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Experimental Investigation of Copper Slag as Partially Replacement of Fine Aggregate and Fly Ash as Cement in Concrete

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Abstract*: The foremost neutral of this study was to identify marginal source of good quality fine aggregates which is exhausting very fast due to the fast pace of construction activities in India. Use of copper slag is a surplus material of copper production and fly ash is a surplus material of power plants provides great prospect to utilize it as an alternative to normally available aggregates and cement. For this work M30 grade concrete was used and tests were conducted for a variety of proportions of copper slag replacement with fine aggregate of 0 to 50% and fly ash replacement with cement of 0% to 25% and also the tests were conducted to the durability properties of the working concrete. The fine aggregate was replaced with copper slag as proportions of 0%, 10%, 20%, 30%, 40%, and 50% and cement was replaced with fly ash as proportions of 0%, 5%, 10%, 15%, 20% to 25% in OPC 53 grade cement. The obtained result was compared with those of control concrete made with Ordinary Portland Cement (OPC) and also finding the mechanical properties of concrete like compressive, split tensile, flexure strengths. The results indicate that compressive and flexural Strengths is increased due to high stiffness of copper slag.*

Keywords: copper slag, fly ash, cement, compressive strength, flexure strength

1. Introduction

Concrete is a most versatile construction material because it is designed to withstand the harsh environments, with adequate strength and durability. Due to over usage of the concrete materials it become scared, and also the production at larger rate create many hazardous to the environment. On other side the waste exposed to our environment is an impact to ecology cycle. The environment is majorly affected by industrial waste. Industrial waste contains many inorganic and toxic substances beyond the acceptable limit cause impact to living life. To overcome these issues industrial waste can be recycled and reused for any useful purpose with acceptance levels. In this experimental investigation work major source of industrial waste creates pollution to environment and left as non-usable materials such as 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. In order to produce every ton of copper, approximately 2.2–3.0 tons copper slag is generated as a by-product material. In India copper slag is producing by Satellite Industries Ltd (SIL), Tuticorin Tamil Nadu. It is producing Copper slag during the manufacture of copper metal. Currently, about 2600 tons of Copper slag is produced per day and a total accumulation of around 1.5 million tons. 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.

Cement is likely the most broadly utilized development material as a part of the world. The principle constituent in the traditional cement is Portland concrete. The measures of bond production discharge roughly break even with measure of carbon dioxide into the air. Bond creation is expending critical measure of normal assets. That has conveyed weights to diminish bond utilization by the utilization of supplementary materials. The fuse of supplementary cementitious material is fly ash is another mineral admixture, which enhance primarily the mechanical properties of cement furthermore lessen the bond utilization by supplanting a portion of concrete with these pozzolanic materials.

1.1. Availability of Natural Sand as Fine Aggregate

In the last 15 years, it has become clear that the accessibility of good quality natural sand is decreasing. The research emphasizes on the use of material to be replaced by natural sand which will give new measurement in concrete mix design and if applied on large scale would transform the construction industry by economizing the construction cost and enable us to conserve natural resources.

2. Experimental Investigation

General: The experimental investigation consists of casting and testing of 9 sets along with control mix. Each set comprises of 15 cubes, 6 cylinders and 6 beams for determining compressive, tensile and flexural strengths respectively. By taking different percentages of copper slag to find the optimum content for the replacement of the fine aggregate, then adding fly ash to cement accordingly with the different percentages by weight of cement and finding the optimum percentage of fly ash.

2.1 Description of the materials

Concrete is an arrangement of three crude materials which are Cement, Fine aggregate and Coarse aggregate. These three crude materials assume a critical part in assembling of concrete. By interchanging the properties and differentiating the amount of these materials, the properties of concrete will change.

2.2 Cement

Cement is the major ingredient in assembling of concrete. The qualities of concrete will be incredibly influenced by changing the Cement content. The Cement used in this project is Ordinary Portland Cement of 53 grade confirming to IS 12269 – 1987.

2.3 Fly ash

Fly ash is by-product obtained from the thermal power plants obtained from combustion of coal. Generally fly ash has higher impact on the environment because of presence of heavy metals like mercury, cadmium, boron. Fly ash being a byproduct was been used in land filling as solution for solid waste disposal purpose where in which these heavy metals leach through this landfills and effect the health of the surrounding population. But India is only country whose 70% of population depends on thermal power which means higher coal consumption resulting in higher fly ash production which should properly disposed. Fly ash production is shown in table given below.

Table 2.1: Fly Ash production

Years	Ash Production(MT)
1995	75
2000	90
2010	110

2.4 Fine aggregate

Aggregates of size ranges between 0.075mm – 4.75mm are generally considered as fine aggregate. The Fine aggregate are selected as per IS-383 specifications

2.5 Copper slag

Copper slag is a byproduct created during copper smelting and refining process. Copper slag is an abrasive blasting grit made of granulated slag from metal smelting processes. Copper slag abrasive is suitable for blast cleaning of steel and stone/concrete Surfaces, removal of scale, rust, old paint, dirt etc.

Physical properties of copper slag

Particulars	Values
Particle shape	Irregular
Appearance	Black and glassy
Fineness modulus	4.39
Water absorption	0.18%
Specific gravity	3.18

2.6 Chemical properties of copper slag

Copper slag has high concentrations of SiO_2 and Fe_2O_3 compared with OPC. In comparison with the chemical composition of natural Pozzolan of ASTM C 618-99, the summation of the three oxides (silica, alumina and iron oxide) in copper slag is nearly 95%, which exceeds the 70% Percentile requirement for Class N raw and Calcined natural Pozzolan. Therefore, copper slag is expected to have good potential to produce high quality Pozzolan. Table 4.6 shows the chemical composition of copper slag which was obtained from National council for cement and building materials, Ballabgarh, India.

2.7 Coarse Aggregate

Sizes of aggregates above 4.75mm are generally considered as coarse aggregate. The maximum size of coarse aggregate used in this experimental work is 20 mm and 12 mm, and chips also have used 20% that is size of 12mm passing and 10mm retaining. A good quality of Coarse aggregate is obtained from nearest crusher unit. The Coarse aggregate are selected as per IS-383 specifications.

3. Compression Test

Compressive strength is obtained by applying crushing load on the cube surface. So it is also called as Crushing strength. Compressive strength of concrete is calculated by casting 150mm x 150mm x 150mm cubes. The test results are presented here for the Compressive strength of 7 days, 28 days of testing.

3.1 Copper slag optimum Content

The mix proportions are taken in different percentages (10%, 20%, 30%, 40%, and 50%) for the replacement of the cement (OPC) in the mix.

Table 3.1: Compressive strength for different copper slag percentages

Compressive strength		
copper slag %	7 Days	28 Days
0%	25.13	37.25
10%	26.25	40.34
20%	28.72	43.82
30%	31.45	45.75
40%	30.13	44.62
50%	29.21	43.37

From the test results it is observed that till 20% the strength is rising and beyond that the strength is falling, so the optimum content of copper slag for fine aggregate replacement is taken as 30%.

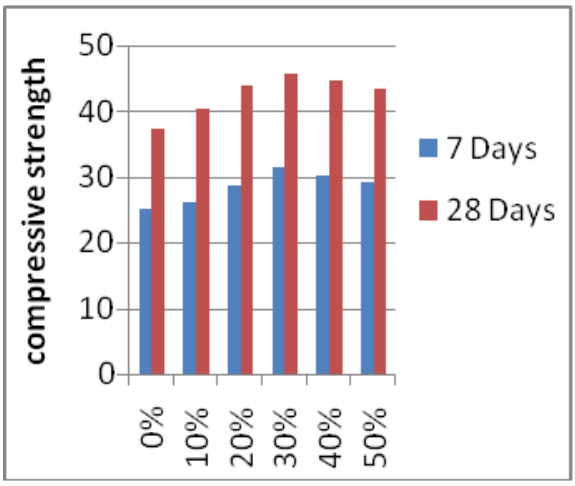

Figure 3.1: Compressive strength of copper slag for 7 & 28 days

Table 3.2: Compressive strength for different fly ash percentages with optimum copper

Compressive Strength			
Copper Slag	Fly Ash	7 days	28 days
optimum	0%	31.45	45.75
	5%	31.89	46.27
30%	10%	32.18	48.21
	15%	32.79	49.56
	20%	29.93	47.32
	25%	26.64	42.85

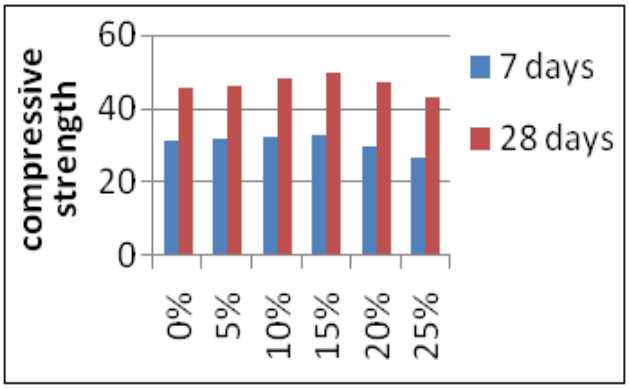

Figure 3.2: Compressive strength of different % of fly ash with optimum copper slag for 7 & 28 days

3.2 Split Tensile Test

Split Tensile strength is obtained by applying crushing load on the cylinder surface. Split Tensile strength of concrete is calculated by casting 150mm diameter and 300mm cylinders. The test results are presented here for the split tensile strength of 28 days and 90 days of testing.

Table 3.3: Tensile strength for different copper slag percentages

Split tensile strength		
Copper slag %	7 days	28 days
0%	2.34	3.72
10%	2.48	3.95
20%	2.56	4.08
30%	2.72	4.20
40%	2.68	4.11
50%	2.42	3.98

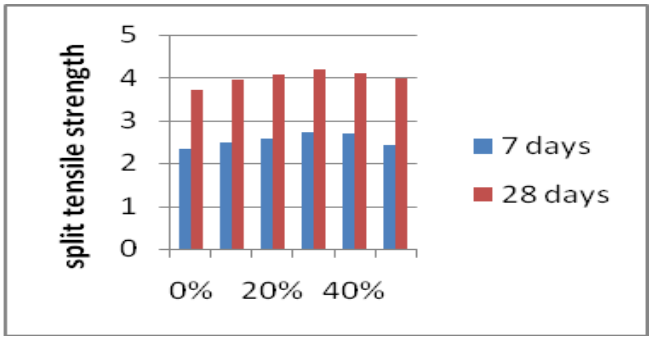

Figure 3.3: Tensile strength for different copper slag optimum percentages

Table 3.4: Split tensile strength for fly ash Percentages with optimum % of copper slag

Split tensile strength			
Copper slag	Fly ash	7 days	28 days
Optimum	0%	2.72	4.20
	5%	2.85	4.29
30%	10%	3.01	4.40
	15%	3.15	4.51
	20%	3.01	4.46
	25%	2.91	4.42

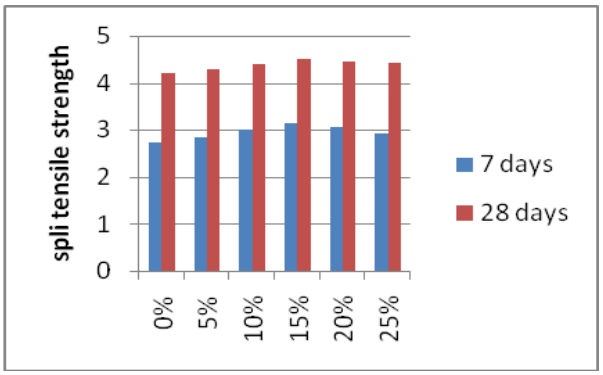

Figure 3.4: split tensile strength of different % of fly ash with optimum copper slag for 7 & 28 days

3.3 Flexural Test

Flexural test was performed on beams size of 500mm ×100mm ×100mmsize by placing them on universal testing machine find out the flexural strength.

Table3.5: Flexural Strength for different copper slag percentages

Flexure strength	
Copper slag %	28 days
0%	4.01
10%	4.17
20%	4.38
30%	4.63
40%	4.51
50%	4.39

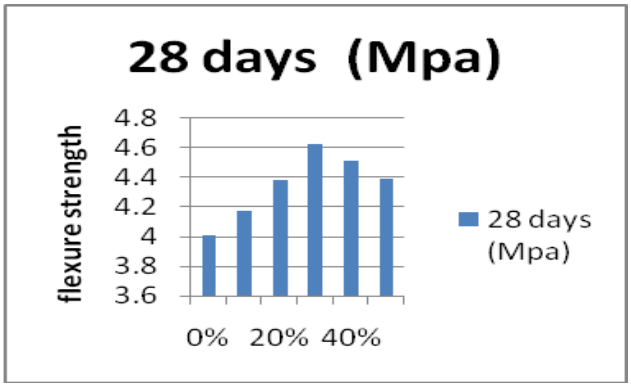

Figure 3.5: Flexural Strength for 28 days for different copper slag percentages

Table 3.6: Flexure strength for different % of fly ash with optimum percentage of copper slag

Flexure strength		
Optimum	Fly ash	28 days
Copper slag 30%	0%	4.63
	5%	4.77
	10%	4.89
	15%	5.13
	20%	4.98
	25%	4.82

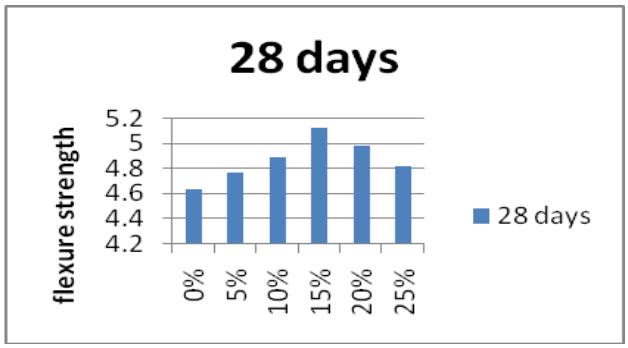

Figure 3.8: Flexural Strength for 28 days for different copper slag percentages

4. Durability Study

4.1 Requirements of Study

To check the Acid resistance of concrete Hydrochloric acid (HCl), Sulphuric Acid (H_2SO_4) is selected. The concentrations of acids in water are taken as 5%. The standard specifications for this study are IS 516-1959 and ASTM C666-1997.

4.2 Test

Durability studies of compressive strength of concrete effected with 0.5% of HCl and H_2SO_4 acid is studied at 15% replacement of fly ash for cement in the concrete mixand replacement of optimum percentage of copper slag.
Considerations taken
Compressive Strength

4.3 Compressive strength consideration:

Table 4.1: 28 days compressive Strength of different percentages of fly ash with optimum copper slag

Copper slag	Fly ash	28 Days (H_2SO_4)	28 Days Water	28 Days (HCl)
Optimum 30%	0%	31.15	45.75	33.71
	5%	32.75	46.27	35.85
	10%	34.14	48.21	37.81
	15%	36.3	49.56	39.45
	20%	33.12	47.32	36.13
	25%	27.57	42.85	29.27

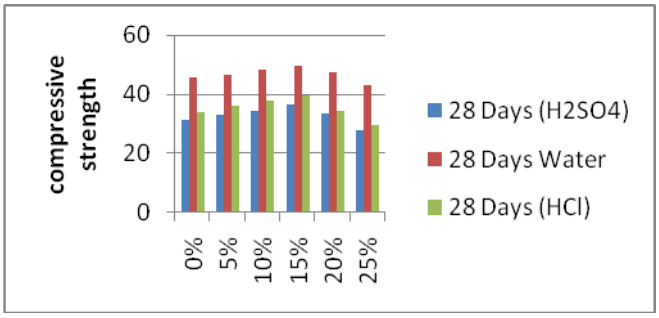

Figure 4.1: 28 days Compressive Strength of H_2SO_4 curing, Water curing and HCl curing (copper slag)

5. Conclusion

- In this experiment the combination of copper slag and fly ash concrete is studied. The utilization of copper slag in concrete provides additional environmental as well as technical advantages for all related industries partial replacement of copper slag in fine aggregate and fly ash in cement reduces the cost.
- The replacement of copper slag as sand attained high strength at 30% replacement with conventional concrete. The replacement of fly ash with copper slag optimum percentage.
- The compressive strength obtained for 28 days containing copper slag 30% is found to be 45.75 N/mm2 increased by 22.8% further replacement there is decrease in strength
- The split tensile strength obtained for 28 days containing copper slag 30% is found to be 4.20 N/mm2 increased by 12% further replacement there is decrease in strength
- The flexural strength obtained for 28 days containing copper slag 30% is found to be 4.63 N/mm2 increased by 15.3% further replacement there is decrease in strength
- It was observed that 35.2% of compressive strength has increased for fly ash with optimum concrete over plain concrete.
- 28% of split tensile strength has increased when it was compared with plain concrete.
- Flexural strength has also significantly increased up to 32% when it was correlated with plain concrete
- In durability the weight loss and strength loss is higher in H_2SO_4 than in HCl.

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