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SAND REPLACEMENT WITH COPPER SLAG ON MECHANICAL PROPERTIES OF CONCRETE

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Abstract-*Research was conducted to investigate the Mechanical properties of concrete which containing copper slag replaced with sand (fine aggregate) and results have been presented in this paper. Two different types of Concrete Grade (M35 & M40) were used with different proportions of copper slag replacement (0 and 40%) in the concrete. Mechanical/ Strength properties such as Compressive Strength, Flexural Strength, UPV(Ultra sonic pulse velocity) for both mixes of concrete. Test results shows that the strength properties of concrete has improved having copper slag as a partial replacement of sand (up to 40%) in concrete.*

Keywords: *Copper slag, Conventional concrete (CC), Copper slag replaced with sand 40% (CS40),Compressive strength, Flexural strength, UPV(Ultrasonic Pulse velocity Test)*

I.

II. INTRODUCTION

Aggregates is the main constitution of Concrete.. Now a days the haphazard use of natural resources, the difficulties create for sand or fine aggregate. So, it is very difficult issue to reduce the use of sand. For this problem many solution has been found out by waste material like ferrous slag, foundry sand, Ground granulated blast furnace slag (GGBS) and many more metal industrial waste. In this research work, we were using Copper slag as partial replacement with sand. Copper slag is the slag which are generated from Copper Industries which has similar physical and chemical properties of sand and utilized as replaced with sand. Copper slag is a by- product obtained during the matte smelting and refining of copper. To produce every ton of copper, approximately 2.2– 3.0 tons copper slag is generated as a by-product material. In India copper slag is produced by many industries one of them is Sterlite Industries Ltd (SIL), Tuticorin Tamil Nadu. It is producing Copper slag during the manufacture of copper metal. Currently, about 2600 tons of Copper slag is produced per day and a total accumulation of around 1.5 million tons. This will helping to resolving the major problem such as depleting the natural resources, major concern of industrial waste disposal and decreased cost of construction. Once the use of this type of slag as partial replacement with sand , it should be required to check its Strength as well as other physical properties.

Table: 1 Copper slag Production in different countries

Country	Copper Smelter Production(million tons)	Copper slag generated(million tons)
China	3.4	8
Japan	1.6	4
Chile	1.5	4
Russia	0.8	1.8
India	**0.7**	**1.6**

(Reference: Properties of Concrete Containing Waste Copper Slag as a Fine Aggregate replacement by Mavroulidou M. & Liya N. C)

II. LITERATURE REVIEW

Al-Jabri et al (2011) investigated the effect of using copper slag as a fine aggregate on the properties of cement mortars and concrete. The results obtained for concrete indicated that there is a slight increase in density of nearly 5% as copper slag content increases. On the other hand, the workability increased significantly as copper slag percentage increased compared with the control mixture. A substitution of up to 40–50% copper slag as a sand replacement yielded comparable strength to that of the control mixture. However, addition of more copper slag resulted in strength reduction due to the increase in the free water content in the mix. Therefore, it was recommended that up to 40–50% (by weight of sand) of copper slag can be used as a replacement for fine aggregates in order to obtain a concrete with good strength and durability requirements.**Binayak Patnaik (2015) studied and an experiment was conducted to investigate the strength and durability properties of concrete having copper slag as a partial replacement of sand (fine aggregate).** Two different types of concrete Grade (M20 & M30) were used with different proportions of copper slag replacement (0 to 50%) in the concrete. Strength and Durability properties such as Compressive strength, Split Tensile Strength & Flexural Strength, Acid Resistivity and Sulphate Resistivity were evaluated for both mixes of concrete. Test results shows that the strength properties of concrete has improved having copper slag as a partial replacement of sand (up to 40%) in concrete however in terms of durability the concrete found to be low resistant to acid attack and higher resistance against Sulphate attack. **Chinmay Buddhadev (2015) review of innovative use of copper slag and foundry sand in design mix concrete.** This study reports the potential use of granulated copper slag as a replacement for sand in concrete mixes. Copper slag is considered as waste material and can be used as replacement of fine aggregates. The possibility of substituting natural fine aggregate with industrial by-products such as waste foundry sand and bottom ash offers technical, economic and environmental advantages which are of great importance in the present context of sustainability in the construction sector. The replacement of river sand by copper slag is possible in concrete mix. For M-20 and M-25 grade concrete, the optimum sand replacement proportion is generally 35-40%. Moreover, generally the sand can be replaced till 50-60% by copper slag in concrete.The replacement of sand by copper slag in concrete increases the compressive strength by 35-40%, split tensile strength by 30-35%. Replacement of sand by copper slag beyond 40-50% leads to decrease strength of concrete. **Binaya et al** reported that when copper slag is partially replaced with sand in M30 Grade concrete, the coefficient of determination for 28 days & 90 days compressive strength found to be 0.9753 and 0.9748 which indicates that the model has a good fit. **K.Sabarishri (2015)** presented that the 28 days compressive strength of concrete mix increases up to 40% of replacement of copper slag and decreases for 50 % replacement of copper slag with fine aggregate. The flexural strength is more for all the proportions of concrete mix and this may be due to toughness of copper slag.The optimum amount of replacement of copper slag for fine aggregate in high performance concrete is 30- 40% (for M45 grade concrete).

III. EXPERIMENTAL MATERIALS AND METHODOLOGY

3.1 Materials

3.1.1 Coarse Aggregate : 20mm size angular crushed granite metal having specific gravity of 2.65 and fineness modulus of 3.08 was used. The water absorption was 1.61%.
3.1.2 Fine Aggregate: River sand having the specific gravity of 2.45 and fineness modulus 3.54 was used. The water absorption was 2.02%.
3.1.3 Cement: 53 Grade OPC having specific gravity of 3.15, standard consistency of 30% was used as per IS 8112-1989.
3.1.4 Copper Slag: Copper Slag with sp. gravity 3.59 and fineness modulus 3.28 was used. The water absorption was 1.81%. As per the chemical analysis of Copper Slag, Silica content and Iron Oxide in Copper Slag was found to be 28.11% and 45% respectively.

3.2 Test Specimens

Test specimens consisting of cube specimens of size 150X150X150 mm and Beam specimen of size 700X150X150 were casted and tested as per IS 516 and 1199.

3.3 Mix Design

Mix Design was done as per the code book, IS: 10262 –1979 and the amount of materials were calculated. Table 3.1 gives the quantities required for M35 and M40 grade of Concrete Mixes. The specimens were casted by replacing fine aggregate 0% & 40 % with copper slag.

3.4 Mixing, Demoulding and Curing

For achieving a good concrete the most important factors are proper mixing and adequate curing which were followed during the casting process. Pan mixture was used for the mixing process and the mixing time was kept for 3-4 minutes. Demoulding was done after 24 hrs of casting. Concrete Cubes were thoroughly cured by using clean water.

Table 2 Physical Properties of Copper Slag

Property	Analysis
Hardness, Moh's Scale	6-7
Specific Gravity	3.51
Plasticity Index	Non-Plastic
Swelling Index	Non-Swelling
Granule Shape	Angular, Sharp edges and Multifaceted
Grain Size Analysis	
Gravel (%)	1.00
Sand (%)	98.90
Silt + Clay (%)	0.05

(Source: Birla Copper Unit, Hindalco's Industries Ltd, Dahej, Gujarat, India) (www.birlacopper.com

Table 3 Chemical Composition of Copper Slag

Property	(%wt.)
Iron Oxide (Fe_2O_3)	42-48
Silica (SiO_2)	26-30
Alumunium Oxide (Al_2O_3)	1-3
Calcium Oxide (CaO)	1-2
Magnesium Oxide (MgO)	0.8-1.5

(Source: Birla Copper Unit, Hindalco's Industries Ltd, Dahej, Gujarat, India) (www.birlacopper.com

Table 4 Mix Design of M-35 grade concrete

Ingredients	Conventional	Copper Slag (40%)
Cement (Kg)	430	430
Water (Lit)	181	181
F.A. (Kg)	794.27	401.55

Copper slag	0	392.72
C.A.(20 mm) (Kg)	651.49	651.49
C.A.(10 mm) (Kg)	468.74	468.74
W/C ratio	0.42	0.42

Table 5 Mix Design of M-40 grade concrete

Ingredients	Conventional	Copper Slag (40%)
Cement (Kg)	455	455
Water (Lit)	182	182
F.A. (Kg)	783.45	396.08
Copper slag	0	387.37
C.A.(20 mm) (Kg)	642.61	642.61
C.A.(10 mm) (Kg)	462.36	462.36
W/C ratio	0.40	0.40

IV. EXPERIMENTAL PROCEDURE

4.1 Mechanical Properties of Concrete

The discussion of the test on fresh concrete as well as hardened concrete are based on the tests such as workability and mechanical properties, which were performed by using copper slag replaced with sand in concrete as well normal mix concrete.

4.1.1 Slump Test: This tests were performed according to IS 7320:1974 to assess concrete workability.

4.1.2 Compressive Strength : 3000 KN capacity Compression testing machine (CTM) was used to measure the compressive strength of concrete. As per IS: 516–1959 [4], loading rate of 2.5kN/s was applied. 150 mm x 150 mm X 150 mm size cubes were used for the testing. Compressive Strength was measured at 28, 56 and 90 days.

4.1.3 Flexural Strength: This test was carried out as per IS- 5816:1999. Beam specimens of 700 mm x 150 mm x 150 mm were used for this testing. Flexural Strength was measured at 28, 56 and 90 days.

4.1.4 UPV (Ultra sonic pulse velocity): This test was conducted as per the procedure given in IS:13311:1992. Ultrasonic Pulse Velocity (UPV) is a non-destructive technique that measures involves measuring the speed of sound through materials inorder to predict material strength, to detect the presence of internal flaws such as cracking, voids, honeycomb, decay and other damage. The time taken for passing the waves from the transmitter to the receiver when kept opposite to each other is recorded.

V. EXPERIMENTAL RESULTS

Test Results of workability and strength properties tests shown in below graph for M35 and M40 grade of Conventional and Copper slag replaced with sand 40%(CS40) concrete.

5.1 Slump test:

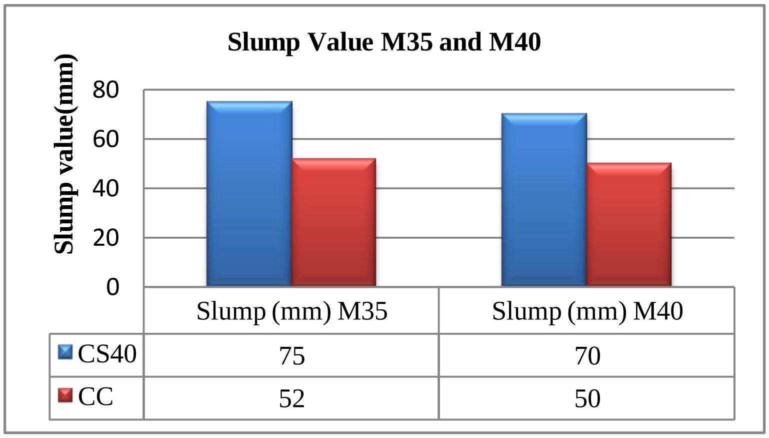

Figure 1 Slump test (M 35 and M40) comparison

5.2 Compressive strength test:

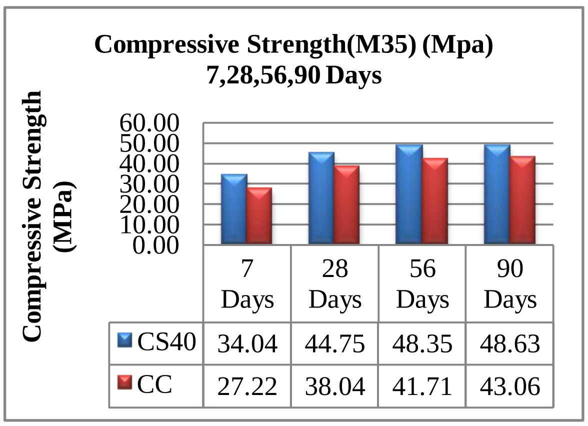

Figure 2 Compressive strength test (M35) comparison

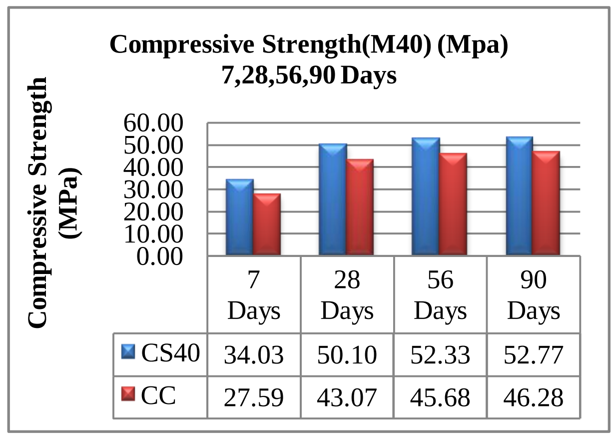

Figure 3 Compressive strength test (M40) comparison

5.3 Flexural strength test:

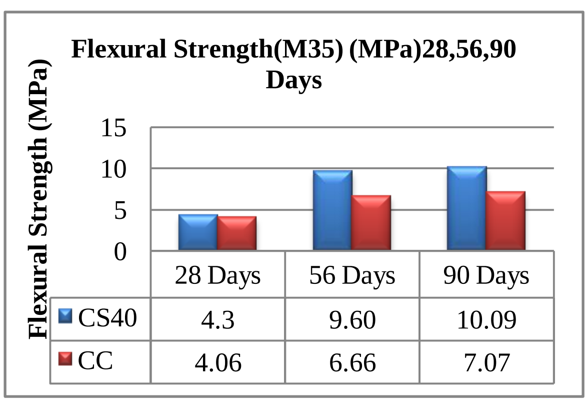

Figure 4 Flexural strength test (M35) comparison

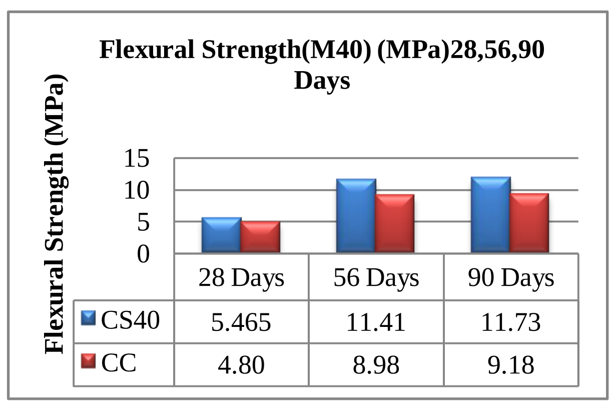

Figure 5 Flexural strength test (M40) comparison

5.4 Ultrasonic Pulse Velocity test:

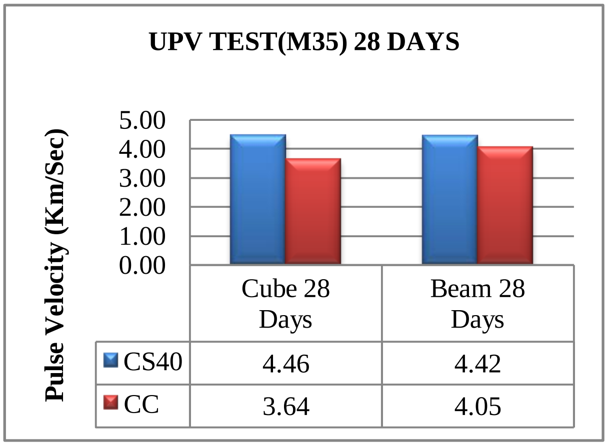

Figure 6 UPV test (M35) comparison

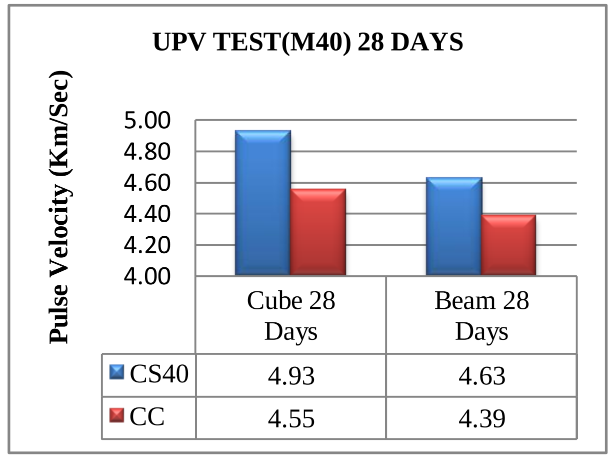

Figure 7 UPV test (M40) comparison

VI. CONCLUSION

The present study investigated the possible use of copper slag (a waste material obtained from Birla Copper Unit, Hindalco's Industries Ltd, Dahej, Gujarat, India) for the partial replacement of sand. Since copper slag is a high density material and contains around 45% of Fe2O3. Based on limited experimental investigations concerning Slump Value, Compressive Strength, Flexural Strength and UPV Test of Concrete for M-35 and M-40 Grade made from Metal industries waste: Copper Slag the following conclusions are drawn out:

1. The utilisation of copper slag in concrete provides additional environmental as well as technical benefits for all related industries. Partial replacement of copper slag in fine aggregate reduces the cost of making concrete.
2. The initial and final setting time of copper slag admixed concrete is higher than control concrete.
3. The results of compressive strength, flexural strength test have shows that the strength of concrete increases with respect to the percentage of copper slag added by the weight of fine aggregate up to 40% (CS40). Further additions of copper slag caused reduction in strength due to an increase of free water content in the mix. There was more than 15% improvement in the Compressive strength of concrete cubes with 40% (CS40) copper slag replacement for sand.
4. There was more than 42% for M-35 and 27% for M-40 grade concrete improvement in the flexural strength of concrete beams with 40% (CS40) copper slag replacement for sand after 56 and 90 days of curing.
5. For control mixes, travel time of ultrasonic waves in Conventional concrete mix is greater and hence pulse velocity in Conventional concrete mix is relatively less when compared to Copper slag replaced with sand 40% (CS40) mix concrete. So, Quality of CS40 mix concrete is better than Conventional concrete.

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