Effect of Copper Slag and Recycled Aggregate in the Behaviour of Concrete Composite

B. Vigneshkarthik, S. Selsiadevi, K. Arunadevi, K. Sivagamasundari and T. S. Sangavi
Dept. of Civil Engineering, Parisutham Institute of Technology and Science,
Thanjavur, Tamilnadu

***Abstract* --The development of construction materials have posed problems and challenge that initiated worldwide research programs and continued conventional and non conventional applications leading to ultimate economy. Researchers developed waste management strategies to apply for advantages for specific needs. The use of Copper Slag (CS) in concrete provides environmental as well as economic benefits for all related industries, particularly in areas where a considerable amount of CS is produced. Owing to the scarcity of fine aggregate for the preparation of mortar and concrete, partial replacement of CS with sand have been attempted. CS are byproducts obtained during matte smelting and refining of CS .This work reports an experimental procedure to investigate the effect of using CS and as partial replacement of sand. The strength characteristics of conventional concrete and slag concrete such as compressive strength, tensile strength were found .Six series of concrete mixtures were prepared with different proportions of CS ranging from 0% to 100%. The test results of concrete were obtained by adding CS to sand in various percentages ranging from 0%, 20%. 40%, 60%, 80% and 100%. All specimens were cured for 7, 28, days before compression strength test and splitting tensile test. The results indicate that workability increases with increase in CS percentage. The highest compressive strength obtained was 48MPa (for 100% replacement) and the corresponding strength for control mix was 35MPa. The integrated approach of working on safe disposal and utilization can lead to advantageous effects on the ecology and environmental also. It has been observed that upto 60% replacement, CS can be effectively used as replacement for fine aggregate. Further research work is needed to explore the effect of CS as fine aggregates on the durability properties of concrete.**

Keyword: High compressive strength, workabilityincreases, durability.

I. INTRODUCTION

Concrete's versatility, durability, and economy have made it the world's most used construction material. The India uses about 7.3 million cubic meters of readymixed concrete each year. It is used in highways, streets, parking lots, parking garages, bridges, highrise buildings, dams, homes, floors, sidewalks, driveways, and numerous other applications.

A. Sustainable Development

Is a pattern of resource use that aims to meet human needs while preserving the environment so that these needs can be met not only in the present, but also for future generations. The field of sustainable development can be conceptually broken into three constituent parts: 1.Environmental sustainability. 2. Economic sustainability. 3. Sociopolitical sustainability. Natural resources are depleting worldwide while at the same time the generated wastes from the industry are increasing substantially; the sustainable development for construction involves the use of nonconventional and innovative materials, and recycling of waste materials in order to compensate the lack of natural resources and to find alternative ways conserving the environment. As review of the recent research showed that it is possible to utilize industrial byproducts as well as other waste material in the production of normal concrete and high strength concrete when used as partial and/or full replacement of cement or/and aggregate . Also, it has been demonstrated that many of the produced concrete (either normal or HSC) made with wastes and industrial resources possesses superior properties compared with the conventional concrete in terms of strength, performance and durability.CS is a byproduct material produced from the process of manufacturing copper. It is totally inert material and its physical properties are similar to natural sand.

B. Copper Slag

CS used in this work was brought from Sterlite Industries Ltd(SIL), Tuticorin, Tamil Nadu,India. SIL is producing CS during the manufacture of copper metal. Currently, about 2600 tons of CS is produced per day and a total accumulation of around 1.5 million tons. This slag is currently being used for many purposes ranging from landfilling to grit blasting. These applications utilize only about 15% to 20% and the remaining dumped as a waste material and this causes environmental pollution. CS is a glassy granular material with high specific gravity. Particle sizes are of the order of sand and have a potential for use as fine aggregate in concrete. In order to reduce the accumulation of CS and also to provide an alternate material for sand, the Sterlite Industries Ltd, proposed to study the potential of CS as replacement material for sand in cement concrete. Many researchers have investigated the use of CS in the production of cement, mortar and concrete as raw materials for clinker, cement replacement, coarse and fine aggregates. The use of CS in cement and concrete

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provides potential environmental as well as economic benefits for all related industries, particularly in areas where a considerable amount of CS is produced and also several researchers have investigated the possible use of CS as fine and coarse aggregates in concrete and its effects on the different mechanical and long term properties of mortar and concrete. While most of the reports point to benefits of using CS as fine aggregates, in some stray cases some negative effects such as delaying of the setting time have also been reported.

II. EXPERIMENTAL PROGRAM

A. Cement

The cement used in this study was 53 grade ordinary Portland cement (OPC).The properties of cement used are given in Table 1.

TABLE1: PROPERTIES OF CEMENT

Sl. No	Descriptions	OPC(53G)
1	Fineness (m^2/kg)	274
2	Normal Consistency (%)	29.0
3	Setting Time (minutes) a)Initial b) Final	a)25 b)300
4	Compressive Strength (MPa) a)7 Days b) 28 Days	a)36 b)53

B. Aggregates

Aggregates used for control concrete were natural river sand and crushed granite aggregate. Coarse aggregates (i.e. 60 % of 20 mm and 40 % of 10 mm) have a specific gravity of 2.65, bulk density 1.6 g/cc respectively.

C. Copper slag

Copper slag from Sterlite Industries India Limited (SIIL), Tuticorin, Tamil Nadu, India was made used.

D. Physical properties of copper slag

The slag is a black glassy and granular in nature and has a similar particle size range like sand. The specific gravity of slag lies between 3.4 and 3.98. The bulk density of granulated copper slag is varying between 1.9 to 2.15 kg/ m3 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 free moisture content present in slag was found to be less than 0.5%. Gradation test was conducted on copper slag and sand showed that both copper slag and sand had comparable particle size distribution. However, it seems that sand has higher fines content than copper slag. Tests to determine specific gravity and water absorption for copper slag and sand were carried out in accordance with ASTM C128. The results presented in Table.1 shows that copper slag has a specific gravity of 3.91 which is higher than that for sand (2.57) and OPC (3.12) which may results in production of HPC with higher density when used as sand substitution. Also**,** Table.2 shows that the measured water absorption for copper slag was 0.16% compared with 1.25% for sand. This suggests that copper slag would demand less water than that required by sand in the concrete mix. Therefore it is expected that the free water content in concrete matrix will increase as the copper slag content increases which consequently will lead to increase in the workability of the concrete.

Table 2: Physical Properties of copper slag

Physical Properties	Sand	Copper Slag
Particle shape	Irregular	irregular
Appearance	Brownish yellow	Black glassy
Type	River sand	Air-cooled
Sp.gravity	2.57	3.91
Percentage of voids	33	43
Bulk density g/cc	1.71	2.08
Finess modulus	2.73	3.47
Angle of internal friction	45°	51° 20’
Ultimate shear stress kg/cm^2	0.299	0.4106
Water absorption %	1.25	0.15 to 0.20
Moisture content %	0.5	0.1
Fineness of copper slag m2 /kg (after grinding)	-----	125

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 fineness of copper slag was calculated as 125 m2/kg. The following Table.2 shows physical properties of copper slag.

E. Chemical analysis of Copper Slag and Portland cement

Chemical analysis of Copper Slag and Portland cement are presented in Table 2. Ordinary Portland cement has a lime content of 63%, whereas copper slag has a very low lime content of <1%. Generally, the free lime content of Copper slag is very low. This indicates that Copper slag is not highly chemically reactive materials in order to be used as cementitious materials. Copper slag must have a sufficient quantity of lime to reach the required rate of hydration and to achieve the required early age strength. Therefore, in this case, in order to increase its Pozzolanic reaction, hydrated lime was added up to 2.0% to the weight of cement. Copper slag has high concentrations of SiO2 and Fe2O3 compared with OPC. In comparison with the chemical composition of natural pozzolans of ASTM C 618-99, the summation of the three oxides (silica, alumina and iron oxide) in copper slag is nearly 95%,(National council for cement and building materials, Ballabgarh)9which exceeds the 70% Percentile requirement for Class N raw and calcined natural pozzolans. Therefore, copper slag is expected to have good potential to produce high quality pozzolans.

III. LABORATORY TESTING PROGRAM

A. Mix design and sample preparation

The basic mix proportions were modified for using CS and FS as a partial replacement for sand. Six Concrete mixes with different proportions of CS and FS ranging from 0% (for the control mix) to 100% were considered. The proportions of fine aggregates mixes are given Table 3. All the mixes were proportioned by the method of absolute volumes considering the specific gravity of the constituent materials. The materials were weighed using a digital balance. The materials were mixed in a pan mixer. The specimens were cured in water after 24 hrs, and then tested in saturated surface dry condition at the required age.

Table 3: Concrete Mixtures with Different Proportions of copper slag with cement

Mix id	**W/C ratio**	**0%**	**20%**	**40%**	**60%**	**80%**	**100%**
Sand kg/m^3	0.48	1.22	0.976	0.732	0.488	0.244	0
Copper slag kg/m^3	0.48	0	0.244	0.488	0.732	0.976	1.22

B. Testing

Compressive strength test were conducted to evaluate the strength development of concrete mix containing CS at the age of 7 & 28 days respectively. The cylindrical specimens were also cast for finding the split tensile strength at 7 & 28 days for each mix specification following the standard test procedure.

C. Effect of CS on the compressive strength of concrete

The average 7 & 28 days compressive strengths and for different concrete mixes are shown in Table 4: The average 7 & 28 days split tensile strengths for different concrete mixes are shown in Table 5:

Table 4: Compressive Strength Test Results

Sl.No	**Mix ID**	**Mix Type**	**Slump (mm)**	**Strength(MPa)**	
				7 days	28 days
1	0%	Control (100% S)	25	25.65	35.66
2	20%	80% S +20%CS	37	26.35	42.06
3	40%	60% S +40%CS	45	26.59	43.46
4	60%	40% S +60%CS	54	28.81	44.56
5	80%	20% S +80%CS	68	31.44	46.66
6	100%	100% CS	82	32.44	48.76

S Sand,CS Copper Slag,

Table 5: Splitting Tensile Strength Test Results

Sl.No	**Mix ID**	**Mix Type**	**Slump (mm)**	**Strength(MPa)**	
				7 days	28 days
1	0%	Control (100% S)	25	3.5	4.75
2	20%	80% S +20%CS	37	3.94	6.70
3	40%	60% S +40%CS	45	4.52	7.60
4	60%	40% S +60%CS	54	4.69	7.90
5	80%	20% S +80%CS	68	5.77	8.45
6	100%	100% CS	82	5.90	8.64

S Sand,CS Copper Slag,

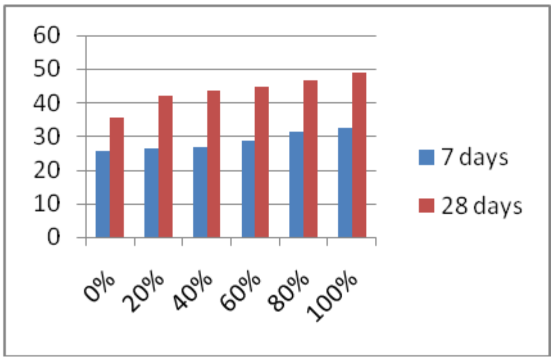

Figure-1 different percentage of CS

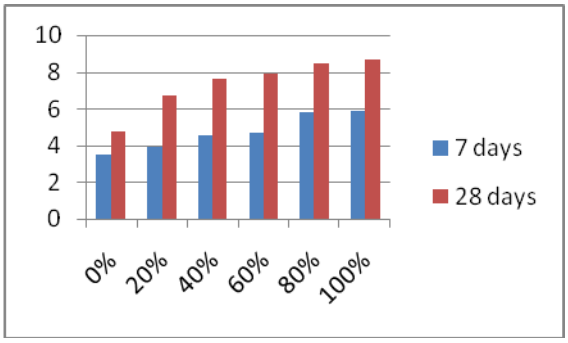

Figure-2 different percentage of CS

The results show that the compressive strength of CS(copper slag) concrete is increased when compared to control concrete (35.66MPa to 48.76MPa cured at 28 days), where as the increase in strength is more or less the same different percentage of CS, as shown in Figure 1 The results show that the split tensile strength of CS concrete is increased when compared to control concrete (4.75 MPa to8.64 MPa cured at 28 days), where as the increase in strength is more or less the same different percentage of CS as shown in Figure 2

The increase in the strength was compared to the control mix. However, the increase in compressive strength of CS based concrete over control concretes was almost of the same order for all CS contents investigated in the study. Therefore, if the concrete mixes are proportioned by absolute volume method and the percentage of replacement of river sand is by mass of the total fine aggregate, the compressive strength is influenced mainly by the percentage of CS.

Compared with OPC concrete, slagcement concrete has a same (or) more longterm compressive strength and split tensile strength. It is shown in Figure 2 & Figure 3 that Compressive Strength Index and Split Tensile Strength Index (where CS are used in proportions of 60% of the total cementitious material) improved the qualities in both plastic and hardened properties of concrete. The slump and bleeding were reduced as the amount of slag increased at low water to cementitious mix ratio.

IV. CONCLUSION

The following conclusions are drawn from the present study:

1. The behavior of CS seems to be similar to river sand for its use as fine aggregate in concrete mixes. However minor adjustment/modifications have to be made in view of the higher specific gravity and rough surface texture and the extent of CS proposed to be used.

2. The CS, as it is, has higher fineness modulus indicating coarser average particle size. Therefore, it may be preferable to avoid the use of CS as the only fine aggregate in concrete mixes; it may be necessary to add conventional sand (and finer materials such as fly ash and stone dust) also in order to improve the particle size distribution of the concrete mix to get the cohesiveness and satisfactory workability.

3. In cases of higher percentage of CS (of the order 60%), finer industrial wastes like quarry dust and fine ash may be gainfully utilized to achieve the necessary particle grading and exclude the possibility of bleeding.

4. Compared to the control mix, the CS based concrete showed an increase in the density up to 20%, whereas the workability was found to be often better for the mixes investigated in the present study.

5. The highest compressive strength obtained was 48.76MPa (100% replacement) and the corresponding strength for control concrete was 35.66MPa.

6. The full replacement of sand by CS yielded higher compressive strength compared to that of the control mix. However, with different replacements, the variation in strength was marginal.

7. With higher levels of replacements (100%) there was a slight bleeding tendency and it is recommended that up to 60% of CS can be used as replacement of sand. The studies show that total replacement of sand by CS is not advisable.

8. Further research work is needed to explore the effect of CS as fine aggregates on the durability properties of concrete.

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