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Strength and geotechnical characterization of copper slag as partial replacement of fine aggregate

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Abstract - *Copper slag is a obtained as a by-product during the smelting and refining process. While drawing metal out of copper ore refineries produce a large volume of non-metallic dust, soot and rock. Collectively these materials makes up slag, which can be used for a surprising number of applications in the building and industrial fields. By the addition of slag, self-weight of the concrete is increased thereby density is increased. Experimental program has done to investigate the effect of using copper slag as a partial replacement of fine aggregate. For this work M20 grade concrete was used and test were conducted for various proportions with sand of 0%, 20%, 40%, & 60% in concrete. The results of compression and split tensile strength test indicated that the strength of concrete increases with respect to the percentage of slag added by weight of fine aggregate up to 40% of addition. The recommended percentage replacement of sand by copper slag is 40%. The compressive strength decreases slightly for above 40% addition of slag. However compared to ordinary sand as fine aggregate the compressive strength value is still greater. From the permeability test conducted it has been observed that the value of permeability is less when compared with that of sand.*

***Key Words*: Copper slag, Chemical composition, Compressive strength, Split tensile strength, Permeability etc.**

1. INTRODUCTION

Copper slag is an abrasive blasting grid made of granulated slag from metal smelting process also called as iron silicate. While drawing metal out of copper ore refineries produce a large volume of non-metallic dust, soot and rock. Collectively these materials makes up slag, which can be used for a surprising number of applications in the building and industrial fields. Copper slag has gained popularity in the building industry for use as a fill material. Due to its high strength /weight ratio copper slag can be used as a best alternative to sand. Unlike many other fill materials, copper slag poses relatively little threat to the environment. This means it can be used to build up the earth to support road, buildings or other surfaces. The slag serves as a fine or binding agent which helps hold the larger gravel particles within the concrete together. When used in this manner the slag helps to improve the properties of concrete and also serves as a form of recycling. One of the primary advantage of copper slag is the low risk it poses to health and the environment. Silica sand which represents the most popular blasting medium and concrete fine currently in use poses serious health risks when inhaled. It may also contribute to pollution and other environmental concerns. Copper slag has high strength to weight ratio, making it an effective option in concrete or as a fill material under the roadway.

Table -1 : Sieve analysis results of fine aggregate, coarse aggregate and copper slag

IS sieve	Coarse aggregate Cumulative %retained	Fine aggregate Cumulative %retained	Copper slag Cumulative %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

Table -2 : Physical properties

SL NO	PROPERTIES	ANALYSIS
1	Hardness, Mohr's circle	7
2	Specific gravity	3.83
3	Electric conductivity	4.8ms/m
4	Chloride content	<0.0002
5	Particle size	0.2 mm up to 3 mm
6	Granular size	Angular, sharp edges, multi-faced

Table -3 : Chemical composition

SL NO	COMPOUND	ANALYSIS RANGE IN %
1	Cu	0.60 - 0.70
2	Feo	42 – 48
3	SiO_2	26 – 30
4	Al_2O_3	1.0 – 3.0
5	S	0.2 – 0.3
6	Cao	1.0 – 2.0
7	Mgo	0.8 – 1.5
8	Fe_3O_4	1.0 – 2.0

2. MATERIALS AND METHODS

2.1. CEMENT

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 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. It conforms to IS 383-1970.

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 shapes like rounded, irregular, or partly rounded, angular, flaky etc. it should be free from any organic impurities and dirt content.

2.4. 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 control mix), 20%, 40% and 60%.

2.5. TESTING PROCEDURE

This work entailed subjecting the designed concrete mixes to a series of tests to evaluate the strength and geotechnical properties. Strength development is monitored with time adequately for each concrete mixes. For each mix three samples were tested at various curing ages and average values were used for analysis.

3. RESULTS AND DISCUSSION

3.1 STRENGTH STUDY

Table – 4 : Compressive strength results

PERCENTAGE REPLACEMENT OF Cu SLAG	7 DAYS COMPRESSIVE STRENGTH (N/mm²)	28 DAYS COMPRESSIVE STRENGTH (N/mm²)
0	20.44	32.22
20	26.44	38.00
40	28.44	42.44
60	26.67	41.55

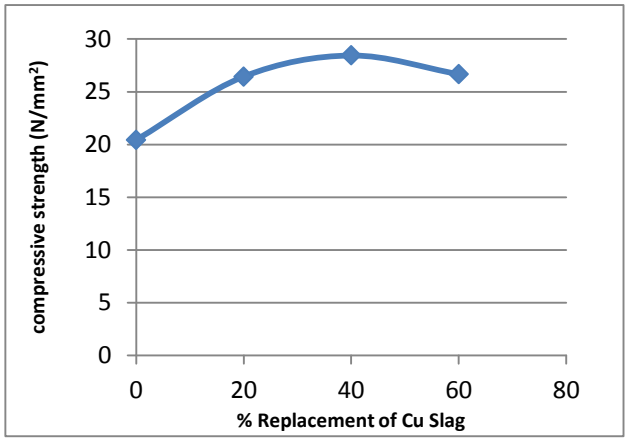

Chart -1: Compressive strength of concrete at 7th day

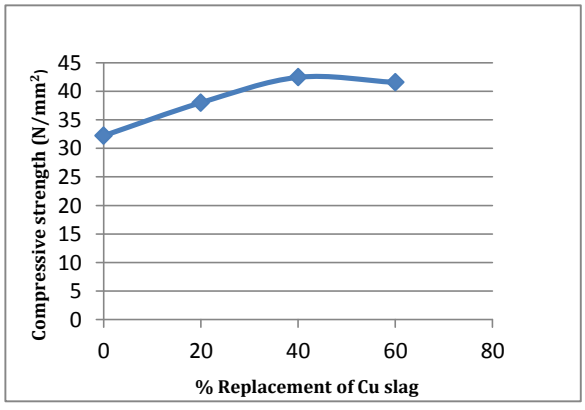

Chart -2: Compressive strength of concrete at 28th day

From the test results it was observed that the compressive strength of concrete mixes with replacement of fine

aggregate with copper slag were higher than the control mixes at all ages. The highest compressive strength was achieved by 40% replacement of copper slag, which was found to be about 42.44 M Pa for 28 days and 28.44 M Pa for 7 days curing compared with 32.22 M Pa and 20.44 M Pa respectively for the control mixes.

Table – 5 : Split tensile strength results

PERCENTAGE REPLACEMENT OF Cu SLAG	7 DAYS SPLIT TENSILE STRENGTH (N/mm²)	28 DAYS SPLIT TENSILE STRENGTH (N/mm²)
0	1.98	2.97
20	2.26	4.52
40	2.40	5.65
60	2.09	4.66

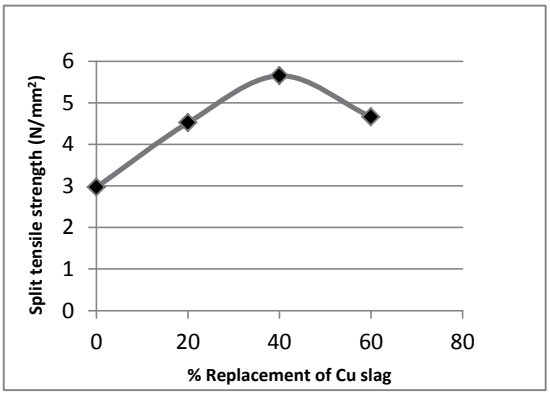

Chart -3: Split tensile strength of concrete at 7th day

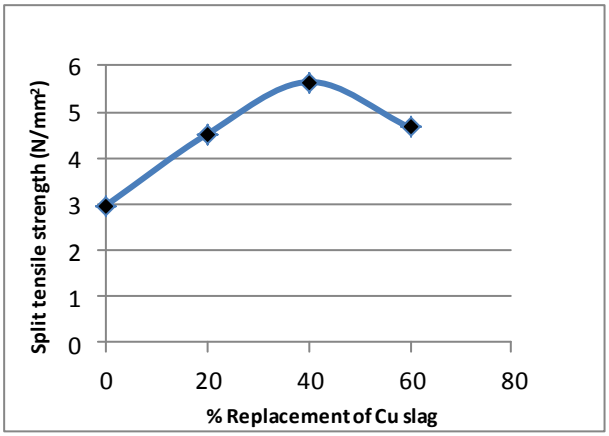

Chart -4: Split tensile strength of concrete at 28th day

From the test results it was observed that the split tensile strength of concrete mixes with replacement of fine aggregate with copper slag were higher than the control mixes at all ages. The highest split tensile strength was achieved by 40% replacement of copper slag, which was found to be about 5.65 N/mm² for 28 days and 2.40 N/mm² for 7 days curing compared with 2.97 N/mm² and 1.98 N/mm² respectively for the control mixes.

3.2 GEOTECHNICAL STUDY

Constant head permeability test was carried out to test coefficient of permeability of copper slag.

The value obtained for constant head permeability test:

- For soil - 8.91×10^{-4}
- For copper slag - 9.81×10^{-4}

4. CONCLUSIONS

[1] The effect of replacing fine aggregate by copper slag on the compressive strength and split tensile strength was studied.

[2] The compressive strength and split tensile strength of concrete with addition of copper slag at 7 days and 28 days was higher than design mixes (without replacement).

[3] The recommended percentage replacement of sand by copper slag is 40%.

[4] Due to usage of Copper slag, the density of concrete has increased by 6-7% due to the higher specific gravity of copper slag (3.68).

[5] Coefficient of permeability was less when compared to that of sand.

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