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Study on Properties of Concrete Containing Copper Slag as a Partial Replacement of Fine Aggregate

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ABSTRACT

In today's times waste-disposal is a difficult task and is causing huge dumpsters everywhere. The best solution for this waste management problem is recycle and re-use of the waste products. Copper Slag is also such a material obtained from the blast furnace during the manufacturing process of copper. India produces around 2.5 to 3 tones slag waste for every ton of metal extracted. This waste has an effective application in concrete industry as it can effectively help to reduce the depletion of natural sources of river sand. Copper Slag is bought from Sterlite Industries, Tuticorin, Tamil Nadu and used as a replacement with fine aggregates for different percentages of 0%, 20%, 40%, 60%, 80% and 100% and analyzed for compression strength. Through this result an optimum percentage replacement is arrived at, at which we can overcome the disadvantages of the material as well as obtain better results in comparison with ordinary concrete mix. RCC beams are designed and casted for this optimum percentage replacement and tested for flexural strength.

Keywords: Copper slag, Waste Management, Replacement, Compressive Strength, Optimum Percentage, Flexure Strength

INTRODUCTION

In present scenario river sand is being depleted and therefore the cost of material is raising eventually. In such situation, the demand for a replacement for the actual material will be high. Copper slag can be one such effective substitution for fine aggregates in concrete mix and also it is much cheaper when compared to other renewals. Generally concrete mix comprises of almost 70% of aggregates which is a major distribution ratio. So, industrial wastes like copper slag are being replaced for fine aggregates due to the similarity in texture and properties of both the materials and also amount of copper present in copper slag is not found to be more than 0.5 to 2%. In India copper slag is produced by Sterlite Industries Ltd (SIL), Tuticorin, Tamil Nadu. When used in optimum quantity copper slag is experienced to have increased the strength of concrete notably when compared to conventional mix.

Table-1: Reports on Composition of Copper Slag as received by SIL, Tamil Nadu

Tests	Result
Alumina as Al_2O_3	3.470%
Cadmium as Cd	0.001%
Calcium as CaO	2.650%
Chloride as Cl	0.001%
Copper as Cu	0.810%
Iron as Fe_2O_3	60.070%
Lead as Pb	0.080%

Magnesium as Mg	1.370%
Potassium as K_2O	0.330%
Silica as SiO_2	29.190%
Sodium as Na_2O_3	0.100%
Sulphur as SO_4	0.110%
Titanium as TiO_2	0.240%
Zinc as Zn	1.040%

2. MATERIALS AND THEIR PHYSICAL PROPERTIES

Cement

Ordinary Portland cement of grade 53 was used. The cement pertaining to the company "Maha Cement" was used as the binding material.

PROPERTY	VALUE
Specific Gravity	2.88
Standard Consistency	At 33% of water
Initial Setting Time	35 min
Final Setting Time	310 min
Fineness of Cement	2%

Table-2: Physical Properties of Cement

Sand

Naturally available river sand is used as fine aggregate which is clean and free from waste stones and impurities.

PROPERTY	VALUE
Specific Gravity	2.57
Water Absorption	0.63%
Fineness Modulus	4.52

Table-3: Physical Properties of Sand

Copper Slag

Copper slag was from Sterlite Industries Ltd. from Tuticorin, Tamil Nadu and distributed by Universal Abrasives & Minerals (P) Ltd, Chennai, Tamil Nadu is used as a partial replacement for fine aggregates.

Fig-1: Copper Slag

Table-4: Physical Properties of Copper Slag

PROPERTY	VALUE
Specific Gravity	3.54
Water Absorption	0.32%
Fineness Modulus	5.55

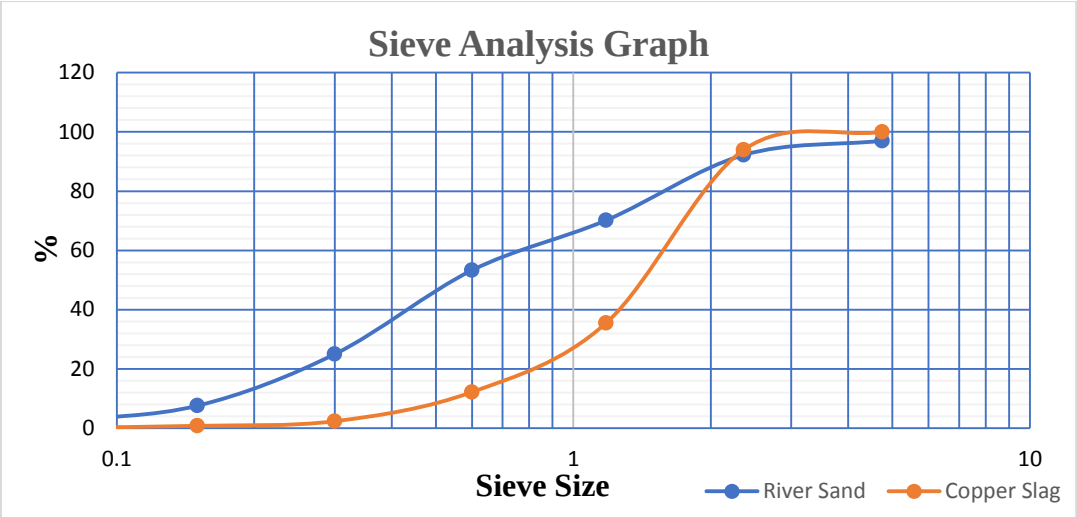

Fig-2: S-Curve for River Sand and Copper Slag

From the comparison of the graphs we can conclude that CS has greater particle size on average and in texture it is more gritty substance when compared to sand and finer particle ratios is less in CS.

Coarse Aggregate

Nominal coarse aggregates of 20mm average size is used.

Table-5: Physical Properties of Coarse Aggregate

PROPERTY	VALUE
Specific Gravity	2.86
Water Absorption	0.167%
Fineness Modulus	3.95
Crushing Value	18.64%
Abrasion Value	21.53%
Impact Value	16.87%

Mix Design

Mix design was carried out as per Indian Standard Codes for M30 grade of concrete. Copper slag was replaced in the intervals of 20% with fine aggregates. Water cement ratio used was 0.4.

Preparation and Casting of Test Specimens

- 150 mm x 150 mm x 150 mm cubes were cast for compression test with replacement of 0%, 20%, 40%, 60%, 80% and 100% replacement of copper slag. The specimens were demoulded after 24 hours and tested for 7 days, 14 days and 28 days of curing.
- 150 mm x 300 mm cylinders were cast for split tensile test with replacement of 0%, 20%, 40%, 60%, 80% and 100% replacement of copper slag. The specimens were demoulded after 24 hours and tested for 7 days, 14 days and 28 days of curing.
- An optimum quantity replacement was finalized from the above experiments and RCC beams were designed and tested for Flexure.

RESULTS AND DISCUSSION

a. Compression Strength Test

Fig-3: Cube Specimen Failure under Compressive Loads

Table-6: Compression Test Results

Percentage of CS	7 Days	14 Days	28 Days
0	29.350	31.170	39.380
20	43.450	43.450	43.450
40	43.590	46.070	48.249
60	40.690	40.680	44.760
80	38.800	40.540	40.838
100	32.840	31.530	37.200

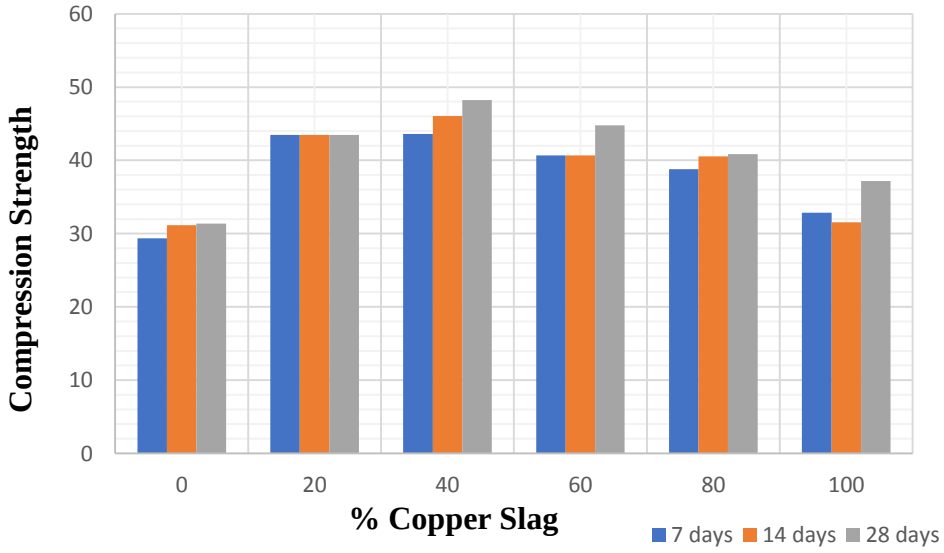

Fig-4: Compression Test Results

From the test results it can be noted that for the addition of copper slag of 20% and 40% the compressive strength increases by 48.51% and 56.96% for 7 days of curing. For 14 days of curing the strength increases by 39.39% and 47.80% respectively and for 28 days of curing the strength increases by 10.33% and 22.52% respectively in comparison with the conventional concrete specimens.

b. Split Tensile Test

Fig-5: Cylinder Specimen Failure under Tensile Loads

Table-7: Split Tensile Test Results

Percentage of CS	7 Days	14 Days	28 Days
0	3.050	4.060	4.299
20	3.690	4.380	4.625
40	4.060	4.750	5.030
60	4.010	4.700	4.810
80	3.690	4.520	4.800
100	3.500	4.300	4.440

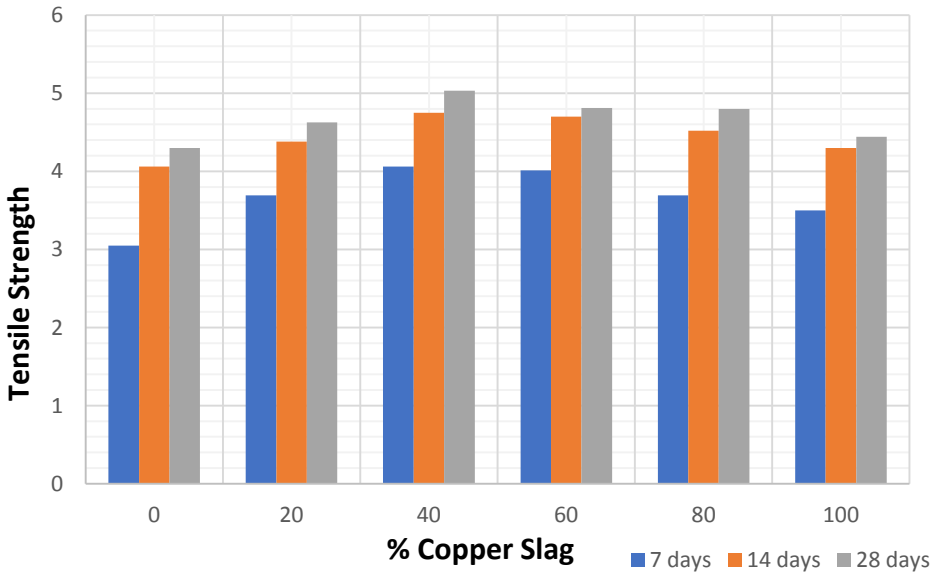

Fig-6: Split Tensile Test Results

From the test results it can be noted that for the addition of copper slag of 20% and 40% the tensile strength increases by 20.98% and 33.11% for 7 days of curing. For 14 days of curing the strength increases by 7.88% and 16.99% respectively and for 28 days of curing the strength increases by 7.58% and 17% respectively in comparison with the conventional concrete specimens.

From the above tests it can be observed that maximum strength for compression and tensile loads both occur at 40% replacement of fine aggregate by copper slag. Therefore, in the current study, 40% replacement is considered optimum.

c. Flexure Test

Beams were casted with conventional concrete mix and 40% copper slag infused mix and results were compared. Considering a span sample of 1 meter length, the beam is designed using Limit State Method of Design as per Indian Standard Code, the width of the beam being 200 mm and the depth of the beam being 300 mm.

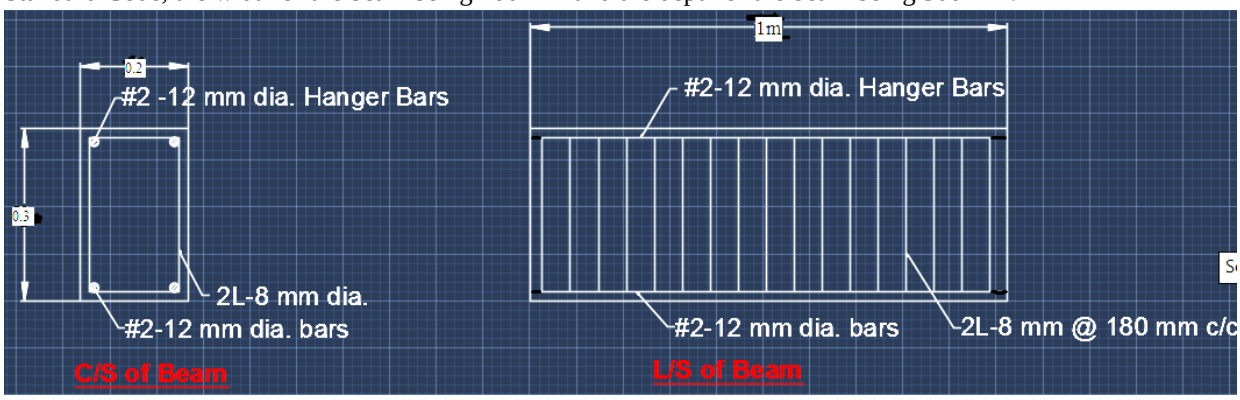

Fig-7: Reinforcement Details of the Beam

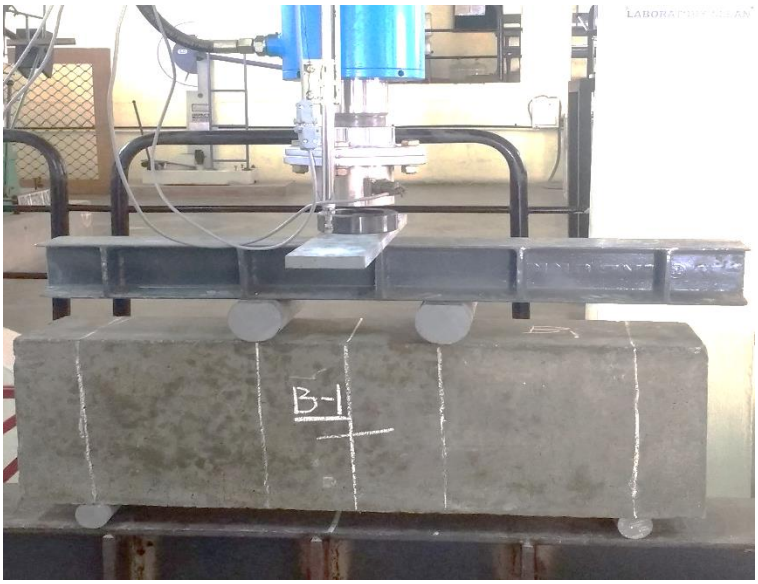

Fig-8: Experimental Setup for Flexure Test

Average Flexural Strength of nominal RCC Beam = 7.715 N/mm^2
Average Flexural Strength of RCC Beams with 40% CS = 11.45 N/mm^2
Percentage increase in Flexural Strength = 48.412%

Summary

- Copper slag has granular texture and also a higher specific gravity and hence is a denser material when compared to river sand.
- Water absorption in copper slag is observed to be almost 50% less than that of river sand which helps in saving water
- The partial replacement of copper slag as fine aggregate considerably increased the compressive strength and tensile strength at 20% and 40%.
- Optimum percentage replacement of copper slag with fine aggregate to obtain maximum strength in concrete is found to be 40%.
- By infusing this optimum content of copper slag in concrete for reinforced beam, an increase of 48.412% of flexural strength was observed.

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