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EXPERIMENTAL INVESTIGATION ON STRENGTH ASSESSMENT OF COPPER SLAG CONCRETE

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ABSTRACT:-*This paper presents the effect of copper slag when included in concrete as a partial replacement material for fine aggregate. It focuses on the effect of copper slag on behavior of concrete. This paper outlines the properties, preparation and testing and finally the results obtained from experimental investigations using copper slag which is a waste by product produced during the smelting process of manufacture of concrete from its ore. Experimental investigations are carried out by replacing sand with copper slag in content of 0% 10%, 20%, 30% and 40% by keeping fly ash as 20% and all other ingredients were constant. It is observed that the optimum content of copper slag that can be used as replacement material is 40%.*

Key words:- *Copper slag, Fly ash, Mechanical properties, Rebound hammer test.*

1. Introduction

The utilization of industrial waste or secondary materials has encouraged the production of cement and concrete in construction field. New by-products and waste materials are being generated by various industries.Dumping or disposal of waste materials causes environmental and health problems. Therefore, recycling of waste materials is a great potential in concrete industry. For many years, by-products such as fly ash, silica fume and slag were considered as waste materials.Concrete preparedwith such materials showed improvement in workability and durability compared concrete and has been used in the construction of power, chemical plants and under-water structures.Over recent decades, intensive research studies have been carried out to explore all possible reuse method.

Construction waste, blast furnace, steel slag, coal fly ash and bottom ash have been accepted in manyplacesasalternativeaggregatesinembankment, roads,pavements,foundationandbuildingconstruction.Copper slag is an industrial by-product material produced from the process of manufacturing copper. For every ton of copper production, about 2.2 tonnes of copper slag is generated. It has been estimated that approximately 24.6 million tons of slag are generated from the world copper industry. Although copper slag is widely used in the sandblasting industry and in the manufacturing of abrasive tools, the remainder is disposed of without any further reuse or reclamation. Copper slag possesses mechanical and chemical characteristics that qualify the material to be used in concrete as a partial replacement as a substitute for aggregates.

2. Material properties

Materials:

There are many types of concrete available, created by varying the proportions of the main ingredients below. In this way or by substitution for the cementitious and aggregate phases, the finished product can be tailored to its application with varying strength, density, or chemical and thermal resistance properties.

2.1 Cement:

In the present investigation, commercially available 53 Grade ordinary Portland cement was supplied by Zuari Cement with Specific Gravity of 3.15 was used for all concrete mixtures.

Table: 1 Cement properties

S.no	Physical tests	Result value
1	Specific gravity	3.15
2	Normal consistency	32%
3	Initial setting time	76min
4	Final setting time	350min

2.2 Copper slag:

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. Copper slag used in this work was bought from Sterilite industries (India) ltd, Tutucorin, Tamil Nadu, India.

2.3 Fly ash:

Any country's economic & industrial growth depends on the availability of power.In India also, coal is a major source of fuel for power generation. About 60% power is produced using coal as fuel. Indian coal is having low calorific value (3000-3500 K cal.) & very high ash content (30-45%) resulting in huge quantity of ash is generated in the coal based thermal power stations. During 2005-06 about 112 million tonn's of ash has been generated in 125 power stations with the present growth in power sector, it is expected that ash generation will reach to 175 million tonn;s per annum.Fly ash produced in modern power stations of India is of good quality as it contains low sulphur & very low un burnt carbon i.e. less loss on ignition.

Table: 2 Chemical compositions (%) of Fly ash and Copper slag

Compound	Content % wt	
	Fly ash	Copper slag
SiO_2	59	25.84
Al_2O_3	21	0.22
Fe_2O_3	3.7	68.29
CaO	6.9	0.15
MgO	1.4	--
SO_3	1	0.11
K_2O	0.9	0.23
LOI	4.62	6.59

2.4 Fine Aggregate

The sand obtained from Cheyyeru river near Nandhalur is used as fine aggregate in this study.The sand is free from clayey matter, silt and organic impurities.The sand is tested for specific gravity, in accordance with IS: 2386-1963 and it is 2.60,Specific gravity are determined found to be 2.65.The sand confirms to zone-II.

2.5 Coarse Aggregate:

In the present investigation locally available crushed granite stone aggregate of size 20mm passing and retained in 10mm IS sieve used and the various tests were carried out as per IS:383-1970 part II. The coarse aggregate used contains 50%

fraction between 20mm – 12.5mm and remaining 50% fraction in between 12.5mm -10mm.Specific gravity are determined found to be 2.70.

Table: 3 Coarse aggregate properties

S.no	Property	Result value
1	Fineness modulus	1.99
2	Specific gravity	2.70
3	Elongation Index	46.21%
4	Flakiness Index	10.38%

2.6 Water:

Ordinary potable water available locally, which is free from concentration of acid and organic substances as per IS: 456-2000, is used for all the studies and experimental investigations considered in this project.

3 Mix Design and Experimental Work:

3.1 **Mix design:**

An integral part of concrete mix proportioning is the preparation of trial mixes and effect adjustments to such trials to strike a balance between the requirements of placement, that is, workability and strength, concomitantly satisfying durability requirements. As per IS 10262:2009, the method is adopted for finding the proportion of M_{25} grade concrete and the arrived mix ratio was 1:0.2:2.218:3.687.

Table: 4 mix proportions

Water L/m^3	Cement Kg/m^3	Fly ash Kg/m^3	Sand Kg/m^3	Coarse aggregate Kg/m^3
138	345	69	765.32	1272.24
0.4	1	0.2	2.218	3.687

3.2 Experimental Work

3.2.1 Casting and Curing of Specimens:

IS standard cube sizes of 150 mm X 150mm X 150mm, cylinder size of 150 mm X 300 mm and beam of size 750 mm X 150mm X 150 mm were cast from each mixture to evaluate compressive strength, split tensile strength and flexural strength. Concrete was prepared us by hand mix.

3.2.2Workability:

Workability is a measure of the ease with which a fresh mix of concrete or mortar can be handled and placed. For various mixes the concrete were prepared. In the fresh concrete, the slump cone test and compaction factor test were carried out.

3.2.3 Slump cone and Compaction factor test:

The slump test result is a measure of the behavior of a compacted inverted cone of concrete under the action of gravity as per IS 1199. It measures the consistency or the wetness of concrete.

3.3 Strength tests:

3.3.1 Compressive strength test:

The size of the cube specimen is 150x 150 x 150 mm. Place the specimen centrally on the compression testing machine and load is applied continuously and surface perpendicular to the direction of tamping. The load is increased until the specimen fails and record the maximum load carried by each specimen during the test.
Compression test Compressive stress was calculated as follows:

$$\text{Compressive strength} = P / A \times 1000$$

Where, P = Load in KN

A = Area of cube surface = 150 x 150 mm^2

3.3.2 Split tensile strength test:

The diameter of specimen to the nearest 0.2 mm by averaging the diameters of the specimen lying in the plane of pre-marked lines measured near the ends and the middle of the specimen. The length of specimen also shall be taken be nearest 0.2 mm by averaging the two lengths measured in the plane containing pre marked lines. The size of the cylinder specimen is of 150 mm diameter and 300 mm length. Centre one of the strips along the centre of the lower platen. Place the specimen on the strip and align it so that the lines marked on the end of the specimen are vertical and centered over the strip. The second strip is placed length wise on the cylinder centered on the lines marked on the ends of the cylinder. Apply the load without shock and Record the maximum load applied to specimen.

Computation of the split tensile strength is as follows:

$$\text{Split tensile strength} = 2P / (3.142 \times dl) \times 1000$$

Where, P = Load in KN

d = Diameter of cylinder = 150 mm

l = Length of cylinder = 300 mm

3.3.3 Flexural strength:

Prepare the test specimen by filling the concrete into the mould in 3 layers of approximately equal thickness.Tamp each layer 35 times using the tamping bar as specified above.Tamping should be distributed uniformly over the entire cross section of the beam mould and throughout the depth of each layer.Clean the bearing surfaces of the supporting and loading rollers, and remove any loose sand or other material from the surfaces of the specimen where they are to make contact with the rollers.Circular rollers manufactured out of steel having cross section with diameter 38 mm will be used for providing support and loading points to the specimens.The length of the rollers shall be at least 10 mm more than the width of the test specimen.A total of four rollers shall be used, three out of which shall be capable of rotating along their own axes. The distance between the outer rollers (i.e. span) shall be 3d and the distance between the inner rollers shall be d.The inner rollers shall be equally spaced between the outer rollers, such that the entire system is systematic.The specimen stored in water shall be tested immediately on removal from water; whilst they are still wet.The test specimen shall be placed in the machine correctly centered with the longitudinal axis of the specimen at right angles to the rollers.For moulded specimens, the mould filling direction shall be normal to the direction of loading.

The Flexural Strength or modulus of rupture (f_b) is given by

$$f_b = pl/bd^2$$

(when **a** > 20.0cm for 15.0cm specimen or > 13.0cm for 10cm specimen)

or

$$f_b = 3pa/bd^2$$

(when **a** < 20.0cm but > 17.0 for 15.0cm specimen or < 13.3 cm but > 11.0cm for 10.0cm specimen.)

Where,

a = the distance between the line of fracture and the nearer support, measured on the center line of the tensile side of the specimen

b = width of specimen (cm),

d = failure point depth (cm),

l = supported length (cm),

p = max. Load (kg),

3.2.4 Rebound hammer test:

A Schmidt hammer, also known as a Swiss hammer or a rebound hammer, is a device to measure the elastic properties or strength of concrete or rock, mainly surface hardness and penetration resistance. The hammer measures the rebound of a spring-loaded mass impacting against the surface of the sample. By reference to the conversion chart, the rebound value can be used to determine the compressive strength.

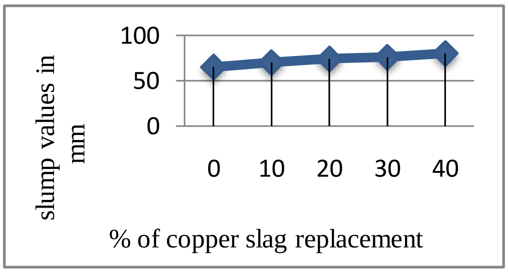
4. Results and Discussions:

Study on fresh concrete Based on the observations from the experimental work, the following results and discussions were presented in this chapter. For workability study, the slump and compacting factor test were conducted on fresh concrete for different proportions as mentioned in Table 5.

4.1 Slump value:

Table: 5 Slump values and compaction factor

S.no	Mix	Slump	Compaction factor
1	C0	65	0.9
2	C10	70	0.82
3	C20	74	0.83
4	C30	76	0.85
5	C40	80	0.86



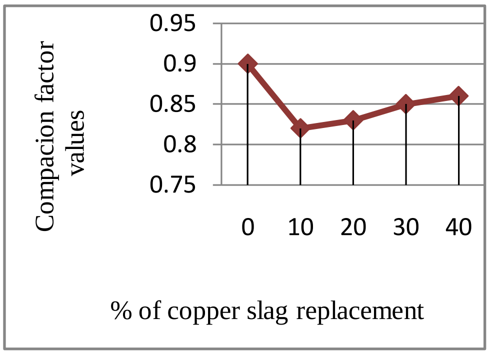


Fig1: Slump and compaction factor

characteristics of copper slag and its glassy surface compared with sand which caused surplus quantity of free water to remain after the absorption and hydration processes have completed. It should be noted that mixes with high contents of copper slag showed signs of bleeding and segregation which can have detrimental effects on concrete performance.

4.2 Compressive strength:

Table: 6 Compressive strength of the cube

S.no	% of F.A replacement	Compressive strength of the cube (N/mm^2)			
		7 days	28 days	60 days	90 days
1	0	18.93	23.10	27.83	29.50
2	10	20.18	24.93	29.96	31.56
3	20	21.13	25.83	31.10	34.60
4	30	24.68	27.90	35.56	34.90
5	40	27.83	29.38	35.80	40.46

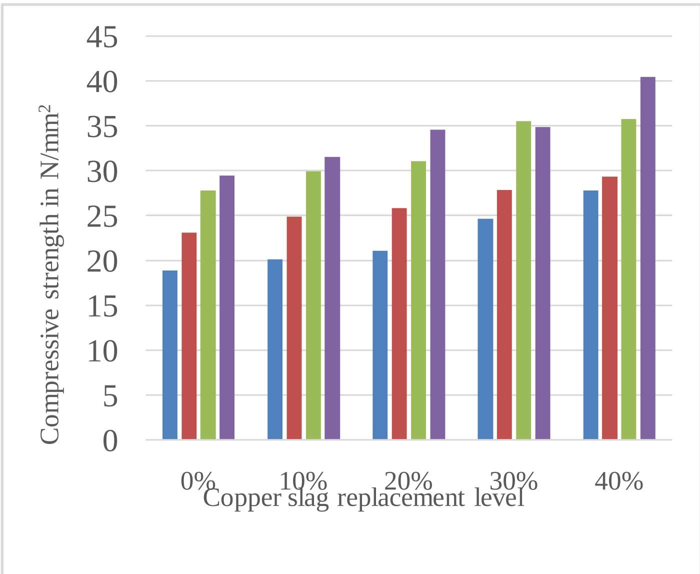


Fig2: Compressive strength of cube

From the figure it showed that the compressive strength of cube was found to be 29.50N/mm^2 at 90 days at 0% fine aggregate replacement and of 40.46 N/mm^2 at 40% fine aggregate replacement of 90 days.

4.3 Split tensile strength:

Table: 7 Split tensile strength of the cylinder

S.no	% of fine aggregate replacement with copper slag	Flexural strength (N/mm^2)
		28 days
1	0	4.78
2	10	5.33
3	20	6.11
4	30	6.81
5	40	9.83

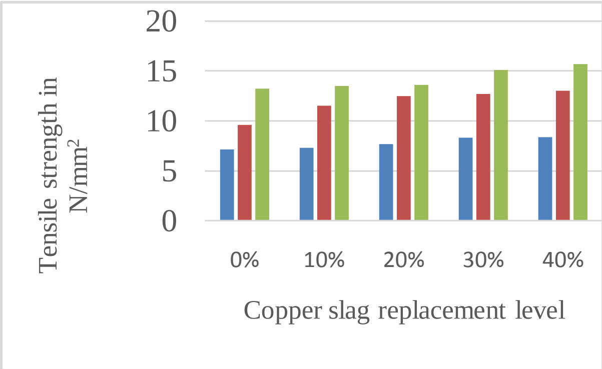


Fig 3: Split Tensile strength of cylinder

4.5 Flexural strength test:

Table: 9 Flexural strength test:

S.no	% of fine aggregate replacement	split tensile strength of the cylinder (N/mm^2)		
		7 days	28 days	60 days
1	0	7.19	9.60	13.28
2	10	7.35	11.55	13.52
3	20	7.72	12.51	13.66
4	30	8.32	12.71	15.13
5	40	8.40	13.05	15.70

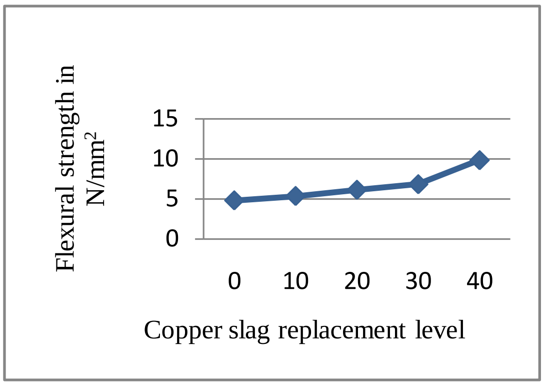


Fig 4: Flexural strength of beam

The maximum flexural strength of beam was found to be at 40% & 0% fine aggregate replacement of about 9.83 N/mm^2 at 28 days and 4.78 N/mm^2.The flexural strength of beam showed higher strength at 40% fine aggregate replacement. The flexural strength of all mixtures showed a similar behavior to the compressive strength results.

4.5 Compressive strength by Rebound hammer:

Table: 9 Compressive strength of the cube by rebound hammer

S.no	% of fine aggregate Replacement	Compressive strength by Rebound hammer test (N/mm^2)	
		7 days	28 days
1	0	18.00	23.00
2	10	20.00	24.00
3	20	21.00	25.00
4	30	24.00	27.00
5	40	27.00	29.00

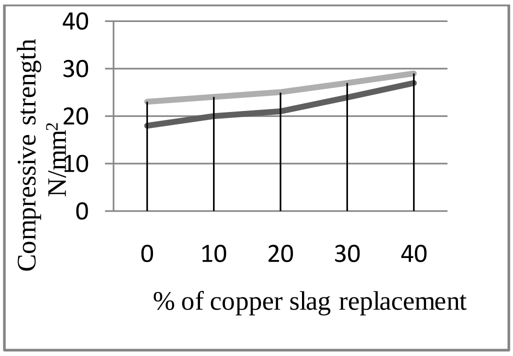


Fig 5: Compressive strength of cube by rebound hammer

Compressive strength of cube at 28 days was found to be 23.00 N/mm^2 at 0% Rebound hammer test for cube. Replacement of fine aggregate (0% and 40%) 7th day Compressive strength 18.00 N/mm^2 & 27.00 N/mm^2, 28th day Compressive strength 23.00 N/mm^2 & 29.00N/mm^2.The maximum compressive strength was found to be at 40% fine aggregate replacement of about 29.00 N/mm^2 at 7 days and of 23.00N/mm^2 at 28 days. The compressive strength of concrete at 7 and 28 days increased gradually up to 40% fine aggregate replacement and then increasedwithincreasein percentage of replacement.

4.6 weight of cube:

Table: 10 weight of the cube

S.no	% of fine aggregate Replacement	Weight of the cube (kg)				
		Before curing	7 days	28 days	60 days	90 days
1	0	8.250	8.650	8.800	8.850	8.900
2	10	8.400	8.700	8.850	8.900	9.000
3	20	8.500	8.850	8.900	8.950	9.000
4	30	8.550	8.800	8.850	8.800	8.950
5	40	8.600	8.850	8.900	8.950	9.000

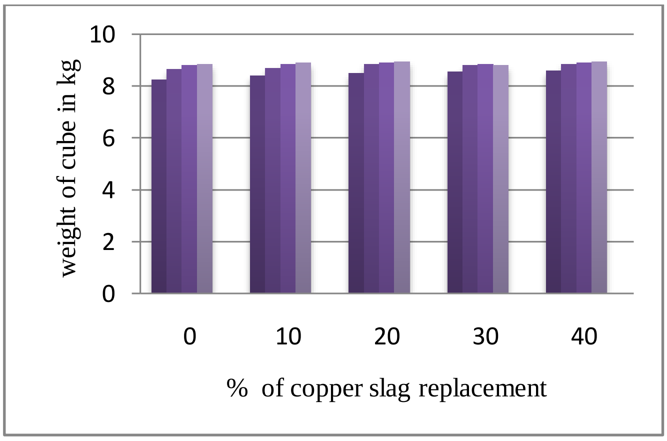


Fig 6: weight of the cube

The maximum weight was found to be at 40% & 0% fine aggregate replacement of about 8.900 kg at 28 days and 8.800 kg. The weight of cube showed higher strength at 40% fine aggregate replacement. The weight of cube of all mixtures showed a similar behavior to the compressive strength result.

5. CONCLUSION

Conclusion from the results and discussions, the following conclusions were made

- The replacement of fine aggregate using copper slag in concrete increases the density of concrete thereby increases the self weight of the concrete.
- The workability of concrete increased with the increase in copper slag content of fine aggregate replacements at same water-cement ratio.
- Form the results of compressive strength, split tensile strength and flexural strength, the concrete shown higher value at 40% replacement of fine aggregate using copper slag. So it is recommended that 40% of fine aggregate can be replaced by copper slag.

• The rebound hammer test revealed the uniformity of concrete and their compressive strength.

• The construction industry is the only area for safe use of waste materials, which reduces the environmental problems, space problems and cost of construction.

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