Effects of Copper Slag as Sand Replacement in Concrete

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Abstract— This paper investigates the technical feasibility of using copper slag as a replacement of fine aggregate in concrete. For this research work, m30 grade concrete was used and tests were conducted for various proportions of copper slag replacement with sand of 0 to 100% in concrete. The results demonstrate that up to certain level the strength of concrete increases with increase in percentage of copper slag.

Keyword- By product, copper slag, compressive strength, concrete, modulus of elasticity.

I. Introduction

The amount and type of generated waste has grown as the world population increases.. Many of the wastes produced today will remain in the environment for a long time. For many years, efforts and practices to minimize disposing wastes to landfills have been minimal. Dumpsites for municipal and hazardous waste attracted little attention and were under few controls. The result of rapid industrialization is the rapid depletion of resources, and environmental impacts due to production of enormous waste exceeding assimilation capacity of the environment. Without any consideration of the wastes and its ill effects on the environment, the people used to throw it without any treatment. And now the time has came that these wastes have become pollutants and have started polluting the surroundings. Therefore a way has been found out that some of these wastes can be used into various industries which will lighten the burden on the environment. Some of the by-products like fly ash, silica fume and slag are being used into construction industry as a partial replacement to the fine aggregate. Similarly copper slag is a by-product from copper industry which can be used as a sand replacement into concrete.

II. Materials and Methods

The raw materials used in this research were cement, fine and coarse aggregate, copper slag, plastisizers and water. The cement used was 53 grade Birla super cement. Fine aggregate and coarse aggregate used was available locally. Copper slag was brought from a dealer in Pune. Along with all the raw materials, to improve the workability of concrete, plastisizers were used.

And final raw material i.e. water, normal drinking water was used for work. The physical properties of coarse fine aggregates and copper slag were determined.

TABLE 2.1

Physical Properties

	C.A.	**Sand**	**C.S.**
Fineness Modulus	7.75	3.95	4.55
Specific Gravity	2.75	2.65	3.30
Water Absorption	0.609	1.20	0.65

Before starting the various tests on concrete, the physical properties of the raw materials were determined. These properties are fineness modulus, specific gravity; water absorption etc. Sieve analysis was performed to determine the fineness modulus of copper slag, sand and coarse aggregate. The specific gravity of sand and copper slag was 2.67 & 2.75 respectively as shown in Table 2.1. The water absorption of 20 mm coarse aggregates, sand &copper slag was found to be 0.609, 1.01 and 0.65 respectively. It was found that water absorption of copper slag was very low as compared with the natural sand and workability of concrete is affected due to it.

A. Laboratory Testing Program

Concrete mixture with different proportions of copper slag ranging from 0 % (for control mix) to 10 to 100 % replacement for sand was considered. The mix design was selected for w/c ratio 0.45 and slump was maintained at 100 ± 10 mm. For this work total 176 cubes specimen, 102 cylindrical specimens and 102 beam specimens were casted and tested for compressive strength, flexural strength and density. For this work total 405 test specimen were casted. The mix designs was selected for w/c ratio 0.45 for controlled concrete and 33 cubes were casted and tested for 7, 28,56 days. The compressive strength at 7, 28 and 56 days was found 23.87 N/mm^2, 36.15 N/mm^2 and 36.72 N/mm^2 respectively. For the cc 33 cubes specimen, 11 cylindrical specimens and 11 beam specimens were casted and tested for 7, 28 days and 56 days & 112 d.

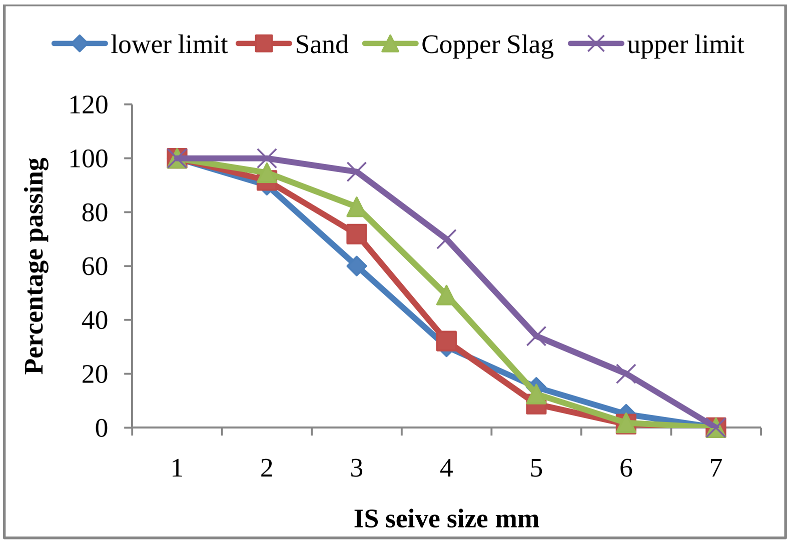

Fig. 1. Grading of sand and copper slag in zone I

III. Test Results and Discussions

A. Fresh Concrete Properties

To determine the effects of adding copper slag on workability of the concrete composites, determination of fresh concrete properties were necessary. Very common method adopted for determination of workability of concrete is slump test.

B. Fresh Concrete Workability (Slump Test)

TABLE 3.1

Workability Test (Slump Test)

Mix	W/C Ratio	Slump (mm)
Normal M-30	0.45	25
CS 10%	0.45	26
CS 20%	0.45	28
CS 30%	0.45	31
CS 40%	0.45	32
CS 50%	0.45	34
CS 60%	0.45	35
CS 80%	0.45	38
CS 100%	0.45	40

The slump of the concrete incorporating the copper slag as fine aggregate increased as more natural sand was replaced by copper slag. Maximum slump obtained was 40mm which occurred at the 100% copper slag replacement as compared to slump of concrete mix. In general, it can be concluded that addition of copper slag improves the workability of concrete mix. From the slump test the amount of water to obtain the targeted slump in the concrete composites was the equivalent conventional concrete.

TABLE 3.2

Concrete Mixtures with Different Proportions of Copper Slag

Mix material/ % replacement	**Cement kg/m^3**	**Copper slag kg/m^3**	**Water kg/m^3**	**Sand kg/m^3**	**C.A. 20mm kg/m^3**	**Admixture kg/m^3**
cc	419	----	188.55	628.50	984.65	-
10	419	62.85	188.55	565.65	984.65	-
20	419	125.70	188.55	502.80	984.65	-
30	419	188.55	188.55	439.95	984.65	-
40	419	251.40	188.55	377.10	984.65	0.817
50	419	314.25	188.55	314.25	984.65	0.854
60	419	377.10	188.55	251.40	984.65	0.898
70	419	439.95	188.55	188.55	984.65	0.928
80	419	502.80	188.55	125.70	984.65	0.992
90	419	565.65	188.55	62.85	984.65	1.067
100	419	628.50	188.55	----	984.65	

TABLE 3.3

Chemical Analysis of Copper Slag

Component	**Unit**	**Copper Slag**
($SiO_2 + Al_2O_3 + Fe_2O_3$)	%	98.11
($CaO + MgO + SO_3$)	%	1.19
($K_2O + Na_2O + TiO_2$)	%	0.26
Mn_2O_3	%	0.002
CuO	%	0.183
Sulphide Sulphur	%	0.082
Water Insoluble Residue	%	98.48
Chloride	%	0.350
Loss on Ignition	%	0.190

C. Compressive Strength

The compressive strength of cube specimen for different copper slag content as a replacement of sand at 7, 28, and 56 days curing period respectively is presented below. These results show an increasing profile up to 40% replacement of copper slag and then it shows decreasing profile as more copper slag is added.

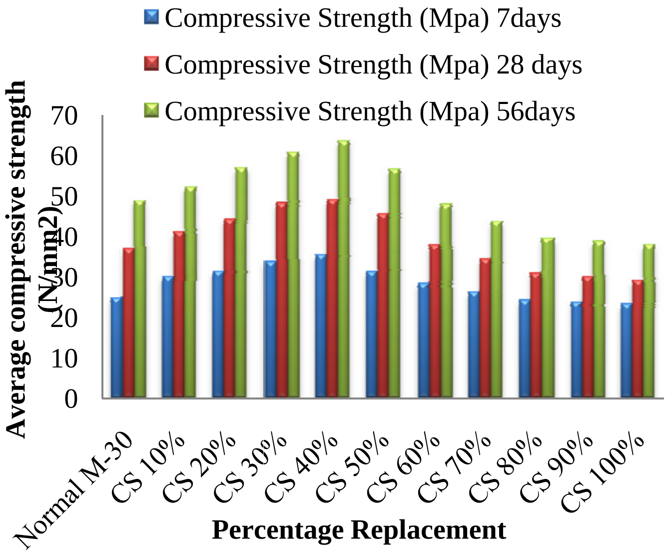

Fig. 2. Compressive Strength

Copper slag contains very fine particles than the sand particles and because of which voids increased in the concrete. And due to increase in voids, the strength of the concrete goes on reducing as copper slag percentages goes on increasing.

The results show that compressive strength of copper slag concrete mixes with 10% 20% 30% 40% 50% 60% and 80 % fine aggregate replacement with copper slag, were higher than the control mix at all ages. It is evident that compressive strength of all mixes continued to mixes with the increase in age. It is also observed that as copper slag increases the strength also increases. The highest compressive strength was gained at 40% replacement of copper slag, which was found about 35.54 Mpa compared with 25.07 Mpa for the control mixture. This means that there was an increase in the strength of almost 41.98% than the control mix at 7 days. The concrete with 100% replacement of copper slag gave the lowest compressive strength 23.37 Mpa which was almost 6.64 % lower than the strength of control mix.

D. Effect of Copper Slag on Split Tensile Strength

The 28 days split tensile strength of concrete showed similar behaviour to the compressive strength. The results showed that the split tensile strength was increased as copper slag quantity increases up to 20% addition, further the split tensile strength value goes on slightly decreasing but yet more than 60% compared with control concrete.

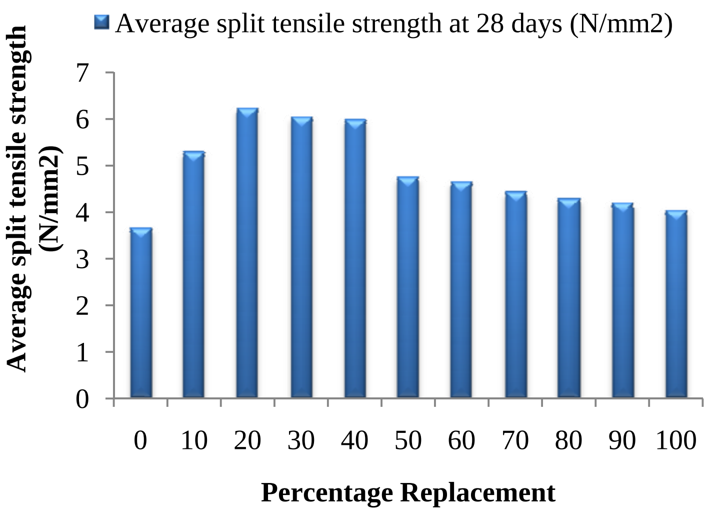

Fig. 3. Split Tensile Strength at 28 days

E. Flexural Strength

The flexural strength of beam specimens for different copper slag content as a sand replacement at 28 days curing period is presented below. It is evident that flexural strength continued to increase with the increase in the copper slag percentages at 28 days and there was significant increase in strength with that of strength of control mix.

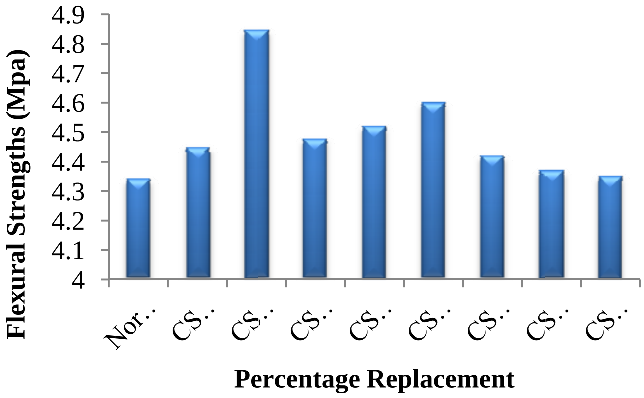

Fig. 4. Flexural Strength

F. Density

The effect of copper slag replacement as fine aggregate on density of concrete is presented in Fig. 5 for different proportions of copper slag. The density of hardened concrete at saturated-surface dried condition was measured at the age of 28 days. It is clear that the density of hardened concrete increased with the increase of the copper slag as sand content. This is due to the higher specific gravity of the copper slag, which were 3.30 compared to 2.65 of the natural sand. However compared with the large difference in the specific gravity of the copper slag and the natural sand, it increased density of concrete.

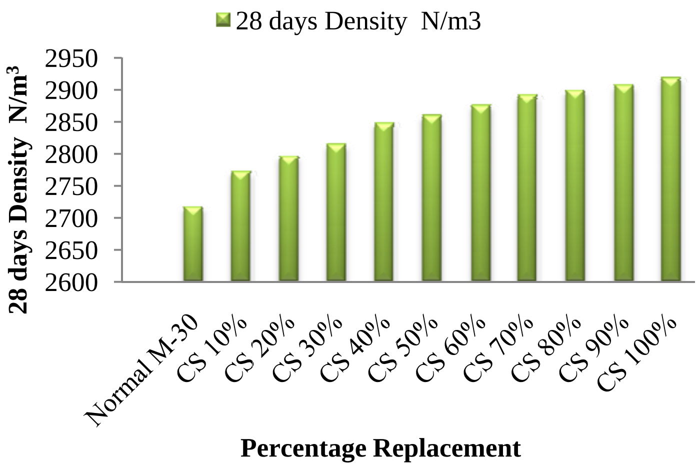

Fig. 5. Density

G. Effect of Copper Slag on Modulus of Elasticity at 28 Days

The modulus of Elasticity of cube specimen was calculated according to IS: 456-2000 by the formula $E = 5000\sqrt{Fck}$ Fck where Fck is 28 days cube compressive strength. It was found that the modulus of elasticity decreased in accordance with an increase of replacement of natural sand by copper slag. The modulus of Elasticity of reference concrete was 30.06 x 10^3 N/mm^2. The modulus of elasticity for 10%, to 60% replacement was increased by 1.33%, to 15.22 % with respect to controlled concrete then the modulus of elasticity was decreased up to 11.11 % as compared to controlled concrete.

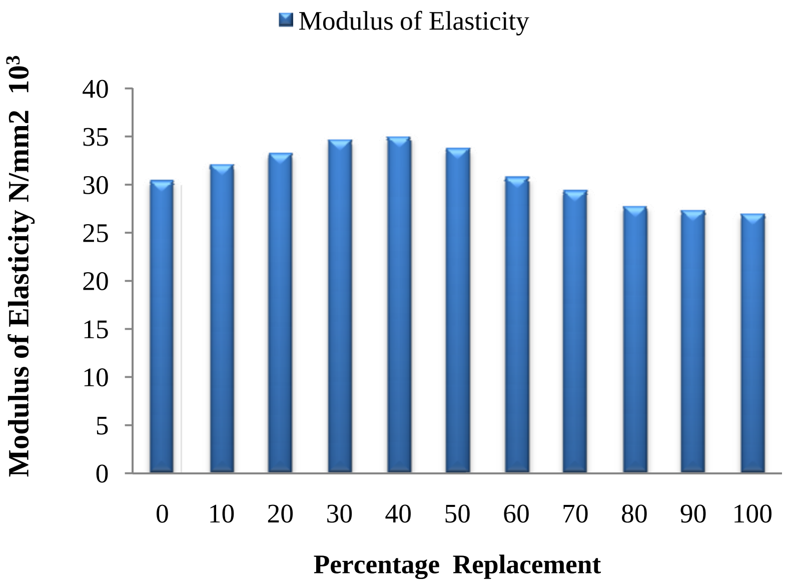

Fig. 6. Modulus of Elasticity at 28 days for cube specimen

H. Effect of Copper Slag on Permeability of concrete at 28 days

This test was conducted according to German Code DIN-1048. It is found that the permeability up to 40 % is decreased and after that the permeability was increased from 50 % to 100% replacement. Fig.7 shows the variation in the in permeability with respect to the reference concrete.

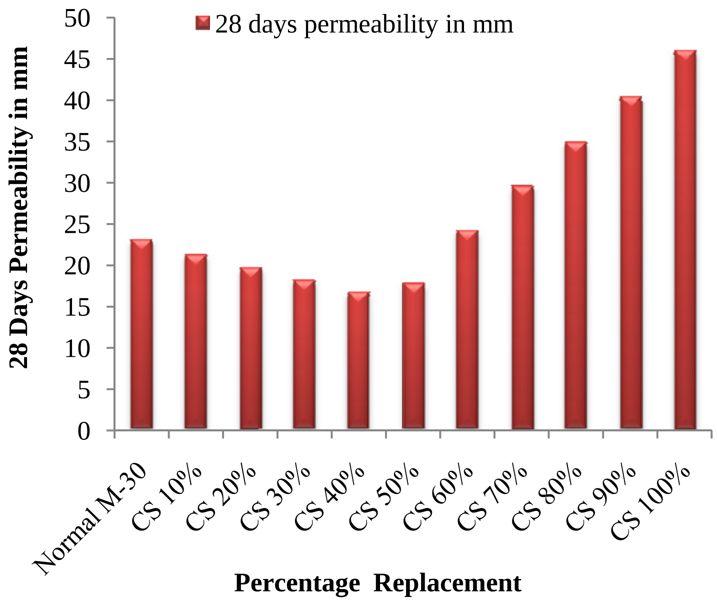

Fig.7. Percentage variations in permeability at 28 days

I. X-ray defractor graphs (XRD) of different proportions of copper slag in concrete at 28 days

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

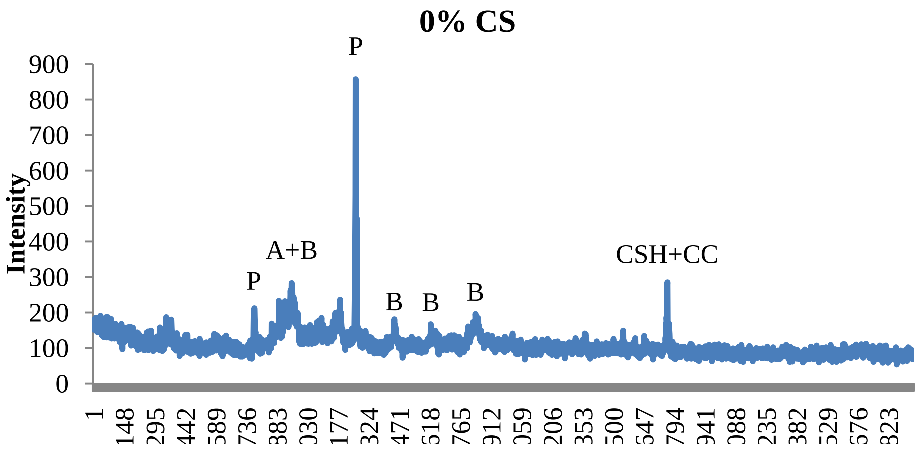

Fig.8.(a)

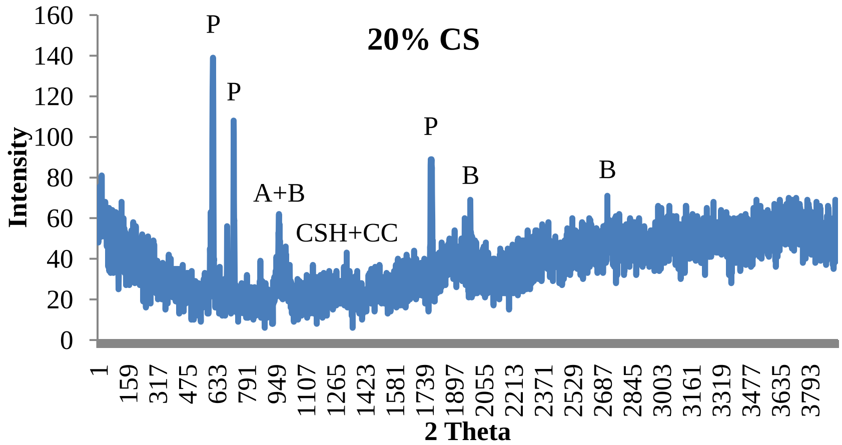

Fig.8.(b)

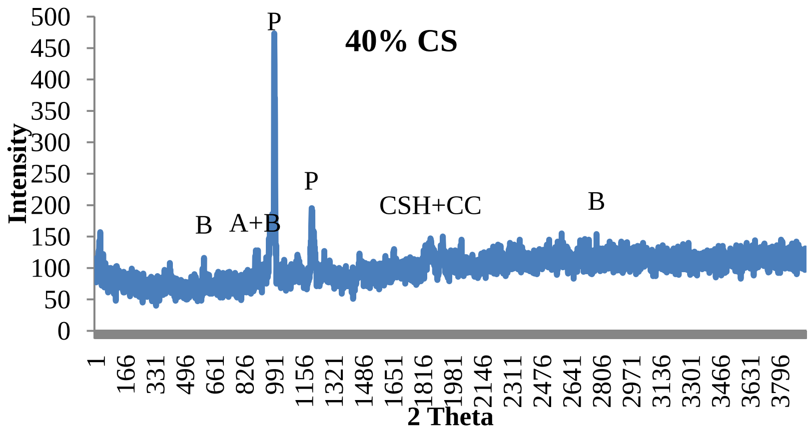

Fig.8.(c)

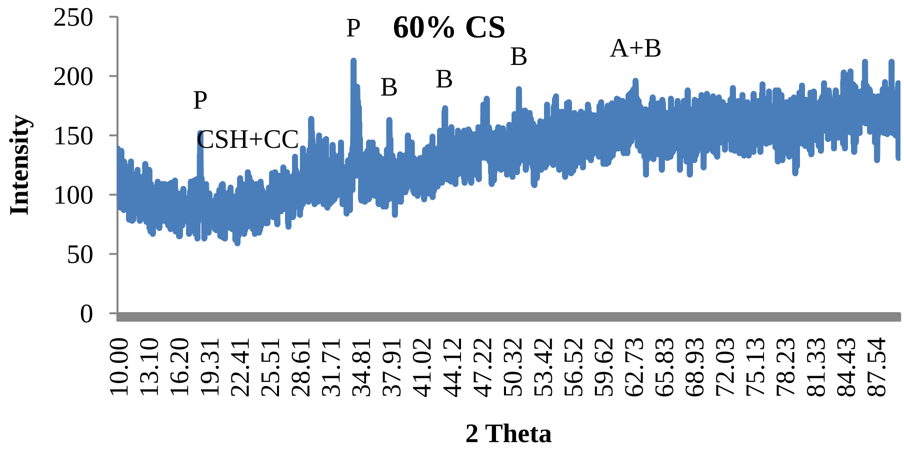

Fig.8.(d)

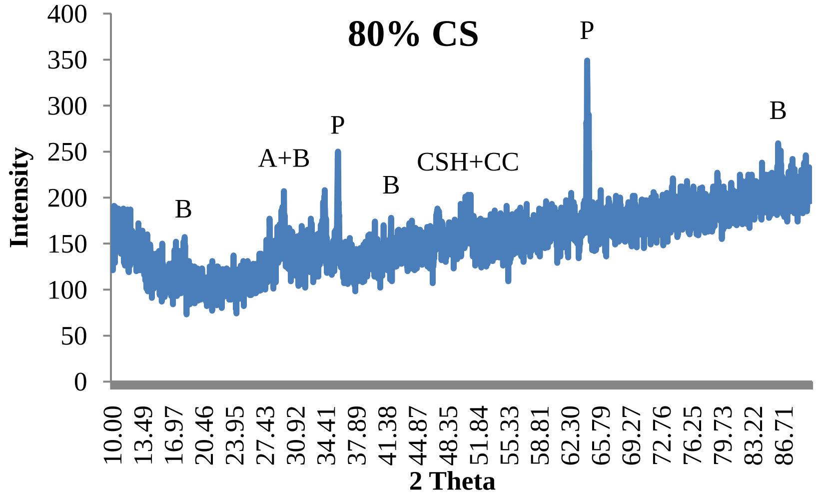

Fig.8.(e)

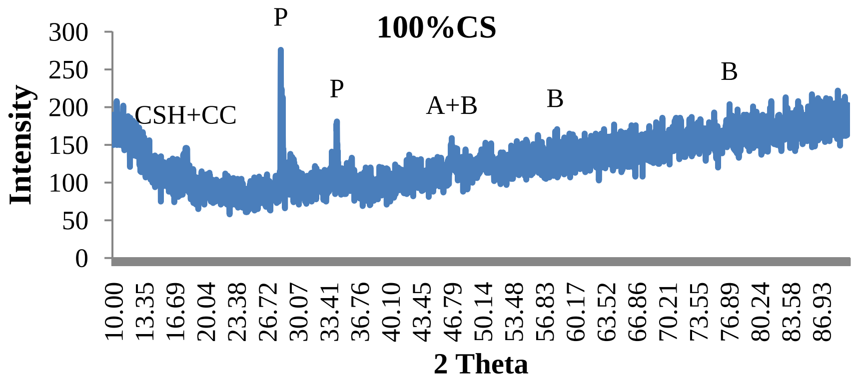

Fig.8.(f)

Fig.8 a, b, c, d, e, f shows X-ray defractor graphs (XRD) of concrete with different proportions of copper slag. Fig. a and b shows X-ray defractor graphs (XRD) of 0% and 20% of copper slag and 100% and 80% of natural sand respectively. Fig. c and d shows XRD graphs of 40% and 60% of copper slag and 60% and 40% of natural sand respectively. Fig. e and f shows XRD graphs of 80% and 100% of copper slag and 20% and 0% of natural sand respectively.

These XRD shows the completion of structure as they are compared with JCPDS file (Joint Committee on Powder Diffraction Standards) to find different compounds in concrete structures.

J. Scanning Electron Microscope (SEM) of different proportions of copper slag and natural sand in concrete at 28 days

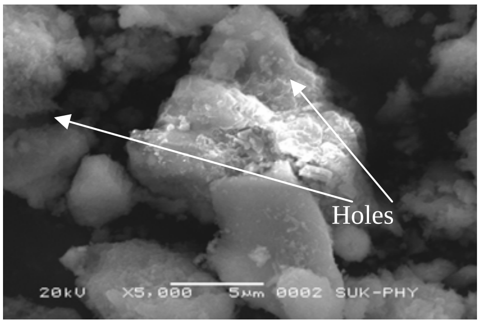

Fig.9.(a)

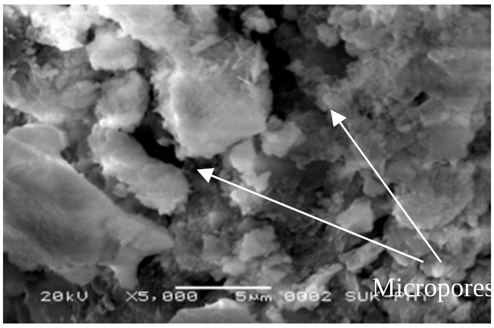

Fig.9.(b)

Fig.9 (c)

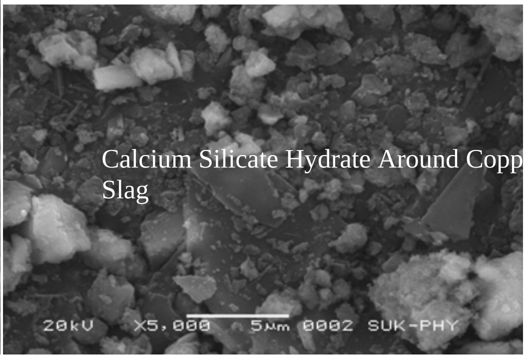

Fig.9 (d)

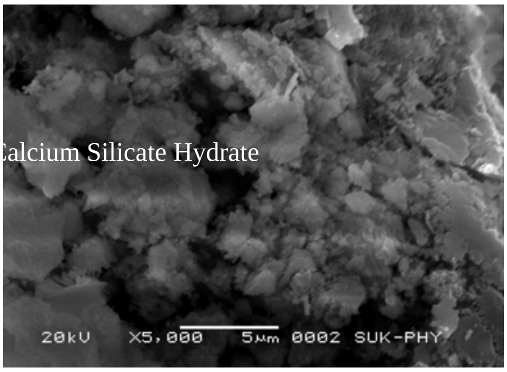

Fig.9 (e)

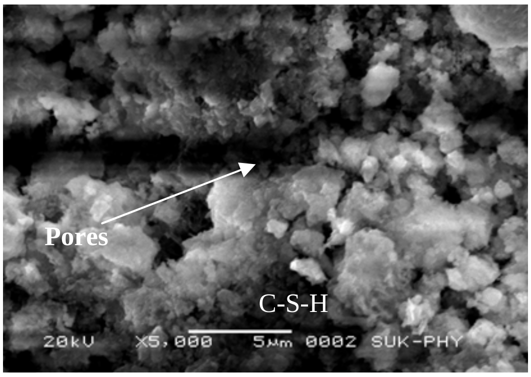

Fig.9 (f)

Fig.9 a, b, c, d, e, f. shows scanning electron microscope (SEM) images of concrete. Fig. a and b shows SEM of 0% and 20% of copper slag and 100% and 80% of natural sand respectively. Fig. c and d shows SEM images of 40% and 60% of copper slag and 60% and 40% of natural sand respectively. Fig. e and f shows SEM images of 80% and 100% of copper slag and 20% and 0% of natural sand respectively.

It is observed that in 0%, 20%, 40% of copper slag the voids are decreasing and from 60%, 80%, 100% the voids are increasing. It is also seen that homogeneity is increasing from 0%, 20%, 40% of copper slag and 60% ,80%, 100% homogeneity starts decreasing due to increase in voids and is observed from SEM images of 0%, 20%, 40%, 60%, 80%,100% of copper slag replacement for sand. It is also seen that permeability has been decreased from 10% to 40% of copper slag and from 50% it started increasing up to 100% so compression strength is increasing from 0% to 40% of copper slag till 60% compression strength is more than control concrete and from 70% to 100% compression strength is reduced due to increase in voids and increase in permeability. It is also observed that as the percentage of copper slag increases, the density goes on increasing.

IV CONCLUSION

The following conclusions can be drawn from present study.

1. The workability increases rapidly with increase in copper slag percentage.
2. Addition of up to 40% of copper slag as sand replacement gained 32% more strength with that of control concrete. However further addition of copper slag caused reduction in strength.

3. It was observed that up to 20% replacement of natural sand by copper slag, the split tensile strength of concrete was increased by 70% and flexural strength of concrete was increased by 50%. All percentage replacement of fine aggregate by copper slag the split tensile and flexural strength of concrete was more than normal mix.
4. Compressive strength and flexural Strength was increased due to high toughness of copper slag.
5. As the percentage of Copper slag increases the density of concrete was increased. Density was increased by 7% due to replacement of fine aggregate at 100%.
6. Maximum modulus of elasticity of copper slag concrete increased by 15.22% at 40% replacement of fine aggregate, and up to 60% replacement, concrete gain more modulus of elasticity than normal concrete..
7. It was found that the permeability up to 40 % was decreased and after that the permeability was increased from 50 % to 100% replacement.
8. Replacement of copper slag in fine aggregate reduces the cost of making concrete.

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