

PERFORMANCE OF COPPER SLAG ON STRENGTH PROPERTIES AS PARTIAL REPLACE OF FINE AGGREGATE IN CONCRETE MIX DESIGN

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ABSTRACT:

This paper reports on an experimental program to investigate the effect of using copper slag as a replacement of fine aggregate on the strength properties. Copper slag is the waste material of matte smelting and refining of copper such that each ton of copper generates approximately 2.5 tons of copper slag. Copper slag is one of the materials that is considered as a waste which could have a promising future in construction Industry as partial or full substitute of aggregates. For this research work, M25 grade concrete was used and tests were conducted for various proportions of copper slag replacement with sand of 0 to 100% in concrete. The obtained results were compared with those of control concrete made with ordinary Portland cement and sand.

KEYWORDS: copper slag, Fine aggregate, compressive strength, Flexural strength, partial replacement.

1. INTRODUCTION

In India, there is great demand of aggregates mainly from civil engineering industry for road and concrete constructions. But now days it is very difficult problem for available of fine aggregates. So researchers developed waste management strategies to apply for replacement of fine aggregates for specific need. Natural resources are depleting worldwide while at the same time the generated wastes from the industry are increasing substantially. The sustainable development for construction involves the use of nonconventional and innovative materials, and recycling of waste materials in order to compensate the lack of natural resources and to find alternative ways conserving the environment. Copper slag is one of the materials that is considered as a waste material which could have a promising future in construction industry as partial or full substitute of either cement or aggregates. It is a by-product obtained during the matte smelting and refining of copper. To produce every ton of copper, approximately 2.2–3.0 tons copper slag is generated as a by-product material. In Oman approximately 60,000 tons of copper slag is produced every year (Alnuaimi AS *et al.*, 2012). Copper slag is a by-product material produced from the process of manufacturing copper. As the copper settles down in the smelter, it has a higher density, impurities stay in the top layer and then are transported to a water basin with a low temperature for solidification. The end product is a solid, hard material that goes to the crusher for further processing.

1.1 Copper Slag:

Copper slag is a by-product obtained during the matte smelting and refining of copper. Copper slag used in this work was brought from Sterlite Industries Ltd (SIL), Tuticorin, Tamil Nadu, India. SIL is producing Copper slag during the manufacture of copper metal. Currently, about 2600 tons of Copper slag is produced per day and a total accumulation of around 1.5 million tons. It is a by-product obtained during the matte smelting and refining of copper. To produce every ton of copper, approximately 2.2–3.0 tons copper slag is generated as a by-product material. Utilization of copper slag in applications such as Portland cement substitution and/or as aggregates has threefold advantages of eliminating the costs of dumping, reducing the cost of concrete, and minimizing air pollution problems.

1.2 Uses of copper slag

- Copper slag has also gained popularity in the building industry for use as a fill material.
- Contractors may also use copper slag in place of sand during concrete construction.
- Copper slag can also be used as a building material, formed into blocks.
- Copper slag is widely used in the sand blasting industry and it has been used in the manufacture of abrasive tools.
- Copper slag is widely used as an abrasive media to remove rust, old coating and other impurities in dry abrasive blasting due to its high hardness (6-7 Mohs), high density (2.8-3.8 g/cm³) and low free silica content.

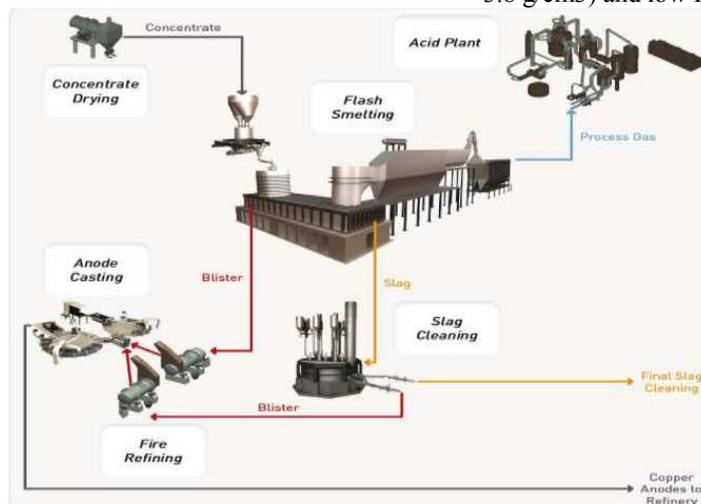


Fig.1.1 Process of generation of copper slag



Fig.1.2 Grinded copper slags from industry

2. SELECTIONS OF MATERIALS:

2.1 Cement

Ordinary Portland Cement (OPC) is by far the most important type of cement. The OPC was classified into three grades, namely 33 grade, 43 grade and 53 grade depending upon the strength of the cement at 28 days when tested as per IS 4031-1988. If the 28 days strength is not less than 33N/mm², 43N/mm² and 53 N/mm² it called 33 grade and 53 grade cement respectively. Ordinary Portland cement 53 Grade of Ultra Tech Cement brand conforming to IS: 8112-1989 and IS 12269-1987 is used in this experimental work.

2.2 Fine Aggregate:

The aggregate size is lesser than 4.75 mm is considered as fine aggregate. The sand particles should be free from any clay or inorganic materials and found to be hard and durable. It was stored in open space free from dust and water. In our region fine aggregate can be found from bed of Krishna River. It conforms to IS 383 1970 comes under zone II.

2.3 Coarse Aggregate:

The aggregate size bigger than 4.75 mm, is considered as coarse aggregate. It can be found from original bed rocks. Coarse aggregate are available in different shape like rounded, Irregular or partly rounded, Angular, Flaky. It should be free from any organic impurities and the dirt content was negligible.

3. EXPERIMENTAL WORK:

3.1 Sieve Analysis:

The experimental work starts with the sieve analysis. IS specified sieves of varying sizes are used. The details of sieve analysis are shown in Table 3.1

Table 3.1 Sieve Analysis of fine and Coarse Aggregate, Bottom Ash and Copper Slag.

IS sieve	Coarse aggregate	Fine aggregate	Copper Slag
	Cumulative percentage retained	Cumulative percentage retained	Cumulative percentage retained
20.00	0.7	0	0
16.00	4.15	0	0
12.50	15.85	0	0
10.00	48.75	0	0
4.75	97.25	1.17	0.20
2.36	100	5.68	4.75
1.18	100	28.14	50.65
.600	100	57.07	88.25
.300	100	95.39	96.15
.150	100	98.68	98.00
FINENESS MODULUS	5.32	2.87	3.38

3.2 Mix design and sample preparation

Concrete mixtures with different proportions of Copper slag used as a partial or full substitute for fine aggregates were prepared in order to investigate the effect of Copper slag substitution on the strength normal concrete. Concrete mixtures were prepared with different proportions of Copper slag. The proportions (by weight) of Copper slag added to concrete mixtures were as follows: 0% (for the control mix), 10%, 20%, 30%, 40%, 50%, 60%, 75%, and 100%. The control mixture was designed to have a target 28 day compressive strength of 25 N/mm² (M-

25), using a water-to-binder ratio of 0.52. The mix proportion chosen for this study is given in Table 3.2

Table 3.2: Mix proportion (Kg/ m³) and mix ratio

Cement	Water	Sand(fine aggregate)	Coarse Aggregate
368.42	191.58	741.39	1192.42
1	0.5	2.01	3.23

3.2 Testing Procedures:

This project entailed subjecting the designed concrete mixes to a series of tests to evaluate the strength, and other properties. For this project, it was important to monitor the strength development with time to adequately evaluate the strength of each concrete mix. For each test, either 3 samples from each mix were tested at each curing age, and the average values were used for analysis. The following sections present the procedures used for the various tests.

3.3.1 Compressive Strength Test:

One of the most important properties of concrete is the measurement of its ability to withstand compressive loads. This is referred to as a compressive strength and is expressed as load per unit area. One method for determining the compressive strength of concrete is to apply a load at a constant rate on a cube (150×150×150 mm), until the sample fails. The compression tests performed in this project were completed in accordance with IS standard 516 “Methods of Tests for Strength of Concrete”. The apparatus used to determine the compressive strength of concrete in this project was a testing machine. For this study samples were tested for compression testing at 7, 28, days of curing.



Figure 3.1 Compression Testing Apparatus.

The compressive strength of the concrete in terms of pressure was then calculated using the Equation:

$$f_c = \frac{P}{A}$$

Where,

f_c = Compressive Strength of Concrete,

P = Maximum load applied (KN), and

A = The cross-sectional area of the sample (mm²)

3.3.2 Flexural Strength Test:

Another important strength property of concrete is the flexural strength of a concrete. Samples were tested for flexural strength at 28 days of curing. The testing machine apparatus used to measure the flexural strength of concrete in this project is operated by hydraulics and has Dial Gauge displays for monitoring the rate of loading and the peak load on the sample at the time of failure. The strain rate was manually controlled by turning a knob either clockwise or counter clockwise. The flexural strength was then calculated using Equation:

$$f_{cr} = \frac{Pl}{bd^2}$$

Where

f_{cr} = Flexural Strength of Concrete, (kPa or psi)

P = Maximum load applied (KN or lb),

l = Length of the specimen between the lower supports (mm or in),

b = Width of the beam (mm or in), and

d = Depth of the beam (mm or in)



Figure 3.2 Flexural Strength Testing Machine

4. TESTS AND RESULTS:

The different tests conducted in laboratories are shown in fig. 4.1 to fig. 4.3 It consist mixing of concrete in the laboratory by replacing Copper Slag as 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%, 60%,75%, and 100%. Concrete samples were prepared and cured in the laboratory, and are tested, to evaluate the concrete fresh and harden properties like compressive strength and flexural strength requirements.



Figure 4.1 Compressive strength test for Cube



Figure 4.2 Flexural strength test of Beam



Figure 4.3 Flexural strength test of Beam

4.2 Compressive Strength:

Compression tests were performed on samples made during at various curing ages. As discussed earlier, a targeted compressive strength was used for this investigation. Results from compression strength tests performed.

Here cube samples of size 150 x 150 x 150 mm, were prepared and tested at 7, 28 days of curing in water under controlled laboratory conditions. 3 samples were tested at each curing age. Tables 4.7 show the average

compressive strengths of the concretes tested. Figures 4.4 graphically display the compressive strength of concrete composites tested.

Table 4.1: Compressive Strengths test result

MIX	Compressive Strengths (Mpa)	
	7 days	28 days
NORMAL M-25	18.29	30.36
CS 10%	24.12	35.17
CS 20%	25.43	38.22
CS 30%	27.75	42.29
CS 40%	28.48	43.01
CS 50%	23.25	39.53
CS 60%	22.37	35.89
CS 75%	21.21	26.88
CS 100%	18.31	25.14

Table 4.2 Strength Gained By Copper Slag

MIX	Comp. Strength 7 days Mpa	Strength Gained 7 days	Comp. Strength 28 Days Mpa	Strength Gained 28 Days
M-25	18.29	100.00	30.36	100.00
CS 20%	25.43	139.03	38.22	125.88
CS 40%	28.48	155.71	43.01	141.67
CS 60%	22.37	122.30	35.89	118.21
CS 75%	21.21	115.96	26.88	88.53
CS-100	18.31	100.10	25.14	82.80

From the test results, it can be seen that the compressive strength of Copper Slag concrete mixes with 10%, 20%, 30%, 40%, 50%, 60%,75% and 100% fine aggregate replacement with Copper Slag, were higher than the control mix at all ages. It is evident from Table 6.1 and Fig 6.1 that compressive strength of all mixes continued to increase with the increase in age. From Fig. 6.1, it can be seen that there is increase in strength with the increase in Copper Slag percentages; However, from table 6.1 the highest compressive strength was achieved by 40% replacement of copper slag, which was found about 28.48 Mpa compared with 18.29 Mpa for the control mixture. This means that there is an increase in the strength of almost 55% compared to the control mix at 7 days. However, mixtures with 100% replacement of copper slag gave the lowest compressive strength 18.31 Mpa which is almost 1% greater than the strength of the control mix.

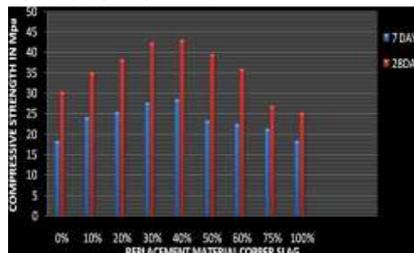


Figure 4.4 Compressive Strengths test result for copper slag

4.3 Flexural Strength:

Table 4.3 Flexural Strengths of the Concrete

MIX	Flexural Strengths (Mpa) f_{cr}
NORMAL M-25	3.49
CS 10%	3.60
CS 20%	4.00
CS 30%	3.63
CS 40%	3.67
CS 50%	3.75
CS 60%	3.57
CS 75%	3.52
CS 100%	3.83

Here samples of size 500 x 100 x 100mm, were prepared and tested for flexural strength at 28-days of curing. At least 3 samples were tested at each curing age. The average flexural strengths of the concrete

composites measured during this phase of the project are presented in Table 4.3 and graphically on Figure 4.5

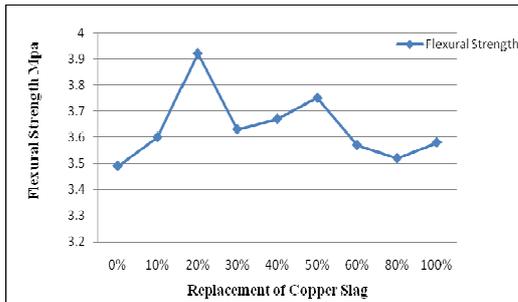


Figure 4.5 Flexural Strengths of the Concrete

5. CONCLUSIONS

The following conclusions were drawn from this study

1. Maximum Compressive strength of concrete increased by 55% at 40% replacement of fine aggregate by copper slag, and up to 75% replacement, concrete gain more strength than control mix concrete strength.
2. It is observed that for all percentage replacement of fine aggregate by Copper slag the flexural strength of concrete is more than control mix.
3. It is observed that, the flexural strength of concrete at 28 days is higher than design mix (Without replacement) for 20% replacement of fine aggregate by Copper slag, the flexural strength of concrete is increased by 14%. This also indicates flexural strength is more for all percentage replacements than design mix.
4. Compressive strength and flexural Strength is increased due to high toughness of Copper slag.

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