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EFFECT OF COPPER SLAG REPLACED WITH FINE AGGREGATE ON DURABILITY PROPERTIES OF CONCRETE

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Abstract-*Research was conducted to investigate the durabilities studies 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. Durability studies such as Rapid Chlorine Penetration Test (RCPT), Accelerated Corrosion Test, Sorptivity Test, Water absorption test, Acid attack and Sodium Chlorine attack test for both concrete mixes. Test results shows that the Durability properties of concrete has improved in sorptivity and water absorption but it should not able to resist in RCPT and Accelerated corrosion test and result of acid attack and Sodium chlorine attack concrete mix shows weaken strength and considerable weight loss which having copper slag as a partial replacement of sand (upto 40%) in concrete.When copper slag replaced with sand 40% it shows considerable high compressive strength than Conventional Concrete mix (CC).*

Keywords: *Copper slag, Conventional concrete (CC), Copper slag replaced with sand 40%(CS40), Rapid Chlorine Penetration Test (RCPT), Accelerated Corrosion Test, Sorptivity Test, Water absorption test, Acid attack and Sodium Chlorine attack.*

I. INTRODUCTION

In India, there is great demand of aggregates mainly from civil engineering industry for road, Building and any other concrete constructions. 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. Now a days concrete structure is weaken due to durability effects. Durability is the ability to resist weathering action, chemical attacks, Abrasion, Corrosion etc. So, the durability checks of concrete is very important as well as Strength properties or Mechanical properties. In present study we were conclude some durability test on the conventional concrete and Copper slag replaced with sand 40% (CS40) mix.

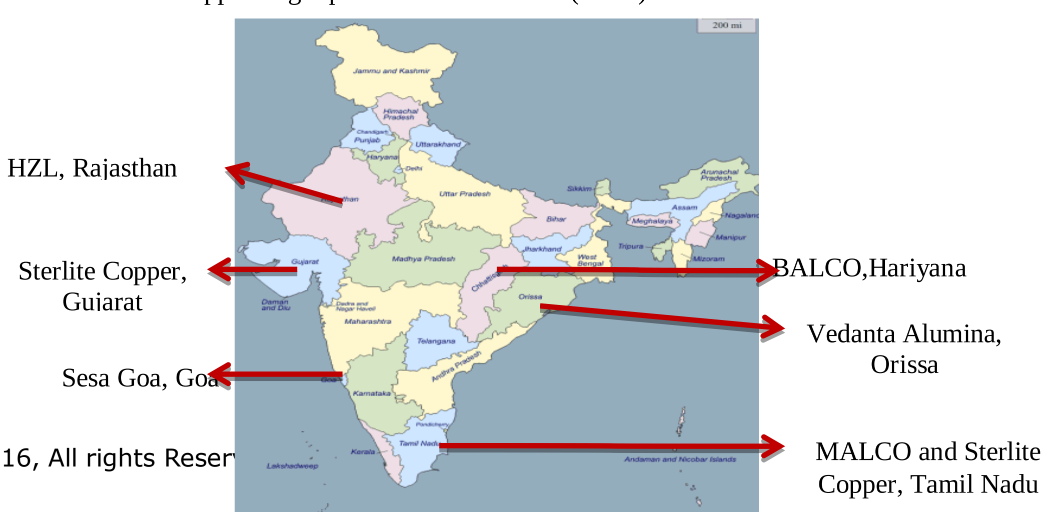

Figure 1 Availability of Copper Slag in India

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. **Najimi et al (2011) investigated the performance of copper slag contained concrete in sulphate solution**. In this regard, an experimental study including expansion measurements, compressive strength degradation and micro structural analysis were conducted in sulphate solution on concretes. This was made by replacing 0%, 5%, 10% and 15% of cement with copper slag waste. The results of this study emphasized the effectiveness of copper slag replacement in improving the concrete resistance against sulphate attack. **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 DETAILS 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 1 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 2 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 3 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 4 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 Durability Properties

The durability of cement concrete is defined as its ability to resist weathering action, chemical attack, abrasion, or any other process of deterioration. Durable concrete will retain its original form, and serviceability when exposed to its environment. When designing a concrete mix or designing a concrete structure, the exposure condition at which the concrete is supposed to withstand is to be assessed in the beginning with good judgment.

4.1.1 Rapid Chloride Permeability Test (RCPT): RCPT containing in this study ASTM C1202, “Standard Indication Test Method for Co Ability to Resist Chloride Ion Penetration. The test method involves obtaining a 100 mm (4 in.) diameter core or cylinder sample from the concrete being tested. A 50 mm (2 in.) specimen is cut from the sample. The side of the cylindrical specimen is coated with epoxy, and after the epoxy is dried, it is put in a vacuum chamber for 3 hours. The specimen is vacuum saturated for 1 hour and allowed to soak for 18 hours. It is then placed in the test device (see test method for schematic of device). The left-hand side (–) of the test cell is filled with a 3% NaCl solution. The right-hand side (+) of the test cell is filled with 0.3N NaOH solution. The system is then connected and a 60-volt potential is applied for 6 hours. Readings are taken every 30 minutes. At the end of 6 hours the sample is removed from the cell and the amount of coulombs passed through the specimen is calculated.

4.1.2 Accelerated corrosion test: Corrosion of steel in concrete is slow process. In this study the procedure as per ASTM G1. For corrosion test the cylindrical specimen of 100mm diameter & 200mm height is taken. While casting, a 25mm rod is placed at the center such that there is 25mm cover at bottom. The test setup that essentially measures resistivity of concrete consists of a constant DC supply providing constant voltage of 60V through a shunt in a constant voltage mode 80mA in constant current mode. The test was carried out in a 3% NaCl solution with an embedded reinforcement bar as a working electrode and a rectangular copper bar as a counter electrode. Set-ups used for inducing reinforcement corrosion through impressed current consist of a DC power source, a counter electrode, and an electrolyte. The positive terminal of the DC power source is connected to the steel bars (anode) and the negative terminal is connected to the counter electrode (cathode).

4.1.3 Sorptivity Test: Sorptivity test carried out for capillary rise absorption rate for concrete structure. Water was used as the test fluid. The specimen were drowned as shown in figure with water level not more than 5mm above the base of specimen and the flow from the peripheral surface is prevented by sealing it properly with non absorbent coating. The quantity of water absorbed in a time period of 6Hrs. was measured by weighing the specimen on a top pan balance weighing up to 0.1mg.Surface water on the specimen was wiped off with a dampened tissue and each weighing operation was completed within 30 seconds. With a space of 15 minutes reading were taken.

4.1.4 Water absorption test: In this investigation the procedure of water absorption test as per BS 1881-122. The 100 mm X 50 mm discs after casting were immersed in water for 28, 56, 90 days curing. These specimens were then oven dried for 24 hours at the temperature 110°C until the mass became constant and again weighed. This weight was noted as the dry weight (W1) of the cube. After that the specimen was kept in water for 24 hours. Then this weight was noted as the wet weight (W2) of the cube.

4.1.5 Acid attack test: This test was carried out on the 150×150×150 mm^3 Concrete cube. Cubes are casted and demoulded after 24 hours and at the ends of 28 days of normal curing period tested. The specimens were taken out from the curing tank and initial weight was taken. 5% of Hydro chloric acid (HCL) and 5% Sulphuric acid (H2SO4) by weight of water was added with water as per earlier investigators.

4.1.6 Chloride attack test: This test was carried out on the 150×150×150 mm^3 Concrete cube. Cubes are casted and demoulded after 24 hours and at the ends of 28 days of normal curing period tested. The specimens were taken out from the curing tank and initial weight was taken. 5% of sodium chloride by weight of water was added with water as per earlier investigators. The concentration of the solution was maintained throughout this period by changing the solution periodically.

V. EXPERIMENTAL RESULTS

Test Results of different durability properties shown in below graphs.

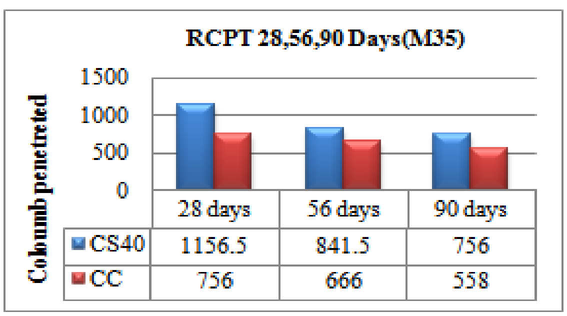

Figure 2 RCPT test (M35) comparison

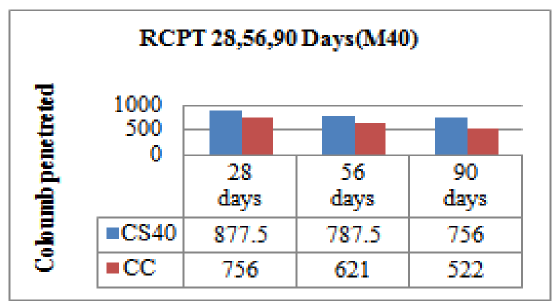

Figure 3 RCPT test (M40) comparison

5.2 Accelerated corrosion test:

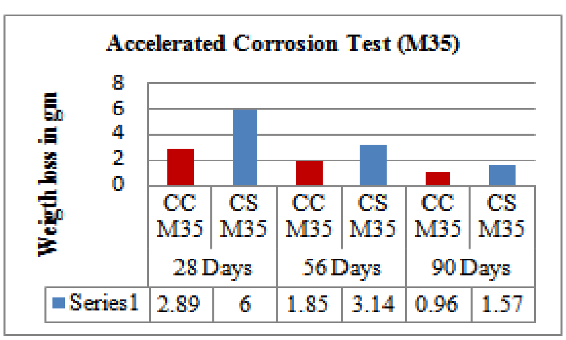

Figure 4 Accelerated Corrosion Test (M35) comparison

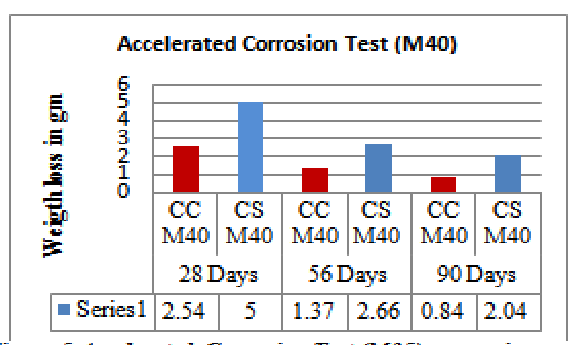

Figure 5 Accelerated Corrosion Test (M35) comparison

5.3 Sorptivity Test:

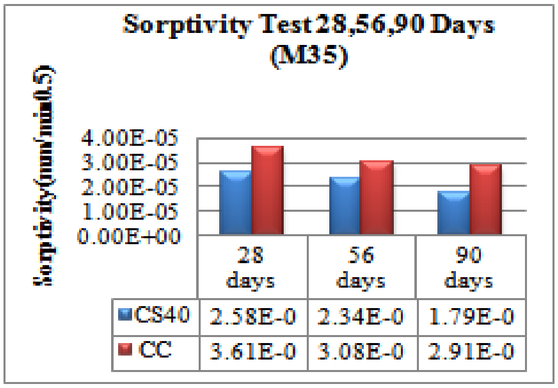

Figure 6 Sorptivity Test (M35) comparison

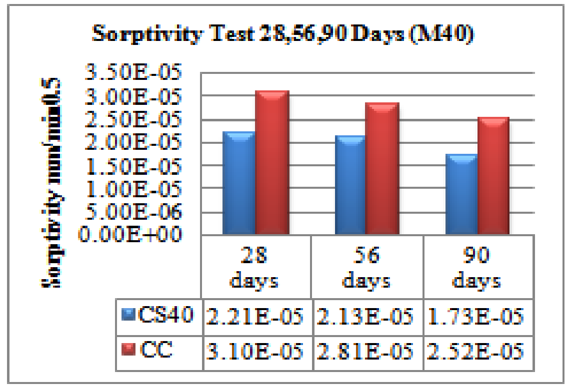

Figure 7 Sorptivity Test (M40) comparison

5.4 Water absorption test:

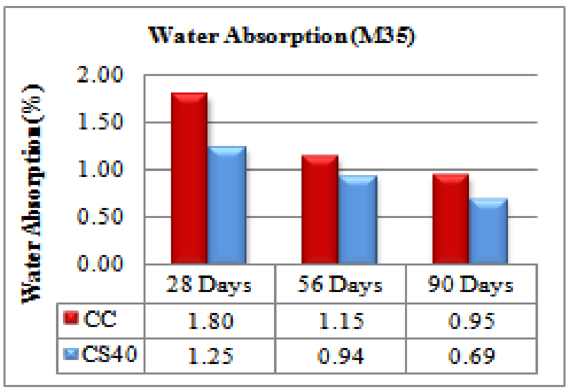

Figure 8 Water Absorption (M35) comparison

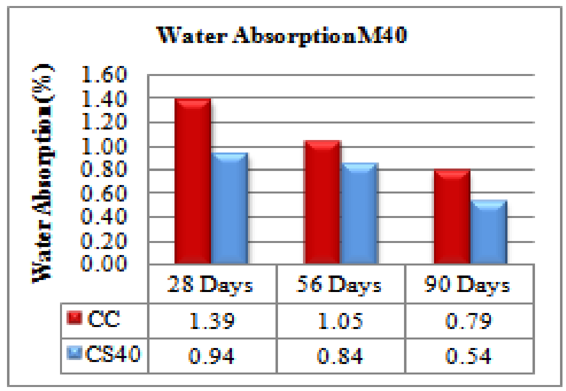

Figure 9 Water Absorption (M35) comparison

Figure 8 Water Absorption (M35) comparison

5.5 Acid attack test:

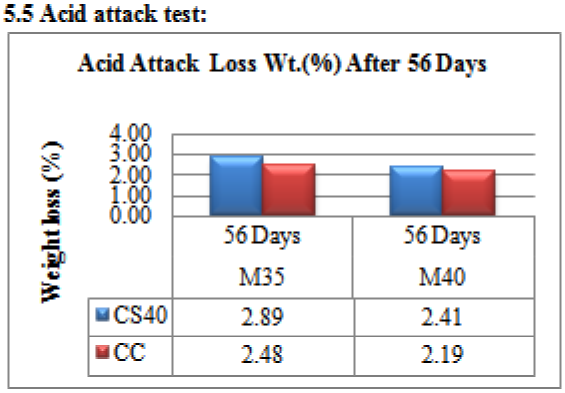

Figure 10 Acid attack weight loss comparison

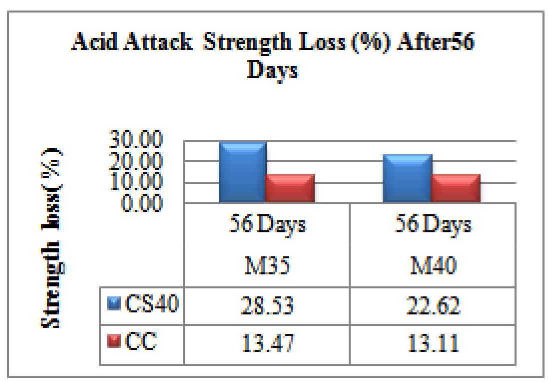

Figure 11 Acid attack strength loss comparison

5.6 Sodium chloride attack test:

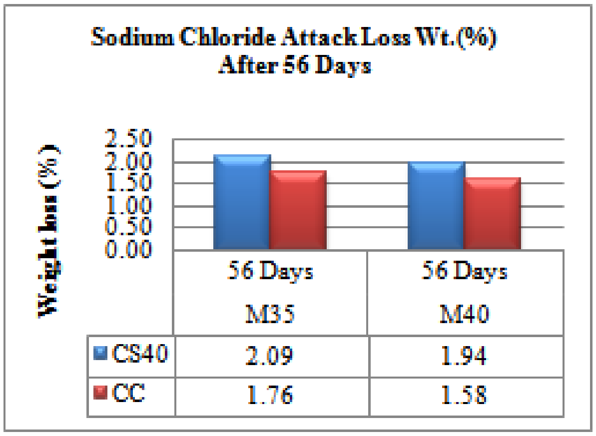

Figure 12 Sodium chloride attack weight loss comparison

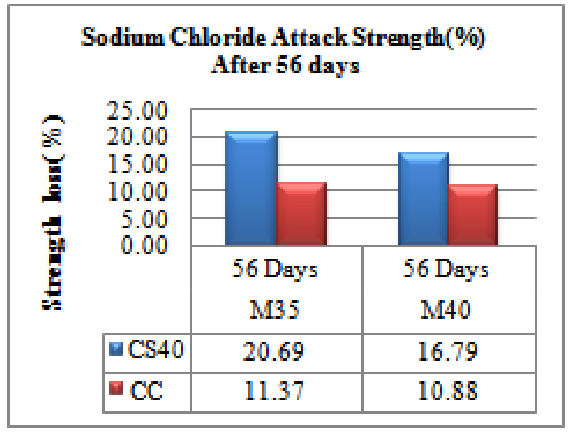

Figure 13 Sodium chloride attack strength loss comparison

VI. CONCLUSION

The present study investigated the optimum use of copper slag in concrete mix and check the durability properties. The comparison of M-35 and M-40 grade conventional concrete mix and Copper slag replaced concrete mix test conclusion explained below.

6.1 Copper Slag replaced with sand (CS40) for M-35 Grade Concrete:

1. In RCPT test, conventional mix, the average charge passed was found to be 558coulombs and for CS40 mix concrete the average charge passed was 756 coulombs after 90 days of curing. The charge passed for copper slag admixed concrete has showed slightly higher values than conventional concrete but within the limits.
2. In Accelerated corrosion test, corrosion rate for CS40 mix concrete is 1.69 and 1.64 times greater than Conventional concrete mix at 56 and 90 days.
3. Copper slag replaced concrete absorb 0.69% water and conventional concrete absorb 0.95% water after 90 days that shows slag replaced concrete lower water absorption than conventional concrete.
4. Acid attack value shows that reduction of weight 2.89% for slag replaced concrete and 2.48% of conventional concrete mix and compressive strength of specimens reduced 28.53% for slag replaced concrete and 13.47% for conventional concrete after 56 days.
5. In Chloride attack test there is a reduction of weight 2.09% for slag replaced concrete and 1.76% for conventional concrete and compressive strength of control specimens reduced 20.69% for slag replaced concrete and 11.37% for conventional concrete after 56 days.

6.2 Copper slag replaced with sand (CS40) for M-40 Grade concrete:

1. In RCPT test, conventional mix, the average charge passed was found to be 522 coulombs and for CS40 mix concrete the average charge passed was 756 coulombs after 90 days of curing. The charge passed for copper slag admixed concrete has showed slightly higher values than conventional concrete but within the limits.
2. In Accelerated corrosion test, corrosion rate for CS40 mix concrete is 1.94 and 2.42 times greater than Conventional concrete mix at 56 and 90days.
3. Copper slag replaced concrete absorb 0.54% water and conventional concrete absorb 0.79% water after 90 days that shows slag replaced concrete lower water absorption than conventional concrete.
4. Acid attack value shows that reduction of weight 2.41% for slag replaced concrete and 2.19% of conventional concrete mix and compressive strength of specimens reduced 22.62% for slag replaced concrete and 13.11% for conventional concrete after 56 days.
5. In Chloride attack test there is a reduction of weight 1.94% for slag replaced concrete and 1.58% for conventional concrete and compressive strength of control specimens reduced 16.79% for slag replaced concrete and 10.88% for conventional concrete after 56 days.

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