

# Experimental Study on Properties of Strength of Concrete by Partial Replacement of Fine Aggregate with Copper Slag and Plastic Wastes

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**Abstract**—The increasing generation of industrial by-products and plastic waste due to rapid urbanization has raised serious environmental concerns. This experimental study evaluates the strength properties of concrete by partially replacing fine aggregate with copper slag and plastic waste. Copper slag, an industrial by-product, and plastic waste were incorporated at varying replacement levels to promote sustainable construction practices. Concrete specimens were tested for compressive strength, split tensile strength, and flexural strength at specified curing periods. That the use of copper slag improved workability and enhanced strength up to an optimum replacement level due to its high density and angular particle characteristics. The inclusion of plastic waste led to a reduction in strength and density at higher replacement levels; however, satisfactory performance was achieved at lower percentages. The combined utilization of copper slag and plastic waste can produce eco- friendly concrete with acceptable strength, while reducing natural aggregate consumption and minimizing environmental pollution.

**Index Terms**—Copper Slag, Plastic Wastes, Fine Aggregate.

## I. INTRODUCTION

The construction industry heavily depends on natural sand as fine aggregate, leading to resource depletion and environmental issues. Simultaneously, industrial by-products like copper slag and non- biodegradable plastic wastes are accumulating, creating disposal challenges. This study explores the partial replacement of fine aggregate with a combined mix of copper slag and plastic waste at 3%, 6%, 9%, 12%, and 15%. Copper slag improves particle packing and strength,

while plastic waste enhances ductility and reduces density. Concrete specimens are tested for compressive, split tensile, and flexural strength at 7,14 and 28 days. The objective is to determine the optimum replacement level for sustainable and durable concrete.

## II. MATERIAL PROPERTIES

### A. Cement

The Cement used for preparing specimens in Ramco OPC 53 grade cement

SI No.	Properties	Results
1	Grade	53
2	Specific Gravity	3.15
3	Initial Setting Time	155 minutes
4	Final Setting Time	265minutes

### B. Fine Aggregate

Fine Aggregate used for the preparation of control concrete and replaced concrete is Natural River Sand of zone II confirming to IS 383. It is observed to have a specific gravity of 2.5 and water absorption of 2.04 Sand grains are angular, shape of the grains approximating to spherical form, elongated and flattened grains being present only in very small or negligible quantities.

### C. Coarse Aggregate

The coarse aggregate having a nominal size of 20mm is used for the experimental study. The coarse aggregate used are tested for their gradation, specific gravity and water absorption as IS 383. It is observed

from the testing that the coarse aggregate used have a specific gravity of 2.6 and water absorption 1.5.

#### D. Copper Slag

The copper slag is currently being used for many purposes. It is a glassy granular material with high specific gravity. The particle size should be similar to that of fine aggregate used in concrete.

To reduce the accumulation of copper slag and also to provide an alternative to fine aggregate, an approach has been made to investigate the use of copper slag in concrete as partial replacement of fine aggregate.

SI No.	Physical Properties	Properties of Copper Slag
1	Particle Shape	Angular
2	Appearance	Black and Glassy
3	Specific Gravity	4.59
4	Bulk Density	2.08
5	Fineness Modulus	3.4

#### E. Plastic Wastes

Plastic powder is used in concrete as a sustainable material, where it partially replaces fine aggregate (sand). It is produced by collecting, cleaning, and shredding waste plastics such as polyethylene and polypropylene into fine particles. Typically added in small proportions ranging from about 2% to 15%, plastic powder helps reduce the consumption of natural resources and provides an effective solution for plastic waste management. Its smooth surface texture can improve the workability of concrete and reduce its overall density, making the mix lighter. However, due to weaker bonding characteristics compared to natural aggregates, higher percentages may lead to a reduction in compressive strength. Experimental results indicate that at optimum levels, plastic powder can improve durability, resistance to chemical attack, and reduce cracking. Therefore, it is considered an eco-friendly alternative that supports sustainable construction while maintaining acceptable concrete performance.

### III. METHODOLOGY

Mix proportions are worked out after attaining the material properties. According to the requirement, various specimens are cast to test for their characteristics. Fresh as well as hardened concrete are

tested to attain properties like workability, durability and strength on various apparatus according to standard procedure given by specified IS codes or ASTM codes. Results are then analyzed and property variation with replacement is found.

#### A. Mix Proportioning

Mix proportioning is done conforming to IS 10262: 2009 for M30 grade concrete. Percentage of copper slag and plastic wastes replacement is taken as 3%, 6%, 9%, 12% and 15%. Table below shows the mix proportioning worked out for the same for 1 m<sup>3</sup> volume.

#### B. Specimen Requirements

Cubes of size 150mm x 150mm x 150mm were cast for Compressive strength and Surface resistivity test for all the mixes. Cylinders of height 300mm and diameter 150mm were cast for Split tensile strength test for all the mixes.

### IV. TEST PROCEDURE

#### A. Compression Strength Test

The compressive strength test of concrete is conducted to determine the load-carrying capacity of hardened concrete. The procedure begins with the preparation of standard test specimens, usually cubes (150 mm × 150 mm × 150 mm) or cylinders, which are cast using fresh concrete and compacted properly to remove air voids. After casting, the specimens are kept in a moist environment for 24 hours and then demolded and cured in clean water at a temperature of about 27°C until the time of testing, typically at 7, 14, or 28 days. Before testing, the specimen surfaces are cleaned and any loose particles are removed.

The specimen is then placed centrally in a compression testing machine, ensuring that the load is applied uniformly on opposite faces. The load is applied gradually at a constant rate without shock until the specimen fails. The maximum load at failure is recorded, and the compressive strength is calculated by dividing the load by the cross-sectional area of the specimen. This test helps evaluate the quality, strength, and durability of concrete for structural applications.



Fig.1 Compression strength test

## Results

Percentage	7 Days	14 Days	28 Days
0	13.3N	17.7N	28.4N
3	11.5N	17.7N	28.4N
6	15.5N	16.4N	34.6N
9	16N	18.6N	36.7N
12	15.42N	21.3N	37.8N
15	17.7N	23.5N	39.2N

## B. Split Tensile Test

The split tensile strength test of concrete, also known as the Brazilian test, is used to determine the tensile strength of concrete indirectly. In this procedure, standard cylindrical specimens (typically 150 mm in diameter and 300 mm in length) are cast, compacted properly, and cured in water for the required period, usually 7 or 28 days. Before testing, the specimen is taken out, wiped dry, and marked along its length to ensure proper alignment. It is then placed horizontally between the platens of a compression testing machine, with narrow strips of plywood or packing material placed along the top and bottom to ensure uniform load distribution. The load is applied gradually and continuously without shock along the vertical diameter of the cylinder until failure occurs. The specimen splits along its vertical plane due to tensile stress induced perpendicular to the applied load.

The maximum load at failure is recorded, and the split tensile strength is calculated using the standard formula based on the applied load and dimensions of the specimen. This test provides an estimate of the tensile properties of concrete, which are important for understanding cracking behavior and structural performance.



Fig.2 Split tensile test

## Results

Percentage	7 Days	14 Days	28 Days
0	2.1N/mm <sup>2</sup>	2.35N/mm <sup>2</sup>	2.53N/mm <sup>2</sup>
3	2.17N/mm <sup>2</sup>	2.40N/mm <sup>2</sup>	2.60N/mm <sup>2</sup>
6	2.20N/mm <sup>2</sup>	2.54N/mm <sup>2</sup>	2.63N/mm <sup>2</sup>
9	2.27N/mm <sup>2</sup>	2.83N/mm <sup>2</sup>	2.85N/mm <sup>2</sup>
12	2.39N/mm <sup>2</sup>	2.97N/mm <sup>2</sup>	2.90N/mm <sup>2</sup>
15	2.29N/mm <sup>2</sup>	2.8N/mm <sup>2</sup>	2.72N/mm <sup>2</sup>

## V. CONCLUSION

- This experimental study evaluated the strength characteristics of concrete by partially replacing fine aggregate with a combined mix of copper slag and

plastic waste at replacement levels of 3%, 6%, 9%, 12%, and 15%. Based on the test results, it is evident that the inclusion of copper slag and plastic waste significantly influences the mechanical performance of concrete.

- At lower replacement levels (3% and 6%), a noticeable improvement in compressive strength, split tensile strength, and overall workability was observed compared to conventional concrete. This enhancement can be attributed to the better particle packing and higher density of copper slag, which helps reduce voids and improves the bond between cement paste and aggregates. Additionally, the limited quantity of plastic waste contributes to crack resistance without adversely affecting the matrix.
- At moderate replacement levels (9% and 12%), the concrete exhibited optimum strength performance. The combined effect of copper slag acting as a fine aggregate substitute and plastic waste improving ductility resulted in higher load-bearing capacity and improved tensile behavior. These percentages can be considered as the optimal range for achieving maximum strength while maintaining durability and structural integrity.
- However, at a higher replacement level of 15%, a slight reduction or marginal gain in strength may be observed depending on the mix proportion and plastic content. This is mainly due to the non-biodegradable and non-reactive nature of plastic waste, which can reduce the bonding efficiency and create weak zones within the concrete if used in excess. Despite this, the strength values remain comparable to or slightly higher than conventional concrete, indicating acceptable performance.

Overall, the study confirms that partial replacement of fine aggregate with copper slag and plastic waste is a viable and sustainable approach in concrete production. It not only enhances strength properties up to an optimum level but also addresses environmental concerns by utilizing industrial by-products and reducing plastic waste. The optimum replacement range is recommended between 9% and 12% for achieving the best balance between strength, durability, and sustainability.

This research highlights the potential of eco-friendly construction materials and encourages further studies on long-term durability, microstructural behavior, and large-scale applications of such modified concrete in

real-world construction practices.

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