The behaviour of Concrete by Partial Replacement of Fine Aggregate and Cement with Copper Slag - An Experimental Study

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Abstract— Concrete has occupied an important place in construction industry in the past few decades and it is used widely in all types of constructions ranging from small buildings to large infrastructural dams or reservoirs. It is the most widely used man-made construction material in the construction world. Ever since concrete has been accepted as material for construction, civil engineers have been trying to improve its quality, strength etc., against adverse conditions. The OPC is one of the main ingredients used for the production of concrete. However in the context of increased awareness regarding over exploitation of natural resources to manufacture cement, an eco-friendly technology has to be developed for the effective management of resources. The replacement of natural resources in the manufacture of cement and sand is the present issue in the present construction scenario. Copper slag is an industrial by-product material produced from the process of manufacturing copper. Use of Copper slag does not only reduce the cost of construction but also helps to reduce the impact on environment by consuming the material generally considered as waste product. Hence in the current study an attempt has been made to minimize the cost of cement and sand with concrete mix grade M25 by studying the mechanical behavior of these concrete mixes by partial replacing with advanced mineral admixture such as Copper slag in concrete mixes as partial replacement of cement and sand. In this study, partial replacement of Cement and fine aggregate with Copper Slag considered. Experimental study is conducted to evaluate the workability and strength characteristics of hardened concrete, by partially replacing the cement and sand by various percentages of copper slag for M25 grade of concrete at different ages. The mixes were designed using IS Code method. In this project, properties of concrete have been assessed by partially replacing cement and sand with Copper slag is separately done in two different phase. The cement has been replaced by Copper slag accordingly in the range of 0% (without Copper slag), 5%, 10%, 15%, and 20% is one phase and sand has been replaced by Copper slag accordingly in the range of 0% (without Copper slag), 10%, 20%, 30%, 40% and 50% is second phase by weight of cement for M25 mix. Concrete mixtures were produced, tested and compared in terms of compressive, flexural and split strength with the conventional concrete.

Key words: Copper Slag, Workability, Compressive Strength, Split Tensile Strength, Flexural Strength

I. INTRODUCTION

In the present scenario, as a result of continuous growth in population, rapid industrialization and the accompanying technologies involving waste disposal, the rate of discharge of pollutants into the atmosphere, copper slag is one of the industrial waste which comes out from blast furnace during metal extraction process. In many countries, there is a scarcity of natural aggregate that is suitable for construction, whereas in other countries the consumption of aggregate has increased in recent years, due to increases in the construction Industry. In order to reduce depletion of natural aggregate due to construction, artificially manufactured aggregate and some industrial waste materials can be used as alternatives, copper slag is considered as best options available.

Copper slag which is an industrial by-product of Sterlite Industries Ltd (SIL), Kolkata, India. The main objective of this thesis is to determine the concrete strength of M25 Grade by partial replacement of cement from 0% to 20% and sand from 0% to 50% with copper slag separately in two phases. The other objective is to reduce the cost of construction but also helps to reduce the impact on environment by consuming the material generally considered as waste product.

The mix design of M25 grade concrete was designed as per the method specified in IS 10262-2009.

Cubes of size 150mm × 150mm × 150mm, Cylinders of size 300mm×150mm and prisms of size 100mm × 100mm × 500mm were casted and tested for compressive strength, split tensile strength and flexural strength after the completion of respective curing periods.

II. EXPERIMENTAL PROGRAM

A. *Materials Used*

- Cement: Ordinary Portland cement of grade 53 is used for this experimental work.
- Fine aggregate: The material which passes through BIS test sieve number 4 (4.75mm) is termed as fine aggregate usually natural sand is used as a fine aggregate at places where natural sand is not available crushed stone is used as fine aggregates. In our region fine aggregate can be found from bed of Krishna River. It conforms to IS 383 1970 comes under zone II.
- Coarse aggregate: The material which is retained on BIS test sieve number 4 (4.75mm) is termed as coarse aggregate. The broken stone is generally used as a stone aggregate. Coarse aggregate used is locally available crushed angular aggregate of size 20mm and 10mm are used for this experimental work.
- Copper slag: Copper slag is an industrial by-product material produced from the process of manufacturing copper. Copper slag used in this work was brought from Sterlite Industries Ltd (SIL), Kolkata, India.

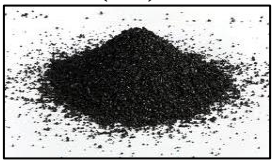

Fig. 1: Copper Slag

Physical Properties	Copper slag	Natural sand
Appearance	Black & Glassy	Grainy& white
Type	Air cooled	Air cooled
Specific gravity	3.91	2.5 to 2.8
Percentage of voids	43	47.8
Bulk density g/cc	2.08	2.7
Fineness modulus	3.47	2.65
Water absorption %	0.15 to 0.20	2.3
Moisture content	0.1	1.3

Table 1: Physical Properties of Copper slag and Natural Sand

B. Mix Design

The mix proportion chosen for this study is M25 grade with water-cement ratio of 0.475. In this test total 60 Cubes of standard size 150x150x150mm and 60 Cylinders of standard diameter 150mm and height 300mm and 60 Prisms of size 500x100x100mm were casted and cured for 28 and 56 days and tested as per code IS: 516-1959. The mix proportion chosen for this study is given in Table 2.

Water	Cement	Fine Aggregate	Coarse Aggregate (60% + 40%)
175	368	605.4	1332.6 (800.4 + 532.9)
0.475	1	1.62	3.62

Table 2: Mix proportion (Kg/m^3) and mix ratio

III. TESTS AND RESULTS

The different tests were conducted in the laboratories as shown in below. It consists of mixing of concrete in the laboratory by partial replacing fine aggregate with proportions (by weight) of Copper Slag added to concrete mixtures were as follows: 0% (for the control mix), 10%, 20%, 30%,40% &50% and Cement with proportions (by weight) of Copper Slag added to concrete mixtures were as follows: 0% (for the control mix), 5%.10%,15% & 20% Concrete samples were prepared and cured in the laboratory, and are tested, to evaluate the concrete fresh and harden properties like compressive strength, Split tensile strength and flexural strength requirements.

A. Partial replacement of Sand with Copper slag results

1) Slump Cone Test

Slump cone test was conducted to determine the workability of concrete.

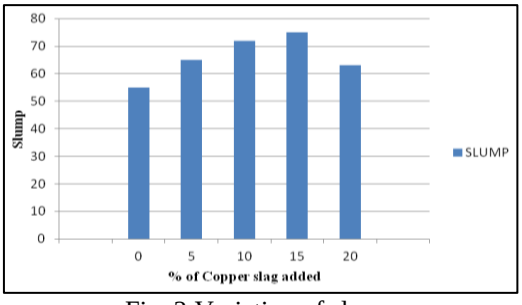

Fig. 2:Variation of slump

a) Description of Result

From Fig 2, the variation of slump for the partial replacement of Fine aggregate with copper slag increased in the order of 54, 57, 62, 64 & 67 mm for 0%, 10%, 20%, 30% &40% proportions and decreased by 54 mm for 50% proportions replacements respectively.

2) Compaction Factor Test

Compaction factor test was conducted to determine the workability of concrete.

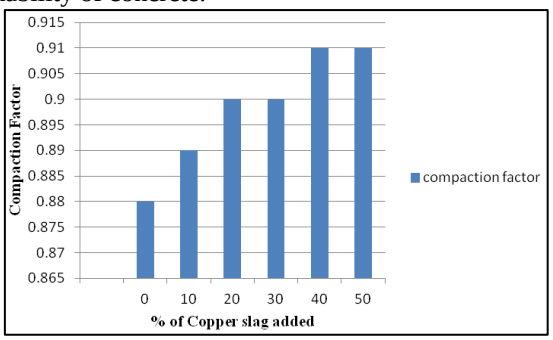

Fig. 3:Variation of Compaction factor

a) Description of Result

From Fig.3, The variation of compaction factor for the partial replacement of Fine aggregate with copper slag and Cement with GGBS increased in the order of 0.88, 0.89, 0.9,0.9 &0.91 for 0%,10%,20%,30%&40% proportions and same by 0.91 for 50% proportions replacements respectively.

3) Compressive Strength Test

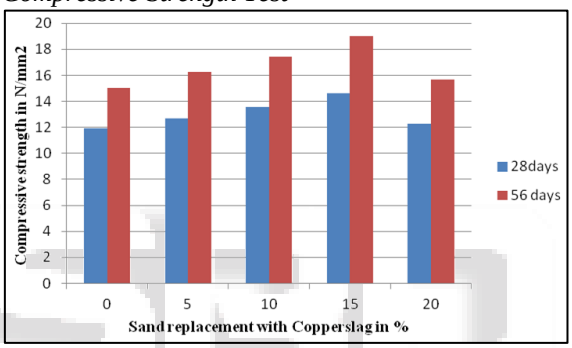

Fig. 4: Compressive strength of concrete by partial replacing sand with copper slag

a) Description of Result

From Fig.4, The compressive strength for partial replacement of fine aggregate with copper slag increased in the order of 6.27%, 11.11%, 15% & 17.51% for 10%, 20%, 30% & 40% partial replacements respectively and decreased by 9.02% for 50% partial replacement with respect to control specimen.

4) Split tensile strength test

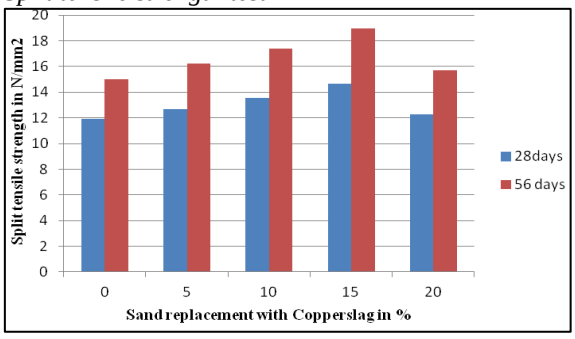

Fig. 5: Split tensile strength of concrete by partial replacing sand with copper slag

a) Description of Result

From Fig.5, The split tensile strength for partial replacement of fine aggregate with copper slag increased in the order of 6.98%, 12.40%, 20.28% & 24.28% for 10%, 20%, 30% & 40% partial replacements respectively and decreased by 8.70% for 50% partial replacement with respect to control specimen.

5) Flexural strength test

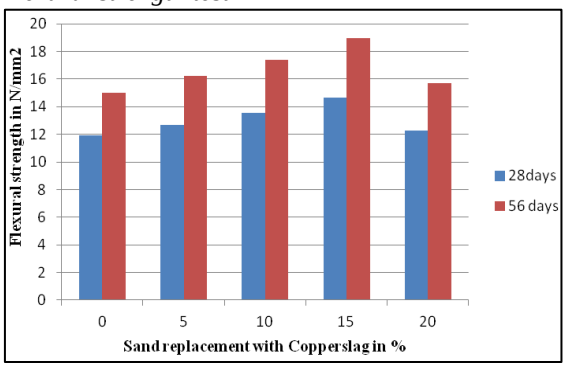

Fig. 6: Flexural strength of concrete by partial replacing sand with copper slag

a) Description of Result

From Fig.6, The Flexural strength for partial replacement of fine aggregate with copper slag increased in the order of 10.32%, 15.67%, 21.64% & 26.83% for 10%, 20%, 30% & 40% partial replacements respectively and decreased by 2.09% for 50% partial replacement with respect to control specimen.

B. Partial replacement of Cement with Copper slag results

1) Slump Cone Test

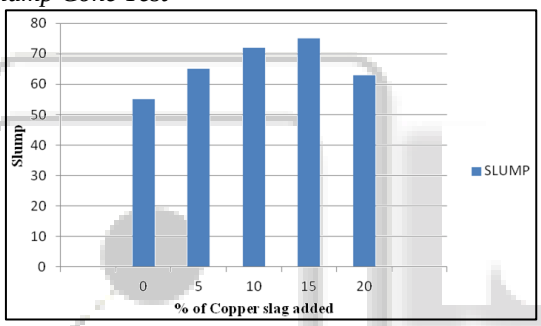

Fig. 7: Variation of slump

a) Description of Result

From Fig7, The variation of slump for the partial replacement of Fine aggregate with copper slag increased in the order of 53, 62, 68 & 75mm for 0%, 5%, 10% & 15% proportions and decreased by 58 mm for 20% proportions replacements respectively.

2) Compressive strength test

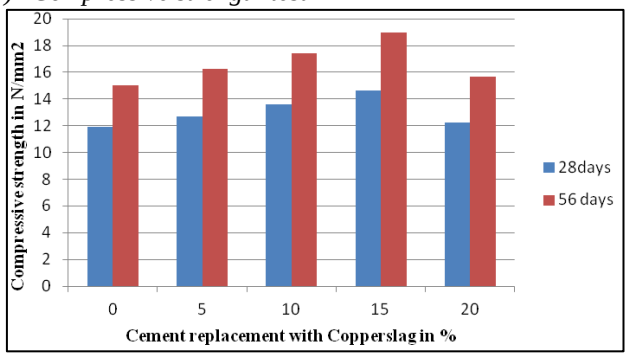

Fig. 8: Compressive strength of concrete by partial replacing cement with copper slag

a) Description of Result

From Fig.8, The compressive strength for partial replacement of cement with copper slag increased in the order of 5.88%, 11.46% & 15.46 for 5%, 10% & 15% partial replacements respectively and decreased by 3.86 for 20% partial replacement with respect to control specimen.

3) Split tensile strength test

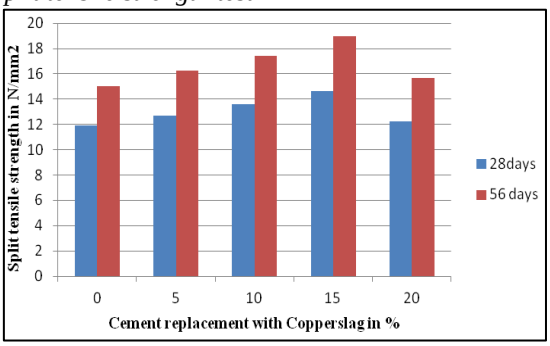

Fig. 9: Split tensile strength of concrete by partial replacing cement with copper slag

a) Description of Result

From Fig.9, The Split tensile strength for partial replacement of cement with copper slag increased in the order of 8.22%, 13.06% & 18.39% for 5%, 10% & 15% partial replacements respectively and decreased by 8.09% for 20% partial replacement with respect to control specimen.

4) Flexural strength test

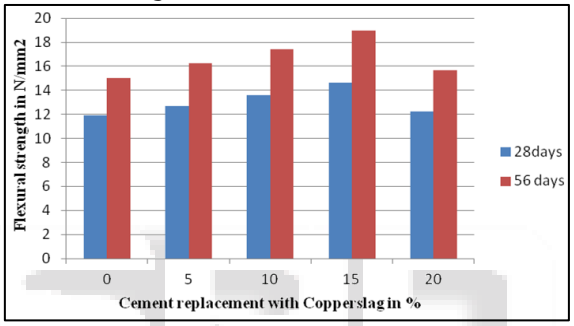

Fig. 10: Flexural strength of concrete by partial replacing cement with copper slag

a) Description of Result

From Fig.10, The Flexural strength for partial replacement of cement with copper slag increased in the order of %, 5.73%, 14.12% & 20.31% for 5%, 10% & 15% partial replacements respectively and decreased by 1.93% for 20% partial replacement with respect to control specimen.

IV. CONCLUSIONS

1) The Compressive strength of concrete for partial replacement of fine aggregate with copper slag increased by 17.5% with 40% partial replacement and decreased by 9.02% with 50% partial replacement while compared with control Specimen.
2) The Split tensile strength of concrete for partial replacement of fine aggregate with copper slag increased by 24.3% with 40% partial replacement and decreased by 8.70% with 50% partial replacement while compared with control Specimen.
3) The Flexural strength of concrete for partial replacement of fine aggregate with copper slag increased by 26.83% with 40% partial replacement and decreased by 2.09% with 50% partial replacement while compared with control Specimen.
4) The Compressive strength for partial replacement of cement with copper slag increased by 15.4% with 15% partial replacement and decreased by 3.86% with 20% partial replacement while compared to with control specimen.

5) The Split tensile strength for partial replacement of cement with copper slag increased by 18.39% with 15% partial replacement and decreased by 8.09% with 20% partial replacement while compared to with control specimen.
6) The Flexural strength for partial replacement of cement with copper slag increased by 20.31% with 15% partial replacement and decreased by 1.93% with 20% partial replacement while compared to with control specimen.

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