days of testing. The samples, labeled as Sample 1, Sample 2, and Sample 3 were subjected to the compressive strength test at the end of the fourteen-day curing period. The values of the compressive strength for each sample, measured in megapascals

(MPa), are presented in the corresponding column. The tabulated data provides a quantitative representation of the compressive strength results for the river sand concrete samples at the fourteen-day mark. This information allows for tracking the strength development over time and evaluating the performance of the concrete mix incorporating river sand. The average compressive strength value is essential for assessing the overall strength characteristics and further analysis of the concrete samples in the context of the experimental investigation.

Table 5: Twenty-Eight Day Compressive Strength using River Sand

Sample	Weight (kg)	Load (N)	Area (mm ²)	Compressive Strength (N/mm ²)	Average Value (N/mm ²)
1	8.775	912	150 x 150	40.53	35.65
2	8.545	695	150 x 150	30.88	
3	8.680	800	150 x 150	35.55	

2. Results for Compressive Strength using Crushed Sand:

- Three Day Compressive Strength:** In Table 6, the compressive strength of each individual concrete sample containing crushed sand is presented. The samples, labeled as Sample 1, Sample 2, Sample 3 were subjected to the three-day compressive test. The compressive strength values of each sample, expressed in megapascals (MPa), are listed in the corresponding column. To determine the average compressive strength of the river sand concrete samples, the values were summed and divided by the total number of samples tested. The tabulated data provides a quantitative representation of the compressive strength results for the river sand concrete samples. This information serves as a basis for comparing the performance of the concrete mix incorporating river sand and for further analysis and interpretation in the context of the experimental investigation

Table 6: Three Day Compressive Strength using Crushed Sand

Sample	Weight (kg)	Load (N)	Area (mm ²)	Compressive Strength (N/mm ²)	Average Value (N/mm ²)
1	8.690	472	150 x 150	20.97	21.07
2	8.475	411	150 x 150	18.26	
3	8.500	440	150 x 150	19.55	

- Seven Day Compressive Strength:** In Table 7, the compressive strength of each individual concrete sample containing crushed sand is tabulated after seven days of testing. The samples, labeled as Sample 1, Sample 2, Sample 3 were subjected to the compressive strength test at the end of the seven-day curing period. The values of the compressive strength for each sample, measured in megapascals (MPa), are presented in the corresponding column. The tabulated data provides a quantitative representation of the compressive strength results for the river sand concrete samples

at the seven-day mark. This information allows for a comparison of the strength development over time and provides insights into the performance of the concrete mix incorporating river sand. The average compressive strength value is essential for evaluating the overall strength characteristics and further analysis of the concrete samples in the context of the experimental investigation.

Table 7: Seven Day Compressive Strength using Crushed Sand

Sample	Weight (kg)	Load (N)	Area (mm ²)	Compressive Strength (N/mm ²)	Average Value (N/mm ²)
1	8.800	690	150 x 150	30.66	22.84
2	8.505	383	150 x 150	17.02	
3	9.165	469	150 x 150	20.84	

- Fourteen Day Compressive Strength:** In Table 8, the compressive strength of each individual concrete sample containing crushed sand is tabulated after fourteen days of testing. The samples, labeled as Sample 1, Sample 2, and Sample 3 were subjected to the compressive strength test at the end of the fourteen-day curing period. The values of the compressive strength for each sample, measured in megapascals (MPa), are presented in the corresponding column. The tabulated data provides a quantitative representation of the compressive strength results for the river sand concrete samples at the fourteen-day mark. This information allows for tracking the strength development over time and evaluating the performance of the concrete mix incorporating river sand. The average compressive strength value is essential for assessing the overall strength characteristics and further analysis of the concrete samples in the context of the experimental investigation.

Table 8: Fourteen Day Compressive Strength using River Sand

Sample	Weight (kg)	Load (N)	Area (mm ²)	Compressive Strength (N/mm ²)	Average Value (N/mm ²)
1	8.770	608	150 x 150	27.02	29.62
2	8.635	539	150 x 150	23.95	
3	8.955	853	150 x 150	37.91	

- Twenty-One Day Compressive Strength:** In Table 9, the compressive strength of each individual concrete sample containing crushed sand is tabulated after twenty-one days of testing. The samples, labeled as Sample 1, Sample 2, and Sample 3 were subjected to the compressive strength test at the end of the fourteen-day curing period. The values of the compressive strength for each sample, measured in megapascals (MPa), are presented in the corresponding column. The tabulated data provides a quantitative representation of the compressive strength results for the river sand concrete samples at the fourteen-day mark. This information allows for tracking the strength development over time and evaluating the performance of the concrete mix incorporating river sand. The average compressive strength value is essential for

assessing the overall strength characteristics and further analysis of the concrete samples in the context of the experimental investigation.

Table 9: Twenty-One Day Compressive Strength using River Sand

Sample	Weight (kg)	Load (N)	Area (mm ²)	Compressive Strength (N/mm ²)	Average Value (N/mm ²)
1	8.865	1019	150 x 150	45.28	36.89
2	8.575	678	150 x 150	30.13	
3	9.025	794	150 x 150	35.28	

- Twenty-Eight Day Compressive Strength:** In Table 10, the compressive strength of each individual concrete sample containing crushed sand is tabulated after twenty-eight days of testing. The samples, labeled as Sample 1, Sample 2, and Sample 3 were subjected to the compressive strength test at the end of the fourteen-day curing period. The values of the compressive strength for each sample, measured in megapascals (MPa), are presented in the corresponding column. The tabulated data provides a quantitative representation of the compressive strength results for the river sand concrete samples at the fourteen-day mark. This information allows for tracking the strength development over time and evaluating the performance of the concrete mix incorporating river sand. The average compressive strength value is essential for assessing the overall strength characteristics and further analysis of the concrete samples in the context of the experimental investigation.

Table 10: Twenty-Eight Day Compressive Strength using River Sand

Sample	Weight (kg)	Load (N)	Area (mm ²)	Compressive Strength (N/mm ²)	Average Value (N/mm ²)
1	8.555	703	150 x 150	31.24	39.13
2	8.615	907	150 x 150	40.31	
3	8.630	1032	150 x 150	45.86	

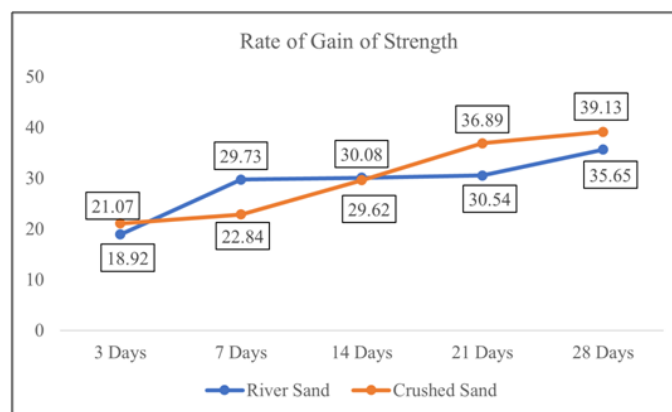


Figure 1: Compressive Strength comparison of River sand and Crushed Sand

IV. CONCLUSIONS

The compressive strength of concrete samples containing river sand at three days is observed to be less than that of concrete samples containing 11.36% fine aggregate. This indicates that the fine aggregate concrete, which includes a higher proportion of fine aggregates, demonstrates greater strength development at the early age of three days compared to the concrete with river sand.

The compressive strength of concrete samples containing river sand at seven days is observed to be greater than that of concrete samples containing 30.17% crushed sand. This indicates that the river sand concrete, with a higher proportion of river sand as fine aggregate, exhibits superior strength development at the seven-day mark compared to the concrete with crushed sand.

The compressive strength of concrete samples containing river sand at fourteen days is observed to be higher than that of concrete samples containing 15.53% crushed sand. This indicates that the river sand concrete, which includes a higher proportion of river sand as fine aggregate, exhibits greater strength development at the fourteen-day mark compared to the concrete with crushed sand.

The compressive strength of concrete samples containing river sand at twenty-one days is observed to be lower than that of concrete samples containing 20.79% crushed sand. This indicates that the fine aggregate concrete, which includes a higher proportion of fine aggregates, exhibits greater strength development at the twenty-one-day mark compared to the concrete with river sand.

The compressive strength of concrete samples containing river sand at twenty-eight days is observed to be lower than that of concrete samples containing 9.76% crushed sand. This indicates that the fine aggregate concrete, which includes a higher proportion of fine aggregates, exhibits greater strength development at the twenty-eight-day mark compared to the concrete with river sand.

The rate of gain of strength for concrete samples containing crushed sand gradually increases from day one to the end of the curing period. This indicates that the concrete exhibits a progressive strength development over time.

The rate of gain of strength for concrete samples containing river sand remains relatively constant between the 7th and 21st day of the curing period. This suggests that the concrete demonstrates a consistent and steady rate of strength development during this specific timeframe. This constant rate of gain of strength during the 7th to 21st day of curing can be attributed to the continuous hydration process of cement and the ongoing formation and maturation of the cementitious matrix. The particle characteristics and distribution of river sand contribute to a stable and consistent packing arrangement within the concrete, which promotes uniform strength development over time.

REFERENCES

- [1] Rajput, S.P. (2018), An experimental study on crushed stone dusts as fine aggregate in cement concrete. *Materials Today: Proceedings*, Vol. 5, Issue No. 9, pp. 17540 – 17547.
- [2] Nadeem, M., Pofale, A.D. (2012), Experimental investigation of using slag as an alternative to normal aggregates (coarse and fine) in concrete. *International Journal of Civil & Structural Engineering*, Vol. 3, Issue No. 1, pp. 117 – 127.
- [3] Shinu, N.M.T., Needhidasan, S. (2020), An experimental study of replacing conventional coarse aggregate with E-waste plastic for M40 grade concrete using river sand. *Materials Today: Proceedings*, Vol. 22, pp. 633 – 658.
- [4] Rani, M. U., Jenifer, J. M. (2016). An Experimental study on partial replacement of sand with crushed brick in concrete. *International Journal of Science Technology & Engineering (IJSTE)*, Vol. 2, Issue No. 08, pp. 316-322.
- [5] Thamilselvi, P. (2016). Experimental Studies on Partial Replacement of Natural Sand with Manufactured Sand, *Journal of Advances in Chemistry*, Vol. 12, Issue No. 20, pp. 5266 – 5272.
- [6] Kumar, N. V. S., & Ram, K. S. (2018). Experimental study on properties of concrete containing crushed rock dust as a partial replacement of cement, *Materials Today: Proceedings*, Vol 5, Issue No. 2, pp. 7240-7246.
- [7] Bhavagna, C. S., Lalitha, G. (2017). Experimental study on concrete (M30) by partial replacement of fine aggregate with copper slag. *International Journal of Civil Engineering and Technology*, Vol. 8, Issue No. 1, pp. 1031-1038.
- [8] Rajan, R. G., Sakthieswaran, N., Babu, O. G. (2021). Experimental investigation of sustainable concrete by partial replacement of fine aggregate with treated waste tyre rubber by acidic nature. *Materials Today: Proceedings*, Vol. 37, pp. 1019-1022.
- [9] Needhidasan, S., Ramesh, B., & Prabu, S. J. R. (2020). Experimental study on use of E-waste plastics as coarse aggregate in concrete with manufactured sand. *Materials Today: Proceedings*, Vol. 22, pp. 715-721.
- [10] Daniel, R. J., & Sangeetha, S. P. (2021). Experimental study on concrete using waste ceramic as partial replacement of aggregate. *Materials Today: Proceedings*, Vol. 45, pp. 6603-6608.
- [11] Kumar, B. N. N., Kumar, P. K., Babu, E. R., Gopal, M., Reddy, D. S., Sreekanth, K., & Yellppa, U. (2016). An experimental study on sea sand by partial replacement of sea sand in concrete. *International Journal of Scientific Research in Science and Technology*, Vol. 2, Issue No. 2, pp. 181-184.
- [12] Chavan, B. V., & Modani, P. O. (2019). Experimental investigation on self-compacting concrete by replacing natural sand with artificial sand. *International Research Journal of Engineering and Technology (IRJET)*, Vol. 6, Issue No. 5, pp. 6901-6903.
- [13] Ali, M. M., & Hashmi, S. M. (2014). An experimental investigation on strengths characteristics of concrete with the partial replacement of cement by marble powder dust and sand by stone dust. *International Journal for Scientific Research & Development*, Vol. 2, Issue No. 7, pp. 360-368.
- [14] Sravani, A., & Sravanthi, M. (2018). Experimental Investigation on Mechanical Properties of Geopolymer Concrete When River Sand Replaced with Manufactured Sand in Fine Aggregate. *Journal of Ceramics and Concrete Technology*, Vol. 7, Issue No. 12, pp. 1 – 9.
- [15] Meyyappan, P. L., Selvasofia, S. A., Asmitha, M., Praveena, S. J. (2023). Experimental studies on partial replacement of crumb rubber as a fine aggregate in M30 grade concrete. *Materials Today: Proceedings*, Vol. 74, pp. 985-992.

STABILIZATION OF BLACK COTTON SOIL BY USING CALCIUM CARBIDE RESIDUE AND BAGASSE ASH

Abstract

The development of road alignment over expansive clayey soil is becoming challenging in India. Smectite minerals are seen in black cotton soil. It exhibits strong swelling and shrinking characteristics. The construction of pavement structures on Black Cotton Soil is becoming irksome, because of its propensity to exhibit volume change behaviour and cause uplift pressure to light structures and pavement layers. In the process of stabilising the soil, its physical characteristics are changed for long-term tensile strength. Soil is stabilizing with addition of chemical additives. Calcium Carbide Residue (CCR) & Bagasse ash are two additives which are used for stabilization of Black cotton soil.

Keywords: Smectite, Black Cotton Soil, Calcium Carbide residue, Bagasse Ash.

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I. INTRODUCTION

1. General: The most significant layer on the surface of the Earth is the soil. Rocks undergo weathering, which creates this layer. There are numerous different soil kinds in India as well. The main varieties of soil found in India are alluvial, black, arid, lateritic, red, and yellow soil. Around 20% of Indian land is covered with black dirt, which comes from these sorts of soil. Central states including Maharashtra, Gujarat, Madhya Pradesh, Andhra Pradesh, and sections of Tamil Nadu have black soil. The majority of the particles in this soil are clay, which helps it retain moisture. The nature of Black Cotton soil with moisture content is quite fragile. Black cotton soil changes volume and has a very expansive nature. When in touch with moisture, this soil expands and contracts in dry conditions. Cracks emerge in the natural world as a result of such swelling and shrinkage. The primary cause of structural damage is those soil surface fissures. Black Cotton soil possesses very low bearing capacity to withstand against heavy structural load. The industry that produces acetylene gas produces calcium carbide residue, or CCR. Calcium Carbide reacts with water to form Calcium Hydroxide and Acetylene gas. Calcium carbide and water undergo a reaction to create CCR. Around 500,000 tonnes of calcium carbide are used globally to produce acetylene gas, which produces 1.4 million tonnes of CCR. CCR is typically deposited in a dump yard because it is viewed as a waste product. Due to its alkaline nature, it has an impact on the amount of landfills and contributes to environmental issues there. The biodegradation of other wastes is likewise slowed down by CCR.

The by-product of the sugarcane industry is bagasse. After the sugarcane juice is extracted, bagasse is produced. It is a dry, fibrous, pulpy substance. Additionally, bagasse has various applications.

The purpose of this work is to investigate the combined effects of Bagasse ash and Calcium Carbide residue with Black Cotton soil. How the rising amount of CCR affects the engineering qualities of Black Cotton soil by maintaining a constant bagasse ash percentage. The Soaked and Unsoaked condition CBR test, Direct Shear test, and Unconfined compression test are three major engineering property determining tests that have an impact on pavement design. The needed pavement thickness for the relevant test values is derived from the results of the soaked CBR testing. The findings of this study can help engineers make decisions on how much soil, CCR, and bagasse ash to mix with water will effective for designing a subbase.

2. Objectives

- To evaluate engineering properties of Black cotton soil before & after stabilization with CCR & Bagasse ash.
- To design flexible pavement by utilizing various proportions of CCR and Bagasse ash.
- To perform cost analysis for blended soil.

3. Combinations to be Used

- Virgin soil (100% BCS).
- 92% BCS + 4% Bagasse ash + 4% CCR.
- 88% BCS + 4% Bagasse ash + 8% CCR.
- 84% BCS + 4% Bagasse ash + 12% CCR.

II. MATERIALS

1. Black Cotton Soil: Black cotton soil required for this investigation is collected from Yavat in Pune district. This soil is primarily used for cultivation purpose. Most of the soil is in Greyish Black colour. Majorly Sugarcane, Wheat, Soyabean crops are cultivated in this Black soil. Soil used for this study is air dried by using Sunlight. From Grain size analysis test, most of the soil contains sandy particles.

Table 1: Physical Properties of Soil

Sr. No	Physical Properties	Obtained Values
1.	Colour	Greyish Black
2.	Specific Gravity	2.50
3.	Grain Size Analysis (in %)	
	Gravel	6%
	Sand	59%
	Silt	15%
	Clay	19.8%
4.	Free Swell Index	24.40%
5.	Plasticity Index	18.86%

2. Calcium Carbide Residue: Calcium Carbide residue is a waste by product formed during production of Acetylene gas. When Calcium Carbide stones are added in water an exothermic reaction takes place and produces acetylene gas and Calcium Carbide waste. Calcium Carbide residue is also known as Lime sludge or Carbide Lime which is primarily considered as waste product. It can be beneficially uses for soil stabilization due to presence of chemical component in it. During chemical composition test on Calcium Carbide residue, it is observed that it contains primarily high percentage of Calcium Oxide (CaO), which is a key ingredient in soil stabilization. This Calcium Oxide reacts with water and forms Calcium Hydroxide which helps in to improve engineering property of Soil. Calcium Carbide residue contains pozzolanic properties which helps in to bind the soil particles together. The hydraulic behaviour of Calcium Carbide residue helps in to set and harden the soil particles in presence of water. This property is beneficial for stabilizing soil, as it helps to create a solid matrix and improves soil strength and durability. Calcium Carbide residue also helps in to fill the voids in soil particles. Calcium Carbide residue is examined for chemical composition test and obtained test results are as follows.

Table 2 Chemical Properties of CCR

Sr. No	Chemical Composition	Observed Value (in %)
1.	CaO	87.7
2.	SiO ₂	8.3
3.	Al ₂ O ₃	1.36
4.	Fe ₂ O ₃	0.25
5.	Na ₂ O	1.35

3. Bagasse Ash: Bagasse ash is the residual product obtained after burning sugarcane bagasse in boilers during the process of sugar production. Sugarcane bagasse is the fibrous material left over after the juice has been extracted from the sugarcane stalks. It is commonly used as a fuel source in sugar mills to generate steam and electricity for the sugar production process.

In Maharashtra state, there are many Sugarcane Industries are available for Bagasse. Bagasse ash contains reactive silica, which, when mixed with soil, forms a cementitious gel. This gel binds the soil particles together, resulting in increased soil strength and stability. Bagasse ash can help reduce the permeability of the soil, making it less susceptible to water infiltration and erosion. The pozzolanic reactions of bagasse ash with soil minerals create stable compounds that contribute to the long-term durability of the soil structure.

III. RESEARCH METHODOLOGY

Basic Physical and Chemical Composition test on testing materials is done and tested results are mentioned earlier.

To examine engineering properties of Virgin soil as well as blended soil combination following tests are carried out.

Table 3: Laboratory Testing on Soil Specimen

Laboratory Testing	
Index properties of soil Grain Size analysis. Consistency Indices.	Engineering Property of Soil Specific Gravity test. Free Swell Index. Permeability. Compaction test. Direct Shear test. Unconfined compression test. California Bearing ratio.

IV. RESULTS AND DISCUSSIONS

1. Grain Size Analysis: For dry sieve analysis, 10 sunlight dried soil samples are collected and sieved using motorized sieve shaker. On the basis of results obtained during sieve analysis Black cotton soil will be classified.

Table 4: Grain Size Analysis Result

Sieve Sizes	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10
6.3mm	100	100	100	100	100	100	100	100	100	100
4.75m m	78.4	92.4	87.8	88.8	81	95	91	87.8	87.2	83.45
2.36m m	55.95	73.15	67.8	70.6	57.5	80	71	70.95	68.2	61.05
1.18m m	32.65	48.25	38.4	43.9	33	51.5	43.5	44.95	43	34.8
600	19.05	31.7	19.8	24.95	18	31	25.5	24.9	25.95	19.1
300	8.65	15.65	7.65	10.9	7.8	14.5	11	9.65	10.65	8.4
150	3.95	6.95	3.65	5.3	3.8	7	5	4.3	4.4	4.4
75	2	3	1.85	2.7	1.97	3.35	2	2.1	2.1	2.3
Pan	0	0	0	0	0	0	0	0	0	0

With referring to above particle size table, Particle size distribution curve is represented in following chart.

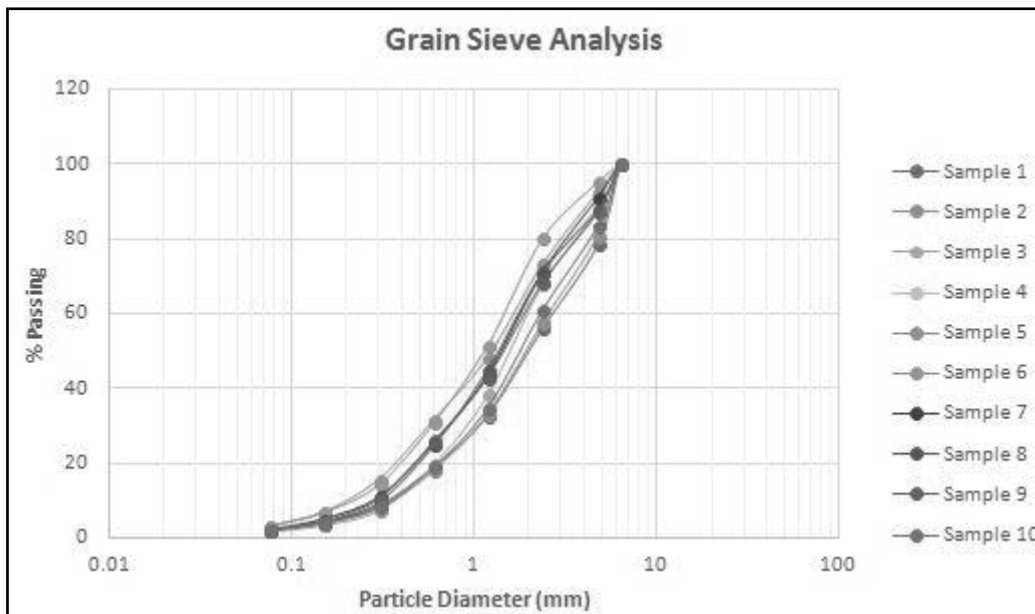


Figure 1: Grain size analysis chart

2. Consistency Indices: Consistency indices of virgin soil and combination of samples is determined. Plastic limit, liquid limit and shrinkage limit are derived from obtained results. These 3 limits are represented in following table.

Table 5: Consistency Indices Result

	Virgin BCS Soil	92% BCS +4% CCR+4% B.A	88% BCS +8% CCR+ 4% B.A	84% BCS +12% CCR + 4% B.A
Liquid Limit	45.84	54.47	56.336	58.11
Plastic Limit	32.91	46.93	48.67	49.91
Shrinkage Limit	18.47	19.89	21.62	23.46

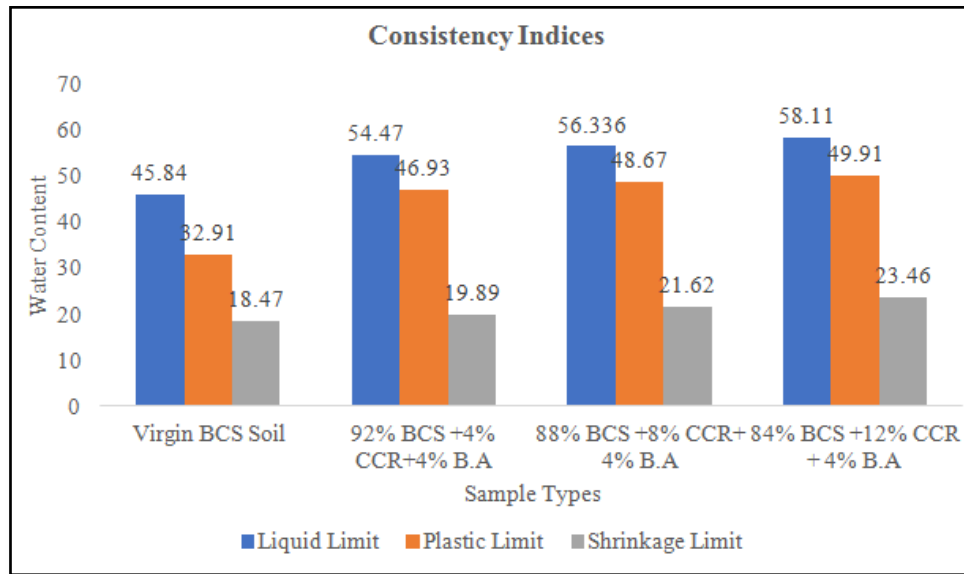


Figure 2: Consistency Indices Graph

It is clearly signifying that on addition of CCR and bagasse ash, Liquid limit value of BCS is increasing. Same trend is observed with plastic limit and shrinkage limit.

- Specific Gravity Test:** To examine the Density of soil and combined specimen, Specific Gravity test is carried by using Pycnometer method. The void ratio present in between soil particles can be calculated by using this density value.

Table 6: Specific Gravity value

Sr. no	Soil Specimens	Specific Gravity value
1	Virgin BCS Soil	2.5
2	92% BCS +4% CCR+4% B.A	2.25
3	88% BCS +8% CCR+ 4% B.A	2.36
4	84% BCS +12% CCR + 4% B.A	2.39

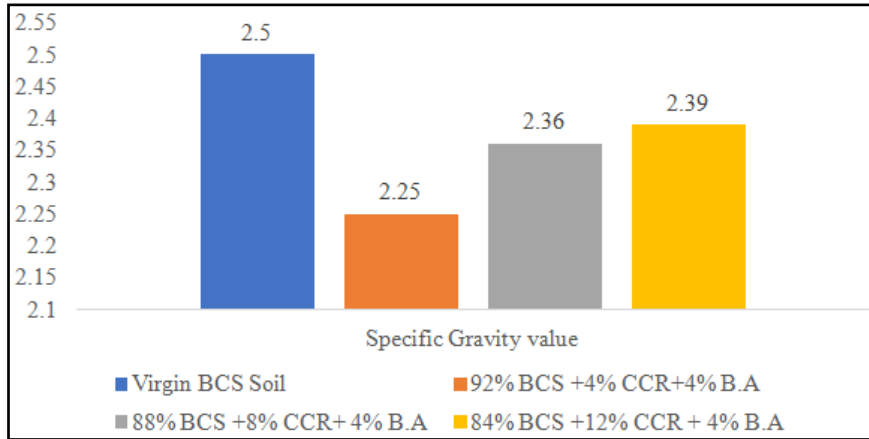


Figure 3: Specific Gravity Value

Sudden drop is observed in specific gravity of soil blended with 4% CCR and 4% Bagasse ash. With increasing percentage of CCR in soil specimen slowly increases specific gravity value.

- Free Swell Index:** Swelling potential of soil samples in presence of water is examined using this test. By keeping soil samples in distilled water and kerosene for 24 hrs Free swell index of soil specimens can be calculated.

Table 7: Free Swell Index Value

Sr. No	Soil Specimens	Free Swell Index
1	Virgin BCS Soil	24.4
2	92% BCS +4% CCR+4% B.A	19.6
3	88% BCS +8% CCR+ 4% B.A	18.23
4	84% BCS +12% CCR + 4% B.A	16.94

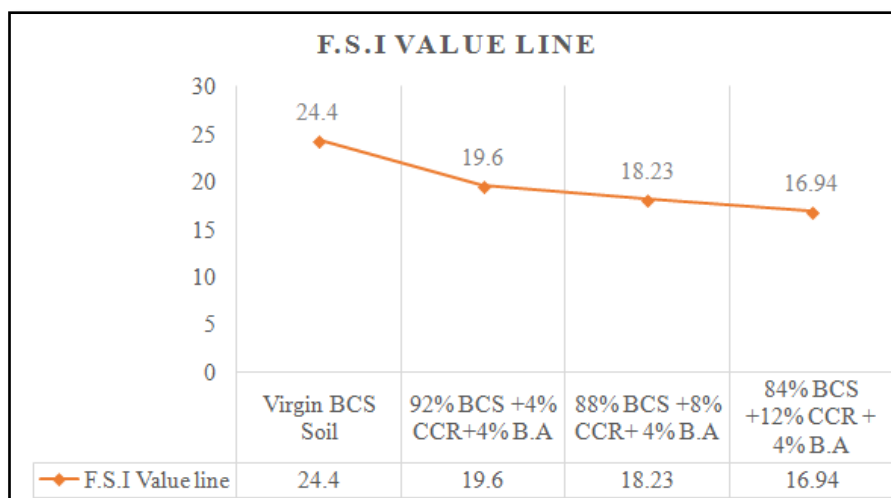


Figure 4: F.S.I Value Line

Free swell index value of virgin soil is higher than F.S.I value of other blends. The decreasing trend observed on addition of CCR and Bagasse ash will definitely help in to reduce crack formation.

5. **Permeability:** Permeability of soil specimens aids in evaluation of behaviour of soil to barrier ground water flow. This test also helps to determine the hydraulic conductivity of soil specimens. This test helps in understanding the flow of water through soil particles.

Table 8: Permeability values

Sr. No	Soil Specimens	Coefficient of permeability values (in Cm/s)
1.	Virgin BCS Soil	0.0000249
2.	92% BCS +4% CCR+4% B.A	0.0000193
3.	88% BCS +8% CCR+ 4% B.A	0.0000167
4.	84% BCS +12% CCR + 4% B.A	0.0000151

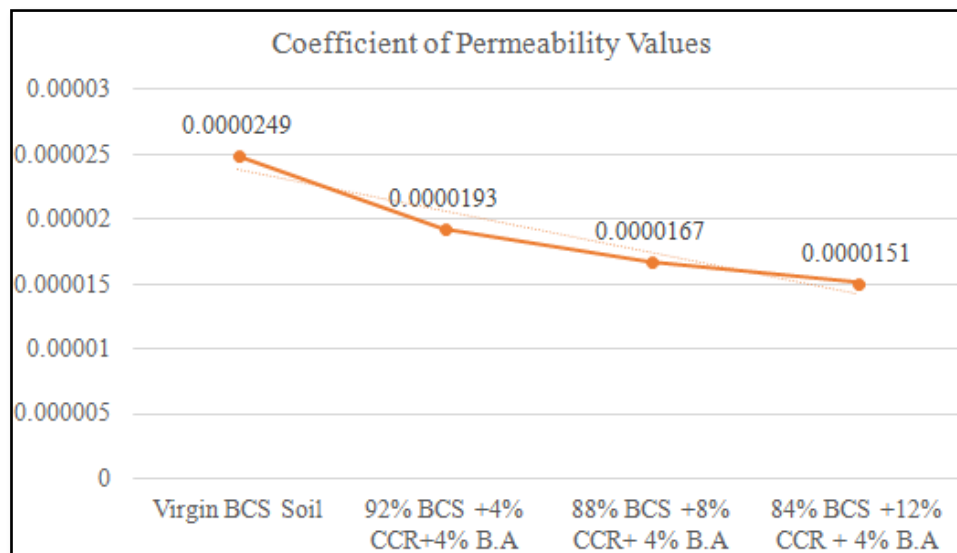


Figure 5: Coefficient of Permeability Value

From above line chart, clears addition of CCR and Bagasse ash in virgin soil is reducing the permeability of soil which will helps in to reduce uplift hydraulic pressure.

6. **Compaction Test:** For the evaluation of Virgin soil and Blended soil, next most important test performed is compaction test. This test helps to achieve maximum density of soil under standard loading condition with certain increase in water content. To understand the maximum dry density can be achievable from virgin soil and blended soil, standard proctor test was performed.

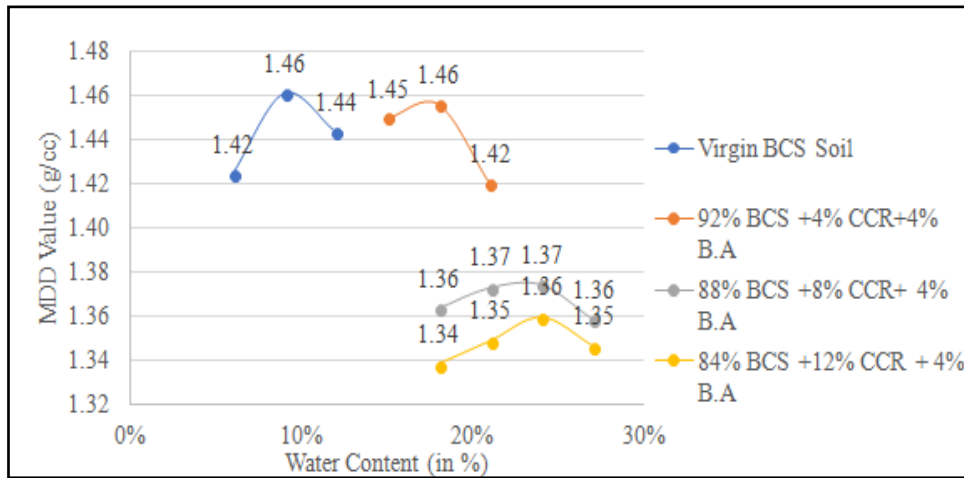


Figure 6: MDD vs OMC Curve

Table 9: Compaction Test Result

Sr. No	Soil Specimens	MDD value (in gm/cc)	OMC value (in %)
1.	Virgin BCS Soil	1.46	9%
2.	92% BCS +4% CCR+4% B.A	1.46	21%
3.	88% BCS +8% CCR+ 4% B.A	1.37	24%
4.	84% BCS +12% CCR + 4% B.A	1.36	24%

7. **Direct Shear Test:** This test is performed to determine shear strength parameters of soil specimens. Cohesion value and angle of friction of soil specimens is determined using this test. These values are helpful to analyse the slope stability of embankment. Test is performed in consolidated undrained condition. Test results obtained during test are as follows.

Table 10: Shear Stress Value

Normal stress (N/Cm ²)	Shear Stress (N/Cm ²)			
	Virgin BCS Soil	92% BCS + 4% B.A + 4% CCR	88% BCS + 4% B.A + 8% CCR	84% BCS +4% B.A+12% CCR
4.9	3.86	5.12	6.58	8.44
9.8	4.32	7.26	8.37	10.16
14.7	5.94	8.05	9.51	12

From above Normal Stress and shear stress values, a graph is plotted in following chart. The values plotted in graph and by using that values, trendline equations are formed. With Comparing trendline equations with Mohr- Coulomb failure theory equation, value of cohesion angle and angle of internal friction is calculated.

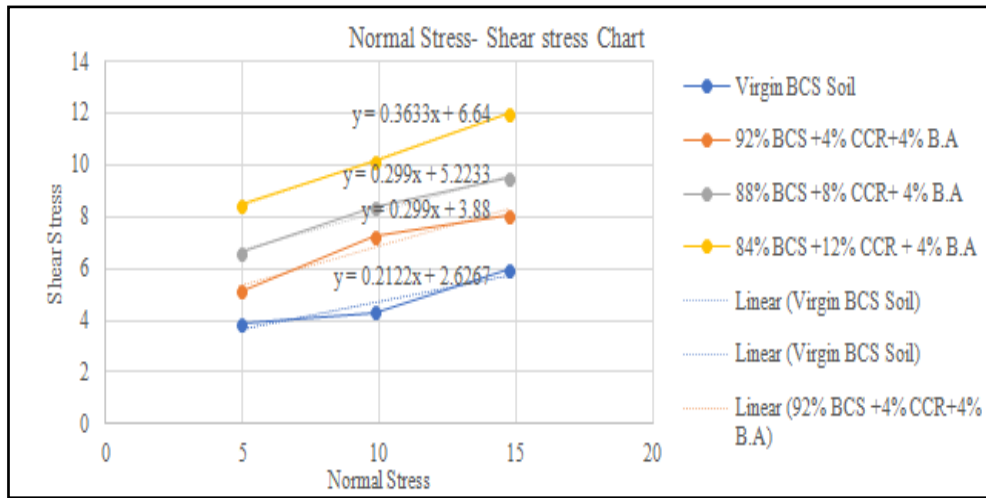


Figure 7: Normal Stress- Shear Stress Line Diagram

Table 11: Shear Stress Value

Sr. No	Soil Specimen	Cohesion (c)	Angle of Internal Friction
1.	Virgin BCS Soil	2.62	11.86
2.	92% BCS +4% CCR+4% B.A	3.88	16.17
3.	88% BCS +8% CCR+ 4% B.A	5.22	16.17
4.	84% BCS +12% CCR + 4% B.A	6.64	19.8

Above table signifies, there is increase in cohesion value observed with respect to angle of Internal friction. Cohesion value of Virgin soil was observed to be 2.62 with angle of internal friction 11.86. Later on, this cohesion value is increased with angle of Internal friction 16.17. On addition of 4% CCR and 4% Bagasse ash cohesion value resulted 3.88. For next blend, 4% increase in CCR resulted cohesion value 5.22 with same angle on internal friction i.e 16.17. For last blend 84%BCS +12% CCR + 4% Bagasse ash, cohesion value resulted 6.64 with 19.8 angle on internal friction.

- 8. Unconfined Compression Test:** The primary purpose of this test is to determine the shear strength parameter of a soil specimen under a uniaxial vertical loading condition. The results obtained for unconfined compression test are as follows.

Table 12: UCS value

Sr. No	Soil Specimen	Strain	Strain in %	UCS test Value (in KPa)
1.	Virgin BCS Soil	0.0197	2	104.97
2.	92% BCS +4% CCR+4% B.A	0.0263	2.6	187.69
3.	88% BCS +8% CCR+ 4% B.A	0.0328	3.3	314.842
4.	84% BCS +12% CCR + 4% B.A	0.0394	3.9	417.906

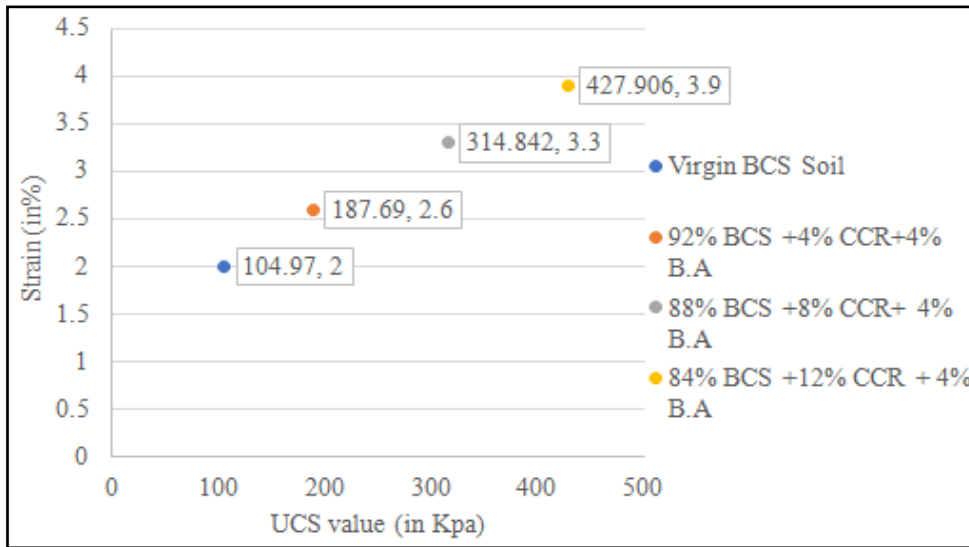


Figure 8: UCS Value

Unconfined compression strength value showing increasing trend with respective strain. For Virgin soil 2% strain is observed with UCS value 104.97Kpa. For specimen 1 obtained strain value is 2.6. Compression strength for specimen 1 in increased by 45% and resulted as 187.69Kpa. For specimen 2 and specimen 3 obtained strain values are 3.3 and 3.9 with Compressive strength of 314.84 and 427.906 Kpa respectively

9. California Bearing Ratio Test: A California Bearing ration test is conducted on soil specimen for pavement design. This test is executed in soaked as well as unsoaked condition. For Soaked condition, Soil specimen was kept in water tank for 4 days with surcharge weight 2.5 Kg. Soil Specimens are compacted to its MDD value with its OMC in mould by using Standard Rammer. The Soaked and Unsoaked results are mentioned in following table.

Table 13 CBR Value for Soaked Condition

Sr. No	Soil Specimens	CBR value for Soaked Condition (in %)
1	Virgin BCS Soil	3.01
2.	92% BCS +4% CCR+4% B.A	4.87
3.	88% BCS +8% CCR+ 4% B.A	6.1
4.	84% BCS +12% CCR + 4% B.A	7.23

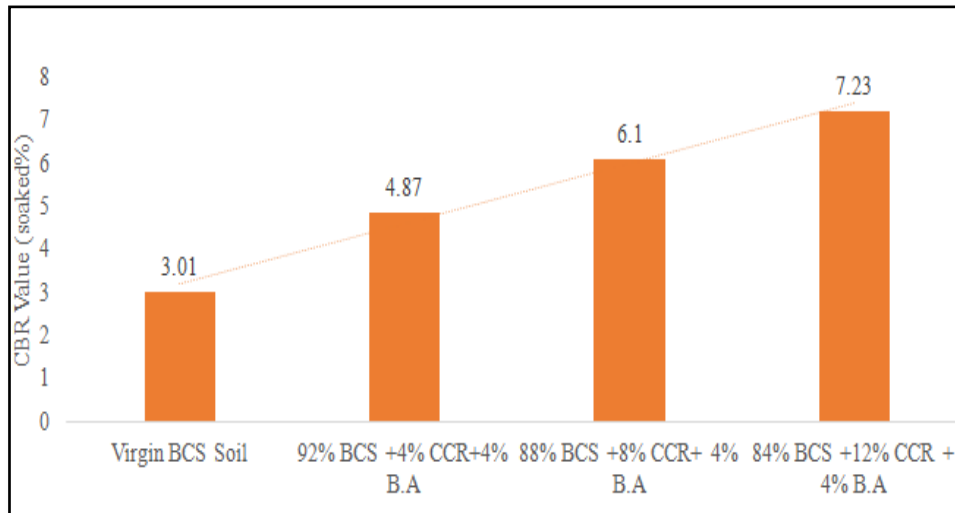


Figure 9: CBR Value for Soaked Condition

CBR value of soil specimen in soaked condition seems to be less. CBR values of soil specimens in soaked condition shown increasing trend. The values of CBR in unsoaked condition are represented in following table.

Table 14: CBR value for Unsoaked Condition

Sr. No	Soil Specimens	CBR Value for Unsoaked Condition (in %)
1.	Virgin BCS Soil	2.59
2.	92% BCS +4% CCR+4% B.A	5.67
3.	88% BCS +8% CCR+ 4% B.A	8.48
4.	84% BCS +12% CCR + 4% B.A	12.18

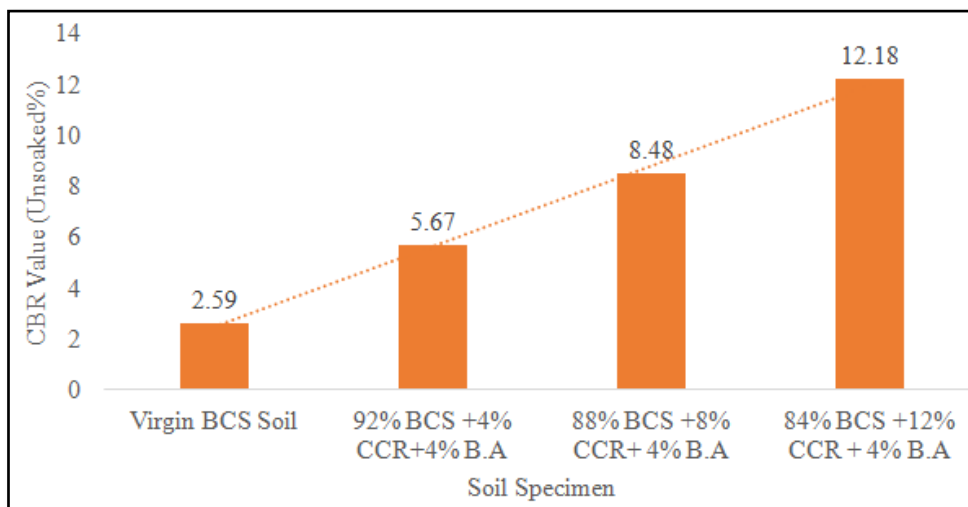


Figure 10: CBR value for Unsoaked Condition

In case of soaked CBR values for soil specimens same increasing trend is observed like unsoaked test conditions. But in soaked condition CBR value of blended specimen is hiked in good way as compared unsoaked condition.

10. Cost Analysis: Cost analysis is concluded for following data

- Road type = Four lane Dual Carriageway (National Highway).
- Initial traffic in the year of completion of Construction = 1450 CVPD (Sum of both directions).
- Traffic Growth rate = 7%
- Design life = 15 years
- Vehicle Damage Factor based on axle load survey = 4.5 Standard axle load per commercial vehicle.
- Lane Distribution factor = 0.45

By using CBR values in soaked condition for respective soil specimens, pavement structure is designed. Following cost analysis is done based on the calculated thickness for each pavement layer.

Table 15: Cost Analysis

Sr. No	Soil Specimens	CBR Value (in %)	Costing (in Rs)
1.	Virgin BCS Soil	5%	3,83,44,180
2.	92% BCS +4% CCR+4% B.A	5%	3,81,33,840
3.	88% BCS +8% CCR+ 4% B.A	6%	3,80,44,580
4.	84% BCS +12% CCR + 4% B.A	7%	3,79,26,980

V. CONCLUSIONS

1. With referring to results observed during grain sieve analysis of 10 samples. Maximum soil is resulted in fine grained fractions. Soil used for research is categorized as Clayey silt on the basis of particle size distribution table.
2. Atterberg’s limits of soil specimens showed increasing trend in liquid limit, plastic limit and shrinkage limit values. For specimen 1 sudden drop observed in plasticity index. However, for next specimens, plasticity index value is increasing gradually. Around 41% plasticity value is dropped for specimen 1. But for specimen 2 and 3 this value is increasing in the range of about 3%. Which means plasticity property is developing with increasing percentage of CCR.
3. As specific gravity of Bagasse ash is less than that of Black cotton soil, which results in decreases the specific gravity of soil specimens. On comparing specific gravity of Virgin soil and soil specimen1 it drops 10%. However specific gravity is increased with increasing percentage of CCR.
4. On Comparing F.S.I values of virgin soil and soil specimens; a decreasing trend is observed throughout the testing. Which means CCR and bagasse ash was impacting on swelling nature of virgin soil.

5. A decreasing trend was observed in values of coefficient of permeability of virgin soil and soil specimens. On performing permeability test on virgin soil and soil specimen's values of coefficient of permeability was decreased 40%.
6. Standard compaction test was performed on virgin soil as well as soil specimens to determine the maximum dry density value and OMC value. With reference to table no. 4.7, this shows that MDD value of virgin soil and specimen 1 is resulted same 1.46gm/cc. But Difference was showed in OMC values. OMC value virgin soil was 9% and OMC value soil specimen 1 was increased by 2.33 times than virgin soil which comes 21%. Which clearly signifies that on addition CCR and Bagasse ash, required water content will be more to obtain maximum density.
7. From the results that obtained from direct shear test, value of cohesion and angle of internal friction values are increased with increasing percentage of CCR and Bagasse ash. Cohesion values of 3rd specimen was increased by 2.53 times than cohesion value of virgin soil.
8. Unconfined Compression test showed increasing trend in strain and shear strength values.
9. CBR values of Specimen 1, Specimen 2, Specimen3 is higher than CBR value of virgin soil in both soaked and unsoaked condition. Which is beneficial in perspective of thickness of pavement required to construct pavement structure.
10. Based on the CBR value and traffic count, the estimated cost for constructing a pavement with the addition of 12% CCR and 4% Bagasse ash with 84% virgin soil is going to be competitive in terms of economically and load bearing capacity for pavement structure.

REFERENCES

- [1] Abdullahi, M. (January- June 2007). Evaluation of plasticity and particle size distribution characteristics of Bagasse ash on cement treated Lateritic soil. Leonardo Journal of Sciences, 137-152.
- [2] Ahmad Batari, A. U. (2017). Effect of bagasse ash on the properties of Cement stabilized Black Cotton soil. IJTEL.
- [3] al., P. G. (March 2015). Improvement in properties of Black Cotton soil with an addition of Natural fibre derived from Coconut covering. International journal of Engineering Research and applications, 36,37.
- [4] Amit S. Kharade, V. V. (March 2014). Waste product 'Bagasse ash' from Sugar Industry can be used as stabilizing material for expansive soils. International journal of Research in Engineering and Technology(IJRET).
- [5] Apichit Kampala, S. H. (May 2013). Engineering properties of silty clay stabilized with Calcium Carbide residue. Journal of Materials in Civil Engineering, ASCE.
- [6] Kiran R.G, K. L. (2013). Analysis of strength characteristics of Black Cotton soil treated with Calcium Carbide residue and Stone Dust. International Journal in Science Engineering and Technology(IJRSET) Vol.2.
- [7] Liet Chi Dang, H. H. (2016). Enhancing the Engineering properties of Expansive soil using Bagasse ash and Hydrated Lime. International Journal of GEOMATE.
- [8] Madurwar, K. V. (2013). Comparative study of Black cotton soil stabilization with RBI Grade 81 and Sodium Silicate. International Journal of Engineering Research and Technology(IJERT) Vol 2.
- [9] Moses, O. K. (2013). Influence of Compactive Effect on Cement- Bagasse ash treatment of Expansive Black Cotton soil. International Journal of Civil and Environmental Engineering Volume 7.
- [10] Neeraj Kumawat, S. A. (2014). Performance analysis of Black cotton soil treated with Calcium Carbide residue and Stone Dust. International Journal of Engineering Research and Technology(IJERST) Vol. 3.
- [11] Sarika B Dhuke, S. V. (Vol. 16 2011). Improvement of flexible pavement with use of Geogrid. EJGE.
- [12] Shimola, K. (December 2018). A Study on soil stabilization using Sugarcane Bagasse ash. International Journal of Innovative Technology and Exploring Engineering.
- [13] V. Ramesh Babu, K. N. (April 2016). Stabilization of Black Cotton Soil with Sand and Cement as a subgrade pavement. International Journal of Civil Engineering and Technology, 341-351.

- [14] Venkatesh Noolu, H. I. (n.d.). Multi scale laboratory investigation on Black cotton soilstabilized with Calcium Carbide residue and Fly ash. International Journal of Engineering Research and Technology(IJERST).
- [15] Y.J. Du, Y. Z. (March 2011). Investigation of strength and California Bearing ratio properties of Natural soils treated by Calcium Carbide residue. Geotechnical Special Publications.

BIOCHAR PRODUCTION OF KITCHEN WASTE AND WATER HYACINTH BY LOW TEMPERATURE STEAM TORREFACTION

Abstract

The rapid industrialization, urbanization, and population growth in India have resulted in a drastic increase in waste generation, particularly food waste, leading to widespread pollution and environmental degradation. This pollution affects all water bodies, including groundwater, soil, air, and even crops such as vegetables and fruits. As a consequence, certain regions of the country are facing a severe proliferation of water hyacinth in their water bodies causing eutrophication

This study proposes the adoption of a new waste management method: biochar production with water hyacinth and food waste. Biochar, with its high carbon content, has garnered attention from researchers worldwide due to its ability to convert waste into valuable products in a remarkably short time. The study explores various methods of biochar production, with a particular focus on torrefaction, which has gained popularity among researchers for its ability to produce biochar at low temperatures (200-300°C) and in a short timeframe (10-120 minutes).

The study conducts various tests on biochar samples, including grain size distribution analysis of raw feedstocks, proximate analysis, pH measurement, water retention capacity assessment, and Brunauer-Emmett-Teller (BET) surface area analysis. This research underscores the potential of biochar production as a viable and sustainable solution for managing waste. By understanding the properties and applications of biochar, researchers and policymakers can promote its adoption to

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address pollution, reduce landfill usage, and foster a healthier environment.

Keywords: Food waste, Water Hyacinth, Biochar, Torrefaction.

I. INTRODUCTION

The global population outbreak has triggered a significant increase in waste generation, posing a grave threat to the environment. Improper waste management, particularly the lack of source segregation in India, has resulted in vast quantities of waste being dumped into landfills, burdening existing sites and necessitating the creation of new ones. As a result, there is an urgent need for effective waste management practices, with a primary focus on waste reduction at the source itself.

According to CPCB 2016, India produced 62 metric tons of municipal solid waste (MSW) in 2015, projected to rise to a staggering 436 metric tons by 2050. Among the states, Maharashtra generated the largest quantity of 14,900 metric tons per day in 2015 [1].

In addition to waste management, eutrophication, exacerbated by the increasing use of chemical fertilizers globally, is a pressing concern. Raising awareness about the detrimental effects of chemical fertilizers and promoting the adoption of natural alternatives, such as biochar, is vital. Eutrophication has led to the proliferation of water hyacinth in rivers, forming a harmful layer that hinders sunlight and air penetration, endangering aquatic life [2].

To address these challenges, various waste management methods are being employed, including composting, incineration, anaerobic digestion, refuse-derived fuel, and biochar production [3]. Biochar production, in particular, is gaining traction among researchers due to its thermochemical process that converts waste into valuable biochar. Efforts are underway to popularize this method globally and create market demand [4].

Among the thermal treatments involved in biochar production, the torrefaction method has garnered significant attention. Researchers are drawn to its ability to produce biochar at low temperatures (200-300°C) and within a short timeframe (10-120 minutes) [5].

In the current scenario, managing waste and adopting sustainable practices, like biochar production, are critical steps towards mitigating environmental issues and promoting a cleaner, greener future.

II. METHODOLOGY

1. Biochar Production Methods: Biochar, a carbon-rich charcoal, is synthesized through diverse thermal decomposition methods employing organic biomass and agricultural residues as feedstocks. Constituting elements like carbon, hydrogen, nitrogen, ash, oxygen, and sulphur, biochar production yields by-products such as bio-oil and biofuels like hydrogen gas. Thermal treatments, including pyrolysis, gasification, carbonization, hydrothermal carbonization, and torrefaction, are integral to its creation. Biochar's porous nature augments soil surface area, enhancing water retention capacity, thereby serving to enrich soil nutrient content and sequester carbon.

Though the biochar concept is ancient, the term itself was coined recently. Evidence of its historical use exists in the Amazon Basin, where regions known as terra preta boasted soil enriched with organic matter and char, contributing to fertility. Amidst escalating global carbon dioxide emissions largely attributed to energy use, biochar

production presents a significant avenue for mitigating greenhouse gases (GHGs). Predicted reductions of up to 12% in human-caused GHG emissions through biochar's carbon sequestration potential are substantial.

Biochar production techniques encompass a range of methods, all converging on the conversion of feedstocks into carbon-rich material under oxygen-deficient conditions. As the world confronts multifaceted sources of CO₂ emissions—ranging from natural carbon cycles to vehicular discharges, deforestation, and wildfires—biochar emerges as a promising solution, embodying potential for carbon reduction, waste management, soil enhancement, and sustainable agriculture.

- **Pyrolysis:** Pyrolysis is a thermochemical decomposition process that converts feedstock into a value-added product, biochar, at elevated temperatures. The temperature range for pyrolysis falls between 250°C and 1000°C, yielding solid, liquid (bio-oil), and gaseous (syngas) products. This process involves reactions such as depolymerization, fragmentation, and cross-linking of lignocellulosic components (lignin, cellulose, and hemicellulose) at specific temperatures. Biochar yield is influenced by the feedstock type and nature, with higher pyrolysis temperatures favouring syngas production over biochar [5], [6].

Classified based on parameters like temperature, residence time, pressure, and heating rate, pyrolysis comprises two types:

- **Slow Pyrolysis:** Operating between 300°C and 700°C, this process features longer residence times exceeding 1 hour and gradual heating at 5-7°C/min. The extended residence time contributes to higher biochar yields, retaining up to 50% of feedstock carbon. It is utilized for producing activated carbon, methanol, and converting ethylene dichloride to polyvinylchloride (PVC) [4], [5].
- **Fast Pyrolysis:** Employing temperatures between 500°C and 1000°C, with a residence time of 0.5-2 seconds, this method is suited for bio-oil production when biochar yield is less emphasized [5].
- **Carbonization:** Carbonization involves pyrolytic processes akin to traditional charcoal production, converting carbon-rich materials. Conversion temperatures range from 280°C to 500°C, spontaneously yielding charcoal alongside combustible and non-combustible gases [4], [7].
- **Gasification:** Gasification is a thermochemical decomposition process converting carbonaceous materials into syngas, primarily composed of CH₄, CO, H₂, CO₂, and trace hydrocarbons, under temperatures exceeding 700°C. Gasification agents like air, oxygen, and steam facilitate the conversion. Syngas can be combusted efficiently at high temperatures or in fuel cells, making it more effective than direct fuel combustion. Biomedical waste can serve as a suitable input for gasification, where corrosive elements like chloride and potassium are effectively removed due to the high temperature [4], [5].

- **Hydrothermal Carbonization (HTC):** Hydrothermal carbonization, conducted under pressure, transforms wet biomass into a carbon-rich product, hydrochar. The process operates within a pressure range of 2 to 10 MPa [6], [8]. Hydrothermal treatment encompasses three categories: hydrothermal carbonization, hydrothermal liquefaction, and hydrothermal gasification.
 - **Hydrothermal Carbonization:** Operating at temperatures below 250°C, this process yields hydrochar (solid product) as the primary output, with a residence time of 1-16 hours [9][10].
 - **Hydrothermal Liquefaction:** Ranging from 250°C to 400°C, this method prioritizes bio-oil (liquid product) yield over solid and gaseous products [5].
 - **Hydrothermal Gasification:** Requiring temperatures above 400°C, these variant yields syngas, including CO₂, H₂, CO, and CH₄, with a higher emphasis on gaseous products over solid and liquid counterparts [5], [11].

HTC stands out as a cost-effective process, eschewing pre-drying procedures, and directly accommodating wet feedstock in the reactor [12]. Often referred to as wet pyrolysis or wet torrefaction, HTC capitalizes on water's dual role as both a catalyst and reactant, particularly in hydrolysis reactions [3], [11]. The resulting hydrochar exhibits an elevated heating value attributed to diminished lignin and cellulose components from the feedstock during the HTC process [11].

- **Torrefaction:** Torrefaction is an emerging methodology within the realm of biochar production. Often referred to as mild pyrolysis, it distinguishes itself by its low heating rate requirement. Operating at temperatures ranging from 200°C to 300°C, and with a residence time spanning 10 to 60 minutes, torrefaction yields higher biochar quantities compared to bio-oil and syngas. This process induces alterations in feedstock properties, encompassing surface area, particle size, energy density, moisture content, and heating rate [5]. Key factors influencing torrefied output's mass and energy yield include torrefaction temperature, residence time, particle size, and biomass type [13].

The Torrefaction process is categorized into four distinct types [5]:

- **Steam Torrefaction:** Under steam action, biochar production occurs at temperatures not exceeding 260°C, with a brief residence time of 10 minutes.
- **Wet Torrefaction:** Also known as hydrothermal carbonization, this process mirrors HTC in terms of required temperature (180-260°C) and residence time (1-16 hours). Wet biomass serves as the feedstock.
- **Oxidative Torrefaction:** Operating at 200-300°C for less than 30 minutes, with a heating rate under 50°C/minute, this partial pyrolysis process utilizes oxidizing agents like combustion gases (CO₂, O₂) for temperature generation.
- **Dry Torrefaction:** This process entails distinct phases - heating, drying (pre-drying and post-drying), torrefaction, and cooling. Feedstock is heated or pre-dried until complete moisture evaporation occurs at 100°C. The torrefaction phase stabilizes the temperature at 200-300°C, followed by post-drying at 200°C to eliminate residual moisture. Mass loss occurs due to temperature increase post-

torrefaction. The final product is cooled at room temperature prior to exposure to air.

Efficient pre-drying hinges on managing feedstock moisture and torrefaction degree. Integrating torrefaction with a combustion/gasification chamber can utilize waste heat for drying, enhancing overall system efficiency. The key advantage of torrefaction is the improved quality of biomass fuel, closely resembling coal combustion behavior [13].

The torrefaction process engages several reactions: hydrolysis, dehydration, decarboxylation, aromatization, and recondensation [8],[14]. Initially containing carbon, hydrogen, oxygen, and nitrogen, hydrolysis adds water, cleaving bonds to form alcohol groups. Dehydration involves water loss, resulting in alkene formation and carbon enrichment. Decarboxylation releases CO₂ gas by removing carboxyl (-COOH) groups. Aromatization removes hydrogen or other atoms, enhancing aromaticity or forming stable products. Recondensation combines molecules by eliminating small entities like -H₂O, -NH₃, and -HCl, facilitating hydrogen, oxygen, and nitrogen reduction while augmenting carbon content. The reaction sequence is variable, with no specific order or timing [6], [7], [11], [15].

- 2. Sample Collection and Preparation:** Household kitchen waste was gathered on a daily basis and subjected to sun drying to eliminate its excess moisture content. Approximately 5kg of the desiccated waste was utilized in the production of biochar, following a fine grinding process.

Water hyacinth is harvested from the Mula Mutha River, which flows behind MIT ADT University in Pune. A substantial quantity of 8-15 large bin bags filled with water hyacinth is collected for the purpose of biochar production. The water hyacinth undergoes sun drying on the rooftop of the house to eliminate excessive moisture. Subsequently, the stems of the plant are separated from the leaves and roots. The dried stems are then finely ground.



Figure 1: Shredded Feedstocks - Kitchen Waste and Water Hyacinth

In research both kitchen waste and water hyacinth have been independently employed for biochar production. In this particular study, a novel approach is undertaken by combining both feedstocks in varying proportions to create biochar.

The biochar samples were prepared using the following ratios:

- Sample 1: Pure water hyacinth (WH) biochar.
- Sample 2: Pure kitchen waste (KW) biochar.
- Sample 3: Equal parts of water hyacinth and kitchen waste biochar (50%:50% or 1:1 ratio).
- Sample 4: A mixture of 40% water hyacinth and 60% kitchen waste biochar (1:1.5 ratio).
- Sample 5: A blend of 30% water hyacinth and 70% kitchen waste biochar (1:2.33 ratio).
- Sample 6: A combination of 60% water hyacinth and 40% kitchen waste biochar (1.5:1 ratio).
- Sample 7: A mix of 70% water hyacinth and 30% kitchen waste biochar (2.33:1 ratio).

These different feedstock proportions were placed in a steel container and processed individually for 14-16 hours during working hours using a laboratory vertical autoclave reactor. The experiments were conducted in the Environmental Engineering Laboratory of the Civil Department at MIT School of Engineering & Science.

The laboratory vertical autoclave reactor is designed to operate at a temperature and pressure of 150°C and 30 kg/cm², respectively. Its maximum achievable temperature and pressure are 124°C and 18-22 kg/cm² (1.76-2.16 MPa), respectively. The autoclave functions using steam. Consequently, the resulting biochar samples underwent additional drying in a hot air oven within the Environmental Engineering Laboratory to eliminate any remaining excess moisture.

III. RESULT AND DISCUSSION

1. Proximate Analysis: Proximate analysis is conducted to assess the moisture percentage, volatile matter, ash content, and, most importantly, the fixed carbon content within the biochar samples. Research indicates that a higher fixed carbon content corresponds to greater product stability. The ensuing findings are elaborated upon in the subsequent discussion.

- **Moisture Content Analysis:** Moisture content analysis is done based on ASTM standard E871[16]

Table 1: Moisture Content Analysis of Biochar Samples

Sample	Moist Weight W_1 (g)	Dry Weight W_2 (g)	Moisture Content (%) $\frac{W_1 - W_2}{W_1} \times 100$
WH raw	1.001	0.948	5.3
KW raw	1.006	0.903	10.24
WH Biochar	1.008	0.965	4.27
KW Biochar	1.007	0.992	1.5
1:1 Biochar	1.005	0.972	3.3
1:1.5 Biochar	1.002	0.961	4.1
1:2.33 Biochar	1.006	0.964	4.2
1.5:1 Biochar	1.006	0.983	2.3
2.33:1 Biochar	1.007	0.968	3.87

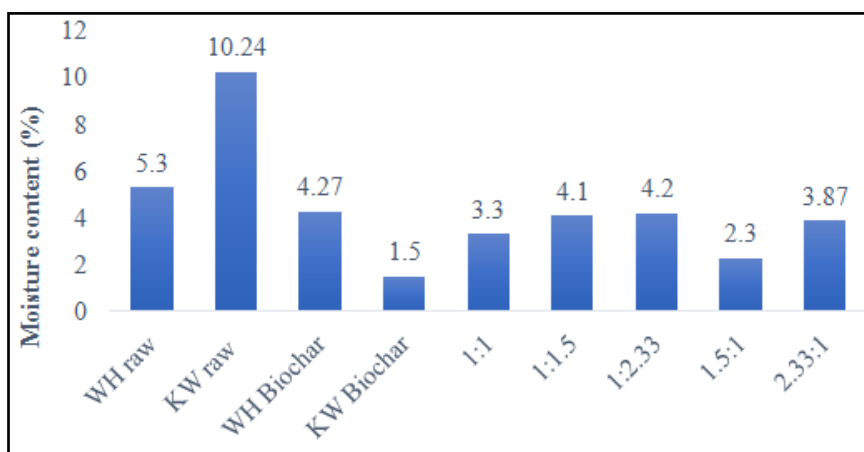


Figure 2: Moisture % of Biochar Samples & Raw Waste Samples

The raw samples exhibit a higher peak value of moisture percentage, reflecting the elevated moisture content in kitchen waste and water hyacinth. Upon comparing biochar samples to their raw counterparts, it becomes evident that water hyacinth biochar retains 4.27% moisture, while kitchen waste biochar contains the least moisture at 1.5%. Studies suggest a reduction in moisture percentage for torrefied biochar. The biochar in these samples demonstrates enhanced soil longevity without compromising the environment, owing to its lower moisture content. This characteristic minimizes nutrient runoff from agricultural fields, reducing the risk of eutrophication.

Consequently, kitchen waste biochar boasts an extended soil residence compared to other samples due to its minimal moisture content. It's noteworthy that the moisture content of biochar, ranging from 1% to 5%, aligns with that of coal (10-15%) and torrefied biochar. Thus, all seven biochar samples illustrated in Figure 15 maintain a moisture percentage within the range of 1-5%.

- **Volatile Matter (%)**

Volatile matter is calculated based on ASTM standard E872[17]

Calculation of weight loss percent is as follows:

$$(A) \text{ weight loss \%} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight} - \text{Weight of crucible}} \times 100$$

Calculation of volatile matter percent in the analysis of samples is as follows:

$$\text{Volatile matter in analysis sample} = (A) - (B)$$

Where,

A = weight loss % and

B = moisture content % determine using ASTM E871

Table 2: Volatile Matter Analysis of All the Seven Biochar Samples

Sample	Weight of crucible w_c (g)	Initial weight w_i (g)	Final weight w_f (g)	Volatile matter (%)
WH raw	18.752	19.257	18.889	67.57
KW raw	19.495	20.001	19.538	81.26
WH Biochar	18.891	19.393	19.064	61.27
KW Biochar	19.439	19.945	19.524	81.7
1:1 Biochar	18.940	19.445	19.073	70.36
1:1.5 Biochar	18.716	19.219	18.860	67.27
1:2.33 Biochar	18.893	19.401	19.047	65.48
1.5:1 Biochar	19.446	19.95	19.627	61.78
2.33:1 Biochar	18.943	19.445	19.121	60.67

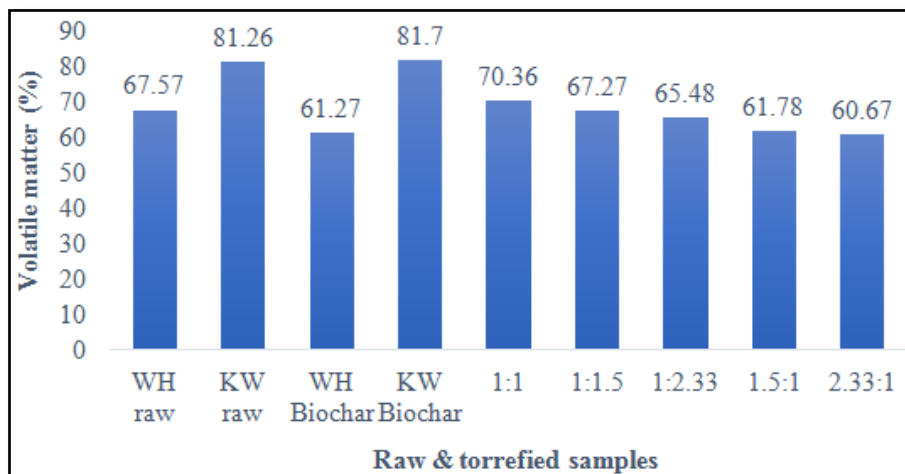


Figure 3: Volatile % of Biochar Samples and Raw Waste Samples

The biochar samples with high volatile percent are considered highly reactive and thus highly reactive torrefied biomass are compared to coal. Torrefied biochar

samples with high volatile matter are best substitute for fuel production and not for soil amendment. Thus, from figure 16. it is observed that 2.33:1 biochar sample which contains 70% by weight water hyacinth and 30% by weight kitchen waste can be best suited for soil amendment as it has the least volatile matter percent in comparison to other biochar samples [13].

- **Ash Content (%):** Ash content is calculated based on ASTM standard E1755 [18]

Table 3: Ash Content Analysis of the Biochar Samples

Sample	Weight of crucible W_c (g)	Weight of sample W_1 (g)	Weight of ash + crucible W_2 (g)	Ash content (%)
WH raw	18.752	0.505	18.792	4
KW raw	19.495	0.506	19.496	0.2
WH Biochar	18.891	0.502	18.949	11.5
KW Biochar	19.439	0.506	19.451	2.37
1:1 Biochar	18.940	0.505	18.975	7
1:1.5 Biochar	18.716	0.503	18.735	3.78
1:2.33 Biochar	18.893	0.508	18.913	3.94
1.5:1 Biochar	19.446	0.504	19.485	7.74
2.33:1 Biochar	18.943	0.502	18.994	10.1

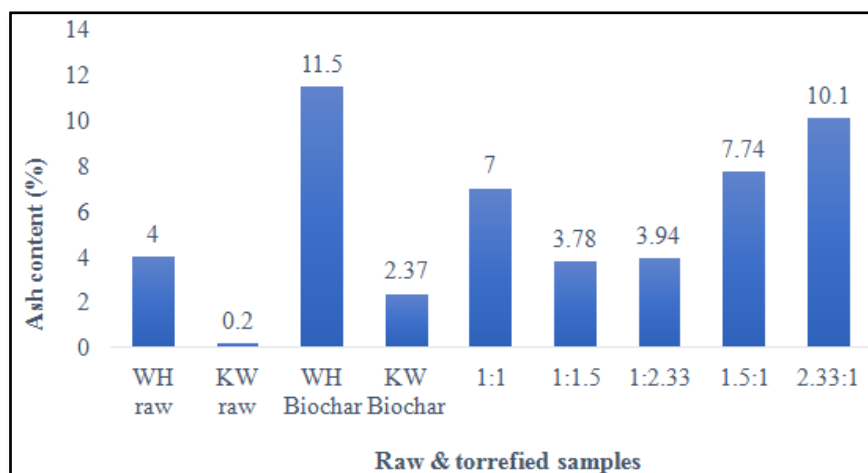


Figure 4: Ash % of Biochar Samples and Raw Waste Samples

According to the studies, low ash content of biochar sample is preferred for soil amendment as properties of biochar play a vital role in deciding the application of biochar in various fields. For example, biochar with high surface area along with presence of binding sites are useful as adsorbents for various contaminants, then biochar having porosity and high structural bound nitrogen groups are best suited for the development of supercapacitors etc.

Thus, from figure 17. We can determine that kitchen waste (KW) biochar is best suitable for soil amendment as it has least ash content [12].

- **Fixed Carbon Content (%)**

Fixed carbon is calculated as shown below [19]

$$\text{Fixed carbon} = 100 - [\% \text{ moisture content} + \% \text{ volatile matter} + \% \text{ ash content}]$$

Table 4: Fixed Carbon Content of Biochar Samples

Sample	% Moisture content	% Volatile matter	% Ash content	Fixed carbon (%)
WH raw	5.3	67.57	4	23.13
KW raw	10.24	81.26	0.2	8.3
WH Biochar	4.27	61.27	11.5	22.96
KW Biochar	1.5	81.7	2.37	14.43
1:1 Biochar	3.3	70.36	7	19.34
1:1.5 Biochar	4.1	67.27	3.78	24.85
1:2.33 Biochar	4.2	65.48	3.94	26.38
1.5:1 Biochar	2.3	61.78	7.74	28.18
2.33:1 Biochar	3.87	60.67	10.1	25.36

Studies say that fixed carbon content increases due to decomposition of lignin to small substances. Higher fixed carbon also signifies the stability of biochar sample. The more the fixed carbon value, more stable is the product. Also, torrefied biochar sample's behavior are compared to coal because coal has a fixed carbon content of 50-55% whereas torrefied biochar sample's fixed carbon content range between 28-35%. Therefore, from figure 18. we can determine that 1.5:1 biochar sample which contains 60% by weight water hyacinth and 40% by weight kitchen waste is the most stable biochar as it is lying within the range of 28-35% of fixed carbon content.

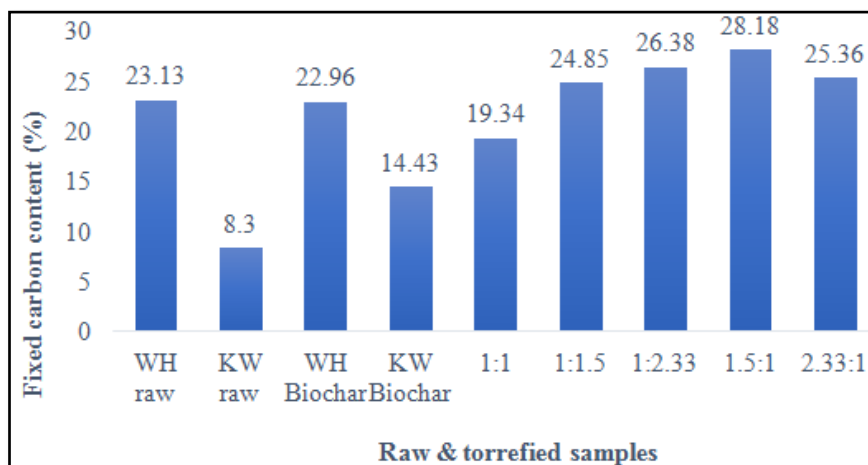


Figure 5: Fixed carbon % of Biochar Samples and Raw Waste Samples

2. Water Retention Capacity: Water retention capacity signifies that how much gram of water is being retained per gram of biochar.

Table 5: Water Retention Capacity of Biochar Samples (cont.)

Sample (1)	Wet weight (g) (2)	Dry weight (g) (3)	Weight of torrefied sample (g) (4)	Water retention capacity ($\frac{g}{g}$) (5) = $\frac{(2)-(3)}{(4)}$	Water retention capacity (%) (6) = $\frac{(2)-(3)}{(2)} \times 100$
WH Biochar	45.181	7.343	10.008	3.78	83.75
KW Biochar	26.692	6.91	10.004	1.98	74.11
1:1 Biochar	33.222	7.033	10.002	2.62	78.83
1:1.5 Biochar	29.827	6.69	10.006	2.31	77.6
1:2.33 Biochar	26.982	6.619	10.003	2.04	75.5
1.5:1 Biochar	32.755	7.041	10.008	2.57	78.5
2.33:1 Biochar	39.88	7.107	10.004	3.27	82.2

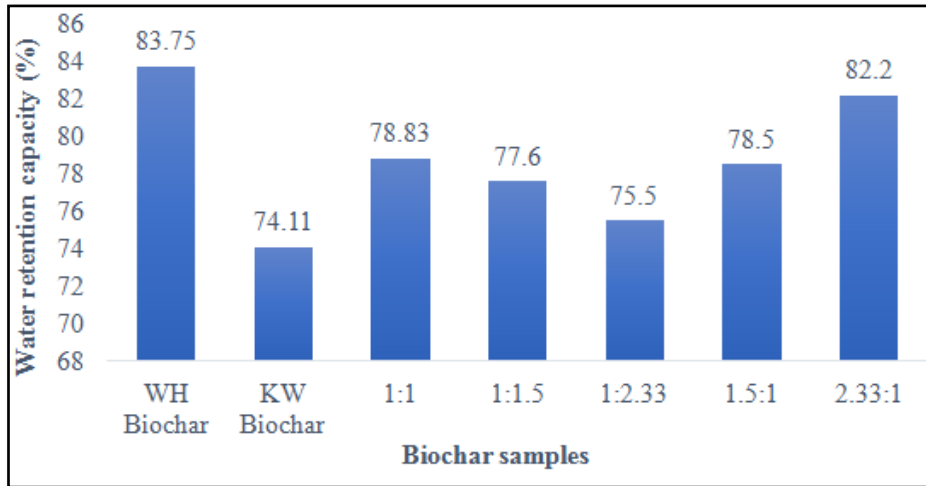


Figure 6: Water Retention Capacity of Biochar

The results in table 5, Column 5 determine that certain gram of water is retained per gram of biochar. Highest water retention capacity is of water hyacinth biochar which means 3.78 g of water is retained per gram of biochar. Also, by calculating percent water retention capacity which is shown in figure 6. We can make out which biochar sample has the maximum capacity to retain water because according to the studies water retention

capacity of biochar ranges between 75-274%. So, after calculating percentage water retained also we can see that water hyacinth biochar has the highest water retention capacity [12][20].

- Brunauer-Emmett-Teller (BET) Surface Area Analysis:** This analysis explains the physical adsorption of gas molecules on a solid surface. Thus, it becomes the important analysis technique for measuring the specific surface area of any material.

Table 6: Surface area of Raw Feedstock & Biochar Samples

Sample	BET surface area (m ² /g)
WH raw	6.11
KW raw	3.04
WH Biochar	0.575
KW Biochar	0.417
1:1	1.87
1:1.5	0.963
1:2.33	0.351
1.5:1	0.723
2.33:1	1.24

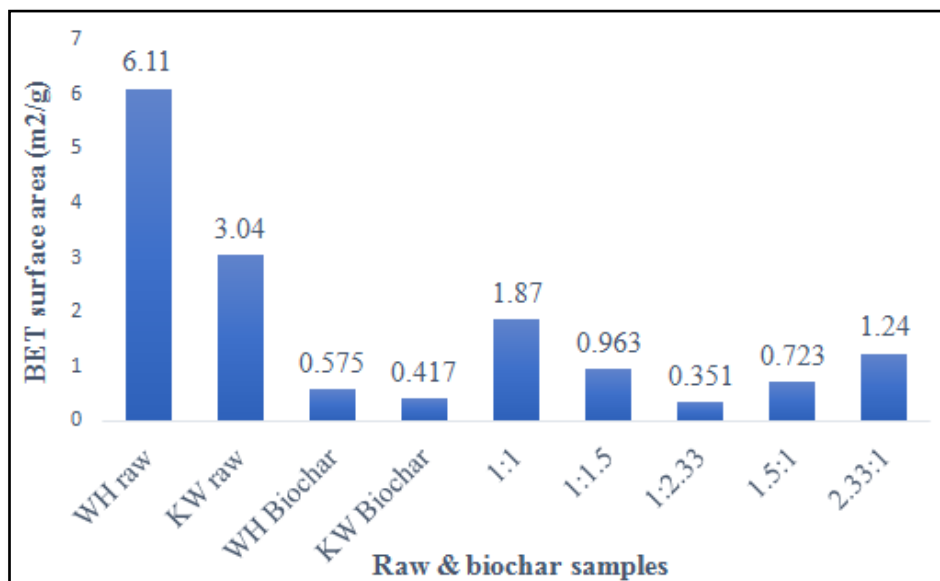


Figure 7: Surface Areas Raw and Biochar Samples

From figure 7. we can see that surface area of raw feedstock is more in comparison to the biochar samples. This may be due to less temperature difference between pre-drying of raw feedstock and the autoclaving to produce biochar. But studies say that even when the surface area is less the biochar can have a good effect in water retention and nutrient retention as it depends on the feedstock properties as well. Thus, this can best be explained when we do the soil application of biochar experiment and then conclude whether the biochar samples work well on soil or not [3].

IV. CONCLUSIONS

The kitchen waste biochar exhibits the highest volatile matter content, attributed to its organic matter composition. Conversely, the biochar sample with a feedstock ratio of 2.33:1, comprising more water hyacinth and less kitchen waste, contains reduced volatile matter due to the lower organic matter content in water hyacinth.

Ash content displays an inverse relationship with volatile matter. Therefore, the biochar from kitchen waste reveals the least ash content at 2.37%, owing to its elevated volatile matter content. On the other hand, the water hyacinth biochar demonstrates the highest ash content at 11.5%, influenced by its lower percentage of volatile matter.

The fixed carbon content is influenced by the proportion of volatile matter. Raw kitchen waste biochar displays the lowest fixed carbon content at 14.43%, primarily due to its elevated volatile matter. In contrast, the biochar with a ratio of 1.5:1 (water hyacinth to kitchen waste) exhibits the highest fixed carbon content at 28.18%, attributed to the lower volatile matter content in water hyacinth.

The determination of water retention capacity serves to gauge the moisture-holding capability of a given biochar sample when applied to soils. Among the samples, raw water hyacinth biochar displays the highest water retention capacity at 83.75%, while raw kitchen waste biochar exhibits the lowest at 74.11%. This discrepancy arises from the dependence of water retention capacity on the specific feedstock used. The fibrous structure of water hyacinth's stem contributes to its exceptional moisture retention ability, reaching up to 95%.

The Brunauer-Emmett-Teller (BET) surface area test is employed to quantify the surface area of the samples. The surface areas for water hyacinth, kitchen waste, and biochars with ratios of 1:1, 1:1.5, 1:2.33, 1.5:1, and 2.33:1 are measured at 0.575 m²/g, 0.417 m²/g, 1.24 m²/g, 0.963 m²/g, 0.351 m²/g, 0.723 m²/g, and 1.87 m²/g, respectively. These biochar samples exhibit relatively smaller surface areas due to their production at a lower temperature of 124°C in the autoclave reactor. Elevated temperatures exceeding 124°C, particularly above 200°C, lead to the expansion of biochar pores and an increase in surface area.

REFERENCES

- [1] K. D. Sharma and S. Jain, "Overview of Municipal Solid Waste Generation, Composition, and Management in India," *Journal of Environmental Engineering*, vol. 145, no. 3, Mar. 2019, doi: 10.1061/(asce)ee.1943-7870.0001490.
- [2] M. Nasir Khan, "Eutrophication: Challenges and Solutions View project", doi: 10.13140/2.1.3673.8884.
- [3] H. S. Kambo and A. Dutta, "A comparative review of biochar and hydrochar in terms of production, physico-chemical properties and applications," *Renewable and Sustainable Energy Reviews*, vol. 45. Elsevier Ltd, pp. 359–378, 2015. doi: 10.1016/j.rser.2015.01.050.
- [4] N. Bordoloi and B. Borkotoki, "Chapter 2-Biochar: An Overview on its Production, Properties and Potential Benefits," 2015, doi: 10.13140/RG.2.1.3966.2560.
- [5] P. R. Yaashikaa, P. S. Kumar, S. Varjani, and A. Saravanan, "A critical review on the biochar production techniques, characterization, stability and applications for circular bioeconomy," *Biotechnology Reports*, vol. 28. Elsevier B.V., Dec. 01, 2020. doi: 10.1016/j.btre.2020.e00570.
- [6] A. Parmar, P. K. Nema, and T. Agarwal, "Biochar production from agro-food industry residues: a sustainable approach for soil and environmental management," 2014.
- [7] D. Kim, K. Y. Park, and K. Yoshikawa, "Conversion of Municipal Solid Wastes into Biochar through

- Hydrothermal Carbonization,” in *Engineering Applications of Biochar*, InTech, 2017. doi: 10.5772/intechopen.68221.
- [8] J. Fang, L. Zhan, Y. S. Ok, and B. Gao, “Minireview of potential applications of hydrochar derived from hydrothermal carbonization of biomass,” *Journal of Industrial and Engineering Chemistry*, vol. 57. Korean Society of Industrial Engineering Chemistry, pp. 15–21, Jan. 25, 2018. doi: 10.1016/j.jiec.2017.08.026.
- [9] A. Y. Krylova and V. M. Zaitchenko, “Hydrothermal Carbonization of Biomass: A Review,” *Solid Fuel Chemistry*, vol. 52, no. 2. Pleiades Publishing, pp. 91–103, Mar. 01, 2018. doi: 10.3103/S0361521918020076.
- [10] R. Tu *et al.*, “The fuel properties and adsorption capacities of torrefied camellia shell obtained via different steam-torrefaction reactors,” *Energy*, vol. 238, Jan. 2022, doi: 10.1016/j.energy.2021.121969.
- [11] R. Sharma *et al.*, “A Comprehensive Review on Hydrothermal Carbonization of Biomass and its Applications,” *Chemistry Africa*, vol. 3, no. 1. Springer Science and Business Media Deutschland GmbH, Mar. 01, 2020. doi: 10.1007/s42250-019-00098-3.
- [12] V. Kuppusamy, “Biochar: production strategies, potential feedstocks and applications Biochar for Energy and Environmental Cleanup View project modelling View project,” Chennai- 600036, Jul. 2016. [Online]. Available: www.vinanie.com/jebr
- [13] B. Acharya, A. Dutta, and J. Minaret, “Review on comparative study of dry and wet torrefaction,” *Sustainable Energy Technologies and Assessments*, vol. 12. Elsevier Ltd, pp. 26–37, Dec. 01, 2015. doi: 10.1016/j.seta.2015.08.003.
- [14] J. A. Libra *et al.*, “Hydrothermal carbonization of biomass residuals: A comparative review of the chemistry, processes and applications of wet and dry pyrolysis,” *Biofuels*, vol. 2, no. 1, pp. 71–106, Jan. 2011, doi: 10.4155/bfs.10.81.
- [15] N. T. L. Chi *et al.*, “A review on biochar production techniques and biochar based catalyst for biofuel production from algae,” *Fuel*, vol. 287, Mar. 2021, doi: 10.1016/j.fuel.2020.119411.
- [16] AMERICAN SOCIETY FOR TESTING AND MATERIALS, “kupdf.net_astm-e871-82-anexo-1pdf,” *Annual Book of ASTM Standards*, vol. Vol 05.05, pp. 1–2, 1982, Accessed: Feb. 23, 2023. [Online]. Available: https://kupdf.net/download/astm-e871-82-anexo-1pdf_5d1ddc3fe2b6f582069e17b4_pdf
- [17] AMERICAN SOCIETY FOR TESTING AND MATERIALS, “Standard Test Method for Volatile Matter in the Analysis of Particulate Wood Fuels 1,” 2013. [Online]. Available: www.astm.org
- [18] AMERICAN SOCIETY FOR TESTING AND MATERIALS, “Standard Test Method for Ash in Biomass 1,” *r Annual Book of ASTM Standards*, pp. 1–3, 2015, doi: 10.1520/E1755-01R15.
- [19] AMERICAN SOCIETY FOR TESTING AND MATERIALS, “E870-82 (Reapproved 2006) Fixed Carbon content,” *r Annual Book of ASTM Standards*, pp. 1–2, 2006, Accessed: Jun. 14, 2023. [Online]. Available: <https://www.astm.org/>
- [20] S. K. Thengane *et al.*, “Oxidative torrefaction for cleaner utilization of biomass for soil amendment,” *Clean Eng Technol*, vol. 1, Dec. 2020, doi: 10.1016/j.clet.2020.100033.

MICROSIMULATION MODELLING IN VISSIM ON EFFECTS OF TRAFFIC CONGESTION DUE TO CONSTRUCTION OF FLYOVER ON SINHAGAD ROAD IN PUNE, INDIA

Abstract

One of the most important aspects of a developing country is transportation, which is essential to ensure the development of metropolitan areas. In India, the number of vehicles has drastically increased due to the country's rapid population growth, urbanization, and improving living conditions. In India, There is a lot of congestion surrounding large urban areas. At intersections, traffic congestion has become a severe issue. In order to look into possible mitigation strategies for these intersections and work zone areas, a traffic simulation model is created that computes traffic flow characteristics and illustrates how congestions behave when certain traffic demands are placed on the system. A 2.75 km stretch of Pune's Funtime cinema to Rajaram Bridge was chosen for the investigation. By providing alternate routes, work zones can lessen the adverse effects of traffic congestion, which frequently result in increased congestion and delays for road users. The condition for traffic volume before and after the construction of the flyover is analysed using VISSIM, a traffic simulation programme. The expected outcomes would demonstrate that the suggested plan can significantly reduce delay time, Queue length, and traffic congestion, greatly enhancing the entire transportation capacity of Sinhagad road.

Keywords: Traffic congestion, flyover, PTV VISSIM.

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I. INTRODUCTION

Pune ranks ninth among the most populated cities in India and is the second-largest city in Maharashtra. With the uncontrollable population surge in India, transportation remains one of the important aspects of concern with respect to population increase. One of the most populated areas of Pune is Sinhagad. As with the rapid increase in population, the dependency on vehicles has also increased, which has a major impact on traffic congestion. And as Sinhagad Road is the major connecting link between the city and the national highway, it is an important transportation component as it provides connectivity within the city and intercity via the highway. Sinhagad road stretch from Rajaram Bridge to Funtime junction is a very busy stretch with over five signalized junctions and traffic getting fed from several internal roads. A dense settlement and mixed-use land use on both sides of the road make its edge cause constant friction with the moving traffic. The growth further towards the Nanded city, kirkitwadi is very high. In absence of the PMRDA ring road and poor connectivity from the Katraj-Hinjewadi bypass highway, Sinhagad road faces major traffic congestion and delays. The dense area of Suncity is only accessible from one single road. The high amount of student traffic a Sinhagad College uses this road daily. There is the absence of riverside road. Comprehensive Mobility Plan proposes METRO over Sinhagad road along with connecting link between Karve Nagar and Suncity via River Bridge and connecting link between Dhankawdi Sahakarnagar and Hingne via tunnel in the form of Intermediate ring road. Therefore it was selected for the concerned study of investigating countermeasures for these intersections and work zone areas a traffic simulation model is created that computes the characteristics of traffic flow and analyzes the behaviour of congestions under specific traffic demands. For the study, VISSIM software was used for modeling. For the modeling data required was obtained with the surveys conducted on the above-mentioned stretch of 2.75 km from Rajaram Bridge to the Funtime cinema.

II. METHODOLOGY

- 1. Study Area:** The stretch of Sinhagad Road from Rajaram Bridge to Fun-time Junction is known for being highly congested, primarily due to the presence of multiple signalized junctions. Along this busy stretch, there are a total of five signalized junctions, consisting of four three-arm junctions and one four-arm junction. The total stretch length is 2.74 Km. the presence of these signalized junctions indicates that traffic flow along Sinhagad Road needs to be regulated to ensure the smooth movement of vehicles and ensure safety for both motorists and pedestrians. However, the frequent stops and signal cycles at these junctions can result in traffic congestion, especially during peak hours when the volume of vehicles is high. The location plan of the research is shown in the figure below

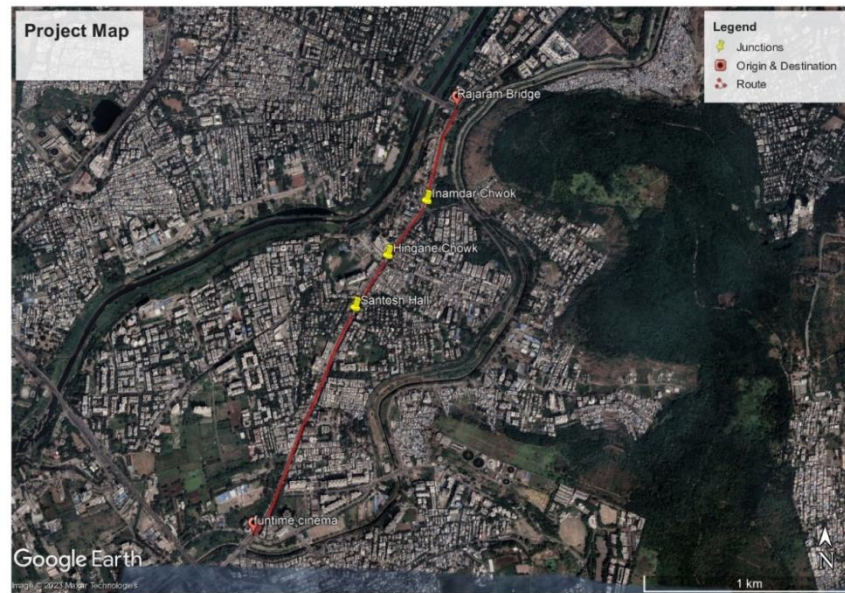


Figure 1: Study Area

At the research site, construction of the flyover is started from Rajaram Bridge to Funtime cinema can be seen in the below figure.



Figure 2: Flyover Construction at Research Site

2. Data Collection: The before-construction data was collected from PMC, and during construction, data was collected by conducting a manual survey from 15th March 2022 to 21st March 2022. During the construction phase of the Rajaram Bridge to Fun-time Cinema project, several surveys were conducted to collect data related to traffic conditions. These surveys included vehicle turning movement, vehicle volume, and vehicle speed. The data collected through these surveys was crucial for understanding the existing traffic patterns and informing the design and planning of the construction project. The traffic survey was conducted manually using the tally and mark method. This method involves trained surveyors stationed at specific locations, typically at the five junctions

along the project route. The surveyors visually observed and tallied the number of vehicles making different types of turns at each junction. This included counting the vehicles turning left, right, or going straight at each junction. The surveyors also recorded the volume of vehicles passing through each junction during the survey period. This information was used to inform the design and planning of the construction project, including considerations for traffic management, lane configurations, signal timings, and other necessary measures to minimize disruption and ensure smooth traffic flow during the construction period.

- 3. Traffic Turning Movement Survey:** A traffic turning movement survey is a method used to collect data on the volume and patterns of vehicles making various types of turns at a specific intersection or road segment. It provides valuable information about the flow of traffic and helps transportation planners and engineers make informed decisions regarding traffic signal timings, lane configurations, and overall intersection design. During a traffic turning movement survey, data is collected on the number of vehicles turning left, right, or going straight at each approach of an intersection or specific locations along a road. The survey team identifies the specific location on each where data needs to be collected. Factors such as traffic volume, complexity of movements, and specific project requirements are taken into consideration. A manual counting method is used for the survey. The survey team collects data over a specific time period, typically several hours or even days, to capture variations in traffic patterns. They recorded the number of vehicles and the specific turning movements made at each approach or location. Once the data collection is complete, the collected data is analyzed to determine the volume of turning movements, the percentage of traffic making different types of turns, and the peak periods of turning activity. This analysis helps identify traffic patterns, congestion hotspots, and potential areas for improvement.

Table 1: Template for TMC Survey

CLASSIFIED TRAFFIC VOLUME COUNT SURVEY									
Road Name:		Date and Day			ADDL INFORMATION				
Section From									
Location Km		Hour			WEATHER				
Direction Towards									
FAST MOVING VEHICLES								SLOW MOVING VEHICLES	
Time	2W	3W	4W	Bus	LCV	HCV	Agri Tractor		Cycle
							With Trailer	Without Trailer	
09:00-09:15									
09:15-09:30									
09:30-09:45									
09:45-10:00									

- 4. PTV VISSIM Software:** Microsimulation modeling in VISSIM (Visual Simulation System) can be a valuable tool for analysing the effects of traffic congestion resulting from the construction of a flyover on Sinhagad Road. VISSIM is a microscopic traffic simulation software that allows to simulate and analyse complex traffic scenarios. Start by creating a virtual representation of Sinhagad Road in VISSIM. This involves creating a network model that includes the road geometry, intersections, traffic signals, and any other relevant features. Collect data on the existing traffic conditions, including traffic volume, vehicle types, turning movements, and travel patterns along Sinhagad Road. Input this data into VISSIM to represent the baseline traffic scenario. Identify the location and extent of the flyover construction zones on Sinhagad Road. Adjust the network model in VISSIM to reflect these construction zones, including any detours, lane closures, or changes in road geometry. Determine how traffic will be diverted or rerouted during the construction period. Modify the network model accordingly to reflect the planned traffic diversions, lane closures, and alternative routes available to drivers. Run multiple simulations in VISSIM to analyse the effects of traffic congestion due to the construction of the flyover. Vary the parameters such as traffic volume, signal timings, and traffic diversion strategies to assess different scenarios. Analyse the simulation results to understand the impacts of the flyover construction on traffic congestion. Evaluate key performance measures such as travel time, delay, and queue lengths. Compare the results of different scenarios to identify the most effective traffic management strategies.



Figure 3: Before Construction Simulation Model Form Hingne Chowk Junction



Figure 4: During Construction Simulation Model for Inamdar and Hingne Chowk Junction

MICROSIMULATION MODELLING IN VISSIM ON EFFECTS OF TRAFFIC CONGESTION DUE TO CONSTRUCTION OF FLYOVER ON SINHAGAD ROAD IN PUNE, INDIA

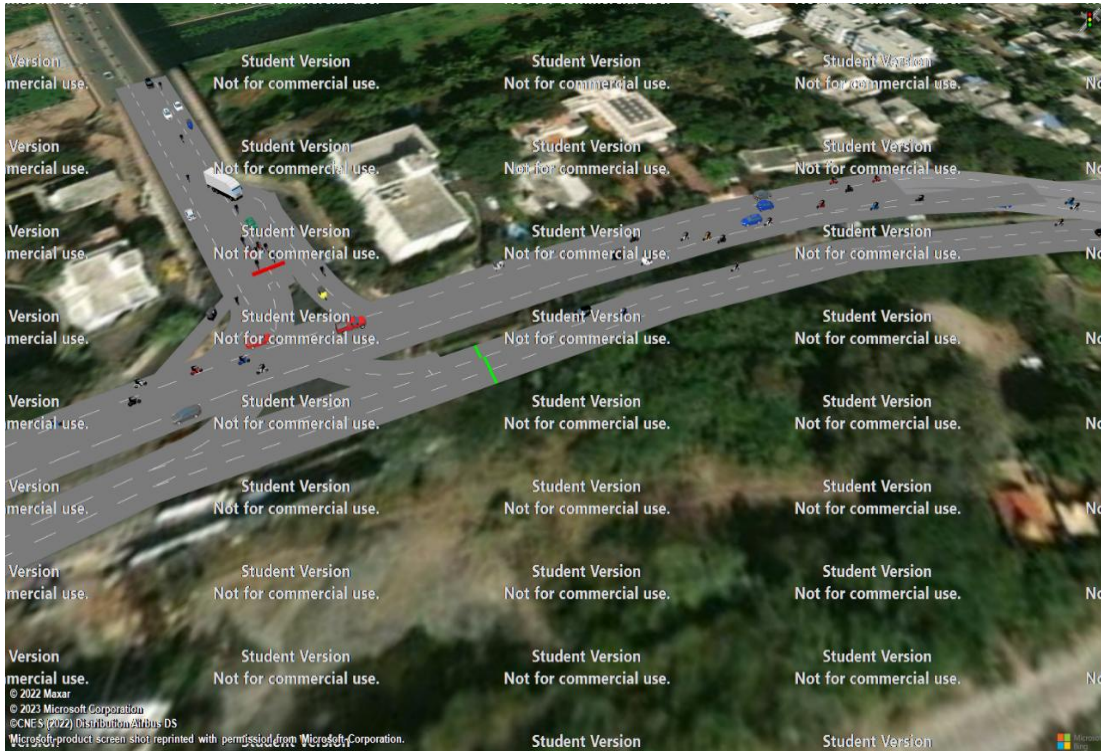


Figure 5: Flyover Simulation Model for Rajaram Bridge Junction

III. RESULTS & DISCUSSION

1. Traffic Turning Movement Survey

Table 2: Before Construction Traffic Behavior for Morning And Evening Peak Hours

	Direction percentages			
	Morning peak hour		Evening peak hour	
	Straight traffic	Turning traffic	Straight traffic	Turning traffic
Rajaram chowk	66	34	58	42
Inamdar chowk	83	17	61	39
Hingne chowk	89	11	59	41
Santosh hall chowk	73	27	54	46
Fun time chowk	88	12	84	16

The above table shows that before construction, the traffic behavior of intersections in morning and evening peak hours.

Table 3: During Construction Traffic Behavior for Morning and Evening Peak Hours

	Direction Percentages			
	Morning Peak Hour		Evening Peak Hour	
	Straight Traffic	Turning Traffic	Straight Traffic	Turning Traffic
Rajaram chowk	55	45	54	46
Inamdar chowk	79	21	58	42
Hingne chowk	84	16	57	43
Santosh hall chowk	73	27	56	44
Fun time chowk	82	18	85	15

The above table shows that during construction, traffic behaviour of intersections in morning and evening peak hours.

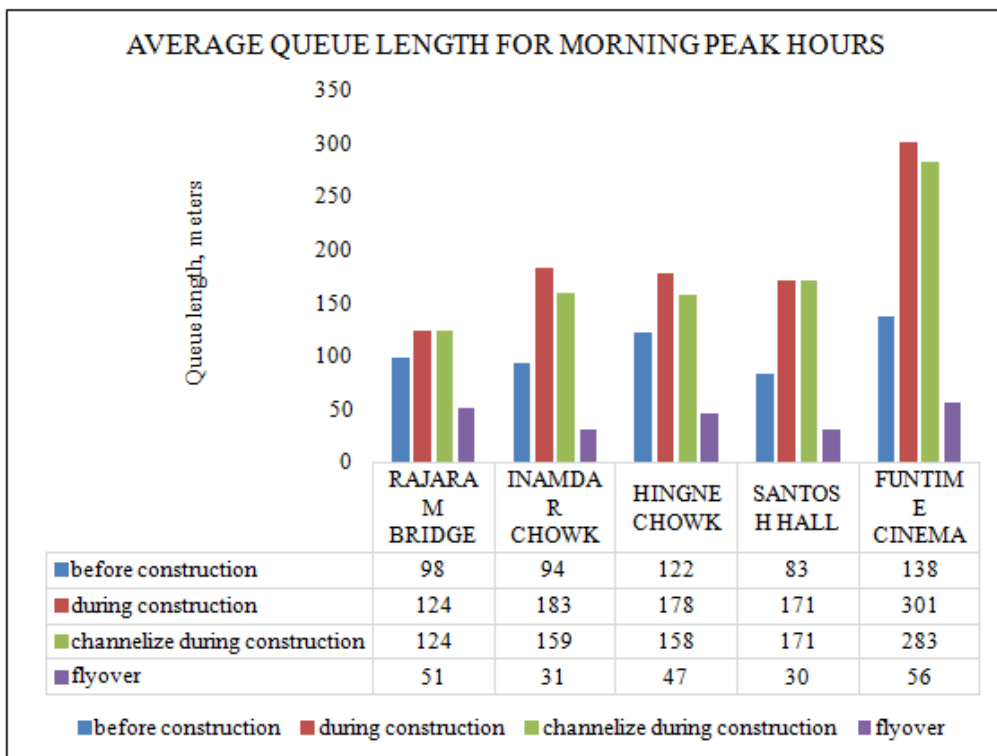


Figure 6: Average Queue Length for Morning Peak Hours

Above figure shows the impact of traffic on queue length before, during, channelization during construction and after the implementation of flyover at different junctions. During morning peak hours, construction work at Rajaram Bridge caused a 1.26 times increase in average queue length, but after the flyover's completion, there was a significant reduction of 1.9 times in queue length. At Inamdar Chowk, construction work increased the average queue length by 1.94 times, but diversion measures reduced it by 1.16 times. After the flyover's completion, there was a substantial reduction of 3 times

in queue length. Hingne Chowk experienced a 1.45 times increase in average queue length due to construction work, but diversion measures lessened it by 1.12 times. After the flyover's completion, there was a slight reduction of 2.5 times in queue length. Santosh Hall faces 2.04 times increase in average queue length (with no diversion measures possible) due to construction, but after the flyover's completion, there was a significant reduction of 2.7 times in queue length. At Funtime Cinema, construction work led to a 2.18 times increase in average queue length, but diversion measures reduced it by 1.06 times. After the flyover's completion, there was a reduction of 2.46 times in queue length. Overall, the completion of flyovers was effective in significantly reducing traffic congestion during morning peak hours in these locations.

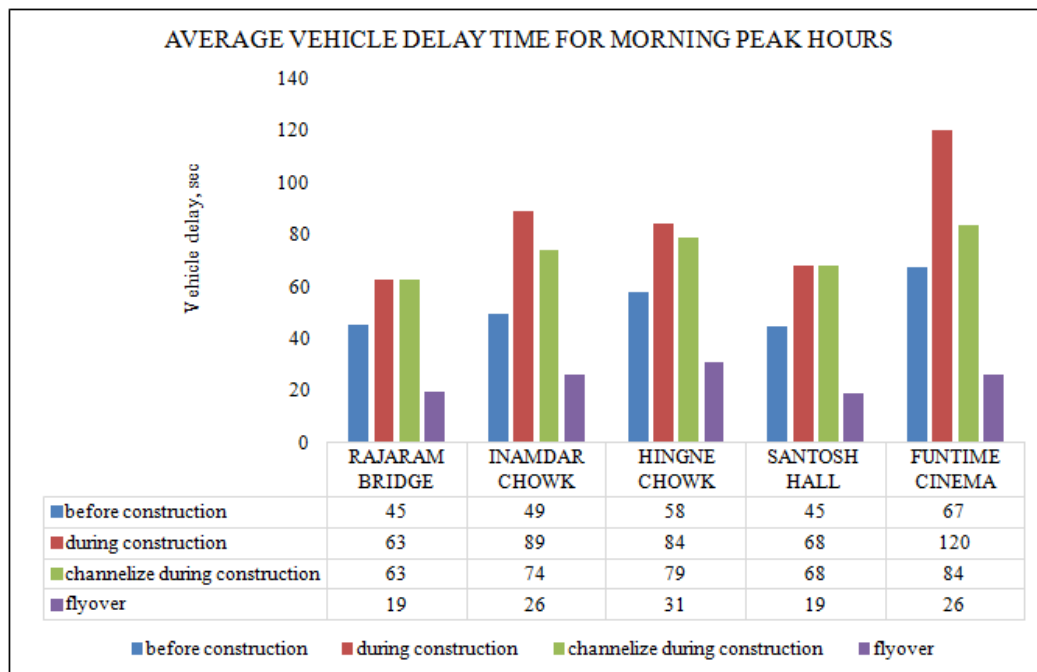


Figure 7: Average Vehicle Delay Time for Morning Peak Hours

During construction, average delay times increased at several locations. At Fun-Time Cinema, the delay time increased from 1.1 minutes to 2 minutes. However, after implementing channelization measures, it reduced by 1.4 minutes, resulting in a 26 second improvement compared to pre-construction. Santosh Hall experienced a slight increase in delay time from 45 seconds to 1.13 minutes during construction, but after the flyover completion, there was a reduction of about 19 seconds. Hingne Chowk faced an increase in average delay time from 58 seconds to 1.4 minutes during construction, but channelization measures led to a decrease of 1.3 minutes, with a significant 31 second reduction after flyover completion. Inamdar Chowk witnessed an increase in delay time from 49 seconds to 1.48 minutes during construction, but channelization measures resulted in a decrease of 1.23 minutes, with an approximate 26 second reduction after flyover completion. At Rajaram Bridge, the delay time increased from 45 seconds to 1.05 minutes during construction, but there was a notable reduction of about 19 seconds after flyover completion. Overall, the completion of flyovers and implementation of channelization measures proved effective in reducing delay times for commuters.

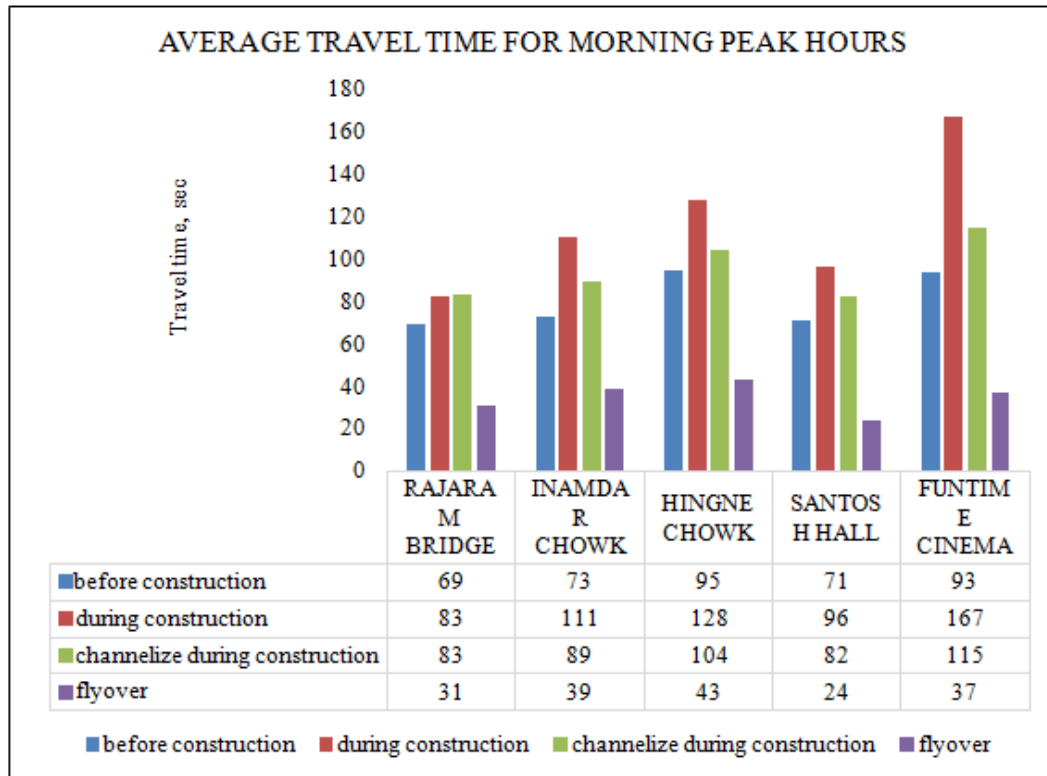


Figure 8: Average Travel Time for Morning Peak Hours

During construction, average vehicle travel times increased significantly at several locations. At Fun-Time Cinema, travel time increased from 1.55 minutes to 2.7 minutes, but after the flyover completion, there was a notable improvement, with a decrease of approximately 37 seconds compared to pre-construction. Santosh Hall experienced an increase from 1.18 minutes to 1.6 minutes during construction, but after the flyover's completion, there was a significant reduction of around 24 seconds compared to pre-construction. Hingne Chowk saw an increase from 1.57 minutes to 2.13 minutes during construction, but implementing channelization measures led to a noticeable improvement, resulting in a decrease of 1.73 minutes compared to the peak travel time experienced during construction. After implementation of flyover significant reduction is about 43 seconds Inamdar Chowk witnessed an increase from 1.21 minutes to 1.85 minutes during construction, but after the flyover's completion, there was a significant decrease of approximately 39 seconds in travel time compared to pre-construction. At Rajaram Bridge, travel time increased from 1.15 minutes to 1.38 minutes during construction, but there was a noteworthy reduction of approximately 31 seconds after the flyover's completion. Overall, the completion of flyovers and the implementation of channelization measures effectively improved travel times for commuters at these locations.

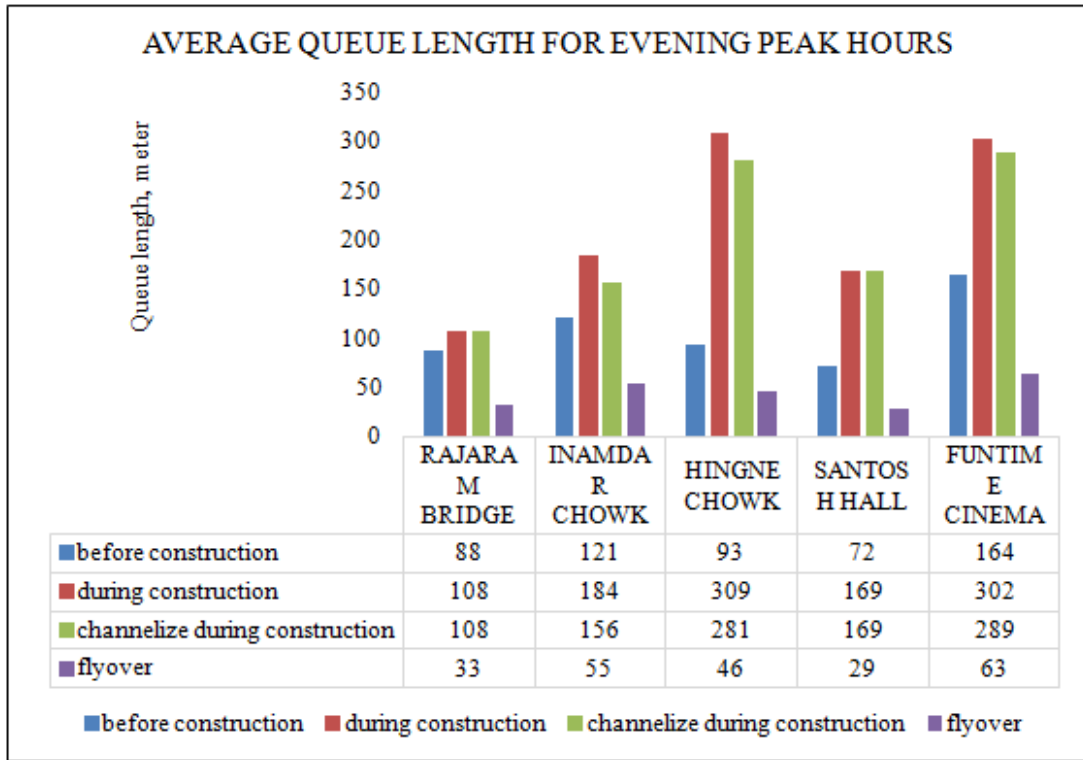


Figure 9: Average Queue Length for Evening Peak Hours

During construction, average queue lengths increased at various locations. At Rajaram Bridge, the queue length increased by 1.22 times, but after the flyover's completion, there was a reduction of 2.66 times. Inamdar Chowk experienced a 1.5 times increase in queue length, but diversion measures reduced it by 1.17 times. After the flyover's completion, there was a reduction of 2.2 times in queue length. Hingne Chowk saw a significant increase of 3.32 times in queue length during construction, but diversion measures reduced it by 1.09 times. After the flyover's completion, there was a reduction of 2.02 times in queue length. Santosh Hall faced a 2.35 times increase in queue length (no diversion measures possible) during construction, but after the flyover's completion, there was a reduction of 2.4 times. Fun-Time experienced a 1.84 times increase in queue length during construction, but diversion measures reduced it by 1.04 times. After the flyover's completion, there was a reduction of 2.6 times in queue length. The completion of flyovers and the implementation of diversion measures proved effective in reducing congestion and queue lengths at these locations, benefiting commuters during peak hours.

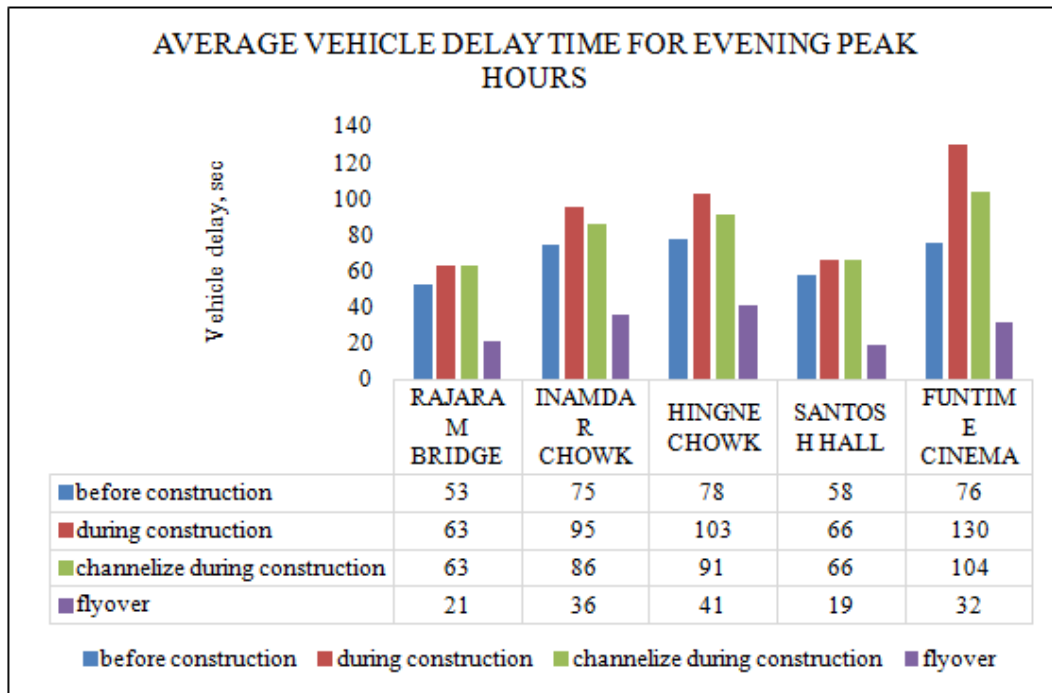


Figure 10: Average Vehicle Delay Time for Evening Peak Hours

During construction, average delay times increased at Fun-Time Cinema, Santosh Hall, Hingne Chowk, Inamdar Chowk, and Rajaram Bridge. At Fun-Time Cinema, delay time increased from 1.2 minutes to 2.16 minutes, but after channelization, it reduced by 1.7 minutes, and following flyover completion, the delay time improved by approximately 32 seconds compared to pre-construction. Santosh Hall experienced an increase from 58 seconds to 1.1 minutes during construction, with no channelization provided, but after the flyover's completion, there was a reduction of about 19 seconds compared to pre-construction. Hingne Chowk average delay time increased from 1.3 minutes to 1.72 minutes during construction, but channelization measures resulted in a decrease of 1.4 minutes, and after flyover completion, there was a significant reduction of about 41 seconds. Inamdar Chowk delay time increased from 1.24 minutes to 1.59 minutes during construction, but channelization measures led to a decrease of 1.43 minutes, and after the flyover's completion, the delay time reduced by approximately 36 seconds. At Rajaram Bridge, the delay time increased from 53 seconds to 1.05 minutes during construction, but there was a notable reduction after flyover completion is about 21 seconds. These findings highlight the effectiveness of flyovers and channelization measures in reducing delay times and improving traffic flow at these locations.

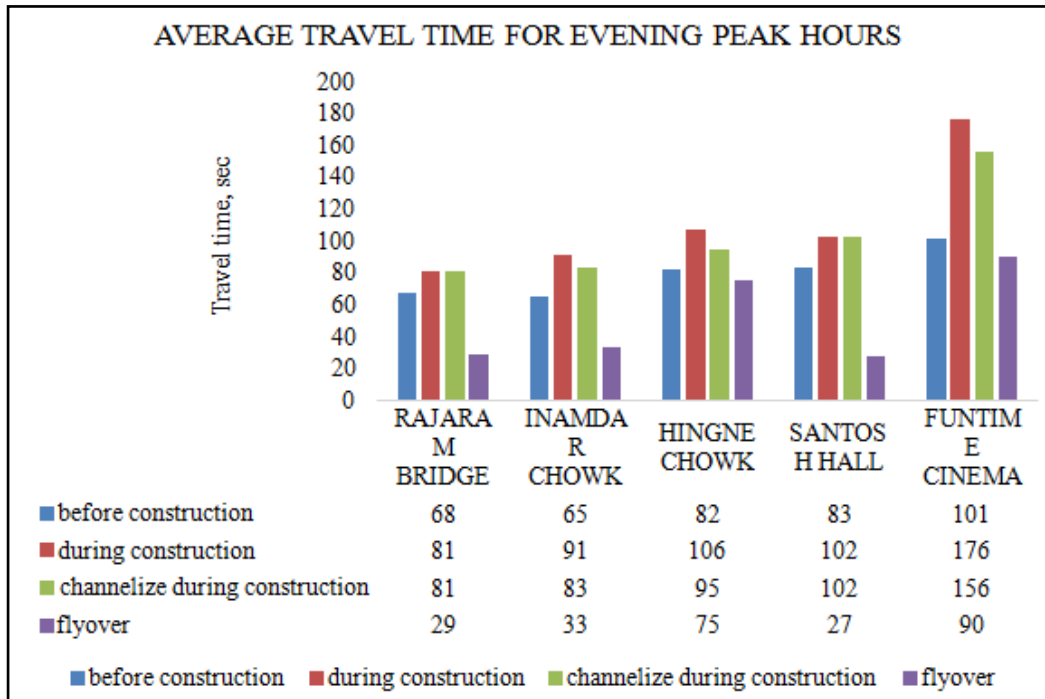


Figure 11: Average Travel Time for Evening Peak Hours

During the construction phases, average vehicle travel times increased at Fun-Time Cinema, Santosh Hall, Hingne Chowk, Inamdar Chowk, and Rajaram Bridge. At Fun-Time Cinema, the travel time increased from 1.69 minutes to 2.93 minutes during construction. However, after the flyover's completion, there was a significant improvement, with a decrease of approximately 1.5 minutes compared to pre-construction. At Santosh Hall, travel time increased from 1.38 minutes to 1.7 minutes during construction. After the flyover's completion, there was a notable reduction of around 27 seconds compared to pre-construction. Hingne Chowk experienced an increase in average travel time from 1.3 minutes to 1.7 minutes during construction. However, implementing channelization measures led to a noticeable improvement, resulting in a decrease of 1.56 minutes compared to the peak travel time experienced during construction. At Inamdar Chowk, travel time increased from 1.08 minutes to 1.51 minutes during construction, but after the flyover's completion, there was a significant reduction of approximately 33 seconds compared to pre-construction. Rajaram Bridge faced an increase in travel time from 1.13 minutes to 1.38 minutes during construction. However, after implementing channelization measures and completing the flyover, there was a notable reduction of approximately 29 seconds compared to pre-construction. These findings highlight the effectiveness of flyovers and channelization measures in reducing travel times and improving traffic flow at these locations.

IV. CONCLUSIONS

1. During construction, the average queue length increased by 1.22 to 3.32 times at the five junctions. Channelizing 30% of traffic reduced the queue length by 1.04 to 1.17 times. After flyover completion, there was a significant reduction of 1.9 to 3 times in the

average queue length, indicating improved traffic flow. The flyover had a positive impact in alleviating congestion at these junctions.

2. During the construction phase, the average vehicle delay time increased significantly, from 56 seconds to 2.16 minutes, leading to longer queues and increased congestion. However, traffic channelization measures reduced the delay time to a range of 1.23 to 1.7 minutes. After the flyover's completion, there was a noticeable improvement, with the delay time decreasing to a range of 19 to 41 seconds compared to pre-construction, indicating a positive impact on traffic flow and significant reduction in delays at the five junctions.
3. During construction, average travel time increased from 1.08 minutes to 2.93 minutes. After channelization, it reduced to 1.35 to 2.6 minutes, improving traffic flow. Post-flyover completion, travel time decreased to 27 to 43 seconds, indicating a significant positive impact on efficiency and reduced delays.

V. ACKNOWLEDGEMENTS

The authors would like to express their gratitude my guide, Prof. Rajshekhar Rathod, Assistant Professor of Civil Engineering Department, MIT School of Engineering, Pune and my co-guide Prof. Sagar K. Sonawane, Assistant Professor of Civil Engineering Department, MIT School of Engineering, Pune for their encouragement during my dissertation work. I am also thankful to Prof. Dr. Satish B. Patil, Head, Civil Engineering Department, MIT School of Engineering, Pune for his support and for giving an immense knowledge about the site and various construction safeties.

REFERENCES

- [1] A PRANATHI and G RAVALI (2016) "An overview of flyover construction for lessening congestion of traffic" International Journal of Innovative Technology and Research Volume No.4, Issue No.3,
- [2] Auttakorn SALA (2018) "Assessment of traffic flow benefits of flyover a case study." Journal of Society for Transportation and Traffic Studies (JSTS) Vol.4 No.3
- [3] Jianyou Zhao, Yongmei Xue and , Qichen Wu (2018) "Optimization Analysis of Urban Road Intersection Based on VISSIM Simulation" ASCE CICTP
- [4] Keman Wu, Nale Zhao and Tao Du (2019) "Research on the Influence of Front Virtual Work Zone on Traffic Operation of Expressway Construction Sections" ASCE CICTP
- [5] Lenjisa Bedada and Mukti Advani (2020) "Estimating the impact of flyover on the vehicle-on-vehicle delay, Fuel consumption, and emission" ResearchGate
- [6] Ning Yang and Gang-Len Chang (2009) "Simulation-Based Study on a Lane-Based Signal System for Merge Control at Freeway Work Zones." Journal of Transportation Engineering Vol. 135
- [7] Rose Mary Xavier, Evelyn Antony and Jubin Mathew (2021) "Traffic Analysis and design of flyover" IRJET Volume: 08 Issue: 06
- [8] Shailesh Singh, Kishore Ravande and Rajshekhar Rathod (2021) "Traffic Study and Road Safety Assessment At Bus Terminal" IRJETS Volume: 03 Issue: 10
- [9] Tarun Patel and Mrs. Krupa Dave (2015) "Feasibility Study and Rapid Construction of Flyover at Sahakari Zin Intersection on NH-8, Himmatnagar" ISSN: 2278-0181 Vol. 4 Issue 04
- [10] Xiang GAO, Li-xia BAO, and Guiyan JIANG (2016) "Congestion Related Analysis and Identification of Urban Road Based on VISSIM" ASCE Integrated transportation system.
- [11] Yali Chen, Xiao Qin and David A. Noyce (2010) "Interactive Process of Microsimulation and Logistic Regression for Short-Term Work Zone Traffic Diversion" journal of transportation engineering

BLACK COTTON SOIL STABILIZATION BY USING BIO-ENZYME AND MARBLE DUST POWDER FOR PAVEMENT SUB-GRADE

Abstract

Black Cotton Soils (BCS) pose challenges due to their susceptibility to vertical ground movements, particularly affecting Geotechnical Structures and Pavement. These issues are exacerbated in areas with poor subgrade soil, where pavement construction becomes prohibitively expensive. To address this, there's a growing shift towards exploring non-traditional, sustainable, and cost-effective alternatives. Despite this need, research on the reaction mechanisms of non-traditional soil stabilization methods is limited. In this context, the study explores the use of Marble Dust (MD) as a soil stabilizer and Bio Enzyme (BE), a natural and non-toxic liquid enzyme that expedites soil stabilization during construction. The study's objectives include evaluating geotechnical parameters like compaction, Atterberg's limits, and unconfined compressive strength while varying the ratios of marble dust and bio enzyme. Additionally, it employs microstructural-driven analytical techniques to investigate the reaction mechanism behind this soil stabilization approach. The findings hold promise for mitigating reactive soil expansion and promoting sustainable solid waste management practices.

Key Words: Subgrade, Black Cotton Soil, Marble Dust, Bio-enzyme, Stabilization.

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I. INTRODUCTION

- 1. General:** Black soils, also known as Regur soils, constitute a substantial portion of India's landscape, encompassing about 20% of the country's total land area. Their distinctive black color is attributed to the presence of humus, and they exhibit a sticky texture when wet due to their high clay content. While black soils are deficient in nitrogen, they contain sufficient phosphorous for plant growth. In hilly regions, particularly in the Deccan Plateau and the plateaus of Madhya Pradesh, Saurashtra, Malwa, and Maharashtra, these soils tend to be thin and sandy. These soils are characterized by essential clay minerals such as montmorillonite and cover an extensive area of approximately 300,000 square kilometers. However, from an engineering standpoint, black soils possess certain properties like high compressibility, low bearing capacity, and low shearing strength. For instance, Maharashtra, a state in India, is renowned for its black cotton soil, which constitutes over three-fourths of its land area, particularly in semi-dry plateau regions. However, constructing roads on highly clayey soils like black cotton soil in Maharashtra can be intricate and is generally discouraged due to potential complications.

In summary, black soils are a significant soil type in India, distinguished by their unique characteristics and engineering challenges. The current research effort on subgrade improvement focuses on the study of soil samples collected from Wagholi, Pune, Maharashtra.

- 2. An Overview of Soil Stabilization:** The most successful approach of ground improvement found worldwide is soil stabilization. In the last forty years, particularly, a variety of soil stabilization techniques have been rigorously applied in field applications and have undergone thorough testing by researchers. These include mechanical stabilization, which densifies the soil by expelling air from the spaces without significantly changing the water content, and chemical stabilization, which contains chemicals to improve soil characteristics, which in turn improve ground strength. For soil stabilization, it is essential to comprehend the properties of the materials that will be combined and the outcomes after mixing. There is other more variables that affect this method's success in addition to the choice of materials and doses.

3. Objectives

- The research aims to evaluate the engineering properties of native soil and blended soil samples with varying proportions of Marble Dust and bio enzyme, aiming to determine the optimal blend proportion for desired soil characteristics and stability.
- The study aims to investigate the engineering properties of blended soil samples using CBR and UCS methods to identify the most effective blend.
- It will design and compare flexible pavements using different proportions of the Blends to assess their suitability for pavement construction.
- The research will perform a cost analysis based on flexible pavement thickness, comparing the expenses of traditional methods to the proposed Blends for soil stabilization.

II. MATERIALS

- 1. Black Cotton Soil:** Usually made up of silicates of aluminium, iron, magnesium, and/or other metals, clayey soil is a particular form of soil that contains these tiny particles. Due to the significant amount of clay deposited, this soil gets sticky when wet. Because of its extreme hardness, the lumps are difficult to cure so they can be used in road building. The chemical composition of this black cotton soil is given in the following Table 1

Serial Number	Parameter	Unit	Observed Value	Methods
1	Moisture	%	4.67	IS:1514-1959
2	Calcium Oxide	Ppm	14.10	IS:6932(Part1)-1973
3	Magnesium Oxide	Ppm	17.20	IS:6932(Part1)-1973
4	CaCO ₃	%	4.00	IS:1514-1959
5	Alumina	%	0.30	IS:6932(Part1)-1973
6	Iron	%	0.15	No Specific Standard values are available
7	Volatile Matter at 150 ^o C	%	0.40	
8	Carbonate	%	1.00	
9	Acid Insoluble Matter	%	0.60	
10	pH	-	6.90	
11	Total Solids	%	4.60	
12	Calcium Carbonate	%	0.08	
13	Specific Gravity	-	2.00	

- 2. Marble Dust:** Waste marble dust is produced because of the building industry's rising demand for marble products. About 25% of the marble that is cut into blocks ends up as dust because of the marble dust and water mixing during the cutting process. Brick, building materials, ceramics, and infiltration techniques are the most prevalent fields and uses.

The chemical composition of this marble dust is given in the following Table 2

Serial Number	Parameter	Unit	Observed Value
1	Specific gravity (G _s)	-	2.64
2	Uniformity coefficient (C _u)	-	2.85
3	Coefficient of curvature (C _c)	-	1.19
4	Density(g/cm ³)	-	2.8

5	SiO ₂	%	71.18
6	Al ₂ O ₃	%	19.42
7	Fe ₂ O ₃	%	3.7
8	CaO	%	4.45
9	MgO	%	1.25

3. Bio-Enzyme: The engineering properties of soil are improved, higher soil compaction densities are made possible, and stability is increased by the use of bio-enzyme, a natural, nontoxic, non-flammable, noncorrosive liquid enzyme formulation fermented from vegetable extracts. The bio-enzyme binds to the soil's microorganisms and encourages their fusion through the formation of strong covalent connections. It was offered by an organisation called "Infinita Biotech," and the bio enzyme's name is "ECO TERRAIN."

The following combinations of Marble Dust and bio enzyme are used for various Blends:

Sr.no	Notation for various Blends	Blend Combination
1	S1	100% Virgin Black Cotton Soil
2	S2	5% Marble Dust + 2% Bio enzyme + 93% Black Cotton Soil
3	S3	10% Marble Dust + 2% Bio enzyme + 88% Black Cotton Soil
4	S4	15% Marble Dust + 2% Bio enzyme + 83% Black Cotton Soil

III. RESEARCH METHODOLOGY

To assess the engineering properties of both the virgin soil and the blended soil combination, a series of tests have been conducted following the initial basic physical and chemical composition analysis, with the test results previously outlined.

Laboratory Testing	
Index properties of soil Grain Size analysis. Consistency Indices.	Engineering Property of Soil Specific Gravity test. Free Swell Index. Permeability. Compaction test. Direct Shear test. Unconfined compression test. California Bearing ratio.

IV. RESULTS AND DISCUSSION

- 1. Grain Size Analysis:** For the Sieve analysis, 14 Soil samples are taken for sieving. Each soil sample is sieved with standard sieve sizes of, 4.75, 2.36, 1.18, 1, 0.600, 0.300, 0.150, 0.075, PAN, respectively.

Table 3 Grain Sieve Analysis of Black Cotton Soil

Sr.no	Samples	Mechanical Sieve Analysis			Total
		Gravel (%)	Sand (%)	Silt and Clay (%)	
1	1	32.95	66.85	0.2	100
2	2	31.2	68.6	0.2	100
3	3	17.05	82.7	0.25	100
4	4	12.8	87	0.2	100
5	5	15.5	84.3	0.2	100
6	6	12.75	86.3	0.95	100
7	7	16.95	82.75	0.3	100
8	8	18.75	80.85	0.4	100
9	9	19	80	1	100
10	10	15.5	84	0.5	100
11	11	18	81.5	0.5	100
12	12	17.5	81.7	0.8	100
13	13	10.5	89.3	0.2	100
14	14	33	66.9	0.1	100

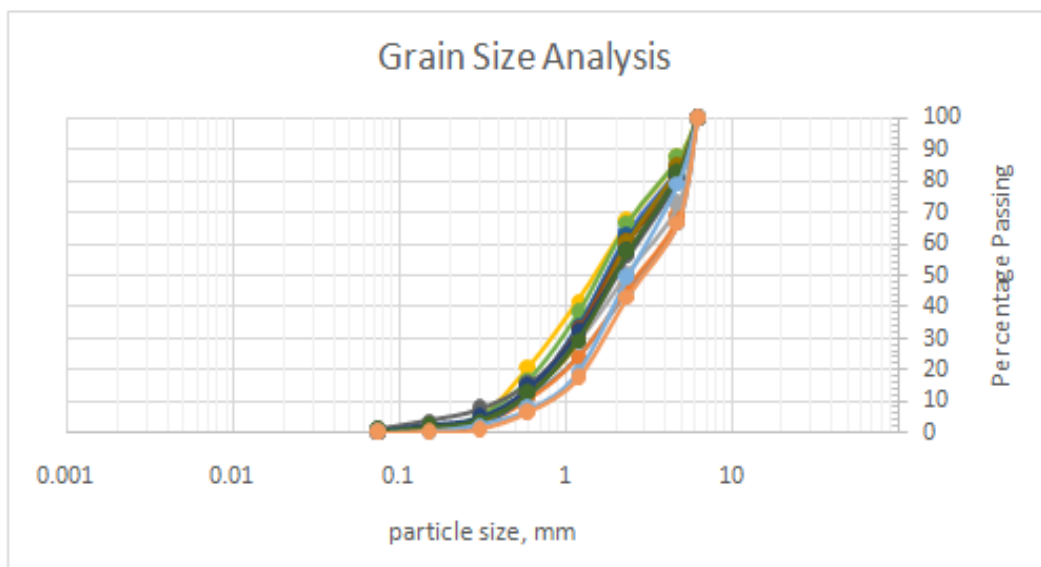


Figure 1: Grain sieve analysis graph

The particle size distribution curves of black cotton soil are shown in the above figure and summarised in Table 3.

- Atterberg’s Limit - Consistency Indices:** The study focused on establishing the Consistency Indices, namely the Liquid Limit, Plastic Limit, and Shrinkage Limit, for both Black Cotton Soil and three distinct Blended samples. The outcomes of these assessments are detailed in Table 4, with Figure 2 offering a visual representation of the collected data.

Table 4: Consistency Indices for different Blends of Black Cotton Soil

Blends	S1	S2	S3	S4
Liquid Limit	56.07	51.053	61.32	58
Plastic Limit	39.95	23.623	44.995	44.63
Shrinkage Limit	38.5	28.2	25.8	22.35

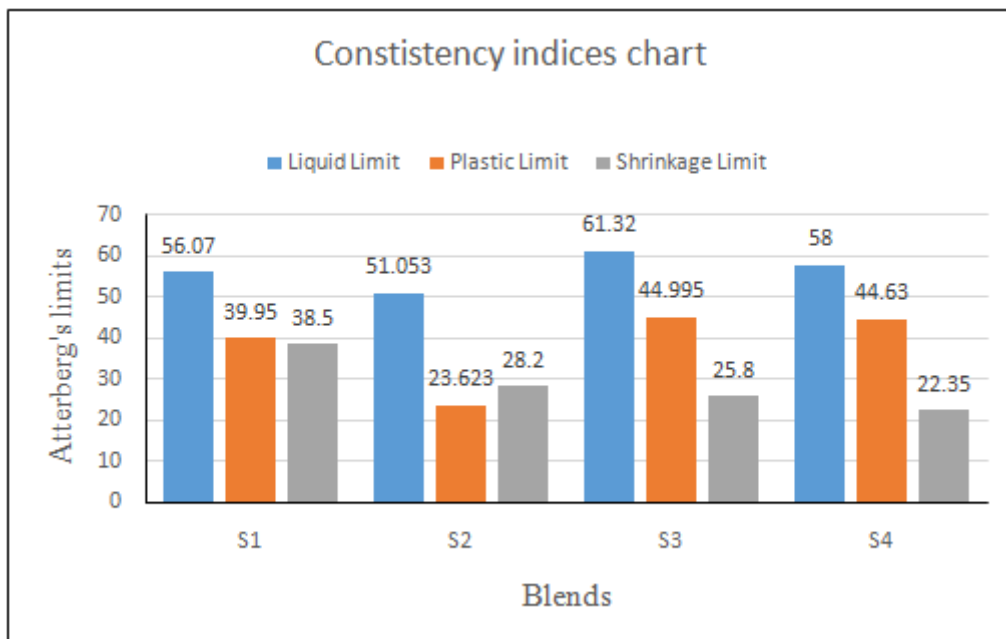


Figure 2: Consistency Indices Chart of Various Blended Soil Samples

- Specific Gravity:** In the laboratory, Specific Gravity was determined for Black Cotton Soil samples blended with Marble Dust and Bio-enzyme. The average values for each blend can be found in Table 5, while Figure3 provides a graphical representation of how Specific Gravity varies with different blend proportions. These findings have a substantial impact on the assessment of soil stability, compaction, and behaviour, particularly in the context of pavement design and construction.

Table 5: Specific gravity of Soil Samples

Notation	Blended Soil Mixture	Specific Gravity
S1	100% BCS	2.2
S2	5% MD + 3% BE + 92% BCS	2.34
S3	10% MD + 6% BE + 84% BCS	2.42
S4	15% MD + 9% BE + 76% BCS	2.45

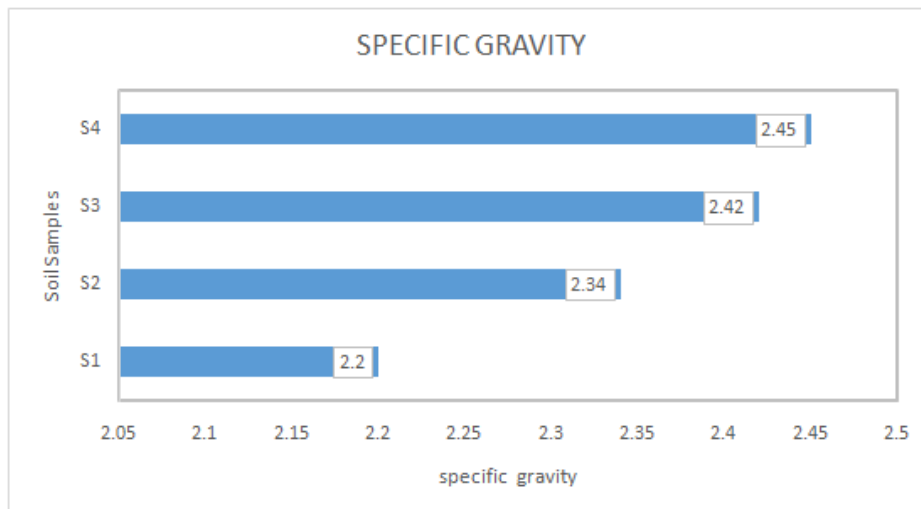


Figure 3: Specific Gravity for Soil sample of different Blends

The Specific Gravity of the Virgin Soil sample (S1) is measured as 2.2, while for the S2 blend, it increases to 2.34. Further, for the S3 and S4 Blends, the Specific Gravity values are determined as 2.42 and 2.45, respectively.

- 4. Compaction Test:** The compaction test, which aims to increase soil density by eliminating voids, was conducted to determine the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) for Blends containing Marble Dust and Bio-enzyme. The results for optimum moisture content and maximum dry density across various soil sample Blends presented in Table 6. These findings are visually represented in Figure 4. This data is crucial for understanding the compaction properties of the soil Blends and assists in identifying the necessary moisture content for achieving maximum density during road construction and pavement design

Table 6 OMC and MDD for Soil Sample of different Blends

Blends	OMC, (%)	MDD, (g/cc)
S1	15	1.39
S2	21	1.43
S3	18	1.453
S4	21	1.85

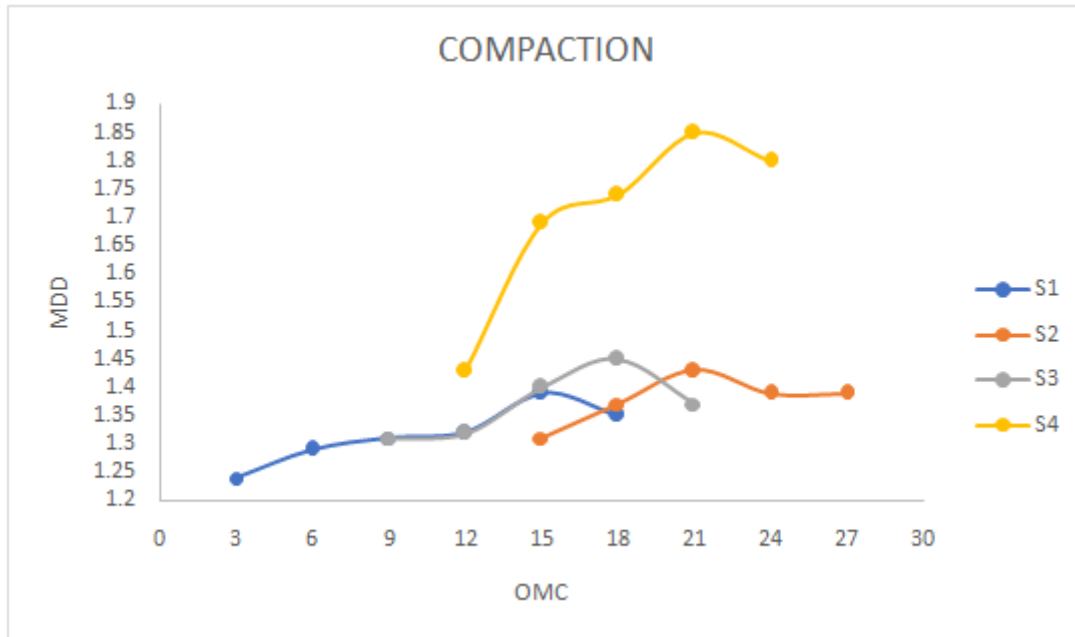


Figure 4: Moisture Content and Dry Density for Soil sample of different Blends

It is observed that the optimum moisture content for the soil sample of Blend S1 and Blend S3 increases by 40% compared to the virgin soil sample (S1), while for the soil sample of Blend S4, it increases by 20%. In terms of maximum dry density, the soil samples of Blends S1, S2, and S3 exhibit increases of 2.8%, 4.5%, and 33.09%, respectively, compared to the virgin soil sample (S1).

- Free Swell Index Test:** The free swell index test assesses soil's swelling potential, a critical factor linked to substructure distress and foundation failure. Results presented in Table 7 and visualized in Figure 5 offer insights into the soil's free swell index, representing the percentage increase in volume upon water exposure. Analyzing data in Table 7 and referring to the bar graph helps identify variations in swelling behaviour among different soil samples, including Blends and the virgin soil.

Table 7: Free Swell Index for Soil Sample of Various Blends

Blended Soil Samples	Free Swell Index, (%)
S1	55.49
S2	48.78
S3	29.09
S4	21.61

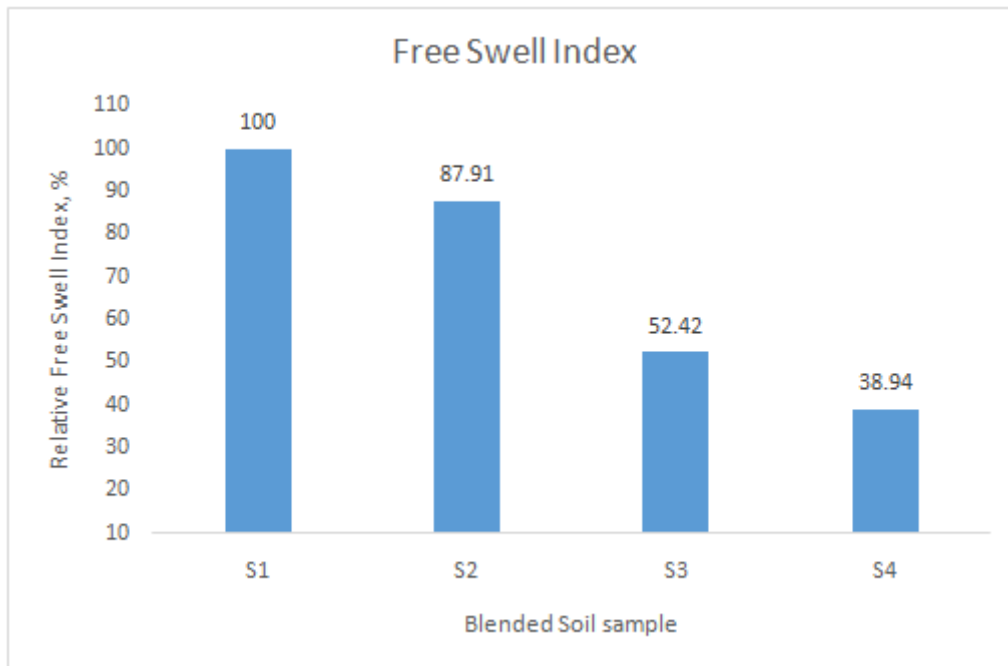


Figure 5: Free Swell Index for Soil sample of Various Blends

This indicates a decrease in the Free Swell Index by 12.09%, 47.57%, and 61.05% respectively, when compared to the Free Swell Index of the virgin soil (S1).

- 6. Permeability Test:** The Permeability test measures how quickly water can flow through soils, a property influenced by soil grain structure and pore spaces. This test is essential for geotechnical investigations, helping assess how efficiently water can permeate soil layers in the designated area, crucial for construction planning. The results of the Permeability test can be found in Table 8, along with a graphical representation in Figure6. These findings offer valuable insights into soil permeability, guiding construction project planning and execution.

Table 8: Coefficient of Permeability for different Blends of Soil

Blended Soil sample	Coefficient of Permeability, cm/s (10^{-4})
S1	232
S2	156
S3	144
S4	148

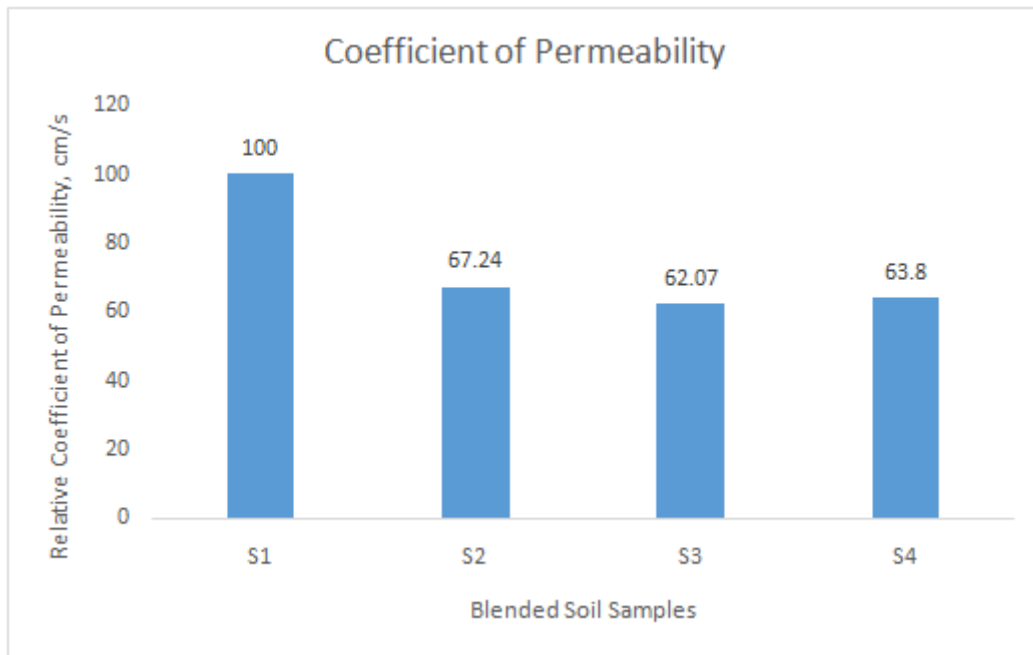


Figure 6: Coefficient of Permeability for various Blends of Soil

Specifically, the Relative Coefficient of Permeability for the soil sample of virgin soil (S1) decreases by 67.24%, 62.07%, and 63.8% for Blends S2, S3, and S4, respectively.

- 7. Direct Shear Test:** The Direct Shear test is a method used to determine the consolidated drained shear strength of soils. The outcomes of this test are presented in Table 9 and visually represented in Figure 7. By scrutinizing these results, one can evaluate the shear strength characteristics of the soil Blends. These findings play a critical role in comprehending the stability and load-bearing capacity of the soil in geotechnical applications. They inform the design and analysis of structures like foundations, retaining walls, and facilitate slope stability assessments. Furthermore, they provide valuable insights into the soil's shear behavior, aiding in the development of suitable soil stabilization and reinforcement techniques.

Table 9: Maximum Shear Stress for different Blends

Normal Stress, N/cm ²	Max Shear Stress, N/cm ²			
	S1	S2	S3	S4
5	5.32	6.48	9.21	11.51
10	6.07	10.2	12.36	14.38
15	7.82	11.53	17.44	20.15

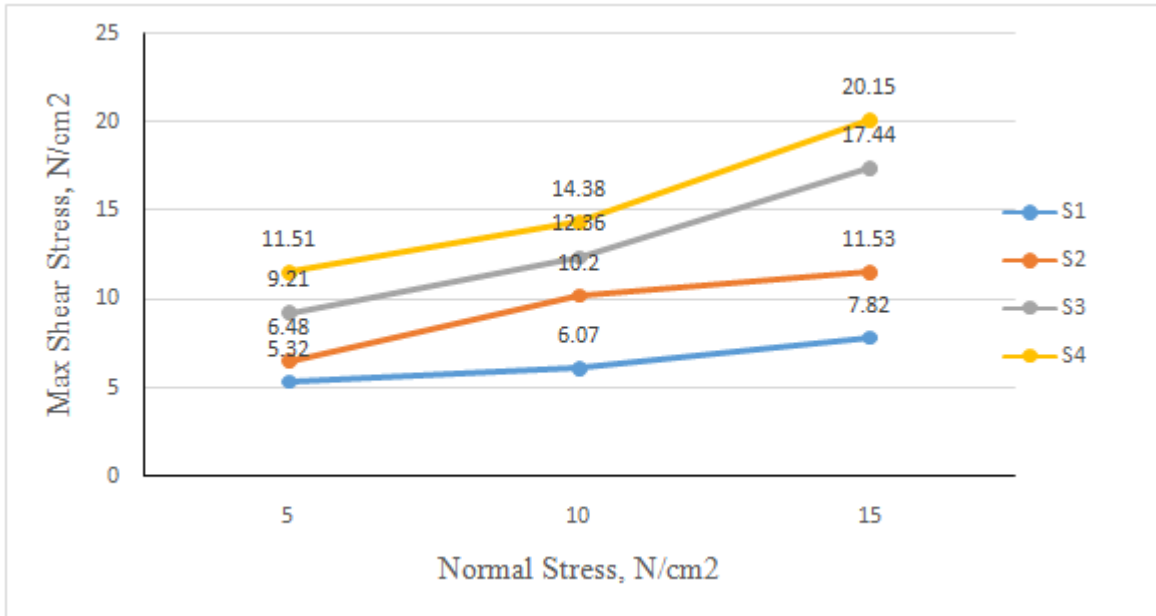


Figure 7: Shear Stress for different Soil samples

Table 10: Cohesion and Angle of Internal Friction for various Blends

Blended Soil sample	Cohesion (C), N/cm ²	Angle of Internal Friction (ϕ)
S1	3.9033	14 ⁰
S2	4.3533	27 ⁰
S3	4.7733	40 ⁰
S4	6.7067	41 ⁰

The angle of internal friction increased by approximately 1.9 times, 2.8 times, and 2.9 times, respectively, compared to 100% virgin soil (S1). Similarly, the cohesion increased by 11.52%, 22.28%, and 71.82%, respectively, compared to the virgin soil (S1) for the various soil samples of Blends S2, S3, and S4.

8. Unconfined Compression Strength: The Unconfined Compression Test is a widely employed method for evaluating the Unconfined Compressive Strength of cohesive soil specimens. The results of this test, displayed in Table 11 and visually depicted in Figure 4.8, offer valuable insights into the strength properties of the studied materials. This test is instrumental in gauging the material's capacity to withstand compressive forces without experiencing substantial deformation or failure, providing essential data for engineering and construction applications.

Table 11: Unconfined compression strength values

Blends	Strain	Strain, %	UCS Test Value (KPa)
S1	0.01956	1.9	104
S2	0.03476	3.5	212
S3	0.05862	5.9	360
S4	0.06585	6.6	375

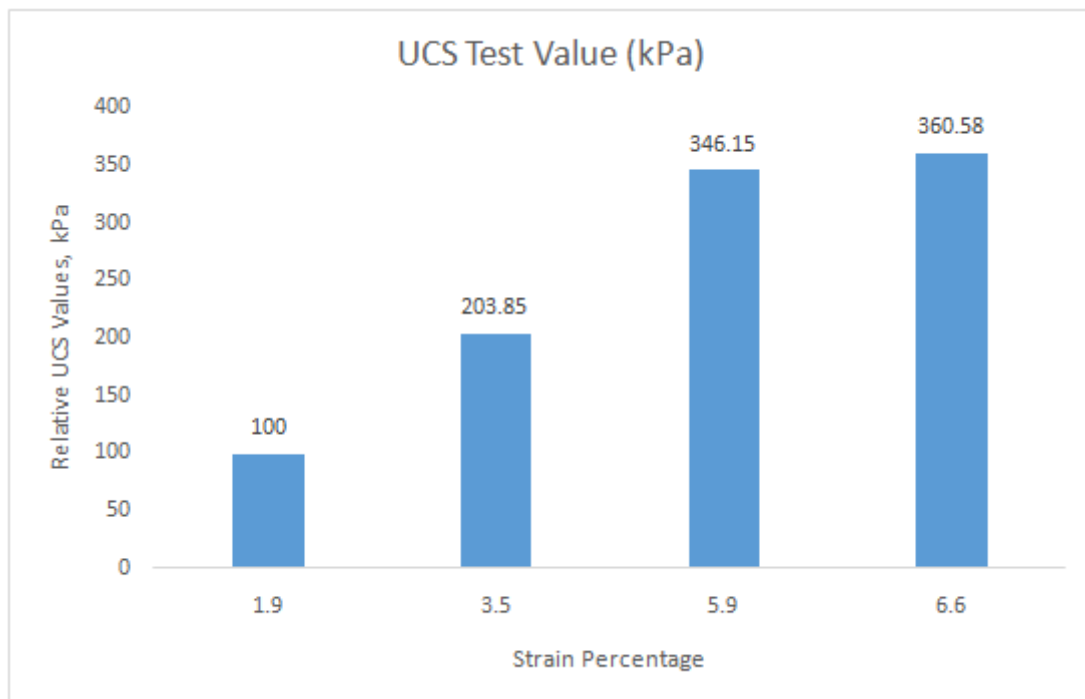


Figure 8: Unconfined Compression Strengths for various Soil sample

The Relative UCS values for Blends S2, S3, and S4 are 203.85%, 346.15%, and 360.58%, respectively. In other words, the UCS values increased by approximately 2 times, 3.46 times, and 3.6 times, respectively.

9. California Bearing Ratio Test: The California Bearing Ratio (CBR) test was conducted on soil samples containing various Blends of Black Cotton Soil, Marble Dust, and Bio-enzyme, assessing the strength characteristics of both soaked and unsoaked soil samples. The resulting CBR values for each condition can be found in Tables12 and 13. Furthermore, the Unconfined Compression Test established the penetration depth versus load relationship for the diverse soil Blends. The CBR values, calculated at penetrations of 2.5mm and 5mm, were illustrated in Figure 9 for the unsoaked soil samples. These findings are pivotal in assessing the suitability and performance of the soil Blends in construction applications, offering insights into their load-bearing capacity and behavior under varying moisture conditions.

Table 12: CBR Values for Unsoaked Soil sample Blends

Blends	CBR unsoaked, (%)
S1	2.54
S2	5.63
S3	7.69
S4	15.91

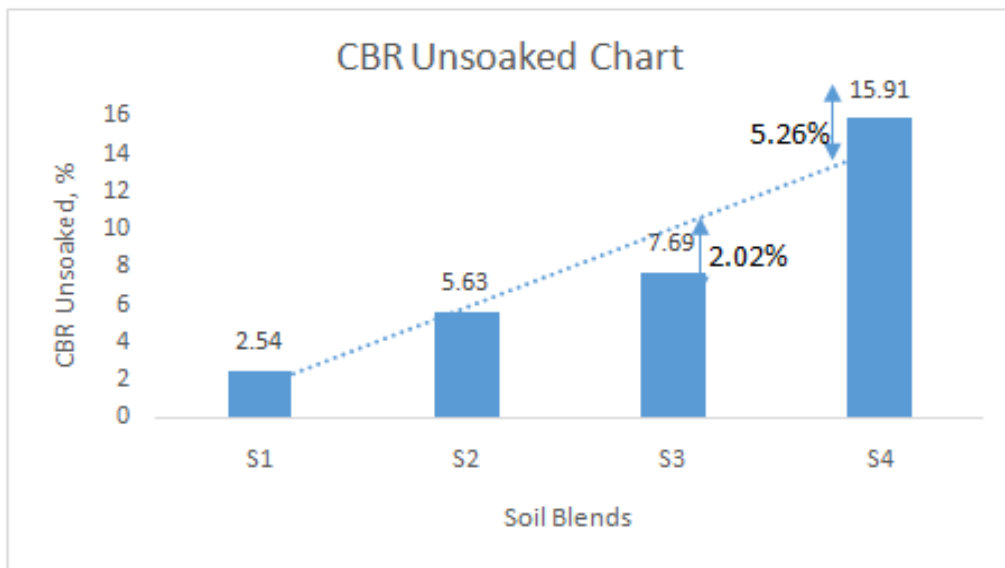


Figure 9: Unsoaked CBR Values for Soil sample of Various Blends

The results indicate a consistent increase in the Unsoaked CBR values for each soil sample blend. Specifically, compared to the Virgin Soil (S1), the Unsoaked CBR value increased by approximately 2.21 times for Blend S2, 3 times for Blend S3, and 6.26 times for Blend S4.

Table 13: CBR Values for Soaked Soil sample Blends

Blends	CBR soaked, (%)
S1	1.26
S2	4.32
S3	6.84
S4	13.91

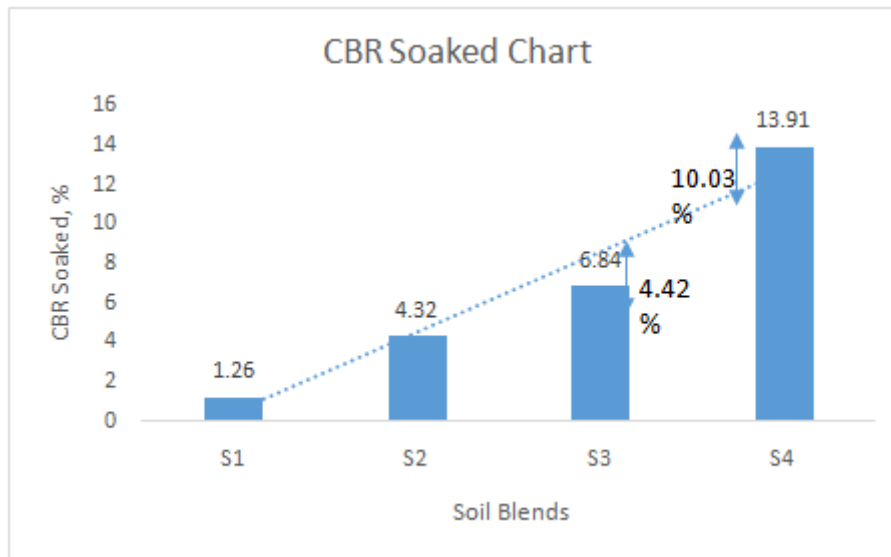


Figure 10: Soaked CBR Values for Soil sample of various Blends

Compared to the Black Cotton Soil, the Soaked CBR values increased approximately by 3.43 times for Blend S2, 5.42 times for Blend S3, and 11 times for Blend S4. These increments indicate a substantial enhancement in the soil's stability and strength. Overall, these findings demonstrate the positive effects of the various soil sample Blends on soil stability, particularly under soaked conditions. The increased Soaked CBR values signify improved strength and densification of the soil, suggesting enhanced suitability for construction applications.

10. Cost Analysis: Cost analysis is concluded for following data

- Four lane dual carriageway
- Initial traffic in the year of completion of construction = 1495 CVPD (sum of both directions)
- Traffic growth rate = 7 %
- Design life = 15 years
- Vehicle damage factor based on axle load survey = 3.9 standard axle per commercial vehicle
- Design CBR of sub-grade Soil = 5%
- Lane Distribution factor = 0.45

In the context of designing flexible pavements, a critical cost analysis has been conducted to assess the financial implications of different Soaked California Bearing Ratio (CBR) values—specifically, 5%, 7%, and 15%. The analysis estimates expenses related to implementing the pavement design under various CBR conditions, including material costs, construction methods, labor, and equipment expenses.

Table 14: Estimated Cost Comparison of Designed Flexible Pavement

Sr. No.	CBR Value, %	Pavement Thickness, mm	Estimated Cost, ₹
1	5	605	3,83,44,180
2	7	590	3,76,67,700
3	12	555	3,15,79,380

V. CONCLUSIONS

1. The results of Grain Size Analysis indicate that the maximum dominancy of Silt and Clay is around 79.2% and above in most of the 14 samples which clearly indicate that the given Soil sample is Expansive in nature. Grain Size Analysis indicate that particle size distribution is more or less same across all the Soil samples.
2. The Atterberg's limit test results reveals that the Shrinkage Limit of the various Blended Soil samples decreases by 42% compared to Virgin Soil sample (S1), whereas the Plastic Limit and Liquid Limit for Soil sample of all three Blends increase by 12% and 3%, respectively over that for Virgin Soil sample (S1). This is due to the addition of marble dust to soil which led to decrease in plasticity and water-holding capacity and reduced shrinkage potential. These enhancements in the soil's characteristics improve its strength and stability, making it more suitable for various engineering applications.
3. The Specific Gravity of blended Soil sample S2, S3, and S4 increases by 6.4%, 10%, and 11.4% respectively, when compared with Virgin Soil sample (S1). This is due to porosity of particles decreases and leads to densification.
4. The Compaction test results indicates the Maximum Dry Density for Soil sample of Blend S4 increased to 1.85 g/cc at Moisture Content 21% from 1.39 g/cc at Moisture Content 15% for Virgin soil sample (S1). However, the Maximum Dry Density for Soil sample of Blend S3 is 1.453 g/cc at Moisture Content 18% and that of Blend S2 is 1.43 g/cc at Moisture Content 21%. Thus, S3 blend is denser due to the resistance of the flocculated structure to the compaction process providing the advantage of improved CBR value.
5. Free Swell Index values for Soil sample of Blend S2, S3, and S4 are 48.78%, 29.09%, and 21.61% respectively, when compared to Free Swell Index of 55.49% for Virgin Soil sample (S1). This is due to the process of flocculation of clay particles, reducing the attraction of moisture and thereby reducing the swelling activity of the soil.
6. Coefficient of Permeability for blended Soil sample S2, S3, and S4 reduces by 32.7%, 37.9%, and 36.2% respectively, when compared to Coefficient of Permeability of Virgin Soil sample (S1). This is due to addition of Marble Dust and Bio-enzyme which reduces the porosity and it restricts the seepage of water through the soil.
7. It is observed from Direct Shear Strength test that as Marble Dust and Bio-enzyme content in the Blended Soil sample is increased, three times increase in the Angle of

Internal Friction (ϕ) and 71.82% increase in Cohesion (C) is observed for Soil sample of Blend S4 as compared to Virgin Soil sample (S1). This is due to particle interlocking, providing a binding effect, and promoting improved compaction.

8. Unconfined Compression Strength for blended Soil sample S2, S3, and S4 increases by 2times, 3.46 times, and 3.6 times, respectively when compared to Unconfined Compression Strength of Virgin Soil sample (S1). This significant increase in strength attributed to the chemical reactions that occur between the calcium content in Marble Dust and Bio-enzyme and the silica and alumina present in the Soil. These reactions lead to the formation of cementitious compounds.
9. The CBR of Unsoaked Soil sample Blends S2, S3, and S4 increases by 2.2 times, 3 times, and 6.3 times respectively, when compared to CBR of Unsoaked Virgin Soil sample (S1) and the CBR of Soaked Soil sample Blends S2, S3, and S4 increases by 3.4 times, 5.4 times, and 11 times when compared to CBR of Soaked Virgin Soil sample (S1). This is due to formation of physical and chemical bonds between the soil particles and blend of bio-enzyme and marble dust. This binding effect reduces particle movement and sliding under loads leading to increased load-bearing capacity.
10. The estimation of pavement thickness was conducted based on the CBR values of the blended soil samples. Among the samples, Blend S2 with a 5% CBR value had a pavement thickness of 605mm, Blend S3 with a 7% CBR value had a thickness of 590mm, and Blend S4 with a 15% CBR value had a thickness of 555mm. A comparison of these samples revealed a reduction in pavement thickness. Specifically, Blend S3 showed a decrease of 15mm, while Blend S4 experienced a significant reduction of 50mm compared to the pavement thickness of Blend S2. These findings emphasize the potential advantages of using soil blends with higher CBR values, as they result in a reduced pavement thickness, potentially leading to cost savings in pavement construction.
11. The cost analysis of the designed flexible pavement clearly indicates that as the CBR value increases, the cost decreases. A thorough comparison of the cost for different CBR values reveals significant reductions. Specifically, when comparing the cost of the designed pavement for a 7% CBR of Blend S3 to the value to that of a 5% CBR value of Blend S2, a noticeable reduction of 5.4% is observed. Furthermore, the cost of the designed pavement for a 15% CBR of Blend S4 value shows a substantial reduction of 18.32% when compared to the cost for a 5% CBR value of Blend S2. These findings underscore the cost-effectiveness of higher CBR values in the design of flexible pavements.

REFERENCES

- [1] F. Yilmaz and M. Yurdakul, Evaluation of Marble Dust for Soil Stabilization. Journal of Special issue of the 3rd International Conference on Computational and Experimental Science and Engineering (ICCESN 2016), Vol-132, page 710-712 (2017)
- [2] Altug SAYGILI, Use of Waste Marble Dust for Stabilization of Clayey Soil. Journal of ISSN 1392–1320 materials science (medžiagotyra), Vol. 21, No. 4. 2015
- [3] R. Ali, H. Khan, A. A. Shah, Expansive Soil Stabilization Using Marble Dust and Bagasse Ash. Journal of International Journal of Science and Research (IJSR), Volume 3 Issue 6, June 2014

- [4] J. Pooni, D. Robert, C. Gunasekara, F. Giustozzi, and S. Setunge, Mechanism of Enzyme Stabilization for Expansive Soils Using Mechanical and Microstructural Investigation. Journal of American society of civil engineers (ASCE 2021)
- [5] RintuRenjith, SujeevaSetunge, Dilan J. Robert, Chamila Gunasekara, and Brian O'Donnell, Optimization of Enzyme-Based Soil Stabilization. Journal of American society of civil engineers (ASCE 2020)
- [6] Vikash Kumar, ShiwanshuShekhar, Santosh Kumar, AkashPriyadarshee, and Niraj Kumar, A Study on Soil Stabilisation using Bio-enzyme. Journal of Journal of Civil Engineering and Environmental Technology Volume 6, Issue 7; October-December 2019
- [7] Jacobs W., et. al., Strength of Sediment Mixtures as a Function of Sand Content and Clay Mineralogy, "In Proceedings in Marine Science", Vol. 9, pp. 91-107, 2008
- [8] Negi A. S., et. al., Soil Stabilization using Lime, "International Journal of Innovative Research in Science, Engineering and Technology", Vol. 2, pp 448-453, 2013.
- [9] Dhule S. B., et. al., Improvement of Flexible Pavement with use of Geogrid, "Electronic Journal of Geotechnical Engineering", Vol. 16, pp 269-279, 2011.
- [10] Reddy B. V. & Latha M. S., Retrieving Clay Minerals from Stabilised Soil Compacts, "Applied Clay Science", Vol. 101, pp 362-368, 2014.
- [11] Butt W. A., et al., Soil Sub-Grade Improvement using Human Hair Fiber, "International Journal of Scientific & Engineering Research", Vol. 5, Issue 12, pp 977-981, 2014.
- [12] Marsh A., et. al., Stabilisation of Clay Mixtures and Soils by Alkali Activation, "Earthen Dwellings and Structures, Springer, Singapore", pp 15-26, 2019.
- [13] Matus F., et. al., Soil Carbon Storage and Stabilisation in Andic Soils: A Review, "Catena", Vol. 120, pp 102-110, 2014.
- [14] Ouhadi V. R. & Goodarzi A. R., Assessment of The Stability of a Dispersive Soil Treated by Alum, "Engineering geology", Vol. 85, Issue 1-2, pp 91-101, 2006.

PLANNING OF MOBILITY AND PARKING SERVICES FOR MIT ADT UNIVERSITY CAMPUS, PUNE

Abstract

This research study delves into the issues of traffic congestion and parking management within the campus of MIT ADT University in Pune, Maharashtra, India. With the growing population, the study focuses on investigating the causes of congestion and other challenges faced by the campus. To gather relevant data, three surveys were conducted as part of the research project. These surveys included a traffic volume survey, an origin-destination survey, and a parking survey. By collecting data on traffic patterns, parking utilization, and vehicle movement, valuable insights were obtained. This data formed the basis for identifying key issues, such as bottlenecks and inadequate intersection design contributing to traffic congestion, as well as parking difficulties near specific buildings due to limited spaces. The study proposes recommendations to address these concerns, encompassing measures to alleviate bottleneck congestion, implement traffic channelizing techniques, consider lane expansion, improve parking design and management, enhance signage and wayfinding systems, and promote sustainable transportation practices. Regular surveys are suggested to monitor the effectiveness of the implemented solutions. By implementing these recommendations, campus authorities can improve traffic management, reduce congestion, and enhance parking facilities, thus improving the overall campus environment.

Keywords: Traffic Planning, Parking Planning, Traffic Congestion, Bottleneck Congestion, Campus Planning.

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I. INTRODUCTION

Traffic planning and parking management in universities play a crucial role in maintaining efficient transportation systems on campus. With a large number of students, faculty, staff, and visitors commuting to universities daily, it is essential to develop comprehensive strategies to alleviate traffic congestion, provide convenient parking options, and promote sustainable modes of transportation. Effective traffic planning and parking management not only enhance the overall mobility experience but also contribute to the safety and well-being of the university community. Traffic planning in universities involves analyzing traffic patterns, identifying bottlenecks, and developing strategies to improve circulation. It aims to minimize congestion, reduce travel times, enhance safety, and promote sustainable transportation options. Effective traffic planning ensures that students, faculty, and staff can commute to and from the university efficiently, reducing frustration and stress associated with traffic congestion.

Campus roads are vital pathways that connect different facilities and individuals within educational institutions. They provide accessibility to students, faculty, and staff, accommodating both vehicular traffic and pedestrians. Safety measures, wayfinding signage, and efficient design ensure a welcoming and inclusive environment for everyone. Campus roads not only serve a functional purpose but also add to the aesthetic appeal of the institution, fostering creativity and tranquility. Embracing sustainability, some campuses incorporate eco-friendly features, promoting green transportation and environmental stewardship.

Parking on campus is a perennial concern for students, faculty, and staff. It plays a crucial role in ensuring smooth transportation and accessibility within the campus environment. Adequate parking options are essential for accommodating the growing number of commuters, facilitating access to classrooms and offices. However, challenges like limited space, inefficient layouts, and parking fees can create frustrations and barriers to accessibility.

University campuses serve as vibrant hubs of academic activities, with a diverse population of students, faculty, staff, and visitors. The movement of individuals within these campuses is essential for the smooth functioning of academic programs, administrative operations, and social interactions. However, the increasing volume of traffic on campus roads and limited parking facilities present significant challenges that need to be addressed.

II. METHODOLOGY

1. Study Area – Mit Art, Design and Technology University, Pune: MIT ADT University, formerly known as MIT Art, Design, and Technology University, is a recognized private university in Pune, Maharashtra, India. Established in 2006, the university focuses on art, design, and technology disciplines. It offers diverse undergraduate, postgraduate, and doctoral programs in fields like architecture, engineering, fashion design, fine arts, and management. The university provides state-of-the-art facilities, promoting practical learning and research. Emphasizing hands-on education, it encourages creativity, critical thinking, and problem-solving skills. Collaborations with industry partners, internships, and industry projects prepare students

for successful careers. Research and innovation are prioritized, fostering an environment of exploration and discovery. Situated on a picturesque 125-acre campus along the Mula-Mutha River, the university blends nature's tranquility with stunning architecture. With around 15 institutions and over 113 courses, MIT ADT University offers a wide range of opportunities for students in various disciplines.



Figure 1: MIT Art, Design and Technology University

MIT enrolls about more than 5000 students every year. The increasing number of students, faculty, staff, and visitors, coupled with limited space and growing vehicular traffic, has led to significant disruptions in campus mobility and accessibility. Insufficient parking spaces, poor traffic flow, and lack of effective management strategies have resulted in frustration, environmental concerns, and safety hazards. Thus, there is an urgent need to address the following problems in traffic planning and parking management on campus:

- Traffic Congestion and Safety Issues
- Inadequate Parking Infrastructure

2. Data Collection: As part of the research project, three surveys were conducted to gather relevant data on traffic patterns and parking utilization. The surveys included a traffic volume survey, an origin-destination survey, and a parking survey. Method adopted for collection of traffic volume is manual counting method while method adopted for origin destination survey and parking inventory survey is via google forms.

- **Traffic Volume Survey:** The manual method of traffic volume count involves physically observing and recording the number of vehicles passing a specific location over a predetermined period. This process typically includes using manual counting devices like tally counters or clickers, where an observer stands by the roadside and manually clicks the counter each time a vehicle passes. The data collected is then compiled and analyzed to determine the traffic volume at that location during the observation period. Manual traffic volume counting is a labor-intensive process but can be useful for smaller-scale studies or when automated counting methods are not feasible or available.

Table 1: Traffic Volume Survey Template

TRAFFIC VOLUME SURVEY OF CAMPUS									
(15 mins)		Two Wheeler (veh)	Three Wheeler (veh)	Four Wheeler (veh)	School Bus (veh)	LCV (veh)	HCV (veh)	Cycle (veh)	Total Vehicles
16-00	16-15	0	0	0	0	0	0	0	0
16-15	16-30	0	0	0	0	0	0	0	0
16-30	16-45	0	0	0	0	0	0	0	0
16-45	17-00	0	0	0	0	0	0	0	0

- **Online Survey:** The online survey was conducted using google forms for O-D survey and inventory parking survey. The survey targeted students, faculties and involved questioning them about their mode of transportation, travelling time, parking time and travel time. To ensure a comprehensive survey, the questionnaire was administered during both peak and off-peak times. The primary objective of conducting this survey was to gather details about the travel patterns of commuters. The questions analyzed the data regarding the origin and destination points, no of days commuting to campus, mode of transport, time of arrival and departure, trip duration, parking preferences.

3. Identifying Problem: The survey identified the certain problems occurring within the campus and are stated as follows:

- **Bottleneck Congestion:** A bottleneck refers to a point in a transportation system where the flow of traffic is restricted or constricted, resulting in reduced capacity and slower movement of vehicles. It is a common cause of traffic congestion and can occur in various forms, such as narrow roads, intersections, or areas with heavy pedestrian traffic. Bottlenecks disrupt the smooth flow of traffic, leading to delays, longer travel times, and increased frustration for motorists. Identifying and addressing bottlenecks is crucial for improving traffic flow and reducing congestion.

This type of congestion can be seen within MIT ADT University campus at a point where the stream of flow is hampered due to shortening of road width i.e. 4 lane road merges to 2 lane. The point 1 in figure 2 shows the point of bottleneck congestion.

- **Improper Intersection Design:** The intersection near the tuck shop is being considered as improper as there is inadequate lane capacity and lacks turning lanes. The point 2 in fig 2 shows the point of improper intersection.



Figure 2: Traffic Congestion Issue within the Campus

- **Parking Issue:** MIT ADT University Campus has well planned parking system surrounding over the 125 Acre. It has in all 20 parking spots, covering all the different schools, sports complex, and cafeteria. The figure 3 gives the information regarding existing parking area within the campus. The increasing population of the college and the rise in the use of private/individual vehicles have posed challenges for parking management on campuses. As more students, faculty, and staff bring their vehicles to campus, the demand for parking spaces often exceeds the available supply. This leads to overcrowded parking lots, increased traffic congestion, and frustration among campus community members. Underground parking areas are particularly susceptible to water intrusion, especially during heavy rainfall or due to water table levels. The IT Building, Design Building, and ISBJ Building are situated in low-lying areas that are particularly susceptible to water accumulation during the rainy season. This poses a significant challenge when it comes to parking, as the presence of standing water in these areas hampers the availability and usability of parking spaces, especially for bicycles. The water tends to collect in these locations, making it nearly impossible to find suitable spots for bike parking. Given this situation, it becomes crucial to implement efficient and targeted parking management measures within these specific areas.



Figure 3: Existing Parking Areas within the Campus

- 4. Vissim Simulation:** VISSIM, developed by PTV Group, is a sophisticated software transforming traffic simulation and analysis. It is a vital tool for transportation engineers, urban planners, and researchers worldwide, offering a microscopic traffic simulation that models individual vehicles and their interactions with accuracy. This enables a comprehensive analysis of traffic flow, congestion, delays, and performance metrics, aiding in identifying bottlenecks and optimizing traffic operations.

VISSIM excels in modeling and analyzing traffic control elements, including traffic signals, stop signs, and roundabouts, allowing users to optimize signal operations and find effective strategies for traffic flow improvement and safety enhancement.

With a comprehensive set of analysis tools, VISSIM measures traffic flow, travel times, delays, and emissions, presenting results through visually appealing graphs and animations, making interpretation clear and effective.

The software allows users to calibrate and validate their models against real-world traffic data, enhancing the credibility and reliability of simulation results.

VISSIM finds applications in transportation planning, urban design, traffic engineering, and research, contributing to advancements in transportation science. It is widely used in various transportation-related fields for traffic impact assessments, signal optimization, and infrastructure planning.

III. RESULTS & DISCUSSION

- 1. Traffic Volume Survey Data:** As part of the research project, a traffic volume count survey was conducted on weekdays for one week, from 13th March 2023 to 17th March 2023, between 06:00 am and 08:00 pm. The survey utilized a manual counting method, where students were stationed at the entry gate and used tally counters to record the number of incoming and outgoing vehicles throughout the observation period. The PCU

adopted for the research project was from Table 5.2 of the INDO-HCM Manual 2017 – PCU values for undivided roads.

Table 2: Adopted PCU Values

Sr. No.	Vehicle Type	PCU Value
1	Two Wheeler	0.20
2	Three Wheeler	0.73
3	Four Wheeler	1.00
4	Bus	3.77
5	Light Commercial Vehicle	2.30
6	Heavy Commercial vehicle	3.70
7	Cycle	0.39

The volume count survey resulted that the peak hour within the campus can be seen twice i.e. one in the morning session and another in the evening session. The morning peak hour accounts to be from 08:30am to 09:30am while the evening peak hour starts from 04:00pm to 05:00pm.

Table 3: Hourly Volume Survey of Incoming Vehicles on Monday (no. of PCU)

Time		Passenger Vehicle			Goods Vehicles			
hour		Two Wheeler (PCU)	Three Wheeler (PCU)	Four Wheeler (PCU)	School Bus (PCU)	LCV (PCU)	HCV (PCU)	Cycle (PCU)
06-00	07-00	3.6	0	4	0	0	0	1.95
07-00	08-00	24.2	5.84	20	26.39	2.3	0	1.56
08-00	09-00	132	21.9	218	203.58	34.5	14.8	4.68
09-00	10-00	229.4	51.83	216	18.85	20.7	0	3.12
10-00	11-00	75.2	21.9	76	0	13.8	0	1.95
11-00	12-00	72.6	18.98	58	3.77	11.5	7.4	1.56
12-00	13-00	42.2	10.95	63	33.93	6.9	14.8	0.39
13-00	14-00	56.6	19.71	64	41.47	6.9	0	2.73
14-00	15-00	114.8	18.98	83	33.93	11.5	3.7	1.17
15-00	16-00	46	28.47	58	18.85	9.2	3.7	0.39
16-00	17-00	23	18.98	33	37.7	9.2	11.1	0.39
17-00	18-00	17.6	8.03	26	22.62	6.9	0	0
18-00	19-00	14	5.11	12	11.31	2.3	7.4	0.78
19-00	20-00	22	4.38	6	3.77	4.6	7.4	0.78

Table 4: Hourly Volume Survey of Outgoing Vehicles on Monday (no. of PCU)

Time		Passenger Vehicle			Goods Vehicles			
hour		Two Wheeler (PCU)	Three Wheeler (PCU)	Four Wheeler (PCU)	School Bus (PCU)	LCV (PCU)	HCV (PCU)	Cycle (PCU)
06-00	07-00	0	0	0	0	0	0	0
07-00	08-00	19.4	2.92	11	3.77	2.3	0	1.95
08-00	09-00	23.6	18.25	34	33.93	2.3	0	1.56
09-00	10-00	19.2	50.37	39	26.39	0	0	0.78
10-00	11-00	31	22.63	30	15.08	2.3	0	0
11-00	12-00	33.2	13.14	32	11.31	0	0	1.95
12-00	13-00	93.8	15.33	83	26.39	2.3	18.5	2.34
13-00	14-00	103.2	16.06	75	11.31	0	0	1.17
14-00	15-00	48.8	17.52	65	45.24	2.3	0	0.78
15-00	16-00	89.8	5.84	75	52.78	0	0	0
16-00	17-00	184.6	3.65	248	131.95	0	0	8.19
17-00	18-00	85.2	6.57	106	30.16	0	0	2.73
18-00	19-00	57.6	20.44	34	0	4.6	3.7	3.12
19-00	20-00	31.2	2.92	30	7.54	4.6	3.7	0

The maximum volume estimated is 1113.68 PCU/hr occurring on Friday. The rate of flow refers to the number of vehicles passing through a given point on a roadway within a specific time period. The rate of flow estimated for the maximum volume during peak hour is estimated to be 1711.68 PCU/hr.

Table 5: Rate of Flow During Peak Hour

Traffic Flow During Peak Hour (08-30 am - 09-30 am)					
Time		PCU	Vehicle	Rate of flow PCU/hr	Rate of flow veh/hr
08-30	08-45	261.76	423	1047.04	1692
08-45	09-00	427.92	601	1711.68	2404
09-00	09-15	243.3	586	973.2	2344
09-15	09-30	180.7	442	722.8	1768
Total		1113.68	2052		

Level of Service (LOS) is a concept commonly used in transportation engineering and planning to measure and evaluate the quality of service provided by transportation facilities, such as roads, intersections, and public transportation systems. It is used to assess the operational performance and efficiency of these facilities in terms of traffic flow, capacity, delays, and user experience. As mentioned in table 21.19 practical

capacities of Two-way urban roads, the capacity of two lane two way road is 1200 PCU/hr. The peak hour volume is 1113.68 PCU/hr. and thus volume to capacity ratio estimates to be 0.92. Hence the LOS as per the volume to capacity ratio estimated is “E”.

2. Online Survey Data: The online survey data can be represented as follows:

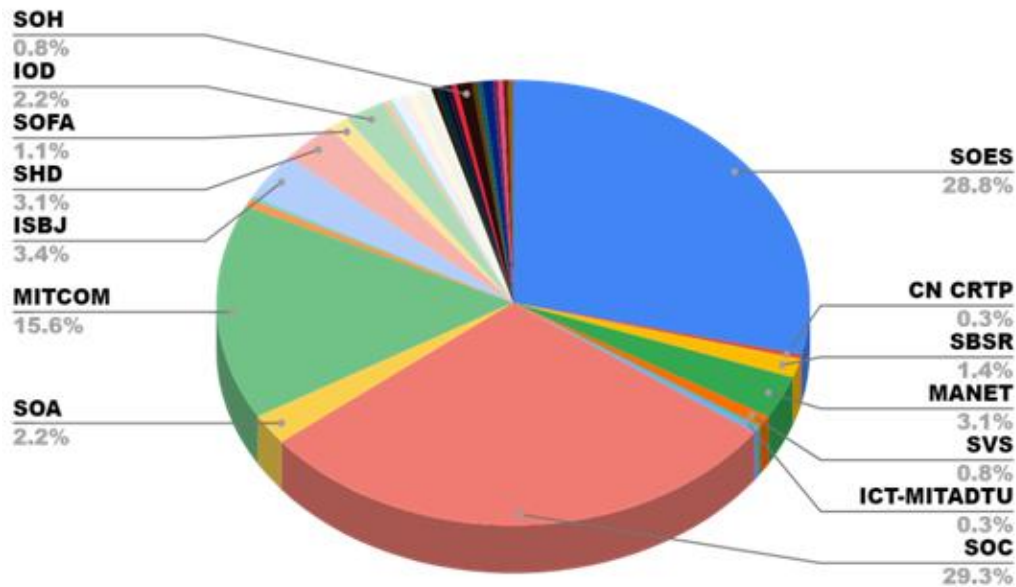


Figure 4: Graphical Depiction of the Public Feedback of Their Destination

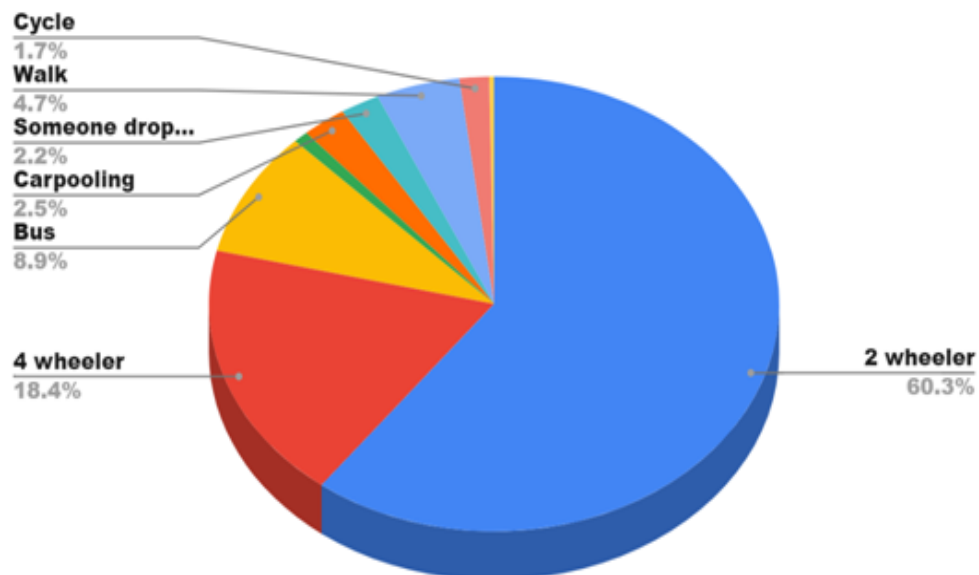


Figure 5: Graphical Depiction of Modes of Transport used by Students and Faculties

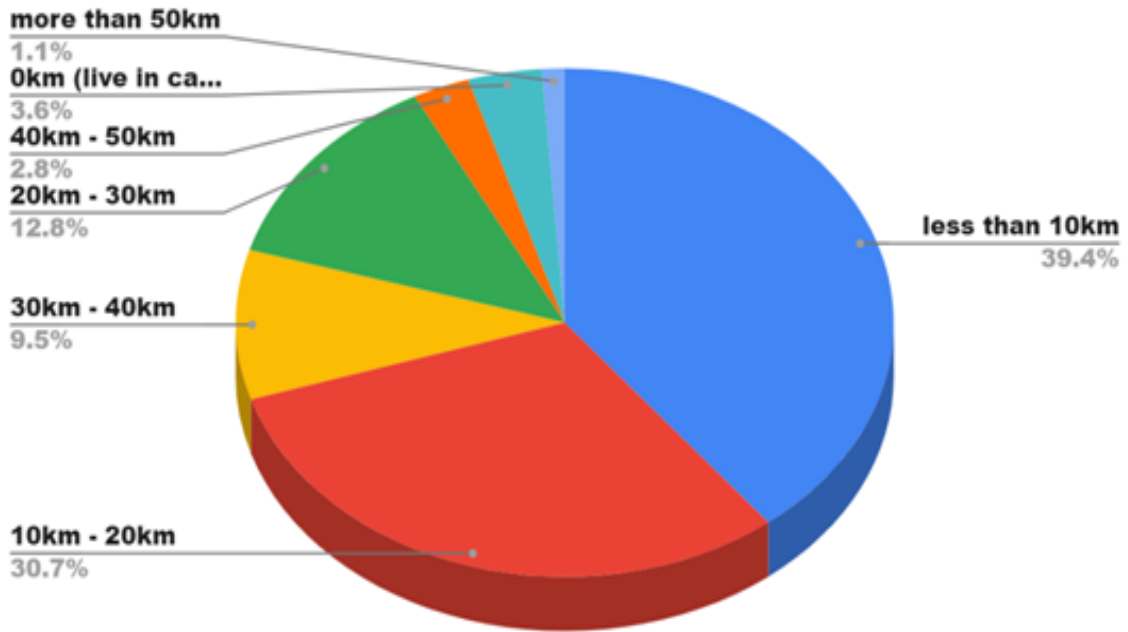


Figure 6: Graphical Depiction of Distance Travelled by Individual to Reach Campus

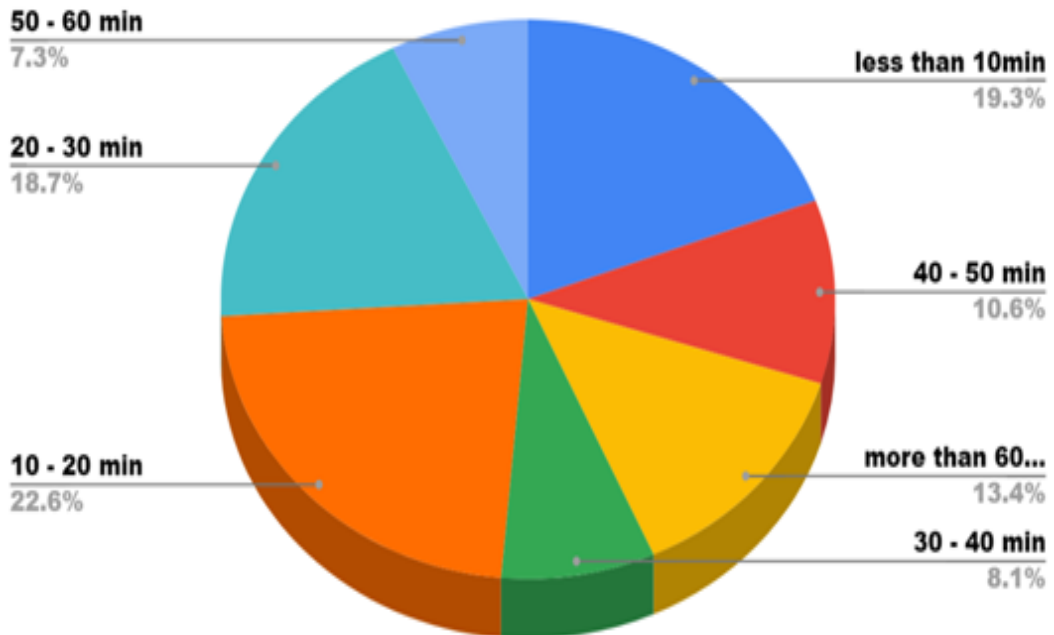


Figure 7: Time Required by Individual to Reach University

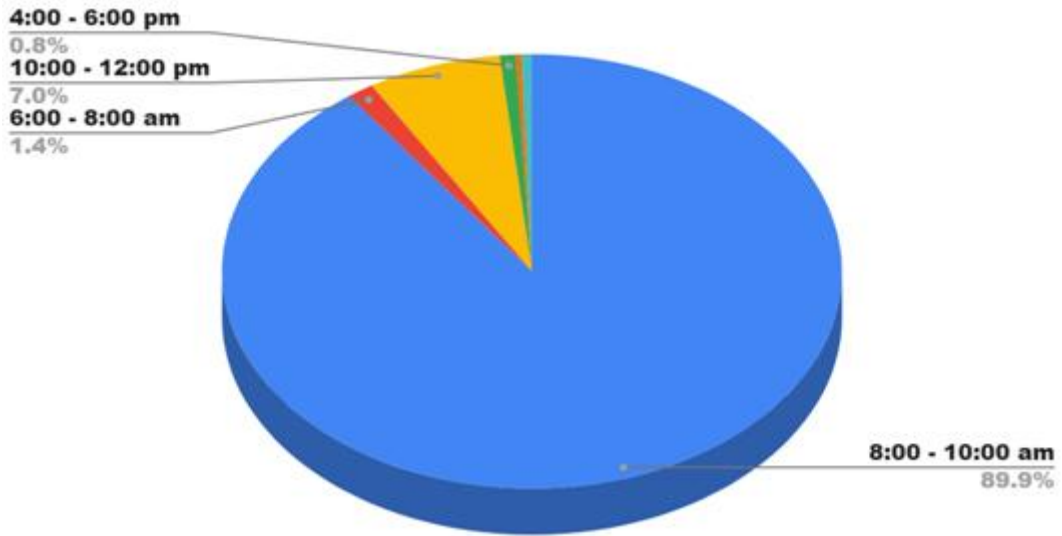


Figure 8: Graph Displaying the Time of Arrival for Students, Staff, and Faculties

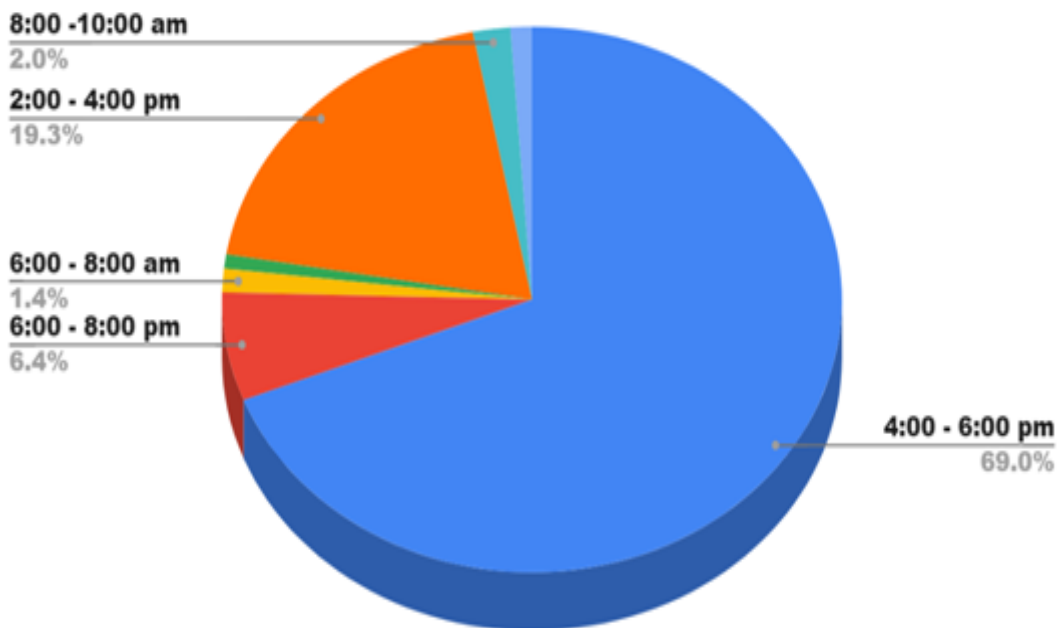


Figure 9: Graph Illustrating the Time of Departure for Students, Staff, and Faculties

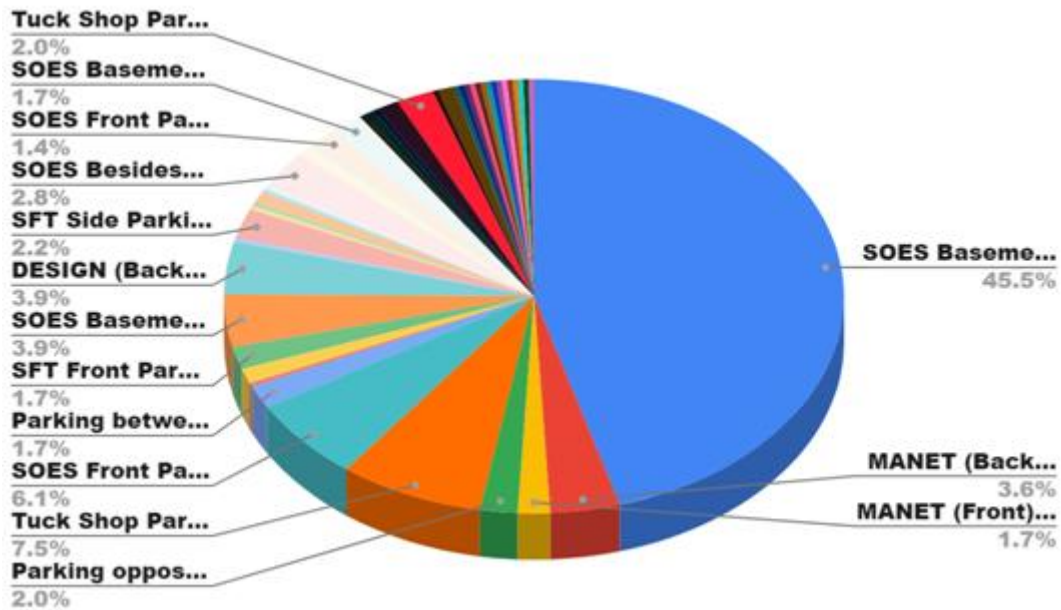


Figure 10: Graphical Representation of Parking Preference

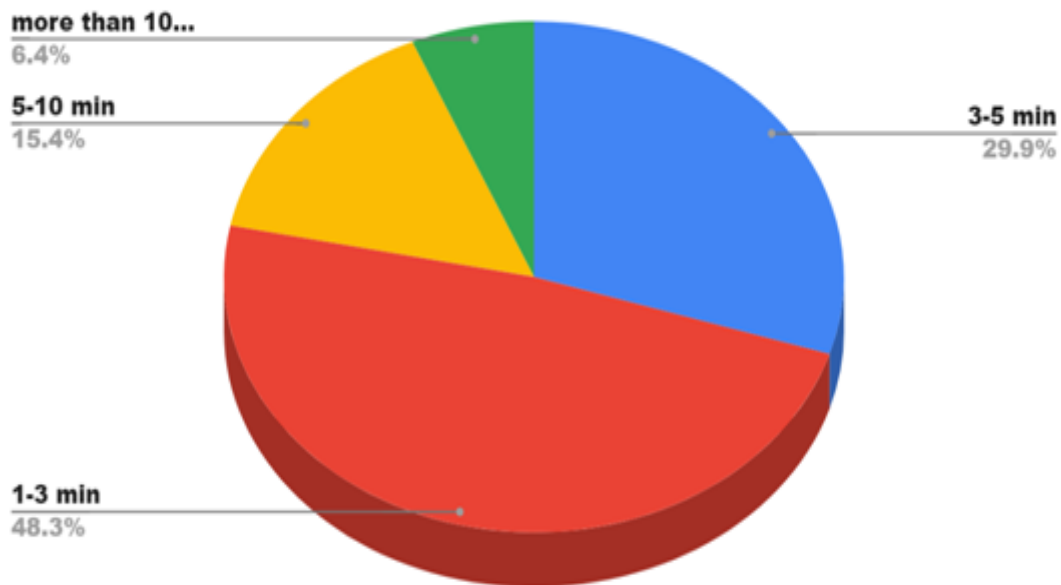


Figure 11: Graphical Depiction of Time Required to Find A Parking Space

3. Proposed Solutions: MIT ADT University offers a wide range of undergraduate, postgraduate, and doctoral programs across various disciplines. The current growth in admission depicts that the population of the campus has almost doubled and will increase eventually in following years. As MIT ADT University expands and admits more students, it becomes crucial to plan and manage the resources, infrastructure, and

facilities effectively. In order to address and tackle above problems following proposals are being suggested.

- **Solution for Congestion:** Congestion on campus poses numerous challenges that hinder the overall efficiency and experience of students, faculty, and staff. However, by implementing a combination of strategies such as efficient infrastructure planning, alternative transportation promotion, technology integration, thoughtful class scheduling, virtual learning opportunities, and effective communication, campuses can address congestion and create a more sustainable and harmonious environment. By prioritizing the mobility and well-being of the campus community, these initiatives not only enhance efficiency but also contribute to a positive and enriching educational experience for all. Following are the proposals suggested to enhance the traffic flow and mitigate the congestion issue.
- **Traffic Channelization:** The objective of this proposal is to minimize traffic congestion by channelizing the traffic through different entry gates based on the destination points within the campus. By utilizing the three entry gates available, namely Main Gate, SOE Gate, and Sports Gate, we aim to optimize the traffic flow and reduce congestion. The strategy of the proposal is to
 - **Identify Destination Points:** Determine the primary destination points within the campus that generate significant traffic. In this case, the SOE Building, Design Building, VGS, and Sports Complex have been identified as major destination points.
 - **Gate Allocation:** Assign specific gates for the traffic heading towards each destination point. Traffic destined for the SOE Building and Design Building will be directed to use the SOE Gate, while traffic headed to VGS and Sports Complex will be directed to use the Sports Gate. All other students and visitors can use the Main Gate.
 - **Signage and Directions:** Install clear signage at strategic locations within the campus to guide drivers and pedestrians towards their intended entry gates based on their destination. This will ensure that everyone is aware of the designated gate for their specific destination.
 - **Communication and Education:** Conduct awareness campaigns and communicate the new traffic channelization plan to all students, faculty, staff, and visitors. This can be done through emails, social media, campus announcements, and orientation sessions. Emphasize the importance of following the designated gates to minimize congestion and improve traffic flow.
 - **Monitoring and Enforcement:** Regularly monitor the traffic flow at each gate to ensure compliance with the designated routes. Security personnel or traffic marshals can be stationed at each gate to guide and enforce the traffic channelization plan. Any violations or deviations can be addressed with reminders and warnings initially, followed by appropriate disciplinary actions if necessary.

Implementing traffic channelization by utilizing different entry gates based on destination points within the campus can significantly reduce congestion, improve traffic flow, and enhance safety. By effectively communicating the plan, educating stakeholders, and enforcing compliance, the proposed strategy can be successfully implemented and contribute to a more efficient and organized campus transportation system.

- **Lane Expansion:** The road network within the campus is of 2 lane. Only the entry route has 4 lane and all other roads are 2 lane. This cuts the stream of the flow thus hampering the speed of the traffic and formation of queue at the point where 4 lane converts into 2 lane. And so in order to resolve this lane expansion should be done. Two lane roads must be upgraded to three lane. Expanding the two-lane roads to three lanes within the campus can indeed help alleviate traffic congestion and improve the flow of vehicles. By providing an additional lane, it allows for more vehicles to travel simultaneously, reducing the chances of bottlenecks and queues forming at the transition point from four lanes to two lanes.
- **Solution for Parking Issue:** The increasing population of the college and the rise in the use of private/individual vehicles have posed challenges for parking management on campuses. As more students, faculty, and staff bring their vehicles to campus, the demand for parking spaces often exceeds the available supply. This can lead to overcrowded parking lots, increased traffic congestion, and frustration among campus community members.

Also parking in low-lying areas becomes difficult as they are prone to water accumulation during the rainy season. This creates a significant obstacle for parking, particularly for bicycles, as the standing water obstructs the availability and usability of parking spaces. The presence of collected water in these areas makes it extremely difficult to find suitable spots for bike parking. To address this issue effectively, it is essential to implement targeted and efficient parking management measures within these specific locations. By employing appropriate strategies such as improved drainage systems, designated parking zones, or alternative parking arrangements, the challenges associated with water pooling can be alleviated. A well-planned parking management plan will optimize the utilization of available spaces, ensuring that parking remains accessible and convenient for all users, even during periods of heavy rainfall.

An elevated parking needs to be constructed in order to address both the issue i.e. inadequate parking area and water intrusion. Elevated or stack parking refers to a parking system where vehicles are vertically stacked on top of each other to maximize the use of available space. It is a solution used in areas where land is limited or expensive, and traditional parking options are impractical. In an elevated parking system, vehicles are parked on multiple levels or platforms, with each level accessible via ramps, lifts, or mechanical systems. The vehicles are typically parked on pallets or platforms that can be raised or lowered to accommodate additional vehicles.

- 4. Vissim Simulation:** In the project, a network model of real-time traffic was designed and simulated using VISSIM software. The process involved creating a network layout, modeling traffic demand, defining vehicle behavior, configuring traffic control elements, and executing the simulation. The simulation results were then analyzed to evaluate network performance and propose optimization strategies. Various metrics were used to assess traffic flow, delays, and queue lengths. The network model of the proposed solutions were also designed and the simulated to compare the results.
- **Existing Network Model:** VISSIM's graphical user interface was utilized to accurately design the network layout, reflecting the existing road network of the MIT ADT area. This involved defining road segments, intersections, and other essential traffic infrastructure elements. The traffic volume was modeled based on real-time data, specifying the number of vehicles, their origins, destinations, and routes. The simulation, executed within VISSIM, incorporated the real-time traffic demand, vehicle behavior, and traffic control configurations, effectively simulating individual vehicle movement and interactions within the network to capture the dynamic traffic conditions of the MIT ADT area. The simulation results were meticulously analyzed to evaluate the performance of the existing road network, employing VISSIM's comprehensive analysis tools and metrics to assess traffic flow, travel times, queue lengths, delays, and other relevant performance indicators. Based on these analysis results, areas of congestion or potential bottlenecks within the MIT ADT Campus were accurately identified.



Figure 12: VISSIM Model of Existing Network

- **Traffic Channelized Network Model:** The second model focused on the proposed solution of traffic channelization, specifically addressing the need to manage internal traffic within the network. This involved designing and analyzing additional routes that could be utilized to direct and channelize the flow of vehicles. In the design phase, the network layout was modified to include the newly proposed routes, taking into consideration the existing road infrastructure and traffic patterns. The additional routes were strategically selected to optimize traffic flow, reduce congestion, and

enhance the overall efficiency of the network. After incorporating the proposed routes, the model was simulated using VISSIM to assess their effectiveness.



Figure 13: VISSIM Model of Channelized Network

- **Lane Expansion Model:** The third model focuses on the network design utilizing the solution of lane expansion. It addresses the need to enhance the capacity and efficiency of the network by adding additional lanes to existing road segments. In this model, the network layout is modified to incorporate the proposed lane expansion. Once the lane expansion design is implemented in VISSIM, the model is simulated to evaluate its effectiveness. The simulation considers various factors such as traffic demand, vehicle behavior, and traffic control configurations to replicate real-world conditions accurately. The analysis phase involves evaluating the performance of the network with the added lanes. This analysis provides insights into the effectiveness of the proposed design in improving traffic flow and reducing congestion.



Figure 14: VISSIM Model of Lane Expanded Network

- **Comparative Analysis of Vissim Results:** This section presents a comparative analysis of the results obtained from the VISSIM simulation for three different network models- the existing network model, the channelized network model, and the lane expansion model. The study focuses on evaluating and comparing the outcomes of these models to assess their effectiveness in addressing traffic congestion and improving traffic flow. By analyzing the results obtained from each model, valuable insights can be gained regarding the impact of different design and management strategies on the overall performance of the network.
- **Vehicle Travel Time Results:** The following table presents a comparison of travel time required for vehicles to reach a common destination point across three different road networks. The data clearly indicates that implementing channelization measures leads to a noticeable reduction in travel time. However, the most significant reduction in travel time is observed when lane expansion is implemented. This highlights the effectiveness of lane expansion in improving travel efficiency and reducing overall travel time for vehicles.

To visually demonstrate the effects of the proposed solutions, the graph provided showcases the disparities in vehicle travel time across three different networks. Despite having identical origin and destination points, each network's unique configuration and the implementation of specific improvements result in varying levels of delay for vehicles. This graphical representation serves as a powerful illustration, highlighting the significance of selecting the appropriate solution to effectively minimize delays and optimize the overall flow of traffic.

Table 6: Vehicle Travel Time Results of Morning Peak Hour Traffic Simulation

VEHICLE TRAVEL TIME RESULTS									
	EXISTING TRAFFIC			CHANNELIZED TRAFFIC			LANE EXPANDED TRAFFIC		
VEHICLE TRAVEL TIME MEASUREMENT	NO OF VEHICLES	TRAVEL TIME	DISTANCE TRAVELLED	NO OF VEHICLES	TRAVEL TIME	DISTANCE TRAVELLED	NO OF VEHICLES	TRAVEL TIME	DISTANCE TRAVELLED
MAIN GATE TO MANET	6	25.894	180.263	5	24.794	210.945	5	28.069	180.769
MAIN GATE - VGS	65	58.074	468.727	65	59.814	489.264	69	59.399	468.729
MAIN GATE - BOI	9	108.328	507.260	6	70.008	538.738	6	63.413	507.482
MAIN GATE - FT	4	143.422	575.904	7	68.767	596.989	5	66.032	572.307
MAIN GATE - SOE	98	210.190	952.162	101	123.765	823.362	109	131.789	955.164
MAIN GATE - ISBJ	33	179.148	798.543	26	110.327	830.645	32	101.745	799.803
MAIN GATE - BANDARA	28	209.137	1025.609	26	139.142	1052.618	32	128.739	1024.111

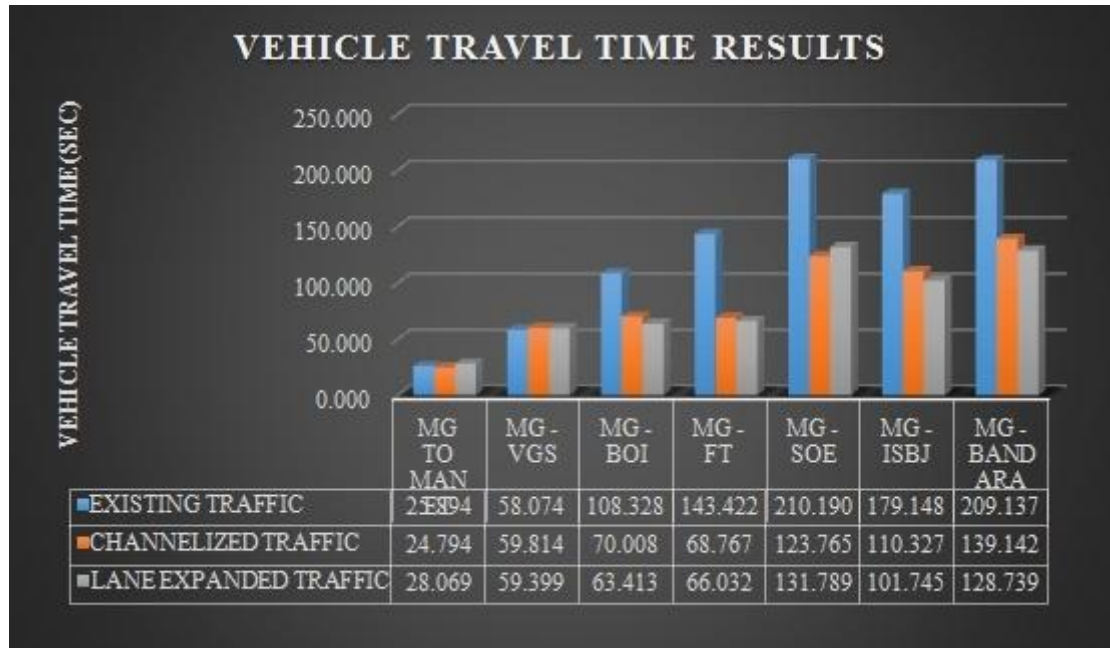


Figure 15: Vehicle Travel Time Results of Morning Peak Hour Traffic Simulation

- **Delay Results:** The presented table provides a comprehensive comparison of the delays resulting from congestion in the current stage and the proposed solutions. The data highlights that implementing lane expansion offers the most effective resolution to the congestion issue, while channelization measures can also contribute to reducing delay times.

Table7: Delay Results of Morning Peak Hour Traffic Simulation

DELAY RESULTS						
DELAY MEASUREMENT	EXISTING TRAFFIC		CHANNELIZED TRAFFIC		LANE EXPANDED TRAFFIC	
	VEHICLE DELAY TIME (ALL)	NO OF VEHICLES (ALL)	VEHICLE DELAY TIME (ALL)	NO OF VEHICLES (ALL)	VEHICLE DELAY TIME (ALL)	NO OF VEHICLES (ALL)
MAIN GATE-MANET	5.9110	6	0.9526	5	0.5950	5
MAIN GATE-VGS	0.7674	65	2.6151	65	0.5361	69
MAIN GATE-BOI	50.5517	9	3.9749	6	5.5074	6

MAIN GATE-FT	72.4324	4	0.9195	7	3.5429	5
MAIN GATE-SOE	96.968	98	25.4889	101	18.6894	109
MAIN GATE-ISBJ	77.4401	33	14.2499	26	5.7751	32
MAIN GATE-BANDHARA	77.4525	28	17.4479	26	5.9763	32

To visualize the impact of these solutions, the accompanying graph illustrates how vehicle delays vary across three distinct networks. Despite sharing the same origin and destination points, each network's configuration and proposed improvements lead to varying levels of delay for vehicles. This visualization emphasizes the importance of selecting the appropriate solution to minimize delays and optimize traffic flow.

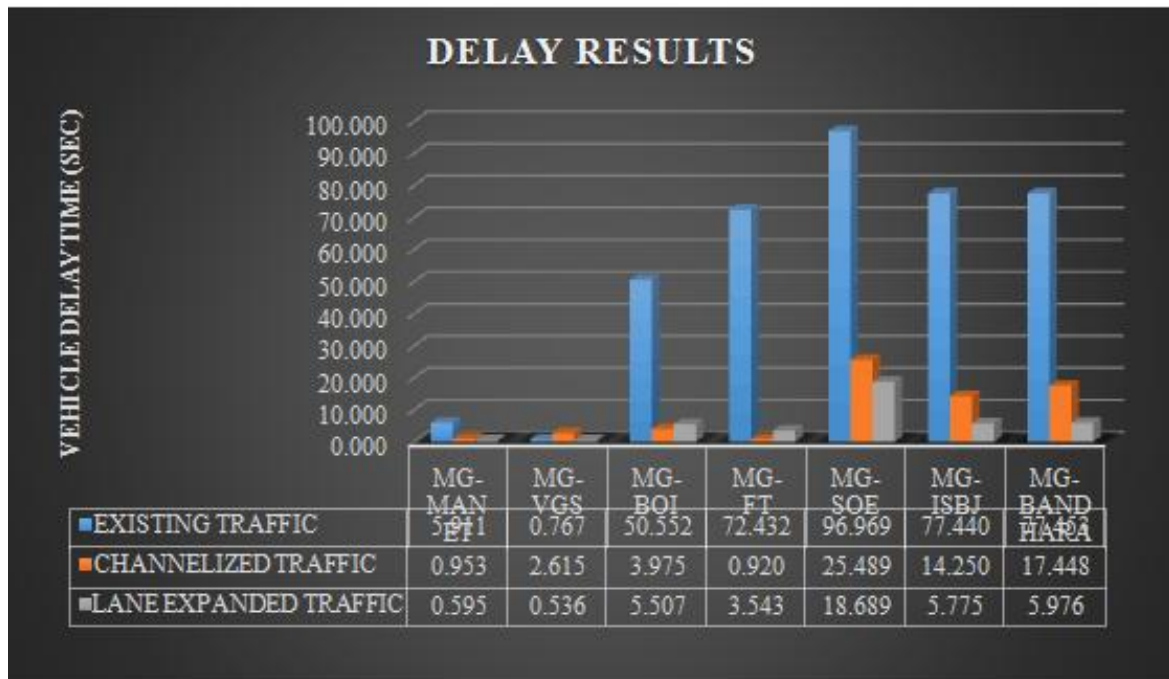


Figure 16: Graph Representing Delay Results During Morning Peak Hour

➤ Queue Results

Table 8: Queue Results

QUEUE LENGTH									
	EXISTING TRAFFIC			CHANNELIZED TRAFFIC			LANE EXPANDED TRAFFIC		
QUEUE COUNTER	QUEUE LENGTH	QUEUE LENGTH MAXIMUM	QUEUE STOPS	QUEUE LENGTH	QUEUE LENGTH MAXIMUM	QUEUE STOPS	QUEUE LENGTH	QUEUE LENGTH MAXIMUM	QUEUE STOPS
BOTTLE NECK POINT	46.356114	112.17274	261	0.850135	48.189985	7	0	0	0

The presented table illustrates the queue length resulting from congestion, ranging from a minimum of 46 meters to a maximum of 113 meters. The findings indicate that implementing lane expansion measures can entirely eliminate the formation of queues, while traffic channelization techniques can effectively reduce the queue length by approximately 50 percent. These results highlight the significant impact of proposed solutions in mitigating congestion and improving the flow of vehicles, ultimately leading to a more efficient and smoother traffic experience.

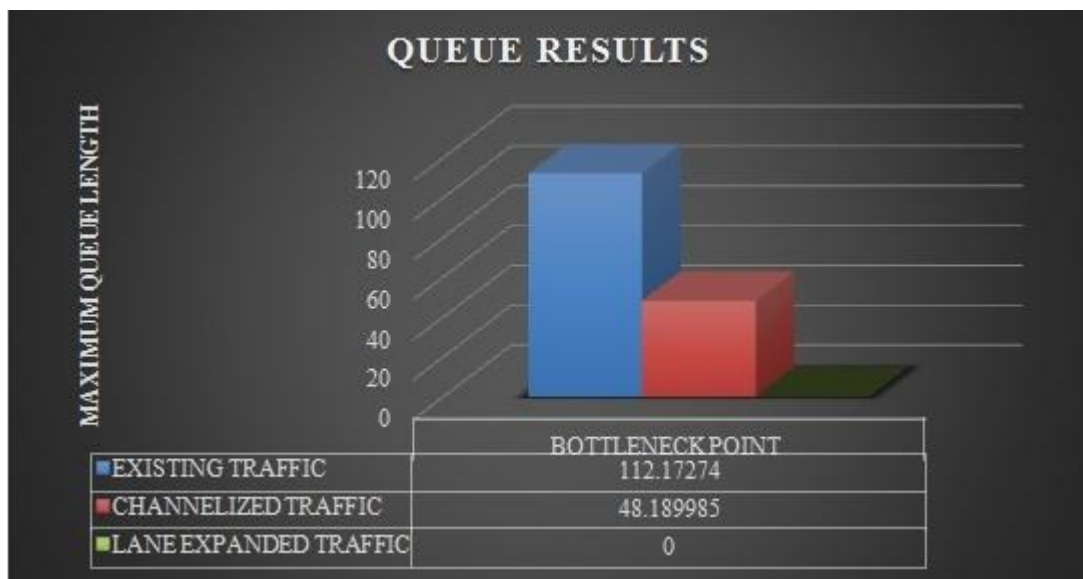


Figure 17: Graph Showing Queue Length During Morning Peak Hour

IV. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

In conclusion, this research study has identified key issues related to traffic congestion and parking management within the campus.

1. The research findings clearly indicate that traffic congestion within the campus stems from bottlenecks and inadequate intersection design.
2. Effective measures such as traffic channelizing and lane expansion can eliminate traffic congestion.
3. The existing internal road has a capacity of 1200PCU/hr, and the volume of traffic currently reaching the road is 1113.68PCU/hr, indicating that the road has reached its maximum capacity. In anticipation of future population growth, it is necessary to expand the lanes in order to increase the road's capacity.
4. By maintaining a width of 10m for the internal road, which corresponds to an undivided three-lane configuration, the road's capacity can be increased to 1800PCU/hr, ensuring a continuous flow of traffic.
5. The issue of parking is primarily observed near the IT Building, Design Building, and ISBJ Building, where low-profile areas and insufficient parking spaces contribute to the problem.
6. Implementing appropriate design and management strategies can effectively address the parking issue.
7. Signage promotes travel awareness and facilitates campus navigation, making it easier for drivers to find their way and follow designated routes.
8. Incorporating sustainable transportation into campus planning and design can enhance the overall functionality and attractiveness of the campus.

RECOMMENDATIONS

After thorough research and analysis, the following recommendations/proposals have been identified as valuable insights

1. Implement measures to address bottleneck congestion and improve intersection design to alleviate traffic congestion within the campus.
2. Explore traffic channelizing techniques and consider lane expansion to effectively manage traffic flow and reduce congestion.
3. Focus on resolving the parking issue in the vicinity of the IT Building, Design Building, and ISBJ Building by implementing proper design and management strategies.
4. Enhance signage and wayfinding systems to provide clear guidance and improve navigation for drivers within the campus.
5. Promote sustainable transportation practices by encouraging the use of alternative modes of transportation, such as carpooling, cycling, walking, and public transit. Promoting use of e-cycles for students coming through bus or walking.
6. Conduct regular traffic volume surveys and parking surveys to monitor and assess the effectiveness of implemented solutions and make necessary adjustments.

By considering these recommendations/proposals, campus authorities can take informed decisions and implement effective measures to improve traffic management, alleviate congestion, and enhance parking facilities within the campus environment.

ACKNOWLEDGEMENTS

The authors would like to express their gratitude my guide, Prof. Rajshekhar G. Rathod, Assistant Professor and Prof. Sagar K. Sonawane, Assistant Professor of Civil Engineering Department, MIT School of Engineering, Pune for their encouragement during my dissertation work. I am also thankful to Prof. Dr. Satish B. Patil, Head, Civil Engineering Department, MIT School of Engineering, Pune for his support and for giving an immense knowledge about the site and various construction safeties.

REFERENCES

- [1] Eom, J. K., Stone, J. R. & Ghosh, S. K. Daily Activity Patterns of University Students. *J. Urban Plan. Dev.* 135, 141–149 (2009).
- [2] Hamad, K., Htun, P. T. T. & Obaid, L. Characterization of travel behavior at a university campus- A case study of Sharjah University City, UAE. *Transp. Res. Interdiscip. Perspect.* 12, (2021).
- [3] Xu, J., Zhang, Z. & Rong, J. The Campus Road Planning and Design Research. *Procedia - Soc. Behav. Sci.* 43, 579–586 (2012).
- [4] dell’Olio, L. et al. A methodology based on parking policy to promote sustainable mobility in college campuses. *Transp. Policy* 80, 148–156 (2019).
- [5] Mohammed Almatar, K. Traffic congestion patterns in the urban road network- (Dammam metropolitan area). *Ain Shams Eng. J.* 14, 101886 (2023).
- [6] Fernandes, P., Sousa, C., Macedo, J. & Coelho, M. C. How to evaluate the extent of mobility strategies in a university campus- An integrated analysis of impacts. *Int. J. Sustain. Transp.* 14, 120–136 (2019).
- [7] Obregón Biosca, S. A. College student mobility in emerging countries- Case study on Universidad Autónoma de Querétaro, México. *Transp. Res. Interdiscip. Perspect.* 6, 100155 (2020).
- [8] Parmar, J., Das, P. & Dave, S. M. Study on demand and characteristics of parking system in urban areas- A review. *J. Traffic Transp. Eng. (English Ed.)* 7, 111–124 (2020).
- [9] Min-Allah, N. & Alrashed, S. Smart campus—A sketch. *Sustain. Cities Soc.* 59, 102231 (2020).
- [10] Gurbuz, O. & Cheu, R. L. Survey to Explore Behavior, Intelligent Transportation Systems Needs, and Level of Service Expectations for Student Parking at a University Campus. *Transp. Res. Rec.* 2674, 168–177 (2020).
- [11] IRC-SP- 73-2018 Manual Of Specifications And Standards For Two Laning Of Highways With Paved Shoulder.
- [12] IRC- 067-2012 Code of Practice for Road Signs.
- [13] IRC- 106-1990 Guidelines for Capacity of Urban Roads in Plain Areas.
- [14] Indian Highway Capacity Manual (Indo-HCM) 2017.
- [15] Traffic Engineering and Transport Planning by Dr. L. R. Khadiyali.

PART 5

Futuristic Trends in Construction Materials & Civil Engineering

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GROUNDWATER POLLUTION STUDIES OF EACHANARI INDUSTRIAL ESTATE, COIMBATORE

Abstract

The South India's geology is unfavorable consisting of hard rocks like granite and basalt, which prevent precipitation from freely penetrating, has a negative impact on the declining groundwater levels besides monsoonal failures and anthropogenic activities. Six groundwater samples were taken for the current study from various places throughout Eachanari, Coimbatore to acquire water that is suitable for drinking and other uses other useful purposes by analyzing the following physiochemical parameters such as turbidity, EC, pH, Total Hardness, BOD, and ions (Ca^{2+} , Cl^- & Mg^{2+}). Also, a mapping of groundwater quality was produced utilizing a geographic information system.

Keywords: Groundwater Studies, Pollution, Physico-Chemical Characteristics, Prediction of Distribution.

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I. INTRODUCTION

After 1854 the rapid industrialization has interconnected panacea of advantages such as optimal use of indigenous resources, raising income of people and thus upgrading the overall livelihood of the compatriots. The drawbacks of industrialization are categorized into two: social and environmental. Despite massive employment generated, rapid industrialization has significant impacts on the abiotic factors of environment such as air, water, and soil. Pollution has become a major concern only after urbanization. The release of toxic gases in the atmosphere by the thermal power plants is one such example of air pollution. Soil and water pollution goes hand in hand which means once the soil gets affected water also gets affected [1]. Water that is found in soil pores, rock pore spaces, and rock formation cracks is known as groundwater. Groundwater makes up to 30% of all readily available freshwater worldwide. Today, groundwater resource pollution has grown to be a serious issue. Groundwater pollution and contamination are influenced by the pollution of the air, water, and land. Toxic chemicals may be dumped by factories, and rainwater may include dangerous pesticides or farm animal excrement. This has contributed to the severe scarcity of groundwater in India which majorly depends on it for meeting more than 50% of its needs. One-fourth of the world's water is used annually, or around 230 cubic kiloliters of groundwater. 85% of the drinking water supplies and more than 60% of irrigated farmland depend on ground water [2]. The prime aim of the paper is to illustrate the characteristics of ground water in and around the vicinity of SIDCO Private Industrial Estate in Coimbatore and direct some remedial measures to reduce the toxicity of contaminated ground water. Thus, the current study paper's objectives are to classify the impact of anthropogenic and natural processes on groundwater quality using simple testing techniques, identify the physicochemical properties of groundwater suitable for drinking, and use the pollution index of groundwater (PIG) to describe variation in groundwater quality.

II. EXPERIMENTAL INVESTIGATIONS

Site Selection: The Coimbatore District is situated in Tamil Nadu's western region. The city is situated along the Noyyal River. According to the 2011 census, it has a population of almost 34.7 lakh people. The city is also known as Manchester of South India. It is one of the most industrialized neighborhoods and is well known for its motor, pump, and wet grinder industries. Establishments in the foundry and electroplating sectors are growing to meet the demands of the aforementioned and to create machinery for the companies. Hence there are panacea of chances for pollutants to intrude the groundwater bodies, so this paper ought to describe the distribution of some of the pollutants in and around Eachanari. The Small Industries Development Corporation (SIDCO) private industrial estate is situated in Kurichi, Coimbatore. The estate is about 700 acres with 300 units. It is one of the industrial clusters and spans an area of 88.43 acres. It is situated 7 kilometers from Coimbatore Town. SIDCO's Kurichi is situated in the Coimbatore District between $10^{\circ} 55' 11''$ N latitude and $76^{\circ} 57' 35''$ E longitude. SIDCO is located adjoining to the Tamil Nadu Colonial Housing Board. Coimbatore Corporation has administrative control over this cluster. This industrial area is situated along the NH-209 from Bangalore to Dindigul. The map provides the location of the SIDCO industrial cluster in the Coimbatore district. along with the site of study i.e., Eachanari. The Coimbatore District is situated in Tamil Nadu's western region. The city is situated along the Noyyal River. According to the 2011 census, it has a population of almost 34.7 lakh people. The area is frequently referred to as the South Indian Manchester. One of

the most industrialized neighborhoods, it is well known for its wet grinders, pumps, and motor manufacturing sector. Establishments in the foundry and electroplating sectors are growing to meet the demands of the aforementioned and to create machinery for the companies. The study area is shown in figure 1 and the sampling area also indicated in this diagram.

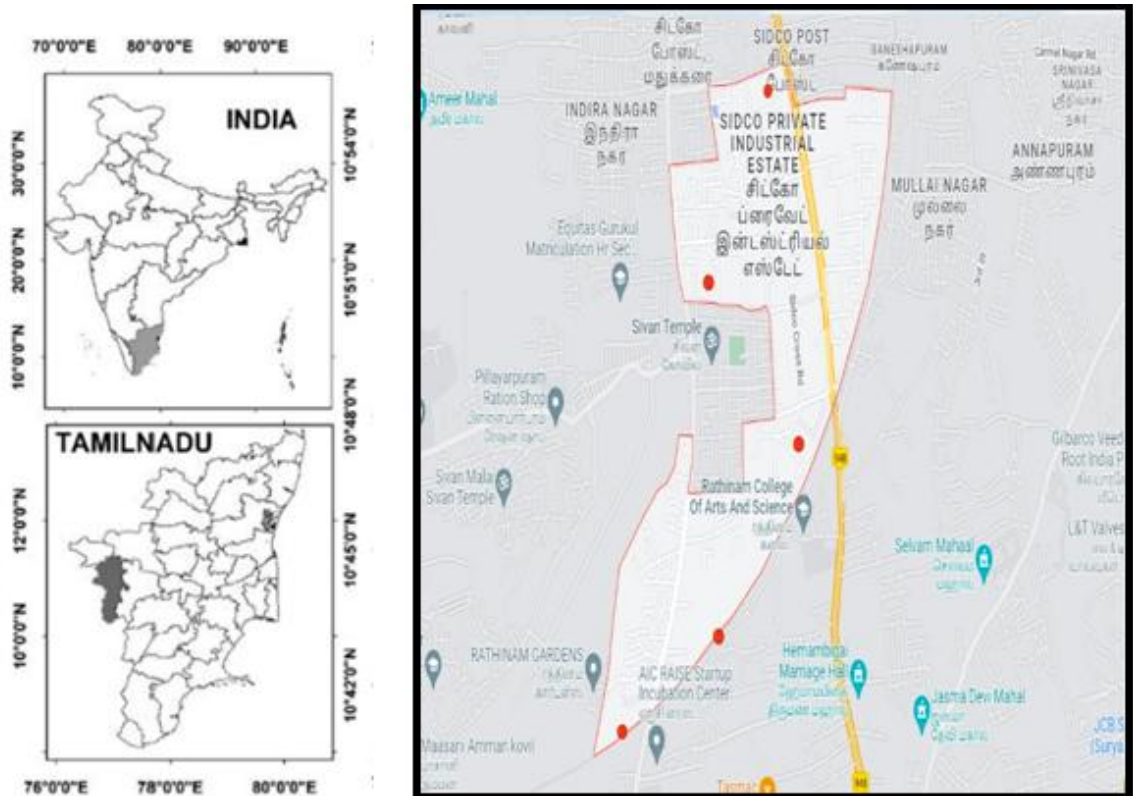


Figure 1 : Study Area – Eachanari, Coimbatore

III.METHODOLOGY

During the month of August 2022, the groundwater samples were collected from 6 locations in and around Eachanari (i.e., SIDCO – Industrial Estate) depicted in Fig 1. From each site 3 liters of water samples were collected in polyethylene bottles and got transported to the laboratory keeping them in them in the ice box and then kept at 4°C in the incubator for further physical and chemical parameter analysis of water samples. The pH, Turbidity and EC were tested in the field using digital water analysis kit. The pH content was measured using pH meter. The MOHR titration method was used to assess the chloride concentration. Nephelometric analysis was used to estimate the turbidity, and EDTA was used to calculate the total hardness. The magnesium and calcium concentration were analyzed using complexometric titration. Biological Oxygen Demand (BOD) was analyzed by using BOD incubator. Electrical conductivity of water was analyzed using conductivity meter. Using Arc-GIS software, spatial distributions of various geochemical parameters were created using the inverse distance weighted (IDW) method.

IV. RESULTS AND DISCUSSION

Eachanari groundwater quality characteristics such as pH, EC, TH, BOD, TDS, and principal cations (Ca^{2+} and Mg^{2+}) and anions are shown in Table 1 together with their minimum, maximum, mean, and standard deviation (CI-). The hydrogen ion concentration is controlled by the amount of dissolved CO_2 , bicarbonate and carbonate in groundwater and is an especially important indicator of quality of ground water [3]. Anthropogenic causes like human induced pollution affects ground water to the maximum. In the flanks of industrial areas, there are high chances of metals getting dissolved if the water is acidic, with a low pH level [4]. Quality of water depends on proper levels of pH. According to BIS, the acceptable limit range for portable water is between 6.5 and 8.5. The pH values in the examined samples ranged from 7.27 to 7.62, showing that the HCO_3^- form of dissolved carbonate was the primary cause of the groundwater's alkaline nature. The variation of pH in the selected areas are shown in figure 2.

Table 1: Assessment of Physiochemical Parameters

Sample No.	Location	Turbidity NTU	EC μ mhos/cm	pH	TH mg/L	Ca mg/L	Mg mg/L	Cl mg/L	BOD ppm
1	Indira	2	1707	7.38	596	150	446	236	4.65
2	Pillayar	1	3270	7.27	769	450	319	380	3.22
3	Annapura	1	4030	7.62	1200	633	567	370	3.1
4	Mullai	2	2160	7.55	498	215	283	232	3.78
5	Sundarapur	2	1203	7.48	377	90	287	78	3.49
6	Madukkara	1	481	7.33	189	72	117	118	3.61
	Min	1	481	7.27	189	72	21	78	3.1
	Max	2	4030	7.62	1200	633	95	380	4.65
	MEAN	1.5	2141.8	7.43	604.	268.	336.	235.	4.37
	Std. Div	0.5	1316.5	0.134	351.	225	154.	124.	3.55
	STD. VALUES	1	620-1820	6.5-8.5	200-600	75-200	100	250	3-5

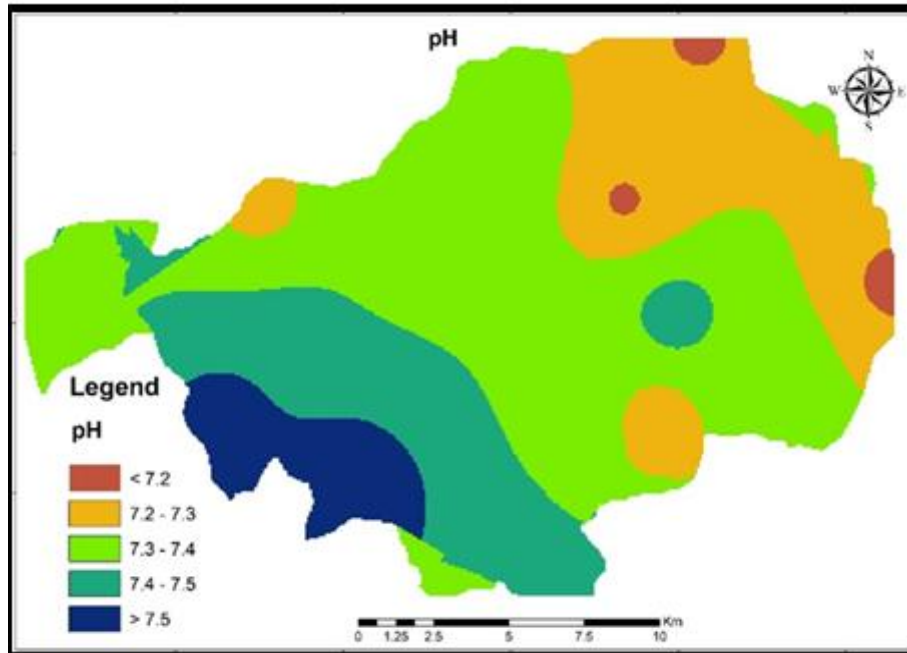


Figure 2 : Variations Ph in the Ground Water at Eachanari Industrial Estate

Pure water is not a good conductor of electricity, as there is absence of ions. Whereas polluted water is a good conductor of electricity due to the presence of ample amount of ions [5]. The measurement of electrical conductivity is important because it shows how much dissolved substances, chemicals and minerals are present in water [6]. The permissible level of electrical conductivity is 620-1820 mhos/cm. According to the analysis, EC is present in 80% of the samples. which is moreover concentrated in the easternmost and central parts of Eachanari. The excess of EC indicates the presence of excess of turbidity. The Conductivity levels of groundwater samples in Eachanari area was shown in figure 3 along with distribution.

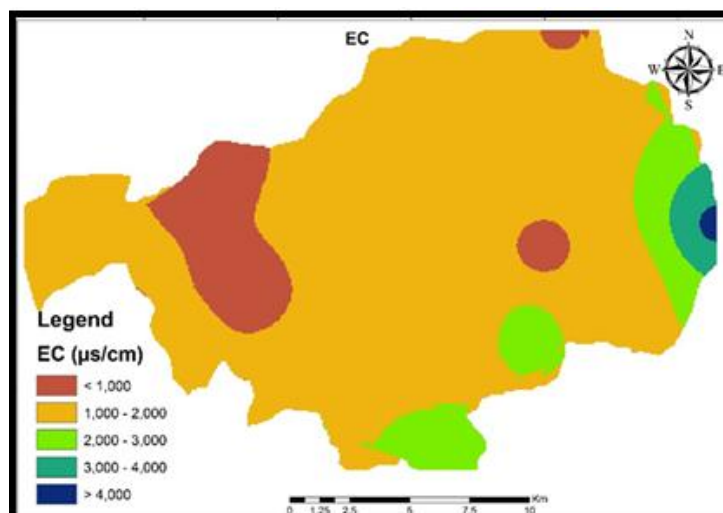


Figure 3 : Variations EC in the Ground Water at Eachanari Industrial Estate

Relative clarity of liquid is measured by turbidity. Nephelometric Turbidity Unit (NTU) is the unit of measurement for turbidity. Turbidity of drinking water should be kept below 1NTU. It makes the water appear cloudy that scatters light caused by suspended particles [7]. The suspended particles include microscopic organisms, organic and inorganic matter, clay, and silt. Tourism can be significantly afflicted by the high turbidity in lakes and streams. Turbidity provides room for various kinds of micro-organisms [8]. Certain studies reveal that the removal of protozoa is related to the removal of turbidity. Turbidity is measured using specially designed equipment. The water sample is subjected to the light rays from a source. The total amount of light scattered is measured. Low turbidity indicates better water quality. Turbidity provides room for various kinds of micro-organisms. Certain studies reveal that the removal of protozoa is related to the removal of turbidity. According to Water quality standards 10500:2012 the permissible level of turbidity is 1. Our observation shows a mean TDS of 1.5 which is slightly above the standard value which makes it clear that the groundwater cannot be consumed directly without purification [9]. Unlike other physiochemical parameter turbidity is found to spread in the groundwater to a larger extent. The turbidity level of selected industrial site and its distribution was shown in figure 4.

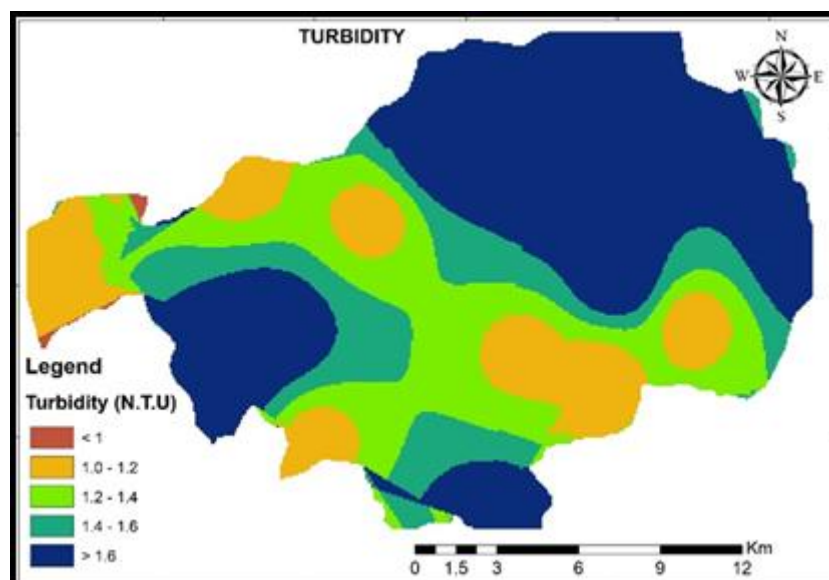


Figure 4 : Variations Turbidity in the Ground Water at Eachanari Industrial Estate

Compounds of calcium, magnesium, and several other metals contribute to hardness. The harder the water is, the less toxic other metals are to aquatic life [10]. Hard water causes some of the metal ions to precipitate out of solution as insoluble precipitates, rendering them indigestible to living things [11]. Hardness levels that are too high are typically undesirable for aesthetic or budgetary reasons. According to Water quality standards 10500:2012 the permissible level of TH is between 200-600 mg/dl. From observing the above table, we find that the maximum and minimum TH is found to be 189 and 1200. The maximum TH observed is found to be double that of the maximum permissible limit. Like EC, the TH is majorly found in the easternmost parts and northern and southern borders of Eachanari. The distribution of hardness in the ground water at Eachanari industrial area is shown in figure 5.

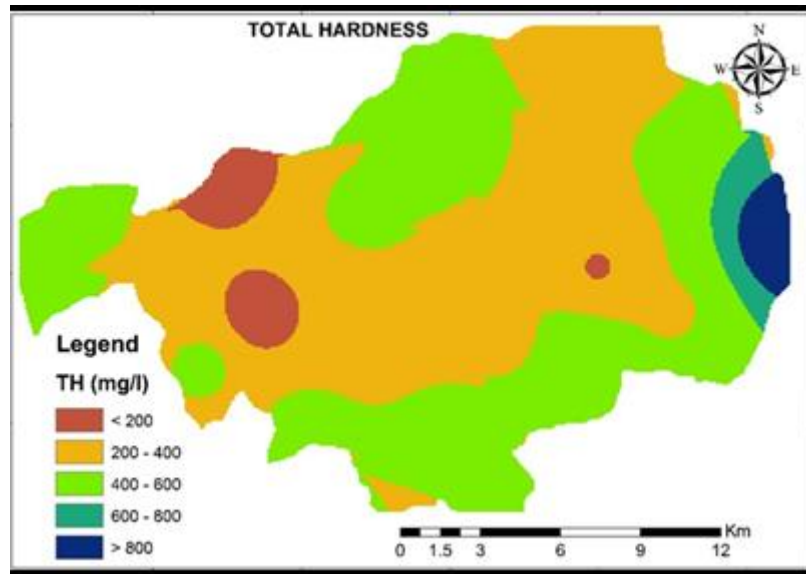


Figure 5: Variations Total Hardness in the Ground Water at Eachanari Industrial Estate

Water is considered to be hard when it contains higher amounts of calcium in it. Hard water is an inconvenience but does not provide any health issues due to mineral buildup on plumbing fittings and poor soap and/or detergent performance [12]. Water works well as a solvent and easily absorbs impurities. The permissible amount of calcium is between 75 to 200 mg/dl. From the table 1 we could observe that the maximum amount of calcium is 268 mg/dl which is slightly above the standard value. Calcium ion distribution also shown in the figure 6 for the entire industrial site at Eachanari, Coimbatore.

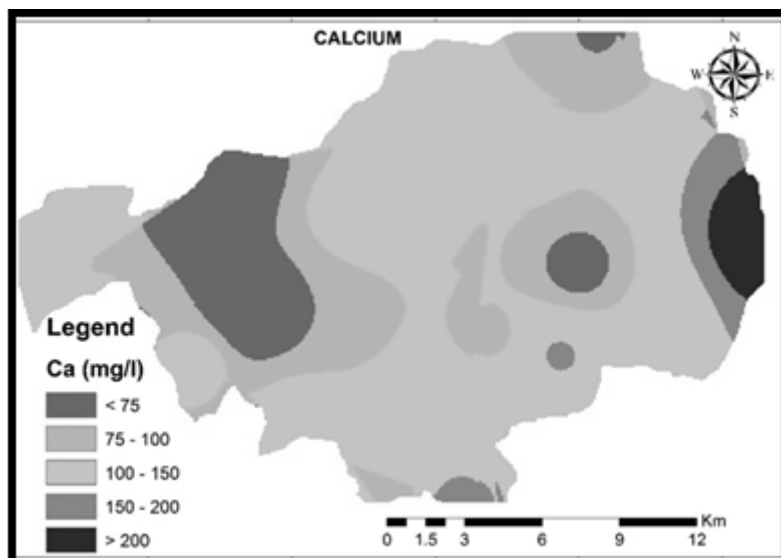


Figure 6 : Variations Total Calcium in the Ground Water at Eachanari Industrial Estate

The acidity of the groundwater at Eachanari was highest in the southwest and gradually decreased towards the east and northeast. Electrical Conductivity (EC) is found to be maximum in the eastern most part of the project site whereas it is moderate in the

remaining parts of the city. The water samples showed higher levels of turbidity in most of the northwestern parts of Eachanari and similar trends is found in some parts of southwestern region. Unlike Electrical conductivity Total hardness is only concentrated in the east central region. The spatial distribution of calcium is more or less similar to total hardness [13, 14]. Magnesium levels also exceeds standards prescribed by IS 10500:2012. The aforementioned facts led to the conclusion that the groundwater in Eachanari's northern and northwestern regions is more contaminated and unfit for direct human consumption than that in its western and southern regions. The greater density of industries in the area may be to blame for this discrepancy [15]. It was discovered that using geostatistical techniques was an effective way to forecast the concentration of groundwater parameters in unmeasured places.

V. CONCLUSION

The groundwater in the northern and northwestern regions of Eachanari is more polluted and unfit for human consumption than the western and southern regions, according to the aforementioned observations. The greater density of industries in the area may be to blame for this discrepancy. It was discovered that using geostatistical techniques was an effective way to forecast the concentration of groundwater parameters in unmeasured places. The Turbidity, Total Hardness, Calcium, and magnesium values of each location were found to be high. Consuming the contaminated water creates severe effects to the living beings – long term effects. Hence, it is necessary to reduce the concentrations of each parameter (Ca, Turbidity, TH, Mg) Therefore, we recommend a normal RO treatment systems or RO treatment plant and its purification before consuming the water in the target locations.

REFERENCES

- [1] Muhammad Mazhar Iqbal, Tehmena Rashid, Saddam Hussain, Muhammad Umer Nadeem, Muhammad Sohail Waqas, Muhammad Amin and Muhammad Naveed Anjum, Eutrophic Status Assessment Based on Very High-Resolution Satellite Imagery in the Coastline Environment of Korea, *Pollutants*. 3 (1) (2023) 59-73.
- [2] Vasant Wagh, Shrikant Mukate, Aniket Muley, Ajaykumar Kadam, Dipak Panaskar, Abhay Varade, Study of groundwater contamination and drinking suitability in basaltic terrain of Maharashtra, India through PIG and multivariate statistical techniques, *Journal of Water Supply: Research and Technology-Aqua*. 69 (4) (2020) 398 – 414.
- [3] Thanh Giao Nguyen, Thi Hong Nhien Huynh, Assessment of surface water quality and monitoring in southern Vietnam using multicriteria statistical approaches, *Sustainable Environment Research*. 32 (2022) 20.
- [4] Ahsan Saif Ullah, Haroon Rashid, Shahbaz Nasir Khan, Muhammad Umar Akbar, Arfan Arshad, Md. Masudur Rahman, Shumaila Mustafa, A Localized Assessment of Groundwater Quality Status Using GIS-Based Water Quality Index in Industrial Zone of Faisalabad, Pakistan, *Water*. 14 (2022) 3342.
- [5] Nandini Krishnan, Suriya Saravanan, Assessment of Groundwater Quality and Its Suitability for Drinking and Irrigation Usage in Kanchipuram District of Palar Basin, Tamilnadu, India, *Polish Journal of Environmental Studies*. 31 (3) (2022) 2637 – 2649.
- [6] T. Riedel, Temperature-associated changes in groundwater quality, *Journal of Hydrology*. 572 (2) (2019) 206.
- [7] Rizwan Reza, Gurdeep Singh, Assessment of Ground Water Quality Status by Using Water Quality Index Method in Orissa, India, *World Applied Sciences Journal*. 9 (12) (2010) 1392 – 1397.
- [8] Hanaa A. Megahed, GIS-based assessment of groundwater quality and suitability for drinking and irrigation purposes in the outlet and central parts of Wadi El-Assiuti, Assiut Governorate, Egypt, *Bulletin of the National Research Centre*. 44 (2020) 187.

- [9] Samir Amrani, Said Hinaje, Mohamed El Fartati, Youssef Gharmane, Driss Yaagoub, Assessment of groundwater quality for drinking and irrigation in the Timahdite–Almis Guigou area (Middle Atlas, Morocco), *Applied Water Science*. 82 (2022) 12.
- [10] Doris O. Okoroh, Johnson Cletus Ibuot, Hydrogeochemical assessment of groundwater quality: a case study of Federal College of Education (Technical), Omoku, Rivers State, *Water Practice and Technology*. 17 (7) (2022) 1458 – 1469.
- [11] H. Annapoorna, M.R. Janardhana, Assessment of Groundwater Quality for Drinking Purpose in Rural Areas Surrounding a Defunct Copper Mine, *Aquatic Procedia*. 4 (2015) 685 – 692.
- [12] Mohamad Najib Ibrahim, Assessing Groundwater Quality for Drinking Purpose in Jordan: Application of Water Quality Index, *Journal of Ecological Engineering*. 20 (3) (2019) 101 – 111.
- [13] Yanan Chen, Yichen Zhang, Jiasheng He, Jiquan Zhang, Qiuling Lang, Huanan Liu, Chenyang Wu, Assessment of Groundwater Quality and Pollution in the Songnen Plain of Jilin Province, Northeast China, *Water*. 13 (2021) 2414.
- [14] P. A. Sakyi, R. Asare, O.F. Fynn, G. M. Osiakwan, Assessment of Groundwater Quality and its Suitability for Domestic and Agricultural Purposes in parts of the Central Region, Ghana, *West African Journal of Applied Ecology*. 24 (2) (2016) 67 – 89.
- [15] Soumaya Aouiti, Fadoua Hamzaoui Azaza, Fetheddine El Melki, Monji Hamdi, Fulvio Celico, Mounira Zammouri, Groundwater quality assessment for different uses using various water quality indices in semi-arid region of central Tunisia, *Environmental Science and Pollution Research*. 28 (2021) 46669 – 46691.

A CRITICAL REVIEW ON THE ALCCOFINE BASED CONCRETE

Abstract

This critical review provides insights into the application of Alccofine 1203 in the construction industry. Presently, numerous researchers are actively working towards making concrete more environmentally friendly and reducing carbon dioxide emissions during the manufacturing and construction processes. Alccofine 1203, as a micro-finer additive for mortars and concrete, offers unique and significant properties, including low calcium silicate, hydraulic and pozzolanic activity, and enhancement of cement past packing density. This review thoroughly examines decades of research on Alccofine 1203 and concluded that the optimal dosage of this additive should range from 8% to 12% by volume of the total binder content, depending on the concrete grades. However, adjustments to this proportion might be necessary to achieve specific properties in the concrete.

Keywords: Alccofine; High Performance Concrete; High Strength Concrete; Micro Fine Particles

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I. INTRODUCTION

Currently, researchers are actively exploring alternatives to traditional cement ingredients in concrete to mitigate greenhouse emissions in the atmosphere. They are using cement replacement materials (CRMs) and new micro-fine generation materials like ground granulated blast furnace slag (GGBS) as partial substitutes. The main purpose of CRMs is to enhance the refinement and production of concrete while densifying its microstructure, resulting in reduced permeability. Alccofine is one such material, that serves the purpose of cement replacement material.

Alccofine is a new micro-fine material of particle size much lower than other hydraulic materials like fly ash, cement, GGBS, silica fume, etc., manufactured in India. It has significant attributes, such as optimized particle size distribution, which will improve concrete performance in the fresh and hardened stages. It will be improving the packing density of the cement paste components, reducing water demand and admixture dosage. Meanwhile, it will improve any concrete's durability and strength parameters at all ages. The calculated amount of Alccofine 1203 will be extra to the concrete mix proportion along with cement and other pozzolanic materials. The recommended dosage is 8% to 12% by volume of the total binder content based on the grades of concrete.

High performance concrete was studied with high-quality ingredients of Alccofine 1203. M50 grade concrete was prepared with partial replacement of conventional cement with Alccofine 1203 by 5%, 10%, 15%, and 20%, respectively. They determined the mechanical properties of HPC, modulus of elasticity, and durability property of rapid chloride permeability values. He concluded that the 10% optimum replacement of Alccofine showed improved strength and durability properties compared to the controlled concrete mix proportion (Srinivasan, 2020). Concrete was manufacturing with full replacement of natural sand and partial replacement of Alccofine 1203 in the ranges of 0 to 25% in the increment of 5%. The experimental results showed that 15% of Alccofine in the concrete mix showed better results and after that gradually decreasing manner was achieved (Suganya, 2019). M80 grade of high strength concrete was prepared with Alccofine and industrial waste products. Strength properties showed that 5% of Alccofine showed high compressive strength results when compared to the other proportions (Varinder Singh, 2018). M60 grade of high performance concrete was developed based on the ACI method blended with flyash of 20% and alccofine of 0 – 15% in the increment of 3% along with water-cement ratio of 0.25. The mechanical properties values showed that 12% addition of alccofine in M60 grade concrete attained higher strength than the remaining proportions (Surendra Kumar, 2018).

The cement mortar cube strength was depended on the partial replacement of alccofine in the mortar mix proportion. Due to its higher pozzolanic nature, hydration process yields denser CSH gel and it exhibits addition of Alccofine 1203 yielded higher strength for the cement mortar cubes (Balamuralikrishnan, 2021). The self compacting concrete was developed with the effective addition of 25% flyash and alccofine of various percentages (5, 10, 15%). The results indicated that the mechanical properties obtained better for the mix proportions of 10% alccofine (Bode Venkata Kavyateja, 2020).

A comprehensive review on the concrete with alccofine powder concluded that the fineness property doesn't increasing the water demand. Meanwhile the dosage of the

alccofine in the ranges of 5 – 15% of the volume of the ordinary Portland cement (Tejashree Chaudhari, 2021). Another comprehensive review on the alccofine based concrete was conducted, their review of literatures showed that low calcium silicate available alccofine (range of 0-20%) increases the strength of the concrete (Narender Reddy, 2017). Another review on the alccofine based high performance concrete suggested that 15% replacement showed better strength properties and enhances the durability and workability of the concrete (Boobalan, 2021).

The objective of this critical review gives an idea of utilization of Alccofine 1203 in the various applications and their optimum proportions in the cement concrete and also for the cement mortars. The addition of alccofine increases the hydration process resulted in the improved CSH gel which in turn increasing the strength of the specimens.

II. MATERIAL PROPERTIES

Alccofine 1203 is used as an additive for the concrete and mortars. It has low calcium silicate content. Its hydraulic and pozzolanic properties resulted in superior hydration process. The optimum proportion of Alccofine 1203 varies from 8 – 12 % by the volume of the cement. The presence of calcium oxide and silica in Alccofine of higher amounts improves the pozzolanic reaction, which in turn additional amount of CSH gel is formed, resulted in the development of superior core concrete matrix (Bhanavath Sagar, 2021). The typical properties of Alccofine 1203 are shown in table 1.

Table 1: Typical Properties of Alccofine 1203

Property Description	Range of Values	Chemical Properties	% Mass
Specific Gravity	2.86	CaO	30 – 34
Fineness	12000 cm ² /gm	Al ₂ O	18 – 25
Average Particle Size	4 – 6 microns	Fe ₂ O ₃	0.8 – 3.0
Bulk Density	600 – 700 kg/m ³	SO ₃	0.1 – 0.4
		MgO	6 - 10
		SiO ₂	30 - 36

Alccofine 1203 mixed with concrete reduces the pores available due to its fineness. The shape, size and morphology of the Alccofine 1203 is presented in SEM image of figure 1. The more amount of calcium oxide in the Alccofine is making the concrete to perform superior with other ultra fine ingredients of concrete. The proportion of Alccofine is presented in figure 2 (Bhanavath Sagar, 2021). The chemical properties of Alccofine form EDAX shown in table 2.

Table 2: Chemical Properties of Alccofine 1203
(Panga Narasimha Reddy, 2020).

Property Description	Weight (%)	Atomic (%)
C K	45.69	57.64
Ca K	8.66	3.27
Al K	4.01	2.25

O K	35.26	33.39
Si K	6.38	3.44

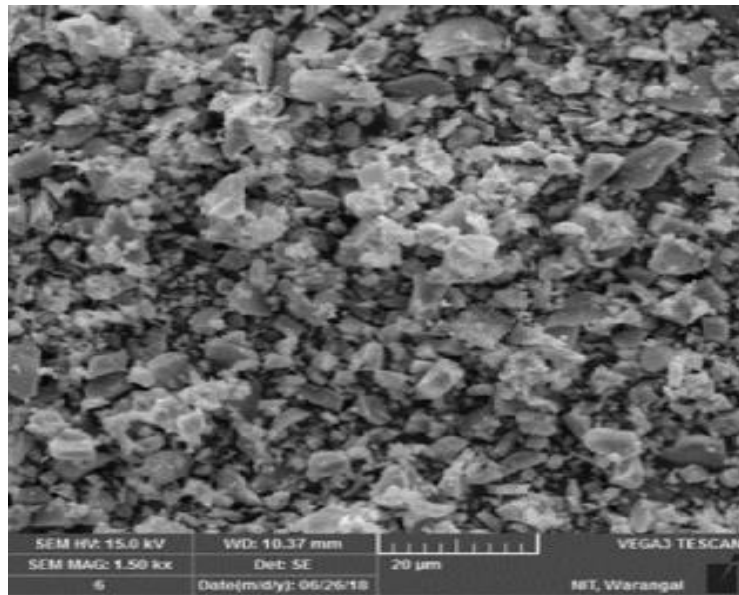


Figure 1: SEM image of Alccofine 1203 (Bhanavath Sagar, 2021)

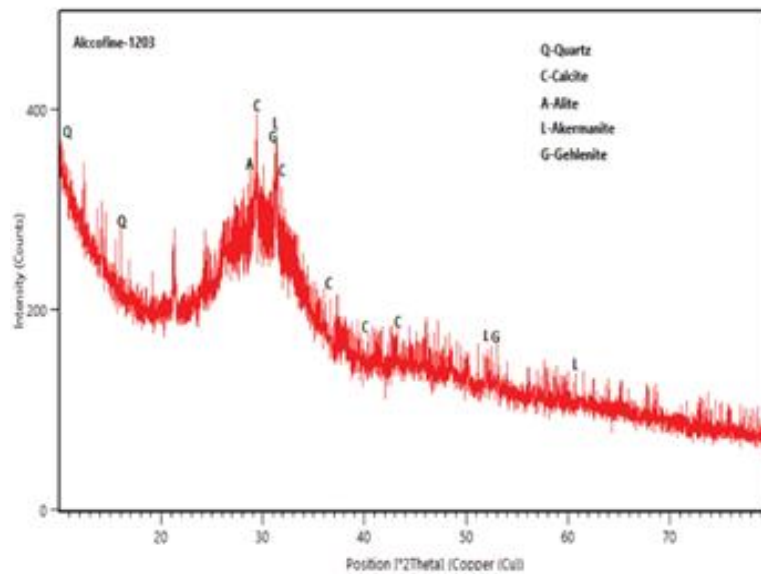


Figure 2: XRD Analysis of Alccofine 1203 (Bhanavath Sagar, 2021)

III. EXPERIMENTAL INVESTIGATION

The experimental investigations carried out with the addition of Alccofine 1203 in the various types of concrete were studied. The physical and chemical properties of the materials used in the concrete are studied and then required materials are selected for the mixing of the concrete. The experimental investigation includes the fresh, hardened and durability properties. The testing of various types of concrete in addition of alccofine is shown in table 3.

Table 3: Testing of Alccofine in the Various Grades and Application of Concrete

Literatures	% of Alccofine	Grade of Concrete	Testing properties description	Optimum proportion of Alccofine
Srinivasan, 2020	5, 10, 15, 20	M50	Mechanical and durability properties	10%
Mahim Mathur, 2018	0, 5, 10, 15, 20	M20	Fresh and hardened properties	10%
Suganya, 2019	5, 10, 15, 20, 25	M20	Mechanical properties	15%
Kaviya, 2017	5, 10, 15	M30	Mechanical Properties	10%
Surendra Kumar, 2018	0, 3, 6, 9, 12, 15	M60	Mechanical Properties	12%
Mahim Mathur, 2018	0, 5, 10, 15, 20	M20	Mechanical Properties	10%
Balamuralikrishnan, 2021	0, 5, 10, 15, 20	Mortar	Strength Properties	10%
Panga Narasimha Reddy, 2020	0, 4, 8, 12, 16	Various Mixes	Durability Properties	8%
Bode Venkata Kavyateja, 2020	0, 5, 10, 15	SCC	Strength Properties	10%
Rajesh Kumar, 2015	0, 5, 10, 15, 20	M60	Mechanical Properties	10%
Kulkarni, 2011	0, 30%	Design mix	Strength and Durability	30%
Pavittar Singh, 2017	0, 3, 6, 9, 12	M80	Strength Properties	12%
Devinder Sharma, 2016	15%	M100	Durability Properties	15%
Mohd. Hamraj, 2014	0, 5, 10, 15, 20	M50	Strength and Durability	15%
Karthick, 2020	0, 5, 10, 15	M60	Strength Properties	10%
Sinha Deepa, 2016	0, 4, 6, 8, 10	M50	Strength Properties	8%
Ardra Mohan, 2017	0, 5, 10, 15	SCC	Mechanical Properties	10%

IV. RESULTS AND DISCUSSION

The development of self compacting concrete was mixed with alccofine in the ranges of 0 – 15% by the increment of 5% resulted in 10% partial replacement of alccofine based SCC concrete achieved high strength properties (Ardra Mohan, 2017), (Bode Venkata Kavyateja, 2020). A comprehensive review of the alccofine based concrete in the recent studies concluded that 8 – 12 % of the partial replacement of alccofine showed higher strength properties (Boobalan, 2021).

The workability properties of the high strength and high performance concretes with addition of alccofine in the ranges of 0 – 15% by the increment of 5% resulted in higher compressive strength, splitting tensile and flexural strength values (Mohd. Hamraj, 2014). In the past two decades, various researchers were going on for utilizing the alccofine in the

effective manner for achieving the higher strength properties due to the calcium silicate content. The durability properties such as water permeability, rapid chloride permeability tester, carbonation, acid resistance values of the concrete was enhanced due to the adding together of alccofine in some percentage to the concrete mix proportions (Devinder Sharma, 2016).

The strength properties of 10% alccofine based high grade concrete resulted in compressive strength of 64.45 MPa (7 days) and 74.48 MPa (28 days). The alccofine proportion increased in the concrete which would be acting as filler materials for the other ingredients and yielding the better workability of the concrete (Rajesh Kumar, 2015). M80 grade of concrete was developed with 3 – 12% of alccofine in the increment of 3%. The strength property values concluded that 12% of alccofine proportion in concrete yield better compressive, splitting and flexural strength (Pavittar Singh, 2017). The experimental investigation of high performance concrete with 100% ordinary portland cement and another proportion of 70% ordinary Portland cement and 30% micro cement were studied. They conducted the physical properties test such as sorptivity tests and colour analysis test, and non destructive tests such as ultrasonic pulse velocity. From the ultrasonic pulse velocity values, compressive strength, splitting tensile strength values were identified and compared with the control specimens. From the concluded values, performance of the all the mix proportions were similar at elevated temperatures (Kulkarni, 2011).

High performance concrete was developed by adding the quart dust and alccofine of 5 to 15% in the increment of 5%. Properties such as compressive, splitting, flexural strength, bending and breaking strength were determined. The test results showed that 15% of alccofine, 5% of quartz dust and 10% of silica fume high performance concrete would be better than other mix proportions (Karthick, 2020). The comprehensive review on the alccofine based high performance concrete concluded that utilization of alccofine materials as an partial replacement upto 20% by the volume of the cement content and it would be acting as an filler material, yields superior workability (Narender Reddy, 2017).

V. CONCLUSION

The following are the conclusions obtained from the studies of various literatures related to alccofine based concrete are as follows: The optimum proportion of alccofine in the cement based concrete is from the ranges of 8 – 12% based on the applications and their other ingredients of the concrete. The addition of alccofine in the concrete improves the durability parameters by refining the pore structure and reduces the permeability. It also maintains the concrete pH and resisting the reinforcement from corrosion. Alccofine based concrete will be having the enhanced slump without increasing the dosages of the chemical admixtures. Especially alccofine is used as an strength enhancer in the high performance concrete with low water-binder ratio. The field of application is commonly for all the types of structures and particularly for the green complaint structures also.

REFERENCES

- [1] G. Srinivasan, "Study on Alccofine Based High-Performance Concrete", IOP Conference Series: Materials Science and Engineering, Vol 993, (2020), 012040.
- [2] Mahim Mathur and Ashish Mathur., "Performance of Concrete by Partial Replacement of Alccofine – 1203", International Journal of Engineering Research & Technology, Vol 6, No 11, (2018), 1-5.

- [3] R. Suganya and R. Lathamaheswari, "Experimental Investigation on Alccofine Concrete", *International Journal of Engineering Research & Technology*, Vol 8, No 4, (2019), 548-550.
- [4] B. Kaviya, K. Rohith, Soniya Kindo., J. Manoj Kumar, and P. Divya, "Experimental Study on Partial Replacement of Cement using Alccofine", *International Journal of Pure and Applied Mathematics*, Vol 116, No13, (2017), 399-405.
- [5] Varinder Singh and Sanjeev Naval., "Strength Evaluation of High Strength Cement Concrete using Alccofine 1203", *Global Journal for Research Analysis*, Vol 7, No 5, (2018), 4-6.
- [6] Bhanavath Sagar and Sivakumar M V N., "Use of Alccofine 1203 in Concrete: Review on Mechanical and Durability Properties", *International Journal of Sustainable Engineering*, Vol 14, No 6, (2021), 2060-2073.
- [7] Surendra Kumar and Rohit Kumar., "Behaviour of High-Performance Concrete using Alccofine and Flyash", *International Journal for Technological Research in Engineering*, Vol 5, No 10, (2018), 3985-3990.
- [8] Tejashree Chaudhari, Surekha Patil, Mayuri Dighe, Pranita Shind, and Sumit Jogdand., "A Review on Experimental Analysis of Concrete with use Alccofine Powder", *International Journal of Advances in Engineering Research*, Vol 22, No 1, (2021), 39-44.
- [9] Mahim Mathur and Ashish Mathur., "Performance of Concrete by Partial Replacement of Alccofine 1203", *International Journal of Engineering Research & Technology*, Vol 6, No 11, (2018), 1-5.
- [10] Balamuralikrishnan R., and Saravanan J., "Effect of Addition of Alccofine on the Compressive Strength of Cement Mortar Cubes", *Emerging Science Journal*, Vol 5, No 2, (2021), 155-170.
- [11] Panga Narasimha Reddy and Bode Venkata Kavyateja., "Durability Performance of High Strength Concrete incorporating Supplementary Cementitious Materials", *Materials Today: Proceedings*, Vol 33, No 1, (2020), 66-72.
- [12] Bode Venkata Kavyateja, Guru Jawahar J., and Sashidhar C., "Effectiveness of Alccofine and Fly ash on Mechanical Properties of Ternary Blended Self Compacting Concrete", *Materials Today: Proceedings*, Vol 33, No 3, (2020), 73-79.
- [13] Parveen, Dhirendra Singhal, Talha Junaid M., Bharat Bhushan Jindal, Ankur Mehta., "Mechanical and Micro structural properties of fly ash based Geopolymer concrete incorporating Alccofine at ambient curing", *Construction and Building Materials*, Vol 180, (2018), 298-307.
- [14] Ardra Mohan and Mini K M., "Strength Studies of SCC Incorporating Silica Fume and Ultra Fine GGBS", *Materials Today: Proceedings*, Vol 5, (2018), 23752-23758.
- [15] Boobalan S C., Aswin Srivatsav V., Mohamed Thanseer Nisath A., Pratheesh Babu A., and Gayathri V., "A Comprehensive Review on Strength Properties for making Alccofine based High Performance Concrete", *Materials Today: Proceedings*, Vol 45, (2021), 4810-4812.
- [16] A. Sinha Deepa, and K. Sabuwala Hasan, "Study of Mechanical and Durability Properties of High-Performance Self Compacting Concrete with Varying Proportion of Alccofine and Fly ash", *International Journal of New Innovations in Engineering and Technology*, Vol 5, No 1, (2016), 72-81.
- [17] A. Narender Reddy and T. Meena, "A Comprehensive Overview on Performance of Alccofine Concrete", *International Journal of Pharmacy & Technology*, Vol 9, No 1, (2017), 5500-5506.
- [18] M. S. Karthick, P. Chandrasekaran, K. Nirmalkumar and M. Raghunanathan, "Effects of Mineral Admixtures in Mechanical Behaviour of High-Performance Concrete", *International Journal of Advanced Science and Technology*, Vol 29, No 3, (2020), 8031-8038.
- [19] Mohd. Hamraj., "Experimental Study on Binary Blended High Strength Steel Fibre Reinforced Concrete using Alccofine as Mineral Admixture", *International Journal of Science, Engineering and Technology*, Vol 2, No 8, (2014), 56-62.
- [20] Devinder Sharma, Sanjay Sharma, and Ajay Goyal., "Utilization of Waste Foundry Slag and Alccofine for developing High Strength Concrete", *International Journal of Electrochemical Science*, Vol 1, (2016), 3190-3205.
- [21] Pavittar Singh., "Study the effect of Alccofine on Development of High Strength Concrete", *International Journal of Advance Research in Science and Engineering*, Vol 6, No 11, (2017), 1985-1992.
- [22] K. S. Kulkarni, S. C. Yaragal and K. S. Babu Narayan, "Effect of Elevated Temperatures on Mechanical Properties of Microcement based High-Performance Concrete", *International Journal of Applied Engineering and Technology*, Vol 1, No 1, (2011), 24-31.
- [23] S. Rajesh Kumar, Amiya K Samantha, Dilip K Singha Roy., "An Experimental Study on the Mechanical Properties of Alccofine based High Grade Concrete", *International Journal of Multidisciplinary Research and Development*, Vol 2, No 10, (2015), 218-224.

PART 6

Futuristic Trends in Construction Materials & Civil Engineering

Series Id: IIPV3EBS05_G28

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ANALYSIS AND DESIGN OF SINGLE VENT BOX CURVET FOR DIFFERENT LOADING CONDITION BY USING STAAD PRO SOFTWARE

Abstract

Box culverts are the optimum monolithic construction to balance the flood water on both sides of a highway or railway embankment. This paper presents a comprehensive examination of box culverts using the manual approach. Live load surcharge, dead load, soil pressure on the side walls, longitudinal force/braking force, impact load utilizing computational techniques like the Staad pro analysis method, the Limit state approach of IRC class AA loading and box culvert design should take into account both internal and external water pressure. The structure under consideration in this research experiences stresses such as bending moments and shear forces. These stresses were calculated using computational methods and were compared.

Keywords: Bending Moment (BM), Shear forces (SF), Area of reinforcement (AST)

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I. INTRODUCTION

The need for a bridge is felt by people and it is communicated to Government through Public representatives or the importance of bridge is felt by Govt. due to the increased traffic demand that may be due to various reasons viz. important road, tourist place, pilgrimage center, industries, etc. The government thus decides to construct a bridge at a particular location. Road Project Division is required to carry out a survey for the bridge location and collect the requisite preliminary survey data that is required for bridge planning and design. When compared to slab or arch culverts, box culvert offers many benefits. The structure of the box is sturdy, stable, safe, and simple to assemble. The key benefit is that, unlike other types of culverts, it may be positioned at any elevation within the embankment with adjustable cushion. A multi-cell box may accommodate a big discharge and fit within an embankment with a reduced height. It can be erected on soft soil without the need for a separate elaborate foundation by projecting an appropriate base slab that will lower base pressure within the foundation soil's safe bearing capacity. No bearings are required. In the event that the roadway needs to be widened in the future, it is easy to expand the current culvert without encountering any design or construction issues. The culvert can be either a box or slab and can span up to 6 metres of waterways (IRC: 5-2016). The box is one whose top and bottom slabs are joined to the vertical walls in a single piece. Although the top slab in a slab culvert is supported over the vertical walls (abutments/piers), there is no monolithic link between them. The placement of a box culvert [1, 3&6] can be such that it has more than one cell and that the top slab is virtually level with the road.

II. ANALYSIS AND DESIGN OF BOX CULVERT

Design of a box culvert must take into account a variety of loads, including Dead load, Live load, Impact load, Longitudinal force/braking force, Soil pressure on the side walls, Surcharge due to Living load, and Water pressure from both inside and outside. Design must be completed using the Limit State Method of IRC Class AA Loading [13&14] and analysis by STAAD Pro Software, with the results of both being finalized. The Indian Road Congress Standards are used as a basis for computing design parameters. In this essay, we also examine the box culvert design and compare various reinforcement features. The culvert's vent size is fixed in accordance with the flood discharge from an upstream side. The box culvert's open size is 3m by 3m. The slab is 300 millimetres thick. M35 is the concrete grade, Fe415 is the steel grade, and 300 is the angle of repose.

Different Analysis Conditions for Box Culvert: A single box culvert is designed by thinking of it as a sturdy frame. The moment distribution method is typically used to calculate final moments at the frame's joints. Critical loading conditions are examined in the culvert. The following three loading conditions are regarded as critical:

Case 1: There is no water pressure from the inside (no flow in the drain), live load, dead load, and earth pressure are all present.

Case 2: Internal water pressure operating against external live load, dead load, ground pressure, and other forces.

Case 3: There is no lateral pressure because of the live load, but there are dead and live loads acting on the top slab, and there is internal water pressure.

III. ANALYSIS AND DESIGN OF BOX CULVERT

- 1. Manual Design Considerations:** The loads considered for the analysis of box culverts are Dead load, Live load, Soil pressure on side walls, Surcharge due to living load, and Water pressure from inside, Design BM and SF for top, Bottom slab, and Sidewalls. In a study, we have to consider IRC class AA loading and Use the limit state method of design is conforming to IRC 112-2011.

- 2. Software Design:** The greatest bending and thus the Box Culvert's overall economics depend on the longitudinal girders' optimal spacing. With the advent of computers, many of these issues have been readily resolved by adopting pertinent software. Manual analysis of various Box Culverts with various longitudinal girder spacing is a time-consuming operation that also encourages human mistake. The same data was used to redesign the Box Culvert in STAADPro, and the outcomes are compared. The box culvert modelling process is as follows:

 - Step 1:** Idealizing slabs into comparable grilling
 - Step 2:** Adding Properties
 - Step 3:** Assigning Subgrade modulus for elastic Mat
 - Step 4:** Assigning Loads on Grillage beams
 - Step 5:** Results of Bending Moment and Shear forces

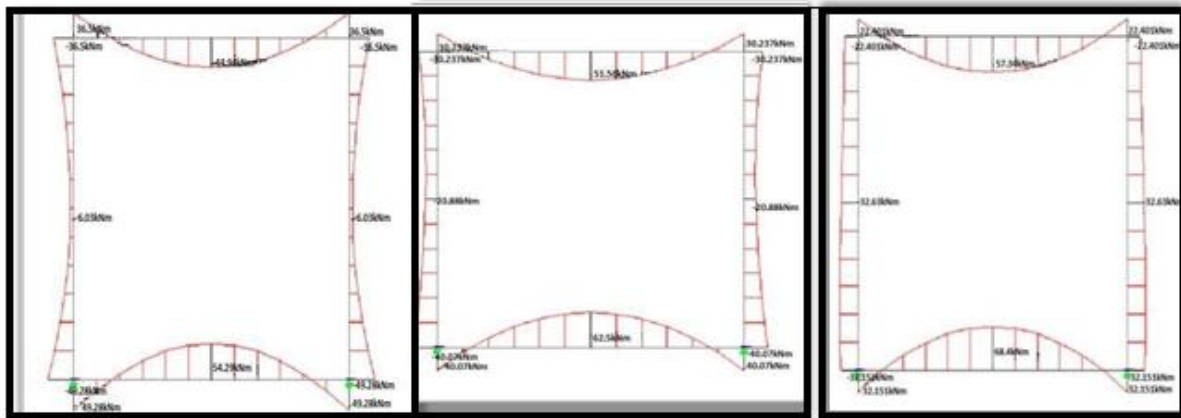
- 3. Comparison between Manual and Software Method:** Now that both techniques are used regularly in civil engineering work, we choose which to use depending on factors like cost, strength, and time to finish the assignment. These are the main criteria we use to decide which method to use when designing or analyzing a beam. Therefore, a basic understanding of manual computation is needed, and software must be chosen for design and analysis reasons. In the present era, software is the most useful instrument for creating and analysing. In terms of economy, the structure is more economical if we choose the software for analysis and designate amount of interest provided by the software is much more compared to the manual. The time it takes to design many beams and many columns or other structure component can be done within minutes while it takes huge time for a manual to design the whole structure.

IV. RESULTS AND DISCUSSION

Researchers in this field have used a number of approaches to study and design RCC box culverts. When comparing this condensed method to the earlier ways, the bending moment and shear force diagrams' values and shapes are the same. Trial and error are used to install the spring spacing until a sensible gap is discovered. The output values are more accurate when the spacing is closer, especially for inverted members. Due to the symmetry of the sectional features and pressures placed on the culvert barrel, the diagrams for joint displacement, support responses, bending moment, and shear force [2, 4&5] are symmetrical. Tables I, II, and III, which compare the results of the following case studies utilizing the manual methodology and software method, respectively.

Table 1: Compression of Bending Moment

Load Case	Bending Moment (kN-m)					
	Top Slab		Bottom Slab		Side Wall	
	Manual	Staad Pro	Manual	Staad Pro	Manual	Staad Pro
1	43.93	44.94	53.25	54.29	5.726	-6.03
2	50.54	51.56	61.32	62.5	20.40	-20.88
3	56.31	57.34	67.1	68.4	31.96	32.63

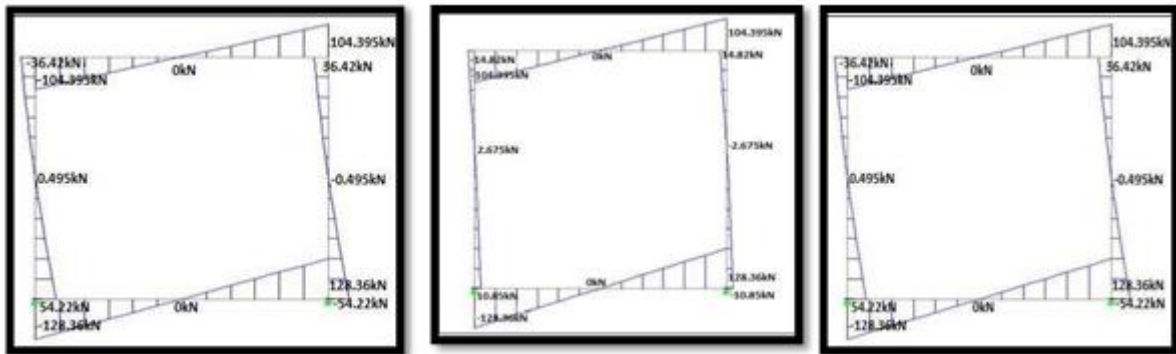


Graph 1: Different Bending Moment Case 1, 2&3

Discussion: The above graph shows the bending moment for different Cases compared with manual and Staad pro results of top slab, bottom slab, and side wall the maximum bending moment will be acting in Case 3. The study shows that the maximum positive moment develops at the center of the top and bottom slab for the condition that the sides of the culvert not carrying the live load and the culvert is running full of water which is case 1 condition. The maximum negative moments develop at the support sections of the bottom slab for the condition that the culvert is empty and the top slab carries the dead load and live load [2, 4&5].

Table 2: Compression of Shear Force

Load Case	Shear Force (kN)			
	Top Slab		Bottom Slab	
	Manual	Staad Pro	Manual	Staad Pro
01	36.24	36.42	53.86	54.22
2	14.71	14.82	10.71	-10.75
3	21.17	-21.34	31.73	32.02

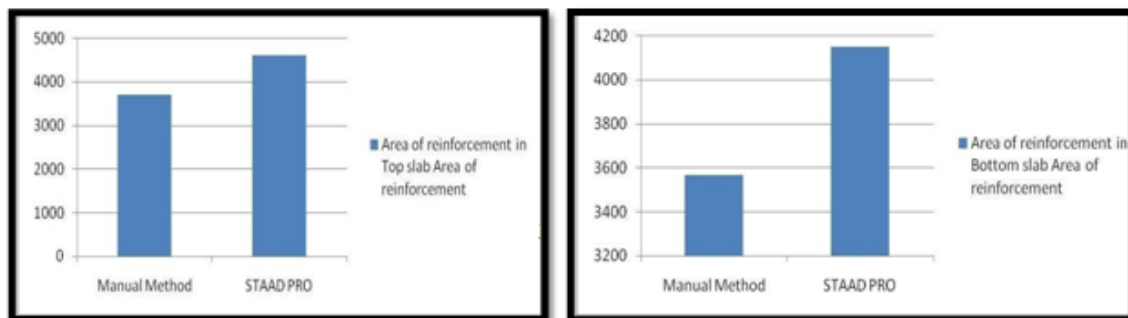


Graph 2: Different Shear Force Diagrams for Case1, 2&3

Discussion: The above graphs and table shows that the Shear force for different Case compared with manual and Staad pro results of top slab and bottom slab the maximum bending moment will be activated at Case. The maximum shear forces develop at the corners of the top and bottom slab when the culvert is running full and the top slab carries the dead and live load [2, 4&5].

Table 3: Compression Area of Reinforcement

Method of Analysis	Area of Reinforcement	
	Top Slab	Bottom Slab
Manual	3703.00	3565.00
Staad Pro	4608.00	4148.00



Graph 3: Reinforcement Details for Top and Bottom Slab

Discussion: From, Table 3, it has been seen that area of reinforcement for the top slab of the Ast is maximum for staad pro. Compare to the manual method and bottom slab the area is also increased in the software method compare to the conventional method, [2, 4&5].

V. CONCLUSION

Finding manual and automated methods for box culvert analysis and design was the study's main goal. The box culvert design is covered by three load cases. For the three load conditions, the design moments, shear forces, and other values are slightly higher (or almost

the same) than the values obtained by hand calculations. The analysis shows that the largest positive moment moments develop at the centre of the top and bottom slab when the culvert is operating at maximum capacity and when uniform lateral pressure brought on by a superimposed dead load operates alone. In contrast, the largest negative moment moments grow at the centre of the vertical wall. Because they require thinner sections and have lower maximum bending moment and shear force values than single-celled box culverts, the study shows that multi-celled box culverts are more cost-effective for longer spans.

VI. ACKNOWLEDGMENT

The authors thank AIT, Chikkamagaluru, AJIET Manglore and ATME, Mysuru for providing the support and facilities in completing the work.

REFERENCES

- [1] P Leela Krishna, Dr. K Rajaskhar, "Analysis and Design of Box Culvert" volume-ISSN: 2349-784X, pp 114-156, April 2018
- [2] Vasu ShekharTanwar, M.P Verma, SagarJamle (2018)," Analytic study of box culvert to reduce bending moments and displacements values" International journal of current engineering technology,
- [3] Afzal Hamif Sharif (2016), "Review paper on analysis and design of railway box bridge" International journal of scientific development & research, ISSN no.2455- 2631, Vol.01, Issue-07, p.p. 204-207 ISSN no.(o) 2277-4106, ISSN no.(p) 2347-5161, Vol.08, Issue-03, p.p. 762-764.
- [4] Kalyan shetti and S.A. Gosavi (2014), "The analysis is done by using stiffness matrix method and a computer program in C language is developed for the cost evaluation". The study is carried out related to variation in bending moment.
- [5] Lande Abhijeet Chandrakant, Patil Vidya Malgonda (2014)," Analysed the box culvert by finite element method". In the paper, they presented the structural elements required to be designed to withstand maximum bending moment and shear force.
- [6] Neha Kolate, Molly Mathew, Snehal Mali, "Analysis and Design of RCC Box Culvert" Volume- 05, ISSN 2229-5518, pp. 36-41, December 2014
- [7] M. G. Kalyan shetti, S. A. Goshavi (2014)," have analyzed the box structure for various conditions by changing the number of cells, for IRC class AA tracked load".
- [8] Sujata Shreedhar, R. Shreedhar (2013)," Design coefficients for single and two cell box culvert" International journal of civil & structural engineering, ISSN no.0976-4399, Vol.03, Issue-03, p.p. 475-494
- [9] H. Chanson (2000). "Analyse the hydraulic design of culvert. The paper presents a new way to teach hydraulic design to civil and environmental engineering students in an undergraduate curriculum".
- [10] Ahmed M et al (1993)."Analyze to study the behavior of a double cell box culvert". The main parameter taken is the soil pressure, moment, and deflection. 2011. ACI Committee 318. Building Code Requirements for Reinforced Concrete (ACI 318-11) American Concrete Institute. Detroit. The USA.
- [11] Bowles, J. E, P.E., S.E. 1996. Foundation Analysis and Design. Fifth Edition. McGraw-Hill, USA. pp. 503-506.
- [12] Coduto, D.P. 2001. Foundation Design Principles and Practices, second edition, Prentice-Hall, New Jersey. The USA. pp. 358
- [13] IRC: 6-2016, "Standard Specifications and Code of Practice for Road Bridges" Section II
- [14] IRC 112,-2011, "Standard Specifications and Code of Limit State Method of Practice for Road Bridges",
- [15] IS 875 part 1 & 2 " Code of Practices for design dead and Live load

A CASE STUDY ON MAN-MADE HAZARDS IN THE INDIAN CONTEXT: ENVIRONMENTAL IMPACT AND THEIR MITIGATION MEASURES

Abstract

This paper examines the environmental consequences of man-made hazards in India and proposes strategies to mitigate their effects and prevent future disasters. While the country is no stranger to natural calamities, man-made incidents such as nuclear power plant accidents, industrial pollution, and environmental degradation due to deforestation have become increasingly prevalent. As per the WHO (World Health Organization) annual report of 2020, over seven million people die annually from air pollution caused by hazardous chemicals, while another one million perish due to waterborne diseases, primarily in developing countries with high population density. Global warming fueled by excessive fossil fuel consumption and deforestation, contributes to climate change and weather-related disasters such as droughts and floods. To address this issue the paper advocates for a reduction in fossil fuel dependency and transmission to renewable energy sources such as solar and wind power. The paper also highlights how we can mitigate the effect of such hazards and what measures must be taken to avoid this kind of disaster. The paper highlights the benefit of large-scale afforestation efforts, particularly in tropical rain forests, to increase Earth's green cover and counteract the rise in atmospheric carbon dioxide concentrations. By implementing these mitigation measures, India can move towards a more sustainable and environmentally resilient future.

Keywords: Deforestation, Climate Change, Global Warming, Nuclear Hazards, Sustainable Development.

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I. INTRODUCTION

Human-induced perils to the environment encompass the unfavorable repercussions or perils presented to the Earth's natural milieu as a consequence of human endeavors. These threats arise directly or indirectly from human conduct, methodologies, or technological operations and possess deleterious repercussions on a multitude of facets of the ecosystem, encompassing ecosystems, air quality, water bodies, soil, and the array of life. These human-initiated hazards assume various forms, encompassing contamination, the annihilation of habitats, shifts in climate patterns, the eradication of forests, hazardous chemical discharges, industrial mishaps, and inept waste control practices. Such hazards possess the capacity to disrupt the equilibrium of the ecological system, depreciate our natural endowments, and create hazards to human well-being and the prosperity of other life forms. The activities carried out by humans, inclusive of industrial operations, transportation systems, agricultural practices, urban expansion, and the generation of energy, contribute substantively to these human-induced perils. These pursuits frequently entail the utilization and exploitation of natural assets, the release of contaminants into the ecosystem, modifications to ecosystems, and the emanation of greenhouse gases.

The exploration of human-induced perils to the environment bears paramount importance for several reasons. In the first instance, it bestows upon us a comprehension of the repercussions of human undertakings on the natural domain. Through an in-depth scrutiny of the antecedents and outcomes of these threats, we glean insights into the mechanisms via which human deeds impact ecosystems, the diversity of life, and the global vitality of the environment. Secondly, such investigations engender the formulation of efficacious alleviation and preventative schemes. By pinpointing the origins and channels of human-induced hazards, we are aptly poised to craft targeted interventions designed to curtail their detrimental effects. This encompasses the implementation of regulations, the embracement of sustainable methodologies, and the advocacy of technological advancements designed to ameliorate environmental damage. Thirdly, the study of human-induced perils empowers us to gauge and oversee transformations in the environment over the passage of time. Through the execution of continuous research, we can assess the efficiency of mitigation endeavors, oversee the progress of environmental restoration initiatives, and identify emerging threats or trends [1].

In sum, a profound understanding of human-induced hazards furnishes us with the wherewithal to make sagacious determinations and undertake premeditated actions to safeguard and judiciously oversee the environment. It affords the knowledge bedrock essential for policymakers, scholars, and communities to collaborate harmoniously toward a more sustainable and robust future, wherein human pursuits coexist in consonance with the natural world.

II. TYPES OF MAN-MADE HAZARDS IN INDIA

Within the realm of man-made hazards, a threefold categorization emerges industrial, urbanization-related, and infrastructure development-induced perils. This article delves into these categories, offering a detailed examination and sub categorization for clarity. Industrial hazards encompass a range of challenges, from chemical spills to environmental pollution, necessitating tailored mitigation. Urbanization brings labyrinthine risks like rapid sprawl and

deforestation, demanding nuanced approaches. Infrastructure development, though a symbol of progress, poses its own complexities, including transportation and energy challenges. Understanding these hazards requires a discerning eye, an enriched lexicon, and commitment to crafting fitting mitigation strategies, equipping us to navigate our modern perilous landscape [1].

1. Industrial Hazards

- **Chemical Hazards:** The industrial hazards may present risks to people, the environment, and nearby communities. These dangers may result from unintentional spills and leaks, poor storage practices, and insufficient safety precautions, causing contamination of the air, water, and soil as well as long-term ecological harm. People exposed to dangerous chemicals may develop chronic illnesses, skin rashes, respiratory issues, and organ damage.
- **Thermal Hazards:** Thermal hazards can have various effects on the environment. Heat exposure can increase chronic disease risks such as obesity, high blood pressure, stroke, and asthma. Heat islands contribute to higher daytime temperatures, reduced night-time cooling, and higher air-pollution levels. Thermal pollutants can affect the environment in every phase and environmental media. Any significant deviations away from the 'normal' temperature range can produce a decrement in performance, cause illness and ultimately lead to accidents. Occupational risk factors for heat illness include heavy physical activity, warm or hot environmental conditions, lack of acclimatization, and wearing inappropriate clothing [2], [3].
- **Nuclear Radiation Hazards:** Nuclear Radiation risks can differently affect the climate. Ionizing radiation can influence the molecules in living things, so it represents a well-being risk by harming tissue and DNA in qualities. A few radioactive substances, such as radium and uranium, gather in the bones and can cause malignant growth. Low portions of ionizing radiation can build the gamble of longer-term impacts, for example, malignant growth. No increment of hereditary impacts from radiation openness has been tracked down in people, yet there have been various creatures concentrates on that show hereditary harm from openness to elevated degrees of radiation. The Chernobyl mishap caused a huge radioactive tainting of the climate. The climate can be permanently changed by an atomic implosion, a disastrous event in which the core of an atomic reactor melts and overheats. The arrival of radioactive materials is the primary determinant of the natural outcomes of an atomic implosion. First and foremost, the arrival of radioactive substances into the climate presents huge dangers to the environment and human wellbeing. Radioactive isotopes can sully the air, water, and soil, spreading over huge distances. This pollution can endure for extended periods, causing long-haul natural interruptions. Radioactive materials can be taken up by plants and creatures, prompting bioaccumulation and biomagnification in natural pecking orders, in this manner influencing whole environments [4], [5].

Besides, soil and water defilement is a main pressing issue. Radioactive substances can invade the dirt, making it unsatisfactory for farming and presenting dangers to plants and creatures. Water bodies near the implosion can become defiled,

influencing amphibian life and possibly entering the human pecking order through fish utilization. Groundwater sources may likewise be impacted, presenting dangers to drinking water supplies. Moreover, untamed life can encounter intense and constant impacts from radiation openness. Elevated degrees of radiation can prompt quick demise or serious well-being impacts, while persistent openness can bring about hereditary transformations, decreased conceptive achievement, and populace decline. The drawn-out biological effects on natural life populations and their territories can be significant [6], [7].

2. Hazards due to Urbanization and Land-Use Change

- **Deforestation:** Deforestation exacts a multifaceted toll on our delicate ecological balance, yielding a litany of adverse repercussions that extend far beyond the immediate loss of wooded terrain. These profound ramifications encompass climate perturbation, desertification, the insidious erosion of soil integrity, diminished agricultural yields, the specter of inundation, an ominous escalation in greenhouse gases permeating the atmosphere, and an intricate web of tribulations burdening Indigenous communities. Moreover, deforestation compounds the conundrum of soil erosion, precipitating a cataclysmic fallout marked by the inexorable depletion of arable expanses and the diminution of bounteous harvests. In its voracious path, deforestation wreaks havoc upon invaluable ecosystems, the veritable lifeblood of both wildlife and humanity.

It is disconcerting to note that the lion's share of deforestation traces its origins to the relentless expansion of industries such as meat, soy, and palm oil production, whose relentless pursuit of profit leaves a wake of environmental devastation in its trail. The brazen act of forest annihilation precipitates a chain reaction, unsettling the intricate balance of weather patterns, obliterating irreplaceable habitats, and casting a long shadow of adversity over rural communities, culminating in the dire spectre of food insecurity and the indelible scars etched upon our fragile planet [8].

- **Soil Erosion:** Soil erosion affects the climate. It decreases the amount and nature of soil environments and arable land, which can adversely influence crop yields. Losing dirt to disintegration adds to a deficiency of innate soil richness levels of nitrogen, P, K, and consequently to a decrease in potential harvest yield. Soil disintegration additionally eliminates significant dirt which is the most useful piece of the dirt profile for farming purposes. The impacts of soil disintegration go past the deficiency of fruitful land. It has prompted expanded contamination and sedimentation in streams and streams, stopping up these streams and causing decreases in fish and different species. Furthermore, debased lands are additionally frequently less ready to clutch water, which can deteriorate flooding [9].
- **Loss of Biodiversity:** The erosion of biodiversity wields a profound sway over our climate, casting a shroud of repercussions. It enervates the efficacy of biological systems, constraining nature's innate adaptability to environmental vicissitudes. A decline in soil heterogeneity renders it less malleable, diminishing its capacity to support both untamed and cultivated flora, thus throwing a somber hue over agricultural ecosystems. The waning of biodiversity exacts a toll on the functionality

of ecosystems, corroding the climatic integrity in an unsettling cascade. When the utility of ecosystem services no longer suffices to meet societal exigencies, the consequences of biodiversity depletion manifest with striking immediacy on human well-being. The attenuation of biodiversity, it appears, rival's environmental metamorphoses, contamination, and other pivotal ecological stressors in its impact on ecosystems. The diminution of biodiversity exerts a profound sway over our climate, casting a pall of repercussions. It enfeebles the efficacy of biological systems, curtailing nature's intrinsic resilience to accommodate environmental shifts. A curtailment in soil heterogeneity renders it less adaptable, diminishing its potential to sustain both indigenous and cultivated flora, thereby enveloping agricultural ecosystems in a shroud. The subsiding of biodiversity exacts a toll on ecosystem functionality, eroding the climatic integrity in a disconcerting cascade. When the utility of ecosystem services no longer suffices to meet societal requisites, the aftermath of biodiversity loss becomes conspicuously evident in human well-being. The depletion of biodiversity, it would seem, stands as a rival to environmental transformations, pollution, and other pivotal ecological stressors in terms of its impact on ecosystems [10].

3. Hazards due to Infrastructure Development

- **Dams:** Dams can have significant negative impacts on the environment. The flooding caused by dams can kill or displace many different organisms, including plants, wildlife, and humans. As reservoirs fill, upstream forests are flooded, eliminating their function as carbon sinks. The drowned vegetation decomposes and releases large amounts of carbon into the atmosphere. Dams also alter the natural sediment load carried by the waters of the previously free-flowing river. Large dams have led to the extinction of many fish and other aquatic species, erosion of coastal deltas, and many other unmitigable impacts. However, there are efforts to make large dams more friendly to the environment [11], [12].
- **Roads and Highways:** Roads and thoroughfares wield a myriad of profound environmental impacts. The construction of road networks can incite habitat depletion and the unwelcome specter of deforestation, thereby unsettling delicate ecosystems and exacerbating the erosive decline of biodiversity. The emissions stemming from vehicular traffic coursing through these transportation arteries play a pivotal role in exacerbating air pollution, releasing noxious contaminants and greenhouse gases that exact pernicious consequences on both the natural milieu and the well-being of the human populace. Furthermore, highways and congested roadways give rise to the discordant menace of acoustic pollution, greatly discomfiting neighboring denizens and unsettling the indigenous wildlife. As these noxious substances, originating from vehicular emissions and road surfaces alike, permeate aquatic bodies, the resultant outflow from the road systems takes on the ominous guise of water pollution. Moreover, the construction and maintenance of roads frequently necessitate the relentless extraction of invaluable natural resources, hastening their depletion in the process. This, in turn, can foment unchecked urban expansion and profound transformations in land utilization, thereby converting erstwhile pristine rural or natural areas into densely populated urban sprawls [13]–[15].

- **Urbanization:** Urbanization, the intricate process of burgeoning population centers and the sprawling expansion of metropolises, exerts profound and far-reaching effects on the natural world. As urban agglomerations burgeon and swell, a panoply of environmental quandaries unfurls. Foremost among these is the inexorable encroachment upon land and the ensuing loss of critical habitats. The inexorable march of cities inexorably transmutes verdant landscapes and arable fields into burgeoning concrete jungles, perpetrating the irrevocable fragmentation and despoilment of once-pristine ecosystems. The resultant cascade of repercussions encompasses the dislodgment of indigenous wildlife species, the lamentable forfeiture of biodiversity, and the perturbing disarray of ecological equilibrium [16].

Another pivotal facet of this urban sprawl is the concomitant escalation in energy requisites and the concomitant escalation in greenhouse gas emissions that this entails. Urbanization serves as the harbinger of heightened energy exigencies, both in terms of infrastructural demands and the concomitant transportation necessities, culminating in the elevation of carbon emissions occasioned by the combustion of fossil fuels [17]. This inexorable march towards urbanization becomes an unwitting accomplice in the grand theater of climate change, casting a long shadow over the landscape and exacerbating the specter of air pollution, which insidiously infiltrates the health and well-being of both humanity and the environment. Furthermore, urbanization is an inadvertent progenitor of atmospheric and aquatic contamination. The labyrinthine activities of industry, the noxious emissions wrought by vehicular transit, and the ceaseless clamor of construction within urban epicenters collectively conspire to engender elevated echelons of atmospheric pollution. Additionally, the extensive veneer of impervious surfaces that drapes urban locales augments surface runoff, facilitating the pernicious transport of pollutants into aquatic reservoirs and engendering a lamentable proliferation of water pollution. This degradation of aqueous ecosystems casts a long shadow over the environmental toll exacted by the relentless march of urbanization [18]–[20].

III. IMPACT OF MAN-MADE HAZARDS ON THE ENVIRONMENT

1. Pollution

- **Air Pollution:** Human-induced perils, particularly the scourge of atmospheric contamination, wield a profound and pernicious influence upon our ecological realm. Atmospheric pollution, primarily instigated by anthropogenic activities such as industrial discharges and the combustion of fossil fuels, engenders far-reaching ramifications: Firstly, this noxious miasma substantially catalyzes climatic vicissitudes. The emission of greenhouse gases, exemplified by carbon dioxide and methane, ensnares thermal energy within the Earth's gaseous envelope, precipitating elevated temperatures and capricious alterations in meteorological patterns. This turbulence disrupts the equilibrium of ecosystems, imperils agrarian pursuits, and perpetuates the attrition of biodiversity. Moreover, the noxious emissions pose an immediate menace to the rich tapestry of life forms and ecological systems. Contaminants have the capacity to despoil vegetal vitality, attenuate agricultural harvests, and befoul the sanctity of terrestrial and aqueous reservoirs. This discordant

intrusion fractures the delicate equipoise of habitats, culminating in the obliteration of sanctuaries and a precipitous decrement in faunal populations [21].

The repercussions of atmospheric contamination are by no means confined to the biological sphere; they invariably intrude upon the human condition. Inhalation of this contaminated aeriform milieu begets a panoply of respiratory maladies, cardiovascular afflictions, and heightened vulnerability to pulmonary infections. The protracted exposure to these insidious pollutants yields chronic health debilitations, inexorably eroding the quality of life for the afflicted populace. Furthermore, atmospheric pollution conspires to precipitate the scourge of acid precipitation, which wreaks havoc upon sylvan landscapes, terrestrial substrates, and aqueous expanses. This acidic deluge casts its ominous pall upon aquatic ecosystems, casting aspersions upon piscine denizens and other aqueous organisms. It also enfeebles flora, resulting in the ebb of biodiversity and the corrosion of natural sanctuaries [21].

- **Water Pollution:** Human-induced perils, particularly the contamination of our waterways, levy a formidable toll upon the delicate equilibrium of our natural world. The scourge of water pollution materializes as a consequence of an array of human pursuits, encompassing the release of industrial effluents, the runoff from agricultural domains, the improper and haphazard disposal of waste materials, and catastrophic chemical spillages. The repercussions arising from water pollution upon our environment are unequivocally profound. Primarily, it is imperative to underscore that water pollution serves as a harbinger of catastrophe for our aquatic ecosystems. The infusion of noxious contaminants into our aqueous realms precipitates a cataclysmic disruption in the delicate equilibrium that sustains aquatic life. The result is a grim tableau of deceased fish and various organisms. This egregious contamination likewise exacts a grievous toll on the fecundity and expansion of aquatic flora, leading to a lamentable erosion of biodiversity and the wholesale transformation of entire ecosystems. Moreover, it is incumbent upon us to acknowledge that the ramifications of water pollution extend beyond the confines of aquatic enclaves. When tainted waters infiltrate our irrigation systems or are consumed by humans and livestock alike, the ominous specter of contagion looms large. Waterborne afflictions, such as cholera, dysentery, and hepatitis, emerge as dire threats to public well-being, capable of unleashing pandemics of alarming proportions [22], [23].
- **Soil Pollution:** Soil contamination, stemming from a myriad of anthropogenic activities, wields profound and far-reaching repercussions upon the natural realm. It transpires when pernicious agents, such as industrial compounds, agrochemicals, heavy metals, and refuse materials, taint the terrestrial substrate. The consequences of soil pollution upon the ecosystem materialize in the ensuing manners: Primarily, soil contamination begets turmoil within the pivotal sphere of soil vitality and fecundity, casting an adverse pall over plant proliferation and agricultural efficiency [24], [25]. Contaminants elicit modifications in the chemical, physical, and biological attributes of the soil, thereby imperiling the accessibility of vital nutrients and diminishing the soil's capacity to sustain vegetative life. Furthermore, soil contamination can incite the contamination of subterranean aquifers, which serve as an indispensable reservoir of potable water for both human denizens and ecosystems. Pollutants infiltrate from the soil into these subterranean water sources, imperiling their quality and posing threats

to human well-being and the welfare of aquatic organisms. The disruption of soil ecosystems constitutes yet another pivotal ramification of soil pollution. Microbial organisms inhabiting the soil, including bacteria, fungi, earthworms, and arthropods, assume pivotal roles in nutrient cycles, decomposition processes, and the preservation of soil structure. Soil pollution can inflict harm upon these organisms, thereby perturbing the delicate equilibrium within the soil ecosystem and influencing overall biodiversity [9], [26].

- 2. Climate Change:** Human-induced perils, especially the environmental shifts resulting from human activities, unleash deleterious consequences upon the natural world. The ramifications of these modifications instigated by human agency span a multitude of facets: Initial spikes in temperatures, driven by heightened emissions of greenhouse gases, set in motion a cascade of ecological disruptions. The dissolution of polar ice caps and glaciers contributes to the upsurge in sea levels, portending dire threats to coastal regions and low-lying terrains. Simultaneously, the oscillating temperature patterns disrupt ecosystems, provoking alterations in the distribution and behavior of flora and fauna [27], [28]. Furthermore, the altered precipitation patterns exacerbate droughts, floods, and tempests. These extraordinary meteorological phenomena inflict cataclysmic consequences upon ecosystems, culminating in the annihilation of habitats, the depletion of biodiversity, and the displacement of species. They also wield a pronounced impact on agriculture, water resources, and human settlements, yielding economic losses and human anguish. Climate change assumes a pivotal role in precipitating the attrition of biodiversity. The upheaval of habitats and living spaces propels species precariously proximate to the precipice of extinction. Ecosystems pivot on biodiversity for stability, as each organism assumes a pivotal role in upholding the vitality and functionality of the ecosystem. The vanishing of species disrupts these intricate interconnections and jeopardizes the overarching resilience of ecosystems [29], [30].
- 3. Loss of Biodiversity:** The erosion of biodiversity owing to human-induced perils stands as a weighty predicament with ramifications extending far and wide. Human undertakings, including the obliteration of habitats, contamination, the relentless exploitation of resources, climate vicissitudes, and the introduction of alien species, have ushered in a swift and alarming descent in biodiversity. These jeopardies unleash tumult within ecosystems, lay waste to abodes, and imperil the very existence of innumerable flora and fauna species. Predominantly steered by deforestation and urbanization, habitat annihilation obliterates pivotal sanctuaries, dissects ecosystems into fragments, and expels species from their customary abodes. Pollution, encompassing the tainting of air, water, and soil, inflicts harm upon biodiversity by envenoming plant life, fauna, and their environments. The inordinate extraction of resources, exemplified by overfishing and the illicit wildlife commerce, leads to the depletion of populations and disrupts the delicate equilibrium of ecological systems. Climate alterations serve to exacerbate the attrition of biodiversity through their transformation of temperature regimes and precipitation patterns, inciting the migration of habitats and heightening the susceptibilities of various species. The intrusion of alien species, introduced via human agency, outcompete indigenous counterparts and sow discord within the dynamics of ecosystems.

The diminution of biodiversity bears dire consequences for the functioning of ecosystems, epitomized by a diminution in resilience, a depletion of ecosystem services, and a skewed alimentary network. Furthermore, it casts a looming shadow over human well-being, as the paucity of biodiversity imperils the security of sustenance, the founts of medicinal resources, and the inheritance of cultural traditions. The redressal of biodiversity depletion necessitates harmonized exertions aimed at shielding habitats, alleviating the scourge of pollution, championing sustainable practices, combating the throes of climate change, and curbing the proliferation of alien species. Preservation initiatives, legislative interventions, and the cultivation of public cognizance assume pivotal roles in upholding the sanctity of biodiversity and safeguarding the well-being of ecosystems and humanity at large [31], [32].

IV. IMPACT OF MAN-MADE HAZARDS ON HEALTH

- 1. Respiratory Problems:** Man-made risks, specifically those connected with air contamination, essentially affect respiratory well-being, prompting different respiratory issues and sicknesses. The burning of fossil fuels, industrial emissions, vehicle exhaust, and other man-made sources of air pollution all release harmful pollutants into the air that can be harmful to the respiratory system. The inward breath of contaminated air can bother the aviation routes and lungs, prompting respiratory issues. Fine particulate matter (PM_{2.5}) and different poisons can infiltrate profoundly into the respiratory lot, causing irritation, oxidative pressure, and harm to lung tissues. Delayed openness to these perilous substances can add to the turn of events or fuel of respiratory circumstances. One of the main respiratory well-being effects of man-made perils is the expanded gamble of respiratory illnesses. Openness to air contamination has been connected to the improvement of constant obstructive aspiratory sickness (COPD), asthma, bronchitis, and respiratory diseases. For people with previous respiratory circumstances, air contamination can set offside effects and deteriorate their respiratory well-being [31].
- 2. Water-Borne Diseases:** Human-induced perils within our natural surroundings play a pivotal role in the genesis and dissemination of waterborne afflictions. These perilous circumstances stem from a myriad of human actions and behaviors, culminating in the adulteration of our water reservoirs and imperiling the sanctity of potable water. A conspicuous malefactor in this realm is the imprudent disposal of refuse, which exerts a profound influence on water purity. When effluents, industrial detritus, or agricultural runoff laden with maleficent pathogens and contaminants infiltrate aqueous bodies, they adulterate this life-sustaining liquid, rendering it perilous for human ingestion.

The quandary is further exacerbated by the inadequacies plaguing our sanitation infrastructure and practices, which provide an untrammelled conduit for untreated sewage and wastewater to directly infiltrate our water sources. This nefarious ingress sets the stage for the dissemination of waterborne maladies, encompassing the likes of cholera, typhoid, and hepatitis A. Inequities within water treatment procedures and the paucity of robust water distribution infrastructure equally conspire to exacerbate the waterborne malaise. When water treatment regimens falter or fall short of efficacy, pathogenic entities may persevere within the water supply, imperiling public well-being [33].

Inadequacies within the infrastructure matrix may usher in a panoply of tribulations, ranging from leakages and cross-contamination to a paucity of access to safe potable water, thereby ratcheting up the susceptibility to waterborne diseases. The phenomenon of urbanization and the burgeoning of human populations serve to further magnify the deleterious ramifications of anthropogenic hazards on waterborne maladies. The whirlwind pace of urbanization oftentimes spawns haphazard settlements bereft of proper access to wholesome water and sanitation amenities. In these overcrowded and underserved locales, the crucible for waterborne maladies festers due to the conspicuous dearth of judicious waste management protocols, sanitation infrastructure, and secure sources of potable water [34].

- 3. Chronic Health Problems:** Human activities, wielding their power to sculpt the environment, wield a dual-edged sword that profoundly shapes the tapestry of chronic health issues. These pernicious menaces, spawned by our own hands, unfurl their malevolence by disseminating noxious agents into the realms of air, water, and soil, casting long shadows of affliction upon those who unwittingly tread their path. Among these, air pollution stands as a formidable antagonist, its insidious presence silently fomenting the genesis of relentless respiratory maladies. The noxious emissions of industrial chimneys, the vehicular exhalations of combustion engines, and the incendiary pyres of fossil fuels all conspire to assail the respiratory citadel. Fine particulate matter, known by its cryptic moniker as PM_{2.5}, nitrogen dioxide, and a coterie of other insalubrious constituents wage a relentless siege upon the pulmonary bulwark, igniting the flames of inflammation and irritation. The prolonged sojourn in this miasma-laden atmosphere paves the treacherous path to the dominion of chronic afflictions, where asthma, chronic obstructive pulmonary disease (COPD), and bronchitis ensnare their hapless victims [35].

Furthermore, in the labyrinth of man-made perils, there loom hazards of industrial descent, sinister chemicals lurking in shadows, and malevolent substances conspiring to unleash the specter of cancer. Carcinogens, those harbingers of doom, exemplified by asbestos, benzene, and certain pesticides, surreptitiously infiltrate the sanctum of the body, amassing their nefarious arsenal over time, with the dread intent of orchestrating an array of malignancies. Lung, bladder, and liver cancer, their sinister banners unfurled, bear testimony to this unholy alliance. The harrowing ordeal of exposure to these man-made machinations extends its malevolence to the realm of the neurological, where chronic disorders lay their claim. The nefarious overture of heavy metal pollution, led by the ominous duo of lead and mercury, coupled with dalliances with industrial elixirs and noxious airs, culminates in a symphony of cognitive impairments, imperils the tender minds of children, and forges unholy alliances with neurodegenerative afflictions like Alzheimer's and Parkinson's disease.

Additionally, within the labyrinthine corridors of man-made perils, there reside dangers of an endocrine nature, lurking in the shadows, poised to disrupt the delicate equilibrium of hormones, thereby unfurling the banner of prolonged infirmity. Pesticides, industrial specters, and the insidious emissaries of plasticization, such as BPA, conspire to breach the hallowed sanctum of the endocrine system. In their wake, they sow seeds of reproductive discord, foment hormonal tumult, and raise the sinister specter of infertility, all while elevating the risk of courting the dread emissaries of cancer [36].

V. MITIGATION STRATEGIES

1. Environmental Impact Assessment (EIA): Policy measures and strategies directed at mitigating adverse environmental impacts wield substantial influence in ensuring the effectiveness of Environmental Impact Assessment (EIA) procedures. Below, a more intricate elucidation is offered for each of the aforementioned strategies:

- **Legislation and Statutes:** Governments are duty-bound to establish robust legislation and statutory frameworks mandating the application of EIA in specified projects. These statutes demarcate the scope of projects necessitating scrutiny, expound upon the protocols for conducting EIA, and prescribe the requisite information and data. Furthermore, they provide benchmarks for environmental safeguarding, mitigation strategies, and mechanisms for enforcement [37].
- **Integration into Decision-Making:** The seamless integration of EIA into the decision-making process concerning project authorization and licensing is paramount. This necessitates the consideration of EIA findings and recommendations in conjunction with economic, societal, and other variables during the decision-formulation stage. Such integration ensures that ecological concerns bear equitable significance, thereby culminating in decisions characterized by sustainability and comprehensiveness.
- **Public Engagement:** The facet of effective public engagement assumes a pivotal role in the realm of transparent and all-encompassing EIA processes. Policies must encompass provisions that guarantee stakeholders, including local communities, non-governmental organizations (NGOs), and indigenous entities, the opportunity to proffer input, voice apprehensions, and actively participate in the decision-making process. Public engagement augments the caliber and legitimacy of the EIA process and permits the assimilation of a spectrum of perspectives and indigenous wisdom.
- **Mitigation and Surveillance:** EIA policies should underscore the amalgamation of mitigation strategies into project blueprints to attenuate adverse environmental ramifications. These strategies may encompass technologies for pollution control, strategies for habitat restoration, plans for waste management, and practices endorsing sustainable resource utilization. In addition, monitoring regimes should be instituted to gauge the efficacy of mitigation endeavors and to ensure adherence to environmental benchmarks throughout project execution and operational phases [38].
- **Capacity Enhancement and Training:** Policies should extend support to capacity enhancement endeavors with the aim of elevating the proficiency and erudition of EIA practitioners, decision-makers, and stakeholders embroiled in the process. Training programs can be tailored to various facets, encompassing EIA methodologies, data compilation and analysis, stakeholder engagement, and surveillance techniques. The augmentation of capacities fortifies the technical expertise and cognizance imperative for the efficacious execution of EIA.

- **Sustained Enhancement and Assessment:** Regular appraisal and enhancement of EIA policies are imperative to adapt to the dynamic ecological challenges and scientific innovations. Feedback from stakeholders, erudition derived from prior projects, and the emergence of best practices should serve as the bedrock for policy refinements. Unceasing enhancement ensures that the EIA process maintains its robustness, relevance, and alignment with the mutable ecological and socio-economic landscapes [39].
 - **International Collaboration:** International collaboration and cooperation can engender the evolution and execution of efficacious EIA policies. Nations can draw insights from each other's experiences, partake in the exchange of best practices, and harmonize EIA benchmarks through international accords and platforms for collaboration. The backing of capacity enhancement initiatives in developing nations facilitates the transference of knowledge and aids in the global propagation of effective EIA practices [40].
2. **Waste Management:** In our ever-evolving world, the critical role played by policy measures and mitigation strategies in fostering sustainability and addressing pressing environmental challenges cannot be overstated. These endeavors possess intricate dimensions that demand a nuanced exploration of multifaceted approaches, transcending the ordinary and pedestrian. As we delve into this complex tapestry of environmental stewardship, we encounter a rich array of initiatives characterized by their intricacy and diversity. From its inception, environmental enlightenment has been intricately interwoven into the very fabric of our educational institutions. It is within the hallowed halls of academia that governments discover an opportune canvas upon which to paint the portrait of sustainable living. Infused with wisdom and colored by ecological consciousness, this integration harmoniously blends with traditional curricula at all educational echelons. The result is an enriched and holistic comprehension of environmental responsibility that takes root within the minds of students, surpassing the confines of conventional pedagogy [39].

However, the labyrinthine journey of environmental awareness extends far beyond the confines of academia. It extends its tendrils into the public domain, where governments orchestrate a symphony of awareness campaigns. These meticulously curated endeavors traverse a diverse array of communication channels, ranging from the timeless allure of television to the ephemeral whispers of social media. Their objective is to disseminate knowledge far and wide, igniting the flames of environmental consciousness within the collective heart of society, compelling it to take action. In this digital age, governments erect virtual bastions dedicated to the dissemination of environmental enlightenment. Websites and mobile applications serve as gateways to a treasure trove of knowledge, offering the masses easy access to educational materials, guidelines, and blueprints for sustainable living. Each digital enclave caters to a distinct audience, ensuring that the spectrum of information remains as diverse as the ecosystem itself. Nevertheless, it is said that knowledge is the cornerstone upon which action is constructed. Therefore, governments invest ardently in capacity-building and training programs, crafting a mosaic of expertise spanning government officials, educators, community leaders, and non-profit organizations. Here, they impart the skills and wisdom necessary to navigate the intricate terrain of sustainable practices and effective

communication. It becomes a symposium of minds, each contributing its unique cadence to the discourse on environmental matters [41].

Collaboration, too, emerges as a melodious component in this symphony of change. Governments, with their vast resources, find willing partners in civil society organizations and non-governmental entities dedicated to the cause. Through these partnerships, a convergence of knowledge, networks, and experience emerges, amplifying the resonance of government-led initiatives. Communities, in the grand tapestry of environmental action, are not mere bystanders but active participants. They engage in dialogues and knowledge-sharing sessions, nurturing a sense of collective responsibility. Environmental projects become the very threads that weave together the bonds of shared stewardship. The allure of financial incentives adds yet another layer of complexity. Governments, with their fiscal prowess, entice individuals, businesses, and organizations to embrace the mantle of environmental education with grants, subsidies, and tax benefits. It evolves into an economic ballet where sustainability becomes a profitable pursuit.

In the realm of ideas, governments foster innovation. Research projects flourish with the support of government funding, academic collaborations span continents, and pioneering tools and technologies emerge. The objective is to create an environment in which environmental education and communication continuously evolve, mirroring the dynamic nature of our planet. Through these intricate and multifaceted policy measures and mitigation strategies, governments do not merely advocate for environmental awareness; they cultivate a culture of it. It is a culture in which individuals and communities embrace the mantle of environmental stewardship, where sustainable behaviors thrive, and where the legacy of a flourishing planet endures. In this grand tapestry of environmental consciousness, we discover the harmonious symphony of humanity and nature, each note resonating with complexity and depth [42], [43].

3. **Awareness and Education:** In the realm of nurturing sustainability and confronting the intricate challenges posed by our environment, policy measures and strategies hold a pivotal sway. Herein, we shall delineate key approaches in this sphere:
 - **Integration of Environmental Pedagogy in Academia:** Governments wield the power to infuse environmental education across the entire spectrum of educational institutions. This encompasses the instillation of erudition concerning environmental quandaries, sustainable methodologies, and the sanctity of conservation. This incorporation of environmental education should permeate myriad academic disciplines, fostering a comprehensive comprehension of environmental stewardship among students.
 - **Targeted Public Cognizance Initiatives:** Governments possess the capability to embark on precision-guided public cognizance campaigns, illuminating the general populace about environmental concerns and the imperativeness of sustainable conduct. Such campaigns should harness an array of communication conduits, spanning from traditional mediums like television and radio to the expansive reach of social media and public congregations, thereby catalyzing action.

- **Dissemination of Information:** Governments can erect dedicated platforms, websites, and mobile applications as citadels for disseminating knowledge and resources germane to environmental consciousness and erudition. These bastions can furnish access to traditional materials, benchmarks, and optimal approaches to sustainable living. Accessibility and customization of information should be the bedrock principles in this endeavor, accommodating diverse target demographics [44].
- **Fortification of Capacities and Training Initiatives:** Governments should channel investments into fortifying capacities and instituting training programs designed to augment the acumen and competencies of various stakeholders. These stakeholders encompass government functionaries, educators, community vanguards, and non-profit entities. Such programs should encompass training in sustainable paradigms, environmental preservation, and the deployment of efficacious communication stratagems for propagating environmental narratives.
- **Synergy with Civil Society and Non-Governmental Entities:** Governments ought to forge symbiotic alliances with civil society entities and non-governmental organizations (NGOs) operating within the realm of environmental consciousness and instruction. Collaborative ventures can be orchestrated to jointly blueprint and execute cognizance campaigns, pedagogical materials, and community outreach forays. NGOs often boast specialized knowledge and expansive networks that can amplify the efficacy of government-driven initiatives [44].
- **Community Involvement:** Governments should proactively induce community involvement in endeavors dedicated to environmental cognizance and pedagogy. This can encompass the orchestration of workshops, colloquiums, and interactive symposia to stimulate discourse and knowledge exchange. Communities can also be integral in environmental undertakings and initiatives, thereby fostering a collective sense of responsibility and custodianship towards the environment [41].
- **Financial Incentives:** Governments hold the leverage to extend financial inducements to individuals, enterprises, and organizations that are actively enmeshed in environmental awareness and pedagogical ventures. This may encompass endowments, grants, and tax concessions, thereby catalyzing investments in environmental educational programs and the cultivation of sustainable practices.
- **Pioneering Research and Innovation:** Governments should actively buttress research and innovation within the purview of environmental awareness and pedagogy. This can span the gamut from underwriting research projects, advocating academic coalitions, to abetting the development of avant-garde tools and technologies that heighten the domain of environmental education and communication [41].

Through the judicious implementation of these policy measures and mitigation strategies, governments can incubate an ecosystem teeming with environmental awareness, erudition, and activism. These initiatives are instrumental in galvanizing

individuals and communities alike, equipping them with the discernment of environmental stewardship's significance, and fomenting practices that are indomitably sustainable, ultimately contributing to the enduring welfare of our planet [45].

VI. CONCLUSION AND FUTURE SCOPE

In recent times, various human activities have emerged as a significant threat to the natural environment and, subsequently, to human health and safety. Activities such as deforestation, urbanization, pollution, and the unsustainable extraction of natural resources have led to a multitude of serious environmental issues. These include habitat destruction, biodiversity loss, air and water pollution, soil degradation, and climate change. The resulting problems don't just stop at environmental degradation; they extend to human societies, causing health issues like respiratory problems, cardiovascular diseases, and other illnesses due to exposure to pollutants and contaminated resources. There's a clear and urgent need for a comprehensive approach to mitigate these man-made hazards. This encompasses adopting sustainable development practices, which balance current societal needs without compromising the environment for future generations. Moreover, environmental regulations, waste management systems, renewable energy adoption, and conservation efforts are critical components of a more sustainable and resilient future. Public awareness campaigns, education on sustainable practices, and international cooperation are crucial for global understanding and collective action against these pressing challenges.

Moving forward, there's a broad spectrum of research areas that could contribute significantly to addressing these hazards. This includes the development of comprehensive risk assessment methodologies to better understand and manage potential hazards. Innovative technological and engineering solutions are crucial to alleviate the impacts of these hazards, alongside improving community resilience through socioeconomic assessments and support strategies. Policies and governance structures need continuous evaluation and enhancement to ensure they remain effective against evolving challenges. Furthermore, Environmental Impact Assessment (EIA) processes need to be refined to accurately evaluate long-term impacts and integrate these assessments effectively into decision-making processes. Research into sustainable technologies and practices will play a vital role in minimizing the environmental impact of man-made hazards. This includes a deeper exploration into renewable energy solutions, waste management techniques, sustainable agriculture practices, and green infrastructure. Additionally, understanding the connection between man-made hazards and climate change is imperative. This research can lead to the development of adaptation and mitigation strategies to reduce vulnerability and greenhouse gas emissions associated with man-made hazards. Finally, effective communication strategies and educational programs are essential to raise public awareness regarding these hazards and promoting sustainable behaviors. Through a collective effort encompassing individual actions, policy interventions, technological advancements, and international collaboration, we can work towards mitigating the negative impacts of man-made hazards. This collective responsibility paves the way towards a more sustainable, resilient, and safer planet for present and future generations.

REFERENCES

- [1] S. Torani, P. Majd, S. Maroufi, M. Dowlati, and R. Sheikhi, "The importance of education on disasters and emergencies: A review article," *J Educ Health Promot*, vol. 8, no. 1, p. 85, 2019, doi: 10.4103/jehp.jehp_262_18.
- [2] US EPA, "Heat island impacts | US EPA - U.S. Environmental Protection Agency," 2023.
- [3] B. Chun, M. Hur, and J. Won, "Impacts of Thermal Environments on Health Risk: A Case Study of Harris County, Texas," *Int J Environ Res Public Health*, vol. 18, no. 11, p. 5531, May 2021, doi: 10.3390/ijerph18115531.
- [4] US EPA, "Radiation health effects | US EPA," 2023.
- [5] I. Manisalidis, E. Stavropoulou, A. Stavropoulos, and E. Bezirtzoglou, "Environmental and Health Impacts of Air Pollution: A Review," *Front Public Health*, vol. 8, Feb. 2020, doi: 10.3389/fpubh.2020.00014.
- [6] N. York State Department of Health, "Radiation and Health," 2007.
- [7] Chernobyl Accident, "Environmental Consequences of the Chernobyl Accident and their Remediation: Twenty Years of Experience," 2006.
- [8] M. Igini, "How does deforestation affect the environment?," 2023.
- [9] K. Mulvihill, "Soil erosion 101," 2021.
- [10] WHO, "Biodiversity and health," 2015.
- [11] International Rivers, "Environmental impacts of Dams," 2002.
- [12] S. A. Diehn, "The environmental impact of mega-dams – DW ," 2020.
- [13] R. T. T. Forman and L. E. Alexander, "ROADS AND THEIR MAJOR ECOLOGICAL EFFECTS," *Annu Rev Ecol Syst*, vol. 29, no. 1, pp. 207–231, Nov. 1998, doi: 10.1146/annurev.ecolsys.29.1.207.
- [14] S. C. Trombulak and C. A. Frissell, "Review of Ecological Effects of Roads on Terrestrial and Aquatic Communities," *Conservation Biology*, vol. 14, no. 1, pp. 18–30, Feb. 2000, doi: 10.1046/j.1523-1739.2000.99084.x.
- [15] A. W. Coffin, "From roadkill to road ecology: A review of the ecological effects of roads," *J Transp Geogr*, vol. 15, no. 5, pp. 396–406, Sep. 2007, doi: 10.1016/j.jtrangeo.2006.11.006.
- [16] C. Calenge, A. B. Dufour, and D. Maillard, "K-select analysis: a new method to analyse habitat selection in radio-tracking studies," *Ecol Modell*, vol. 186, no. 2, pp. 143–153, Aug. 2005, doi: 10.1016/j.ecolmodel.2004.12.005.
- [17] K. C. Seto, B. Güneralp, and L. R. Hutyrá, "Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools," *Proceedings of the National Academy of Sciences*, vol. 109, no. 40, pp. 16083–16088, Oct. 2012, doi: 10.1073/pnas.1211658109.
- [18] V. J. Bennett, "Effects of Road Density and Pattern on the Conservation of Species and Biodiversity," *Current Landscape Ecology Reports*, vol. 2, no. 1, pp. 1–11, Mar. 2017, doi: 10.1007/s40823-017-0020-6.
- [19] X. Bai, J. Chen, and P. Shi, "Landscape Urbanization and Economic Growth in China: Positive Feedbacks and Sustainability Dilemmas," *Environ Sci Technol*, vol. 46, no. 1, pp. 132–139, Jan. 2012, doi: 10.1021/es202329f.
- [20] G. Li et al., "Global impacts of future urban expansion on terrestrial vertebrate diversity," *Nat Commun*, vol. 13, no. 1, p. 1628, Mar. 2022, doi: 10.1038/s41467-022-29324-2.
- [21] I. Manisalidis, E. Stavropoulou, A. Stavropoulos, and E. Bezirtzoglou, "Environmental and Health Impacts of Air Pollution: A Review," *Front Public Health*, vol. 8, Feb. 2020, doi: 10.3389/fpubh.2020.00014.
- [22] R. Fuller et al., "Pollution and health: a progress update," *Lancet Planet Health*, vol. 6, no. 6, pp. e535–e547, Jun. 2022, doi: 10.1016/S2542-5196(22)00090-0.
- [23] I. Bashir, F. A. Lone, R. A. Bhat, S. A. Mir, Z. A. Dar, and S. A. Dar, "Concerns and Threats of Contamination on Aquatic Ecosystems," in *Bioremediation and Biotechnology*, Cham: Springer International Publishing, 2020, pp. 1–26. doi: 10.1007/978-3-030-35691-0_1.
- [24] H. Haller, *Soil Remediation and Sustainable Development-Creating Appropriate Solutions for Marginalized Regions*.
- [25] N. Rodríguez Eugenio, M. J. McLaughlin, D. J. Pennock, Food and Agriculture Organization of the United Nations, and Global Soil Partnership., *Soil pollution : a hidden reality*.
- [26] T. Münzel, O. Hahad, A. Daiber, and P. J. Landrigan, "Soil and water pollution and human health: what should cardiologists worry about?," *Cardiovasc Res*, vol. 119, no. 2, pp. 440–449, Mar. 2023, doi: 10.1093/cvr/cvac082.
- [27] M. C. Sarofim et al., "Ch. 2: Temperature-Related Death and Illness. The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment," Washington, DC, 2016. doi: 10.7930/J0MG7MDX.

- [28] K. Hayhoe et al., "Chapter 2 : Our Changing Climate. Impacts, Risks, and Adaptation in the United States: The Fourth National Climate Assessment, Volume II," Washington, DC, 2018. doi: 10.7930/NCA4.2018.CH2.
- [29] R. S. Vose, D. R. Easterling, K. E. Kunkel, A. N. LeGrande, and M. F. Wehner, "Ch. 6: Temperature Changes in the United States. Climate Science Special Report: Fourth National Climate Assessment, Volume I," Washington, DC, 2017. doi: 10.7930/J0N29V45.
- [30] K. L. Ebi et al., "Chapter 14 : Human Health. Impacts, Risks, and Adaptation in the United States: The Fourth National Climate Assessment, Volume II," Washington, DC, 2018. doi: 10.7930/NCA4.2018.CH14.
- [31] K. R. Shivanna, "Climate change and its impact on biodiversity and human welfare," Proceedings of the Indian National Science Academy, vol. 88, no. 2, pp. 160–171, Jun. 2022, doi: 10.1007/s43538-022-00073-6.
- [32] D. Lipton et al., "Chapter 7 : Ecosystems, Ecosystem Services, and Biodiversity. Impacts, Risks, and Adaptation in the United States: The Fourth National Climate Assessment, Volume II," Washington, DC, 2018. doi: 10.7930/NCA4.2018.CH7.
- [33] U. Lall et al., "Chapter 3 : Water. Impacts, Risks, and Adaptation in the United States: The Fourth National Climate Assessment, Volume II," Washington, DC, 2018. doi: 10.7930/NCA4.2018.CH3.
- [34] I. Manisalidis, E. Stavropoulou, A. Stavropoulos, and E. Bezirtzoglou, "Environmental and Health Impacts of Air Pollution: A Review," Front Public Health, vol. 8, Feb. 2020, doi: 10.3389/fpubh.2020.00014.
- [35] L. Lin, H. Yang, and X. Xu, "Effects of Water Pollution on Human Health and Disease Heterogeneity: A Review," Front Environ Sci, vol. 10, Jun. 2022, doi: 10.3389/fenvs.2022.880246.
- [36] Y. Wang, X. Hu, H. Chang, L. Waller, J. Belle, and Y. Liu, "A Bayesian Downscaler Model to Estimate Daily PM_{2.5} Levels in the Conterminous US," Int J Environ Res Public Health, vol. 15, no. 9, p. 1999, Sep. 2018, doi: 10.3390/ijerph15091999.
- [37] F.-J. Chu, T.-J. Wan, H. Chen, C.-H. Wu, and P.-M. Kao, "Magnetophoretic Harvesting of Nannochloropsis oculata Using Iron Oxide Immobilized Beads," Water (Basel), vol. 12, no. 1, p. 236, Jan. 2020, doi: 10.3390/w12010236.
- [38] R. Fuller et al., "Pollution and health: a progress update," Lancet Planet Health, vol. 6, no. 6, pp. e535–e547, Jun. 2022, doi: 10.1016/S2542-5196(22)00090-0.
- [39] EIA, "Topic 2 Law, policy and institutional arrangements for EIA systems," 2002.
- [40] WHO, "Ambient air pollution: A global assessment of exposure and burden of disease," 2016.
- [41] T. Cadmus Group, "Topic Briefing: An Introduction to Environmental Assessment," 2005.
- [42] Department for natural resources and the environment. and Sida., Guidelines for environmental impact assessments in international development cooperation : July 1998. Sida, 1998.
- [43] S. Momtaz and S. M. Z. Kabir, "Implementation of Mitigation Measures," in Evaluating Environmental and Social Impact Assessment in Developing Countries, Elsevier, 2013, pp. 129–170. doi: 10.1016/B978-0-12-408129-1.00007-3.
- [44] M. Desai, A. Njoku, and L. Nimo-Sefah, "Comparing Environmental Policies to Reduce Pharmaceutical Pollution and Address Disparities," Int J Environ Res Public Health, vol. 19, no. 14, p. 8292, Jul. 2022, doi: 10.3390/ijerph19148292.
- [45] OECD, "Environmental Policy and Regulation in RUSSIA THE IMPLEMENTATION CHALLENGE OECD," 2006.

UNVEILING SOLAR: A THOROUGH EXAMINATION OF ITS ENVIRONMENTAL DIMENSIONS IN ADVANCING RENEWABLE SOLUTIONS AND MITIGATING POLLUTION

Abstract

Solar energy has emerged as a viable and sustainable alternative as the world grapples with climate change and fossil fuel depletion. Nevertheless, it is essential to recognize the disadvantages of solar energy to ensure that its development does not come at the expense of the environment and society. This paper investigates the impacts of solar energy, including its effects on land resources, wildlife habitats, water consumption, and environmental pollution. In addition to environmental impacts, solar energy's negative effects also include social and economic difficulties. Furthermore, there necessitates a concerted emphasis on the maturation of photovoltaic technologies with minimal aqueous dependencies, thereby diminishing competition with agricultural and other water-related imperatives. The paper also discusses potential solutions for mitigating these problems, such as implementing land-use policies that priorities conservation, encouraging rooftop solar panel installations, developing solar panel technologies that require less water, and promoting the use of environmentally friendly materials. In addition, the paper urges policymakers, industry leaders, and individuals to take action to resolve these issues and promote a more sustainable and equitable solar energy industry. While solar energy has the potential to revolutionize the way we generate and use energy, it is essential to resolve its negative aspects to ensure that everyone can enjoy its benefits.

Keywords: Solar Energy, Renewable Energy, Environmental Pollution, Social and Economic Impacts, Sustainability.

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I. INTRODUCTION

Solar power is an enduring source of energy harnessed from the sun's radiance, channeled through photovoltaic cells [1]. The paramount advantages intrinsic to solar energy encompass its perpetual and sustainable essence, its progressively augmenting cost-efficiency, minimal upkeep prerequisites, the potential for self-sufficiency in power generation, and the catalytic effect it has on employment opportunities. In its character as a renewable energy source, solar power remains untarnished by depletion over time and, in comparison to conventional fossil fuels, emerges as a markedly eco-friendly substitute [2]. The financial outlay linked to solar energy has been witnessing a steady decline over the years, rendering it a more economically accessible resource for individuals and enterprises. Solar panels, renowned for their low-maintenance disposition and prolonged life expectancy, signify a source of energy with minimal care obligations. Furthermore, solar energy carries the potential to bestow energy autonomy, diminishing dependence on foreign reserves of oil and natural gas [3]. The burgeoning solar sector has ushered in a wave of job creation, spanning manufacturing, installation, and maintenance [4].

The resurgence of solar power has witnessed a remarkable surge in recent times, predominantly attributable to its well-established advantages. As per the International Energy Agency's findings, solar energy emerges as the globe's most rapidly burgeoning electricity source, poised to amass a substantial 580 gigawatts of electrical prowess by 2025. This extraordinary progression can be ascribed to myriad catalysts [5]. The diminishing cost of solar energy has made it progressively more economical and within reach. This reduction in expense emanates from breakthroughs in technology, heightened competition within the solar sector, and governmental incentives that stimulate its embrace. Consequently, individuals and corporate entities alike are discovering it increasingly pragmatic to harness solar vitality. Moreover, solar energy plays a pivotal role in ameliorating dependency on fossil fuels and alleviating the adverse repercussions of climate fluctuations. Numerous nations globally have acknowledged the exigency of transitioning to eco-friendly energy sources such as solar power to counteract environmental vicissitudes [6].

Solar power harbors certain restrictions and deficiencies that warrant thoughtful consideration. Primarily, solar energy's availability hinges upon the radiant presence of the sun, rendering it incapable of furnishing a perpetual and dependable source of electrical power. This limitation is particularly conspicuous in regions plagued by frequent overcast or inclement weather, as solar panels exhibit diminished efficacy under such meteorological circumstances. Additionally, the generation of solar power necessitates an extensive expanse of land, a demand that can exert deleterious ramifications upon wildlife habitats and ecosystems [7]. Another consequential concern pertains to the fabrication of solar panels, which necessitates the utilization of fossil fuels and noxious chemicals, thereby engendering detrimental ecological repercussions. Furthermore, the viability of solar panels is contingent on the specific architectural configuration of one's roof, rendering them less efficacious for certain roof types. For individuals contemplating relocation shortly, investing in solar panels may prove to be an imprudent choice. The spectre of hazardous materials, akin to those encountered in electronic devices, looms over solar panels, posing a latent threat to the environment and human well-being. Lastly, the fiscal outlay associated with harnessing solar energy can be substantial, although this concern may progressively wane in significance as technological advancements bolster efficiency and augment storage capacity.

Notwithstanding these impediments, solar energy endures as a propitious and sustainable energy reservoir. Vehement efforts are being marshalled to confront these challenges through the prism of innovation and dedicated research [8].

Solar energy has some limitations and drawbacks that need to be considered. Firstly, solar energy can only be produced when the sun is shining, which means that it cannot provide a constant and reliable source of electricity. This is particularly true in areas with frequent cloudy or rainy weather, as solar panels are less effective under such conditions. Additionally, solar panels require a significant amount of land to generate electricity, which can have negative impacts on wildlife habitats and ecosystems. Another concern is the manufacturing of solar panels, which requires the use of fossil fuels and toxic chemicals that can have negative environmental impacts. Furthermore, solar panels may not work for every roof type, and they may not be a good investment if you are planning to move soon. This review paper is mainly focused on the impacts of solar energy production and ways in which it can be made sustainable.

II. CURRENT SOLAR ENERGY PRODUCTION STATUS

As per the Data compiled by Data based on three main sources: - BP Statistical Review of World Energy., Ember Yearly Electricity Data (2023), Ember European Electricity Review (2022) [9]–[11] a world map is being plotted showing the variation of solar energy production is last decade i.e. from 2011 to 2022. This highlights the quick global adoption of solar energy for energy needs.

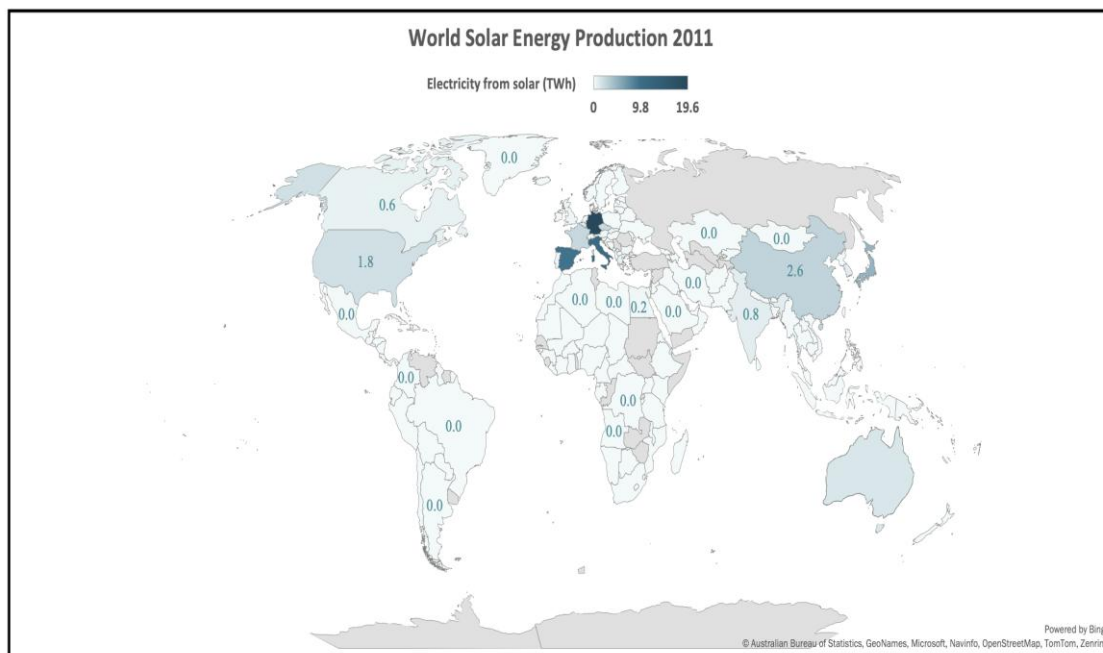


Figure 1a: World Solar Energy Production, 2011 [9]–[11]

generation of electricity on an industrial scale. This endeavor, however, carries the potential for deleterious repercussions on the surrounding ecosystems, manifesting as the forfeiture of wildlife habitat and the perturbation of pristine natural panoramas [12].

In certain instances, solar farms have incurred censure for their development on fertile agricultural terrain or within regions renowned for their biodiversity. Such siting decisions wield profound implications for indigenous ecosystems and agricultural output alike [13]. Nevertheless, it merits acknowledgment that a plethora of solar installations, exemplified by rooftop photovoltaic arrays, obviate the requirement for additional land and can be seamlessly integrated into preexisting developed areas [14]. Moreover, an array of concerted initiatives exists to ameliorate the ecological imprint of solar farms. These include the localization of projects on degraded or marginal land, the implementation of safeguards for wildlife preservation, and the adoption of low-impact techniques for solar panel installation. Such endeavors collectively endeavor to strike a harmonious balance between harnessing solar energy's bounteous potential and preserving the delicate equilibrium of our natural surroundings [15].

The establishment of solar panels and their consequent intrusion into natural habitats has emerged as a formidable environmental concern associated with solar energy deployment. In the grand scheme of solar energy generation, expansive solar farms may necessitate the clearance of indigenous flora and the transformation of pristine landscapes into platforms for solar panel placement and its correlated infrastructure. Such actions can precipitate the disintegration and forfeiture of living spaces for fauna, thus culminating in far-reaching ecological repercussions. To elucidate, the eradication of native vegetation can incite detrimental consequences such as soil erosion, the depletion of biological diversity, and alterations in the indigenous climate patterns. Furthermore, the installation of solar panels often necessitates the employment of substantial machinery and ancillary equipment, thereby escalating the perturbation of ecosystems and provoking the compaction of soil [16].

- **Impact of Water Resources:** Solar panels necessitate a measure of water for cleansing and cooling, yet the quantum of water required is typically markedly inferior when juxtaposed with alternative power generation methodologies such as coal or nuclear power facilities. Water finds its primary utility in the cleansing of panels, ridding them of dust and detritus to ensure the utmost efficiency and optimal energy yield. Furthermore, water occasionally serves to temper the panels, averting the specter of overheating and safeguarding the equipment from potential harm. The magnitude of water consumption for the dual objectives of purification and temperature regulation may exhibit variance contingent upon the specific solar technology in use and the geographical locale, given that certain regions boast a more copious supply of water resources than others. In a concerted effort to ameliorate the water footprint associated with solar energy production, numerous enterprises are engaged in the development of innovative technologies and methodologies that either curtail or eliminate water utilization. For instance, select entities have embraced dry cleaning methodologies that obviate the need for water altogether, while others have

adopted a sustainable approach by repurposing recycled water or wastewater for cleansing and thermal regulation. Moreover, certain solar power installations are strategically situated in regions replete with ample sunlight yet devoid of abundant water sources, rendering the adoption of water-intensive cooling systems unfeasible [17].

Harnessing the potency of solar energy necessitates substantial tracts of land, a resource often engaged in a relentless tussle with agriculture and other essential water requirements. This stems from the fact that solar energy generation frequently unfolds in regions with meagre water reservoirs, thereby engendering a clash between energy production and the multifaceted demands of the land. Furthermore, certain solar technologies, most notably the likes of concentrating solar power (CSP), entail the extravagant utilization of water for cooling, a facet that can only serve to exacerbate the pervasive issue of water scarcity in arid terrains. To grapple with these disconcerting conundrums, a plethora of strategies beckon, poised to mitigate the precarious juggling act between solar energy and agriculture or ancillary water necessities. One stratagem of notable mention advocates for the localization of solar energy production in topographies unsuitable for cultivation, such as arid deserts or barren wastelands. Another avenue of approach advocates for the deployment of solar technologies that exhibit parsimony about water usage, typified by the photovoltaic (PV) solar panels, which remain immune to the necessity of water for cooling. In tandem with these, the prudent adoption of water-conservation methodologies can prove instrumental. These include the judicious utilization of recycled or treated wastewater for cooling purposes or the incorporation of dry cooling systems that circumvent any dependence on water [18].

In the grand tapestry of this discourse, it becomes resoundingly clear that while there may indeed exist a vying competition between solar energy and the exigencies of water, a panoply of strategic measures is at our disposal to temper these conflicts. What remains paramount is the judicious contemplation of the water dynamics inherent to a specific region, coupled with the imperious need to cultivate solar energy production in a manner that not only stands as a bulwark of sustainability but also assiduously curbs deleterious ramifications upon agriculture and the myriad of land applications therein [17].

- 2. Pollution:** Solar panels, hailing from a diverse array of constituents like silicon, aluminum, glass, and plastics, among a myriad of other components, are the prodigious offspring of a labour-intensive genesis. This birthright, fuelled by substantial energy consumption, gives rise to the lamentable emanation of greenhouse gases and sundry noxious airborne byproducts. Moreover, within the crucible of their production, one encounters the utilization of certain chemicals, such as cadmium and lead, whose toxic proclivities pose a pernicious peril to both human well-being and the ambient environment [17].

At the culmination of their productive life, these solar sentinels find themselves confronting the inexorable destinies of disposal or reincarnation, each bearing its distinct ecological footprints. Solar panels, being replete with materials of enigmatic recalcitrance, present formidable challenges in the realm of recycling. The improper

interment of these artifacts can instigate the inadvertent dissemination of pernicious chemical agents into the pristine environs. To contend with these daunting quandaries, a cornucopia of strategic initiatives beckons, promising mitigation of the ecological repercussions that shadow the production and ultimate disposition of these solar behemoths.

One cogent strategy calls for the utilization of materials endowed with diminished toxicity and an innate proclivity for facile reclamation. An alternate avenue for redress lies in the augmentation of the production process's efficiency, thereby curtailing the quantum of energy prerequisites and the concomitant emission emanations. Furthermore, the establishment of conscientious policies that invent proper solar sepulcher and recycling stands as a beacon to guide us through this environmentally treacherous terrain [19].

The fabrication of solar panels encompasses a multifarious amalgamation of substances, some of which harbor the potential for toxicity and peril to both human well-being and the ecosystem. For example, certain variants of solar panels incorporate cadmium telluride (CdTe) or copper indium gallium selenide (CIGS) as their semiconductor substrates, entities prone to expelling deleterious compounds if mishandled or ineffectively disposed of. Furthermore, the production procedure necessitates the utilization of solvents, acids, and assorted chemicals, all of which hold the potential to impose jeopardy upon laborer's and environmental stability when not subjected to meticulous management.

- 3. Social Impacts:** Although the cost of harnessing solar energy is decreasing, the initial investment needed to purchase solar panels and set up the necessary infrastructure is still very high. This financial obstacle is especially challenging for impoverished communities, preventing them from accessing the many benefits of solar power. These benefits include lower electricity costs and decreased reliance on fossil fuels, which are crucial considering growing environmental concerns[20]. In tandem with the substantial installation costs, the upkeep and restoration of solar panels may entail ongoing expenses. Neglecting the proper maintenance regimen can precipitate a decline in efficiency, or worse still, render these panels entirely non-operational. Such setbacks cast a pall over both the economic and ecological merits of this sustainable energy source.

To redress these quandaries, concerted endeavors have been undertaken to democratize and render solar energy more financially viable for underprivileged communities. These initiatives encompass an array of strategies, including the provision of financial mechanisms, the establishment of community-based solar programs, and the promulgation of government incentives. Yet, despite these commendable strides, the journey toward universal access to renewable energy beckons for a sustained commitment to investment and innovation.

IV. MITIGATION METHODS

- 1. Land Impacts:** In order to solve these problems, substantial efforts have been made to democratize solar energy and make it more affordable for impoverished areas. These projects cover a wide range of tactics, such as the construction of community-based solar programmes, the provision of funding channels, and the issuance of government incentives. Nevertheless, the road to achieving widespread access to renewable energy still calls for a persistent commitment to investment and innovation [21], [22].

In order to address the challenge of needing a lot of land for solar farms, a potential solution is to incentivize the installation of rooftop solar panels on both residential and commercial buildings. This strategic utilization of extant rooftop expanses holds the promise of a substantial diminishment in the demand for terrestrial tracts earmarked for the generation of solar energy. Governmental instruments, such as the judicious implementation of tax incentives and the establishment of net metering initiatives, stand poised to serve as potent catalysts in promoting the widespread integration of rooftop solar panels. Furthermore, the fostering of community-driven initiatives and forging strategic alliances with solar installation enterprises can synergistically facilitate the provisioning of cost-effective and easily accessible avenues for the installation of rooftop solar panels. It is important to underscore that a multiplicity of convergent forces coalesce to render this proposition viable and consequential. By harnessing the untapped potential of elevated rooftop domains, a paradigm shift in energy generation paradigms becomes palpable. The strategic alignment of government-backed economic incentives and the collaborative engagement of the private sector augur well for the democratization of solar energy [23].

As solar panels reach the end of their lifespan, there is a growing concern about how to dispose of them properly. Solar panels can contain hazardous materials such as lead, cadmium, and gallium arsenide that can pose risks to human health and the environment if not handled properly. Therefore, implementing regulations on the disposal of solar panels is crucial to minimize their environmental impacts. Several countries have already implemented regulations on the disposal of solar panels. In the European Union, for example, solar panel manufacturers are required to take back and recycle solar panels at the end of their lifespan under the Waste Electrical and Electronic Equipment (WEEE) Directive. In the United States, several states have passed laws that require solar panel manufacturers to establish recycling programs and report on the disposal of their products [24].

In addition to regulations, there are also efforts to develop more sustainable ways of manufacturing and disposing of solar panels. For example, some companies are exploring the use of non-toxic materials in the production of solar panels, and others are developing processes to recycle and reuse solar panel components. By implementing regulations on the disposal of solar panels and promoting sustainable manufacturing practices, it is possible to minimize the environmental impacts of solar energy and ensure its long-term sustainability.

- 2. Water Impacts:** The production of solar panels poses a notable quandary in the realm of sustainability due to its voracious appetite for water, both in the manufacturing phase and the subsequent cleansing and cooling processes. The demand for water can create conflicts in areas where it is scarce and valuable. However, experts are working hard to develop new technologies that can reduce the amount of water used in processes like solar panel production. Their efforts aim to solve this problem and make better use of our limited resources. One such pioneering technology resides in the realm of dry silicon etching, which stands in stark contradistinction to its aqueous counterpart [25]

In the traditional wet etching procedure, silicon undergoes dissolution via the amalgamation of chemicals and copious amounts of water. This *modus operandi* not only begets copious hazardous byproducts but also exacts a toll in the form of substantial water consumption. The dry etching paradigm, in stark contrast, harnesses the power of plasma to etch the silicon, obviating the need for copious water and concomitantly curbing the generation of perilous waste materials [26]. By implementing such groundbreaking technologies, the ecological footprint of solar panel production can be appreciably diminished. Simultaneously, it offers a judicious resolution to concerns entailing water utilization and the contentious competition that ensues in the context of other vital water needs [27].

V. CONCLUSION

In retrospect, the shadowed facets of solar energy encompass an array of ecological and societal repercussions. These encompass the dislodgment of habitats vital to wildlife, the contestation for access to precious water resources and the utilization of noxious substances in the manufacturing process. Furthermore, the sporadic nature inherent in solar energy generation, coupled with the formidable expenses linked to its installation and upkeep, along with potential incompatibilities with particular roofing configurations and relocation complexities, can be appraised as disadvantages. Nevertheless, concerted endeavors are presently underway to redress these concerns. These initiatives encompass the institution of land-use regulations that accord precedence to preservation, the promotion of rooftop photovoltaic systems, the innovation of solar panel technologies characterized by reduced water requirements, the enforcement of stringent regulations governing the disposal of solar panels to curtail environmental repercussions, and the endorsement of ecologically benign materials in the manufacturing process. While indisputably presenting a set of challenges, solar energy stands as an incontrovertible boon as a renewable and sustainable wellspring of power. In tandem with the burgeoning appetite for solar energy, it becomes paramount to accord primacy to the implementation of sustainable principles and policies, thus guaranteeing the enduring constructive influence of solar energy in the realm of global energy transformation.

REFERENCES

- [1] R. Joshi, "Benefits of Extensive Solar Electricity Generation in Reference to Current Climate Change Scenario," *J Phys Conf Ser*, vol. 1714, no. 1, p. 012048, Jan. 2021, doi: 10.1088/1742-6596/1714/1/012048.
- [2] A. O. M. Maka and J. M. Alabid, "Solar energy technology and its roles in sustainable development," *Clean Energy*, vol. 6, no. 3, pp. 476–483, Jun. 2022, doi: 10.1093/ce/zkac023.

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- [3] S. Grover, "Energy, Economic, and Environmental Benefits of the Solar America Initiative," 2007. [Online]. Available: <http://www.osti.gov/bridge>
- [4] C. Leaman, "The benefits of solar energy," *Renewable Energy Focus*, vol. 16, no. 5–6, pp. 113–115, Dec. 2015, doi: 10.1016/j.ref.2015.10.002.
- [5] A. O. M. Maka and J. M. Alabid, "Solar energy technology and its roles in sustainable development," *Clean Energy*, vol. 6, no. 3, pp. 476–483, Jun. 2022, doi: 10.1093/ce/zkac023.
- [6] I. - International Energy Agency, "Renewables 2022," 2022. [Online]. Available: www.iea.org
- [7] M. Johnston, "Solar energy: Benefits and drawbacks," Investopedia, <https://www.investopedia.com/articles/investing/053015/pros-and-cons-solar-energy.asp>.
- [8] V. Aggarwal, "Solar energy: What are its pros and cons?," *EnergySage*, <https://news.energysage.com/advantages-and-disadvantages-of-solar-energy/>.
- [9] N. Wayth, "Statistical Review of World Energy," 2023.
- [10] C. Moore, "European Electricity Review 2022," 2022.
- [11] Nicolas, "Yearly Electricity Data," 2023.
- [12] H. S. Das, M. M. Rahman, S. Li, and C. W. Tan, "Electric vehicles standards, charging infrastructure, and impact on grid integration: A technological review," *Renewable and Sustainable Energy Reviews*, vol. 120, p. 109618, Mar. 2020, doi: 10.1016/j.rser.2019.109618.
- [13] X. M. Chen, Y. Li, B. Y. Zhao, and R. Z. Wang, "Are the optimum angles of photovoltaic systems so important?," *Renewable and Sustainable Energy Reviews*, vol. 124, p. 109791, May 2020, doi: 10.1016/j.rser.2020.109791.
- [14] A. Yapicioglu and I. Dincer, "A review on clean ammonia as a potential fuel for power generators," *Renewable and Sustainable Energy Reviews*, vol. 103, pp. 96–108, Apr. 2019, doi: 10.1016/j.rser.2018.12.023.
- [15] C. W. Mohd Noor, M. M. Noor, and R. Mamat, "Biodiesel as alternative fuel for marine diesel engine applications: A review," *Renewable and Sustainable Energy Reviews*, vol. 94, pp. 127–142, Oct. 2018, doi: 10.1016/j.rser.2018.05.031.
- [16] A. O. M. Maka and J. M. Alabid, "Solar energy technology and its roles in sustainable development," *Clean Energy*, vol. 6, no. 3, pp. 476–483, Jun. 2022, doi: 10.1093/ce/zkac023.
- [17] Union of Concerned Scientists, "Environmental Impacts of Solar Power," <https://www.ucsusa.org/resources/environmental-impacts-solar-power>.
- [18] D.-J. van de Ven et al., "The potential land requirements and related land use change emissions of solar energy," *Sci Rep*, vol. 11, no. 1, p. 2907, Feb. 2021, doi: 10.1038/s41598-021-82042-5.
- [19] L.-C. Liu and G. Wu, "Relating five bounded environmental problems to China's household consumption in 2011–2015," *Energy*, vol. 57, pp. 427–433, Aug. 2013, doi: 10.1016/j.energy.2013.05.043.
- [20] B. Bovarnick and D. Banks, "State Policies to Increase Low-Income Communities' Access to Solar Power," Center for American Progress, 2014.
- [21] W. Sun et al., "Spatial mismatch analyses of school land in China using a spatial statistical approach," *Land use policy*, vol. 108, p. 105543, Sep. 2021, doi: 10.1016/j.landusepol.2021.105543.
- [22] K. Tong, L. Yang, X. Du, and Y. Yang, "Review of modeling and simulation strategies for unstructured packing bed photoreactors with CFD method," *Renewable and Sustainable Energy Reviews*, vol. 131, p. 109986, Oct. 2020, doi: 10.1016/j.rser.2020.109986.
- [23] K. Tong, L. Yang, X. Du, and Y. Yang, "Review of modeling and simulation strategies for unstructured packing bed photoreactors with CFD method," *Renewable and Sustainable Energy Reviews*, vol. 131, p. 109986, Oct. 2020, doi: 10.1016/j.rser.2020.109986.
- [24] WEEE, "DIRECTIVE 2012/19/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 4 July 2012 on waste electrical and electronic equipment (WEEE) (recast) (Text with EEA relevance)."
- [25] N. D. Sintov and G. Schuitema, "Odd couple or perfect pair? Tensions and recommendations for social scientist-industry partnerships in energy research," *Energy Policy*, vol. 117, pp. 247–251, Jun. 2018, doi: 10.1016/j.enpol.2018.03.021.
- [26] H. Huang et al., "Carbonation curing for wollastonite-Portland cementitious materials: CO₂ sequestration potential and feasibility assessment," *J Clean Prod*, vol. 211, pp. 830–841, Feb. 2019, doi: 10.1016/j.jclepro.2018.11.215.
- [27] A. J. Njoh, L. Bigon, E. O. Ananga, and R. A. Ayuk-Etang, "Institutional, economic and socio-cultural factors accounting for gender-based inequalities in land title procurement in Cameroon," *Land use policy*, vol. 78, pp. 116–125, Nov. 2018, doi: 10.1016/j.landusepol.2018.06.038.

PART 7

Futuristic Trends in Construction Materials & Civil Engineering

Series Id: IIPV3EBS05_G29

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EFFECT OF RICE HUSK ASH AS SUPPLEMENTARY CEMENTITIOUS MATERIAL FOR RIGID PAVEMENT CONSTRUCTION

Abstract

The calorific value of the agricultural waste in the form of Rice Husk is very close to the calorific value of coal. Therefore it finds its use as fuel for boilers in cement production. This saves 5% of the country's coal which is the non-renewable resource of fuel. The resultant Rice Husk Ash (RHA) produced is mostly used in land filling which is an environmentally hazardous way to deposit this agro-industrial by product. Researchers have observed the RHA produced has high silica content which makes it a suitable Supplementary Cementitious Material (SCM). This not only reduces the use of coal but also reduces the cement manufacturing cost. The manuscript here is keen to achieve sustainability in industry as well as innovation and infrastructure by not only reducing the usage of non-renewable energy resources but also effectively addressing the environmental and economic concerns. In this study the properties of hydrated cements are investigated when mixed with the RHA. This not only improved the properties of the concrete but also made them sustainable for high grade concrete construction, conventionally used for the construction of rigid pavements. The activity of the RHA made variation in the mortar properties which was analyzed by X-Ray Diffraction (XRD). Experimental results confirmed increased compressive strength of high grade RHA mixed cement concrete by replacement up to 15% and 5% of Ordinary Portland Cement (OPC) and Portland Pozzolana Cement (PPC) respectively by weight compared to high grade virgin cement concrete. The incorporation of RHA also reduced the pH value and consequently the Alkali Aggregate Reaction (AAR).

Keywords: Rice Husk Ash; Cement; Compressive Strength Test; XRD; AAR

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I. INTRODUCTION

In India 63.73 lakh kilometers of road network exists, making it the 2nd largest road network in the world. The road network carries 87% passenger traffic and 60% freight transport (MoRTH, Year End Review 2022, 2023). 90% of these paved roads are bituminous and the remaining 10% are rigid pavement (MoRTH, Specifications for road bridge works 5th revision, 2013). This statistical data shows that the rigid pavements are less favourable, which is mainly due to its high initial construction cost (Mohod & Kadam, 2016). However their low maintenance cost in comparison to the flexible pavement have kept the researchers and engineers ever interested in their implementation whenever possible. In recent years the Government of India has started significant endeavors to implement all weather road connectivity to habitations in Left Wing Extremism (LWE) areas (PMGSY, 2017). This have once again opened up the opportunity of implementation of rigid pavement on a large scale. On the contrary, this project requires a huge quality of material, which is leading to a potential material crisis and utilizing the materials from the neighboring lands. Besides the growing production cost of Portland cement have made researchers interested in partially replacing it with SCM (Mehta & Pitt, 1976). On the other hand, a mounting increase in the amount of siliceous waste material like agricultural waste in the form of RHA has made researchers and industry professionals interested towards the replacement of cement with these (Nehdi, Duquette, & Damatty, 2003). The pozzolanic properties of RHA finds its utility in construction material as it enhances the structural sustainability and service life (Reddy, Jyothy, & Reddy, 2013). This further leads to recycling the RHA. This tackles the disposal issues and consequent environmental threats. It further reduces the cement content as well as reduces the energy consumption, non-renewable raw material consumption and consequent carbon dioxide emissions.

The aptness of utilizing RHA as SCM mainly depends upon its silica content and large surface area, which is due to the porous structure of the particles (Cook, Pama, & Damer, 1976). The reactive silica content of RHA along with its mineralogical properties depend upon the combustion time, temperature and turbulence during combustion (Deshmukh, Bhatt, Peshwe, & Pathak, 2012).

Investigators obtained rapid analytical method for determining the silica in RHA which is present in its amorphous phase. It is highly pozzolanic that can be used as SCM. Its reactivity depends on the temperature of incineration. The RHA becomes highly reactive as the temperature of incineration reaches 500°C (Zain, Islam, Mahmud, & Jamil, 2011). On increasing the temperature of incineration, the nature of RHA changes from amorphous to crystalline (Memon, Shaikh, & Akbar, 2011). It has been investigated that, the RHA mixed concrete produces satisfactory slump as well as setting time (Zhang, Lastra, & Malhotra, 1996). It also has excellent chloride ion penetration resistance, reduced surface scaling and excellent performance under freezing and thawing conditions (Givi, Rashid, Aziz, & Salleh, 2010). Researchers stated that, the pozzolanic reaction lowers the calcium hydroxide content in the RHA blended cement concrete as well as enhance its compressive strength and workability (Jaturapitakkul & Roongreung, 2003). Investigational works showed that, incorporating RHA in structural concrete is a good alternative of the concrete structure (Gastaldini, Isaia, Gomes, & Sperb, 2007). Although numerous research works have been done determining the different properties of the concrete using RHA, most of them have used Low Grade Concrete (M30).

The RHA has been added to the cement in the form of SCM (0%, 2.5%, 5%, 7.5% and 10% by weight of PPC) and (0%, 5%, 10%, 15% and 20% by weight of OPC). Then 150 mm concrete cubes were casted using the blended cement, coarse aggregate, fine aggregate, water and admixture followed by compaction using needle vibrator. The mix proportion conformed to IS: 10262 (10262, 2009). After 24 hours, the casted cubes were taken out from the mould and subjected to curing before they were tested.

II. MATERIALS USED IN THIS INVESTIGATION

The materials used in this investigational work have been described as follows:

- 1. Rice Husk Ash:** The RHA was procured from the Rice Mill of Burdwan, a district of West Bengal, India. It was produced by burning the Rice Husk for over 5 minutes at a temperature of 1000°C. This produced crystalline silica that is built by the repetition of silicon tetrahedron unit, oriented in a three dimensional network (Monteiro, Shomglin, & Wenk, 2001). The framework type structure is made up of quartz shown in Figure 1 which is found later in this study by performing the XRD analysis of the sample. The large silica content of the RHA represented in the Table 1 makes it suitable as a SCM. The physical properties of RHA is in Table 2.

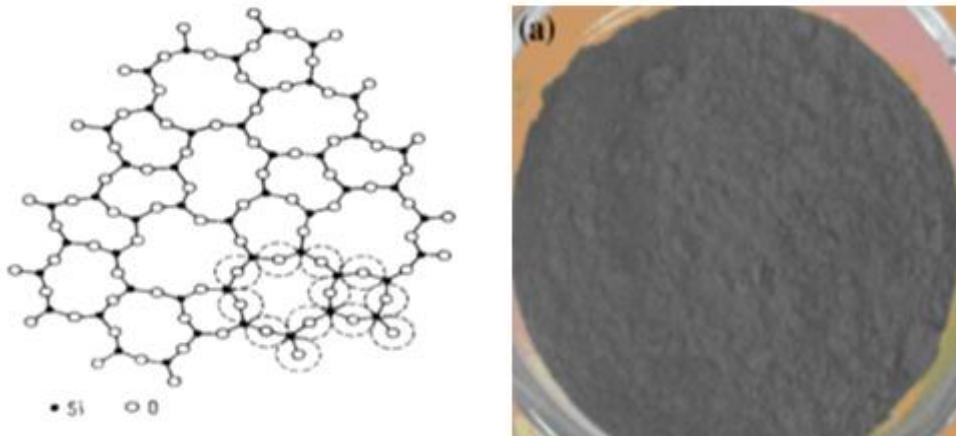


Figure 1: 2-Dimensional Framework of SiO₂ (Shomglin Et Al. 2001) Present in RHA

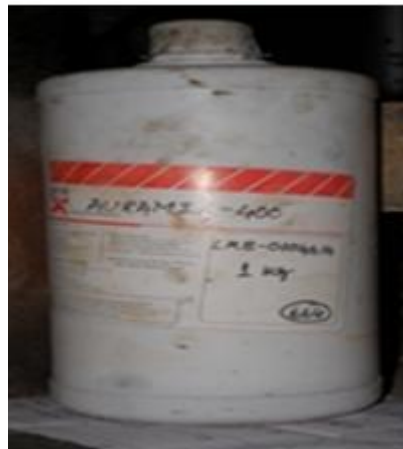
Table 1: Chemical Composition of RHA

Components of RHA	Percentage Present
Silica (SiO ₂)	83.00%
Alumina (Al ₂ O ₃)	12.00%
Ferric Oxide (Fe ₂ O ₃)	0.50%
Titanium Oxide	Nil
Calcium Oxide (CaO)	1.35%
Magnesium Oxide (MgO)	0.70%
Sodium Oxide (Na ₂ O)	0.30%
Potash	0.20%
Loss on Ignition	1.95%

Table 2. Physical Properties of RHA

Physical Properties of RHA	Percentage Present
Plasticity	Non-Plastic
Optimum Moisture Content	86.95%
Maximum Dry Density	0.54 gm/cc
Specific Gravity	2.06
Soaked CBR	4.14%
Unsoaked CBR	8.36%
Moisture Content (by weight)	6.08%
Ash Content	23.39%
Bulk Density	90.0 kg/m ³

- Cement:** The OPC 43 Grade and the PPC used in the investigational work was supplied by the Ultra Tech Cement Limited.
- Super Plasticizer:** The super plasticizer used is of brand FOSROC made Auromix-400 shown in the Figure 2 was collected from local market, which mainly steadies the workability of the concrete mix keeping its strength intact. Auromix-400 used in the concrete mix is also a High Range Water Reducer (HRWR) having polycarboxylic base conforming IS: 9103 with specific gravity of 1.09.

**Figure 2:** The Super Plasticizer AURAMIX-400 used for the Study

- Coarse Aggregate :** In this study the coarse aggregate used is of Pakur variety with sizes ranging 10 mm to 20 mm.
- Fine Aggregate:** Fine aggregate is collected from local market with maximum aggregate size passing 2.36 mm sieve. The sand is thoroughly washed and dried for removing any organic matters present.
- Water:** Potable water is used for preparing the concrete mix samples. The water should be free from any organic substances.

7. **Measurement of Classical Properties of Blended Cement:** Classical properties of the cement used in this study has been evaluated in order to identify their grade and quality. The test methods are presented in a tabulated form in Table 3 along with their standard code.

Table 3: Various Test methods with standard

Name of the Test	Standard Code
Fineness of cement by Specific Surface Method	IS:269-1080
Consistency of Cement used	IS:4031 (Part IV)
Compressive Strength test	IS:516-1959

8. **Determination of the Nature of R.H.A:** X-Ray Diffraction (XRD) analysis was carried out on 4 gm of RHA sample by a Philips PW 1830 Diffractometer in the department of Metallurgy and Material Science, IEST Shibpur. 35 kW, 25 mA power supply was used for this shown in figure 3. The procedure included a filament made out of copper, which is being pelted by electrons for characteristic Cu-K α X-Ray generation. These rays after passing through a Beryllium monochromatic filter, was radiated towards the sample at an incident angle (Θ) from 2.5°-40° ($2\Theta=5^\circ-80^\circ$) (Vayghan, Khaloo, & Rajabipour, 2013). Specific values of Θ were found as peak intensities as the XRD pattern revealed constructive interference. According to Bragg's Law, the inter-atomic spacing (d) of the crystals formed in the sample is related to the value at each peak. Although the peaks of crystalline materials are very sharp and prominent, the amorphous materials gives very broad peaks without an identifiable Θ value (Vayghan, Khaloo, Nasiri, & Rajabipour, 2012).



Figure 3. The X-Ray Diffraction Instrument in IEST Shibpur

9. **Mixing, Casting and Testing of Concrete Cubes:** Design mix of M40 grade of concrete was prepared conforming to IS: 10262-2009. The ingredients were mixed thoroughly by hand-mixing in surface dry condition. Water and admixture in designed amount were mixed to it as represented by the Table 4 and Table 5. Needle vibrator was used to cast the cubes as shown in the figure 4. Design mix of RHA blended cement samples were also prepared identically. Curing of the samples was done, and the compressive strength of the cubes were tested after 7 days and 28 days of curing in the highway engineering laboratory of IEST Shibpur.

Table 4: The Mix Proportion for the Trial Ppc Concrete Mix

Ingredients	Mix Proportions
Cement	370 kg/m ³
Rice Husk Ash (R.H.A)	0%, 2.5%, 5%, 7.5% & 10% to the total weight of PPC
Water	150 l/m ³
Fine Aggregate	858 kg/m ³
Coarse Aggregate	1090 kg/m ³
Chemical Admixture (Super plasticizer)	7 kg/m ³ (1.85% by weight of Cement)

Table 5: The Mix Proportion for the Trial OPC Concrete Mix

Ingredients	Mix Proportions
Cement	348 kg/m ³
Rice Husk Ash (R.H.A)	0%, 5%, 10%, 15% and 20% to the total weight of OPC
Water	140 l/m ³
Fine Aggregate	894 kg/m ³
Coarse Aggregate	1137 kg/m ³
Chemical Admixture (Super plasticizer)	7 kg/m ³ (2.10% by weight of Cement)



Figure 4: Cement Concrete Cube Casting by Compaction with Needle Vibrator

III. RESULTS AND DISCUSSIONS

Interpretations of the experimental results along with their respective discussions have been done in the article as follows:

- 1. Evaluation of Classical Properties of Tested Modified Cement:** The consistency of the cement samples after adding RHA in the proportions of 0%, 2.5%, 5%, 7.5% and 10% to the PPC and 0%, 5%, 10%, 15% and 20% to the OPC have been evaluated and furnished in the Table 6 and Table 7 respectively. The test results showed increasing trend of consistency for increasing proportion of RHA blended with PPC and OPC. Increasing percentage of porous RHA which is shown in the figure 5 as determined by the Scanning Electron Microscopy (SEM) test, makes the blended mix porous, increasing its water absorption (Marthong, 2012). The change in the workability of the OPC and PPC after addition of RHA has been represented graphically by Figure 6.

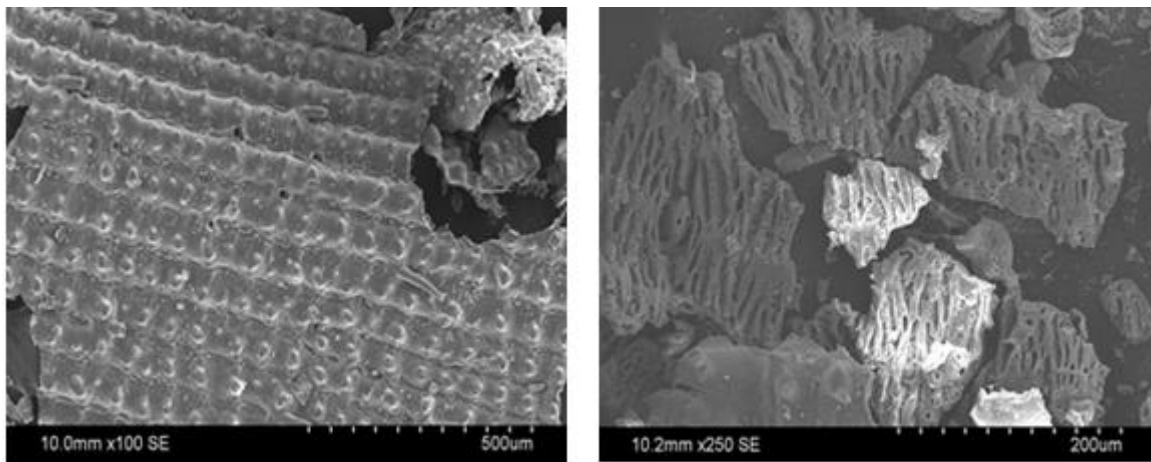


Figure 5: Porous Multi-Layered Structure of RHA Seen under SEM

Table 6: Consistency of PPC Blended With RHA

Percentage of RHA as SCM	Consistency Values
0%	32.0%
2.5%	34.5%
5.0%	36.5%
7.5%	37.5%
10.0%	39.5%

Table 7: Consistency of OPC Blended with RHA

Percentage of RHA as SCM	Consistency Values
0%	28.5%
5.0%	29.0%
10.0%	32.5%
15.0%	38.6%
20.0%	44.0%

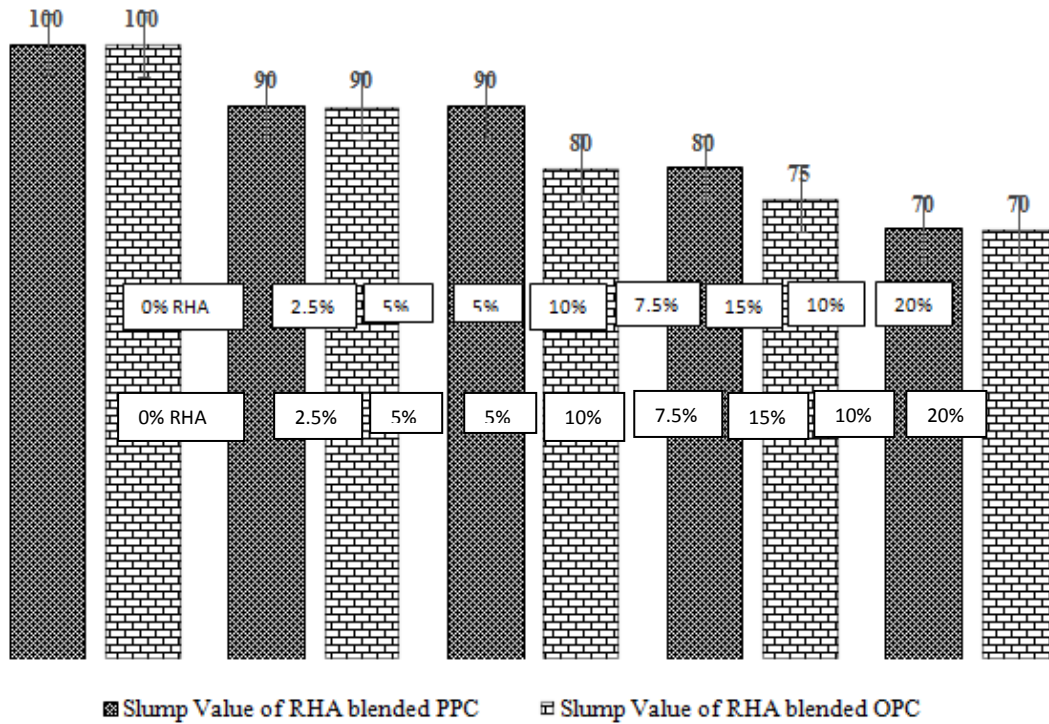


Figure 6: Graphical Representation of the Workability of Concretes When Mixed with the RHA.

2. Detetmination of the Nature of RHA using XRD: XRD analysis was performed on the RHA sample to understand the nature of RHA. According to the analysis as represented by Figure 7 the RHA sample showed crystalline nature. The crystalline nature of the RHA is for the presence of Silica in the form of Cristobalite (Pavia, Lampman, Kriz, & Vyvyan, 2014) and is indicated by the sharp peaks and the identifiable Θ values. This lowers the reactivity of the RHA with the cement.

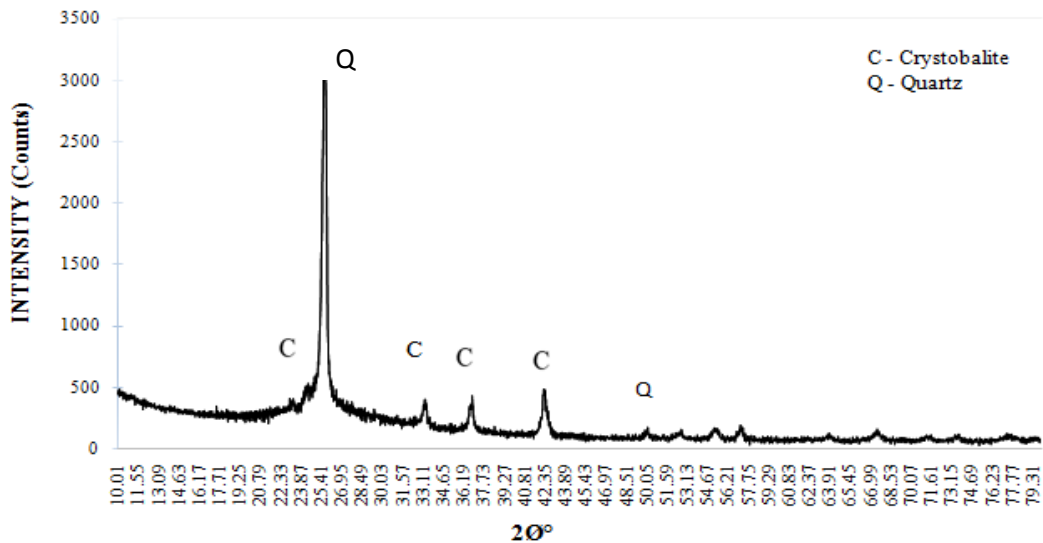


Figure 7: Mineral Phase Detection of RHA using XRD Analysis

- 3. Evaluation of Compressive Strength of RHA Mixed Concrete:** The compressive strength of concrete prepared by varying the ratio of RHA, 0%, 2.5%, 5%, 7.5% and 10% for PPC and 0%, 5%, 10%, 15% and 20% for OPC have been determined for 7 days and 28 days of curing and represented by Table 8, Table 9 and Figure 8, Figure 9 respectively. The compressive strength test machine is shown in Figure 10. Every mortar's compressive strength datum was calculated using the average results of two samples. The test results clearly indicates that with the increase in the content of RHA as SCM the compressive strength also increases initially. However, for both the types of blended cement the value drops after reaching an optimum percentage of SCM, which is 5% for PPC and 15% for OPC. Better results for compressive strength test is observed for RHA blended OPC compared to RHA blended PPC all throughout the curing period. The results confirmed the pozzolanic nature of RHA. The high fineness of the RHA further contributes towards the strength development of the blended concrete (Rajput, Yadav, & Chandak, 2013).

Table 8: Compressive Strength of Concrete Samples Prepared by RHA Blended PPC

Percentage of RHA as SCM	Compressive Strength (MPa)	
	7 days	28 days
0%	20	28
2.5%	22	36
5.0%	34	49
7.5%	30	44
10.0%	28	40

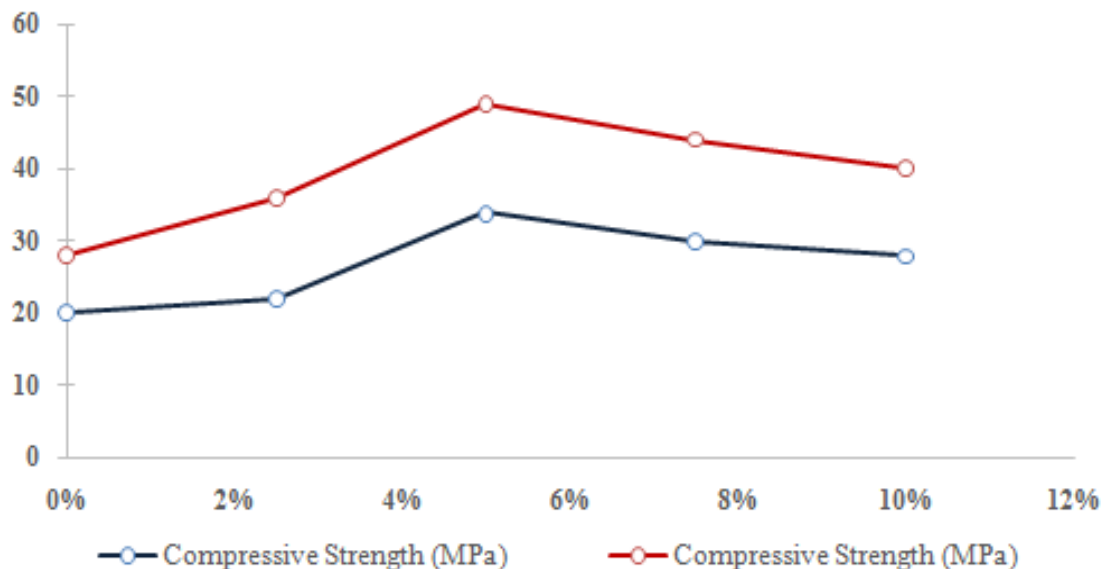


Figure 8: Graphical Representation of Compressive Strength of Concrete Samples Prepared by RHA Blended PPC

Table 9: Compressive Strength of Concrete Samples Prepared by RHA Blended OPC

Percentage of RHA as SCM	Compressive Strength (MPa)	
	7 days	28 days
0%	35	48
5.0%	50	62
10.0%	47	60
15.0%	46	59
20.0%	34	47
25.0%	32	45

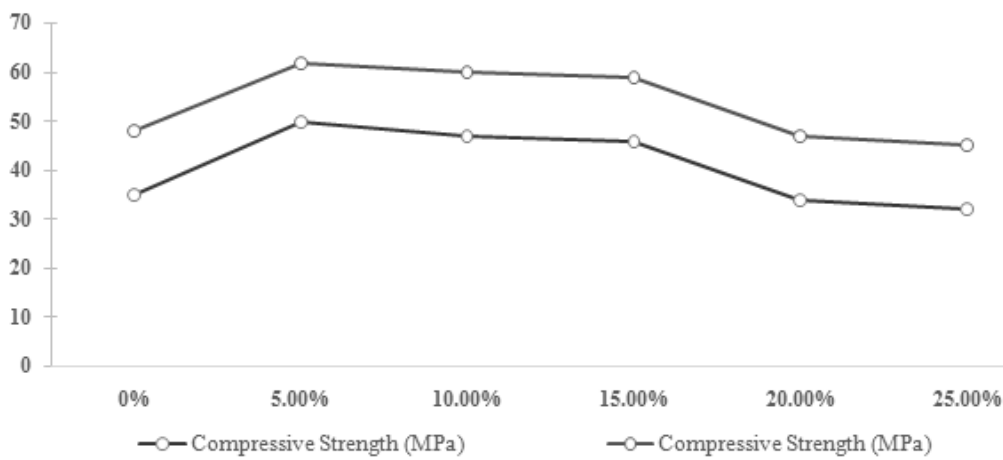


Figure 9: Graphical Representation of Compressive Strength of Concrete Samples Prepared by RHA Blended OPC



Figure 10: Compressive Strength Test Being Conducted

- 4. pH Analysis of Blended Cement Concrete:** The pH determination as shown in figure 11 of the blended OPC with optimum RHA content of 15% and blended PPC with optimum RHA content of 5% after 7 days of curing showed pH reading of 11.20 and 11.68 respectively. This value is substantially lower than the pH value of sound concrete having pore-water pH of 13-13.50 (Dutta, Rakib, Hossain, & Rashid, 2020). RHA consists of silica which is an acidic oxide. On further reaction with water it gives Silicic Acid (H_4SiO_4) having pH 9.02 (Iier, 1979). The lower pH value considerably reduces the concrete brought on by Alkali Aggregate Reaction (AAR) which occurs at higher pH levels. The obtained pH values also reduces the rate of corrosion of the reinforcements in the concrete.

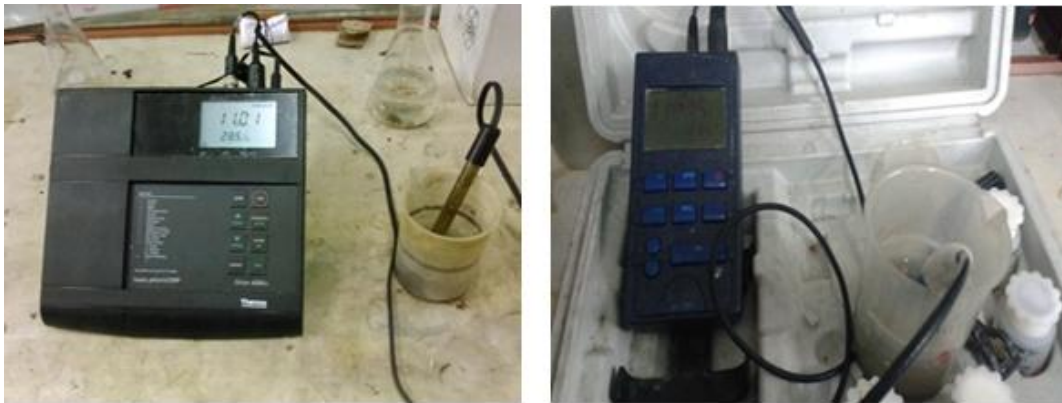


Figure 11: pH Value Determination Of RHA Blended OPC And PPC

IV. CONCLUSION

The above investigational work shows that RHA can be used to replace 15% of OPC by weight. This can be used as SCM for construction of High Grade Concrete (HGC) that is used in Rigid Pavement construction as it gives satisfactory compressive strength. However, the percentage replacement decreases to 5% for PPC which already comes with the Fly Ash mixed in it. Nevertheless, both the blended cement concrete provides satisfactory strength of 49 MPa for PPC with RHA replacement 5% by weight of the cement and 59 MPa for OPC with RHA replacement 15% by weight of the cement, that is required for HGC for roadway rigid pavement. Besides, the utilization of the agricultural by-products not only provides an effective way out towards their disposal but also decreases the construction cost. This further provides a certain amount of advancement towards the sustainable agricultural waste management.

REFERENCES

- [1] 10262, I. (2009). Concrete mix proportioning. New Delhi: Bureau of Indian Standards.
- [2] Cook, D. J., Pama, R. P., & Damer, S. A. (1976). The behaviour of concrete and cement paste containing rice husk ash. Proceedings conference on hydraulic cement pastes: Their structure properties, (pp. 258-262). Sheffield.
- [3] Deshmukh, P., Bhatt, J., Peshwe, D., & Pathak, S. (2012). Determination of silica activity index and XRD, SEM and EDS studies of amorphous SiO_2 extracted from rice husk ash. *Transactions of the Indian Institute of Metals* 65(1), 63-70.

- [4] Dutta, C., Rakib, M. A., Hossain, M. A., & Rashid, M. H. (2020). Effect of mixing water pH on concrete. 5th International Conference on civil engineering for sustainable development. Khulna.
- [5] Gastaldini, A. L., Isaia, G. C., Gomes, N. S., & Sperb, J. E. (2007). Chloride penetration and carbonation in concrete with rice husk ash and chemical activators. *Transportation research board* 29(3), 176-180.
- [6] Givi, A. N., Rashid, S. A., Aziz, F. A., & Salleh, M. A. (2010). Experimental investigation of the size effects of SiO₂ nano-particles on the mechanical properties of binary blended concrete. *Composites Part B: Engineering*, 673-677.
- [7] Iier, R. K. (1979). *The chemistry of Silica: Solubility, polymerization, colloid and surface properties and biochemistry*. New York: John Wiley and Sons Ltd.
- [8] Jaturapitakkul, C., & Roongreung, B. (2003). Cementing material from calcium carbide residue-rice husk ash. *Journal of materials in civil engineering* 15(5).
- [9] Marthong, C. (2012). Effect of rice husk ash as partial replacement of cement on concrete properties. *International journal of engineering research and technology* 1(6), 1-8.
- [10] Mehta, P. K., & Pitt, N. (1976). Energy and industrial materials from crop residues. *Resource recovery and conservation*, 23-38.
- [11] Memon, S. A., Shaikh, M. A., & Akbar, H. (2011). Utilization of Rice Husk Ash as viscosity modifying agent in Self Compacting Concrete. *Construction and Building Materials* 25(2), 1044-1048.
- [12] Mohod, M. V., & Kadam, K. N. (2016). A Comparative Study on Rigid and Flexible Pavement: A Review. *IOSR Journal of Mechanical and Civil Engineering*, e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 13, Issue 3 Ver. VII, 84-88.
- [13] Monteiro, P. J., Shomglin, K., & Wenk, H. R. (2001). Effect of aggregate deformation on alkali silica reaction. *Aci Materials Journal* 98(2), 179-183.
- [14] MoRTH. (2013). *Specifications for road bridge works 5th revision*. New Delhi: Government of India.
- [15] MoRTH. (2023). *Year End Review 2022*. New Delhi: Government of India.
- [16] Nehdi, M., Duquette, J., & Damatty, A. E. (2003). Performance of Rice Husk Ash produced using a new technology as a mineral admixture in concrete. *Cement and concrete research*, 1203-1210.
- [17] Pavia, D. L., Lampman, G. M., Kriz, G. S., & Vyvyan, J. A. (2014). *Introduction to spectroscopy*. Washington: Cengage learning.
- [18] PMGSY. (2017). *Program guidelines for road connectivity projects for left wing extremism affected areas*. New Delhi: Government of India.
- [19] Rajput, J., Yadav, R. K., & Chandak, R. (2013). The effect of rice husk ash used as supplementary cementing material on strength of mortar. *International journal of engineering research and applications* 3(3), 133-136.
- [20] Reddy, B. D., Jyothy, S. A., & Reddy, I. V. (2013). Effect of Rice Husk Ash on the properties of ordinary portland cement and portland slag cement with and without superplasticizers. *International Journal of Civil, Structural Environmental and Infrastructure Engineering Research and Development (IJCSEIERD)* ISSN 2249-6866 Vol. 3, Issue 2, Jun 2013, 1-8, 1-8.
- [21] Sakr, K. (2006). Effects of silica fume and rice husk ash on the properties of heavy weight concrete. *Journal of materials in Civil Engineering* 18(3).
- [22] Vayghan, A. G., Khaloo, A. R., & Rajabipour, F. (2013). The effects of a hydrochloric acid pretreatment on the physicochemical properties and pozzolanic performance of rice husk ash. *Cement and Concrete Composites* (39), 131-140.
- [23] Vayghan, A. G., Khaloo, A. R., Nasiri, S., & Rajabipour, F. (2012). Studies on the effect of retention time of rice husk combustion on the ash's chemo-physical properties and performance in cement mixtures. *Journal of Materials in Civil Engineering* 24(6).
- [24] Zain, M. F., Islam, M. N., Mahmud, F., & Jamil, M. A. (2011). Production of rice husk ash for use in concrete as a supplementary cementitious material. *Construction and Building Materials* 25(2), 798-805.
- [25] Zhang, M. H., Lastra, R., & Malhotra, V. M. (1996). Rice husk ash paste and concrete: Some aspects of hydration and the microstructure of the interfacial zone between the aggregate and paste. *Cement and Concrete Research*, 963-977



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Volume 3 Book 4, 2024, IIP Series

ISBN : 978-93-5747-676-8



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