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The Behaviour of Concrete in Terms of Flexural, Tensile & Compressive Strength Properties by Using Copper Slag as an Admixture

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***Abstract*— In this paper, research has been carried out on the effect of copper slag on the strength properties of both M25 and M30 concrete. Cement was replaced with copper slag in following proportions: 0%, 5%, 10%, 12%, 14%, 16%, 18% and 20%.There was remarkable variation observed in the stress patterns. Tabulated values have been provided depicting the variation pattern of both direct and in-direct stresses. The concrete was tested for 7 days and 28 days strength after casting the moulds. No additional catalyst/plasticizers have been used.**

***Index Terms*— Copper Slag, Flexural Strength, In-Direct Tensile Strength i.e., Split Tensile Strength, Compressive Strength**

I. INTRODUCTION

Major research works are being carried out pertaining to the effect on concrete characteristics due to inclusion of foreign substances as raw material. In this research efforts have been put to replace cement with copper slag for two different mix designs viz. M25 and M30. The concrete blocks have been tested for compression, split- tensile and flexural values. The values have been compared with that of the conventional values further. Also detailed cost analysis has been performed to know the project feasibility.

Copper slag can be added in two stages into cement as follows:

1. At the time of manufacturing of cement (additive)
2. At the time of mixing concrete in-situ (admixture)

In this paper study has been performed on the 2nd step i.e., we have added copper slag while preparing the mix design.

II. MATERIALS USED

A. Cement

Ordinary Portland cement of 53 grade with specific gravity of 3.15 has been used. The initial setting time and final setting time were found to be 33min and 315min respectively.

B. Fine Aggregate

Locally available natural river sand passing through 4.75 mm I.S. Sieve with a fineness modulus of 2.74, and water absorption of 1.5% in saturated surface dry (SSD) condition was used. The specific gravity of the sand is found to be 2.63 and was confining to ZONE-III.

C. Natural coarse aggregate

Crushed granite metal from local sources, passing through 20 mm and retained on 4.75 mm sieve was used as natural coarse aggregate. The fineness modulus of Natural Coarse Aggregate (NCA) is 6.56 and its water absorption is 0.94% in SSD condition. The specific gravity of coarse aggregate is found to be 2.71.

D. *Water*

Potable fresh water available from local sources free from deleterious materials was used for mixing and curing of all the mixes tried in this investigation. W/C ratio is taken as 0.47 for M25 and 0.45 for M30 concrete.

E. Copper Slag

It was procured from Laxmi Pumps Pvt. Ltd., Sholapur, Maharashtra. Its specific gravity was found to be 3.79. The moisture content was found to be 0.0075 and bulk density was recorded as 1886 kg/ m3. After sieve analysis the particle size distribution of the copper slag is shown in table 1. The maximum particles were in the range of 600 microns and 150 microns.

S. No	Sieve Size in mm	Weight Retained in gm	Total Weight Retained in gm	Total Weight Passing in gm	% Passing	% Retained
1	4.75	0	0	500	100	0
2	2.36	21	21	479	95.8	4.2
3	1.18	98	119	381	76.2	23.8
4	0.6	161	280	220	44	56
5	0.3	37	317	183	36.6	63.4
6	0.15	170	487	13	2.6	97.4
7	≤0.075	13	500	0	0	100

Table 1: Sieve Analysis for copper slag

III. EXPERIMENTAL DETAILS

The aim of the experiment was to assess the properties of concrete made with copper slag and to study the various important aspects such as compressive strength, flexural strength and split tensile strength of concrete prepared by using copper slag with different percentage of replacements with cement. The studies were carried out for two mix designs of concrete, that is, M25 and M30.

The specimens used for the tests included cubes, cylinders and prisms. The details and dimensions of the specimens are given in table 2. Cubes were used for compression test, cylinders for split tensile test and prisms for flexural test. Three specimens were tested every time at the required 28 days age and mean value was taken.

Type of test	Type of specimen	Dimensions, mm
Compression test	Cubes	150 x 150 x 150
Split Tensile test	Cylinders	150 dia x 300 height

Table 2: Details of the Standard Specimens

IV. TESTS ON HARDENED CONCRETE

On hardened concrete, tests like compression test, split tensile test and flexural test were conducted as per IS specifications. These tests were conducted for 28 days and the results were tabulated in tables 2 and 3 and the variations are shown in figs 1 to 6.

M25			
Replacement of Cement with Copper slag in %	**7 days compressive strength**	**28 days compressive strength**	**% increase in compressive strength in 28 days**
0	18.37	29.63	0.00
5	19.40	31.11	4.99
10	20.00	32.47	9.58
12	20.29	33.33	12.49
14	21.04	34.37	16.00
16	21.50	35.26	19.00
18	17.93	30.52	3.00
20	15.71	27.41	-7.49

Table 3: Compressive Strength of M25 Concrete mix with % replacement of cement with copper slag

M30			
Replacement of Cement with Copper slag in %	**7 days compressive strength**	**28 days compressive strength**	**% increase in compressive strength in 28 days**
0	24.74	35.11	0.00
5	25.04	35.85	2.11
10	25.77	37.48	6.75
12	26.51	37.93	8.03
14	28.29	38.81	10.54
16	28.74	39.70	13.07
18	25.04	34.96	-0.43
20	22.07	32.15	-8.43

Table 4: Compressive Strength of M30 Concrete mix with % replacement of cement with copper slag

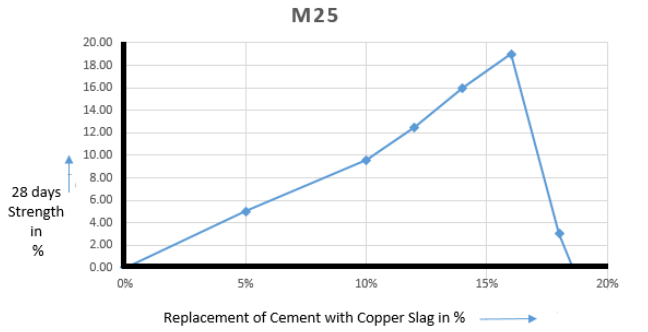

Fig 1: Variation of compressive strength w.r.t. the variation of % of copper slag in M25

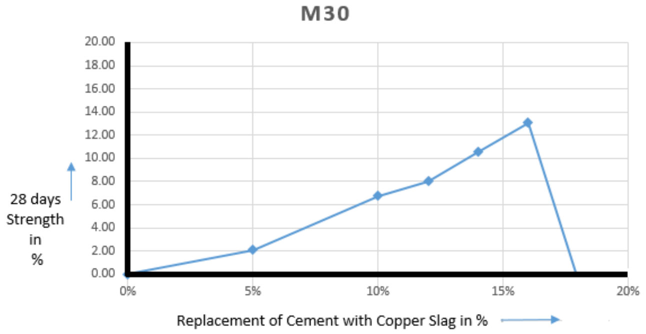

Fig 2: Variation of compressive strength w.r.t. the variation of % of copper slag in M30

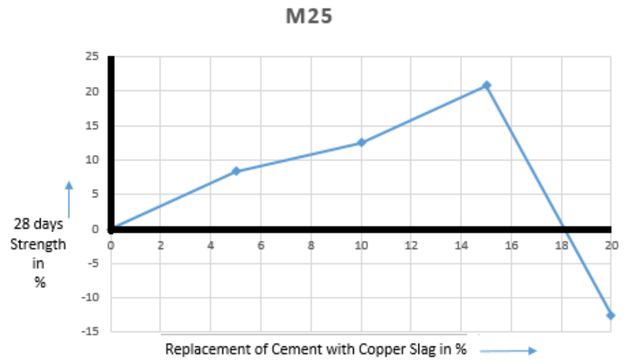

Fig 3: Variation of split tensile strength w.r.t. the variation of % of copper slag in M25

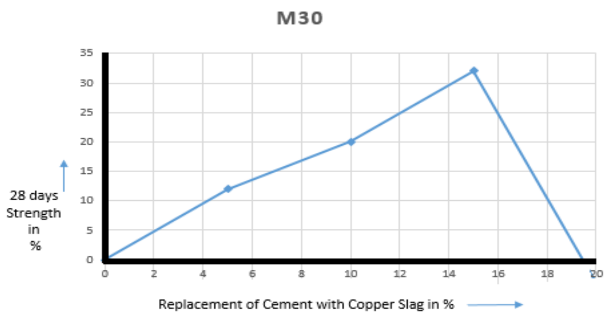

Fig 4: Variation of split tensile strength w.r.t the variation of % of copper slag in M30

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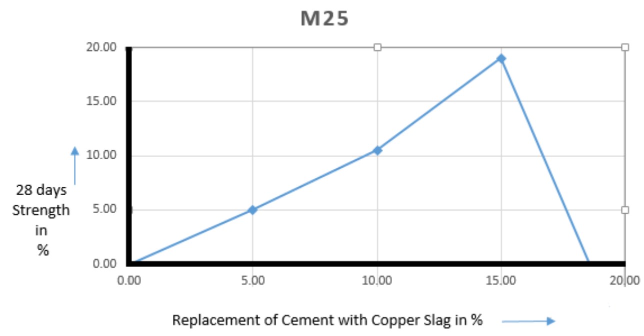

Fig 5: Variation of flexural strength w.r.t. the variation of % of copper slag in M25

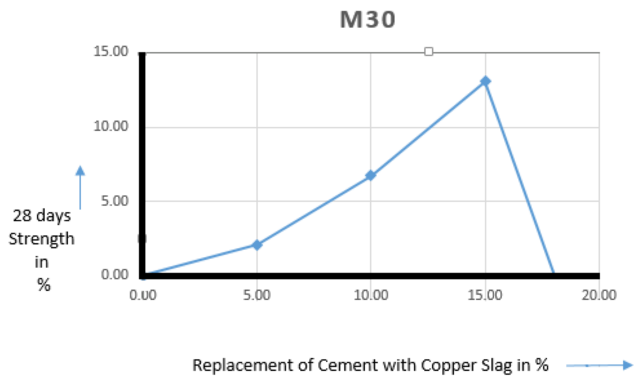

Fig 6: Variation of flexural strength wrt the variation of % of copper slag in M30

V. INTERPRETATION OF TEST RESULTS

In Table 2, it can be clearly seen, in the mix design M25, how rapidly the strength is gained by concrete from 7^{th} day to 28^{th} day as if copper slag is acting as a catalyst. At 16% replacement it can clearly be observed that the compressive strength is very high compared to other replacement proportions. The same trend can be observed for the mix design M30 as shown in Table 3.

Fig. 1, represents mix design M25, the abscissa represents the amount of copper slag by % weight replacing cement content in concrete whereas the ordinate is representing the increase in compressive strength post addition of copper slag to that of the conventional concrete in %.

Fig. 2, represents mix design M30, the abscissa represents the amount of copper slag by % weight replacing cement content in concrete whereas the ordinate is representing the increase in compressive strength post addition of copper slag to that of the conventional concrete in %.

Fig. 3, represents mix design M25, the abscissa represents the amount of copper slag by % weight replacing cement content in concrete whereas the ordinate is representing the increase in split tensile strength post addition of copper slag to that of the conventional concrete in %.

Fig. 4, represents mix design M30, the abscissa represents the amount of copper slag by % weight replacing cement content in concrete whereas the ordinate is representing the increase in split tensile strength post addition of copper slag to that of the conventional concrete in %.

Fig. 5, represents mix design M25, the abscissa represents the amount of copper slag by % weight replacing cement content in concrete whereas the ordinate is representing the increase in flexural strength post addition of copper slag to that of the conventional concrete in %.

Fig. 6, represents mix design M30, the abscissa represents the amount of copper slag by % weight replacing cement content in concrete whereas the ordinate is representing the increase in flexural strength post addition of copper slag to that of the conventional concrete in %.

When cement is being replaced by copper slag, analysis has been performed to study the cost feasibility of the final product. The data in Table 4 shows the comparison of market rates of cement and copper slag as per the market rate in the month of August 2013. It has been found that almost 7% cost of the total cost of concrete can be saved per cubic meter of conventional concrete.

VI. CONCLUSION

From the above graphs and tables the following conclusion is drawn:

1. The specific gravity of copper slag being higher than the raw materials of concrete, it helps in increasing the density of concrete which results in less pores and high compact concrete.
2. This is an eco-friendly concrete as it subsides the stagnation of waste copper slag by consuming it.
3. As much as 7% to 8% of the total cost of cement in conventional method can be saved by this procedure. Cost saving percentage increases with increase in richness of mix design.
4. The W/C ratio has being kept constant even as the surface area is increasing with increase in % of copper slag. This helped in reducing the unwanted bleeding and segregation in concrete.
5. The compressive and flexural strength increase up to 19% whereas the split tensile strength increases by 32% at 16 % replacement of cement with copper slag, compared to the respective conventional concrete strength.
6. Concrete gains early strength and hence shuttering can be removed early thereby reducing the secondary overhead cost.
7. We can achieve more strength concrete mix with lesser quantity of cement, which indirectly reduces the primary overhead cost per m^3 of concrete.

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Table 5: Cost Feasibility of concrete when blended with copper slag

Quantity of Cement in Kg							
Design Mix	**Conventional Quantity**	**Replacement of cement with 15% Copper Slag**		**Market rate per 1 Kg (as in August 2013)**		**Saving per cubic meter**	
	Cement in Kg	**Cement in Kg**	**Copper Slag in Kg**	**Cement**	**Copper Slag**	**%**	**Rs.**
M25	415	348.6	66.4	7	4	6.86	199
M30	434	364.56	69.44			7.17	208