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Performance Evaluation of Hybrid Fiber Reinforced Concrete using Copper Slag as Replacement Material of Fine Aggregate

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ABSTRACT

Concrete is one of the safe, strong and simple building material used in all types of construction works. The main inconvenience in concrete is that the tensile strength is relatively low. The introduction of steel fibers in concrete converts its nature from brittle to ductile. Cracks plays an important role in construction as they change concrete structure into permeable elements and with a high risk of corrosion. It is important to reduce the crack width and this can be achieved by adding polypropylene fibers to concrete. In this experimental investigation, the mechanical properties of HFRC containing Copper slag with various percentages of fibers like Steel fiber and Polypropylene fiber is evaluated. The mixes were designed for five different percentages such as 10%, 20%, 30%, 40% and 50% of Copper slag as replacement of fine aggregate with the small percentage of fibers as constant. The mechanical properties of these mixes were found and then comparing those results with the conventional concrete. The optimum dosage of Copper slag has to be found from these results. By the usage of optimum dosage, structural behaviour and durability characteristics will be evaluated.

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1. INTRODUCTION

Concrete is the most widely used man-made material on earth. It is an essential construction material used extensively in buildings, bridges, roads and dams. It is a mixture composed of cement, fine aggregate, coarse aggregate and water which hardens with time. The amount of concrete used worldwide is twice that of steel, plastics and aluminum combined.

Concrete made from Portland cement is relatively strong in compression but weak in tension and tends to be brittle. The weakness in tension can be overcome by the use of conventional steel bars reinforcement and to some extent by the mixing of a sufficient volume of certain fibers. The use of fibers also recalibrates the behaviour of the fiber-matrix composite after it has cracked through improving its toughness.

A fiber is a small discrete reinforcing material produced from various materials like steel, plastic, glass, carbon and natural materials in various shapes and sizes. Fibers are usually used in concrete to control cracking due to plastic shrinkage and drying shrinkage. They also reduce the permeability of concrete and thus reduce bleeding of water. Some types of fibers produce greater impact, abrasion and shatter resistance in concrete.

Fiber reinforced concrete (FRC) is a concrete containing fibrous material which increases its structural integrity. It contains short discrete fibers that are uniformly distributed and randomly oriented. In addition, the character of FRC changes with varying concretes, fiber materials, geometries, distribution, orientation and densities.

FRC is a new structural material which is gaining increasing importance. Addition of fibers in discrete form improves many engineering properties of concrete. Continuous meshes, woven fabrics and long wire or rods are not considered to be discrete fibers. A composite can be stated as a hybrid when two or more type of fibers is used in a combined matrix that will reflect the benefit of each of the individual fiber used. This will finally provide a synergetic response to the whole structure. Such a composite of concrete is termed as Hybrid fiber reinforced concrete.

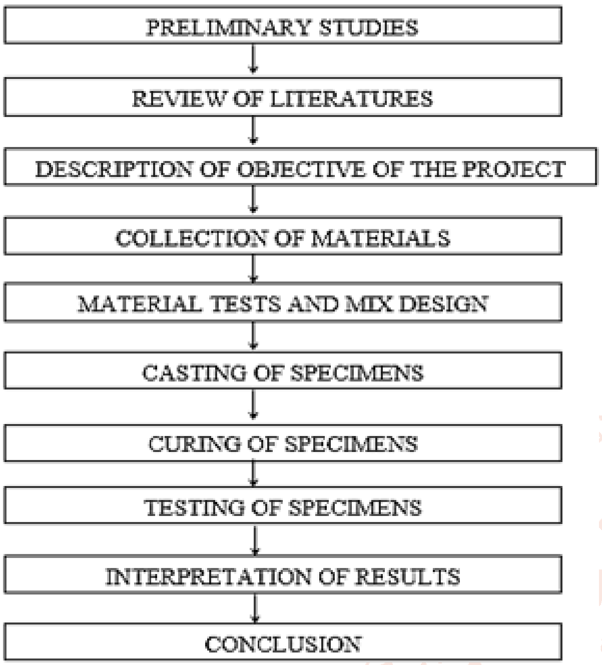
The mechanical properties of concrete are enhanced appreciably using short lengthened fibers. This increases the modulus of elasticity of the concrete. This will reduces the chances of brittleness and hence small crack, as small cracks are the main factors behind propagation and larger cracks formation. It is observed that the use of a combination of both metallic and non-metallic type of fibers helps in improving the concrete properties extensively. The addition of more fibers into the concrete mixture makes it more homogeneous and isotropic in nature. This brings a conversion of concrete nature from brittle to the ductile condition. This enhances the ductility behaviour of the concrete under critical loads.

The basic principles behind the design of HFRC are:

- Use of short and long steel fibers together in the same concrete mix.
- To ensure homogeneous distribution of the fibers in the mix.
- To ensure that each fiber employed in the mix is effectively used.

2. METHODOLOGY

2.1 FLOW CHART OF THE WORK



3. MATERIALS & TESTING METHODS

The material properties and tests are discussed and tabulated. By using the result values, the mix design and mix designation are obtained.

Table 3.1 Physical properties of Cement

S. No	Properties	Values
1	Specific gravity	3.15
2	Fineness modulus	3
3	Standard consistency	33%
4	Initial setting time	34 mins
5	Final setting time	227 mins

Table 3.2 Chemical properties of Cement

S. No	Ingredients	Concentration (%)
1	CaO	66.67
2	SiO_2	18.91
3	Fe_2O_3	4.94
4	Al_2O_3	4.51
5	MgO	0.87
6	Loss of ignition	1.05

3.1.1 Copper Slag

Copper slag is a by-product produced during the smelting and refining process of copper. Copper slag can be used in concrete production as a partial replacement of fine aggregate. Figure 3.1 shows copper slag used. The physical and chemical properties of Copper slag are given below in Table 3.3 and Table 3.4 respectively.

Figure 3.1 Copper Slag

Table 3.3 Physical properties of Copper Slag

S. No	Properties	Values
1	Specific gravity	4.12
2	Fineness modulus	2.68
3	Water absorption	1.01%
4	Grading zone	II
5	Appearance	Blackish grey, Glassy

Table 3.4 Chemical properties of Copper Slag

S. No	Ingredients	Concentration (%)
1	Cu	0.6-0.9
2	SiO_2	33-35
3	FeO	50-55
4	Al_2O_3	4.0-6.0
5	Fe_2O_3	1.5-5.0
6	CaO	0.8-1.5
7	S	0.8-1.2

3.1.2 Steel fiber

Steel fiber is manufactured by quality base steel bar, which has excellent mechanical properties including high tensile strength. Hooked end steel fiber of length 60 mm is used. Figure 3.2 shows steel fiber used.

Figure 3.2 Steel Fiber

3.1.3 Polypropylene fiber

Polypropylene is a white, mechanically rugged and has a high chemical resistance. It has good resistance to fatigue. A transparent white fiber of length 12 mm is used as shown in the Figure 3.3.

Figure 3.3 Polypropylene fiber

4. TESTING OF MATERIALS

Specific gravity of Copper Slag

Specific gravity of fine aggregate (Copper Slag) is the ratio of the weight of given volume of aggregates to the weight of equal volume of water. The specific gravity of Copper slag was determined by pycnometer as shown in the Figure 4.1.

Figure 4.1 Pycnometer used for Specific Gravity of Copper Slag

5. EXPERIMENTAL INVESTIGATION

5.1 MIXING

Mixing concrete is simply the complete blending of the materials which are required for the production of a homogeneous concrete. This can vary from hand to machine mixing and machine mixing being the most common one. Mixing was done as per the mix proportions obtained using IS 10262:2019 as shown in the Figure 5.1

Figure 5.1 Mixing

5.1.1 CASTING OF SPECIMENS

In order to prepare the specimen for determining the compressive strength, flexural strength and split tensile strength, permanent steel moulds of standard size were used and it has been filled with a fresh concrete. The compaction is carried out manually and the top surface was levelled and finished.

The cube specimens of size 150 mm x 150 mm x 150 mm were casted and the compressive strength at the age of 7 and 28 days were tested. The prism specimens of size 500 mm x 100 mm x 100 mm were casted and the flexural strength at the age of 7 and 28 days were tested. Cylinder specimens of length 300 mm and diameter 150 mm were casted and the split tensile strength at the age of 7 and 28 days were tested. All the test specimens were casted in the removable standard moulds as shown in the Figure 5.2.

Figure 5.2 Casting of specimens

5.1.2 CURING OF SPECIMENS

Curing is the process by which fresh wet *concrete* is allowed to complete its reaction to attain its planned strength. The specimens were demoulded approximately after 24 hours of their casting and cured in a water tank for 7 and 28 days as shown in the Figure 5.3.

Figure 5.3 Curing of specimens

5.1.3 TESTING OF SPECIMENS

Compressive strength

Compression strength of concrete is a measure of the concrete's ability to resist loads which tends to compress it. The cube specimens of size 150 mm x 150 mm x 150 mm are loaded to find the compressive strength. The load is applied until the specimen fails and the strength is noted. The prepared specimens were tested on Compressive Testing Machine as shown in Figure 5.4. The specimens were tested after completion of curing period of 7 and 28 days.

Figure5.4 Compressive strength testing of cube

6. RESULTS AND DISCUSSION

Comparison of Compressive Strength Results

The results of compressive strength of HFRC mixes with the different percentage of copper slag are presented in the Figure 6.1, 6.2

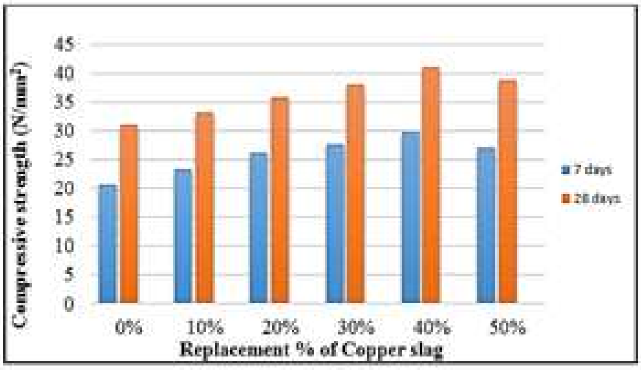


Figure 6.1 Comparison of compressive strength at 7 and 28 days Using bar chart

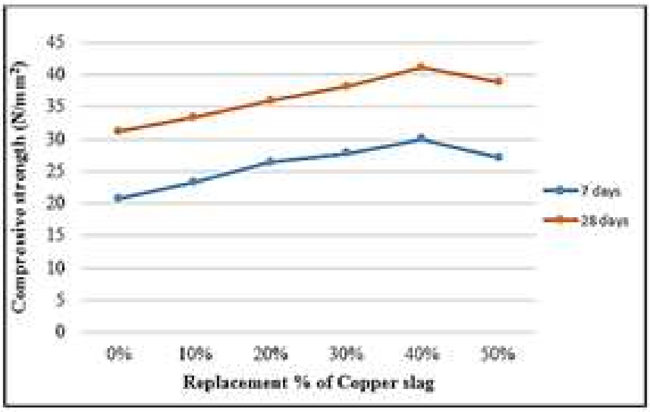


Figure 6.2 Comparison of compressive strength at 7 and 28 days Using line chart

- by adding different dosages of copper slag in conventional concrete we observed that compressive strength at 7 and 28 days gain early strength for lower percentage dosages of copper slag.
- The split tensile strength and flexural strength of concrete increased with increased copper slag content in concrete and the results were more than empirical design values.
- There is improvement in mechanical properties of HFRC compared to conventional concrete because of addition of fibers. The maximum increase in mechanical properties were observed at having hybrid ratio of fibers along with the replacement of fine aggregate by 40% copper slag.
- Keeping in view of savings in natural resources environment, production cost, maintenance cost and all other CS properties, it can be recommended as an innovative construction material for the use of constructions.

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