STRENGTH AND DURABILITY PROPERTIES OF COPPER SLAG ADMIXED CONCRETE

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Abstract

An experiment was conducted to investigate the strength and durability properties of concrete having copper slag as a partial replacement of sand (fine aggregate) and results have been presented in this paper. Two different types of Concrete Grade (M20 & M30) were used with different proportions of copper slag replacement (0 to 50%) in the concrete. Strength & 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 (upto 40%) in concrete however in terms of durability the concrete found to be low resistant to acid attack and higher resistance against Sulphate attack.

***Keywords**: Copper Slag, Durability, Compressive Strength, Partial Replacement, Flexural Strength, Split Tensile Strength*

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1. INTRODUCTION

River Sand is common form of fine aggregate used in the manufacturing of concrete. However because of increased cost and large scale depletion of sources alternatives for river sand are being considered. There have been many alternative materials with similar physical & chemical properties of Sand found (Lime stone waste, marble powder, furnace slag and welding slag, stone dust etc.) and research have being carried out to check the suitability of its use as partial replacement of sand. Copper Slag is an industrial by-product abundantly available near copper producing industries having similar physical &chemical properties of Sand can be considered as an alternative to the river sand. This will help in resolving a major concern of industrial waste disposal along with decreased cost of construction.

2. LITERATURE REVIEW

Brindha et al studied the strength behavior of concrete where sand was partially replaced with Copper Slag in the concrete manufacturing process. The strength was found to be increasing till 40% of sand replacement with copper slag after which the strength was found to be decreasing. **Brindha and Nagan** studied the durability properties of copper slag admixed concrete and found that the concrete with copper slag has less resistance to the H2So4 solution than the control concrete. **Saveria Monosi et al** studied impact of Foundry Sand in Mortars and Concrete and found structural mortar and concrete can be manufactured with UFS as partial replacement of natural sand. A suitable recycling of the discarded foundry sand as building construction material was suggested. **Ishimaru et al** used class II fly ash and copper slag as fine aggregates in concrete and found that the by substituting copper slag or class II fly ash up to 20% (in volume) as fine aggregates the best results achieved in terms of compressive strength. **Chandana Sukesh et al** investigated the impact of using quarry dust as a partial replacement of sand in concrete and found an improved performance of concrete in terms of compressive strength. **Sreekrishnaperumal Thanga Ramesh et al** used welding slag and furnace slag as partial replacement for sand and found a better performance towards compressive strength. As per the experimental result, 10% of Furnace Slag & 5% of Welding Slag as sand replacement was very effective. **Ion Dumitru et al** did Field Trials Using Recycled Glass as Natural Sand Replacement and powdered glass as Cementitious Materials Replacement in Concrete pavement and found that recycled sand glass can be used to partially replace natural sand in concrete, producing concrete with at least equivalent fresh and hardened properties. **Omar M. Omara et al** used marble powder and limestone waste as partial replacement material for sand and found that compressive strength of the concrete increases with increase in the percentages of M.P additions at all curing ages. **Al-Jabri et al** used Cement by-Pass Dust (CBPD) and Copper Slag as partial replacement of cement in mortar preparation. The optimum strength achieved with 95% cement +5% CBPD mix and 1.5% CBPD + 13.5 CS + 85% cement mix. **Washington Almeida, Moura et al** studied the strength properties of concrete when copper slag was used as a partial replacement of the sand and found an increased compressive, split tensile strength. It also showed a decreased carbonation depth which shows an improved durability quality. **Binaya et al** reported that sand can be partially replaced with copper slag in concrete manufacturing process and for M20 Grade mix the maximum strength can be attained with 40 % of Copper

Slag replacement. **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.

3. EXPERIMENTAL DETAILS

3.1 Materials

3.1.1 Coarse Aggregate

20mm size angular crushed granite metal having specific gravity of 2.6 and fineness modulus of 7.1 was used. Bulk Density in loose state and compacted state were found to be 1414 kg/m^3 and 1550 kg/m^3 respectively. The water absorption was 1.1%.

3.1.2 Fine Aggregate

River sand having the sp.gravity of 2.6 and fineness modulus 2.4 was used. The Bulk Density in loose state and compacted state were found to be 1597 kg/m^3 and1700kg/m^3 respectively. The water absorption was 1.20%.

3.1.3 Cement

53 Grade OPC having specific gravity of 3.094, fineness modulus of 4.62% and normal consistency of 32% was used. As per IS 4031-1988, various tests were conducted to check the quality of cement and confirmed to specifications of 12269-1987.

3.1.4 Copper Slag

Copper Slag with sp. gravity 3.47 and fineness modulus 3.3 was used. Bulk Density in loose state and compacted state was found to be 1898 kg/m^3 and 2024 kg/m^3 respectively. The water absorption was 0.24%. As per the chemical analysis of Copper Slag, Silica content in Copper Slag was found to be 33.52%.

3.1.5 Test Specimens

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

3.2 Mix Design

Mix Design was done as per the code book, IS: 10262 – 1979 and the amount of materials were calculated. Table 1.0 gives the quantities required for M20 and M30 grade of Concrete Mixes. The specimens were casted by replacing fine aggregate from 0% & 40 % with copper slag.

3.3. 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.

4. EXPERIMENTAL PROCEDURE

4.1 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 and 90 days.

4.2 Split Tensile Strength

This test was carried out on a universal testing machine (UTM) of capacity 1000kN. As per IS: 516–1959 [4] loading rate of 2.5kN/s was applied. Cylinder specimens (size 150 mm diameter X 300 mm long) were used for this testing. Split Tensile Strength was measured at 28 and 90 days.

4.3 Flexural Strength

This test was carried out as per IS – 516:1964. Beam specimens of 100 mm x 100 mm x 500 mm were used for this testing. Flexural Strength was measured at 28 and 90 days.

4.4 Durability

4.4.1 Test of Sulphate Resistance on Copper Slag Admixed Concrete

Sulphate resistance of concrete is determined by immersing test specimens of size 100 X100 X 100 mm cubes in 10% sodium sulphate. The deterioration of specimens was presented in the form of percentage reduction in weight and percentage reduction in compressive strength of concrete specimens at 28 and 56days.

4.4.2 Test of Acid Attack Copper Slag Admixed Concrete

Acid attack is determined by immersing test specimens of size100 X100 X 100 mm cubes in 10% H2So4 solution and 10%HCl solution respectively. The deterioration of specimens was presented in the form of percentage reduction in weight and percentage reduction in compressive strength of concrete specimens at 28 and 56days.

5. DISCUSSION OF RESULTS

5.1 Compressive Strength

From the Tables 2.0, it can be observed that by partially replacing sand with copper slag up to 40%, the compressive strength of concrete increased. For M20 Grade Mix Concrete (40% of copper slag replacement), the compressive strength at 28 & 90 days were 41.05 N/mm2 and 55.17 N/mm2 compared with 36.8 N/mm2 and 44.34

N/mm2 for the control mixture. For M30 Grade Mix Concrete (40% of copper slag replacement), the compressive strength at 28 & 90 days were 47.41 N/mm2 and 57.24 N/mm2 compared with 41.16 N/mm2 and 51.28 N/mm2 for the control mixture. These variations are shown in fig 1.0. Copper Slag has a lower water absorption capacity when compared with Sand. The lower water absorption capacity causes increased free water content there by decrease in Compressive Strength. This further causes increase in the workability.

5.2 Split Tensile Strength

Split Tensile Strengths for M-20 and M-30 concrete are as shown in Table 3.0. For M20 Grade Mix Concrete (40% of copper slag replacement) the 28 days and 90 days Split Tensile strength were 2.204 N/mm2 and 2.58 N/mm2 compared with 2.17 N/mm2 and 2.3 N/mm2 for the control mixture. For M30 Grade Mix Concrete (40% of copper slag replacement), the 28 days and 90 days Split Tensile strength were 2.982 N/mm2 and 3.67 N/mm2 compared with 2.924 N/mm2 and 3.3 N/mm2 for the control mixture. They are also plotted pictorially as shown in fig. 2.0. The results shows that compared to control concrete the Copper slag mixed(40%) concrete has higher Split Tensile strength the 28-Day and 90-Days.It was also observed that the, early strength gain for Copper slag admixed concrete is less compared to the control concrete. This property was observed for both M-20 and M-30 concrete.

5.3 Flexural Strength

The results of Flexural Strengths for M-20 and M-30 concrete are as shown in Table 4.0. For M20 Grade Mix Concrete (40% of copper slag replacement) the 28 days and 90 days Flexural strength were 4.747 N/mm2 and 5.74 N/mm2 compared with 4.44 N/mm2 and 5.31 N/mm2 for the control mixture. For M30 Grade Mix (40% of copper slag replacement), the 28 days and 90 days Flexural strength were 5.28 N/mm2 and 6.41 N/mm2 compared with 4.87 N/mm2 and 5.83 N/mm2 for the control mixture. They are also plotted pictorially as shown in fig. 3.0. The results show that at 28 & 90 days is Copper slag mixed (40% replacement) concrete has a higher Flexural Strength than the control concrete.

5.4 Durability

5.4.1 Acid attack of Concrete Specimens (H2SO4)

5.4.1.1 Loss of Weight (In %) - 10 % H2So4 Solution Immersion

From table 5.0 it can be observed that for M20 grade mix the percentage loss of weight for controlled mix is 19.68 % for 28 days, 22.35 % for 56 days while for 40% of copper slag replacement the percentage loss of weight is 13.16 % for 28 days, 14.92 % for 56 days. For M30 grade mix the percentage loss of weight for controlled mix is 13.985 % for 28 days, 17.01 % for 56 days while for 40% of copper slag replacement the percentage loss of weight is 7.409 % for 28 days, 11.27 % for 56 days. The percentage weight loss is observed to be increasing in correspondence with time. The behavior is given in fig 4.

5.4.1.2 Loss of Compressive Strength (In %) - 10 % H2So4 Solution Immersion

From table 6.0 it can be observed that for M20 grade mix the percentage loss of compressive strength for controlled mix is 19.02% for 28 days, 38.21 % for 56 days respectively while for 40% of copper slag replacement the compressive strength loss is 51.38 % for 28 days, 64.99 % for 56 days respectively. For M30 mix, the % loss of compressive strength for controlled mix is 21.55 % for 28 days, 39.19 % for 56 days respectively while for 40% of copper slag replacement the compressive strength loss is 53.15 % for 28 days, 67.14 % for 56days respectively. The behavior is given in fig 5.

The test result indicates that the concrete with copper slag has lesser in resistance to the H2So4 solution than the control concrete. Therefore, the following conclusions were made on acid attack. The concrete prepared with copper slag showed relatively higher mass change. Although both control and copper slag concrete suffered slight mass losses during the early periods, the overall loss in mass of the copper slag replaced specimens was much higher. All concrete specimens get affected by acid attack. The outer portion of cubes gets destroyed and there is a maximum reduction of 3mm at all sides for all specimens. Control specimens showed higher resistance to acid attack than copper slag replaced specimens. So the conclusion is made that controlled specimen has higher resistance to acid attack compared to copper slag admixed concrete.

5.4.2 Acid attack of Concrete Specimens (HCl)

5.4.2.1 Loss of Weight (In %) - 10 % HCl Solution Immersion

From table 5.0 it can be observed that for M20 grade mix the percentage loss of weight for controlled mix is 7.695 % for 28 days, 10.03 % for 56 days while for 40% of copper slag replacement the percentage loss of weight is 6.629 % for 28 days, 8.83 % for 56 days. For M30 grade mix the percentage loss of weight for controlled mix is 3.75 % for 28 days, 6.64 % for 56 days while for 40% of copper slag replacement the percentage loss of weight is 2.769 % for 28 days, 3.73 % for 56 days. The percentage weight loss is observed to be increasing in correspondence with time. The behavior is given in fig 6.

5.4.2.2 Loss of Compressive Strength (In %) - 10 % HCl Solution Immersion

From table 6.0 it can be observed that for M20 grade mix the percentage loss of compressive strength for controlled mix is 8.23 % for 28 days, 27.39 % for 56 days respectively while for 40% of copper slag replacement the loss in compressive strength is 41.42 % for 28 days, 53.25 % for 56

days respectively. For M30 grade mix controlled concrete the % loss of compressive strength is 11.13 % for 28 days, 28.16 % for 56 days respectively while for 40% of copper slag replacement the loss in compressive strength is 42.73 % for 28 days, 61.13 % for 56 days respectively. The behavior is given in fig 7.

The percentage loss is observed to be increasing in correspondence with time. Control specimens showed higher resistance to HCl acid attack than copper slag replaced specimens. Deterioration of concrete was not occurring due to HCl attack. There will not be any considerable reduction in mass due to HCl attack.

5.4.3 Sulphate attack of Concrete Specimens (Na2So4)

5.4.3.1 Loss of weight (In %) - 10 % Na2So4Solution Immersion

Table 5.0 shows the percentage loss of weight is Nil. This shows that Copper slag admixed concrete have the resistance against Na2So4 solution.

5.4.3.2 Loss of Compressive Strength (In %) - 10 % Na2So4 Solution Immersion

Table 6.0 shows the percentage loss of compressive strength is Nil. Deterioration of concrete was not occurring due to sulphate attack. There will not be any considerable reduction in mass due to sulphate attack.

6. CONCLUSION

- Cost of Concrete production reduces when Copper Slag is used as a fine aggregate in concrete.
- High toughness of Copper Slag attributes to Increased Compressive strength.
- Due to low water absorption, coarser (in nature than sand) and glassy surface of Copper slag the workability of Concrete increased substantially with increase of Copper Slag content in the concrete mixture.
- Use of copper slag helps in waste management and dumping industrial wastes.
- Copper Slag behaves similar to River Sand as it contains Silica (SiO2) similar to sand.
- Addition of Copper Slag increases the density of concrete thereby increasing the Self-weight.
- The water absorption of Copper Slag was measured to be 0.24% which is less than that of Natural Sand (1.2%). Because of this Copper Slag would demand less water compared to sand in concrete mix. Hence as the Copper slag content increases in the concrete the free water content in concrete matrix also increases which leads to increased workability.
- The Compressive Strength of Concrete with partial replacement of Sand with Copper Slag up to 40% can be comparable with control mix. However with increased copper slag content there by increased free water content the compressive strength decreased**.**
- Acid resistance test showed that the concrete containing copper slag has a low resistance to H2So4 and HCl solution than the control concrete
- Concrete with Copper slag as Partial replacement of Sand shows good resistance to sulphate attack.

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TABLES

Table 1: Concrete Mix Design Details – M20 &M30 Mix

Grade	% of Copper Slag	Cement in kg	Fine Aggregate in kg			20mm Metal in kg	Water in kg
			Natural Sand	Copper Slag	Total FA		
M20	0%	320	712	0	712	1178	176
	40%	320	640.8	71.2	712	1178	176
M30	0%	350	703.6	0	703.6	1164	175
	40%	350	422.16	281.44	703.6	1164	175

Table 2: Compressive Strength of M20& M30 Mix Copper Slag Admixed concrete

Grade of Concrete	Days	Compressive Strength (N/mm2)	
		0% Copper Slag Replacement	40% Copper Slag Replacement
M20	28	36.8	41.05
	90	44.34	55.17
M30	28	41.16	47.41
	90	51.28	57.24

Table 3: Split Tensile Strength of M20& M30 Mix Copper Slag Admixed concrete

Grade of Concrete	Days	Split Tensile Strength (N/mm2)	
		0% Copper Slag Replacement	40% Copper Slag Replacement
M20	28	2.171	2.204
	90	2.39	2.58
M30	28	2.924	2.982
	90	3.34	3.67

Table 4: Flexural Strength of M20& M30 Mix Copper Slag Admixed concrete

Grade of Concrete	Days	Flexural Strength (N/mm2)	
		0% Copper Slag Replacement	40% Copper Slag Replacement
M20	28	4.44	4.747
	90	5.31	5.74
M30	28	4.87	5.28
	90	5.83	6.41

Table 5: Percentage Loss of Weight of Copper Slag Admixed concrete

Grade of Concrete	% of Copper Slag	10% HCl Solution		10% Na2So4 Solution		10% H2So4 Solution	
		28 days	56 days	28 days	56 days	28 days	56 days
M20	0%	7.695	10.03	0	0	19.68	22.35

M20	40%	6.629	8.83	0	0	13.16	14.92
M30	0%	3.750	6.64	0	0	13. 985	17.01
M30	40%	2.769	3.73	0	0	7.409	11.27

Table 6: Percentage Loss of Compressive Strength of Copper Slag Admixed concrete

Grade of Concrete	% of Copper Slag	10% HCl Solution		10% Na2So4 Solution		10% H2So4 Solution	
		28 days	56 days	28 days	56 days	28 days	56 days
M20	0%	8.23	27.39	0	0	19.02	38.21
M20	40%	41.42	53.25	0	0	51.38	64.99
M30	0%	11.13	28.16	0	0	21.55	39.19
M30	40%	42.73	61.13	0	0	53.15	67.14

GRAPHS

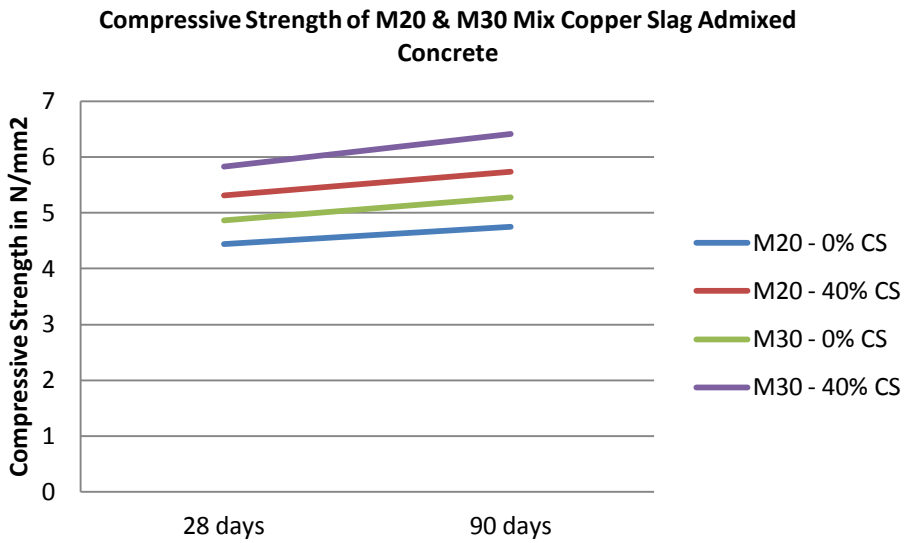

Fig. 1: Compressive Strength - M20 & M30 Grade Mix with0 % and 40 % of Copper Slag Replacement at 28 and 90 days

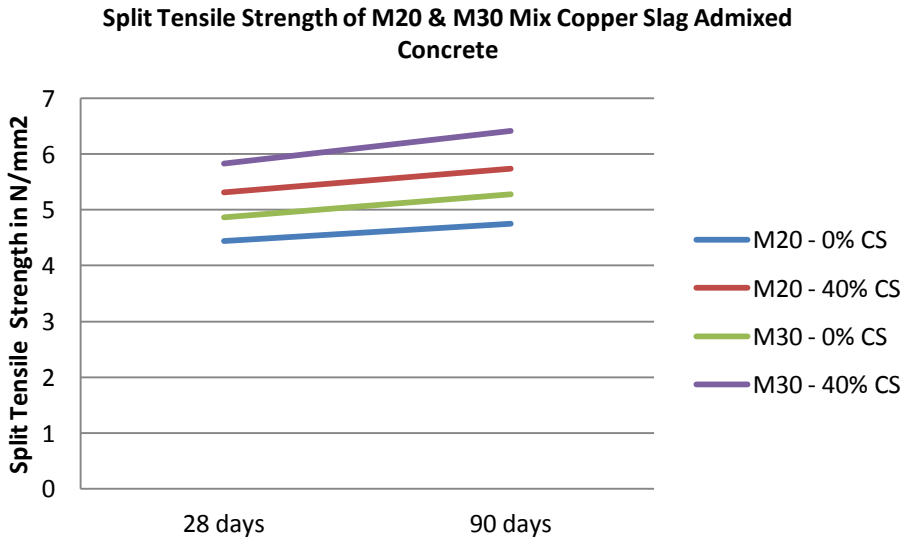

Fig. 2: Split Tensile Strength - M20 & M30 Grade Mix with0 % and 40 % of Copper Slag Replacement at 28 and 90 days

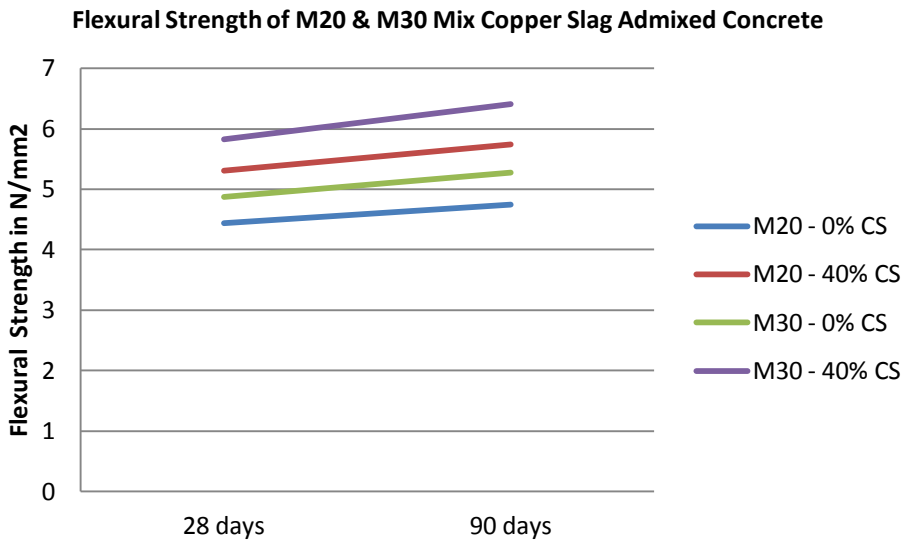

Fig. 3: Flexural Strength - M20 & M30 Grade Mix with0 % and 40 % of Copper Slag Replacement at 28 and 90 days

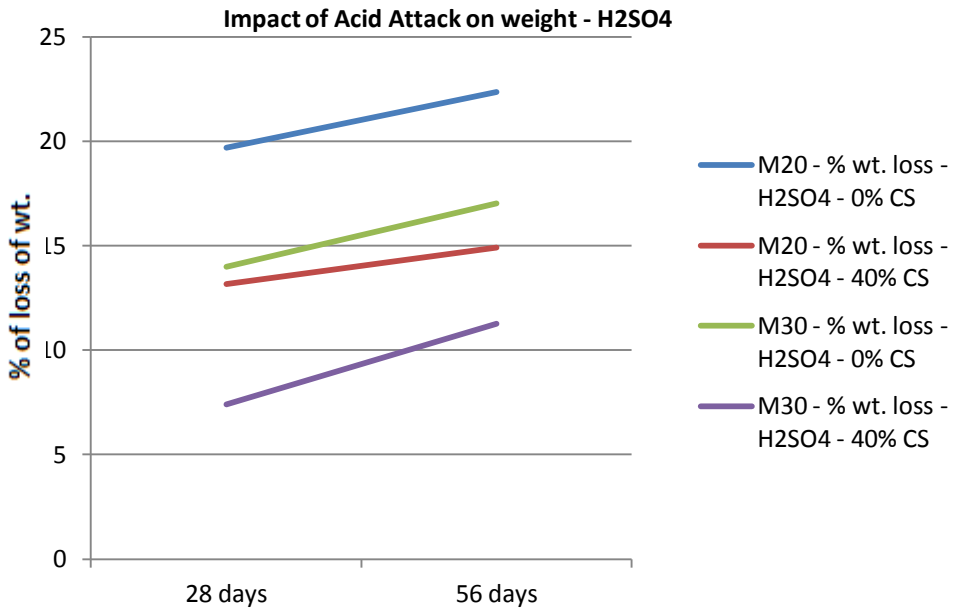

Fig. 4: Impact of Acid Attack (H2SO4) on weight - M20 & M30 Grade Mix with 0 % and 40 % of Copper Slag Replacement at 28 and 56 days

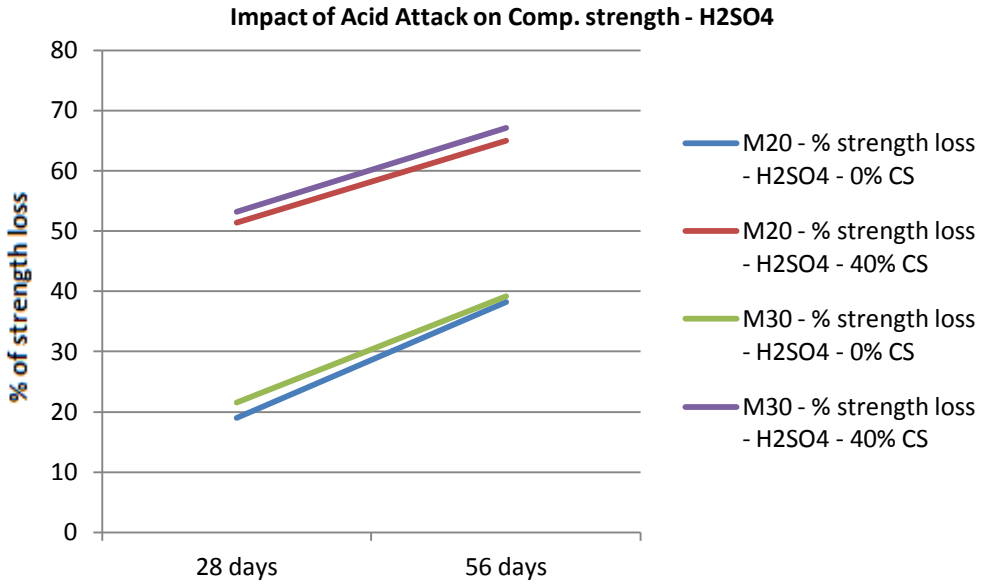

Fig. 5: Impact of Acid Attack (H2SO4) on Compressive Strength - M20 & M30 Grade Mix with 0 % and 40 % of Copper Slag Replacement at 28 and 56 days.

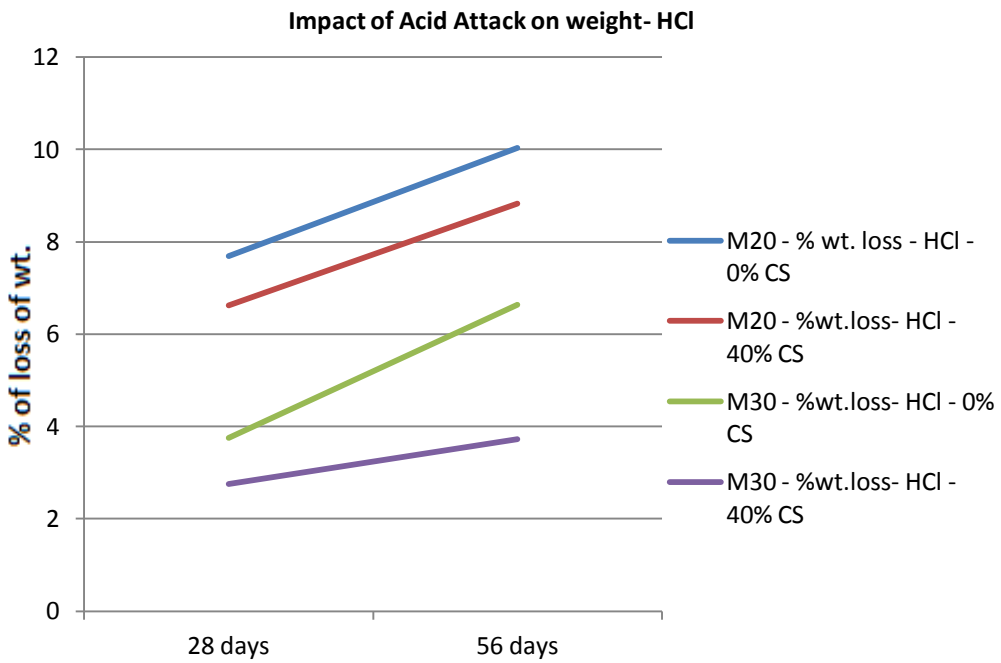

Fig. 6: Impact of Acid Attack (HCl) on weight - M20 & M30 Grade Mix with 0 % and 40 % of Copper Slag Replacement at 28 and 56 days

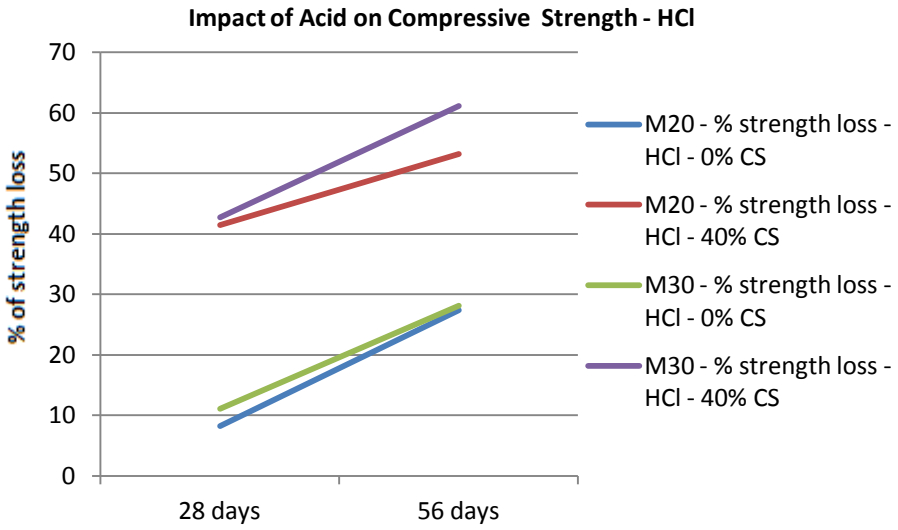

Fig. 7: Impact of Acid Attack (HCl) on Compressive Strength - M20 & M30 Grade Mix with 0 % and 40 % of Copper Slag Replacement at 28 and 56 days

BIOGRAPHIES

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