INFLUENCE OF COPPER SLAG AS FINE AGGREGATE ON THE WORKABILITY AND COMPRESSIVE STRENGTH OF CONCRETE

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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 workability of concrete increases significantly with the increase of copper slag content in concrete mixes. The use of copper slag in concrete increases the compressive strength of more than 30% as compared to control mixture. It is recommended that up to 40% of copper slag can be use as replacement of fine aggregates.*

Keywords: *Cement, Copper slag, Compressive Strength, Workability*

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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 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

Materials 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

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 strength of 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 Compressive strength of concrete, moulds of size 150mm 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.

Workability of Concrete

Workability is that property of freshly mixed concrete or mortar which determines the ease and homogeneity with which it can be mixed, placed, consolidated, and finished. Workability is not just based on the properties of the concrete, but also on the nature of the application. The strength and durability of hardened concrete, in addition to labour costs, depend on concrete having appropriate workability. Workability test methods have been classified in terms of the type of flow produced during the test. Compaction factor test was used for finding workability of freshly prepared concrete in laboratory in this research.

Compressive Strength of Concrete

The quantities of cement, coarse aggregates (20 mm and 10 mm), fine aggregates, copper slag and water for each batch i.e. for different percentage of copper slag were weighed separately. The cement, copper slag and fine aggregates were mixed in dry form. The coarse aggregates were mixed to get uniform distribution throughout the batch. Water was added to the mix and then mixed thoroughly for 3 to 4 minutes in mechanical mixer. Cube moulds were cleaned and oil was applied on its inner surface. The mould was filled 1/ 3 with the concrete and manual compaction was done with 25 strokes of tamping rod. Again the process was repeated 2 more times for completely filling the mould. The surface of the concrete was finished level with the top of the mould. The finished specimens were left to harden in air for 24 hours. The specimens were removed from the moulds after 24 hours of casting and were placed in the water tank filled with potable water in the laboratory. Specimens were taken out from the curing tank at the ages of 7 and 28 days. Surface water was wiped off and specimens were immediately tested on removal from the curing tank. The compressive strength of concrete cubes was found on Compression Testing Machine (CTM) by applying load gradually without shock till the failure of the specimen occurs.

RESULTS AND CONCLUSIONS

Workability of Concrete

Workability of concrete was tested using compacting factor test apparatus immediately after preparing fresh concrete. The value of compacting factor for each mix is given in Table 7. The compacting factor of concrete with different replacement levels of fine aggregate with copper shown in Figure 1. The compacting factor of each mix is given in Table 7.

Table 7: Workability of concrete

Mix Designation	Weight of Partially Compacted Concrete (W_p) (kg)	Weight of Fully Compacted Concrete, (W_f) (kg)	Compacting Factor (W_p/W_f)	Degree of Work ability
C1	7.330	8.842	0.829	High
C2	7.840	9.278	0.845	High
C3	7.730	9.083	0.851	High
C4	7.780	9.015	0.863	High
C5	7.910	9.041	0.875	High
C6	7.660	8.530	0.898	High

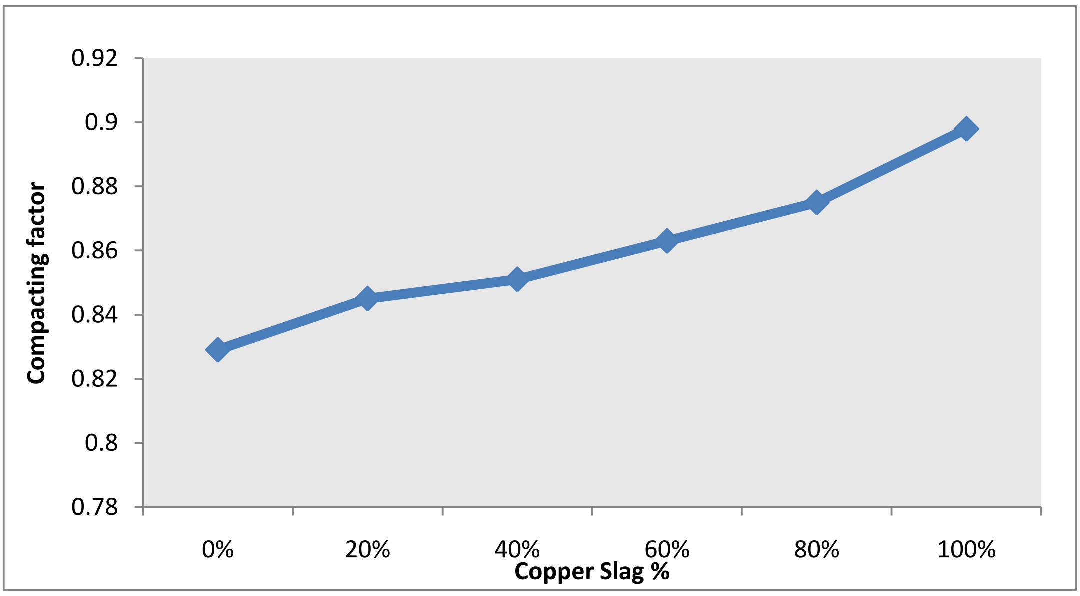

Figure 1: Compacting factor of concrete with different replacement levels of fine aggregates with copper slag

From Figure 1, it is clear that the workability of concrete increases significantly with the increase of copper slag content in concrete mixes. For the control mixture (i.e. Mix C1), the compacting factor was .829 whereas for Mix C6, with 100% replacement of copper slag, the compacting factor was .898. This considerable increase in the workability with the increase of copper slag quantity is attributed to the low water absorption characteristics of copper slag and its glassy surface compared with fine aggregates. The glassy surface of copper slag increases the free water content in the mix hence increases the workability of concrete.

Compressive strength of concrete

The compressive 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 compressive 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 8. These values are plotted in Figure 2 & Figure 3.

Table 8: Test results for compressive strength of concrete

Mix	Compressive Strength in N/mm^2	
	7 Days	**28 Days**
C0 (Copper Slag 0%)	21.54	32.31
C20 (Copper Slag 20%)	25.5	38.25
C40 (Copper Slag 40%)	28.76	43.15
C60 (Copper Slag 60%)	24.61	36.91
C80 (Copper Slag 80%)	19.41	29.12
C100 (Copper Slag 100%)	16.78	25.18

From Figure 2 and Figure 3 it can be observed that the compressive strength of concrete is increased as copper slag content increases up to 40%, beyond that compressive strength was significant decreases due to increases free water content in the mixes. The excessive free water content in the mixes with copper slag content causes the bleeding and segregation in concrete. Therefore, it leads reduction in the concrete strength. The highest compressive strength was achieved with 40% replacement of copper slag, which was found about 43.15N/mm^2. This indicates that there is an increase of compressive strength of more than 30% compared to the control mix. In 100% replacement of fine aggregates with copper slag shows the compressive strength of 25.18N/mm^2. It is recommended that up to 40% of copper slag can be use as replacement of fine aggregates.

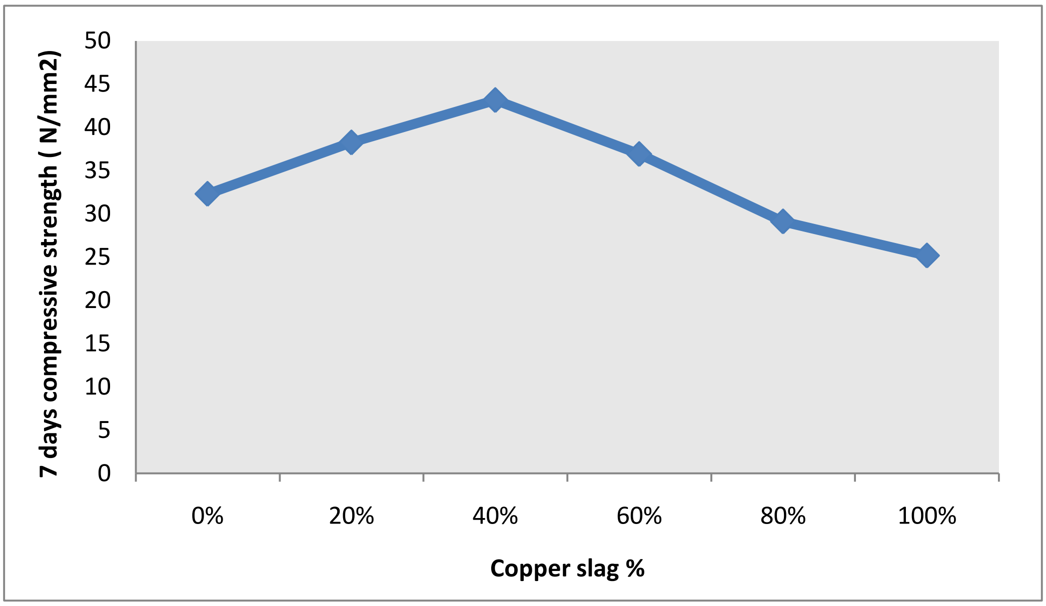

Figure 2: 7 day's compressive strength of concrete with different replacement levels of fine aggregates with copper slag

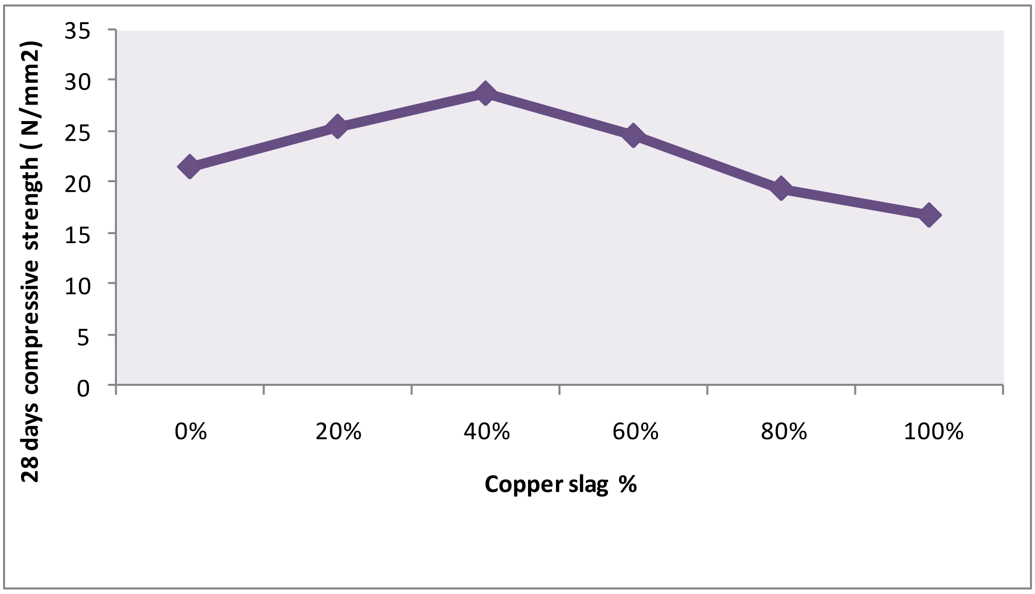

Figure 3: 28 day's compressive strength of concrete with different replacement levels of fine aggregates with copper slag

CONCLUSIONS

1. The workability of concrete increases significantly with the increase of copper slag content in concrete mixes. The glassy surface of copper slag increases the free water content in the mix hence increases the workability of concrete.

2. The compressive strength of concrete is increased as copper slag content increases up to 40%, beyond that compressive strength was significant decreases due to increases free water content in the mixes.This indicates that there is an increase of compressive strength of more than 30% compared to the control mix. It is recommended that up to 40% of copper slag can be use as replacement of fine aggregates.

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