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Research Article

Behavior of Copper Slag Admixed Concrete in Acidic Environment

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Abstract

Non-conventional building materials are in huge demand these days because of rapid urbanization and huge cost associated with conventional building materials. Sand is majorly used fine aggregate in the preparation of concrete, however heavy depletion of river beds and rising cost of sand have made the builders and construction industry to think about alternative form of fine aggregate. Many alternatives like industrial wastes, different types of slags, stone dust and agro wastes etc. have been tried to fully or partially replace river sand in preparation of concrete and the results have been encouraging. Out of the non-conventional materials, copper slag is one such type which has a capable future to be used as a fine aggregate in preparation of concrete. The initial strength studies carried out have shown that the optimum percentage of copper slag as a partial replacement of sand in concrete is 40%. To ascertain any material as a building material it is highly important that along with the strength aspects of the material the durability characteristics also verified. So as part of durability studies of copper slag concrete, an attempt has been made here to examine the impact of acid attack on copper slag concrete and the effects have been compared with that of normal concrete. M30 grade of concrete has been used for this experimental investigation. The test results indicate that durability of the copper slag concrete found to be higher resistant to HCl as compared H_2SO_4 and also normal concrete has better resistance to acid and sulphate attack compared to copper slag concrete.

Keywords*: Copper Slag, Strength, Durability, H_2SO_4 Solution, HCL Solution.*

1. Introduction

Copper slag is an industrial waste produced during the metal smelting process of copper production. According to ICSG (International Copper Study Group), the world wide copper production is valued to be 19.1 million tons in 2017. For producing 1 kg of copper about 2.5 kgs of copper slag is produced which creates a waste disposal issue for the copper manufacturing industries. Huge piles of copper slag can be seen around the industries which is a major concern as it also creates environmental pollution. Copper slag have been used a land filling material and also the preliminary strength studies have indicated that copper slag can be used as a partial replacement of sand in preparation of concrete. However, durability of the concrete structures is a major concern these days due to several types of deteriorations produced by manmade as well natural environmental conditions. In past, for concrete, strength was the only factor which drew the attention of the engineers and researchers. Late it was recognized that durability was also a substantial factor as that of the strength factor. In general, durability of concrete may be defined as the ability of concrete to resist weathering action, abrasion and chemical attack without compromising 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, this paper presents the preliminary experimental investigation results for finding the optimum percentage of copper slag as partial replacement of sand in concrete. Further the impact of environmental condition of acid attack (*H_2SO_4, HCl and Na_2SO_4*) on copper slag concrete (with optimum percentage of copper slag) have been presented and been compared with that of normal concrete.

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2. Materials

2.1 Coarse Aggregate

In the current experiment, machine crushed angular granite metal of maximum size 20 mm retained on IS sieve 4.75 mm conforming to IS 383-1970 was used. It was made sure that the coarse aggregate was free from any form of impurities such as dust, organic matter, and clay particle etc. Different physical properties of the coarse aggregate were tested according to IS 2386-1963. The results of different physical properties studied are given in the table 1.

Table 1: Physical Properties of Coarse Aggregate

S. No.	Property	Test Result
1	Specific Gravity	2.637
2	Fineness Modulus	7.102
3	Bulk Density (Loose State)	1414 kg/m^3
4	Bulk Density (Compacted State)	1550 kg/m^3
5	Water Absorption	1.1%

2.2 Fine Aggregate

In the current experiment, locally found clean river sand was used in form of fine aggregate and various physical properties of sand were tested as per IS 2386-1963. It was made sure that the sand used was free from organic impurities, salt and clayey matter. The fine aggregate confirmed to grading zone – II of IS 383-1970. The sand was passing through 4.75mm IS sieve and retained on 0.075 mm IS sieve. The results of different physical properties studied are given in the table 2.

Table 2: Physical Properties of Fine Aggregate

S.No	Property	Test Result
1	Specific Gravity	2.601
2	Fineness Modulus	2.43
3	Bulk Density (Loose State)	1597 kg/m^3
4	Bulk Density (Compacted State)	1700 kg/m^3
5	Water Absorption	0.012

2.3 Cement

Ordinary Portland cement of 53 grade was used for the current investigation. It was made sure that the cement was used from the same brand and a single batch. To avoid the cement from moisture and humidity it was stored in air-tight containers. The cement was tested in complying to IS 4031-1988 standards. The results of different physical properties studied are given in the table 3.

Table 3: Physical Properties of Ordinary Portland Cement (53 Grade)

S. No.	Property	Test Result
1	Specific Gravity	3.094
2	Fineness	4.62%
3	Normal Consistency	32%
4	Setting Time i. Initial (min) ii. Final (min)	i. 120 ii. 320

2.4 Copper Slag

Copper slag was procured from nearby copper industry and different set of tests were conducted to access the physical properties which are presented in table 4. The chemical analysis was also carried out to understand the chemical compositions of copper slag are mentioned in the table 5. Figure 1 shows the appearance of the copper slag. The grading of copper slag has been presented in figure 2.

Table 4: Physical Properties of Copper Slag

S. No.	Property	Test Result
1	Specific Gravity	3.476
2	Fineness Modulus	3.301
3	Bulk Density (In Loose State)	1898 kg/m^3
4	Bulk Density (In Compacted State)	2024 kg/m^3
5	Water Absorption	0.24%
6	Particle Shape	Irregular
7	Types	Air Cooled
8	Appearance	Glassy Black

Table 5: Chemical Properties of Copper Slag

S. No.	Composition	Contribution (in %)
1	Silica - SiO_2	33.52
2	Iron - Fe_2O_3	55.8
3	Aluminium - Al_2O_3	3.8
4	Calcium –CaO	3.14
5	Magnesium –MgO	0.72
6	Sodium - Na_2O	0.4
7	Potassium - K_2O	0.76
8	Titanium - TiO_2	0.5
9	Copper – Cu	0.99

Figure 1: Appearance of Copper Slag

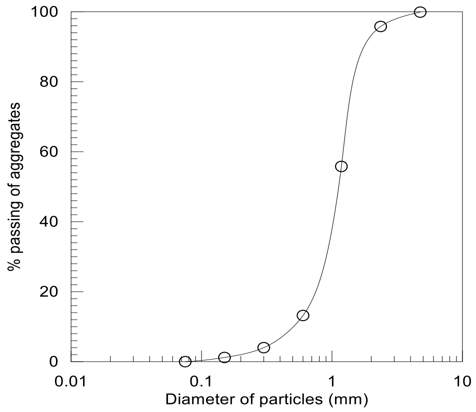

Figure 2: Grading of Copper Slag

2.5 Test Specimens

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

3. Mix Design and Different Mixes

Mix Design was done as per the code book, IS: 10262 – 2009 and the amount of materials were calculated. For finding the optimum percentage of copper slag as a partial replacement of sand in concrete, six different mixes (CS0, CS10, CS20, CS30, CS40 and CS50) were prepared by partially replacing sand from 0% to 50% with copper slag. After finding the optimum percentage of copper slag from compressive strength test, test specimens were again casted with optimum % of copper slag for studying the resistance to acid attack and been compared with that of normal concrete. The mix proportions are 1:2.01:3.33 with water/cement ratio as 0.50.

4. Casting and Testing Procedure

For preparing a good concrete, the most important factors are proper mixing, compaction and adequate curing which were practiced during the concrete test sample casting process. Pan mixture was used for the mixing process and the mixing time was kept for 3-4 minutes. Test samples were demoulded after 24 hrs of casting. Concrete cubes were adequately cured by using potable water and tested for their compressive strength at different 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 for identifying the variations in weight and compressive strength.

5. Discussion of Results

5.1 Effect of copper slag as a partial replacement of sand in concrete

The influence of partial replacement of sand with copper slag from 0% to 50% on compressive strength at various ages has been presented in table 6. The variation in compressive strength of copper slag concrete with different percentage of copper slag as partial replacement of sand has been presented in figure 3.

Table 6: Effect of copper slag as a partial replacement of sand in concrete

Grade of Concrete	% Copper Slag replacement	Density (Kg/m^3)	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
M30	0%	2571	-	-	-	-	24.59	29.86
	10%	2578	5.03	4.17	3.61	-	23.57	28.11
	20%	2588	10.96	7.45	7.07	-	20.65	25.31
	30%	2679	13.97	9.42	10.57	-	19.61	25.99
	40%	2696	15.18	11.62	12.68	-	20.73	27.04
	50%	2724	11.39	9.17	8.48	-	22.09	26.46

It can be observed that, the compressive strength of CS40 mix is increasing by 15.18% at 28 days, 11.62% at 90 days and 12.68% at 180 days when compared to its normal concrete. The compressive strength of CS40 mix is increasing by 20.73% and 27.04% at 90 and 180 days respectively compared to its 28 days compressive strength. For normal concrete the compressive strength is increasing by 24.59% and 29.86% 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%.

Copper slag has a relatively lower water absorption capacity compared to sand. The test results exhibited that the workability of concrete increases significantly with increase in copper slag content in the concrete mix due to the glassy surface, coarser particles and low water absorption of copper slag, thereby the strength properties also improved. Beyond 40% of copper slag replacement with sand the free water content increases in the concrete there by decreasing in the compressive strength.

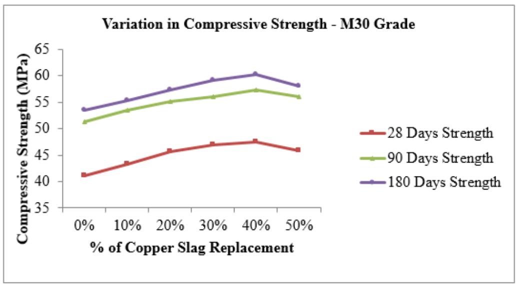

Figure 3: Variation in Compressive Strength of Copper Slag Concrete

Figure 4: Compressive Strength Test Setup in CTM

5.2 Impact on Compressive Strength Due to HCl Acid Attack

The impact on compressive strength of M30 grade copper slag concrete after immersing in HCl solution measured at various ages are presented in table 7.

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

M30 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	11.13	28.16	51.29
CS40	42.73	61.13	66.36

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 M30 grade copper slag concrete after immersing in HCl solution measured at various ages are presented in table 8.

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

M30 Grade	Percentage decrease in Weight at 28 Days	Percentage decrease in Weight at 56 Days	Percentage decrease in Weight at 90 Days
CS0	3.75	6.64	16.28
CS40	2.77	3.73	14.23

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 M30 grade copper slag concrete after immersing in H_2SO_4 solution measured at various ages are presented in table 9.

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 56 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 be 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 56 days.

Table 9: Impact on Compressive Strength of Copper Slag Concrete due to H_2SO_4 Acid Solution attack

M30 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	21.55	39.19	100
CS40	53.15	67.14	100

5.5 Impact on Weight Due to H_2SO_4 Acid Attack

The impact on weight of M30 grade copper slag concrete after immersing in H_2SO_4 solution measured at various ages are presented in table 10.

Table 10: Impact on Weight of Copper Slag Concrete due to H_2SO_4 Acid Solution attack

M30 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 Percentage Decrease in Compressive Strength Due to Sulphate Attack

The percentage decrease in compressive strength of M30 grade of CS0 and CS40 mixes after immersing in Na_2SO_4 is found to be negligible at 30, 56 and 90 days. This indicates that copper slag concrete has good resistance against Na_2SO_4 solution.

Figure 5: Concrete Specimens Absorbed in HCl, H_2SO_4 and Na_2SO_4

Figure 6: Concrete Cube Specimens Exposed to HCl, H_2SO_4 and Na_2SO_4 at 56 days

Conclusions

Base on the experimental investigation following conclusions have been made.

- The optimum percentage of copper slag as partial replacement of sand in concrete is found to be 40%.
- The compressive strength of copper slag concrete decreases beyond 40% of partial replacement because of increase in the free water content in the mix.
- The self-weight and density of concrete increases with addition of copper slag.
- The utilization of copper slag in concrete helps in reducing its negative impacts on the environment and also helps in resolving waste disposal issues.
- Cost of concrete reduces by using copper slag as fine aggregates in concrete.
- Normal concrete has a better resistance to the H_2SO_4 and HCl attack than copper slag 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.

References

IS: 383-1970. “Specifications for Coarse and Fine Aggregates from Natural Sources for Concrete”. Bureau of Indian Standards, New Delhi.

IS 456-2000. “Indian Standard-Plain and Reinforced Concrete- Code of Practice”, Bureau of Indian Standards, New Delhi, India

Vagelis G. Papadakis, Costas G. Vayenas, and Michael N. Fardis (1991),“Physical and Chemical Characteristics Affecting the Durability of Concrete”, ACI Materials Journal, 88(2) : 186-196.

Brinda D and Nagan (2010), “Utilization of Copper Slag as a partial replacement of fine aggregate”, International Journal of Earth Sciences and Engineering 3(4): 579-585.

Brinda D and Nagan (2011), “Durability studies on Copper Slag Admixed Concrete”, Asian Journal of Civil Engineering (Building and Housing) 12 (5): 563-578.

Binaya Patnaik, Seshadri Sekhar T (2014), “An experimental Investigation on Optimum Usage of Copper slag as Fine Agrregate in Copper Slag admixed Concrete”, International Journal of current Engineering and Technology 4(5) : 3646-3658.

Binaya Patnaik, Seshadri Sekhar T (2014), “Relationship between the optimum usage of Copper Slag as Fine Aggregate and Compressive Strength in Copper Slag Admixed Concrete”. I managers Journal of Civil Engineering 4 (2) : 20-24

Al-Jabri, K., Taha, R. and Al-Ghassani, M. (2005) “Use of copper slag and cement by-pass dust as cementitious materials”, Cement, Concrete Aggregates, Vol. 24, No.1, pp. 7-12

Alpa, I. and Deveci, H. (2008), “Utilization of flotation wastes of copper slag as raw material in cement production”, Journal of hazard materials, Vol. 159, No. 2, pp. 390-395

Arino, A.M. and Mobasher, B. (1999), “Effect of copper slag on the strength, and toughness of cementitious mixtures”, ACI Materials Journal, Vol. 96, No. 1, pp. 68-75

Bipra Gorai, Jana, R. K. and Premchand (2002), “Characteristics and utilisation of copper slag-a review”, Resources, Conservation and Recycling, Vol. 39, No. 4, pp. 299-313

Das, B.M., Tarquin, A.J. and Jones, A.D. (2003) “Geotechnical properties of copper slag”, Resources conservation and recycling, Vol. 39, No. 4, pp. 299-313

Huang, K. (2001)“Use of copper slag in cement production”, Sichuan Cement, No. 4, pp. 25-27

Ishimaru, K., Mizuguchi, H., Hashimoto, C., Ueda, T., Fujita, K. and Ohmi, M. (2005) “Properties of copper slag and second class fly ash as a part of fine aggregate”, Joual of Society Material Science Japan , Vol. 54, No. 8, pp. 828-833

Malhotra, V.M. (1993)“Fly ash, slag, silica fume, and rice-husk ash in concrete: a review”, Concrete International, Vol. 15, No. 4, pp. 23-28

Mobasher, B., Devaguptapu, R and Arino (2000), “Effect of copper slag on the hydration of blended cementitious mixtures”, Proceedings of the ASCE Materials Engineering Conference, Materials for the New Millennium, pp. 1677-1686

Moura, W., Masuero, A., Molin, D. and Dal Vilela, A. (1999)“Concrete performance with admixtures of electrical steel slag and copper slag concerning mechanical properties”, American Concrete Institute, Vol. 186, pp. 81-100

Taeb, A. and Faghihi, S. (2002)“Utilization of copper slag in the cement industry”, Zement Kalk Gips International, Vol.55, No.4, pp. 98-100

Caroline Morrison, Rebecca Hoope, and Kevin Lardner, “The use of ferro-silicate slag from ISF zinc production as a sand replacement in concrete”, Cement and Concrete Research, Vol.33, No. 12, pp. 2085-2089.

Isa Yuksel, Turhan Bilir, and Omer Ozkan (2006), “Use of Granulated Blast Furnace Slag in Concrete as Fine Aggregate”, Materials journal, Vol. 103, No. 3, pp. 203-208