Utilization of Copper Slag in M25 Grade of Concrete

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Abstract: **Copper slag is an industrial by-product produced during the pyro-metallurgical extraction of copper metal from copper concentrate. In this study, mix design of M25 grade of concrete was carried out by using crushed stone aggregates and river sand as coarse and fine aggregates respectively. In the designed concrete, fine aggregates were replaced with copper slag by 10%, 20%, 30% & 40%, by weight and blended mixes were prepared. The compressive strength and flexural strength tests were carried out on control mix and blended mixes. The experimental results showed that compressive and flexural strength of concrete increased by the replacement of fine aggregates up to 20% by copper slag, but beyond that got decreased. On the basis of present research, it has been concluded that copper slag can be utilized by the partial replacement of fine aggregates in the tune of 20% in M25 grade of concrete. The utilization of this industrial by-product in concrete can solve the dumping problem of copper industries and can be a step towards sustainable construction.**

Key Words: Copper Slag, Concrete, Fine Aggregates, Compressive Strength, Flexural Strength.

1. INTRODUCTION

Concrete is a versatile construction material which is economical and most durable. In India, around 470 million cubic metres per annum concrete is expected to be used by the year 2017 [1]. Copper industries produce around 6.5 million ton copper slag per annum in India [2]. Presently there are limited uses of copper slag such as in the highway embankment, shot blasting, and manufacturing of abrasive tools. The remaining part of copper slag is being dumped unattended in the landfills. The dumping of copper slag requires a huge land in the nearby area of copper smelters and also pollutes the environment. Therefore, there is an immediate need to find out utilization of copper.

Zain et al. [3] studied the replacement of cement by copper slag in cement mortar and recommended that 5% cement can be replaced. The utilization of fly ash and copper slag mix in the construction of embankment was investigated by Patel et al. [4] and authors concluded that 70% copper slag and 30% fly ash mix can be successfully utilized in place of natural soil. Experimental study was conducted by Brindha and Nagan [5] by replacing sand with granulated copper slag by 5%, 10%, 15%, 20%, 30%, 40% and 50% and observed that compressive strength and split tensile strength got increased by about 35%-40% and 30%-35% respectively. On the basis of this study, Brindha and Nagan concluded that percentage replacement of sand by copper slag shall be up to 40%. In an experimental study Alnuaimi [6] replaced fine aggregates by copper slag in reinforced concrete slender columns up to 40% and observed no major changes in column failure.

On the basis of literature review, the present research was planned, with the prime objective to study the possible application of copper slag in cement concrete by partial replacement of fine aggregates.

2. EXPERIMENTAL WORK

In this study, mix design of M25 grade concrete by using natural aggregates was carried out as per IS: 10262-2009 [7]. The fine aggregates were replaced by copper slag with 10%, 20%, 30% and 40%, by weight. The compressive strength and flexural strength were evaluated as per relevant Indian standards.

2.1 Materials

For this study, fine aggregates and coarse aggregates were procured from local quarry and their physical properties were determined. The test results of physical properties are shown in Table:1. The copper slag used in this research was procured from Birla copper, a unit of Hindalco industries situated at Dahej in Gujarat state of India. The specific gravity and water absorption of copper slag are 3.52 and 0.33% respectively. The gradation of copper slag and fine aggregates are given in Table 2.

2.2 Concrete Mix Design

Concrete mix design for M 25 grade was done as per IS: 10262-2009 [7] by using conventional materials such as fine aggregates, coarse aggregates, cement and admixture Naphthalene Formaldehyde for a slump of 100 - 125 mm. The mix proportion is shown in Table3.

Table 1: Physical Properties of Aggregates

Property Test	Coarse Aggregates		Fine Aggregates
	20 mm	10 mm	
Sp. Gravity	2.68	2.68	2.70
Water Absorption	0.80%	0.80%	1.10 %

Table 2 : Sieve Analysis of Fine Aggregates and Copper Slag

Sieve Size (mm)	% Passing	
	Fine Aggregates (River Sand)	Copper Slag
10.0	100.00	100.00
4.75	98.60	100.00
2.36	96.00	97.80
1.18	88.40	74.00
0.600	38.70	15.60
0.300	9.35	3.50
0.150	1.00	0.00

Table 3 : Proportioning of materials for M25 Grade of Concrete (w/c ratio 0.48, Cement 350 kg, Water 185.42 kg)

Mix (FA+CS)	Coarse Aggregates		FA (kg)	CS (kg)
	20 mm (kg)	10 mm (kg)		
100+0	683.15	448.59	745.38	0.00
90+10	683.15	448.59	670.84	74.54
80+20	683.15	448.59	596.3	149.08
70+30	683.15	448.59	521.76	223.62
60+40	683.15	448.59	447.22	298.16

Note- Materials are in kg for 1 Cubic metre of concrete

3. CONCRETE

The results of slump test, compressive strength and flexural strength for control mix and blended mixes are as follows:

3.1 Slump Test

The workability of fresh concrete was measured by slump test. The slump values with 0%, 10%, 20%, 30% & 40 copper slag was obtained 110, 120, 130, 142 & 160 mm respectively. It can be seen from the test results that by increasing the quantity of copper slag, slump also increased which might be due to the fact that water absorption of copper slag (0.33%) is less as compared to fine aggregates (1.10%). Hence more water is available in the mix which increased the slump value.

3.2 Compressive Strength Test

The compressive strength was determined by testing cube specimens of size 150 mm for all the mixes at the age of 7 and 28 days and results are shown in Table 4. The variation in compressive strength with copper slag is presented by Figure1. The compressive strength of blended concrete increases up to 20% addition of copper slag and afterwards decreases. The increase in compressive strength at initial level of replacement might be due to less number of copper slag (Specific Gravity 3.52) particles in the same weight of mix as compared to fine aggregates (Specific Gravity 2.70); hence more cement is available for bonding. Furthermore addition of copper slag causes reduction in strength due to an increase of free water content in the mix, as the water absorption of copper slag (0.33%) is less as compared to fine aggregates (1.1%).

3.3 Flexural Strength Test Result

Another important strength property of concrete is the flexural strength. Beam specimens of size 700 mm x 150 mm x 150 mm were tested for flexural strength at the age of 28 days of curing and results are presented in Table 5. The results indicate that flexural strength increases up to 20 % replacement of fine aggregates by copper slag & afterwards decreases as shown by Fig.2.

Flexural strength might be increased at the initial level of replacement due to less number of copper slag particles in the same weight of the mix as compared to fine aggregates; hence more cement is available for bonding. Furthermore additions of copper slag causes reduction in strength due to an increase of free water content in the mix, as the water absorption of copper slag (0.33%) is less as compared to fine aggregates (1.1%).

Table 4: Compressive Strength at 7 and 28 days of M25 Grade Concrete

Copper Slag (%)	Compressive Strength at age of 7 days		Compressive Strength at age of 28 days	
	(N/mm^2)	% Change	(N/mm^2)	% Change
0	20.79	-	31.92	-
10	21.56	+3.70	32.51	+1.84
20	22.37	+7.59	33.56	+5.13
30	21.01	+1.05	28.71	-10.05
40	20.11	-3.27	25.52	-20.05

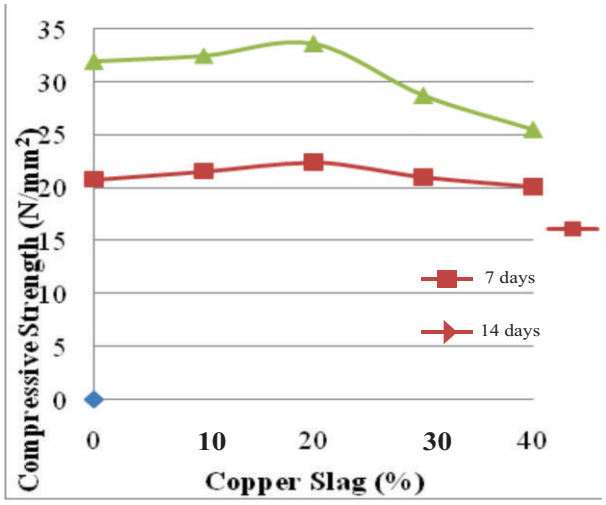

Fig.1 Compressive Strength (7 days and 28 days) v/s. % of Copper Slag

Table 5: Flexural Strength at 28 days of M 25 Grade Concrete

Copper Slag (%)	Compressive Strength at age of 7 days	
	(N/mm^2)	% Change
0	3.68	-
10	4.11	+11.68
20	4.24	+15.21
30	3.84	+4.34
40	3.42	-7.06

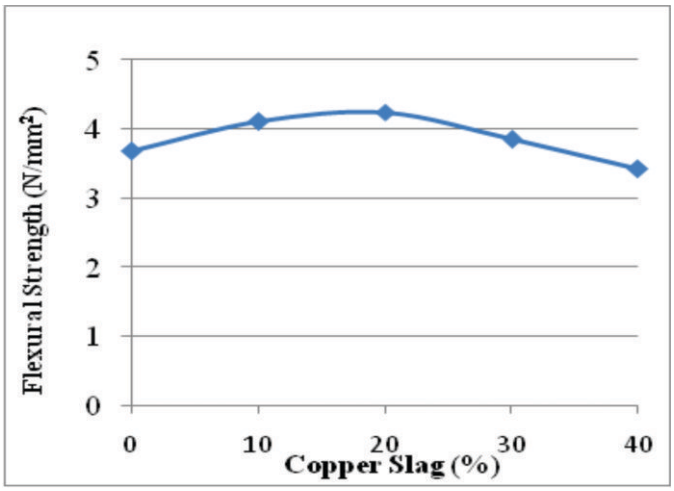

Fig.2 Flexural Strength (28 Days) v/s. % of Copper Slag of M 25 Grade Concrete

4. CONCLUSIONS

In the present study, technical feasibility for utilization of copper slag in M25 grade of concrete was carried out. On the basis of test results, it can be concluded that fine aggregates can be replaced in a tune of 20% by copper slag in concrete without having any adverse effect on its compressive and flexural strength. In this way, the dumped copper slag can be utilized in bulk by the construction industries in concrete which can preserve the natural aggregates as well as can solve the dumping problem faced by copper smelters. It can be a step towards sustainable construction practices.

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