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Research Article

An Experimental Investigation on Optimum Usage of Copper Slag as Fine Aggregate in Copper Slag Admixed Concrete

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Abstract

In the current arena, infrastructure development holds the key for the development of every nation. Concrete is one of the most utilized material by the construction industry which is a homogeneous material prepared of heterogeneous materials like Cement, sand and aggregate. However rapid urbanization has created a huge demand for natural sand hence made it even more expensive. This led the researchers to find other materials which could be used as a replacement of sand whose main chemical composition is Silica (SiO2). After a great extent of research, researchers found that materials like Stone dust, Copper Slag, Coal Fly Ash, Carbonate Sand etc. having silica composition could be used as a replacement of sand. The Present experimental investigation is carried out forM20 grade of concrete mixes with partial replacement of Fine Aggregate (Sand) with Copper Slag. Compressive Strength at the ages of 7, 28 &90 days for various combinations of Copper Slag and Sand were investigated. Sand was replaced with Copper Slag by 0%, 10%, 20%, 30%, 40% and 50%.

Keywords: *Copper slag, Fine aggregate, Compressive Strength, Replacement*

Literature Review

Ishimaru *et al* investigated the fundamental properties of concrete using copper slag and class II fly ash as fine aggregates and the following conclusion was drawn. The results indicated that up to 20% (in volume) of copper slag or class II fly ash as fine aggregates substitution can be used in the production of concrete. Al-Jabri *et al* investigated the effect of copper slag (CS) and cement by-pass dust (CBPD) as replacements on the strength of cement mortars. The results indicated that the mixture containing 5% CBPD + 95% cement yielded the highest 90 days compressive strength of 42 MPa in comparison with 40 MPa for the mixture containing 1.5% CBPD + 13.5 CS + 85% cement. The optimum CS and CBPD used was 5%. In addition, it was determined that using CBPD as an activating material would operate better than using lime. Washington Almeida Moura *et al* investigated the strength properties of copper slag admixed concrete and found that an addition of copper slag to concrete results in an increase on the concrete's axial compressive, splitting tensile strength and decrease in the absorption rate by capillary suction, carbonation depth and hence improved its durability. Al-Jabri *et al* studied the Effect of using copper slag as a fine aggregate on the properties of cement mortars and concrete. The results indicated that all mixtures with different copper slag proportions yielded comparable or higher compressive strength than that of the control mixture. More than 70% improvement in the compressive strength of mortars with 50% copper slag substitution. Brindha and Nagan studied the effect of replacing fine aggregate by copper slag on the compressive strength and split tensile strength and found that the percentage replacement of sand by granulated copper slag were 0%,5%,10%,15%,20%,30%,40% and 50%. The compressive strength was observed to increase by about 35-40% and split tensile strength by 30-35%. The experimental investigation showed that percentage replacement of sand by copper slag shall be up to 40%. Chavan and Kulkarni investigated the effect of using copper slag as a replacement of fine aggregate on the strength properties. The observations were that Maximum Compressive strength of concrete increased by 55% at 40% replacement of fine aggregate by copper slag, and up to 75% replacement, concrete gain more strength than control mix concrete strength. For all percentage replacement of fine aggregate by Copper slag the flexural strength of concrete is more than control mix. The flexural strength of concrete at 28 days is higher than design mix (Without replacement) for 20% replacement of fine aggregate by Copper slag, the flexural strength of concrete is increased by 14%. This also indicates flexural strength is more for all percentage replacements than design mix. Compressive strength and flexural Strength is increased due to high toughness of copper slag.

Experimental Investigation

The present investigation is aimed to study the Compressive Strength of M20 grade of concrete mix with

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Table 1 Concrete Mix Design Details – M20 Mix

% of Copper Slag	Cement in kg	Fine Aggregate in kg			20mm Metal in kg	Water in kg
		Natural Sand	Copper Slag	Total FA		
0%	320	712	0	712	1178	176
10%	320	640.8	71.2	712	1178	176
20%	320	569.6	142.4	712	1178	176
30%	320	498.4	213.6	712	1178	176
40%	320	427.2	284.8	712	1178	176
50%	320	356	356	712	1178	176

Table 2 Compressive Strength of M20 Mix concrete in N/mm^2

% Replacement of Sand with Copper Slag	7-Days	28-Days	90-Days
0%	24.12	36.8	44.34
10%	25.67	37.62	46.86
20%	26.34	39.12	51.22
30%	27.44	40.63	52.37
40%	27.96	41.05	55.17
50%	23.98	39.25	50.75

Table 3 % Increase in Compressive Strength of M-20 Grade Concrete with varying Proportions of Copper Slag

% Replacement of Sand with Copper Slag	Compressive Strength (N/mm^2)		% Increase in Strength w.r.t. 7 Days	Compressive Strength (N/mm^2)		% Increase in Strength w.r.t. 28 Days
	7-Days	28-Days		28-Days	90-Days	
0%	24.12	36.8	52.57%	36.8	44.34	20.49%
10%	25.67	37.62	46.55%	37.62	46.86	24.56%
20%	26.34	39.12	48.52%	39.12	51.22	30.93%
30%	27.44	40.63	48.07%	40.63	52.37	28.90%
40%	27.96	41.05	46.82%	41.05	55.17	34.40%
50%	23.98	39.25	63.68%	39.25	50.75	29.30%

a partial replacement of sand with copper slag. The sand was replaced from a minimum of 0% to a maximum of 50% with copper slag. A total of five combinations were studied for M20 concrete mix. Sand was Partial replaced with copper slag in proportions of 0%, 10%, 20%, 30%, 40% & 50%. The Compressive Strength was calculated at the age of 28, 60 and 90 days.

Materials

Cement

Ordinary Portland cement of 53 grade having specific gravity of 3.094 and fineness modulus of 4.62% was used. The Cement used has been tested for various proportions as per IS 4031-1988 and found to be confirming to various specifications of 12269-1987.

Coarse Aggregate

Crushed angular granite metal of 10 mm size having the specific gravity of 2.637and fineness modulus 7.102 was used.

Fine Aggregate

River sand having the specific gravity of 2.601 and fineness modulus 2.43 was used.

Copper Slag

Copper Slag with specific gravity 3.476 and fineness modulus 3.301 was used.

Test Specimens

Test specimens consist of 150X150X150 mm cubes and tested as per IS 516 and 1199.

Discussion of Results

Quantities of Materials

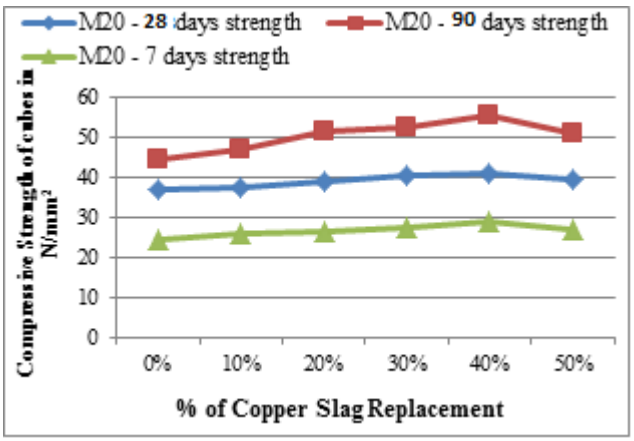
Table 1.0 gives the quantities required for M20 grade of Concrete Mixes. The specimens are casted by replacing fine aggregate up to 50 % with copper slag.

Compressive Strength

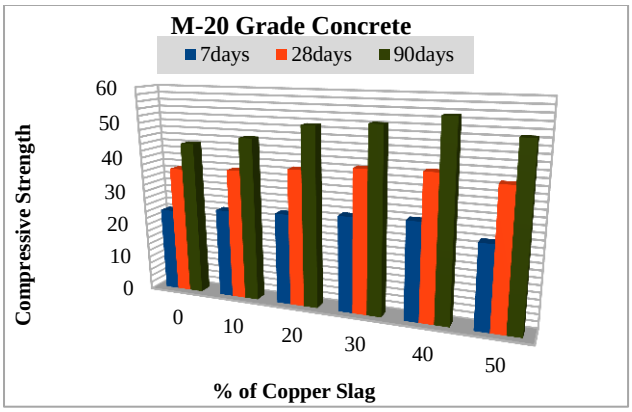
From Tables 2.0 and 3.0, we observe that up to 40% copper slag replacement, the compressive strength of concrete increased. However, for mixtures with 50% copper slag replacement, the compressive strength decreased rapidly. For M20 Grade Mix Concrete with 40% of copper slag replacement the 7 days, 28 days and 90 days compressive strength were 27.96 N/mm^2, 41.05 N/mm^2 and 55.17 N/mm^2 compared with 25.67 N/mm^2, 37.62 N/mm & 46.86N/mm^2 for the control mixture.

For M20 Grade Mix Concrete with 50% of copper slag replacement the 7 days, 28 days and 90 days compressive strength were 23.98 N/mm^2, 39.25 N/mm^2 and 50.75 N/mm^2. These variations are shown in Graph 1.0 and 2.0.

Copper Slag has a lower water absorption capacity when compared with Sand. The lower water absorption capacity causes increased free water content there by decrease in Compressive Strength. This further causes increase in the workability.



Graph 1 Compressive Strength of M20 Grade Mix with various % of Copper Slag Replacement at the age of 7, 28 and 90 days.



Graph 2 Pattern of Compressive Strength variation for M20 Grade Mix with various % of Copper Slag Replacement at the age of 7, 28 and 90 days.

Conclusions

Copper Slag behaves similar to River Sand, for its use as fine aggregate (partially or in blending) in Concrete mixes. Addition of Copper Slag in Concrete increases the density, thereby the self-weight of Concrete. The results showed that the workability of Concrete increased substantially with increase of Copper Slag content in the concrete mixture due to the low water absorption, coarser (in nature than sand) and glassy surface of Copper slag, thereby the Strength properties also improved. The Compressive Strength of Concrete is comparable to the control mix up to 40% of Copper Slag substitution, but they decrease with a further increase in Copper Slag contents (due to the increase of free water content in the mix). Compressive Strength of Copper Slag admixture Concrete, increased due to high toughness of Copper Slag. For longer curing periods (i.e. 90-Days), no detrimental effect (i.e. Strength reversal) was observed, when using Copper Slag. Replacement of Copper Slag as fine aggregate in concrete mixes reduces the cost of concrete production. The utilization of Copper Slag in Concrete production provides additional environmental as well as effective waste management technique for all the related Industries.

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