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To Investigate the Mechanical and Durability Properties of Concrete Replacing Natural Coarse Aggregate with Plastic Made Coarse Aggregate

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Abstract – In order to determine how waste plastic affected the mechanical properties of the concrete, tests for compressive strength, splitting tensile strength, and flexural strength were carried out. This goal led to the initial usage of plastic made coarse aggregate in place of some natural aggregate, with four distinct ratios of plastic made coarse aggregate being employed in the manufacturing of concrete: 2%, 4%,6% and 8%.In order to investigate the combined impact of varying plastic made coarse aggregate ratios on concrete performance, mixed samples (2%, 4%,6% and 8%)were created by substituting plastic made coarse aggregate for natural aggregate, fine and coarse aggregates, and cement. In its fresh form, the workability and slump values of concrete made with various percentages of left over plastic made coarse aggregate were measured and contrasted with those of plain concrete. The compressive and splitting tensile strengths of the hardened concrete made from plastic made coarse aggregate were measured using 6 inch by 6 inch by 6 inch cubic specimens and cylindrical specimens with a 6 inch diameter and a 12 inch height. Based on the acquired data, the ideal dosage for natural aggregate is all the percentages(2% ,4%,6%and 8%). Conversely, the mechanical qualities of concrete made with a combination of plastic made coarse aggregate rose up to a certain point before declining due to poor workability. As a result, 2%,4% and6% is thought to be the ideal replacement level since combined plastic made coarse aggregate exhibits much higher strength and improved workability qualities. The discarded glass and cementitious concrete showed good adherence. Finally, useful empirical formulas have been created to calculate the flexure, splitting tensile, and compressive strengths of concrete containing various percentages of plastic made coarse aggregate. Using the suggested expressions, it is simple to estimate these strength values of the concrete made using plastic made coarse aggregate during the design stage as opposed to performing an experiment.

Keywords – Eco-Friendly Environment, Plastic Made Coarse Aggregate Replaced By Natural Aggregate, Waste Plastic Bags, Workability, Compressive And Splitting Tensile Strength.

I. INTRODUCTION

The production of plastic waste has increased day by day globally [1]. According to the United Nations Environment Program (UNEP), the global production of plastic waste amounts to approximately 400 million tons annually, experiencing a yearly growth rate of 4.6%. Regarding waste management practices, only 9% of the total waste plastic generated worldwide undergoes recycling, while 12% is subjected to incineration [2]. The remaining 79% of plastic waste is disposed of either in landfills or aquatic environments. Unregulated disposal and open incineration of plastic waste contribute to severe environmental issues, including the release of toxic air pollutants such as dioxins, furan, and particulate matter. Additionally, these practices lead to an escalation in micro plastic and heavy metal concentrations in aquatic systems, negatively impacting water quality. Furthermore, the degradation processes associated with plastic waste contribute to reduced water permeability and soil fertility in agricultural fields.

In recent years, there has been a substantial global surge in the production of single-use plastic, particularly due to the heightened demand for safety equipment during the COVID-19 pandemic. Approximately 20% of the total plastic waste consists of polyethylene terephthalate (PET), and 29% comprises items with a polyethylene (PE) foundation [3].The notable rise in single-use plastic waste has spurred researchers to urgently explore effective, safe, cost-efficient, and sustainable management methods [4]. The desirable qualities of waste plastic, such as low water adsorption capacity, corrosion resistance, low electrical and thermal conductivity, and high impact resistance, suggest its potential as an environmentally friendly and efficient substitute for natural coarse aggregate in the production of cement concrete. This integration of plastic waste into the circular economy presents a promising solution. Life cycle assessment of plastic waste also proves that recycling of plastic waste can improve environment by reducing global warming potential and human toxicity [4]. Around 60–80% of concrete is made up of aggregate [5]. To achieve this requirement, aggregate usage worldwide is around 13.12 billion tons per year [6].The extraction of natural aggregates from quarries is associated with numerous adverse environmental effects, including heightened energy consumption, resulting greenhouse gas (GHG) emissions, landscape degradation, compromised land stability, water resource pollution, atmospheric pollution from particulate matter, and societal consequences such as vandalism. In contrast, employing waste plastic as a substitute for natural aggregates in recycling processes offers a promising avenue to mitigate the environmental hazards, social issues, and health risks linked to traditional natural aggregate extraction methods [7].

II. PROBLEM STATEMENT

The construction industry faces increasing challenges in sourcing sustainable materials and reducing its environmental impact. One promising approach is the incorporation of plastic-based coarse aggregate as a substitute for traditional natural aggregate (NAG) in concrete mixes. This research aims to investigate the mechanical and durability properties of concrete when NAG is replaced with plastic-made coarse aggregate.

The project aims to address the following key research questions

- What is the effect of replacing NAG with plastic-made coarse aggregate on the compressive strength of concrete?
- How does the use of plastic aggregates impact the flexural strength and tensile strength of concrete?
- What are the changes in the workability of concrete when plastic aggregates are incorporated, and how can this be optimized?
- What is the influence of plastic aggregates on the durability properties of concrete, such as chemical attack, and long-term performance?
- Are there any environmental benefits associated with using plastic aggregates in concrete, such as reduced plastic waste and carbon footprint?

This study is involving to conduct laboratory experiments and tests on concrete specimens with varying proportions of plastic-made coarse aggregates to assess their mechanical properties (strength, stiffness) and durability properties (resistance to environmental factors). We are hopeful that these results of this research will contribute to the development of sustainable and environmentally friendly concrete mixes while addressing the issue of plastic waste disposal.

III. AIM AND OBJECTIVES

- Investigate the impact of partially replacing natural coarse aggregate with plastic waste on the compressive strength of concreteand establish a clear understanding of how different levels of plastic made coarse aggregate.
- Check the tensile strength of concrete. Tensile strength is determined by applying a compressive load to a cylindrical or prismatic concrete specimen along its longitudinal axis while transmitting a tensile load diametrically across the specimen.
- Determine the Flexural strength of beam.Flexural testing measures the force required to bend a beam of plastic material and determines the resistance to flexing or stiffness of a material.

IV. MATERIALS AND METHODS

4.1 Mix Proportion

Throughout the study, a fixed proportion of 1:2:4 was immersed in a water tank for the purpose of curing.

Table 1: Details of batches of specimens

Serial No	Batch	Plastic Made Coarse Aggregate%
1	B-1	0% plastic aggregate is replaced by coarse aggregate
2	B-2	2% plastic aggregate is replaced by coarse aggregate
3	B-3	4% plastic aggregate is replaced by coarse aggregate
4	B-4	6% plastic aggregate is replaced by coarse aggregate
5	B-5	8% plastic aggregate is replaced by coarse aggregate

4.2 Testing of the Specimens

Workability of concrete is determined by Slump Cone test. We follow ASTM C143. In this study,compressive strength, and split tensile strength tests, Flexural strengthwere conducted.

4.2.1 Compressive strength:

Compressive strength of concrete is a measure of its ability to resist axial loads pushing it togetherConcrete. ASTM C39 used in this test for cylinder testing and ASTM C109 for cube testing. Specimens that are cylindrical are broken in a compression testing equipment to determine the compressive strength. Compressive strength is expressed in megaPascal (MPa) or pounds-per-square-inch (psi) units and is computed by dividing the failure load by the cross-sectional area resisting the load.

4.2.2.Split Tensile strength:

Concrete's split tensile strength indicates how well it can withstand tensile stresses under diametrical compression. The procedure of this test based on the ASTM C496. A cylindrical concrete specimen is subjected to a compressive load along its length to evaluate its fracture strength. The split tensile strength is then determined by measuring the force necessary to create this splitting.

4.2.3.Flexural strength:

Concrete's flexural strength, commonly referred to as its modulus of rupture, gauges how well it can withstand bending or flexural forces. We follow ASTM C78 for this test. It is ascertained by placing a load on a concrete prismatic or cylindrical specimen until the failure to bend occurs. The specimen's dimensions and the maximum bending moment applied to it are used to compute the flexural strength. This characteristic is essential for evaluating how concrete behaves in bending structural elements like walls, slabs, and beams.

V. RESULTS

This study's main goal was to investigate how waste plastic made coarse aggregate affects concrete's strength characteristics. Plastic made coarse aggregate was used in the concrete mixture as a partial natural aggregate substitute. Replaced with 0%, 2%, 4%, 6% and 8% of the natural aggregate.

Table 2: Workability of concrete by using plastic made coarse aggregate as partial replacement of natural aggregate.

Sr. No.	% of plastic made coarse aggregte	Slump value (mm)
1	0%	85
2	2%	87
3	4%	94
4	6%	103
5	8%	110

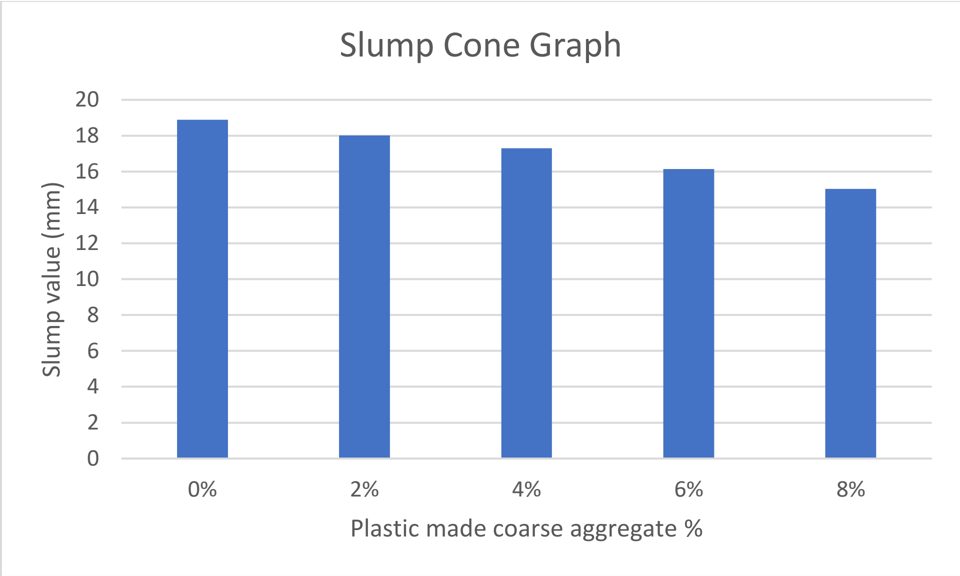

Figure 1: Graph showing workability of concrete with respect to % of plastic made coarse aggregate

By adding plastic made coarse aggregate in M15 concrete as a partial replacement of natural aggregate workability increase in the results.

The Compressive strength of all mixes is determined concrete with different proportions of plastic made coarse aggregate was determined at 28 days. For each set of plastic made coarse aggregate content, the development of compressive strength with respect to different plastic made coarse aggregate percentages are shown in table 3 and figure 2 shows graphical representation of table.

Table 3: Compressive strength of concrete achieved through the incorporation of plastic made coarse aggregate as a partial substitute for natural aggregate.

Sr. No.	**% of plastic made coarse aggregate**	**Avg. compressive strength MPa**
1	0%	18.89
2	2%	18.01
3	4%	17.31
4	6%	16.15
5	8%	15.03

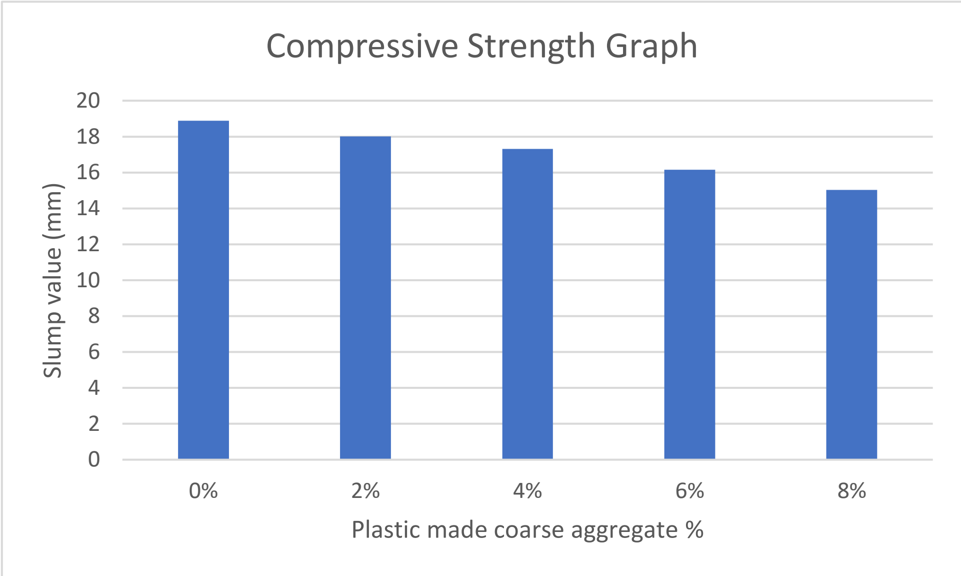

Figure 2: Graph showing compressive strength of concrete with respect to % plastic made coarse aggregate

Compressive strength decreases when natural aggregate is replaced by plastic made coare aggregate

The results of splitting tensile strength of concrete with respect to different plastic made coarse aggregatepercentages are shown in table 4and figure 3 shows the graphical representation of table 4.3. The splitting tensile strength with 0%, 2%,4%, 6% and 8%as partial replacement of natural coarse aggregate.

Table 4: Splitting tensile strength of concrete by using as plastic made coarse aggregatefractional replacement of natural aggregate.

Sr. No.	% of plastic made coarse aggregate	Avg. split tensile strength MPa
1	0%	3.23
2	2%	2.89
3	4%	2.51
4	6%	2.02
5	8%	1.70

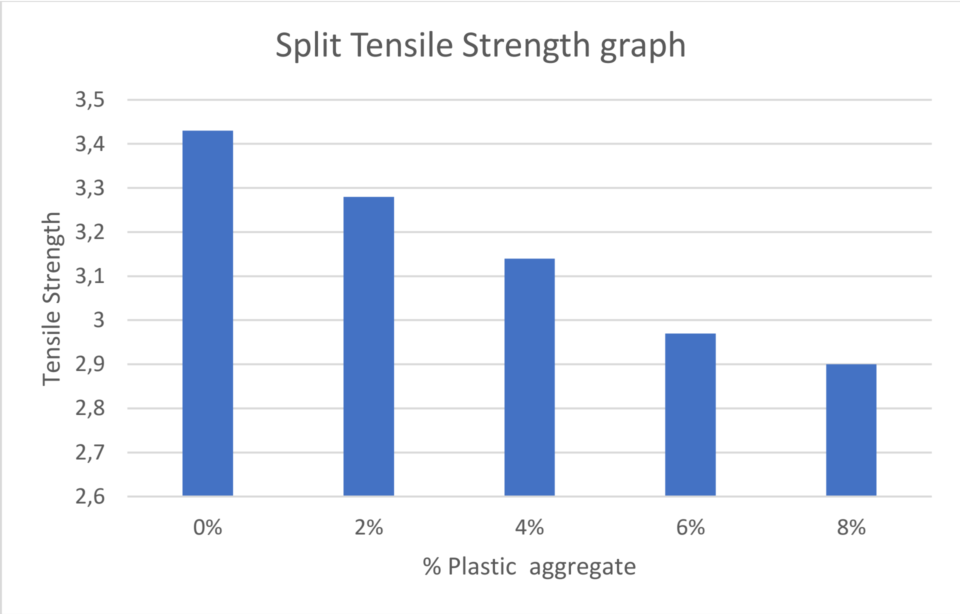

Figure 3: Graph showing splitting tensile strength of concrete with respect to different % of plastic made coarse aggregate.

Tensile strength decreases when plastic aggregate replace the natural aggregate in concrete.

The results of Flexural strength of concrete with respect to different percentages plastic made coarse aggregate are shown in table 5 and figure 4 shows the graphical representation of table 4.4. The Flexural strength with 0%, 2%, 4%, 6% and 8%as partial replacement of natural aggregate.

Table 5:Flexural strength of concrete by using plastic made coarse aggregate asfractional replacement of natural aggregate.

Sr. No.	**% of plastic made coarse aggregate**	**Avg. Flexural strength MPa**
1	0%	3.43
2	2%	3.28
3	4%	3.14
4	6%	2.97
5	8%	2.90

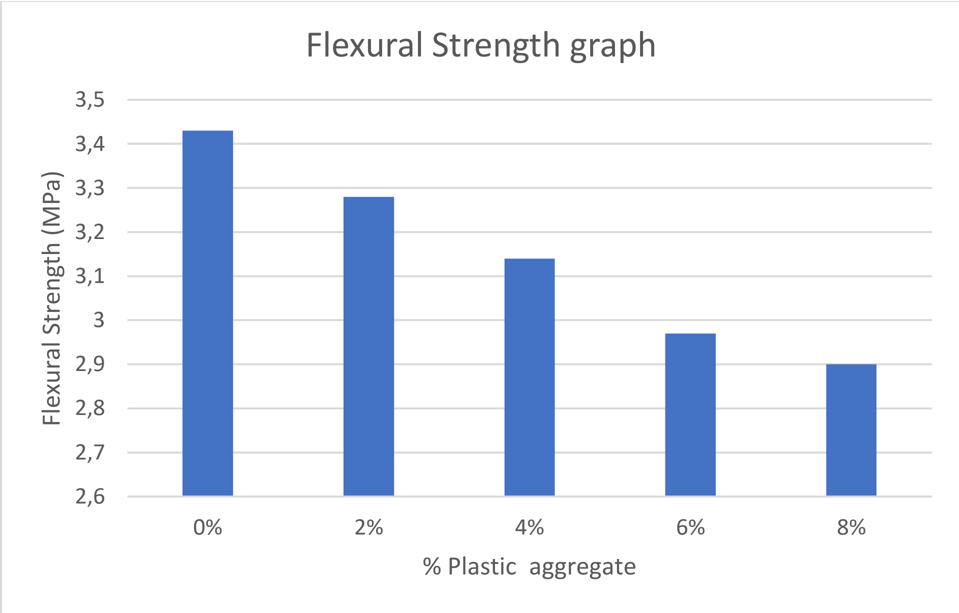

Figure 4: Graph showing splitting flexural strength of concrete with respect to different % of plastic made coarse aggregate.

The value of the Splitting flexural strength decreases when natural aggregate replaced by plastic made coarse aggregate.

VI. CONCLUSION

The experimental study on the compressive, splitting tensile strength and Flexural strength of concrete, considering the use of plastic made coarse aggregate as a fractional replacement for natural aggregate, yields the following conclusions:

- By using different percentages of plastic made coarse aggregate all the values decrease but in limit ranges.
- It is very safe to use plastic made coarse aggregate upto 8% in low level or into mass concrete.
- Good workability achieved when 8% of plastic made coarse aggregate replaced natural coarse aggregate.

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