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REPLACEMENT OF SAND BY COPPER SLAG

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Abstract - Sand is the most commonly used fine aggregate which occurs naturally. But there is scarcity of natural sand day by day. Hence there is a need to find any other material which can replace sand. So many researches were takes place to find alternative for the sand. In this paper we replaced sand by copper slag. Copper slag is one of the materials that is considered as a waste material which could have a promising future in construction industry as partial or full substitute of either cement or aggregates. It is a by-product obtained during the matte smelting and refining of copper. The different tests conducted in laboratories consists 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), 10%, 20%, 30%, 40%, 50%, 60%, 75%, and 100%. Concrete samples were prepared and cured in the laboratory, and are tested, to evaluate the concrete fresh and harden properties like compressive strength and flexural strength requirements.

Key Words: Sand, Copper slag, Compressive strength, Flexural strength.

1. INTRODUCTION

In India, there is great demand of aggregates mainly from civil engineering industry for road and concrete constructions. But now days it is very difficult problem for available of fine aggregates. So researchers developed waste management strategies to apply for replacement of fine aggregates for specific need. Natural resources are depleting worldwide while at the same time the generated wastes from the industry are increasing substantially. Researcher and Engineers have come out with their own ideas to decrease or fully replace the use of river sand and use recent innovations such as M-Sand (manufactured sand), robot silica or sand, stone crusher dust, filtered sand, treated and sieved silt removed from reservoirs as well as dams besides sand from other water bodies. On the other hand, lack in required quality is the major limitation in some of the above materials. Now a day's sustainable infrastructural growth requires the alternative material that should satisfy technical requisites of fine aggregate as well as it should be available locally with large amount.

Copper Slag:

At present about 33 million tonnes of copper slag is generating annually worldwide among that India contributing 6 to 6.5 million tonnes. 50 % copper slag can be used as replacement of natural sand in to obtain mortar and concrete with required performance, strength and durability. In India a study has been carried out by the Central Road Research Institute (CRRI) shown that copper slag may be used as a partial replacement for river sand as fine aggregate in concrete up to 50 % in pavement concrete without any loss of compressive and flexural strength and such concretes shown about 20 % higher strength than that of conventional cement concrete of the same grade.

Copper slag is one of the materials that is considered as a waste material which could have a promising future in construction industry as partial or full substitute of either cement or aggregates. It is a byproduct obtained during the matte smelting and refining of copper. To produce every ton of copper, approximately 2.2–3.0 tons copper slag is generated as a by-product material. In Oman approximately 60,000 tons of copper slag is produced every year. Copper slag is a by-product material produced from the process of manufacturing copper. As the copper settles down in the smelter, it has a higher density, impurities stay in the top layer and then are transported to a water basin with a low temperature for solidification. The end product is a solid, hard material that goes to the crusher for further processing.

Granulated copper slag (or) copper slag which is a byproduct of metallurgical operations in Sterlite industries (India) Ltd. Tuticorin was used for the experimental investigation. For every tone of metal production, about 2.2 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 shows that it can be used to make products like coarse and fine aggregates, cement, fill, ballast, roofing granules, glass, tiles etc.

2. PHYSICAL AND CHEMICAL PROPERTIES OF COPPER SLAG

The slag is a black glassy and granular in nature and has a similar particle size range like sand which indicates that it could be tried as replacement for the sand in cementations mixture. The specific gravity of the slag is 3.68. The bulk density of granulated copper slag is varying between 1.70 to 1.90 g/cc which is almost similar to the bulk density of conventional fine aggregate. The hardness of the slag lies between 6 and 7 in MoH scale. This is almost equal to the hardness of gypsum. The pH of aqueous solution of aqueous extract as per IS 11127 varies from 6.6 to 7.2. The limiting water soluble chloride content as per IS 11127 is 11ppm. The slag is conforming to the above standards. The free moisture content present in slag was found to be less than 1%. The sieve analysis for copper slag infers that the gradation properties of fine aggregates at all the replacement levels are similar to the specification for sand zone II as per IS: 383. The chemical composition of slag is presented in Table 1. The presence of silica in slag is about 26% which is desirable since it is one of the constituents of the natural fine aggregate used to normal concreting operations. The presence of copper, alumina, sulphate in the slag were only traces and hence not harmful Properties of fine aggregates at all the replacement levels are similar to the specification for sand zone II as per IS: 383. The chemical composition of slag is presented in Table 1.

Table -1 Chemical Composition of Copper Slag

Sr. No	Chemical Compounds	% of Compounds
1	Fe_2O_3	68.29
2	SiO_2	25.84
3	Al_2O_3	0.22
4	CaO	0.15
5	MgO	0.2
6	Mn_2O_3	0.22
7	Na_2O	0.58
8	CuO	1.2
9	K_2O	0.23
10	TiO_2	0.41
11	LOI	6.59
12	Insoluble residue	14.88

3. TEST CONDUCTED

A. Sieve Analysis

The experimental work starts with the sieve analysis. IS specified sieves of varying sizes are used. The details of sieve analysis report are shown in Table. 2.

Table -2 Sieve Analysis Report

Sr. No.	Sieve Size (mm)	Weight Retained (gm)	Total weight Retained (gm)	Total Weight Passing (gm)	% Passing	% Retained
1	4.75	0	0	500	100	0
2	2.36	29	29	471	94.2	5.8
3	1.18	106	135	365	73	27
4	0.6	154	289	211	42.2	57.8
5	0.3	5	294	206	41.2	58.8
6	0.15	197	491	9	1.8	98.2
7	≤0.075	9	500	0	0	100

B. 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 the control mix), 10%, 20%, 30%, 40%, 50%, 60%, 75%, and 100%. The control mixture was designed to have a target 28 day compressive strength of 25 N/mm2 (M-25), using a water-to-binder ratio of 0.52.

C. Testing Procedures

This project entailed subjecting the designed concrete mixes to a series of tests to evaluate the strength, and other properties. For this project, it was important to monitor the strength development with time to adequately evaluate the strength of each concrete mix. For each test, either 3 samples from each mix were tested at each curing age, and the average values were used for analysis. The following sections present the procedures used for the various tests.

i. Compressive 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 7, 28, days of curing. The compressive strength of the concrete in terms of pressure was then calculated using the Equation:

$$fc = P/A$$

Where,

fc = Compressive Strength of Concrete,

P = Maximum load applied (KN), and

A = the cross-sectional area of the sample (mm2)

ii. Flexural Strength Test

Another important strength property of concrete is the flexural strength of a concrete. Samples were tested for flexural strength at 28 days of curing. The testing machine apparatus used to measure the flexural strength of concrete in this project is operated by hydraulics and has Dial Gauge displays for monitoring the rate of loading and the peak load on the sample at the time of failure. The strain rate was manually controlled by turning a knob either clockwise or counter clockwise. The flexural strength was then calculated using Equation:

$$fcr = Pl/bd^2$$

Where,

fcr = Flexural Strength of Concrete, (kPa or psi)

P = Maximum load applied (KN or lb),

l= Length of the specimen between the lower supports (mmor in),

b = Width of the beam (mm or in), and d = Depth of the beam (mm or in)

IV. EXPERIMENT AND RESULT

The different tests conducted in laboratories consists 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), 10%, 20%, 30%, 40%, 50%, 60%, 75%, and 100%. Concrete samples were prepared and cured in the laboratory, and are tested, to evaluate the concrete fresh and harden properties like compressive strength and flexural strength requirements.

A. Compressive Strength

Compression tests were performed on samples made during at various curing ages. As discussed earlier, a targeted compressive strength was used for this investigation. Results from compression strength tests performed. Here cube samples of size 150 x 150 x 150 mm, were prepared and tested at 7, 28 days of curing in water under controlled laboratory conditions. 3 samples were tested at each curing age. DWT Decomposition model.

Table -3 Strength Gained By Copper Slag

MIX	Comp. Strength 7 days Mpa	Strength Gained 7 days	Comp. Strength 28 Days Mpa	Strength Gained 28 Days
M-25	18.29	100.00	30.36	100.00
CS 20%	25.43	139.03	38.22	125.88
CS 40%	28.48	155.71	43.01	141.67
CS 60%	22.37	122.30	35.89	118.21
CS 75%	21.21	115.96	26.88	88.53
CS-100	18.31	100.10	25.14	82.80

From the test results, it can be seen that the compressive strength of Copper Slag concrete mixes with 10%, 20%, 30%, 40%, 50%, 60%,75% and 100% fine aggregate replacement with Copper Slag, were higher than the control mix at all ages. It is evident that compressive strength of all mixes continued to increase with the increase in age. It can be seen that there is increase in strength with the increase in Copper Slag percentages; however the highest compressive strength was achieved by 40% replacement of copper slag, which was found about 28.48 Mpa compared with 18.29 Mpa for the control mixture. This means that there is an increase in the strength of almost 55% compared to the control mix at 7 days. However, mixtures with 100% replacement of copper slag gave the lowest compressive strength 18.31 Mpa which is almost 1% greater than the strength of the control mix.

Fig. 1- Compressive Response of Concrete with Copper Slag at 7th Day

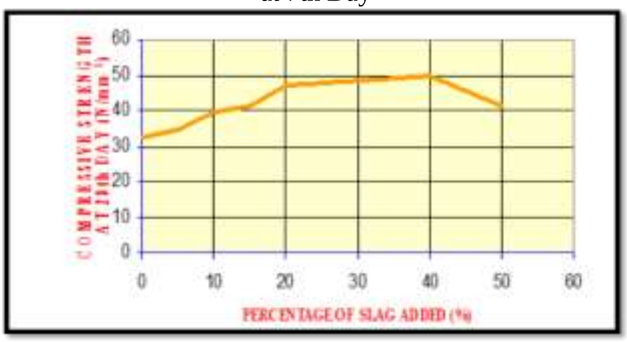

Fig. 2- Compressive Response of Concrete with Copper Slag at 28th Day

B. Flexural Strength

Here samples of size 500 x 100 x 100mm, 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 the concrete composites measured during this phase of the project are presented below.

Table -4 Flexural Strengths of the Concrete

MIX	Flexural Strengths (Mpa) f_{cr}
NORMAL M-25	3.49
CS 10%	3.60
CS 20%	4.00
CS 30%	3.63
CS 40%	3.67
CS 50%	3.75
CS 60%	3.57
CS 75%	3.52
CS 100%	3.83

4. CONCLUSIONS

1. It can be seen that there is increase in strength with the increase in Copper Slag percentages; however the highest compressive strength was achieved by 40% replacement of copper slag, which was found about 28.48 Mpa compared with 18.29 Mpa for the control mixture.
2. This means that there is an increase in the strength of almost 55% compared to the control mix at 7 days. However, mixtures with 100% replacement of copper slag gave the lowest compressive strength 18.31 Mpa which is almost 1% greater than the strength of the control mixture.
3. It can be seen that there is increase in strength with the increase in Copper Slag percentages; however the highest flexural strength was achieved by 20% replacement of copper slag, which was found about 4 Mpa compared with 3.49 Mpa for the control mixture.

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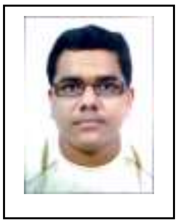
BIOGRAPHIS



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