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Experimental Study of Copper Slag on Mechanical Properties of Concrete

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Abstract

This paper is about the experimental study of effect of copper slag as partial replacement of fine aggregate on mechanical properties of concrete. In this study, M30 grade concrete was considered to study the strength of concrete developed for the curing period of 7 and 28 days. Accordingly, tests were conducted for various proportions of sand replacement with copper slag of 0%, 25%, 50% and 75% in concrete. Concrete samples were produced, tested and compared in terms of compressive and split tensile strengths. From the results, it is concluded that the maximum strength is attained at 50% replacement of copper slag as fine aggregate.

Keywords: Copper slag, Waste material, compressive strength, split tensile strength.

INTRODUCTION

Worldwide the average consumption of sand for construction increases 40 billion tonnes annually as sand is used as a construction material. The large scale of extraction leads to cause impact in marine and biodiversity. So, there is an immediate attention to be taken in construction industry to find an alternative construction material. Copper slag is one of the materials that can be considered as a waste material which could have a promising future in construction industry as partial substitute of aggregates.

Figure 1. Copper slag

Copper slag is a by-product of copper extraction by smelting. During smelting, impurities become slag which floats on the molten metal. Slag that is quenched in water produces angular granules which are disposed of as waste.

Amount of waste (Copper Slag) generating

Copper slag is an industrial byproduct 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 tonnes of slag is generated from the world wide copper industry. Dumping of such huge quantitites of slag cause environmental and space problems.During the past two decades, attempts have been made by several investigators and copper producing units all over the world to explore the possible utilisation of copper slag.

Advantages of Copper Slag in concrete

① Cost of conc

rete production is reduced when copper slag is used as a fine aggregate in concrete.

② Copper Slag has similar properties as river sand as it contains silica (SiO2) similar to sand.

③ High toughness of copper slag contributes to increased compressive strength.

④ Due to low water absorption and due to glassy surface of copper slag the workability of concrete is increased.

⑤Use of copper slag has helped in waste management and dumping of industrial wastes.

⑥Copper slag is widely used in the sand blasting industry and it has been used in the manufacture of abrasive tools.

TESTS CONDUCTED

Tests on Cement:

Ordinary Portland cement of grade 53 is used for this experimental work. The following tests were conducted on cement and the results are tabulated below (as per IS 12269:1987)

S.NO.	TEST NAME	TEST RESULT
1.	Specific gravity	3.15
2.	Standard consistency	32%
3.	Initial setting time	45 min

Tests on Fine Aggregate:

Locally available river sand was used. The following tests conducted and the results are tabulated below (as per 383:1970)

S.NO.	TEST NAME	TEST RESULT
1.	Specific gravity	2.56
2.	Sieve analysis	Well graded sand
3.	Bulking of sand	4%

Tests on Coarse Aggregate:

Locally available coarse aggregate from quarry was used.The following tests conducted and the results are tabulated below (as per 383:1970)

S.NO.	TEST NAME	TEST RESULT
1.	Specific gravity	2.74

Tests on concrete:

The following workability tests were conducted on concrete and the results are tabulated below

S.NO.	TEST NAME	TEST RESULT
1.	Slump cone test	80 mm
2.	Compaction factor test	0.92
3.	Vee bee test	8 sec

MIX DESIGN (IS 10262:2009)

- Grade of concrete = M_{30}
- Type of cement = OPC 53 grade
- Maximum size of aggregate = 20mm
- Minimum cement content = 320kg/m^3
- Slump = 100mm
- Super plasticizer = SP-430

•Target strength for mix proportioning (f_{ck1}) = 38.25 N/mm^2

• Based on experience, adopting water-cement ratio as 0.40

Proportions: for 1m^3 of mix

- Cement = 350 kg/m^3
- Water = 140 lit
- Fine aggregate = 896 kg/m^3
- Coarse aggregate = 1140 kg/m^3
- Ratio = 350: 896:1140
- Mix proportion = **1: 2.56: 3.25**

METHODOLOGY

Compressive strength test

One of the most important properties of concrete is the measurement of its ability to withstand compressive loads.This is referred to as a compressive strength and is expressed as load per unit area. In order to determine compressive strength of concrete cubes were casted and are placed correctly to the machine plate and the load will be applied to the specimen axially.Now slowly apply the load at the specified rate per minute till the cube collapse.The maximum load at which the specimen breaks is taken as the compressive load.Compressive strength of concrete at 7 and 28 days were determined by taking average of 3 samples respectively.

Figure 4.1 Compression testing machine

$$f_c = \frac{P}{A}$$

Where,

f_c = Compressive Strength of Concrete,

P = Maximum load applied (KN)

A = Cross-sectional area of the sample (in mm^2)

Split tensile strength test

In order to determine split tensile strength of the concrete cylinders were prepared. The cylindrical specimen is placed in a manner that the longitudinal axis is perpendicular to the load. Now slowly apply the load at the specified rate per minute till the cylinder collapse.The maximum load at which the specimen breaks is taken as the split tensile load. Split tensile strength of concrete at 7 and 28 days were determined by taking average of 3 samples respectively.

Figure 4.2 Split tensile testing machine

$$\text{Split tensile strength} = \frac{2P}{\pi l d}$$

Where,

P = Split tensile load (in KN)

l = length of thespecimen (in mm)

d = diameter of the specimen (in mm)

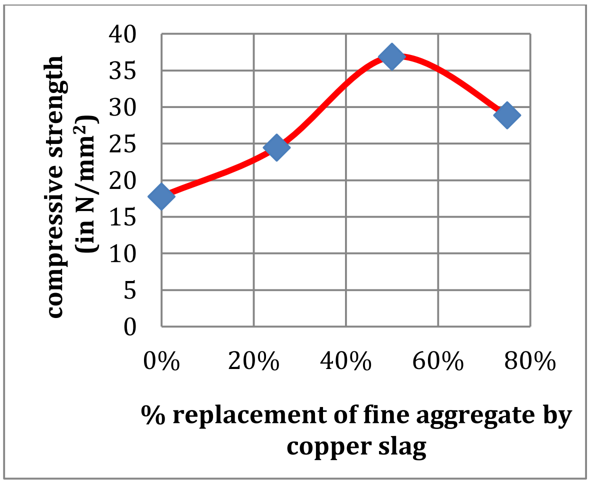
RESULTS AND DISCUSSION

Compressive strength

The following compressive strength results were obtained after curing cubes for 7 and 28 days for different proportions of copper slag as given below.

Curing period	Compressive strength of cube (in N/mm^2)			
	0%	25%	50%	75%
7 days	17.77	24.44	36.88	28.88
28 days	38.5	42.2	54.22	46.66

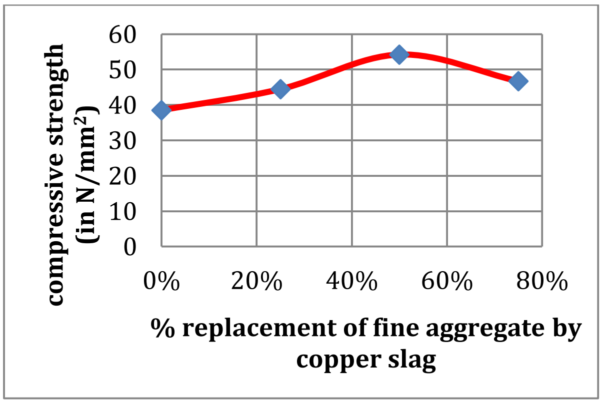
Graph for compressive strength of cube at 7th day :-



Graph 5.1.1 Compressive strength of the cube after 7 days

From the above graph, maximum compressive strength of the cube after 7 days curing is achieved at 50% replacement of copper slag and the value is 36.88 N/mm^2

Graph for compressive strength of cube at 28th day :-



Graph 5.1.2 Compressive strength of the cube after 28days

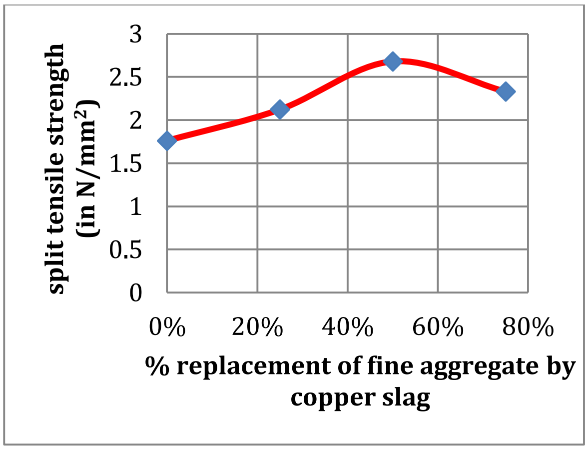
From the above graph, maximum compressive strength of the cube after 28 days curing is achieved at 50% replacement of copper slag and the value is 54.22 N/mm^2

Split tensile strength

The following split tensile strength results were obtained after curing cubes for 7 and 28 days for different proportions of copper slag as given below.

Curing period	Split tensile strength of cylinder (in N/mm^2)			
	0%	25%	50%	75%
7 days	1.76	2.12	2.68	2.33
28 days	2.19	2.75	3.96	2.68

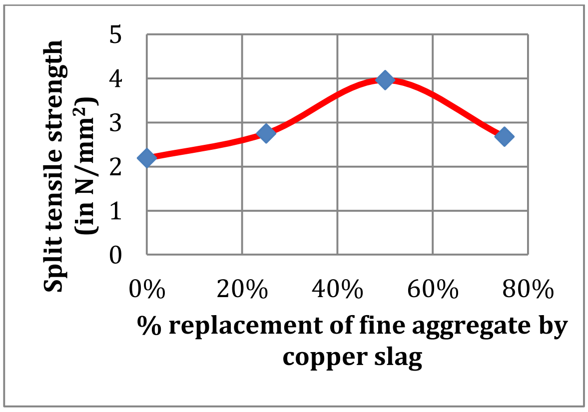
Graph for split tensile strength of cylinder at 7th day :-



Graph 5.2.1 Split tensile strength of cylinder after 7 days

From the above graph, maximum split tensile strength of the cylinder after 7 days curing is achieved at 50% replacement of copper slag and the value is 2.68 N/mm^2

Graph for split tensile strength of cylinder at 28th day :-



Graph 5.2.2 Split tensile strength of cylinder after 28 days

From the above graph, maximum split tensile strength of the cylinder after 28 days curing is achieved at 50% replacement of copper slag and the value is 3.96 N/mm^2

CONCLUSIONS

The following conclusions were drawn from this study

1. As the percentage of copper slag increasesworkability increases.
2. As the percentage replacement of copper slag increases the compressive strength of concrete increases gradually up to 50% and then decreases.
3. As the percentage replacement of copper slag increases the split tensile strength of concrete increases gradually up to 50% and then decreases.
4. Compressive strength and split tensile strength are increased due to high toughness of copper slag.
5. Replacement of copper slag in fine aggregatereduces the cost of making concrete.
6. By using copper slag as fine aggregate we can make environment more sustainable.
7. Thus alternative construction material is identified.

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