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Copper Slag in Concrete

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Abstract: **In the manufacture of copper, slag is an important by-product produced during the smelting process. This waste by-product which is difficult to dispose can be used in concrete as a replacement material for sand. This paper reports the behavior of concrete containing copper slag. Copper slag is used in concrete in small increments of 20, 30, 40, 50, 60, 70, 80, 100% and its behaviour in each case is compared with that of conventional concrete containing sand. The results of the experimental investigations carried out on concrete containing copper slag are presented. The compressive strength is investigated after 7 days and 28 days and the effect of Copper slag on the early age strength and also after 28 days age is studied. The results are compared and presented. The objective of this paper is to advocate utilization of the copper slag as replacement for sand while improving the quality and strength of concrete.**

Keywords: **Copper Slag, compressive strength, experimental, concrete**

I. Introduction

Most commonly used material in construction are steel, concrete, cement, sand, stones, glass, aluminum, plastics, bricks, etc. It is not possible to meet the ever-growing demand for housing by using only traditional energy-efficient material. Thus, there is a need for identification of new raw material to produce simple, energy-efficient, environment- friendly and sustainable building alternatives. It is in this context that the eco-friendly and recycled waste material gains importance. Large amounts of industrial waste accumulate every year in the developing countries. Sustainability, eco-friendly and resource efficiency are the most important area of interest in today's construction industry. For these reasons, of late, utilization of secondary materials is being encouraged in construction field. Production of conventional concrete using cement, sand and coarse aggregate involves high amount of energy consumption and environmental pollution. Producing good and durable concrete by using Industrial by-products can reduce harmful effects of concrete.

There are many types of new concrete being developed by varying the proportions of the main ingredients and by substitution of the cementitious and aggregate materials. The finished product can be tailored to its application with varying strength, density, chemical and thermal resistance properties.

Different types of slag produced as by product in manufacture of metals, according to the property can be utilized for different purposes. Copper slag is one such waste industrial product that is considered to have a promising future in construction industry as partial or full substitute of fine aggregate.

II. Copper Slag

Copper slag is one of the waste materials produced in the copper smelting and refining process. The molten copper slag collects in the furnace. The molten copper slag is then drained off and quenched with water or left in the air to cool down.

Copper slag is produced in large quantities from various industries around the world. The safe disposal of this waste is a very difficult task. It not only proves costly to dispose but also causes environmental pollution. One application of copper slag is for blasting. During blasting, copper slag breaks into smaller particles on impact with metal surfaces. After several rounds of reuse, the copper slag gets contaminated with rusts and paints and becomes a waste material but without any change in its chemical composition

Construction industry is one other area where, the safe use of copper slag is possible. When copper slag is used in concrete as a replacement material, it reduces the environmental pollution and reduces the cost of concrete. This way, we can also solve the problem of disposal of this industrial waste. Copper slag has a promising future in construction industry as partial or full substitute of fine aggregate.

III. Experimental Investigations

The concrete is prepared by using copper slag in the proportions of 20%, 30%, 40%, 50%, 60%, 70%, 80% and 100% as replacement material for sand. The test specimens are cubes of size 150 x 150 x150 mm which are used for measuring the compressive strength of concrete containing varying content of copper slag. The following materials are used in the investigations

3.1 Materials

3.1.1 Cement

Ultratech Ordinary Portland cement 53 grade is used.

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3.1.2 Fine Aggregate

Fine aggregate or sand with size less than 4.75mm is used. The sand used in the making of concrete is ensured to be free from any clay or inorganic materials. It is stored in open space free from dust and water. It conforms to IS 383:1970 and falls under zone II.

3.1.3 Coarse Aggregate

Maximum size of aggregate used is 20mm.

3.1.4 Copper slag

Copper slag used in this investigation is obtained from Sterlite Industries India Ltd, Tuticorin

3.1.5 Water

Domestic water free from salts is used for mixing of concrete.

3.2 Mix Design

The mix design adopted is 1:1.47:2.62 with water cement ratio of 0.40.

3.3 Casting And Testing

Cubes of size 150 x 150 x 150 mm are cast in steel moulds as shown below and demoulded after 24 hours. The cubes are cured in water tank for 28 days and are tested in the compression testing macchine for compressive strength after 7 days and 28 days.

3.4 Compressive Strength Of Copper Slag Concrete

One of the most important properties of concrete is its compressive strength which measures its ability to withstand compressive loads. Compression test is the most common test conducted on hardened concrete and partly because it is the most desirable characteristic property of concrete. Compressive strength is expressed as load per unit area. The compression tests performed in this project were in accordance with IS standard 516 “Methods of Tests for Strength of Concrete”.

One of the methods for determining the compressive strength of concrete is by applying a load at a constant rate. The unconfined compressive strength test was carried out on 150 x 150 x 150 mm cube until the specimen fails.

The test is carried out in a compression testing machine of 200 tones capacity. A loading rate of 2.5 N/s was applied which approximately equals to the 140 kg/cm^2/minute as given in IS: 516-1959.

Concrete with seven partial replacement levels of 20%, 30%, 40%, 50%, 60%, 70%, 80% and 100% have been tested for their compressive strength after 7 days and 28 days of immersion of samples in curing tank. Before testing, the specimens were allowed to air dry before testing.

Fig 1 Testing for Compressive strength

The compressive strength increased with increase in copper slag content. An increase of upto 20% was observed for copper slag with 60% volume. However, after 28 days of curing the increase in strength due to the presence of copper slag increased upto 23.64% compared to conventional concrete.

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Table 1
Compressive strength after 7 days

Copper slag %	Load (kN)	Compressive strength (N/mm^2)	Inc. in compressive strength (%)
CS 0	800	35.56	-
CS 20	860	38.22	7.50
CS 30	930	41.33	16.25
CS 40	950	42.22	18.75
CS 50	800	35.56	0.00
CS 60	650	28.89	-18.75
CS 70	645	28.67	-19.38
CS 80	640	28.44	-20.00
CS 100	640	28.44	-20.00

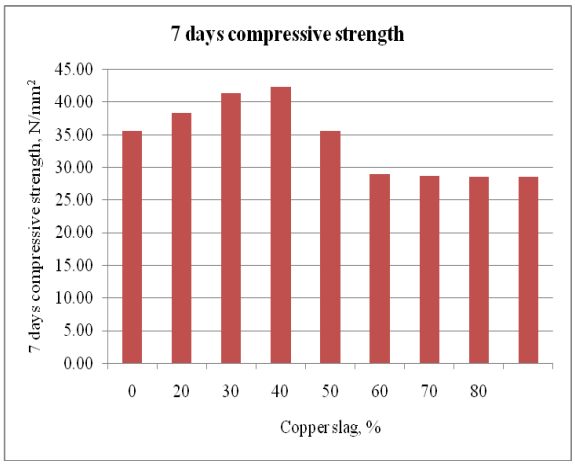

Figure 2 Compressive strength at 7days

Table 2
Compressive strength after 28 days

Copper slag %	Load (kN)	Compressive strength (N/mm^2)	Inc. in compressive stress (%)
0	1050	46.67	-
20	1070	47.56	1.90
30	1150	51.11	9.52
40	1200	53.33	14.29
50	1190	52.89	13.33
60	1160	51.56	10.48
70	1140	50.67	8.57
80	1140	50.67	8.57
100	1060	47.11	0.95

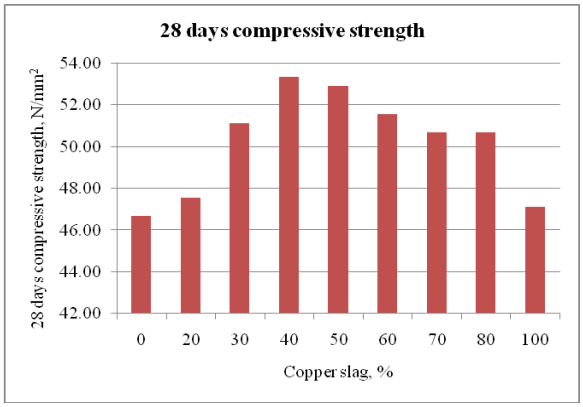

Fig 3 Compressive strength of cubes at 28 days

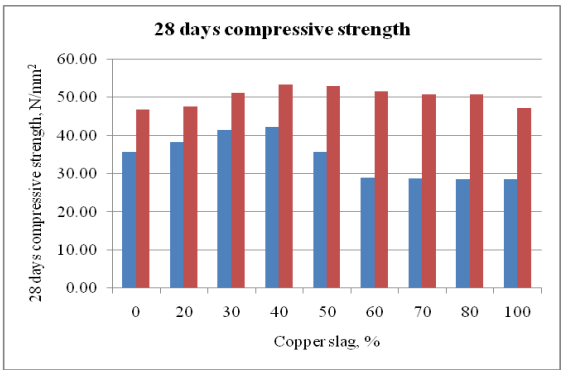

Figure 4. Comparison of 7 and 28 days strength

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IV. CONCLUSIONS

The following conclusions were obtained from this study. With replacement of sand with copper slag, the compressive strength of concrete varied as below.

- The addition of copper slag has improved the compressive strength after 28 days.
- It was observed that with the partial replacement of fine aggregate with copper slag, the compressive strength increased linearly at 20%, 30% and 40%.
- The 7 days compressive strength increased by 7.50%, 8.75% and 2.50% when copper slag content was 20% , 30% and 40% respectively.
- The 28 days compressive strength increased by 1.90%, 9.52%, 14.29% when copper slag content was 20%, 30%, 40% respectively.
- The results clearly indicated that the replacement of fine aggregate with copper slag increased the compressive strength and the increase in strength is more pronounced in the later stages.
- The increase in compressive strength decreased with larger volume of copper slag content.
- The maximum compressive strength observed was 53.33 $N/mm^{2.}$
- Hence concrete with copper slag replacement is recommended upto 40% which proves to be most efficient than the other mixes.

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