EFFECTS OF ACIDS ATTACK ON COPPER SLAG ADMIXED CONCRETE

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Abstract: Rapid urbanization has created a huge demand for non-conventional building materials by the construction industry. Sand is the major form of fine aggregate used in the preparation of concrete, however large scale depletion of river beds and increasing cost of sand have made the construction industry to go for other alternative form of fine aggregate. Many alternatives like different types of slags, industrial wastes, stone dust and agro wastes etc. have been tried to partially or fully replace river sand in preparation of concrete and the results have been encouraging. Copper slag is one of the alternative materials which has a promising future to be used as a fine aggregate in preparation of concrete. The preliminary strength studies conducted have shown that the optimum percentage of copper slag to be used as a partial replacement of sand in concrete is 40%. To prove any material as a building material it is highly imperative that along with the strength aspects of the material the durability aspects also verified. So as part of durability studies of copper slag concrete, an attempt has been made here to study the impact of acid attack on copper slag concrete and the results have been compared with that of normal concrete. M20 grade of concrete has been used for this experimental investigation. Test results shows that durability of the copper slag concrete found to be lower resistant to H_2SO_4 as compared to HCl and also controlled concrete has higher resistance to acid and sulphate attack as compared to copper slag concrete.

Index Terms **- Copper Slag. Strength. Durability. HCl Solution. H_2SO_4 Solution.**

1. INTRODUCTION

Copper slag is an industrial waste which is produced during the met-smelting process of copper production. According to ICSG (International Copper Study Group), the word wide copper production is estimated to be 19.1 million tonnes in 2017. For 1 kg of copper production around 2.5 kgs of copper slag is produced. So huge piles of copper slag can be found around copper manufacturing industries and dumping problems is a major concern for the copper manufacturing industries. So far, copper slag have been used a filling material and also the strength studies have shown that copper slag can be used as a partial replacement of sand in preparation of concrete. However, durability of the structures is a prime concern now a days due to several types of deteriorations produced by natural as well as manmade environmental conditions. In past as far as concrete is concerned, strength was the only factor which drew the attention of the researchers and engineer. Later it was recognized that durability was also a significant factor as that of the strength criteria. In general, durability of concrete may be defined as the ability of concrete to resist abrasion, weathering action and chemical attack without conceding its required strength properties. A durable concrete is one that performs satisfactorily in the working environment during its anticipated exposure conditions during service. Durability of concrete is majorly influenced by the type of materials, environment, and water to cement ratio. The other factors impacting the durability of concrete are curing, cover to reinforcement and compaction etc. So, in this present research the impact of environmental condition of acid attack (*H_2SO_4, HCl and Na_2SO_4)* on copper slag concrete have been studied and been compared with that of normal concrete.

2. MATERIAL PROPERTIES

2.1 Coarse Aggregate

20mm size, angular and 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/m3 and 1550 kg/m3 respectively. The water absorption was 1.1%.

2.2 Fine Aggregate

River sand having specific 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/m3 and 1700kg/m3 respectively. The water absorption was 1.20%.

2.3 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.

2.4 Copper Slag

Copper slag with specific gravity 3.47 and fineness modulus 3.3 was used. Bulk Density in loose state and compacted state was found to be 1898 kg/m3 and 2024 kg/m3 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%.

2.5 Test Specimens

Test specimens consisting of cube specimens of size 100x100x100 mm were casted and tested as per IS 516 and 1199.

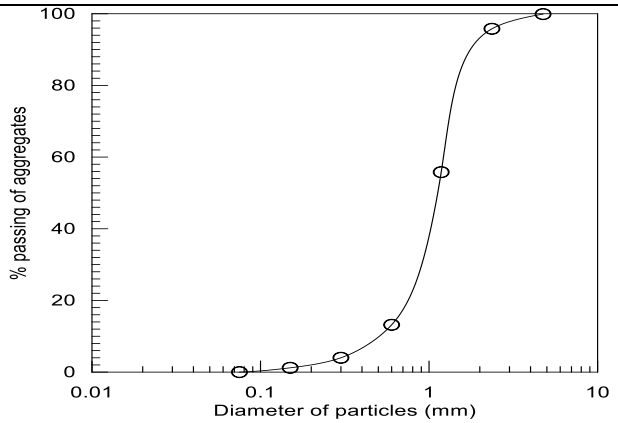

Figure 1: Grading of Copper Slag

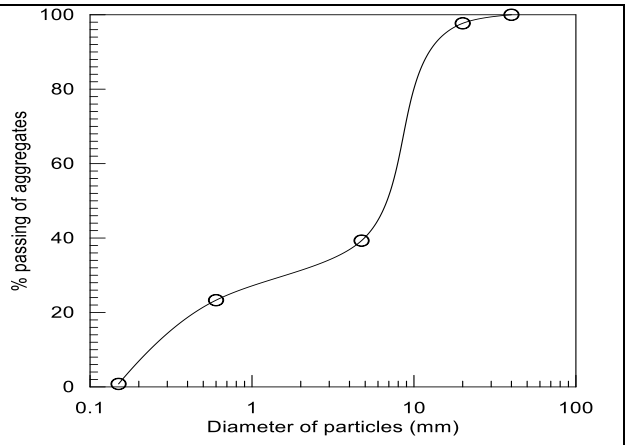

Figure 2: Combined grading of Aggregates

Table 1: Chemical Composition of Cement

S. No.	Composition	Percentage (in %)
1	Sulphuric Anhydride	1.93
2	Loss of Ignition	1.39
3	Magnesia	1.12
4	Insoluble Residue	1.14
5	Alumina Iron Ratio	1.18
6	Alkali Oxides	0.6
7	LimeSaturation Factor	0.82

Table 2: Chemical Composition of Copper Slag

S. No.	Composition	Percentage (in %)
1	Iron - Fe_2O_3	55.8
2	Silica - SiO2	33.52
3	Aluminium - Al_2O_3	3.8
4	Calcium –CaO	3.14
5	Potassium - K_2O	0.76
6	Magnesium –MgO	0.72
7	Sodium - Na_2O	0.4
8	Titanium - TiO_2	0.5
9	Copper – Cu	0.99

3. Mix Design and Mixes

Mix Design was done as per the code book, IS: 10262 – 1979 and the amount of materials were calculated. The specimens were casted by replacing fine aggregate with 0% (CS0) & 40 % (CS40) copper slag. The mix proportions are 1:2.09:3.68 with water/cement ratio as 0.55.

Table 3: Proportions of M20 grade Concrete

Grade	Cement (Kg/m3)	Fine Aggregate (Kg/m^3)	Coarse Aggregate Kg/m^3)	W/C Ratio	Water (Kg/m3)	Mix Proportion
M-20	320	712	1178	176	0.55	1:2.225:3.68

4. MIXING, DEMOULDING AND CURING

For achieving a good concrete the most important factors are proper mixing, compaction 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 and tested for their compressive strength at various ages. For acid resistance test, post 28 days curing period the specimens were immersed in the acid solutions and tested at ages of 28, 56 and 90 days.

5. Results and Discussion

5.1 Effect of Copper Slag as a Partial Replacement of Sand in Concrete

The effect of partial replacement of sand with copper slag from 0% to 50% at various ages has been presented in Table 4.

Table 4: Effect of copper slag as a partial replacement of sand in concrete

Mix	% Copper Slag replacement	Density (Kg/m3)	Percentage increase in Compressive Strength with respect to CS0			Percentage increase in Compressive Strength with respect to Age		
			28 days	90 days	180 days	28 days	90 days	180 days
M20	0%	2560	-	-	-	-	20.49	25.54
	10%	2575	2.23	5.68	5.41	-	24.56	29.45
	20%	2582	6.3	15.52	16.17	-	30.93	37.19
	30%	2681	10.41	18.11	17.71	-	28.89	33.84
	40%	2684	11.55	24.42	27.92	-	34.4	43.97
	50%	2710	6.66	14.46	19.78	-	29.3	40.99

It can be observed that, the compressive strength of CS40 mix is increasing by 11.55% at 28 days, 24.42% at 90 days and 27.92% at 180 days when compared to its normal concrete. The compressive strength of CS40 mix is increasing by 34.4% and 43.97% at 90 and 180 days respectively compared to its 28 days compressive strength. For normal concrete the compressive strength is increasing by 20.49% and 25.54% at 90 and 180 days respectively compared to its 28 days compressive strength. For the above test results it has been established that the optimum percentage of copper slag as a partial replacement of sand in preparation of concrete is 40%.

5.2 Impact on Compressive Strength due to HCl Acid Attack

The impact on compressive strength of M20 grade copper slag concrete after immersing in HCl solution measured at various ages are presented in Table 5.

Table 5: Impact on Compressive Strength of Copper Slag Concrete due to HCl Acid Solution attack

M 20 Grade	Percentage decrease in Comp. Strength at 28 Days	Percentage decrease in Comp. Strength at 56 Days	Percentage decrease in Comp. Strength at 90 Days
CS0	8.23	27.39	49.21
CS40	41.41	53.25	65.23

It can be observed that normal concrete (CS0) has lower loss of compressive strength compared to copper slag concrete (CS40) when exposed to HCl. The percentage loss in compressive strength is observed to be increasing in correspondence with time as well for both type of mixes. CS0 specimens showed higher resistance to HCl acid attack than CS40 specimens in terms of strength loss.

5.3 Impact on Weight due to HCl Acid Attack

The impact on weight of M20 grade copper slag concrete after immersing in HCl solution measured at various ages are presented in Table 6.

Table 6: Impact on Weight of Copper Slag Concrete due to HCl Acid Solution attack

M 20 Grade	Percentage decrease in Weight at 28 Days	Percentage decrease in Weight at 56 Days	Percentage decrease in Weight at 90 Days
CS0	7.7	10.04	18.25
CS40	6.63	8.84	16.32

It can be observed that copper slag concrete (CS40) has lower loss of weight compared to normal concrete (CS0) when exposed to HCl. The percentage loss in weight is observed to be increasing in correspondence with time as well for both type of mixes. CS40 specimens showed higher resistance to HCl acid attack than CS0 specimens in terms of weight loss.

5.4 Impact on Compressive Strength due to H_2SO_4 Acid Attack

The impact on compressive strength of M20 grade copper slag concrete after immersing in H_2SO_4 solution measured at various ages are presented in Table 7.

Table 7: Impact on Compressive Strength of Copper Slag Concrete due to H_2SO_4 Acid Solution attack

M 20 Grade	Percentage decrease in Comp. Strength at 28 Days	Percentage decrease in Comp. Strength at 56 Days	Percentage decrease in Comp. Strength at 90 Days
CS0	19.09	38.21	100
CS40	51.38	64.99	100

It can be observed that normal concrete (CS0) has lower loss of compressive strength compared to copper slag concrete (CS40) when exposed to H_2SO_4 upto 60 days. For both types of mixes, the percentage loss of compressive strength is observed to be increasing in correspondence with time as well and the specimens can been seen to be disintegrated completely at 90 days. CS0 specimens showed higher resistance to H_2SO_4 acid attack than CS40 specimens in terms of strength loss upto 60 days.

5.5 Impact on Weight due to H_2SO_4 Acid Attack

The impact on weight of M20 grade copper slag concrete after immersing in H_2SO_4 solution measured at various ages are presented in Table 8.

Table 8: Impact on Weight of Copper Slag Concrete due to H_2SO_4 Acid Solution attack

M 20 Grade	Percentage decrease in Weight at 28 Days	Percentage decrease in Weight at 56 Days	Percentage decrease in Weight at 90 Days
CS0	19.69	22.35	58.25
CS40	13.13	14.9	64.32

It can be observed that copper slag concrete (CS40) has lower loss of weight compared to normal concrete (CS0) when exposed to H_2SO_4. The percentage loss in weight is observed to be increasing in correspondence with time as well for both type of mixes. CS40 specimens showed higher resistance to H_2SO_4 acid attack than CS0 specimens in terms of weight loss.

5.6 Impact on Copper Slag Concrete due to Sulphate Attack

The percentage decrease in compressive strength of M20 grade of CS0 and CS40 mixes after immersing in Na_2SO_4 is found to be nil at 30, 60 and 90 days. This indicates that copper slag concrete has good resistance against Na_2SO_4 solution.

6. Conclusions

- The optimum percentage of copper slag as a partial replacement of sand in preparation of concrete is found to be 40%.
- Beyond 40% the strength of copper slag concrete decreases because of increase in the free water content in the mix.
- Addition of copper slag increases the self-weight and density of concrete.
- The utilization of copper slag in concrete provides environmental as well as technical benefits for all related industries.
- Replacement of copper slag with fine aggregates reduces the cost of making concrete and also helps in resolving the wastage disposal issues.
- Concrete containing copper slag is low resistant to the H_2SO_4 and HCl attack than the controlled concrete.
- Copper slag concrete is higher resistant to HCl attack as compared to H_2SO_4 attack.
- Copper Slag concrete has good resistance against Na_2SO_4 solution.

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