USE OF COPPER SLAG AS FINE AGGREGATE - A CASE STUDY

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ABSTRACT

Many countries are witnessing a rapid growth in the construction industry which involves the use of natural resources for the development of the infrastructure. In order to reduce dependence on natural aggregates as the main source of aggregate in concrete, artificially manufactured aggregates and artificial aggregates generated from industrial wastes provide an alternative for the construction industry. The present study encouraged the utilization of industrial waste copper slag as replacement of natural aggregates in concrete. The results indicate that the use of copper slag in concrete increases the flexural strength of about 17% with that of control mixture. It is recommended that up to 40% of copper slag can be use as replacement of fine aggregates.

KEYWORDS: Cement, Compressive strength, Copper slag**,** Flexural strength, Workability

INTRODUCTION

Many countries are witnessing a rapid growth in the construction industry which involves the use of natural resources for the development of the infrastructure. This growth is jeopardized by the lack of natural resources that are available. The sustainable development for construction involves the use of non-conventional and innovative materials, and recycling of waste materials in order to compensate the lack of natural resources and to find alternative ways for conserving the environment. Aggregates are considered one of the main constituents of concrete since they occupy more than 70% of the concrete matrix. Therefore, utilization of aggregates from industrial wastes can be alternative to the natural and artificial aggregates. In the last few decades there has been rapid increase in the waste materials and by-products production due to the exponential growth rate of population, development of industry and technology and the growth of consumerism. The basic strategies to decrease solid waste disposal problems have been focused at the reduction of waste production and recovery of usable materials from waste as raw materials as well as utilization of waste as raw materials whenever possible. The beneficial use of byproducts in concrete technology has been well known for many years and significant research has been published with regard to the use of materials such as coal fly ash, pulverized fuel ash, blast furnace slag and silica fume as partial replacements for Portland cement. Such materials are widely used in the construction of industrial and chemical plants because of their

ISSN: 2394-3696
VOLUME 2, ISSUE 5, MAY-2015

enhanced durability compared with Portland cement. The other main advantage of using such materials is to reduce the cost of construction. (Al-Jabri et al 2009).Copper slag (CS) 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 (Shi et al 2008). It is a by-product obtained during the smelting and refining of copper. Therefore, numerous contemporary researches have focused on the application of copper slag in cement and concrete production as a suitable path towards sustainable development. Several researchers have investigated the possible use of copper slag as cement, fine and coarse aggregates in concrete and its effects on the different mechanical and long term properties of mortar and concrete. (Khanzadi and Behnood 2009., Najimi and Pourkhorshidi 2011). The use of copper slag in cement and concrete provides potential environmental as well as economic benefits for all related industries, particularly in areas where a considerable amount of copper slag is produced. The addition of copper slag as fine aggregate in various bituminous mixes improves interlocking and eventually improves the volumetric properties as well as the mechanical properties of the mixes (Pundhir et al 2005).

MATERIAL AND METHODS USED

In the present study, ordinary Portland Cement (OPC) of 43 grade type cement and a copper slag obtained from Synco Industries Limited located at Jodhpur (Rajasthan) was used in concrete mixtures. Properties of the OPC cement were given in Table 1. The physical and chemical properties of copper slag are given in Table 2 & 3 respectively. The sand was conforming to grading zone II as per IS 383- 1970. The sieve analysis of fine aggregates and coarse aggregates are given in Table 4 & 5respectively. Water used in the concrete mixture was drinkable water confirming to IS 456-2000.

Table 1: Properties of OPC 43 Grade Cement

Sr. No	Characteristics	Value Obtained experimentally	Values specified by IS: 8112-1989
1.	Specific Gravity	3.17	-
2.	Standard consistency	31%	-
3.	Initial Setting time	152 minutes	30 minutes (minimum)
4.	Final Setting time	260 minutes	600 minutes (maximum)
5.	Compressive Strength 3 days 7 days 28 days	 26.60 N/mm^2 34.97 N/mm^2 47.65 N/mm^2	 23 N/mm^2 33 N/mm^2 43 N/mm^2

ISSN: 2394-3696
VOLUME 2, ISSUE 5, MAY-2015

Table 2: Physical properties of copper slag (Source: Synco Industries Limited, Jodhpur)

S.No	Physical properties	Copper slag
1.	Particle shape	Irregular
2.	Appearance	Black & glassy
3.	Type	Air cooled
4.	Specific gravity	3.51
5.	Bulk density (g/cm^3)	1.9 - 2.4
6.	Hardness	6 - 7mohs

Table 3: Chemical properties of copper slag (Source: Synco Industries Limited, Jodhpur)

S.No	Chemical component	% of Chemical component
1.	SiO_2	28%
2.	Fe_2O_3	57.5%
3.	Al_2O_3	4%
4.	CaO	2.5%
5.	MgO	1.2%

Table 4: Sieve analysis of fine aggregates

IS- Sieve Designation	Weight Retained on sieve (g)	%age Weight retained on sieve	Cumulative %age weight retained on sieve	%age passing	%age passing for grading zone-II as per IS: 383-1970
10 mm	Nil	Nil	Nil	100	100
4.75 mm	45	9	9	91	90-100
2.36 mm	26	5.2	14.2	85.8	75-100
1.18 mm	70	14	28.2	71.8	55-90
600 micron	102	20.4	48.6	51.4	35-55
300 micron	124	24.8	73.4	26.6	8-30
150 micron	121	24.2	97.6	2.4	0-10

Table 5: Sieve analysis of proportioned of coarse aggregates

IS- Sieve Designation	50:50 Proportion (10 mm: 20mm) Weight Retained	Cumulative weight retained (g)	Cumulative %age weight retained	% age passing	IS: 383-1970 Requirement
80 mm	Nil	Nil	Nil	100	100
40 mm	Nil	Nil	Nil	100	100
20 mm	4.5	4.5	0.225	99.775	95-100
10 mm	1286	1290.5	64.525	35.475	26-55
4.75 mm	640.5	1931	96.55	3.45	0-10

Concrete mixes and mix proportions

In this experimental program, to determine the values of compressive and flexural strength, a control mix without copper slag was prepared. The 5 mixes were prepared other than control mix at different replacement levels of CS (0%, 20%, 40%, 60%, 80% & 100%). Fine aggregate was replaced with copper slag. The water/cement (w/c) ratio in all the mixes was kept 0.43. The specimens were tested after 7, and 28 days of curing. The ratio of different materials used in each mix and mix designation are shown in Table 6.

Table 6: Mix proportions of different concrete mixes

Mix	W/C Ratio	CS %	CS (Kg/m^3)	Fine Aggregates (Kg/m^3)	Coarse Aggregates (Kg/m^3)	Water (L/m^3)	Cement (Kg/m^3)
C1	0.43	0%	0	548.55	1167.70	186	432.56
C2	0.43	20%	109.71	438.84	1167.70	186	410.93
C3	0.43	40%	219.42	329.13	1167.70	186	389.3
C4	0.43	65%	329.13	219.42	1167.70	186	367.67
C5	0.43	80%	438.84	109.71	1167.70	186	346.04
C6	0.43	100%	548.55	0	1167.70	186	410.93

Preparation and casting of test specimens

For determining the flexural strength of concrete, moulds of size 700 mm x 150mm x 150mm were used. All the specimens were prepared in accordance with Indian Standard Specifications IS 516-1959. After casting, test specimens were removed from the moulds after 24 hours of casting and were placed in the water tank. Specimen was taken out from the curing tank for testing after 7 and 28 days of curing.

Flexural Strength of Concrete

Flexural strength of concrete was done as per IS: 516-1959 using beam size (15cm x 15cm x 70cm). Flexural strength of concrete was determined using three point loading system. The flexural strength of beams was found after 7 and 28 days of curing. The bearing surfaces of the supporting and loading rollers are wiped clean before loading. The beams are placed in the machine in such a manner that the load is applied to the uppermost surface along the two lines spaced 13.3 cm apart. The axis of the specimen is aligned with the axis of the loading device. The load is applied at a rate of 180 kg/min without shock. The specimen is loaded till it fails and the maximum load (P) applied to the specimen during test is noted. After fracture the distance (a) between the crack and nearest support is measured.

RESULTS AND CONCLUSIONS

Flexural strength of concrete

The flexural strength of all the mixes was determined at the ages of 7 and 28 days for the various replacement levels of copper slag with fine aggregates. The values of average flexural strength for different replacement levels of copper slag (0%, 20%, 40%, 60%, 80% and 100%) at the end of different curing periods (7 days & 28 days) are given in Table 7. These values are plotted in Figure 1 & Figure 2 shows the variation of 7 and 28 days' flexural strength due to different percentages of copper slag respectively.

Table 7: Test results for flexural strength of concrete

Mix	Flexural Strength in N/mm^2	
	7 Days	28 Days
C0 (Copper Slag 0%)	4.67	5.70
C20 (Copper Slag 20%)	5.03	6.18
C40 (Copper Slag 40%)	5.38	6.67
C60 (Copper Slag 60%)	4.97	6.01
C80 (Copper Slag 80%)	4.41	5.45
C100 (Copper Slag 100%)	4.13	5.07

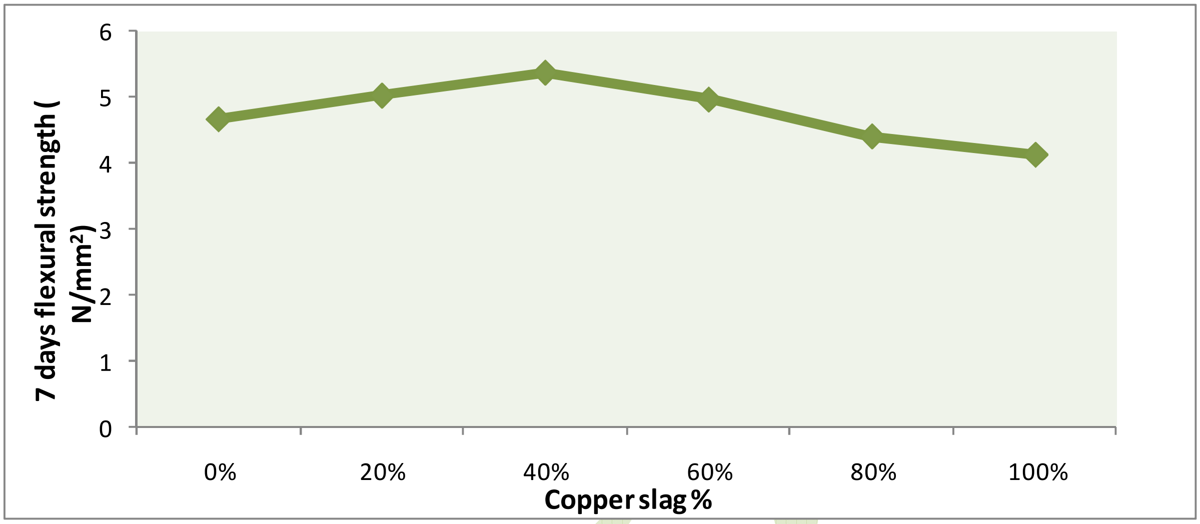

Figure 1: 7 day's flexural strength of concrete with different replacement levels of fine aggregates with copper slag

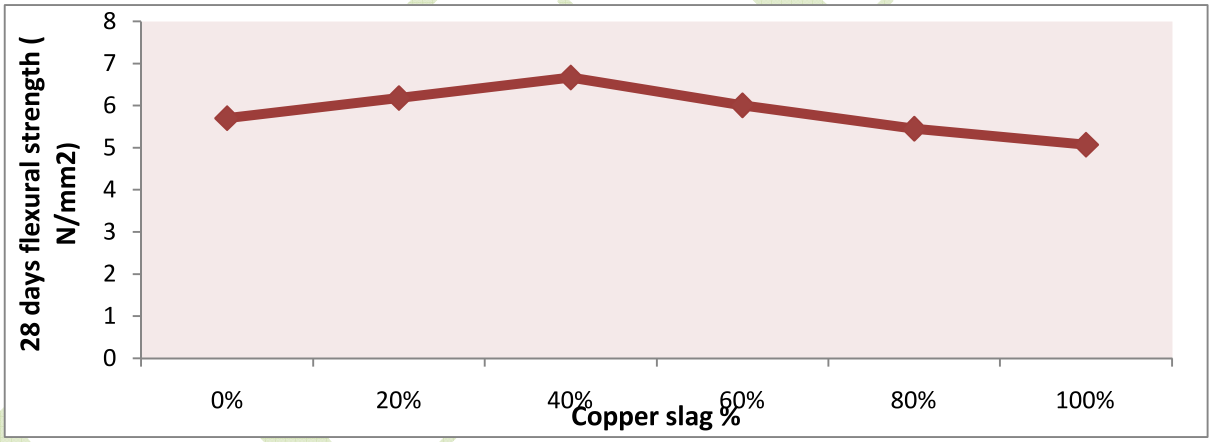

Figure 2: 28 day's flexural strength of concrete with different replacement levels of fine aggregates with copper slag

The results show that the flexural strength is increased as copper slag quantity increases up to 40% addition. Beyond that the flexural strength value reduces, but up to 60% still more than control mix. The results showed that the use of copper slag in concrete increases the flexural strength of about 17% with that of control mixture.

CONCLUSIONS

The results showed that the use of copper slag in concrete increases the flexural strength of about 17% with that of control mixture. It is recommended that up to 40% of copper slag can be use as replacement of fine aggregates.

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