Innovating Concrete Production: Harnessing the Waste Plastic Bottles for Sustainable Construction

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Abstract - **Concrete production has long relied on traditional materials, but the growing concerns surrounding plastic waste and sustainability have prompted the exploration of alternative solutions. The creative use of leftover plastic bottles as a revolutionary material in the manufacturing of concrete for environmentally friendly building techniques is the main topic of this study. The purpose of the study is to examine the viability and possible advantages of using used plastic bottles as a concrete alternative. It assesses the durability, workability, mechanical qualities, and environmental impact of concrete mixtures made from recycled plastic bottles. The study investigates several kinds of plastic bottles, methods of processing, and mix designs in order to maximize the sustainability and performance of the final concrete. The concrete mix design for M20 grade was established in this study based on a thorough review of the literature. It included different proportions of waste crushed plastic bottles to replace fine aggregate. In particular, we took into account replacement weights of 5%, 10%, and 15% of the fine aggregate. Plastic bottle addition has a substantial impact on concrete's compressive strength; strength enhancement and the percentage of plastic are positively correlated. Interestingly, after 28 days of curing, the addition of 15% plastic by weight causes a significant increase in strength, roughly 23.65%.**

***Keywords* — waste plastic bottles, innovation, sustainable construction, harnessing, sustainability.**

I. INTRODUCTION

Traditionally, the process of making concrete, a basic building material, has involved using standard materials like cement, aggregates, and water. However, the growing concerns surrounding plastic waste and the urgent need for sustainable construction practices have prompted researchers and practitioners to explore innovative approaches to revolutionize concrete production. The goal of this project is to employ used plastic bottles as a revolutionary material in the production of concrete for environmentally friendly building.

Plastic waste has emerged as a significant global environmental challenge, with its improper disposal leading to detrimental impacts on ecosystems and human health. The accumulation of plastic bottles, in particular, has reached alarming levels, necessitating effective waste management strategies. A viable way to address the plastic waste problem and the need for sustainable building materials is to use used plastic bottles in concrete.

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The research investigates various aspects of innovating concrete production with waste plastic bottles. In order to determine whether waste plastic bottle concrete is suitable for structural applications, it looks at its mechanical characteristics, including impact resistance, flexural strength, and compressive strength. Furthermore, the resilience of waste plastic bottle concrete is assessed in terms of its ability to withstand weathering, chemical deterioration, and exposure to the environment. This study advances the use of discarded plastic bottles in the manufacturing of concrete, which is in line with the circular economy principles and sustainable construction methods. The results and understandings obtained from this study will offer significant direction for the application and acceptance of recycled plastic bottle concrete in the building sector, opening the door to a more ecologically conscious and sustainable future.

The first lightweight concrete products were created in the early 1960s after extensive research and development employing polystyrene-based granulates in place of standard aggregates. Growing awareness of waste management and the rising cost of aggregates drove this invention. But this concrete's delicate consistency was initially a problem. By adding particular additives, a team of engineers created and patented an industrially stable version of polystyrene concrete in 1990. Despite the fact that the original ingredients were costly and unfriendly to the environment, the finished product had a compressive strength of 3–4 N/mm2, which qualified it for use as wall insulation. This achievement proved that the procedure wasworkable.

An attempt was made to commercialize the technology in 2001 by substituting a health-neutral polymer component for the binding elements. To evaluate compressive strength and fire resistance, numerous laboratory tests were carried out. The lightweight polystyrene concrete demonstrated exceptional fire-retardant qualities and proved to be structurally stable, with a density ranging from 100 to 300 kg/m3. Following a request from Argentina, the potential use of pine tree leaf waste as aggregates was explored in 2004, leading to the discovery that not only polystyrene but also various other types of shredded solid waste could serve the purpose. This insight led to the filing of a patent application in 2015, which was later granted in 2017–2018.

The patent covers any additive that permits the partial or complete replacement of natural aggregates with mixed shredded solid waste granules. There are over 3000 possible final goods that can be made from the waste lightweight concrete product that is produced. Concrete made of polystyrene, concrete made of heavy plastic, concrete made of burned bottom ash, concrete made of desert sand, and many more are examples. Approximately 400 samples with various physical characteristics have been created as of the time of writing. These finished goods typically have weights between 100 and 800 kg/m3 and compressive strengths between 3 and 12 N/mm2. By contrast, the compressive strength of conventional gravel- concrete can reach 40 N/mm2.

II. NEED OF THE STUDY

A. *Plastic Waste Crisis:*

There is a serious plastic trash problem in the world, with improper plastic disposal and accumulation having detrimental effects on the environment and human health. Plastic bottles, in particular, contribute substantially to this crisis. Finding effective solutions to manage and utilize plastic waste is essential to mitigate the detrimental impacts on ecosystems and human well-being.

B. *Sustainable Construction Practices:*

One of the biggest users of natural resources and a major cause of environmental deterioration is the construction sector. Adopting sustainable construction practices is imperative to reduce the industry's ecological footprint and promote environmental stewardship. Exploring alternative materials, such as waste plastic bottles, can contribute to achieving sustainable construction goals.

C. *Resource Efficiency:*

The depletion of natural resources used in concrete production, such as sand and aggregates, calls for novel techniques to boost resource efficiency. Waste plastic bottles can be used as an alternative material to help lessen the dependency on conventional resources, protecting natural resources and encouraging a more circular economy.

D. *Performance Enhancement:*

Ensuring safe and long-lasting constructions requires improving concrete's mechanical qualities, durability, and workability. These qualities could be improved by adding used plastic bottles to concrete, creating stronger, more resilient infrastructure and concrete that performs better.

E. *Market Demand and Competitiveness:*

Due to government initiatives, market competition, and environmentally concerned customers, there is an increasing need for sustainable construction materials and techniques. Developing innovative concrete production methods using waste plastic bottles can provide a competitive edge to construction companies and attract environmentally responsible customers.

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III. PROBLEM STATEMENT

Addressing the issue of plastic waste while pursuing sustainable practices presents a big challenge for the building sector. Sand and aggregates are examples of natural resources that are used extensively in conventional concrete manufacturing yet are limited and non-renewable. In addition, inappropriate plastic bottle disposal pollutes the environment, endangers ecosystems, and is harmful to people's health. The use of used plastic bottles in the manufacturing of concrete is still quite low, despite their potential as a resource for environmentally friendly building. When it comes to using used plastic bottles as a concrete substitute, there is a dearth of thorough research and useful application. Important problems and gaps that require attention include:

1. Limited Knowledge: The mechanical characteristics of concrete that contains leftover plastic bottles are not well understood. Research is required to determine how adding used plastic bottles to concrete impacts its impact resistance, flexural strength, and compressive strength. Such knowledge is vital for assuring the structural integrity and performance of concrete buildings.
2. Durability Assessment: It is necessary to carefully evaluate how long-lasting concrete made from used plastic bottles is. Examining elements including weathering, chemical resistance, and exposure to the environment is necessary to guarantee the long-term viability and lifespan of concrete structures.
3. Workability Considerations: The workability of concrete, including aspects such as slump, flow ability, and setting time, is essential for its practical application in construction. Investigating the workability characteristics of concrete incorporating waste plastic bottles is necessary to ensure compatibility with construction practices and ease of placement.
4. Environmental Impact Evaluation: A comprehensive assessment of the environmental impact of waste plastic bottle concrete is required. Life cycle assessments should be conducted to quantify factors such as energy consumption, carbon emissions, and waste reduction, providing a clear understanding of the environmental benefits and trade-offs associated with this innovative approach.

- **Environmental Pollution:** One of the major challenges of waste plastic is its environmental pollution. Improper disposal and inadequate waste management systems lead to plastic waste entering water bodies,soil, and ecosystems, causing harm to wildlife and marine life.
- **Non-Biodegradability:** The majority of plastic materials are non-biodegradable, meaning they do not undergo natural decomposition processes over time. Instead, they remain in the environment for extended periods, often spanning hundreds of years. This inherent quality of plastic waste significantly contributes to the pollution issue, as the accumulated plastic waste persists in landfills and continues to contaminate the environment.
- **Microplastic Contamination:** With the passage of time, larger plastic objects gradually disintegrate into smaller fragments called microplastics, which measure less than 5mm in size. These microplastics are widely distributed throughout the environment and can be detected in water bodies, soil, and even the air we inhale. Their ability to infiltrate the food chain poses risks to both human health and ecosystems, exerting potential impacts.

IV. LITERATURE REVIEW

[1] The effects of adding ground granulated blast furnace slag (GBFS) to waste plastic bottle lightweight aggregate (WPLA) concrete were studied by Yun-Wang Choi, Dae-Joong Moon, et al. in 2005. Through a reaction with calcium hydroxide, the connected GBFS increased the surface area of WPLA and decreased the transition zone. Although structural efficiency and compressive strength were reduced, WPLA's increased workability and surface highlighted the possible advantages of utilizing discarded PET bottles in lightweight concrete. [2] The shear strength of glass fiber-reinforced concrete (PFRC) composed of recycled plastic (PET) was the main topic of study for R. N. Nibudey et al. (2014). The study looked at M20 and M30 grade concrete that included unprocessed PET fibers taken from old mineral water bottles. Concrete samples were examined following a 28-day curing period, during which different quantities of fiber (ranging from 0% to 3%) were applied. [3] The viability of adding waste PET bottle fibers with varying aspect ratios (17, 33, and 50) into concrete was examined by P. Ganesh Prabhu et al. (2014). In place of fine aggregate, various fiber contents (0.5%, 1%, and 1.5% were added). After 3, 7, and 28 days, tests were conducted to determine the compressive strength, splitting tensile strength, and flexural strength in comparison to an unaltered control mix. [4] In order to partially replace fine aggregates in concrete with crushed waste plastic bottles, Sahil Verma et al. (2015) tackled the problem of managing waste plastic materials. The study emphasized the possible advantages for the environment of correctly encasing used plastic bottles in concrete, so lessening their influence on the ecosystem. [5] The use of plastic waste material as a partial substitute for fine and coarse aggregates in M-40 grade concrete was investigated by M Lokeshwari et al.

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(2019). The study discovered that even while the qualities of both fresh and hardened concrete decreased, they were still appropriate for lower-grade uses such canal lining, precast bricks, panel walls, and partition walls. [6] In order to provide a sustainable alternative for managing plastic waste, P.P. Sambhaji (2016) concentrated on the use of recycled plastics as coarse aggregates in concrete. The building industry may efficiently and sustainably use this waste material by adding recycled plastics. [7] Md.

Zakaria Habib et al. (2017) found that the compressive strength, tensile splitting strength, and flexural strength of concrete decreased with higher percentages of recycled plastic aggregate. The dry density of the concrete also decreased as the percentage of recycled plastic increased compared to the reference concrete. [8] Pramod S. Patil et al. (2014) found that concrete showed strength within allowable bounds when plastic aggregates were used to partially substitute coarse aggregates, up to a 20% threshold. Following a 20% substitution of coarse particles in the concrete, density dropped. [9] K. Sai Gopi et al. (2020) In the study, recycled plastic trash was used in varying percentages to partially replace the fine aggregate (river sand) in concrete of M30 grade. It was found that as the proportion of recycled plastic waste rose, the concrete's workability fell. The best replacement percentage for polyethylene terephthalate (PET) was determined to be 10%; the use of polypropylene (PP) resulted in a minor decrease in compressive strength, up to a replacement percentage of 5%. [10]The workability, mechanical, microstructural, economic, and thermal qualities of concrete were evaluated by Gideon O. Bamigboye (2021). Different ratios of river sand, granite, and heat-processed waste PET were used in a mix design for M25 grade concrete. The results showed that the concrete's workability increased up to a PET level of 40%, after which it began to decrease. As the proportion of waste PET in the concrete increased, so did its compressive and split tensile strengths. Nevertheless, the concrete mixtures nevertheless reached the required strength for M20 concrete, even with 10% to 40% PET component. [11]PET waste has been studied as a potential partial substitute for fine aggregate in concrete by Mastan Vali N et al. (2017). Different substitution levels (0%, 5%, 10%, 15%, and 20%) were used to make concrete samples, which were then compared to the control mix. Compressive strength fell by 15% and 20% and increased by up to 10% when fine aggregate made from PET waste was substituted. Flexural strength was constant for 20% of replacement and rose to 10% of it. [12] The use of recycled PET waste bottles as a partial substitute for natural coarse aggregate in green concrete was investigated by Rashedul Haque et al. in 2021. Four replacement percentages (0%, 1%, 5%, and 10%) were investigated using PET fibers of varying diameters. Insights into the ideal replacement percentages and fiber sizes for PET-based green concrete were gained by examining the relationship between compressive strength and fiber size and replacement percentage.

[13]Shubbar, Sawsan D. A. et al. (2016) looked at the effects of adding granulated waste PET to concrete. Granulated plastic was substituted for sand in several ratios, and the resulting concrete's characteristics were assessed. The study determined that 2% was the ideal replacement dosage for fine aggregate, leading to the maximum split and compressive strengths. [14]The physical and mechanical characteristics of concrete with different percentages of processed plastic aggregates used in place of natural aggregates were examined by Zoe Harmonie Lee et al. (2019). Chemical treatment improved bond strength, reduced the interfacial transition zone gap, enhanced compressive strength, and reduced permeability and porosity. The treated plastic aggregates' roughened surface reduced the slump, but the fresh density stayed unchanged.

[15] Rahul Mane et al. (2019) evaluated the usage of plastic coarse particles in the M20 concrete mix for casting paver blocks. For replacements of 2.5%, 3%, and 4% plastic coarse aggregate, compressive strength was found to be high; at 10% replacement, it began to decrease. [16] Pathil (2015) states that adding plastic aggregate to the concrete mix up to a maximum of 20% will successfully improve the mix and produce suitable strength values. It should be observed, nevertheless, that the density of the concrete begins to drop beyond this point, notably after replacing 20% of the coarse aggregates. [17] Ramamadevi et al. (2012) discovered that while strength declined at 4%, adding 1% to 2% PET fiber to concrete enhanced both compressive and flexural strength. [18] In 2015, Magalhães et al. looked into how recycled PET fibers performed as reinforcement in cementitious matrices. The toughness, deflection capacity, and post-cracking behavior of mortars were all markedly enhanced by the addition of PET fibers. It was discovered that 2% of PET fibers was the ideal volume for the optimum workability and performance. [19] Using recovered PET trash, Rebeiz and Fowler (2012) investigated the flexural behavior of steel-reinforced polymer concrete (PC). Recycled PET was added to increase the material's flexural strength, which made it appropriate for use in overlays for walls, floors, and bridges, as well as precast components and concrete repair materials. [20] An analysis of the book Use of Waste Plastic as Binder to Create Construction Elements in Place of Cement. (© June 2023| ISSN: 2349-6002, IJIRT, Volume 10, Issue 1). [21] In their discussion of theories and case studies, Dakshayini R. Patil et al. (2023) emphasized the creative application of municipal solid waste (MSW) in urban architecture,

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placing equal emphasis on utility and aesthetics. The study underlined the significance of zero- waste and reasonably priced municipal projects that improve cities' usability and aesthetic appeal.

V. SUMMARY AND FINDINGS FROM LITERATURE SURVEY

Use CGS or SI (MKS) as your main units. (SI units are highly recommended.) You can use English units (in parentheses) as secondary units. Data storage papers fall under this category. Write "15 Gb/cm2 (100 Gb/in2)" as an example. The usage of English units as trade identifiers, as "3½-in disk drive," is an exception. Units such as current in amperes and magnetic field in oersteds should not be combined with SI and CGS units. The fact that equations do not balance dimensionally frequently causes difficulty. If you must use mixed units, make sure each quantity in an equation has a defined unit of measurement.

A/m is the SI unit used to express magnetic field strength

H. But if you want to work in units of T, you can utilize magnetic flux density B or the magnetic field strength represented by µ0H. To distinguish between compound units, such as "A·m2," use the center dot.

Findings from the Literature Review :

The following points can be summed up based on the completed literature review:

1. Influence on workability: Up to a specific proportion, the workability of concrete can be increased by adding used plastic bottles. But the workability starts to decline beyond that point. To keep the concrete mix's intended workability, it's critical to maximize its plastic content.
2. Impact on compressive strength: There are both favorable and unfavorable impacts of waste plastic bottle content in concrete. Greater levels of plastic material typically result in a loss in compressive strength. Nonetheless, some research indicates that a small quantity of plastic can improve the concrete's strength.
3. Flexural and tensile strength: The addition of waste plastic bottles may have an impact on the flexural and tensile strength of concrete. The addition of plastic may increase these qualities in some situations while decreasing them in others. The impact could change according on the kind and percentage of plastic used.
4. Durability considerations: The long-term durability of concrete incorporating used plastic bottles has not been extensively studied. Further investigation is needed to assess the performance of plastic-modified concrete under various durability aspects, such as chemical resistance, freeze-thaw cycles, and creep.
5. Optimum plastic content: The ideal proportion of used plastic bottles to replace in concrete varies depending on the study. Determining the right amount of plastic content to balance the concrete mix's strength, workability, and other performance attributes is essential.
6. Environmental benefits: The usage of waste plastic bottles in concrete gives environmental benefits by minimizing plastic waste and saving natural resources. It offers an alternate method of disposing of plastic trash and supports environmentally friendly building techniques.

VI. RESEARCH GAP

A list of some of the research gaps is as follows:

1. **Optimization of plastic content:** One critical issue that needs more research is the ideal replacement ratio of used plastic bottles in concrete. Different studies have reported varying results regarding the replacement levels at which the desired strength and properties are achieved. Additional research is necessary to determine the optimum content of waste plastic bottles that balances strength, workability,and other performance characteristics.
2. **Effects on other properties:** Although workability and compressive strength of concrete have been extensively researched, other properties of concrete that are affected by waste plastic bottles need to be investigated. These consist of permeability, shrinkage, modulus of elasticity, and flexural strength. Understanding the influence of waste plastic bottles on these qualities will enable a more comprehensive assessment of the feasibility of plastic bottle integration in concrete.

VII. AIM AND OBJECTIVES

The objectives obtained from this project are as follows:

1) Examine the viability of using used plastic bottles as a substitute material while producing concrete.
2) Examine the slump value of concrete by analyzing its workability using leftover plastic bottles.
3) Access the mechanical properties of concrete containing plastic bottles including compressive and flexural strength.
4) Improve the workability and strength of the waste plastic bottle concrete mix design.

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VIII. METHODOLOGY

1. Literature Review: carried out a thorough analysis of pertinent research papers and literature on the use of used plastic bottles to make concrete. This review will lay the groundwork for current understanding, point out areas in need of further research, and guidethe study's methodology.
2. Collection and Sorting of Waste Plastic Bottles: Collect a sufficient quantity of waste plastic bottles from various sources. Sort and categorize the bottles based on their material composition and quality. Ensure that the collected bottles are clean and free from contaminants.
3. Bottle Preparation: Prepare the waste plastic bottles for incorporation into concrete by removing labels, caps, and other non-concrete-friendly components. Cut the bottles into appropriate sizes or shred them to facilitate their integration into the concrete mixture.
4. Concrete Mix Design: Provide ideas for M20 Grade concrete mixes that use recycled plastic bottles in place of some of the traditional aggregates. Based on the desired attributes of the concrete, such as strength, workability, and durability, determine the ideal proportion of plastic bottle aggregates.
5. Mixing and Casting: Mix the concrete ingredients, including cement, water, fine aggregates, and plastic bottle aggregates, using suitable mixing techniques. Ensure proper dispersion and homogeneity of the plastic bottle aggregates within the concrete mixture. Cast the concrete into molds or formwork according to the desired shape and dimensions.
6. Testing and Evaluation: To assess the capabilities and characteristics of the concrete including plastic bottles, run a number of experiments. Tests for water absorption, durability, flexural strength, and compressive strength are all included in this. For performance study, compare the test results with those of traditional concrete.
7. Because plastic has been used more and more carelessly in recent decades, its perceptibility is rising dramatically. Its natural breakdown might take millennia, and it would be harmful to both human health and the environment. Global plastic trash disposal is severely hampered by the volume of rubbish that has accumulated in the twenty-first century. The 3.5 million tons of plastic trash produced in India each year present a significant challenge for waste management and disposal.

- **Materıals used and mix proportions:**

The different materials used in this investigation are:

1. Clinker, gypsum, and a few additional ingredients, including limestone or pozzolanic minerals, are ground to create OPC 53 grade cement. OPC 53 grade cement's increased strength makes it appropriate for a range of construction projects, such as those involving high-rise buildings, bridges, and infrastructure.
2. Filling the spaces between the coarse aggregate particles and producing a workable mixture is the primary purpose of fine aggregate in concrete. It facilitates easier placement and compacting of the concrete mix by enhancing its cohesion and workability. Furthermore, fine aggregate enhances the hardened concrete's strength, longevity, and general quality.
3. The main function of coarse aggregate in concrete is to provide bulk and volume to the mixture. It helps to reduce the shrinkage and cracking potential of concrete by minimizing the cement-to-water ratio. Coarse aggregate also enhances the workability of concrete by providing a solid framework for the cement paste to bind with.
4. There are many advantages to reusing used plastic bottles for building. First of all, it contributes to a decrease in the quantity of plastic trash that contaminates the environment or ends up in landfills. Second, adding leftover plastic bottles to building supplies may improve the end goods' characteristics and functionality. In the context of concrete manufacturing, waste plastic bottles can be utilized as a partial replacement for traditional aggregates such as fine aggregate or coarse aggregate. Usually, the bottles are broken into tiny fragments or made into granules so they may be mixed into the concretemixture.

- **Mix proportions:**

Following the guidelines outlined in IS 10262:2019, a concrete mix was proportioned to achieve a target compressive strength of 20MPa. Two sets of mixed designs were formulated: one incorporating waste plastic and the other without any inclusion of waste plastic. Furthermore,

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multiple variations of mix designs were created by replacing a percentage of the fine aggregate with waste plastic.

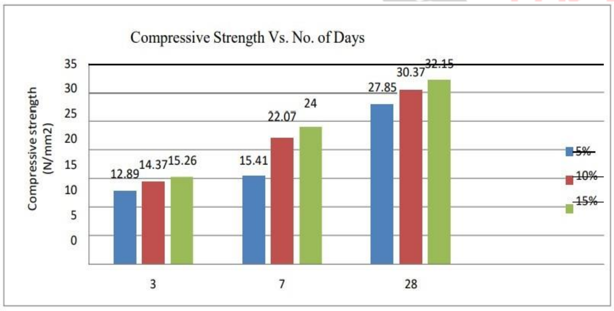
- **Quantity of material for 1m3 concrete:**

Percentage	Weight of Cement (kg)	Weight Waste plastic bottles (kg)	Weight of M-Sand (Kg)	Weight of aggregate(kg)
0%	360	0	745	1156
5%	360	37.25	707.75	1156
10%	360	74.5	670.5	1156
15%	360	111.75	633.25	1156

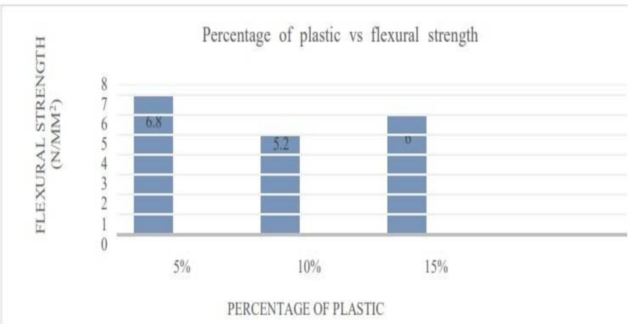
Result and discussion:

The results of the study indicate that the incorporation of waste plastic in the concrete mixture has a noticeable impact on various properties and characteristics of the concrete. The following discussions summarize the findings:

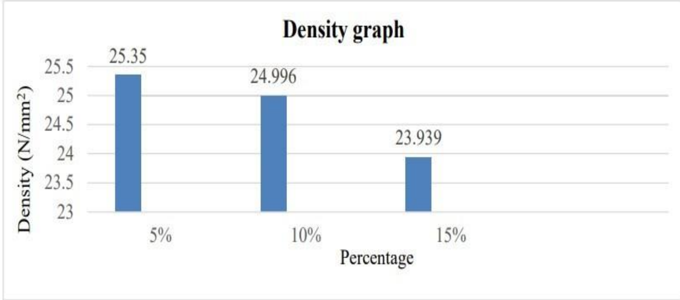
The graph shows the results for the compressive strength of concrete by adding the different percentages of plastic waste bottles.



The graph shows the result for the flexural strength of concrete by the addition of different percentages of plastic waste bottles.



The graph shows the result for the density of concrete by the addition of different percentages of plastic waste bottles.



IX. CONCLUSION

Crushed waste plastic bottles were used in place of the fine aggregate in a concrete mix design for M20 grade, with the fine aggregate being replaced at weight percentages of 5%, 10%, and 15%. It was investigated how the inclusion of plastic bottles affected the concrete's density, flexural and compressive strengths.

The findings showed that adding plastic bottles to the concrete had a favorable impact on its compressive strength, with strength increasing as the proportion of plastic increased. In particular, after 28 days, the addition of 5% plastic increased the compressive strength by about 7%. Similarly, after 28 days, the addition of 10% plastic significantly increased the compressive strength by 16.80%.

In terms of flexural strength, it was observed that the inclusion of plastic bottles had an impact, with the optimum strength achieved at a 10% inclusion. However, as the percentage of plastic increased beyond this optimal level, the flexural strength showed a decrease. Moreover, the average density of the concrete decreased in proportion to the increase in plastic content.

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