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Experimental Study on Strength of Concrete by Using Partial Replacement of Coarse Aggregate with Plastic Waste

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Abstract -The plastic waste is one of the most hazardous pollutant for environment because of slow degradation process, the plastic take a year to degrade. Plastic waste accumulation has become a major environmental issue worldwide. One innovative approach to addressing this challenge is its incorporation into concrete as a partial replacement for conventional materials. This study explores the feasibility of using plastic waste, such as polyethylene terephthalate (PET) bottles, polyvinyl chloride (PVC) pipes, or other types of plastic waste, in concrete mixtures to enhance sustainability. The idea behind this experiment is to overcome these plastic waste with the reuse as a constructional material in order to overcome the environmental problems that the world is facing. The research investigates the effects of replacing fine or coarse aggregates with plastic waste in varying proportions. Key properties, including workability, compressive strength, tensile strength, and durability, are analyzed. Results indicate that while excessive plastic content may reduce mechanical strength, an optimal percentage can improve impact resistance, reduce density, and offer an eco-friendly alternative to traditional concrete. This paper aim to review the usage of the plastic waste. It is added into the concrete in a range of 5% , 10% and 15%. After the casting and curing of concrete cubes, we are going to conduct destructive compression tests, non destructive compression tests, characteristic properties of concrete tests on modified concrete cubes and conventional concrete cubes of M25 grade concrete. As the result the experiment result is compared with modified concrete cubes to conventional concrete cubes the strength is decreased.

***Key Words*:** Plastic waste, Environmental pollution, Sustainable construction, Concrete modification, Waste management, Recycling.

INTRODUCTION

Plastic's widespread use has generated a massive waste problem due to its low biodegradability. Its durability and strength, however, offer potential in concrete mixes, providing a sustainable disposal method. The escalating volume of plastic waste, particularly polyethylene from packaging like water bottles, poses a significant environmental challenge. Recycling rates for plastics are notably lower than for materials like glass and paper.

Utilizing plastic flakes as a partial aggregate replacement in non-load-bearing concrete blocks presents a viable solution. This approach addresses waste disposal while potentially enhancing concrete properties such as tensile strength and chemical resistance. Furthermore, it aligns with the construction industry's growing emphasis on sustainability.

Polyethylene's desirable characteristics, including chemical and corrosion resistance, make it a suitable material for this application. The continuous increase in disposable plastic waste necessitates urgent research into eco-friendly disposal methods. Improper disposal contributes to global pollution, with materials like polystyrene and terephthalate exacerbating the issue. Reusing plastic waste is crucial for conserving non-renewable resources. Incorporating it into concrete offers a dual benefit: safe disposal and potential improvement in concrete performance. This method provides a long-term strategy for managing plastic waste and reducing environmental impact.

HISTORY AND BACKGROUND

Concrete, a composite of aggregate and cement, is the world's second most used substance after water. Its history spans over 8,000 years, with early forms used by the Nabataeans (6500 BC) and Egyptians (2580 BC). The Romans significantly advanced concrete technology with Opus cementitious, constructing iconic structures like the Pantheon and Colosseum. After the Roman Empire, concrete use declined in Europe but revived during the Renaissance.

The 18th century saw crucial advancements with hydraulic lime and Joseph Aspdin's invention of Portland cement in 1824, leading to more refined concrete. The 20th century marked the introduction of reinforced concrete, enabling taller and stronger buildings.

Concrete is vital for climate-resilient structures and can incorporate industrial wastes like fly ash. Mixing Portland cement, aggregate, and water creates a fluid slurry that hardens through hydration, forming a durable material. This process allows for shaping and tooling. Hydration is exothermic, influenced by ambient temperature. Additives improve wet mix properties and alter curing. Reinforcement provides tensile strength, creating reinforced concrete.

Historically, lime-based binders were common, sometimes combined with hydraulic or Portland cement. Non-cementitious concretes, like asphalt and polymer concretes, also exist. Concrete differs from mortar, which is a bonding agent. Today, concrete continues to evolve with high-performance materials and sustainable practices, maintaining its fundamental role in modern construction. Concrete grades (e.g., M20, M25) denote compressive strength and are crucial for structural integrity based on load and environmental conditions.

OBJECTIVES

- Evaluate the feasibility of utilizing various plastic waste materials (PET, PVC, etc.) as a partial replacement for aggregates in M25 grade concrete.
- Determine the optimal percentage of plastic waste (5%, 10%, 15%) that can be incorporated into concrete mixtures without significantly compromising mechanical strength.
- Analyze the impact of plastic waste inclusion on the workability, compressive strength (destructive and non-destructive), and tensile strength of modified concrete compared to conventional concrete.
- Investigate the durability characteristics of plastic-modified concrete, specifically focusing on its resistance to environmental factors and potential degradation.
- Assess the potential of using plastic waste in concrete as a sustainable waste management solution, contributing to environmental pollution reduction.
- Compare the characteristic properties of M25 grade concrete with and without added plastic waste to quantify the changes in material behavior.
- Explore the potential benefits of plastic waste incorporation, such as improved impact resistance and reduced concrete density, in the context of sustainable construction practices..

METHODOLOGY

Material Acquisition and Preparation: Gather and prepare plastic waste (PET, PVC, etc.) and standard concrete aggregates.

Mix Design Formulation: Develop M25 grade concrete mix designs, including variations with 5%, 10%, and 15% plastic waste as aggregate replacement, and a control (conventional) mix.

Concrete Cube Casting: Fabricate standardized concrete cubes for each mix design (conventional and plastic-modified).

Curing Process: Cure the concrete cubes under controlled conditions for a specified duration.

Workability Assessment: Conduct workability tests on fresh concrete mixes to evaluate ease of placement.

Mechanical Strength Testing: Perform destructive and non-destructive compression tests, and tensile strength tests on hardened concrete cubes.

Durability and Density Analysis: Evaluate the durability of concrete samples under environmental stress, and measure the density of the cubes.

Data Analysis and Comparison: Analyze the test results, compare the performance of plastic-modified concrete with conventional concrete, and determine the optimal plastic waste percentage

MATERIALS

1Cement
2Fine Aggregate
3Coarse Aggregate
4Plastic waste

1. Cement:

Ordinary Portland Cement is by far the most common type of cement in general use around the world. This cement is made by heating limestone (calcium carbonate) with small quantities of other materials (such as clay) in a kiln, in a process known as calcination, where by a molecule of carbon dioxide is liberated from the calcium carbonate to form calcium oxide, or quicklime, which is then blended with the other materials that have been included in the mix. The resulting hard substance, called "Clinker", is then ground with a small amount of gypsum into a powder to make 'Ordinary Portland Cement', the most commonly used type of cement(often referred to as OPC). Portland cement is a basic ingredient of concrete, mortar and most non-specialty grout.

2. Fine Aggregate

Aggregate is the granular material used to produce concrete or mortar and when the particles of the granular material are so fine that they pass through a 4.75mm sieve, it is called fine aggregate. Fine aggregate is the essential ingredient in concrete that consists of natural sand or crushed stone. The quality and fine aggregate density strongly influence the hardened properties of the concrete. It is formed by decomposition of sand stones due to various effects of weather. The shape and surface structure of fine aggregate as a greater influence on water demand of concrete than because fine aggregate contains a much higher surface area for a given weight. Smooth and rounded fine aggregate particles are better for workability than sharp and rough particle.

Fig: sieve analysis of fine aggregate

Table: Result of sieve analysis of fine aggregate

Sieve size (mm)	Weight Retained (g)	Cumulative weight retained (g)	Retained %	% Passing
4.75 mm	50	50	5%	95
2.36mm	100	150	10%	85%
1.18mm	150	300	15%	70%
600μm	250	550	25%	45%
300μm	250	800	25%	20%
150μm	150	950	15%	5%
Pan	50	1000	5%	0%

3. Coarse Aggregate

Coarse aggregates refer to irregular and granular materials such as sand, gravel, or crushed stone, and are used for making concrete. In most cases, Coarse is naturally occurring and can be obtained by blasting quarries or crushing them by hand or crushers. Coarse aggregates are any particles greater than 0.19 inch, but generally range between 3/8 and 1.5 inches in diameter. Gravels constitute the majority of coarse aggregate used in concrete with crushed stone making up most of the remainder. Coarse aggregates are a crucial component of concrete mixtures, playing a vital role in providing strength, stability, and durability to the final product. Typically, coarse aggregates consist of crushed stone, gravel, or a combination of both, with particle sizes ranging from 4.75 mm to 40 mm. The most commonly used coarse aggregates in concrete are limestone, granite, and basalt.

Sieve size (mm)	Weight Retained (g)	Cumulative weight retained (g)	Retained %	% Passing
40mm	0	0%	0%	100%
20mm	200	20%	20%	80%
10mm	350	35%	55%	45%
4.75mm	400	40%	95%	5%
Pan	50	5%	100%	0%

4. Plastic Waste

Plastic is material consisting of any of a wide range of synthetic or semi-synthetic organic compounds that are malleable and so can be moulded into solid objects. Plastics are typically organic polymers of high molecular mass and often contain other substances. They are usually synthetic, most commonly derived from petrochemicals. The use of plastic waste in concrete, also known as "plastic concrete" or "polymer concrete," is a growing trend in the construction industry. This innovative approach involves mixing plastic waste, such as polyethylene terephthalate (PET) bottles, polyvinyl chloride (PVC) pipes, or other types of plastic waste, with cement, sand, and water to create a durable and sustainable building material. The plastic waste is typically shredded or crushed into small pieces and then mixed with the concrete ingredients.

Fig: Plastic Waste

RESULTS AND DISCUSSIONS

COMPRESSIVE STRENGTH OF CONCRETE

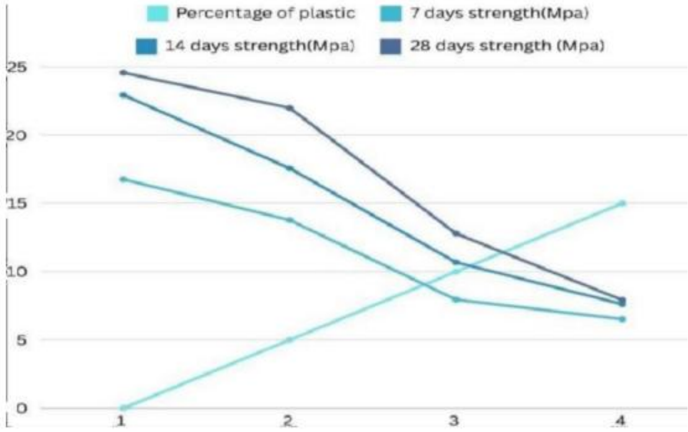
The Compressive Strength of concrete is described as the load that causes the failure of a standard specimen divided by the area of cross section in uniaxial compression underneath a given rate of loading. The compressive strength test is done on standard cube specimens using Compressive Testing Machine (CTM) or Universal Testing Machine (UTM).

S.NO	Percentage of plastic waste	7days strength(Mpa)	14days strength(Mpa)	28days strength(Mpa)
1	0	16.75	22.92	24.56
2	5	13.77	17.56	21.98
3	10	7.95	10.68	12.79
4	15	6.52	7.62	7.92

Fig: Compressive Testing Machine

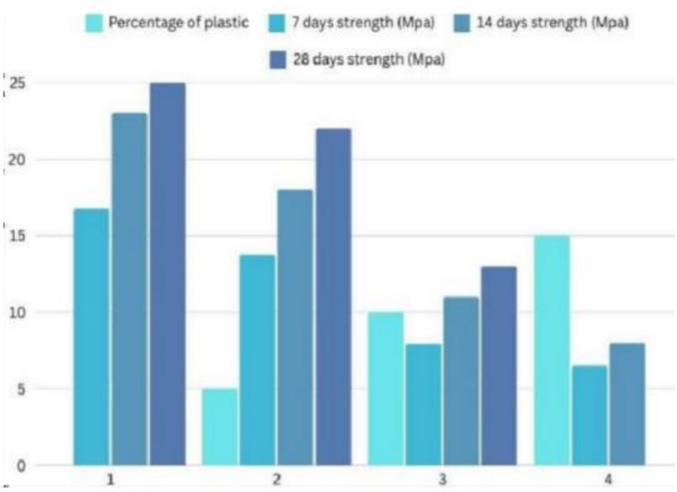
In order to determine the compressive strength cube mould of size 150 X 150 X 150 mm were casted. The cubes were casted for different percentage of copper slag ranging from 0 percent to 30 percent. Then the cubes are kept curing for 28 days. Three samples were tested at each concrete mixture. The compression test is done according to the specification IS 516:1959.

The compressive strength test is performed to determine the ability of a material, usually concrete, to withstand axial loads before failure. The standard test follows procedures outlined by ASTM C39 (for concrete cylinders) or IS 516 (for concrete cubes).



Graph: Line Graph Of Compressive Strength

From the above graph compressive strength ofconcrete cubes is decreases gradually as compared to the modified cubes by 100% to 15% for each percentage.



Graph: Bar Graph Of Compressive Strength

TENSILE STRENGTH OF CONCRETE

Concrete is a strong and durable building material, but its tensile strength is relatively low compared to its compressive strength. The tensile strength of concrete depends on various factors such as the quality of materials used, the ratio of cement to aggregate, the water-cement ratio, and the curing conditions.

To test the tensile strength of concrete, the most commonly used machine is the Universal Testing Machine (UTM). The UTM is a versatile testing machine that can apply different types of loads such as tension, compression, bending, and shear.

The standard dimensions for a concrete cube used for testing the tensile strength of concrete are:

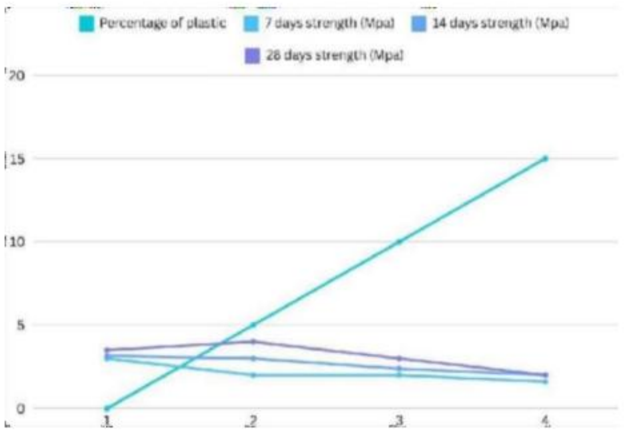
Size: 150 mm × 150 mm × 150 mm (for general testing)

Fig: Universal testing machine

Fig: taking values from UTM

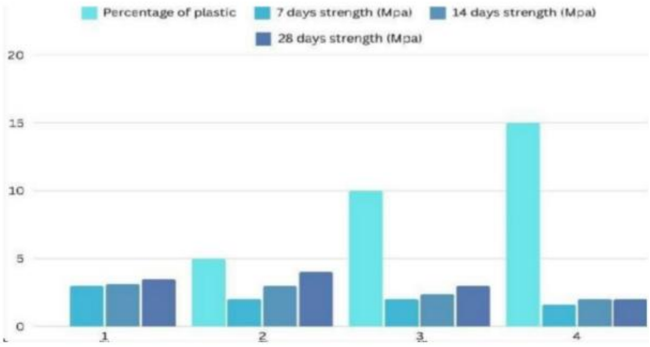
Table : Tensile Strength results

S.NO	Percentage of plastic waste	7days strength(Mpa)	14days strength (Mpa)	28days strength(Mpa)
1	0	2.28	3.15	3.5
2	5	2.02	2.97	3.39
3	10	1.91	2.38	2.89
4	15	1.6	1.78	1.98



Graph: Line Graph Of Tensile Strength

From the above graph Tensile strength of concrete cylinders is decreases gradually as compared to the modified cylinders by 100% to 15% for each percentage.



Graph: Bar Graph Of Tensile Strength

CONCLUSION

The experimental results demonstrate a clear inverse relationship between the percentage of plastic waste incorporated into M25 grade concrete and its compressive and tensile strength. Specifically, as the plastic waste replacement increased from 5% to 15%, a progressive reduction in both compressive and tensile strength was observed when compared to the conventional concrete mix. The strength reduction ranged from approximately 15-20% at 5% plastic replacement, to 30-35% at 10%, and finally, 40-45% at 15%. This indicates that while utilizing plastic waste in concrete offers a sustainable waste management solution, it significantly compromises the mechanical strength of the concrete. Therefore, the direct replacement of aggregates with plastic waste in M25 concrete, at the tested percentages, is not recommended for applications requiring high structural integrity. Further research is needed to explore methods for mitigating the strength reduction, such as using additives or optimizing the plastic waste processing, to achieve a balance between sustainability and structural performance

Key Points:

1.This experiment showed that the strength of the concrete was reduced by15-20% when 5% of the plastic was replaced in the concrete.

2.This experiment showed that the strength of the concrete was reduced by 30-35% when 10% of the plastic was replaced in the concrete.

3.This experiment showed that the strength of the concrete was reduced by 40-45% when 15% of the plastic was replaced in the concrete.

4.By adding plastic Waste, the compressive strength and tensile strength is getting decreased.

5.We observed that the conventional concrete cubes and cylinders are got more strength compare to the modified concrete cubes and cylinders hence the use of plasmega in conventional concrete is demerit in the form of strength.

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