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A Partial Replacement of Fine Aggregate by Copper Slag In Concrete

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Abstract: Many countries are witnessing a rapid growth in the construction industry which involves the use of natural resources for the development of the infrastructure. In order to reduce dependence on natural aggregates as the main source of aggregate in concrete, artificially manufactured aggregates and artificial aggregates generated from industrial wastes provide an alternative for the construction industry. In this study we are using copper slag as a partial replacement to fine aggregates in concrete, in which cubes were casted for various grades of concrete and for various proportions of sand replacement with copper slag ranging from 20% to 50%. Obtained results on different parameters like strength, workability and density were compared with those of control concrete made with ordinary Portland cement and sand.

Keywords: concrete, copper slag, strength, density, workability.

1. Introduction

India as itself is a developing country lots of construction activities are going on everywhere like skyscrapers ,roads, bridges ,dams etc and concrete is the base of all these construction activities. India itself consume 450 million cubic meter of concrete annually which approximate translates to 1 to 1.5 ton per Indian. But the important question that arises is, is we have enough natural resources? Aggregates considered as one of the main constituent of concrete and occupy more than 70% of concrete mix. As so much fight is going on for obtaining Fine aggregates we have to find different alternative to this. Many by products and waste material like Quarry dust, Foundry sand, Sheet powder glass, copper slag, washed bottom ash are available and can be replace by sand .In this paper copper slag is used as a alternative to sand.

Copper slag is a by-product obtained during matte smelting and refining of copper. For every tone of copper metal production, about 2 to 2.5 ton of waste slag is generated. Dumping or disposal of such huge quantities of slag cause environmental and space problems. During the past two decades, attempts have been made by several investigators and copper producing units all over the world to explore the possible utilization of copper slag.

The physical and mechanical properties of granulated copper slag show that it can be used for following.

1. Copper slag can be used in building industry as a filling material.
2. Copper slag is widely used in the sand blasting industry and it has been used in the manufacture of abrasive tools.
3. Copper slag can also be used as a building material, formed into blocks.

2. Materials used

2.1 Cement

Ordinary Portland cement from Ultratech Company of 53 grades was used for this study. This cement is the most widely used one in the construction industry in India.

Initial setting time	65 minutes
Final setting time	231 minutes
Consistency	29.50
Fineness	8.50 % retained
Specific gravity	3.15
28 days compressive strength	56.86

Table no 2.1. Test performed on cement

2.2 Coarse and Fine aggregates

Coarse aggregates of 20mm and 10mm size and fine aggregates of Zone II were procured from the basins of Bhīma River which is nearby available.

Water absorption	0.917
Specific gravity	2.917
Impact value	10.70
Crushing value	13.90
Zone	II

Table no 2.2. Test performed on Coarse Aggregate

Fineness modulus	2.93
Zone	II
Water absorption	1.818
Specific gravity	2.653

Table no 2.3. Test performed on Fine Aggregate

2.3 Copper Slag

Copper slag from Birla Copper unit was used for this project.

2.4 Properties of copper slag

1. Copper Slag is the black glassy material, produced during matte smelting and copper conversion was previously considered waste and disposed as landfill. It has been estimated that for every ton of copper production about 2-2.5 tons of slag are generated.

2. Copper slag, a copper production residue, shows in its chemical composition high contents of aluminum, silica and iron oxides, similar to that of cement.

3. Additionally, its hardness and gradation seems to indicate its suitability for use as alternative aggregate for applications in construction products.

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Physical Properties	Copper Slag
Hardness on Mohr's Scale	6-7
Specific Gravity	3.51
Bulk Density	1.87
Particle Shape	Irregular
Appearance	Black and Glassy
Fineness Modulus	3.47
Angle of Internal Friction	51°20´

Table no2. 4. Physical properties of copper slag

Chemical Composition	Percentage
Fe	42-48
SiO2	26-30
Al2O3	1.0-3.0
Cu	0.6-0.7
S	0.2-0.3
Cao	1.0-2.0
Mgo	0.8-1.50
Fe3O4	1.0-2.0
As	0.02-0.05
Pb	0.06-0.08
Co	0.01-0.03
Cr	0.02-0.04
Zn	0.2-0.4
Ni	0.005-0.008
Chloride	0.001-0.002
PH	7.0-7.5

Table no2.5. Chemical properties of copper slag

Figure no 1. Grinded copper slag from the industry

Sieve size mm	% Passing of River Sand	%Passing of copper Slag	Zone II (As per IS 383)
4.75mm	95.32	99.60	
2.36mm	85.41	97.9	75-100
1.18mm	67.22	75.5	55-90
600micron	41.95	35.3	35-59
300micron	13.32	8.5	8-30
150micron	3.88	0.3	0-20
ZONE	ZONE II	ZONE II	

Table no 2.6. Sieve Analysis comparison between sand and copper slag

3. Concrete Mix Design

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. Proportions (by weight) of Copper slag added to concrete mixtures were as follows: 0% (for the control mix), 20%, 25%, 30%, 35%, 40%, 45% and 50%. The control mixture was designed to have a target 28 day compressive strength of 20 N/mm^2 (M- 20) and 30 N/mm^2 (M-30), using a water cement ratio of 0.55 and 0.45. Mix proportion chosen for this study is given in Table 7 & 8.

Cement	Sand	Coarse Aggregate	Water
349	704	1243	202
1	2.01	3.56	0.578

Table no 3.1.Mix Design Summary for M-20 Grade (kg/m$^{3)}$

Cement	Sand	Coarse Aggregate	Water
426.60	678	1199.78	203
1	1.42	2.81	0.475

Table no3.2.Mix Design Summary for M-30 Grade (kg/m$^{3)}$

4. Test and Results

The different tests conducted in laboratories are shown following 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), 20%, 25%, 30%, 35%, 40%,45%, and 50%. Concrete samples were prepared and cured in the laboratory, and are tested, to evaluate the concrete fresh and harden properties like Slump, Density and compressive strength.

4.1 Slump Test

Workability can be measured by the concrete slump test. The test is carried out using a metal mould in the shape of a conical frustum known as a slump cone or **Abrams cone** that is open at both ends and has an attached handle. The tool typically has an internal diameter of 4 in (100 mm) at the top and of 8 in (200 mm) at the bottom with a height of 1 ft (300 mm).

Figure 2. Slump Test

% Replacement	M-20	% Increase	M-30	% Increase
CS 0	54	1.000	51	1.000
CS 20	62	1.148	55	1.078
CS 25	67	1.241	61	1.196
CS 30	71	1.315	63	1.235
CS 35	73	1.352	68	1.333
CS 40	77	1.426	71	1.392
CS 45	81	1.500	78	1.529
CS 50	83	1.537	81	1.588

Table No.4.1: Slump Results Final

Graph 4.1 % Slump variation for various grades with normal concrete

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4.2 Density Test

The density of concrete is a measure of its unit weight. It is simply a mass to volume ratio. Perhaps the easiest and most accurate way to calculate the concrete density is to measure some into a cube of known volume and weighing it. Fresh mix concrete pours into concrete moulds of standard size 150*150*150 mm. After setting of concrete, demould it and keep it in curing tank for 28 days. Once the curing period completes take it out and weighs it in Surface saturated manner. And after dividing this weight with the known volume of cube mould will get the density of concrete for 28 days.

% Replacement	M-20	% Increase	M-30	% Increase
CS 0	2610.070	1.000	2638.815	1.000
CS 20	2642.370	1.012	2688.593	1.019
CS 25	2661.926	1.020	2698.074	1.022
CS 30	2698.667	1.034	2722.963	1.032
CS 35	2742.815	1.051	2736.593	1.037
CS 40	2756.741	1.056	2757.926	1.045
CS 45	2769.481	1.061	2770.667	1.050
CS 50	2786.074	1.067	2790.519	1.057

Table No 4.2: Density Results Fina

Graph 4.2 % Density variation for various grades with normal concrete

4.3 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 3, 7, & 28 days of curing

Figure 3. Compression Testing Machine

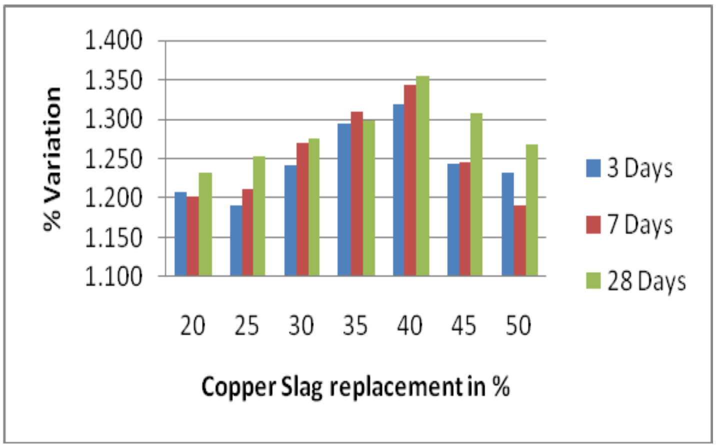
% Replace	3 Days		7 Days		28 Days	
	Mean	%Increase	Mean	%Increase	Mean	%Increase
CS 0	12.26	1.000	18.81	1.000	27.82	1.000
CS 20	16.18	1.320	24.16	1.285	34.44	1.238
CS 25	16.27	1.327	24.18	1.286	35.19	1.265
CS 30	16.61	1.354	24.64	1.310	37.18	1.336
CS 35	16.94	1.382	25.48	1.355	38.53	1.385
CS 40	17.65	1.439	26.53	1.411	40.11	1.442
CS 45	16.51	1.346	24.77	1.317	37.11	1.334
CS 50	16.21	1.322	23.38	1.243	35.64	1.281

Table No.4.3: Strength for M-20 grade of concrete

Graph4.3. Variation of Strength for various days with respect to normal concrete for M-20 Grade

% Replace	3 Days		7 Days		28 Days	
	Mean	%Increase	Mean	%Increase	Mean	%Increase
CS 0	17.090	1.000	26.957	1.000	40.847	1.000
CS 20	20.633	1.207	32.370	1.201	50.347	1.233
CS 25	20.333	1.190	32.660	1.212	51.173	1.253
CS 30	21.233	1.242	34.210	1.269	52.100	1.276
CS 35	22.113	1.294	35.290	1.309	53.080	1.299
CS 40	22.530	1.318	36.230	1.344	55.350	1.355
CS 45	21.257	1.244	33.583	1.246	53.413	1.308
CS 50	21.077	1.233	32.067	1.190	51.787	1.268

Table No.4.4: Strength for M-30 grade of concrete



Graph4.4. Variation of Strength for various days with respect to normal concrete for M-30 Grade

5. Conclusions

Following are the various conclusions that can be drawn from this study.

Slump

1. For lower percentage replace of copper slag workability is lower than higher percentage replacement.

2. As percentage of copper slag replacement increases workability is also increases comparatively for 35 to 45 percentage replacement of copper slag, ,moderate workability is observed.

3. For higher grade of concrete moderate workability is observed for little bit higher percentage of replacement of copper slag.

Density

1. For lower grade of concrete for 30% replacement of sand results into 35% more dense concrete. This percentage lowers down up to 32% in case of higher grade of concrete.

2. As more copper slag replaces sand, concrete becomes denser which is observed in lower grade of concrete but for higher grade of concrete replacement of sand also affecting the density but relatively lower as compared with lower grade.

3. For non structural and high density required construction replacement of higher percentage of copper slag may worked found better option. For example P.C.C, Curbs, Heavy mass concrete.

Strength

1. For lower grade of concrete 43.90% increase in strength of concrete is observed. Similarly 31.80% highest in the range for higher grade of concrete is noted for 40% replacement of copper slag.

2. For 7 days strength the highest percentage increase is 41.10% and 34.4% for lower grade and higher grade of concrete respectively.

3. For final strength the increase in percentage are observed as 44.20% and 35.50% for lower and higher grade of concrete respectively.

4. From the observations and results obtained 40% replacement of copper slag gives highest strength in lower grade of concrete. Further increase in percentage of replacement copper slag reduces strength in lower as well as higher grade of concrete.

5. Referring to earlier conclusions 40% replacement of copper slag is the optimum replacement for natural sand which gives comparatively 45 to 55 percentage dense concrete with moderate slump which is applicable for routine construction work.

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