Journal of Chemical and Pharmaceutical Sciences ISSN: 0974-2115

Experimental Study on Strength Properties of High performance Concrete Using Copper Slag as a Partial Replacement of Fine Aggregate

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ABSTRACT

This paper presents an experimental investigation of the effects of copper slag on the strength properties of concrete as a partial replacement for fine aggregate. Copper slag is a byproduct of copper production produced mainly through pyrometurllurgical processes. RR chawan et al reported that 2.5 tons of copper slag is produced for each ton of copper in the production process. This copper slag is disposed of as a waste material into the environment. The potential use of this slag as a replacement of fine aggregate in concrete solves the environmental problem of pollution due to dumping, in addition to increasing the strength properties of concrete. M45 grade of concrete is used for the work and studies were conducted for different proportions of copper slag replaced with sand from 0%, 30%, 40% and 50%. A comparative study of the results obtained with copper slag and those with the control samples made of normal concrete was done.

Keywords: Copper slag, fine aggregate, partial replacement, compressive strength, flexural strength.

INTRODUCTION

In India, the increasing demand and cost of construction materials for infrastructure development, in addition to the environmental issues in their disposal has made researchers to focus on the use of innovative and ecofriendly materials for construction. Copper slag is one such material which is a byproduct of copper production, disposed of as a waste. It is chemically stable and its physical properties are similar to that of natural sand. Due to fast depletion and increase in cost of natural sand, copper slag can be a potential alternative material for fine aggregates as a partial or full substitute in concrete. Alnuaimi AS et al in 2012 reported that In Oman approximately 60,000 tons of copper slag is produced every year. RR chawan et al in 1998 studied the use of copper slag in increasing the strength properties of concrete as a partial replacement of fine aggregate. It is a byproduct obtained during the matte smelting and refining of copper. Copper slag used for this study is obtained from sterile industries limited located in tuticorin, Tamil Nadu. The industry produces 294kt of copper cathodes per year in turn generating a huge amount of copper slag as its by product. The advantage of using copper slag as a partial replacement of fine aggregate is twofold. One it solves the environmental problem of dumping it as a waste in landfills and on the other hand increases the strength properties concrete in an economical way as copper slag is cost effective.

MATERIALS AND METHODS

Materials used: Ordinary Portland cement of grade 53 is used for this experimental work. The fine aggregates used is river sand and copper slag from Sterilite Industries, Tamil Nadu.The coarse aggregate is crushed aggregate angular size of 20mm and 10mm. The basic material testing was done as per code IS: 383-1970.

Copper slag: Copper slag is a by-product material produced from the process of manufacturing of copper. The manufactured copper which has higher density settles down in the smelter, leaving impurities in the top layer which is transported to the water basin for solidification at lower temperature. The solidified product is a hard material which goes to the crusher and is called the copper slag. This by product becomes a scrap from the industry.

Figure.1.Copper slag, Sand, Coarse aggregate and fine aggregates

Journal of Chemical and Pharmaceutical Sciences ISSN: 0974-2115

Table.1.Physical properties of fine and coarse aggregates

Parameter	Natural sand	Copper slag	Coarse aggregate	
			10mm	20mm
Specific gravity	2.66	3.55	2.71	2.78
Fineness modulus	2.67	3.23	7.10	7.30
Water absorption (%)	1	0.75	0.5	0.7
Grading	Zone II	Zone I	-	-

Sieve analysis: The Experimental work was started with a sieve analysis with IS specified sieves. The details of sieve analysis shown in table 2

Figure.2.Sieve Analysis

Table.2.Sieve analysis of fine and coarse aggregate and copper slag

IS Sieve	Coarse Aggregate		Fine Aggregate	Copper Slag
	Cumulative percentage retained		Cumulative percentage retained	Cumulative percentage retained
	10mm	20mm		
10	14.90	96.07	0	0
4.75	92.555	99.17	3.5	4.75
2.36	99.360	100	9.2	10.3
1.18	100	100	26.2	30.1
600	100	100	55.7	50.65
300	100	100	83.9	90.05
150	100	100	98.5	98.15

Mix Design: The grade of concrete used in the present study is M45 grade and water cement ratio of 0.42 . Mix design of the concrete is carried as per the specific code IS 10262 – 2009.

Table.3.Mix proportion for M 45 grade

Content	Water (liters)	Cement (Kg)	Sand (Kg)	Coarse aggregate(Kg)	
				20mm	10mm
Meter cube content	186	453.65	186	648.18	421.24
Ingredient ratio	0.42	1	1.6	2.3	

Sample preparation: Concrete with different proportions of copper slag as a partial replacement of fine aggregate was prepared for investigating its effects in strength properties. The proportions of copper slag by weight of sand added to the concrete mixture is 0% (control mix), 30%,40% and 50%. The target strength of control mix was 45N/mm2 by 28 days (M45 grade) with a water cement ratio of 0.42

Workability: Slump test was conducted to determine the workability of concrete. The test results indicated that with increase in percentage of copper slag there is an increase in workability of concrete.

Journal of Chemical and Pharmaceutical Sciences ISSN: 0974-2115

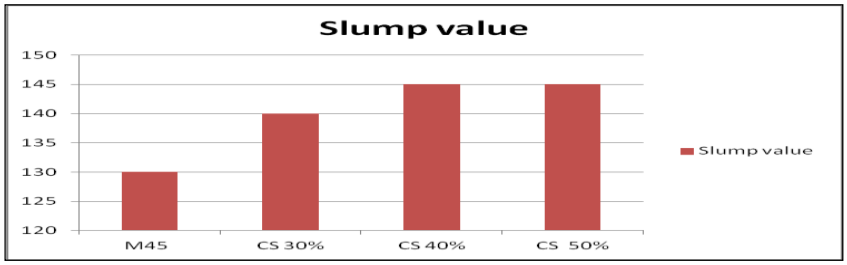

Figure.3.Slump value for different mix proportions

Testing procedure: The concrete cubes and beams of various proportions of copper slag were casted and cured in the laboratory to evaluate the properties of hardened concrete such as compressive strength and flexural strength.

Compressive strength test: The compressive strength of concrete with various proportions of copper slag was tested in accordance with IS 516 "Methods of test for strength of concrete" in compression testing machine on a cube of 150×150×150mm. The compressive strength of concrete was tested for 3, 7 and 28 days.

Flexural strength test: The flexural strength of concrete was tested for various proportions of copper slag in concrete were tested in flexural testing machine on a beam of 500×100×100mm. The flexural strength was tested for 3, 7, and 28 days.

Figure.4.Compression test on concrete cube

Figure.5.Flexural test on concrete beam

RESULTS AND DISCUSSION

Compressive strength: A target compressive strength was used for the investigation as indicated earlier. The table 4 shows the average compressive strength of the control mix and concrete mix with 30%, 40% and 50% copper slag.

Table.4.Compressive strength test results

Mix	Compressive strength of concrete cube (N/mm^2)			
	3 Days	7 Days	14 Days	28 Days
Normal M45	37.11	41.22	43.25	50
CS 30%	38.66	42.88	44.44	50.54
CS 40%	39.55	43.33	45.6	56.3
CS 50%	37.11	40	43.3	45.13

From the test results it can be seen that, the compressive strength of concrete with 30%, 40% copper slag is clearly high than control mix. But decreases with 50 % replacement. Though the target strength of the control mix is obtained, the objective of increased strength is not fulfilled.

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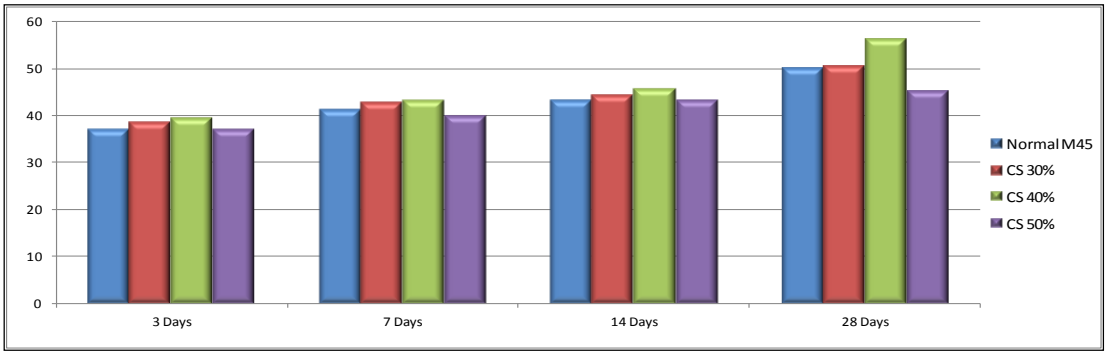

Figure.6.Compressive strength variation of different mix proportions

Flexural strength: Table 5 shows the flexural strength of control mix and concrete mix with 30%, 40% and 50% copper slag.

Table.5.Flexural strength test results

Mix	Flexural strength of concrete (Mpa)		
	3 Days	14 Days	28 Days
Normal M45	3.75	4	5.8
CS 30%	3.9	4.56	6.12
CS 40%	3.93	4.62	6.11
CS 50%	3.89	4.98	6.58

From the test results it is seen that there is an increase in flexural strength of the all the specimens.

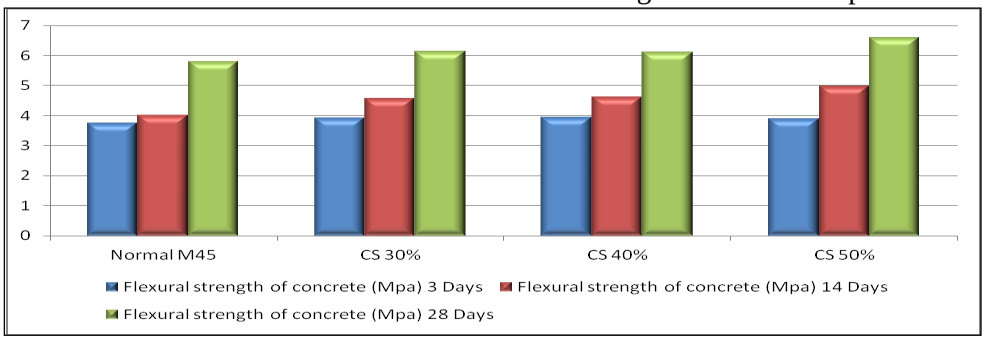

Figure.7.Flexural strength variation different mix proportions

CONCLUSIONS

Based on the investigations the following can be concluded.

1. The workability of concrete increases with increase in replacement of copper slag.

2. The 28 days compressive strength of concrete mix increases up to 40% of replacement of copper slag and decreases for

50 % replacement of copper slag with fine aggregate.

3. The flexural strength is more for all the proportions of concrete mix and this may be due to toughness of copper slag.

4. The optimum amount of replacement of copper slag for fine aggregate in high performance concrete is 30- 40%.

5. Copper slag is readily available from copper industries and is economical to be used as a replacement for fine aggregate when compared to certain other materials.

6. Copper slag which goes as a scrap from copper industry can be used in an effective to improve strength properties of concrete and it also reduces the cost dumping it in landfills.

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