EFFECT OF COPPER SLAG AS A SAND REPLACEMENT ON THE PROPERTIES OF CONCRETE

Momin Aaquib[1], Jha Nilesh[2], Tanveer Ahmed[3], Bhavsar R.S.[4]

[1,2,3]*Dept. of Civil Engg., Brahma Valley College of Engg, Anjaneri Nashik, (India)*

[4]*Asst. Professor Brahma Valley College of Engg, Anjaneri Nashik, (India)*

ABSTRACT

In this project, a study was made to obtain low cost building materials using industrial wastes (welding and furnace slag). The objective of the study is to use these wastes in low-cost construction with adequate compressive strength. Sustainability and resource efficiency are becoming increasing important issues within today's construction industry. This study reports the potential use of granulated copper slag from Sterile Industries as a replacement for sand in concrete mixes. The effect of replacing fine aggregate by copper slag on the compressive strength and Flexural strength are attempted in this work. The percentage replacement of sand by granulated copper slag were 0%, 10%, 20%, 30%, 40%, 50% and 60%. The compressive strength was observed to increase by about 35-40% and Flexural strength by 30-35%. The experimental investigation showed that percentage replacement of sand by copper slag shall be upto 40%.

Keywords: Copper slag, Physical & chemical properties, Compressive strength, Flexural strength, etc.

I. INTRODUCTION

Copper slag is a by-product obtained during the smelting and refining of copper. Production of one ton of copper generates, approximately 2.2–3 tons copper slag. World at present produces around approximately 46.54 Million Tons of Copper Slag when India at present produces around 96.72 thousand Tons of Copper Slag per annum. Even though the beneficial use of Copper slag in Industries and production has been known for many decades, it is still not yet fully utilized. The major obstacles to further use of Copper slag are the large variation in physical and chemical properties. Current options for management of copper slag include recycling, recovering of metal, production of value added products and disposal in slag dumps or stockpiles. Currently, copper slag has been widely used for abrasive tools, roofing granules, cutting tools, abrasive, tiles, glass, road-base construction, railroad ballast, asphalt pavements, cement and concrete industries.

Another option of reusing copper slag is by using it as a partial replacement of concrete, it will be possible to reuse a waste by-product material beneficially. Large amounts of copper slag can be utilized by using it as fine and coarse aggregates in concrete because more than 75% volume of concrete is occupied by aggregates. 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. However, due to the process in smelting and refining of copper, there are variation in the mineral contents and elements in the

copper slag from different sources or countries. Virgin copper slag is the copper slag formed after refining and blasted copper slag is copper slag created after using virgin copper slag for blasting and abrasive purpose.
Blasted copper slag has a different chemical composition and physical properties compared to virgin copper slag as sizes of blasted copper slag would be smaller and impurities from target of blasting changes the composition of the copper slag. Therefore, the purpose of this project is to discover how the various properties of washed copper slag change the usual properties of the concrete and the designed loads. Therefore, making the end product render safe to use. Possible ways on improving the quality of the washed copper slag containing concrete would be suggested at the end of this project.

II. PHYSICAL AND CHEMICAL PROPERTIES

The slag is a black glassy and granular in nature and has a similar particle size range like sand which indicates that it could be tried as replacement for the sand in cementitious mixture. The specific gravity of the slag is 3.68. The bulk density of granulated copper slag is varying between 1.70 to 1.90 g/cc which is almost similar to the bulk density of conventional fine aggregate. The hardness of the slag lies between 6 and 7 in MoH scale. This is almost equal to the hardness of gypsum. The pH of aqueous solution of aqueous extract as per IS 11127 varies from 6.6 to 7.2. The limiting water soluble chloride content as per IS 11127 is 11ppm. The slag is conforming to the above standards. The free moisture content present in slag was found to be less than 1%. The sieve analysis for copper slag infers that the gradation properties of fine aggregates at all the replacement levels are similar to the specification for sand zone II as per IS: 383. The chemical composition of slag is presented in Table .1 and sieve analysis report is shown in Table. 2. The presence of silica in slag is about 26% which is desirable since it is one of the constituents of the natural fine aggregate used to normal concreting operations. The presence of copper, alumina, sulphate in the slag were only traces and hence not harmful.

Table 1: Chemical Composition of Copper Slag

Sl. No	Chemical Compounds	% of Compounds
1	Fe_2O_3	68.29
2	SiO2	25.84
3	Al_2O_3	0.22
4	CaO	0.15
5	MgO	0.2
6	Na_2O	0.58
7	K_2O	0.23
8	Mn_2O_3	0.22
9	TiO_2	0.41
10	CuO	1.2
11	LOI	6.59
12	Insoluble residue	14.88

Properties of fine aggregates at all the replacement levels are similar to the specification for sand zone II as per IS: 383. The chemical composition of copper slag is presented in Table .1..

III. THE METHODOLOGY AND INVESTIGATIONS

Materials Used With Their Properties

Cement

Ultra Tech 53 grades Ordinary Portland cement is used for this study. This cement is the most widely used one in the construction industry in India.

Course and fine aggregates

Coarse aggregates of 10 mm and 20 mm size is used for this study which taken from satpur Nasik, Maharashtra, and Artificial sand is used confirming to grading Zone –I of table 4 of IS 383 were procured from Deccan trap basalt, Nasik Maharashtra.

Copper Slag

Copper Slag is black glassy particle and granular in nature, it is the waste material which can be used for strengthening concrete with partial replacement of sand.

Water

Portable water is used for casting and currying of the concrete blocks.

IV. TEST ON MATERIAL

Test on Cement:

Type of cement: Portland Pozzolana Cement (PPC)

Table No. 2 Fineness of cement

Sr. no.	Description	Weight
01	Weight of cement	100gm
02	Weight of residue on 90 IS sieve	5gm
03	% Fineness	5%

Requirement:

As per IS 269-197, the fineness of cement by dry sieving should not exceed 10% by weight showed in table No. 2.

Table No. 3: Consistency of Cement

Sr. No.	Weight of cement	Weight of water	$P_n=(w_2/w_1)*100$	Penetration of plunger from top in mm	Remark
1	500	120	24	07	P_n=33.5
2	500	135	27	12	
3	500	145	29	20	
4	500	155	31	28	

5	500	168	33	35	

Weight of water required to produce a paste of standard consistency = 168ml.

Standard consistency (p_n) of cement paste

$$= \frac{\text{Quantity of water}}{\text{Weight of cement}} * 100$$

$$= \frac{168}{500} * 100$$

$$P_n = 33.6\%$$

As per IS: 4031-1968 the standard consistency is obtained the Vicat plunger penetrate to a point 5 to 7 mm from bottom of Vicat mould shown in table no. 3.

Setting Time of cement:

Standard consistency (P_n) = 33.5%

Weight of cement sample (W_1) = 400gm

Weight of water added (W_2) = 0.85 P_n*W_1

= 0.85*0.335*400

= 197ml

Initial setting time (t_1) = 45 minute

Final setting time (t_2) = 420 minute

Requirement

As per IS 269-1976, the initial setting time shall be not less than 30 minute and final setting time shall be not greater than 600 minutes.

Compressive strength of cement:

The compressive Strength is shown in Table No. 4.

Standard consistency P_n = 33.5%

Mix proportion =1:3

Weight of cement =1500gm

Weight of standard sand =4500gm

Weight of water = (P_n/4+3)*(W_1+W_2)/100

= (33.5/4 +3)*(1500+4500)/100

= 675 ml.

Size of Cube =70.7mm x 70.7 mm x 70.7 mm

Table No. 4: Compressive strength of cement

Sr. No.	Compressive strength		Average Compressive Strength (N/mm^2)	
	3 days	7days	3 days	7 days
1	31.32	40.18	31.67	41.15
2	30.52	42.11		

3	33.17	41.18		

Fineness Modulus:

To determine the fineness modulus of coarse aggregates, sand and Copper Slag details sieve analysis is performed. The fineness modulus of coarse aggregates, sand and Copper Slag are 7.64, 2.73 and 3.47respectively. Table 5 to 7 shows the fineness modulus of coarse aggregates, sand and Copper Slag respectively. It was ensured that both aggregates had a grain size distribution within 4.75-13.20 mm by sieving in order to prevent any effect of aggregate size. According to IS 383 – 1970 the grading falls outside the limits of any particular grading zone of sieves other than 600-micron IS Sieve by a total amount not exceeding 5 percent, it shall be regarded as falling within that grading zone. This tolerance shall not be applied to percentage passing the 600-micron IS Sieve or to percentage passing any other sieve size on the coarse limit of Grading Zone I or the finer limit of Grading Zone IV. Sand used for this work is from grading zone I and Copper Slag used in this work is in zone II. Table 8 show IS requirement of fine aggregates in zone I and zone II.

Table No. 5: Sieve analysis of coarse aggregates

I.S. Sieve Size (mm)	Weight Retained(kg)	Total weight retained(gm)	Total weight of passing(gm)	% of retained	% of passing
20	0.126	0.126	2.875	4.2	95.83
16	2.263	2.389	0.611	79.63	20.36
12.5	0.152	2.541	0.459	84.7	15.3
10	0.338	2.879	0.121	95.96	4.03
4.75	0.121	3.000	0.000	100.0	0.000

FM = Total cumulative percentage retained / 100 = 764.50/100 = 7.64

Table No. 6: Sieve analysis of sand sample.

I.S.Sieve Size (mm)	Weigh Retained(kg)	Total weight retained(gm)	Total weight of passing(gm)	% of Passing	% of retained
4.75	73.00	73.00	927.0	92.70	7.300
2.36	269.0	342.0	658.0	65.80	34.20
1.18	216.0	558.0	442.0	44.20	55.80
0.60	158.0	716.0	284.0	28.40	71.60
0.30	122.0	838.0	162.0	16.20	83.80
0.15	134.0	972.0	28.00	2.800	97.20
0.075	26.00	998.0	2.000	0.200	99.80
Pan	2.000	1000	1000	0.000	100.0

Table No. 7: Sieve analysis of Copper Slag.

I.S.Sieve Size (mm)	Weight Retained(gm)	Total weight retained(gm)	Total weight of passing(gm)	% of passing	% of retained
4.75	00.00	00.00	1000	100	00.00
2.36	89.00	89.00	911.0	91.10	8.900
1.18	405.0	494.0	506.0	50.60	49.40
0.6	384.0	878.0	122.0	12.20	87.80
0.3	82.00	960.0	40.00	4.000	96.00
015	18.00	978.0	22.00	2.200	97.80
0.075	10.00	988.0	12.00	1.200	98.80
Pan	12.00	1000	00.00	00.00	100.0

Table No. 8: IS limit for fine aggregates for zone I and zone II.

ZONE II		ZONE I	
100	100	100	100
90	100	90	100
75	100	60	95
55	90	30	70
35	59	15	34
08	30	05	20
00	10	00	00

Specific gravity:

To determine the specific gravity of 20mm aggregates weighing bucket is used and the specific gravity of 20 mm aggregates are found to be 2.74 and are shown in Table 9. The specific gravity of sand and Copper Slag is 3.56. It is observed that the specific gravity of sieved Copper Slag is more as compared to sand and is shown in the Table 10 and Table 11 respectively.

Table No. 9: Specific gravity of coarse aggregate.

Size of aggregate	Specific gravity
20 mm	2.74

Table No. 10: Specific gravity of fine aggregate (sand).

Size of aggregate	Specific gravity
0.075mm-4.75mm	2.74

Table No. 11: Specific gravity of Copper Slag.

Size of aggregate	Specific gravity
0.075mm-4.75mm	3.56

Water absorption:

The water absorption of 20 mm coarse aggregates, sand & Copper Slag are determined by conventional method and found to be 0.601, 2.55 and 0.20 respectively. It is found that water absorption of Artificial Sand is very high as compared to Copper slag and it affects on workability of concrete. The water absorption of coarse aggregates, sand and Copper Slag are shown in table 12.

Table No. 12: Physical properties of coarse aggregates, fine aggregates and Copper Slag.

Fineness modulus			Specific gravity			Water absorption		
C.A.	Sand	C.S.	C.A.	Sand	C.S.	C.A.	sand	C.S.
7.64	2.73	3.47	2.74	2.74	3.56	0.601	2.55	0.20

Laboratory testing program:

The mix proportion and mix ratio chosen for this study is shown Table 13 concrete mixture with different proportions of Copper Slag ranging from 0 % (for control mix) to 10 to 90 % replacement for sand was considered. The M-40 grade mix design was selected for w/c ratio 0.40. In this study slump was kept 100 ± 10 mm. For this work total 7 cubes specimen, and 7 beam specimens were casted and tested for compressive strength and flexural strength,. For this work total 14 test specimen were casted. The mix designs is selected for w/c ratio 0.40 for controlled concrete and 6 cubes are casted and tested for 7, 28 days.

Table 13: Mix proportions (Kg /m^3) and mix ratio.

Cement	Fine aggregates (sand)	Coarse aggregates (10 mm)	Water
450	1140	896	180
1	1.9	2.53	0.40

V. CONCLUSIONS

- Addition of slag in concrete increases the density thereby the self weight of the concrete.
- The results of compression & split-tensile test indicated that the strength of concrete increases with respect to the percentage of slag added by weight of fine aggregate upto 40% of additions.
- The recommended percentage replacement of sand by copper slag is 40% but when used beyond 50% results in decrease in strengths.-

VI. ACKNOWLEDGEMENT

With deep sense of gratitude, we wish to express our sincere thanks to, **Prof. Bhavsar R.S** for her immense help in planning and executing work in time. Our grateful thank to the departmental staff members for their support.

We would also like to thank my wonderful colleagues and friends for listening my ideas, asking questions and providing feedbacks and suggestion for improving our ideas. In the end our special thanks to colleagues for providing various resource such as laboratory, for our project.

REFRENCES

[1] D. Brindha And S. Nagan, Utilization of Copper Slag as a Partial Replacement of Fine Aggregate in Concrete, International Journal of Earth Sciences and Engineering ISSN 0974-5904, 3(4), August 2010, 579-585.

[2] Meenakshi Sudarvizhi S And Ilangova, Performance of Copper slag and ferrous slag as partial replacement of sand in Concrete, International Journal Of Civil And Structural Engineering Volume 1(4), 2011.

[3] Ayano Toshiki, Kuramoto Osamu, and Sakata Kenji, Concrete with copper slag fine aggregate, Society of Materials Science, Vol. 49, 2000, pp. 1097-1102.

[4] Mustafa Khanzadi, Ali Behnood, Mechanical properties of high-strength concrete incorporating copper slag as coarse aggregate, Construction and Building Materials, 2009, Vol. 23, 2183–2188.

[5] M.Chockalingam, D.Jayganesh, J.Vijayaraghavan and Dr.J.Jegan, Scope for Reuse of Copper Slag in Concrete – A Review, International Journal of Civil Engineering & Technology (IJCIET), Volume 4, Issue 6, 2013, pp. 89 - 100, ISSN Online: 0976 - 6316.

[6] Demirboga R, Orung I and Gu l R., Effects of expanded perlite aggregate and mineral admixtures on the compressive strength of low density concretes. Cement and Concrete Research 2001; 31(11):1627–1632.

[7] Kuramoto Osamu, Sakata Kenji, Concrete with Copper Slag Fine Aggregate, Journal of the Society of Materials Science, Japan Vol. 49(10), 2000, 1097-1102.

[8] SBipra gorai , R.K. Jana and Premchand, Characteristics and utilization of copper slag - a review. Resources, Conservation and Recycling 39, 2003, 299-313.