Study of the Properties of Concrete Containing Copper Slag as a Fine Aggregate

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Abstract - **Copper slag is one of the materials which is considered as waste materials in the production of copper, which can be used as partial replacement of fine aggregates in concrete. This paper presents the results of an experimental study on various durability tests on concrete containing copper slag as partial replacement of sand. In this report, M30 grade of concrete was designed and tests were conducted with different percentage of copper slag as fine aggregate in concrete. The results indicate that workability increases with increases in the copper slag percentages. The Compressive Strength is increased upto 8.63 % as compared to normal concrete. The Rapid chloride penetration test is carried out to know the chloride ion penetrability. Also, accelerated corrosion process by galvano static weight loss method is carried out to know the corrosion rate of concrete.**

1.INTRODUCTION

Concrete is a widely used construction material for various types of structures due to its durability. For a long time it was considered to be very durable material requiring a little or no maintenance. In the recent revision of IS:456-2000, one of the major points discussed is the durability aspects of concrete. The use of concrete is unavoidable, at the same time the scarcity of aggregates are also increasing nowadays. Utilization of industrial soil waste or secondary materials has been encouraged in construction field for the production of cement and concrete because it contributes to reducing the consumption of natural resources. For many years, by-products such as fly ash, silica fume and slag were considered as waste materials. They have been successfully used in the construction industry for partial or full replacement for fine and coarse aggregates. The maximum percentage of increase in strength is found to be 32.93 % at 40 % replacement of sand in concrete. BRINDA.D [1]. Copper slag, which is the waste material produced in the extraction process of copper metal in refinery plants, has low cost and its application as a fine aggregate in concrete production have many environmental benefits such as waste recycling and solves disposal problems. It has been observed that up to 80 % replacement, CS and FS can be effectively used as replacement for fine aggregate. The compressive strength increases with increase in percentage of combine mixes is illustrated in Figure 2.2 (copper slag and ferrous slag). [2]Wei Wu. CS is a glassy granular material with high specific gravity. Particle sizes are of the order of sand and have a potential for use as fine aggregate in concrete. In order to reduce the accumulation of CS and also to provide an alternate material for sand, CS was used as a replacement material for sand in cement concrete. It shows that the water consumed by the copper slag during mixing is very less as compared with river sand. The water absorption for 30 % replacement of cement with GGBS decreases by 4.58%[3]. Therefore, it is recommended that 40 % weight of copper slag can used as replacement of sand in order to obtain HPC with good strength and durability properties. The increase in the percentage of copper slag increase in slump value and decrease the compressive strength[4] KHALIF S.AL-JABRI.A substitution of up to 40–50 % copper slag as a sand replacement yielded comparable strength to that of the control mixture. However, addition of more copper slag resulted in strength reduction due to the increase in the free water content in the mix. Also, the results demonstrated that surface water absorption decreased as copper slag content increases up to 50 % replacement[5]. Therefore it can be concluded that the use of copper slag as sand substitution improves HSC strength and durability characteristics at same workability while super plasticizer is very important ingredient in HSC made with copper slag in order to provide good workability and better consistency for the concrete matrix. The increase in the percentage of copper slag decrease in the water cement ratio [6].

2. MATERIALS AND METHODOLOGY

2.1 Materials

In this work we used cement, fine aggregates, coarse aggregate andchemical admixtures such as Conplast SP - 430 ES2 are used. The cement used in this study has 43 grade ordinary Portland cement (OPC) which is having specific gravity of 3.15.Coarse aggregate of 20 mm down size is used.Fine aggregates used for normal concrete were natural river sand and copper slag. Copper slag is procured from Mythri Metallizing India Company, Bangalore, Karnataka, India.The Physical and Chemical of Fine aggregates are shown in table.1.and table.2.

Table 1.Physical Properties of Fine aggregate.

Physical Properties	Sand	Copper slag
Particle shape	Irregular	Irregular
Appearance	Brownish yellow	Black & glassy
Type	River sand	Air cooled
Specific gravity	2.7	3.44
Bulk density g/cc	1.71	1.9
Fineness modulus	2.73	3.47
Water absorption %	1	0.19
Moisture content %	0.5	0.033

Table 2.Chemical Properties of Copper Slag.

Sl. No.	Chemical Component	% of Chemical Component
1	SiO_2	37.26
2	Fe_2O_3	47.45
3	Al_2O_3	3.95
4	CaO	2.38
5	Na_2O	0.65
6	K_2O	2.62
7	Mn_2O_3	0.086
8	TiO_2	0.33
9	SO_3	2.75
10	CuO	1.12

2.2 Mix Design for M_{30} Grade Concrete

The mix design is calculated as per IS code 10262:2009 [7]. In this present work we varied the copper slag from 0 to 100% by replacing the river sand. To reduce the water content from the concrete 2% of Super Plasticizers by mass of cement. The mix proportions for M_{30}grade concrete is 1:2.04:3.32. (Cement: fine aggregate: coarse aggregate). The varied fine aggregate proportions of copper slag with sand are presented in the table.3.

Table 3.Concrete Mixtures with Different Proportions of Copper Slag with Sand.

Sl. No	Fine aggregate-copper slag replacement	Water (Lit/m^3)	Cement (kg/m^3)	Fine aggregate (kg/m^3)	Copper slag (kg/m^3)	Coarse aggregate (kg/m^3)
1	80-20 %	165	366.67	600.88	191.39	1218.31
2	60-40 %	165	366.67	450.66	382.78	1218.31
3	40-60 %	165	366.67	300.44	574.17	1218.31
4	20-80 %	165	366.67	150.22	765.57	1218.31
5	0-100 %	165	366.67	0	956.96	1218.31

2.3 Testing Methods

2.3a Compressive Strength

Cube specimens of size 150 × 150 × 150 mm were used for determining characteristic compressive strength. The cubes were tested in a compression testing machine of capacity 3000 kN.The compression test was conducted after curing the concrete cubes at 7 days and 28 days.

2.3b Rapid Chloride Permeability Test (RCPT)

The RCPT is a table or bench mounted unit, which measures the electrical charges passed through a 2-inch thick slice of 4-inch nominal diameter concrete core or cylinder during a period of 6 hours. A potential difference of 60 volts D.C. is maintained across the ends of the specimen. One end of the cell is filled with sodium chloride solution while the other end of the cell is filled with sodium hydroxide solution. The total charge passed, in coulombs, is related to the resistance of the specimen to chloride ion penetration.[8] ASTMC1202.

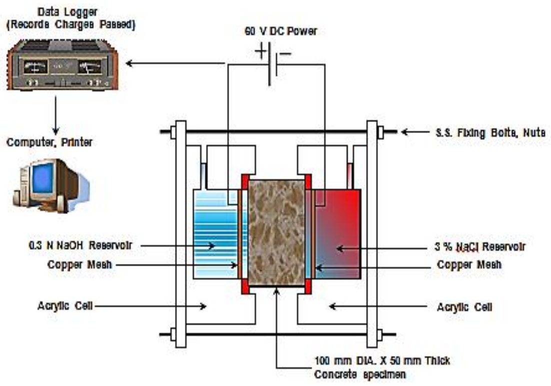

Fig 3.1: Schematic Diagram of RCPT Setup.

Fig 3.2 Laboratory Setup of RCPT.

2.3c. Accelerated corrosion process: Galvano static weight loss method

weighed TMT steel of 8 mm diameter specimens were embedded in concrete cylinder of size 150 mm diameter and 300 mm height. The concrete samples were subjected to alternate wetting and drying exposure in 3.0 % NaCl solution. Regular D.C power supply of 0.3A is supplied continuously throughout the corrosion period of 7 days. Positive terminal is connected to the bar with soldered wires and negative terminal is connected with graphite rod. After the process of accelerated corrosion was over, all the specimens were disconnected and removed from tank. After the corrosion period, the rod was taken out and weighed. The loss in weight was calculated.From the weight loss values,[1] the corrosion rates were obtained from the relationship:

$$\text{Corrosion Rate} = (K \times W) / (A \times T \times D)$$

Where K is a constant, K = 87.6 in case of expressing Corrosion rate in mm/yr.

T is the exposure time expressed in hours.

A is the surface area in cm2.

W is the mass loss in milli gram. and

D is the density of the corroding metal (7.85g/cm3).

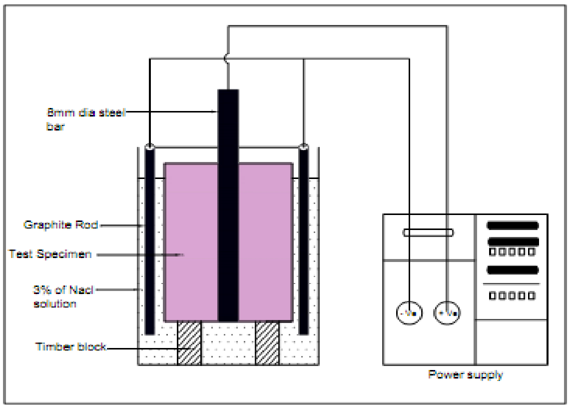

Fig.3 Accelerated corrosion set up.

3.RESULTS AND DISCUSSION

This chapter deals with the test results and discussions on compressive strength, RCPT and accelerated corrosion process of concrete containing copper slag as mineral admixture. Mix proportions have been obtained for M30 grade control concrete as per code IS 10262:2009. Then copper slag is replaced by 20 %, 40 %, 60 %, 80 % and 100 % of sand to study the compressive strength, rapid chloride penetration test and accelerated corrosion process.

3.1 Slump Test

The slump test was conducted on fresh concrete for various percentage replacement of fine aggregate with copper slag. Slump values are increasing with increase in percentage of copper slag. The workability increased substantially with the increase of copper slag content in the concrete mixture as shown in fig.4 due to the low water absorption and glassy surface of copper slag compared with sand in concrete.

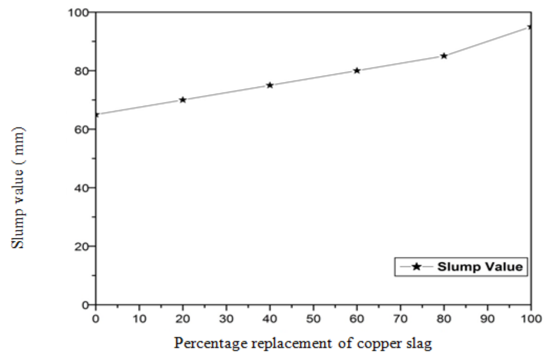

Fig. 4.Effect of copper slag replacement on slump value of concrete.

3.2 Compressive Strength Test Results

The optimum percentage of replacement was obtained at 20 % replacement of sand by copper slag. The compressive strength for normal concrete was found to be 38.11 N/mm2. The maximum percentage of increase in strength is found to be 8.28 % at 20 % replacement of sand by copper slag after 28 days curing. Afterwards there was gradually a decrease up to 18.23 % for 100 % replacement of sand in concrete as shown in fig.5 is due to the excessive free water content in the mixes with high copper slag content causes the particles of the constituents to separate leaving pores in the hardened concrete which consequently causes reduction in the concrete strength.

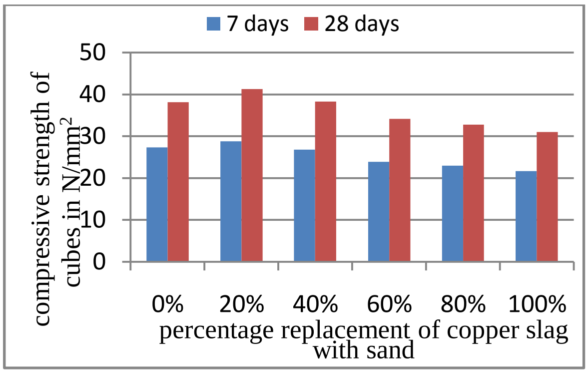

Fig.5. Compressive strength for various replacement percentage of copper slag in concrete.

3.3 Rapid Chloride Ion Permeability Test Results (RCPT)

For normal concrete, the average charge passed was found to be 950.5 coulombs and for copper slag admixed concrete the maximum charge passed was 1538.5 coulombs after 28 days curing as shown in fig.6. The charge passed for copper slag admixed concrete has shown slightly higher values than normal concrete but within the limits. As per ASTM C1202, the value obtained for copper slag admixed concrete is graded under the category "low". As such, it is indicating lesser permeability of copper slag admixed concrete. The important observation is that addition of copper slag definitely reduces the pores of concrete and makes the concrete impermeable.

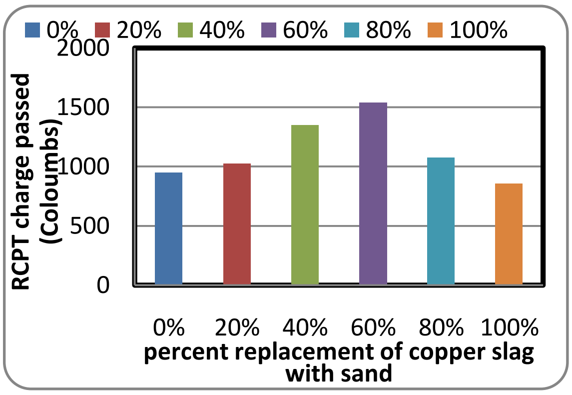

Fig.6. Rapid chloride ion permeability test on copper slag concrete.

3.4Accelerated corrosion process: Galvano static weight loss method

From the fig.7 it was observed that the copper slag admixed concrete showed higher corrosion rates than normal concrete in various percentages of replacements. The corrosion rate of copper slag admixed concrete increases as percentage of copper slag increases. The corrosion rate can be controlled by coating the bar with Zinc Phosphate paint.

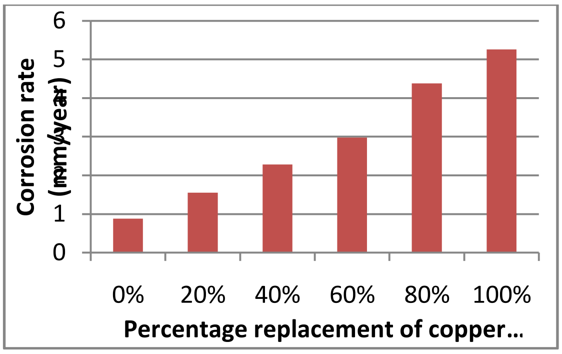

Fig.4.3 Corrosion rate for various percentage of copper slag in concrete.

4.CONCLUSION

1) The workability increases up to 31.57 % for 100 % replacement of copper slag as a fine aggregate fine aggregate.
2) The maximum compressive strength of concrete increases up to 8.63 % for 20 % percentage replacement of fine aggregate, but up to 40 % percentage of copper slag can be replaced which is greater than the target strength.
3) The maximum charge passed was 1538.5 coulombs for copper admixed concrete which is graded as per ASTM C1202 under category "low". As such it is indicating the addition of copper slag definitely reduces the pores of concrete and makes the concrete impermeable.
4) Accelerated corrosion test reveals that the corrosion rate of copper slag admixed concrete with rebar is increases as compared to normal concrete specimens.

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