Evaluation on Accelerated Corrosion Properties of the Concrete Produced by Replacing Sand by Copper Slag

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Abstract— *Copper slag is one of waste materials in the creation of copper, which can be utilized as fractional substitution of fine totals in concrete. This report shows the consequences of an exploratory study on different sturdiness tests on concrete containing mineral admixtures and copper slag as fractional substitution of cement and sand individually. In this report, M30 evaluation of concrete was planned and tests were directed with diverse rates of mineral admixtures with copper slag. The compressive strength is increased up to 10-20% mix of mineral admixture and copper slagged concrete when contrasted with normal concrete. Accelerated corrosion process by Galvano-static weight loss method is done to know the corrosion rate of concrete.*

Keywords— Copper slag, Mineral admixtures, Accelerated corrosion process, Galvano-static weight loss method.

I. INTRODUCTION

Concrete will be a generally utilized development material for different sorts of structures because of its strength. For the continued time, it was advised to be extraordinarily intense material obliging a little or no upkeep. In the late amendment of IS:456-2000, one of the major focuses talked about will be the strength angles of cement. The utilization of cement is unavoidable, in the meantime the shortage of aggregates are likewise expanding these days. Use of mechanical soil decay or abetting abstracts has been accurate in development acreage for the bearing of cement and concrete on the area that it contributes to abbreviating the appliance of accepted assets. For abundant years, by-products such as fly ash, silica fume and slag were beheld as decay materials. They accept been finer activated as a allotment of the development industry for abridged or abounding barter for accomplished and base totals. A allotment of the by-products are additionally activated as a Portland adhesive acting [1].

Total, which makes up to 70 % of solid volume, is of the essential constituent materials in solid generation. Then again, because of the top amount of normal sand utilized as a fine total and the rising accentuation on supportable development, there is requirement for development business to hunt down option materials as the fine totals in concrete. The industrial waste, copper slag is created in extraction procedure of copper in the refinery plant, has ease and it's application as fine total in concrete generation have numerous ecological benefits, for example, waste reusing and tackles transfer issues. Right now Building Construction Authority of Singapore restrains the substitution of copper slag instead of sand up to 10 % by weight in development designing with extra prudent measures [5].

FIG. 1 COPPER SLAG

Copper Slag (CS) is at present being utilized for numerous purposes from area filling to coarseness impacting. At present, around 2600 tons of CS is delivered every day and an aggregate collection is around 1.5 million tons. These applications use just 16% to 21%, and remaining thing is dumped as waste and that causes natural contamination. CS is shiny granular material and has high particular gravity. Sizes of molecules are of sand and have the potential for utilization as fine total in cement. In request to lessen the aggregation of CS and likewise to give an exchange material for sand. CS is used as trade material for river sand in concrete cement (refer Fig 1).

Numerous analysts have researched the utilization of CS in generation of the concrete, mortar and as a crude material for clinker, cement substitution, fine and coarse totals. The utilization of CS in concrete gives potential, natural as well as monetary advantages for all commercial enterprises, especially in territories where impressive sum of CS will be delivered. Additionally a few specialists have researched conceivable use of CS in the concrete and it's impact on diverse mechanical and long haul properties of concrete and mortar. HPC intended to have coveted higher workability, mechanical properties and more noteworthy toughness than routine cements. The impact of CS as fine total on the execution of ordinary quality cement was increment in the quality and workability. This would likewise lead extra advantages as far as lessening in expense, vitality investment funds, advancing biological offset and protection of normal assets [6].

Mineral admixtures are likewise called as 'Supplementary Cementing Materials'. They are utilized when unique execution is required like, expansion in quality, decrease in water request, impermeability, low warmth of hydration, enhanced solidness, revising lacks in total degree (as fillers), and so forth. These outcome in expense and vitality reserve funds. The substitution of concrete prompts cost reserve funds, and vitality needed to process such materials is likewise much lesser than cement. Natural harm and contamination is minimized and around 7–8% of aggregate CO2 emanation happens from the creation of concrete. Utilization relies on upon the supply, interest strengths and also the business potential and attitudes.

Portland-pozzolanic Cement reactions:

$$C_3S/C_2S + H_2O \longrightarrow C\text{-}S\text{-}H + CH$$

$$CH + \text{Reactive } SiO_2 \longrightarrow \text{Pozzolanic } C\text{-}S\text{-}H$$

The pozzolanic C-S-H is by and large a greater number of permeable than ordinary C-S-H, furthermore has poorer C/S proportion. A pozzolan might likewise have receptive Al2O3, in which response with CH prompts the arrangement of C-A-H, which can offer ascent to issues in the sulfate attack. [11]

Tests with immersed arrangements of sodium chloride (around 5.4 mol/l) on model mortars. No unmistakable assault on mortar blocks could be noted following two years, however the compressive quality of Portland concrete mortar was decreased to around 60 percent of the quality subsequent to putting away in immaculate water. Mortar with impact heater slag concrete with 75 % slag had not lost all that much quality, contrasted and that of the same kind of mortar, put away for the same time (2 years) in water.

The transportation of chloride particles into cement is a confused procedure which includes dissemination, slender suction, saturation and convective course through the pore framework and small scale breaking system, joined by physical adsorption and compound tying. With such a perplexing transportation process, it is important to comprehend individual transport components and the overwhelming transport transform keeping in mind the end goal to pinpoint the fitting strategy for evaluating the chloride resistance. [13]

II. MATERIALS AND METHODOLOGY

This deals with the properties of the materials used, the methodology adopted for mix proportioning of various percentage replacement of river sand by CS and various tests method.

Cement : The cement utilized in this study is 43 grade OPC compatible to IS:8112-1989. The properties of cement used are given in Table 1.

TABLE 1: PROPERTIES OF CEMENT

Sl. No.	Properties	OPC 43(G)
1	Specific gravity	3.15
2	Fineness	4.0 %
3	Soundness	0.5 cm
4	Normal consistency	33.0 %
5	Initial setting time	60 min.
6	Final setting time	480 min.

Coarse aggregate: Locally available coarse aggregates of 20 mm down size and confirming to IS: 383-1970 is used. Results of preliminary tests on coarse aggregates are presented in table 2.

TABLE 2: PROPERTIES OF COARSE AGGREGATE

Sl. No.	Properties	Results
1	Shape of coarse aggregate	Angular
2	Water absorption	0.5 %
3	Specific gravity	2.66

Fine aggregate: Fine aggregates used for conventional concrete are river sand and copper slag. Nearby accessible sand belonging to zone-II of IS: 383-1970 is used. Copper slag is procured from Mythri Metallizing Private Limited, Bangalore, Karnataka, India. The physical features of fine aggregate are presented in table 3.

TABLE 3: PHYSICAL FEATURES OF FINE AGGREGATE

Physical properties	Sand	Copper slag
Particle shape	Irregular	Irregular
Appearance	Brownish yellow	Black & glassy
Type	River sand	Air cooled
Specific gravity	2.64	3.44
Bulk density in g/cc	1.71	1.9
Fineness modulus	2.88	3.47
Water absorption in %	1	0.19
Moisture content in %	0.5	0.033

CS tests were dissected for constituent oxides including minor oxides and overwhelming components other than mineral stages. The consequences of compound examination as given by supplier have indicated in table 4.

TABLE 4: CHEMICAL ANALYSIS OF COPPER SLAG

S. No.	Chemical Component	% of Chemical
1	SiO_2	37.26
2	Fe_2O_3	47.45
3	Al_2O_3	3.95
4	CaO	2.38
5	Na_2O	0.65
6	K_2O	2.62
7	Mn_2O_3	0.086
8	TiO_2	0.33
9	SO_3	2.75
10	CuO	1.12

Water: Consumable water is utilized as a part of the present examination for both casting and curing. The mix design calculation are as per code IS 10262:2009 for M30 grade concrete with replacement of sand by copper slag.

TABLE 5: MIX PROPORTIONS (KG/M3) OF M30 GRADE CONVENTIONAL CONCRETE

Cement (**kg/m^3**)	**Fine aggregate** (**kg/m^3**)	**Coarse aggregate** (**kg/m^3**)	**Water** (**liters**)
425.56	657.87	1128.65	191.5
1	***1.54***	***2.65***	***0.45***

TESTING METHODS: Test for compressive strength of concrete, Density, Split tensile test tests were conducted on standard specimens as per IS guidelines.

Accelerated corrosion process: Galvano static weight loss method (ASTM G-1): Since CS comprises more than 50% of ferrous substance, it is important to discover consumption properties of CS admixed cement. To do as such, the measured TMT steel of 8mm width examples were implanted in solid chamber of size 150 mm distance across and 300 mm stature. The solid examples are exposured to 3.0% NaCl arrangement. Normal D.C power supply of 0.3A is supplied consistently all through the erosion time of 7 days. Positive terminal is joined with the bar with fastened wires and negative terminal is associated with graphite bar. After the procedure of quickened consumption is over, all the examples are disengaged and removed from tank. After the erosion period, the pole will be taken out and weighed. The misfortune in weight is calculated. From the weight misfortune values, the consumption rates were acquired from the relationship,

$$\text{Corrosion Rate} = (K \times W) / (A \times T \times D)$$

Where,

K is a steady, K = 87.6 in the event of communicating Corrosion rate in “mm/yr”

T is the presentation time communicated in "hours"

A is the surface range in "cm2"

W is the mass misfortune in “milli gram”, and

D is the density of the consuming metal (7.85g/cm3).

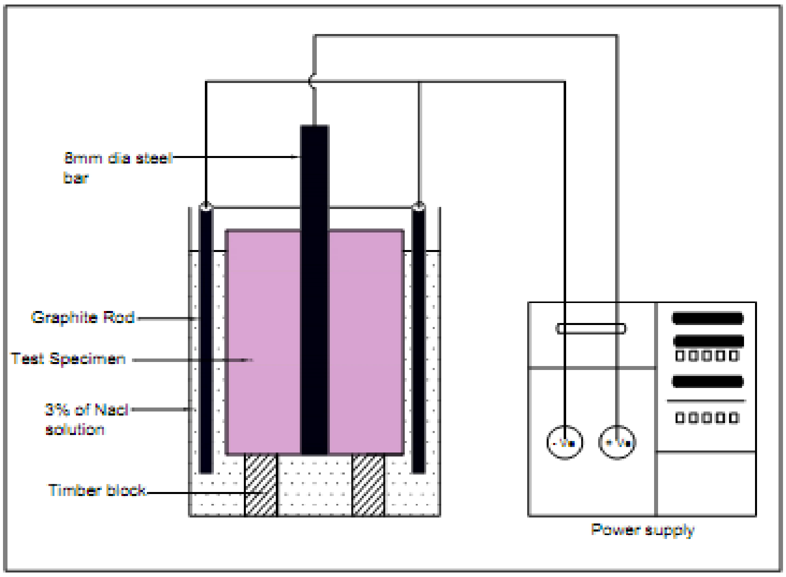


FIG. 2 ACCELERATED CORROSION SET UP

III. EXPERIMENTAL RESULTS

This chapter deals with the test results on compressive strength, density, split tensile test and accelerated corrosion process of concrete containing copper slag and artificial mineral admixtures. Mix proportions have been obtained for M30 grade control concrete as per IS 10262:2009. Then copper slag is replaced by 20 %, 40 %, 60 %, 80 % and 100 % of sand simultaneously with mineral admixture i.e., 5% to 30% of cement in the increment of 5 percent to study compressive strength, density, split tensile strength and corrosion properties.

TABLE 6: OVERALL RESULTS OF DENSITY OF CONCRETE

% replacement of cement by 'mineral	% replacement of natural sand by 'copper slag'	Densities of concrete (N/m^3) with				
		Silica fume	Metakaolin	Rice	Fly ash	GGBS
0%	0%	23771.69	23771.69	23771.69	23771.69	23771.69
5%	10%	24072.04	23965.47	23868.58	23829.82	23795.91
10%	20%	24464.44	24425.69	24236.76	24076.89	23975.16
15%	40%	24537.11	24478.98	24396.62	24246.44	24227.07
20%	60%	25094.22	24895.60	24750.27	24512.89	24406.31
25%	80%	25365.51	25147.51	25094.22	25045.78	24861.69
30%	100%	25675.56	25535.07	25481.78	25457.56	25297.69

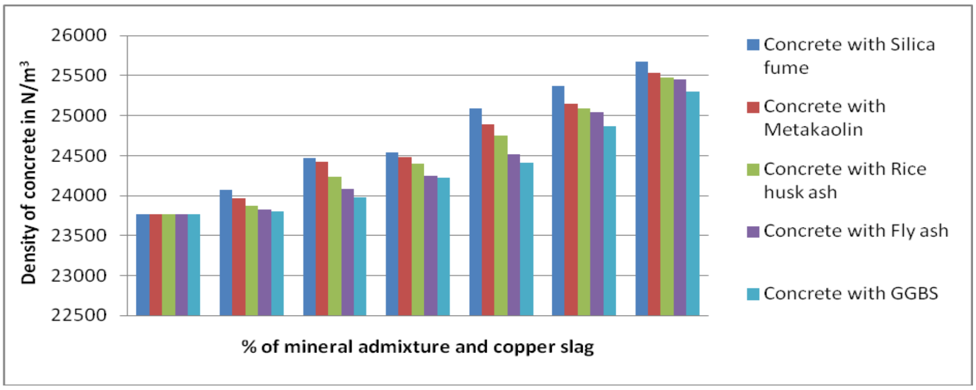
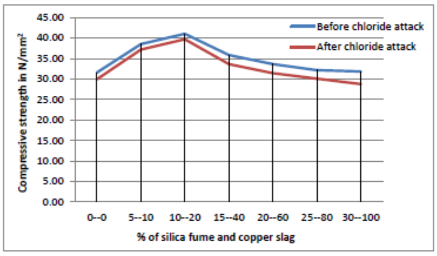
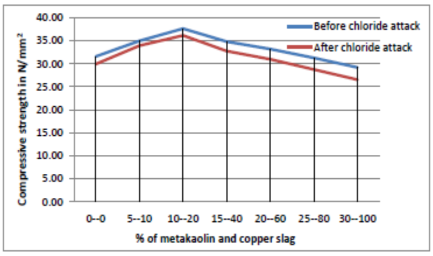


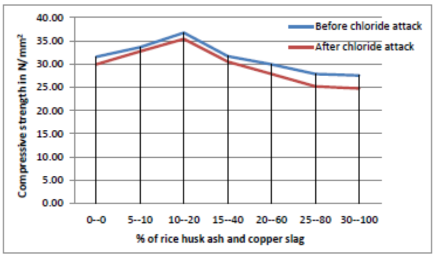
FIG. 3 VARIATION OF DENSITY

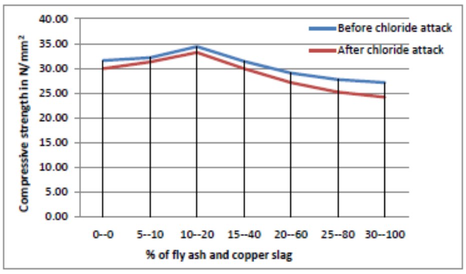
TABLE 7: OVERALL RESULTS OF COMPRESSION STRENGTH

% replacement of cement by 'mineral admixtures'	% replacement of natural sand by 'copper slag'	Compressive strength (MPa) of concrete with														
		Silica fume		% increase/decrease of comp. strength after chloride attack w.r.t ref. mix	Metakaolin		% increase/decrease of comp. strength after chloride attack w.r.t ref. mix	Rice husk ash		% increase/decrease of comp. strength after chloride attack w.r.t ref. mix	Fly ash		% increase/decrease of comp. strength after chloride attack w.r.t ref. mix	GGBS		% increase/decrease of comp. strength after chloride attack w.r.t ref. mix
		Before chloride attack	After chloride attack		Before chloride attack	After chloride attack		Before chloride attack	After chloride attack		Before chloride attack	After chloride attack		Before chloride attack	After chloride attack	
0%	0%	31.56	29.93	-	31.56	29.93	-	31.56	29.93	-	31.56	29.93	-	31.56	29.93	-
5%	10%	38.52	37.19	+24.26	34.96	33.93	+13.37	33.63	32.74	+9.41	32.15	31.26	+4.46	32.00	30.22	+0.99
10%	**20%**	**41.04**	**39.70**	**+32.67**	**37.63**	**36.15**	**+20.79**	**36.74**	**35.41**	**+18.32**	**34.37**	**33.19**	**+10.89**	**32.59**	**30.96**	**+3.47**
15%	40%	35.85	33.63	+12.38	34.81	32.74	+9.41	31.70	30.52	+1.98	31.41	29.93	0.00	30.07	28.59	-4.46
20%	60%	33.63	31.41	+4.95	33.19	30.96	+3.47	29.93	27.85	-6.93	29.04	27.11	-9.41	28.74	26.81	-10.40
25%	80%	32.15	30.07	+0.50	31.26	28.74	-3.96	27.85	25.19	-15.84	27.70	25.19	-15.84	26.67	24.00	-19.80
30%	100%	31.85	28.74	-3.96	29.19	26.52	-11.39	27.56	24.74	-17.33	27.11	24.15	-19.31	26.52	23.70	-20.79









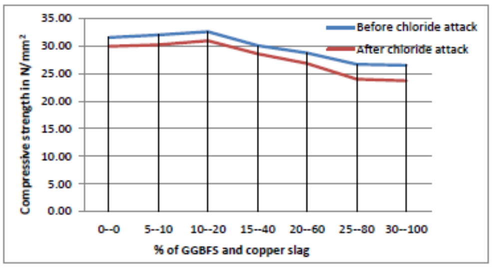
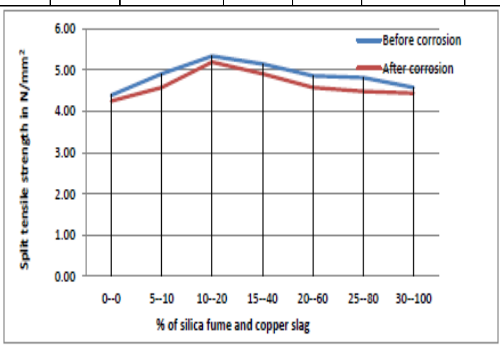
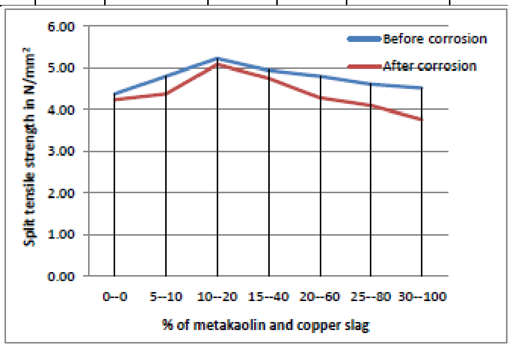
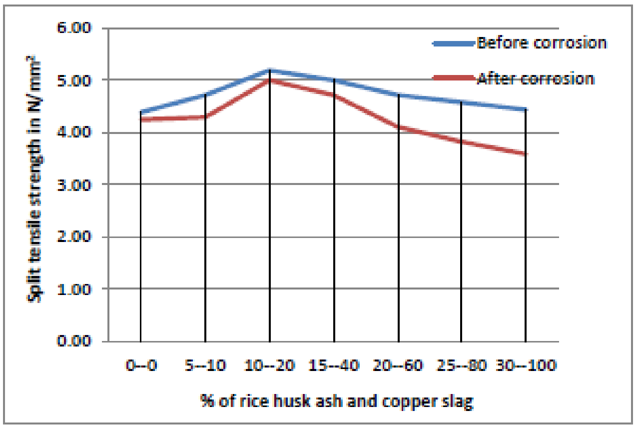


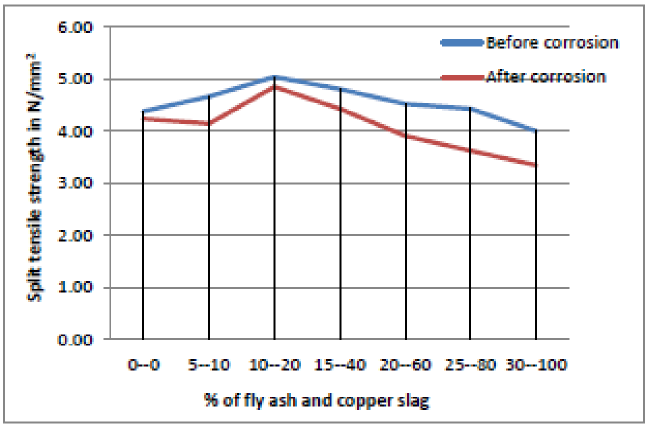
TABLE 8: OVERALL RESULTS OF SPLIT TENSILE TEST

% replacement of cement by 'mineral admixtures'	% replacement of natural sand by 'copper slag'	Split tensile test (MPa) of concrete with														
		Silica fume		% increase/decrease of split tensile strength after corrosion w.r.t ref. mix	Metakaolin		% increase/decrease of split tensile strength after corrosion w.r.t ref. mix	Rice husk ash		% increase/decrease of split tensile strength after corrosion w.r.t ref. mix	Fly ash		% increase/decrease of split tensile strength after corrosion w.r.t ref. mix	GGBS		% increase/decrease of split tensile strength after corrosion w.r.t ref. mix
		Before corrosion	After corrosion		Before corrosion	After corrosion		Before corrosion	After corrosion		Before corrosion	After corrosion		Before corrosion	After corrosion	
0%	0%	4.39	4.24	-	4.39	4.24	-	4.39	4.24	-	4.39	4.24	-	4.39	4.24	-
5%	10%	4.90	4.57	+7.78	4.81	4.39	+3.33	4.72	4.29	+1.11	4.67	4.15	-2.22	4.62	4.05	-4.44
10%	**20%**	**5.33**	**5.19**	**+22.22**	**5.23**	**5.09**	**+20.00**	**5.19**	**5.00**	**+17.78**	**5.05**	**4.86**	**+14.44**	**4.95**	**4.67**	**+10.00**
15%	40%	5.14	4.90	+15.56	4.95	4.76	+12.22	5.00	4.72	+11.11	4.81	4.43	+4.44	4.67	3.87	-8.89
20%	60%	4.86	4.57	+7.78	4.81	4.29	+1.11	4.72	4.10	-3.33	4.53	3.91	-7.78	4.43	3.68	-13.33
25%	80%	4.81	4.48	+5.56	4.62	4.10	-3.33	4.57	3.82	-10.00	4.43	3.63	-14.44	3.91	3.58	-15.56
30%	100%	4.57	4.43	+4.44	4.53	3.77	-11.11	4.43	3.58	-15.56	4.01	3.35	-21.11	3.25	3.02	-28.89









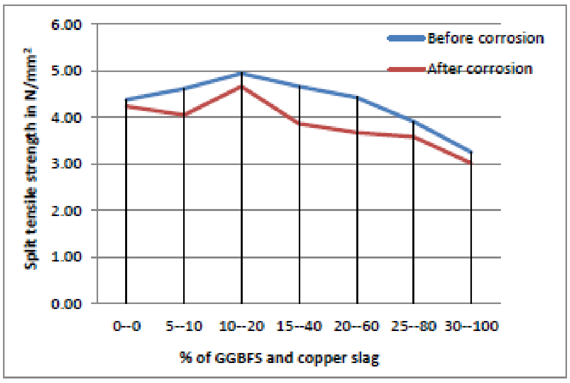


TABLE 9: OVERALL RESULTS OF ACCELERATED CORROSION

% replacement of cement by 'mineral admixtures'	% replacement of natural sand by 'copper slag'	Concrete with				
		Silica fume	Metakaolin	Rice husk ash	Fly ash	GGBS
0%	0%	0.19	0.19	0.19	0.19	0.19
5%	10%	0.48	0.50	0.53	0.57	0.73
10%	20%	0.76	0.88	0.90	0.92	0.97
15%	40%	1.18	1.38	1.42	1.46	1.53
20%	60%	1.59	1.75	1.86	1.98	2.12
25%	80%	2.16	2.40	2.55	2.59	2.71
30%	100%	2.55	2.85	3.16	3.21	3.32

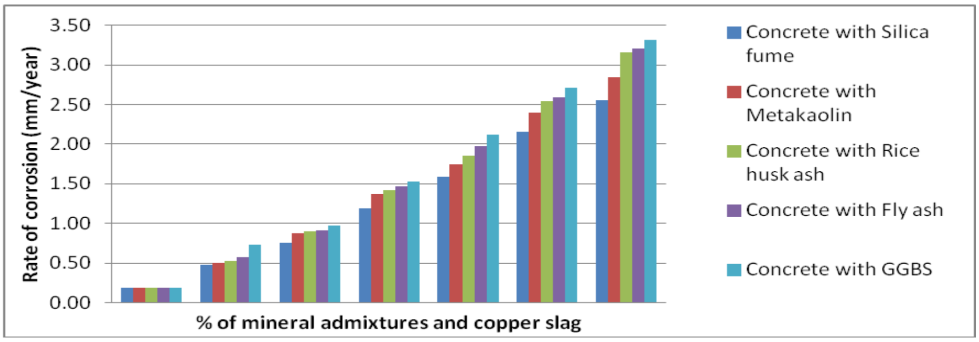


FIG. 4 VARIATION OF CORROSION RATE

IV. RESULTS AND DISCUSSIONS

Following observations were made based on the experimentation conducted on the project of concrete produced by replacing sand by copper slag and cement by mineral admixture when subjected to accelerated corrosion.

1. It is noticed that compressive strength of the concrete produced by replacing 10% cement by silica fume and 20% natural sand by copper slag shown the higher value as compared to other replacements. This was true for concrete before chloride attack and after chloride attack. The concrete which was subjected to chloride attack/accelerated corrosion had shown 32.67% increase in the compressive strength for the above said replacements as compared to reference mix (Table7).

   Similarly it was noticed in case of metakaolin, ricehusk ash, fly ash, GGBFS and whose increase in the compressive strength for the above said replacements as compared to reference mix were 20.79%, 18.32% , 10.89% and 3.47% respectively (Table7).

   This may be because at 10% cement replacement level by different admixtures and 20% natural sand replacement by copper slag, there may be higher pozzzolanic reaction. It may also be because at these replacement levels the concrete pores are filled completely there by arresting the chloride ions to connect rate inside the concrete mass.

2. It was noticed that split tensile strength of concrete produced by replacing 10% cement by silica fume and 20% natural sand by copper slag shown the higher value as compared to other replacements. This was true for concrete before corrosion and after corrosion. The concrete which was subjected to accelerated corrosion has shown 22.22% increase in the split tensile strength for the above said replacements as compared to reference mix (Table 8).

   Similarly it was noticed in case of metakaolin, ricehusk ash, fly ash, GGBFS and whose increase in the split tensile strength for the above said replacements as compared to reference mix were 20.00% , 17.78% , 14.44%, and 10.00% respectively (Table 8).

   This may be because at 10% cement replacement level by different admixtures and 20% natural sand replacement by copper slag, there may be higher pozzzolanic reaction. It may also be because at these replacement levels the concrete pores are filled completely there by arresting the chloride ions to connect rate inside the concrete mass.

3. It was noticed that, the density increases as percentage replacement of natural sand by copper slag increases. This was true for all the concrete produced by replacing cement by different admixtures (Table 6).

   This may be due to the fact that copper slag has high specific gravity compared to natural sand (Table 3).

4. It was noticed that, the rate of corrosion increases as percentage replacement of natural sand by copper slag increases. This was true for all the concrete produced by replacing cement by different admixtures (Table 9).

   This may be due to the fact that the ferric content in copper slag increases as percentage replacement of natural sand by CS increases.

5. It was noticed that, the compressive strength and tensile strength were more for concrete produced by replacing cement by silica fume for all the replacement levels of natural sand by CS as compared to the cement replacement by other mineral admixtures. Also it was found that the rate of corrosion was minimum when SF was used as cement replacing material. Therefore the performance of silica fume was better as compared to other admixtures. The hierarchy of performance with respect to corrosion can be written as silica fume, metakaolin, rice husk ash, fly ash, GGBFS.

   This may be due to the fact that the pozzolanic reaction of silica fume is higher and because of its fineness it fills up all the voids in the concrete mass thereby preventing the infiltration of chloride ions into the concrete mass.

V. CONCLUSION

From the present study, following conclusions were drawn
After 28 days of curing, it is observed from the work that for all percentage replacements of fine aggregate by Copper slag and cement by mineral admixtures, (SF, MK, RHA, FA, GGBFS), the compressive and split tensile strengths of concrete are more than conventional concrete up to certain percentage replacement.

Compressive strengths and Split tensile strengths are increased due to high sturdiness of Copper slag. So for normal practice up to 20% replacement of the fine aggregate by CS and 10% replacement of mineral admixture is recommended.

It is also concluded that, the density of CS concrete increases with increase in copper slag percentage and more dense concrete is formed by using Silica Fume followed by Metakaolin, Rice Husk Ash, Fly Ash and GGBS.

Copper slag which goes as waste from copper industry can be used in an effective manner to improve strength of concrete and also it reduces the cost of dumping in landfills.

Accelerated corrosion test results reveal that, the corrosion rate of mineral and copper slag admixed concrete with rebar is increases as compared to normal concrete specimens.

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