www.cafetinnova.org

ISSN 0974-5904, Volume 10, No. 04

DOI:10.21276/ijee.2017.10.0428

International Journal of Earth Sciences and Engineering

August 2017, P.P. 920-923

Strength and Micro Structural Properties of Copper Slag as Sand Replacement in Mortar

M V PATIL AND Y D PATIL

Department of Applied Mechanics, S.V. National Institute of Technology, Surat, Gujarat, INDIA

Email: *mvpatil_consultant@rediffmail.com, chipatil@yahoo.com*

Abstract: *The effect of copper slag as a fine aggregate on properties of cement mortars is studied in this paper. Various specimens with different proportions of copper slag were prepared with 0% to 100% sand replacement. The specimens were tested for compressive strength, split tensile strength, flexural strength, density, modulus of elasticity and permeability. The results obtained revealed that all specimens with different proportions of sand replacement yielded higher strength results than the control concrete.*

Keywords: *copper slag, fine aggregate, mortar, concrete, hardened properties*

1. Introduction

As like the construction industry, there are many more industries in India which consumes lots of energy and resources. Along with the consumption of raw materials, these industries produce a huge amount of by-products with them [3]. The generation and dumping of these by-products has become a problem for the industries. Also on the other hand construction industry is facing the problem of scarcity of raw materials [2]. Therefore the researches are working to find the reuse of these industrial wastes into construction industry. The industrial wastes are like copper slag, micro silica, coal bottom ash, ferrous slag etc. In this paper copper slag is used in cement mortar as a sand replacement for 7, 28 56 and 112 days. The various tests are conducted on specimens like compressive strength, flexural strength, density and modulus of elasticity and results are found out.

2. Materials

Birla Super 53 grade ordinary Portland cement is used for this study. Coarse aggregates of 10mm and 20mm size is used for the study which is taken from Shiroli MIDC area Kolhapur.And natural sand of river bed is used confirming to grading zone –I of table 4 of IS 383 were procured from local river in Maharashtra.Copper slag used for this work is taken from Suyog suppliers (zone-II), a dealer in Pune which is used for sand blasting and the supplier brought the slag from Baruch, Gujarat.Drinking water is used for casting and curing of the concrete blocks.

3. Physical Properties

Table 1 and table 2 shows the physical properties of the cement and sieve analysis of the coarse aggregate, fine aggregate and copper slag which was performed before casting of the specimen. From Table 2 it can be observed that the fineness modulus of coarse aggregate, fine aggregate and copper slag is 7.75, 3.95 and 4.55 respectively.

Table 1. *Properties of Cement*

Property	Average value for OPC used in investigation	Standard value for OPC
Specific Gravity	3.15	-
Consistency (%)	29%	-
Fineness By Dry Sieving	7.8%	<10%
Initial Setting Time (Min)	45	>30
Final Setting Time (Min)	245	<600
Soundness (mm)	1.6	<10
Compressive strength (N/mm^2)		
3-days	30.5	>23
7-days	41.25	>33
28-days	56.38	>43

Table 2*. Sieve Analysis of Coarse Aggregate, Fine Aggregate, Copper Slag*

IS Sieve size (mm)	Coarse Aggregate	Fine Aggregate	Copper Slag
	Cumulative % retained	Cumulative % retained	Cumulative % retained
20	3.3	0	0
16	14.3	0	0
12.50	19.73	0	0
10	47.26	0	0
4.75	91.45	1.5	18
2.36	99.1	8.2	5.36
1.18	100	28.14	50.78
600 micron	100	67.85	87.52
300 micron	100	91.25	95.28
150 micron	100	98.68	98.2
Fineness modulus	7.75	3.95	4.55

Received: March 12 2017; Accepted: June 25, 2017; Published: August 30, 2017
International Journal of Earth Sciences and Engineering, 10(04), 920-923 2017, DOI:10.21276/ijee.2017.10.0428

4.1 Effect copper slag on compressive strength of mortar

Compressive strength of mortar mixed made with and without copper slag of cubes size 70.7mm x 70.7mm x 70.7mm was determined at 7,28,56 and 112 days. The results are given in the Figure 1. The maximum load at failure reading was taken and average compressive strength is calculated using the following relation:

Compressive strength ($N/mm^{2)}$

$$= \frac{\text{Ultimate load in N}}{\text{Area of cross section } (mm^2)}$$

Here 0 to 100% of copper slag was replaced by sand and optimum percentage of replacement was obtained. For controlled mortar the compressive strength was found to be 20.57, 31.39, and 40.09 N/mm^2 for 7, 28 and 56 days respectively. It was observed that for 10% replacement of sand by copper slag in mortar found to greater than controlled mortar by 21.92% ,10.13% and 9.70% at 7,28 and 56 days respectively. It was also observed that from 20% replacement of sand by copper slag in mortar found to greater than controlled mortar by 27.17 %,18.29% and 21.17% at 7,28 and 56 days respectively. From 70 to 100% replacement the compressive strength is reduced than controlled mortar. The variation in compressive strength with percentage replacement and with age is graphically shown in Figure 1. The copper slag concrete gains strength at a slower rate in the initial period and acquires strength at faster rate after 28 days due to pozzolanic action of copper slag [1].

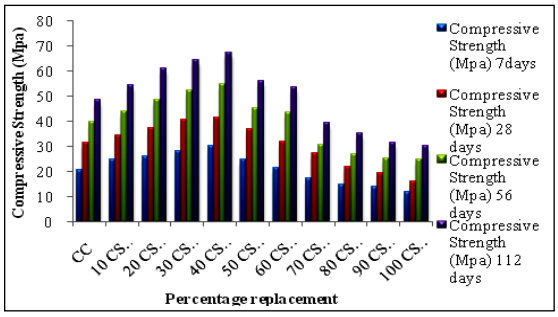


Figure 1: *Compressive strength of mortar with different percentage of Copper slag*

4.2 Effect copper slag on flexural strength of mortar

The beam specimen of size 100mm x100mm x 500mm was tested for single point load at the midpoint under UTM of capacity 100 ton. The flexure strength is calculated as per IS -456-2000 and IS 516-1959 code by using the relation $\sigma_b = \frac{PL}{bd^2}$. The flexure strength was increased for 10% and 20% replacement of sand with copper slag by 7.69 % and 15.38% at 7 days, 4.61% and 21.53% at 28 days, 1.76%, 6.33% at 56 days respectively with controlled mortar. The copper slag mortar gains flexural strength with the age at different percentage with respect to controlled mortar. It is believed to be due to the poor interlocking between the aggregates, as copper slag particles are spherical in nature. The variation in flexural strength from 0 to 100% replacements with different percentage of copper slag in mortar is shown in Figure 2 at 7, 28, 56 and 112 days.

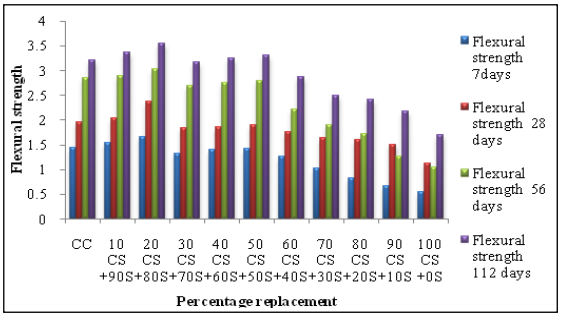


Figure 2: *Flexure strength of mortar with different percentage of Copper slag*

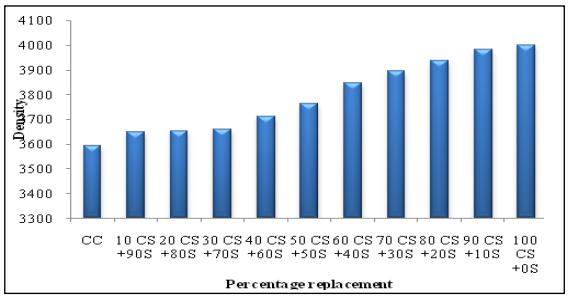


Figure 3: *Density of mortar with different percentage of Copper slag*

4.3 Effect copper slag on density and modulus of elasticity of mortar

The density of hardened mortar specimens with different percentage replacement of natural sand by copper slag is shown in Figure 3. The density of hardened mortar was linearly increased as the replacement ratio of copper slag was increased. The density controlled mortar was 3593.08 Kg/m^3 for 28 days. The density of concrete is linearly increased from 10% replacement to 100% replacement. The modulus of elasticity of concrete mortar is presented in figure 4. The modulus of elasticity goes on increasing up to 40% replacement and then goes on decreasing up to 100% sand replacement.

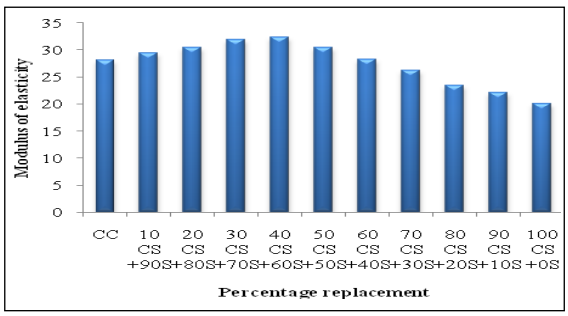
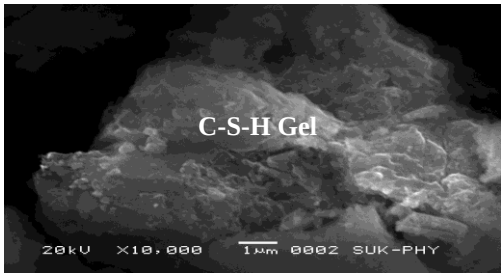


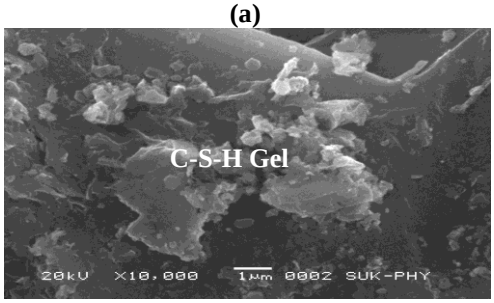
Figure 4. *Modulus of elasticity of mortar with different percentage of Copper slag*

4.4 SEM observations of hardened copper slag mortar

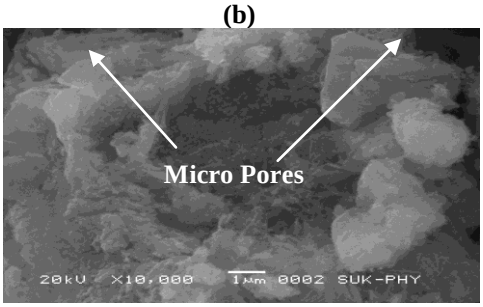
Figure 5 (a) is a scanning electron micrograph of the control concrete mix which reveals the presence of sand particles in a mixed state and as separate particles but prominently visible. The mix also shows a dense matrix with no pores or cracks. Gel formation is clearly visible around the sand particles in the micrograph. Figure 5 (b) shows micrographs of the 20% copper slag and 80% sand. This micrograph shows the copper slag particles with micro pores having some micro cracks. The gel formation is clearly visible. Figure 5 (c), (d), (e), (f) shows the SEM of 40%, 60 %, 80% and 100% copper slag replacement in the concrete. The C-S-H gel is more finely spread than in the control concrete. The availability of more gel has resulted in the greater strength, stronger than even the control mix. Due to the C-S-H gel formation at its peak the mix becomes denser which causes the increase in the strength [4].



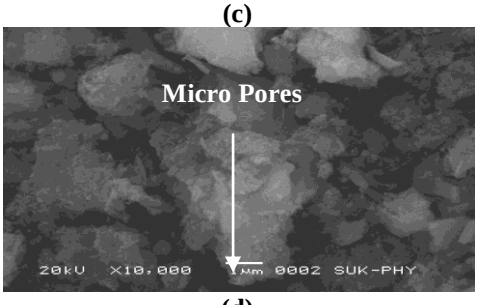
(a)



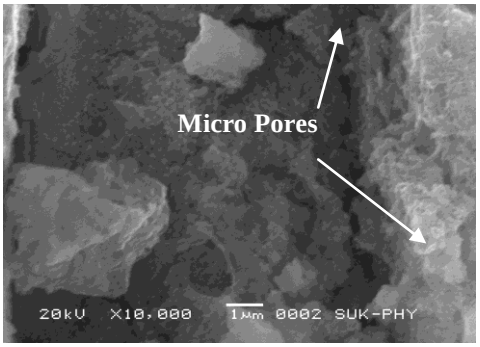
(b)



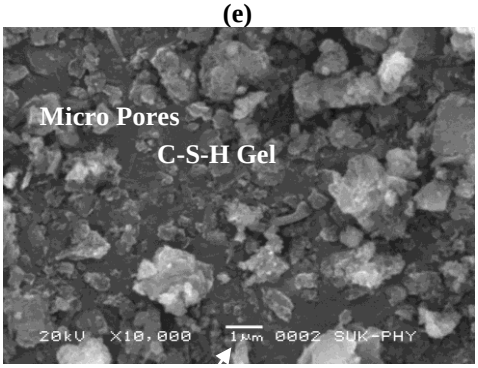
(c)



(d)



(e)



(f)

Figure 5: *SEM images of copper slag mortar*

Fig.5 (a) shows SCM of concrete with CS 0%, fig (b) with CS 10% +Sand 90%, fig (c) with CS 20%+ Sand 80%, fig (d) with CS 30%+ Sand 70%,, fig (e) with CS 40%+ Sand 60%, and fig (f) shows SCM of concrete with CS 50%+ Sand 50%

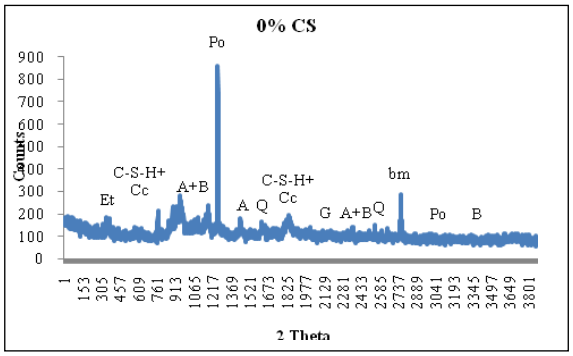


Figure 6: *XRD showing results with CS 0%*

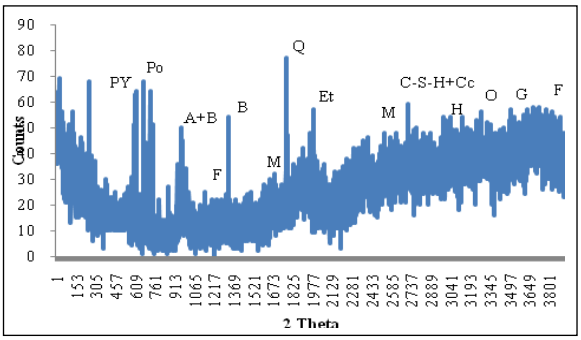


Figure 7: *XRD showing results with CS 10% +Sand 90%*

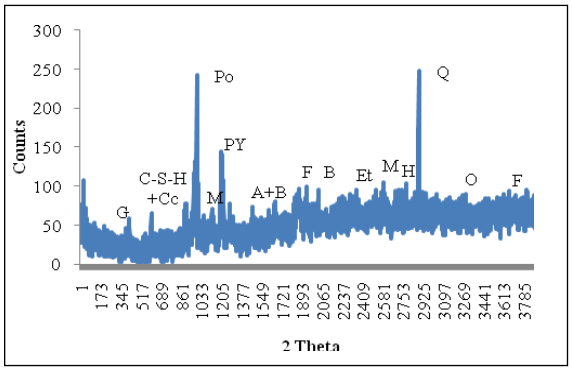


Figure 8: *XRD showing results with CS 20%+ Sand 80%*

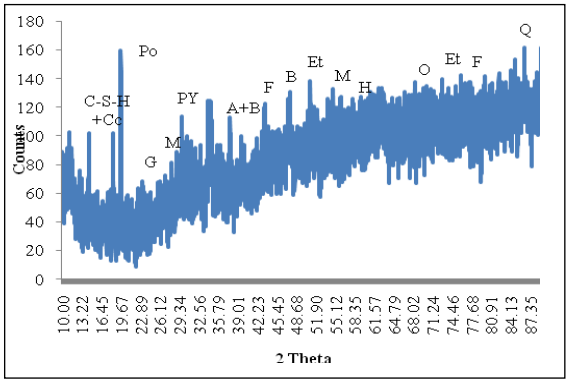


Figure 9: *XRD showing results with CS 30%+ Sand 70%*

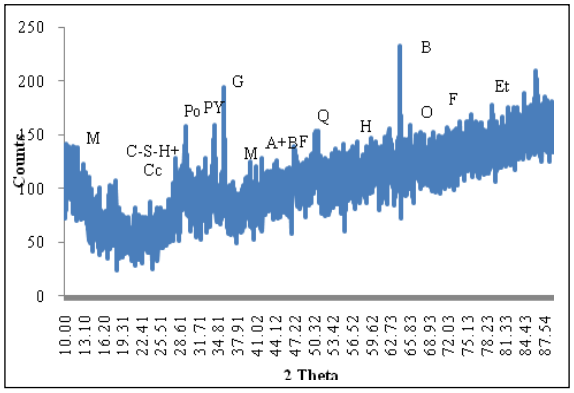


Figure 10: *XRD showing results with CS 40%+ Sand 60%*

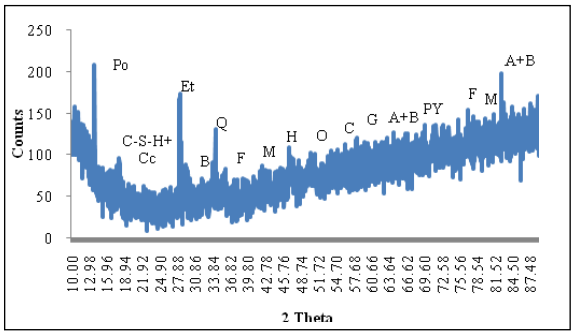


Figure 11: *XRD showing results with CS 50%+ Sand 50%*

Table 3.

A- Alit	P-Portlandite
B-Belite	CC- calcite
CSH- Calcium silicate hydrates	

5. Conclusions

- The compressive strength and modulus of elasticity were increased when up to 60% of sand was replaced with copper slag. However the rest of the replacements (70%-100%) caused a decrease in these parameters when compared with those of the control mortar.
- The flexural strength were increased when up to 20% of sand was replaced with copper slag. However the rest of the replacements (30%-100%) caused a decrease in these parameters when compared with those of the control mortar.
- The density of the copper slag mortar linearly increased as the replacement was increased from 10% to 100%.
- When the mortar specimens were immersed in NaCl and $MgSO_4$ solutions for 180 days, loss in compression strength and weight was observed. However this loss was less, when compared with that noted in the control mortar, which showed the ability of the test specimens to withstand adverse environments.

References

[1] Akihiko Y, Takashi Y, "Study of Utilization of Copper Slag As Fine Aggregate For Concrete", 1996; 23; 79-85.

[2] Al-Jabri KS, Hisada M, Al-Oraimi SK, Al-Saidy AH (2009a), "Copper Slag as Sand Replacement for High Performance Concrete", Cement and Concrete Composites 31:483-488.

[3] Al-Jabri KS, Hisada M, Al-Saidy AH, Al-Oraimi SK (2009b), Performance of high strength concrete made with copper slag as fine aggregate. Construction and Building Materials 23:2132-2140.

[4] Gorai P, Jana RK, Premchand. Characteristics and utilization of copper slag -a review. Resour Conserv Recycl 2003; 39; 299-313.

[5] Shi C, Meyer, C Behnood A," Utilization of copper slag in cement and concrete- a review. Resour Conserv Recycl 2006; 20; 322-331