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Study on Mechanical Properties of Concrete by Partial Replacement of Fine Aggregate with Copper Slag and Cement with Silica Fume

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ABSTRACT

Concrete is the most widely used building material in civil engineering industry throughout the globe because of its high structural strength and constancy, where the fine aggregate is generally natural sand. The usage of sand in construction activity results in the excessive mining, causing depletion of natural resources resulting increase in scour depth and sometimes flood possibility. Copper Slag waste is most usually made from the copper industry, whereas Silica Fume is a by-product from many manufactures. Chuck out of both copper slag waste and Silica Fume is one of the major environmental problems worldwide today. Hence the reuse of waste material has been emphasized to sustainable growth.

This research paper presents a study of the Strength properties of concrete by partial replacement of fine aggregate with copper slag and cement with silica fume. In the present Experimental Investigation, for M40 grade of concrete, fine aggregate (River Sand) was partially replaced with Copper Slag (40%) and cement was partially replaced with Silica Fume from 5% to 15% at an interval of 5%. This research gives a detailed observational study on Compressive strength, split tensile strength, flexural strength at age of 28 days. Test results indicate that the strength properties of concrete were improved having copper slag as a partial replacement of Sand (up to 40%) and Silica fume as a partial replacement of cement (up to 10%).

INTRODUCTION

Concrete is a mixture of cement, fine aggregate, coarse aggregate and water. River Sand is a common kind of fine aggregate used in the fabrication of concrete. Alternative to river sand, which is a usual pattern of fine aggregate in preparation of concrete have been in demand due to large scale depletion of river bottom and increasing price of river sand. Many non-established resources such as Stone Dust, Carbonate Sand, Fly Ash, Copper Slag etc. with a larger percentage of Silica (SiO_2) have been strained out as an alternative to river sand as fine aggregate in preparation of concrete. Copper Slag is an industrial by-product abundantly available near copper producing industries having similar physical &chemical properties of Sand can be regarded as an alternative to the river sand. This will help in resolving a major concern of industrial waste disposal along with decreased cost of construction [1-5].

Concrete is one of the most widely used construction material. Concrete is a mixture of three basic ingredients are sand, gravel (crushed stone), and cement, as well as chemical compounds known as admixtures. Combining this mixture with water turns cement into a hard paste that binds the sand and gravel together. The demand for concrete as a construction material is on the increase. It is estimated that the production of concrete will increase

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from about from 1.5 billion tons in 1995 to 6 billion tons in 2015. India consumes an estimated 450 million cubic meter of concrete annually and which approximately comes to 1 tonne per Indian. The increasing demand for cement concrete is met by partial cement replacement. Substantial energy and cost savings can result when industrial by products are used as a admixture in concrete is known to impart significant improvements in workability and durability [3].

CEMENT

Cement is a binder, a substance that sets and hardens independently, and can bind other materials together. The word "cement" traces to the Romans, who used the term opus cement to describe masonry resembling modern concrete that was made from crushed rock with burnt lime as binder. The volcanic ash and pulverized brick additives that were added to the burnt lime to obtain a hydraulic binder were later referred to as centum, cements, and cement.

In 2010, the world production of cement was 3,300 million tones. The top three producers were China with 1,800, India with 220 and U.S.A with 63.5 million tons respectively. The most important uses of cement are as an ingredient in the production of mortar in masonry and of concrete, a combination of cement and an aggregate to form a strong building material.

Cement is made by heating limestone (calcium carbonate) [8] with small quantities of other materials (such as clay) to 1450 °C in a kiln, in a process known as calcination, whereby 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. The most common use for Portland cement is in the production of concrete. Concrete is a composite material consisting of aggregate (gravel and sand), cement, and water. As a construction material, concrete can be cast in almost any shape desired, and once hardened, can become a structural (load bearing) element. Portland cement may be grey or white. Cements used in construction can be characterized as being either hydraulic or non-hydraulic. Hydraulic cements (e.g., Portland cement) harden because of hydration, a chemical reaction between the hydrous cement powder and water. Thus, they can harden underwater or when constantly exposed to wet weather. The chemical reaction results in hydrates that are not very water-soluble and so are quite durable in water. Non-hydraulic cements do not harden underwater; for example, slaked limes harden by reaction with atmospheric carbon dioxide [6].

Aggregates

Aggregates are defined as inert, granular, and inorganic materials that normally consist of stone or stone-like solids. Aggregates can be used alone (in road bases and various types of fill) or can be used with cementing materials (such as Portland cement or asphalt cement) to form composite materials or concrete Aggregates were first considered to simply be filler for concrete to reduce the amount of cement required. However it is now known that the type of Aggregate used for concrete can have considerable effects on the plastic and hardened state properties of concrete. Aggregates can form up to 80% of the concrete mix so their properties are crucial to the properties of the concrete [10].

The most popular use of aggregates is to form Portland cement concrete. Approximately three-fourths of the volume of Portland cement concrete is occupied by aggregate. It is inevitable that a constituent occupying such a large percentage of the mass should have an important effect on the properties of both the fresh and hardened products. As another importantapplication, aggregates are used in asphalt cement concrete in which they occupy 90% or more of the total volume. Once again, aggregates can largely influence the composite properties due to its large volume fraction. Aggregates

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are the important constituents in concrete. They give body to the concrete, reduce shrinkage and effect economy. One of the most important factors for producing workable concrete is good gradation of aggregates. Good grading implies that a sample fractions of aggregates in required proportion such that the sample contains minimum voids. Samples of the well graded aggregate containing minimum voids require minimum paste to fill up the voids in the aggregates. Minimum paste will mean less quantity of cement and less water, which will further mean increased economy, higher strength, lower shrinkage and greater durability.

METHODOLOGY

The evaluation of Copper Slag as a replacement of fine aggregate and Silica Fume as a replacement of Cement begins with the concrete testing. The study is conducted to analyze the compressive strength, split tensile Strength and Flexural Strength of concrete when the base materials, i.e. Fine Aggregate is replaced with Copper Slag and Cement is replaced with Silica Fume respectively. Firstly, the copper slag replacement was made at proportions 0%, 10%, 20%, 30%, 40%, and 50% by weight of M-40 grade concrete. Nine samples per batch were tested with the average strength values reported in this paper [7].

The maximum mean value of the strength of a certain definite replacement proportion of fine aggregate with copper slag was noted. Now, the copper slag replacement is kept at the constant proportion (proportion attaining maximum average value of strength) and silica fume replacement was made at proportions 5%, 10% and 15%, by weight of M-40 grade concrete. Again, nine samples per batch were tested with the average strength values reported in this paper. In all total 27 cubes of OPC (150mm × 150mm × 150mm), 27 cylinders of OPC (150x 300 mm) and 27 beams of OPC (100 mm x 100 mm x 500 mm) were examined and results were analyzed after curing 28 days. The result obtained from the partial replacement of fine aggregate with copper slag and partial replacement of cement with Silica fume is compared to conventional concrete.

PROPERITIES OF MATERIALS AND TESTS:

Materials Used and Tests

Cement

Ordinary Portland cement of 43 grades manufactured by Shree Ultratech Cement was used throughout the Experimental investigation. The quality of the cement was confirming to IS 8112:1989 was used in the field (Specification, Bureau of Indian Standards, and New Delhi). ThePhysical Properties of OPC Cement.

Fine Aggregate

Fractions from 4.75 mm to 150 microns are termed as fine aggregate. Locally availableriver sand passed through 4.75mm IS sieve is applied as fine aggregate conforming to therequirements of IS 383:1970 [17]. The specific gravity of sand is 2.60 and fineness modulusis 3.30. The free and compacted bulk density values obtained are 1645 Kg/m^3 and 1780 Kg/m^3 and water absorption is 1.10%.

Coarse Aggregate

Fractions from 20 mm to 4.75 mm are used as coarse aggregate. The Coarse aggregate areobtained from a local quarry, conforming to IS 383:1970 is used. The coarse aggregate with a maximum size 20 mm. The free and compacted bulk density values obtained are 1600 Kg/m^3 and 1790 Kg/m^3 respectively, water absorption of 1.50%.

Copper Slag

Copper slag used in this work was brought from Taj Abrasive Industries. Physical and Chemical Properties of copper slag Used in the Study are tabulated in table 4 and 5. Copper Slag used in the Experiment is shown in Figure 1.

Figure : Copper Slag

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Silica Fume

Silica Fume used in this work was brought from Taj Abrasive Industries, Rajasthan. Physical and Chemical Properties of Silica Fume used in the experiment are tabulated in Table 6 and 7. Silica Fume used in the experiment is shown in figure 2.

Figure: Silica Fume

Tests on Hardened Concrete

Cube compressive strength test According to IS 516-1959

The test set up for conducting cube compressive strength test is depicted Compression test on the cubes is conducted on the 200T compression testing machine. The cube was placed in the compression testing machine and the load on the cube is applied at a constant rate up to the failure of the specimen andthe ultimate load is noted. The cube compressive strength of the concrete mix is then computed. A sample calculation for determination of cube compressive strength is presented in Appendix-III (A). This test has been carried out on cube specimen sat 7, and 28days age. The values are presented in Table 6.1, 6.2, 6.7, 6.8.

Compressive strength =

Where, P = Compressive load, A = Area of the cube (150 X150mm)

Fig. Compressive Strength

Split Tensile Strength

Split Tensile Strength According to IS 5816-1999

This test is conducted on 200T compression testing machine. The cylinders prepared for testing are 150mm in diameter and 300mm height. After noting the weight of the cylinder, diametrical lines are drawn on the two ends,such that they are in the same axial plane. Then the cylinders placed on the bottom compression plate of the testing machine aligned such that the lines marked on the ends of the specimen are vertical. Then the top compression plate is brought into contact at the top of the cylinder. The load is applied at uniform rate, until the cylinder fails and the load is recorded. From this load, the splitting tensile strength is calculated for each specimen. A sample calculation for computation of split tensile strength is presented in Appendix-(B). In the present work, this test has been conducted on cylinder specimens after 7 and 28days of curing.

Fig Split tensile Strength

Flexural Strength Test

The prism specimens of size 500x 100x 100 mm were used for the determination of the flexural strength. The bearing surface of the supporting and loading rollers were wiped clean and any other loose fine aggregate or other materials removed from the surface of the specimen where they are to make contact with the rollers. The specimen was then placed in the machine and two point loads was applied. Load was increased

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Flexural Strength Test

RESULTS AND DISCUSSION OF TESTS

Compressive strength

Table-. Compressive Strength of M40 Grade Concrete with Specimen / control sample

S.No	Test Period	Average Compressive strength of the concrete at different ages(N/mm²)
1	7days	20.92
2	28days	31.28

Table-Compressive Strength of M40 Grade Concrete With different proportions of Copper Slag
Target Mean Strength: 31.6 MPa

S.No	Sand replacement	Average Compressive strength of the concrete at different ages(N/mm²)	
		7days	28days
1	0%	35.06	47.92
2	10%	36.02	48.72
3	20%	37.26	49.20
4	30%	37.92	49.65
5	40%	38.87	50.36
6	50%	36.12	48.92

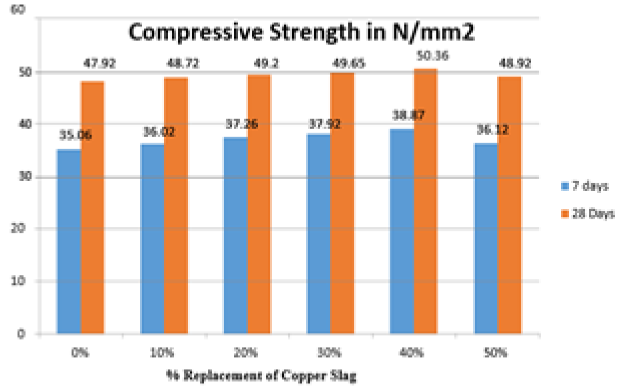

Figure Compressive Strength of Concrete with Partial Replacement of fine aggregate by copper slag

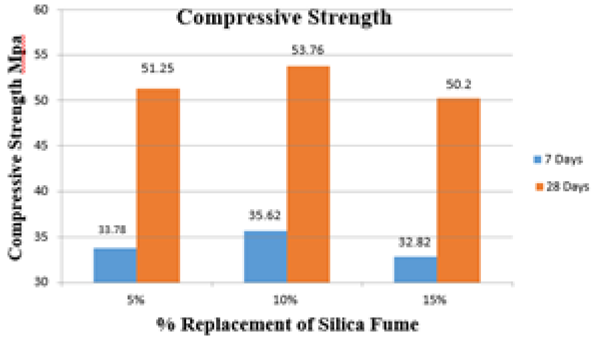

Figure Compressive Strength of Concrete with Partial Replacement of Cement by Silica Fume

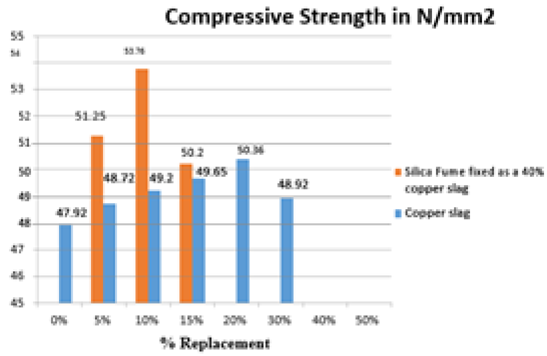

Figure Comparison of Compressive Strength

Split Tensile Strength Test Results

The results in table-12 shows the Split Tensile strength of M40 grade concrete with Copper slag and table-13 shows Split Tensile strength with copper slag fixed as 40% and varying silica fume at 28 days. The percentage change in strength with respect to normal concrete at 28 days is graphically plotted.

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Table 6.4 Spilt Tensile Strength of concrete at 28 days

% Replacement of Copper Slag	Split Tensile Strength (N/mm²)
0	5.92
10	5.94
20	5.97
30	6.15
40	6.50
50	6.01

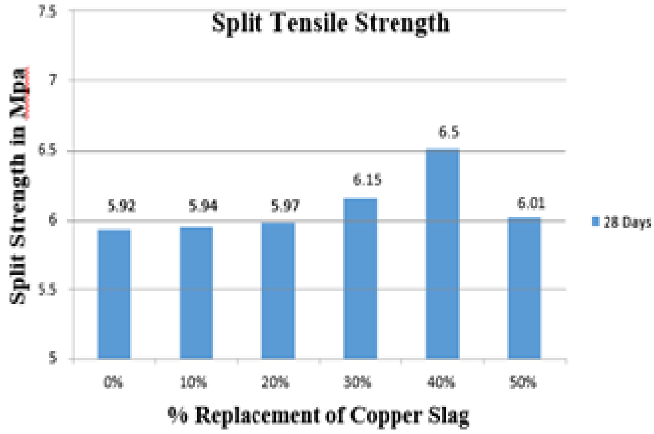

Figure: Split Tensile Strength of Concrete with Partial Replacement of fine aggregate by copper slag

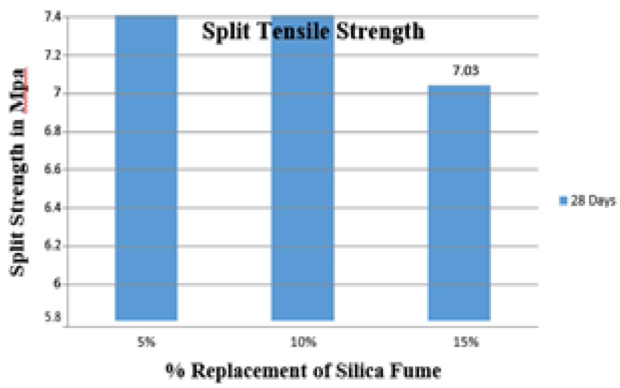

Figure: Split Tensile Strength of Concrete with Partial Replacement of Cement by Silica Fume

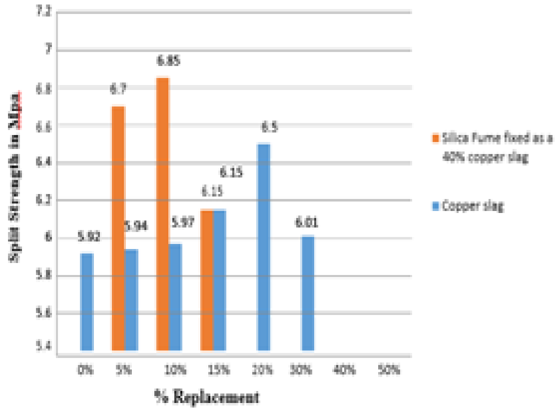

Figure Comparison of Split Tensile Strength

CONCLUSION

In this present study from the experimental results, we are obtained the following conclusions.

- Copper slag is a desirable material for replacement of fine aggregate in concrete.
- Copper slag concrete showed a considerable gain in effectiveness when use.
- Within permissible quantities.
- The outmost intensity was achieved for 40% replacement of fine aggregate with copper slag. Further increase of copper slag reduces the effectiveness.
- The Outmost intensity was achieved for 10% replacement of Cement with Silica Fume. Further addition of Silica Fume reduces the effectiveness.
- Compressive Strength was increased by 3.16% when compared to the Nominal mix for 40% replacement of fine aggregate with Copper Slag
- Split tensile Strength was increased by 9.79% when Compared to Nominal mix for 40% replacement of Copper Slag
- Flexural Strength was increased by 8.75% when Compared to Nominal mix for 40% Replacement of Copper Slag
- Copper Slag have a potential to provide alternative to fine aggregate Up to 40% and helps in maintaining the environment as well as economical balance.

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