PROPERTIES AND EFFECTS OF COPPER SLAG IN CONCRETE

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Abstract: Copper slag is a by-product obtained during matte smelting and refining of copper. This work reports an experimental procedure to investigate the effect of using CS as partial replacement of sand. Six series of concrete mixtures were prepared with different proportions of CS ranging from 0% to 100%. The test results of concrete were obtained by adding CS to sand in various percentages ranging from 0% to 100%. All specimens were cured for 7, 28, 56 days before compression strength test. The results indicate that Compressive strength and flexural Strength is increased due to high toughness of copper slag.

Keywords: waste, Copper slag, compression strength, flexural Strength.

I. INTRODUCTION

The amount and type of generated waste has grown as the world population increases. Numerous waste materials result from manufacturing, sewage treatment plants, industries, households, and mining. Many of the wastes produced today will remain in the environment for a long time. At the beginning of this industrialization process, not enough attention was given about the state of the environment; assumptions were made that the nature has the capacity to restore the resources we extract and accept what we throw into it. Copper slag is a by-product obtained during matte smelting and refining of copper. One of the greatest potential applications for reusing copper slag is in cement and concrete production. Many researchers have investigated the use of copper slag in the production of cement, mortar and concrete as raw materials for clinker, cement replacement, coarse and fine aggregates. The use of copper slag in cement and concrete provides potential environmental as well as economic benefits for all related industries, particularly in areas where a considerable amount of copper slag is produced.

1.2 Availability of Natural Sand as Fine Aggregate:

In the last 15 years, it has become clear that the availability of good quality natural sand is decreasing. The research emphasizes on the use of material to be replaced by natural sand which will give new dimension in concrete mix design and if applied on large scale would revolutionize the construction industry by economizing the construction cost and enable us to conserve natural resources.

II. MATERIALS AND METHODS

2.1 Cement

Ultra tech 53 grade ordinary Portland cement is used for this study. This cement is the most widely used in the construction industry in India. The different property of cement is shown in table below. It conforms to various standard test as per IS recommendation.

Table 2.1 Properties of Cement

Property	Average value for OPC used in investigation	Standard value for OPC
Specific Gravity	3.15	-
Consistency (%)	31.5%	-
Fineness By Dry Sieving	8%	<10%
Initial Setting Time (Min)	48	>30
Final Setting Time (Min)	225	<600
Soundness (mm)	2.8	<10
Compressive strength (N/mm^2)		
3-days	28.7	>27
7-days	39.63	>37
28-days	55.94	>53

2.2 Fine Aggregates

The sand particles should be free from any clay or inorganic materials and found to be hard and durable.

2.3 Coarse Aggregates

Coarse aggregates of 10mm and 20mm size is used for the study which is taken from Shiroli MIDC area Kolhapur.And natural sand of river bed is used confirming to grading zone –I of table 4 of IS 383 were procured from local river in Maharashtra.

2.4 Plastizers

Emceplast BV Plastizers is used as directed by the manufacture to improve the workability of fresh concrete mix.

2.5 Water

Water gives strength to cement and workability to the concrete. Drinking water is used for casting and curing of the concrete blocks.

2.6 Physical properties

The physical properties of coarse fine aggregates and copper slag are determined.

2.7 Fineness Modulus

The fineness modulus of coarse aggregates (20 mm & 10 mm), sand and copper slag are 7.10, 6.77, 2.94 and 4.06 respectively. Table 3.2 to 3.3 shows the fineness modulus of 20 mm, 10 mm coarse aggregates, sand and copper slag respectively.

Table 2.2 Sieve Analysis of Coarse Aggregate, Fine Aggregate and Copper Slag

IS Sieve size (mm	Coarse Aggregate	Fine Aggregate	Copper Slag
	Cumulative % retained	Cumulative % retained	Cumulative % retained
20	0.70	0	0
16	4.15	0	0
12.50	15.85	0	0
10	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 micron	100	57.07	88.25
300 micron	100	95.39	96.15
150 micron	100	98.68	98.00
Fineness modulus	6.77	2.94	4.06

Table 2.3 IS Limit for Fine Aggregates for Zone I and Zone II

Zone II		Zone I	
100	100	100	100
90	100	90	100
75	100	60	95
55	90	30	70
35	59	15	34
08	30	05	20
00	10	00	00

2.7.1 Specific Gravity

The specific gravity of 20 mm & 10 mm aggregates are found to be 2.67 & 2.75 respectively and are shown in Table 2.6. The specific gravity of sand and copper slag is determine by using pycnometer and found to be 2.62 & 3.30 respectively. It is observed that the specific gravity of copper slag is more as compared to sand and is shown in the Table 2.7 & 2.8 respectively.

Table 2.4 Specific Gravity of 20 and 10 mm Aggregate

Size of Aggregate	Specific Gravity
10 mm	2.67
20 mm	2.75

Table 2.5Specific Gravity of Fine Aggregate (Sand)

Sr. No.	Particulates	Sample-1	Sample-2	Sample-3
1	Wt. of empty pycnometer (W1)	0.438	0.438	0.438
2	Wt. of pyc. + agg.(W2)	0.776	0.773	0.775
3	Wt. of pyc. + Agg. + water(W3)	1.457	1.450	1.455
4	Wt. of pyc. + water (W4)	1.246	1.246	1.246
5	Wt.of agg. Sample (W5) = W2 - W1	0.338	0.335	0.337
6	Wt. of water of eq. volume (W6) = (W4 - W1) - (W3 - W2)	0.127	0.131	0.128

Average specific gravity = (2.67+2.56+2.63)/3 = 2.62

2.7.3 Water Absorption

The water absorption of 20 mm coarse aggregates, sand & copper slag are determined by conventional method and found to be 1.21, 1.01 and 0.65 respectively. It is found that water absorption of copper slag is very low as compared with the natural sand and it affects on workability of concrete. Results from specific gravity and water absorption tests revealed that copper slag has a specific gravity of 3.30 which is higher than that of sand, whereas the water absorption values for copper slag and sand were about 0.65% and 1.01%, respectively. This suggests that concrete produced with large copper slag substitution would have larger density values than concrete produced with sand alone. On the other hand, due to its low water absorption it is expected that the free water content in concrete mixtures will increase as copper slag content increases. This will lead to an increase in the workability of concrete mixtures containing high copper slag percentages.The water absorption of coarse aggregates, sand and copper slag are shown in Table 2.7. Table 2.8 shows the physical properties of coarse aggregates, sand and copper slag.

Table 2.6 Water Absorption for Aggregate Sand and Copper Slag

Particulates (gm)	Aggregate	Sand	Copper slag
Wet wt. of agg. (W1)	340	400	400
Dry wt. of agg. (W2)	337.97	396	397.40
Water absorption = [(W1-W2)/W2] x 100	0.601%	1.01%	0.65%

Table 2.7 Physical Properties of Coarse Aggregates, Fine Aggregates and Copper Slag

Fineness Modulus			Specific Gravity			Water Absorption		
C. A.	Sand	C. S.	C. A.	Sand	C.S.	C. A.	Sand	C. S.
7.10	2.94	4.06	2.67	2.62	3.30	0.601	1.01	0.65

Table 2.8 Chemical Analysis of Copper Slag

Component	Unit	Copper Slag
SiO_2	%	97.01
Al_2O_3	%	0.095
Fe_2O_3	%	1.05
CaO	%	1.064
MgO	%	0.118
SO_3	%	0.008
K_2O	%	0.028
Na_2O	%	0.118
TiO_2	%	0.120
Mn_2O_3	%	0.002
CI	%	0.01
CuO	%	0.183
Sulphide Sulphur	%	0.082
Water Insoluble Residue	%	98.48
Chloride	%	0.350
Loss on Ignition	%	0.190

Table 2.9 Mix Proportions (Kg / m^3) and Mix Ratio

Cement	Fine Aggregates (Sand)	Coarse Aggregates (20 Mm)	Water
435	575	1216	208.8
1	1.32	2.79	0.48

Table 2.10 Sizes and Types of Moulds Used for Testing

Type of Test	Sample Type	Sample Size
Compression test	Cube	150x150x150 mm
Flexural	Rectangular	500x100x100 mm

III. TEST RESULTS AND DISCUSSION

3.1.1 Fresh Concrete Properties.

Determination of fresh concrete properties are necessary to determine the effects of adding copper slag on workability of the concrete composites. The most widely used procedure for evolution of workability of concrete is slump test.

3.1.2 Fresh Concrete Workability (Slump Test)

A slump of 25 mm generally provides good workability of concrete. The water to cement ratio was kept at approximately 0.48.

Table 3.1 Workability Test (Slump Test)

Mix	W/C Ratio	Slump (mm)
Normal M-30	0.48	25
CS 10%	0.48	25
CS 20%	0.48	26
CS 30%	0.48	28
CS 40%	0.48	30
CS 50%	0.48	30
CS 60%	0.48	32
CS 80%	0.48	33
CS 100%	0.48	35

From the slump test it was concluded that the amount of water to obtain the targeted slump in the concrete composites was the equivalent conventional concrete. As the amount of copper slag increased the amount of slump increased.

3.2 Hardened Concrete Properties

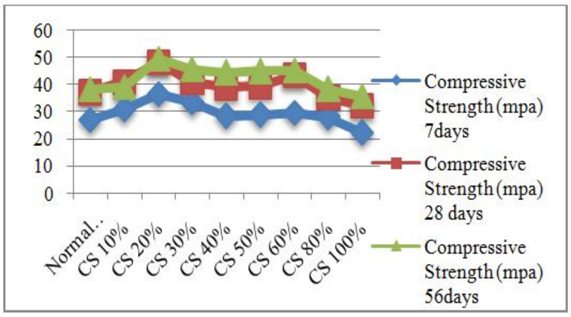
Hardened concrete compression test and flexural tests were performed on hardened concrete samples to evaluate the effects of using copper slag on hardened properties of concrete composites.

3.3 Compressive Strength

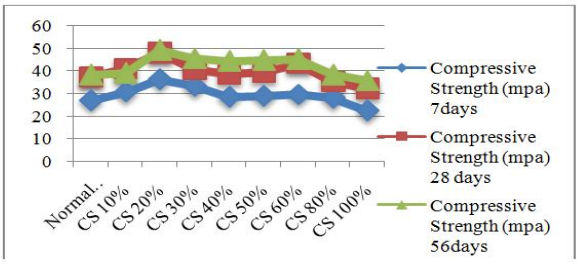
Cube of size 150 mm × 150 mm × 150 mm were used and tested at 7,28 and 56 days of curing in water under controlled laboratory conditions. three samples were tested at each curing stage. Table 4.2 shows average compressive strengths of concrete tested.

Table 3.2 Compressive Strength

Mix	Compressive Strength (Mpa)		
	7 days	28 days	56 days
Normal M-30	26.97	37.27	38.27
CS 10%	30.73	40.97	39.10
CS 20%	36.33	48.13	49.37
CS 30%	33.27	40.83	45.47
CS 40%	28.43	38.80	44.43
CS 50%	28.87	39.43	44.90
CS 60%	29.53	43.33	45.17
CS 80%	28.00	35.17	38.43
CS 100%	22.30	32.07	35.70



Graph 3.1 Compressive Strength



Graph 3.2 Compressive Strength

Table 3.3 Strength Gained

Mix	Comp. Strength 7days Mpa	Strength Gained 7 days	Comp. Strength 28days Mpa	Strength Gained 28 days	Comp. Strength 56 days Mpa	Strength Gained 56 days
Normal M-30	26.97	100.00	37.27	100.00	38.27	100.00
CS 10%	30.73	113.97	40.97	109.93	39.10	102.18
CS 20%	36.33	134.73	48.13	129.16	49.37	129.01
CS 30%	33.27	123.36	40.83	109.57	45.47	118.82
CS 40%	28.43	105.44	38.80	104.11	44.43	116.11
CS 50%	23.30	86.40	34.10	91.50	36.90	96.43
CS 60%	29.53	109.52	43.33	116.28	45.17	118.03
CS 80%	28.00	103.83	35.17	94.36	38.43	100.44
CS 100%	22.30	82.69	32.07	86.05	35.70	93.29

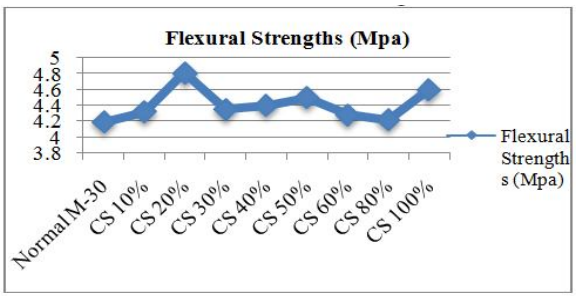
It is possible that the reduction in strength resulting from increasing copper slag is due to increased voids due to the fact that copper slag possesses fewer fine particles than fine aggregate. It could also be due to the increase of the free water because the copper slag absorbs less water than the fine aggregate.It is evident from Table 3.2 and Graph3.1 and Graph 3.2 that compressive strength of all mixes continued to mixes with the increase in age. There is increase in strength with the increases in copper slag percentages. However from Table 3.3 the highest compressive strength was achieved by 20% replacement of copper slag, which was found about 36.33 Mpa compared with 26.97 Mpa for the control mixture. This means that there is an increase in the strength of almost 34% compared to the control mix at 7 days. However, mixture with 100% replacement of copper slag gave the lowest compressive strength 22.30 Mpa which is almost 17% lower than the strength of control mix.

3.4 Flexural Strength

Samples of size 500 x 100 x 100 mm ,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 concrete composites measured during this phase of the project are presented in Table 3.4 and Graph 3.3.

Table 3.4 Flexural Strength

Mix	Flexural Strengths (Mpa)
Normal M-30	4.19
CS 10%	4.32
CS 20%	4.81
CS 30%	4.33
CS 40%	4.40
CS 50%	4.50
CS 60%	4.28
CS 80%	4.22
CS 100%	4.60



Graph 3.3 Flexural Strength

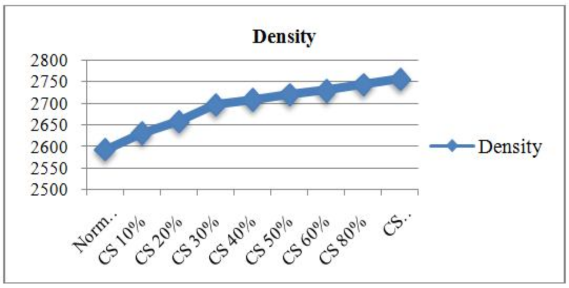
It is evident from Table 3.4 and Graph 3.3 that flexural strength continued to increase with the increase in the copper slag percentages at 28 days and there is significant increase in strength with that of strength of control mix.

3.5 Density

From the results in the table, it can be seen that the density of hardened concrete increased with the increase of the copper slag as sand content. This is due to the higher specific gravity of the copper slag, which was 3.30 compared to 2.62 of the natural sand. however compared with the large difference in the specific gravity of the copper slag and the natural sand, it increased density of concrete.

Table 3.5 Density of Concrete

Mix	Density
Normal M-30	2592.59
CS 10%	2631.11
CS 20%	2657.78
CS 30%	2696.30
CS 40%	2708.15
CS 50%	2720.00
CS 60%	2728.89
CS 80%	2743.70
CS 100%	2755.56



Graph 3.4 Density

CONCLUSIONS

4.1 Conclusions:

1. As the percentage of copper slag increases workability increases.
2. Maximum Compressive strength of concrete increased by 34 % at 20% replacement of fine aggregate, and up to 80% replacement ,concrete gain more strength than normal concrete strength.
3. It is observed that up to 30% replacement of natural sand by copper slag, the flexural strength of concrete is increased by 14%.and all percentage replacement of fine aggregate by copper slag the flexural strength of concrete is more than normal mix.
4. Compressive strength and flexural Strength is increased due to high toughness of copper slag.
5. As the percentage of Copper slag increases the density of concrete is increased. Density is increased by 7% due to replacement of fine aggregate at 100%.
6. Replacement of copper slag in fine aggregate reduces the cost of making concrete.

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