PARTIAL REPLACEMENT OF FLY ASH BASED GEOPOLYMER CONCRETE WITH COPPER SLAG AS FINE AGGREGATE

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Abstract - *AS we all known that copper slag is a by-product huge quantities of industrial waste accumulated every year by various industries in the developing countries. The main focus of environmental protection agencies to minimize the dual problems of disposal and health hazards of these by-products. In India 8 lakhs tons of copper slag is generated every year and in world-wide generation of annually about 24.8 million tons of copper slag. Which is produce during the copper smelting process. In this study we investigated that the constructive use of copper slag as a replacement to fine aggregate. Copper slag is mixed with fine aggregate in different proportions and tested for various properties of concrete such as compressive strength, split tensile strength, dry density and workability test. For sand replacement, six test groups (including control mixture) were constituted with replacement of 0% (control specimen), 20%, 40%, 60%, 80% and 100% copper slag with sand in each series. Sodium silicate to sodium hydroxide ratio was taken as 0.35. The combination of sodium hydroxide solution of 14M concentration and sodium silicate are used as an alkaline activator.*

Key Words: By-product, Waste material, copper slag, alkaline activator, Sodium Hydroxide, Sodium Silicate, Geopolymer.

1. INTRODUCTION

The term 'geopolymer' was first introduced by Davidovits in 1978 to describe a family of mineral binders with chemical composition similar to zeolites but with an amorphous microstructure. Unlike ordinary Portland cements, geopolymers do not form calcium- silicate-hydrates for matrix formation and strength, but utilize the polycondensation of silica and alumina precursors to attain structural strength. Two main constituents of geopolymers are source materials and alkaline liquids. The source materials on alumino-silicate should be rich in silicon (Si) and aluminum (Al). They could be by-product materials such as fly ash, silica fume, slag, rice-husk ash, red mud, etc. Geopolymers are also unique in comparison to other alumino-silicate materials (e.g. alumino-silicate gels, glasses, and zeolites) (Davidovits 1978). The geopolymer technology may reduce the total energy demand for producing concrete, lower the CO_2 emission to the atmosphere caused by cement and aggregates industries by about 80%, thereby reducing the global warming. They possess the advantages of rapid strength gain, elimination of water curing, good mechanical and durability properties and can serve as eco-friendly and sustainable alternative to ordinary Portland cement concretes.

For many years, by-products such as, fly ash and copper slag etc. were considered as waste materials. They have been successfully used in the construction industry as a fine aggregate substitute. These industries utilize only about 16% to 20% of the copper slag generated and the remaining material is dumped as a waste, which requires large areas of land material and also causes environmental pollution. Material like copper slag can be used as one which can reduce the cost of construction. The present study investigate the possibilities of using copper slag as a fine aggregate in geopolymer concrete in ambient curing condition has been examined. The strength development in the concrete is studied, with different percentage of copper slag added as a partial replacement of the fine aggregate in the mix.

1.1 Motivation

Fly ash based geopolymer concrete cement is replaced by fly ash and partially fine aggregate replaced by copper slag gives desirable compressive strength and split tensile strength. Copper slag is less expansive when compared to fine aggregate similarly Fly ash less expensive when compare to cement since fly ash is a waste materials.

The main advantages of fly ash based geopolymer concrete is the normal concrete produces more CO_2 increasing the global warming in order to avoid this emission of CO_2 gas, fly ash based geopolymer concrete came into usage since CO_2 emitted is very low. This motivated us to do this project.

1.2 Research Gap

The various authors have studied properties of geopolymer concrete with fly ash and other by-product material and various hardened properties but limited works found in the area of geopolymer concrete with copper slag as fine aggregate hence considering this research gap the work is carried out on fly ash based geopolymer concrete with copper slag as partial replacement.

1.3 AIM, OBJECTIVE AND SCOPE OF THE PROJECT

1.3.1 Aim

To study the Partial replacement of fly ash based geopolymer concrete with various proportions of copper slag as fine aggregate.

1.3.2 Objective

- This research is intended to examine the partial replacement of copper slag as fine aggregate in fly ash based geopolymer concrete.
- The main objective of replacement of fine aggregate and cement is to increase the strength of fly ash based geopolymer concrete.
- Reduce disposal problem by using industrial waste as a geopolymer concrete ingredient.

1.3.3 Scope Of The Project

- To investigate the properties of fly ash based geopolymer concrete with partial replacement of fine aggregate by copper slag.
- Partial replacement of fine aggregate by copper slag by weight varies as 0%, 20%, 40%, 60%, 80%and 100%.
- Ambient curing was adopted.
- To determine the compressive strength at various ages such as 7 days and 28 days.
- To determine the split tensile strength at 28 days.

2. MATERIALS AND PROPERTIES

2.1 Fly Ash

Fly ash is an industrial by product generated at coal electricity generating power plants that contain silica, alumina & calcium based minerals. Classifies fly ash to either class F or C depending on the $SiO_2 + Al_2O_3 + Fe_2O_3$ content which must be greater than 70% for class F and 50% for class C fly ashes. In this investigation Class F Fly ash is use which is brought from Rattan India Pvt. Amravati.

Table -1: Physical properties of fly ash

Physical properties Fly ash	
Specific gravity	2.11
Density (Kg/m3)	986
Color	Dark gray
Fineness: passing 45μ	66%

2.2 Fine Aggregate

The fine aggregate which passes through 4.75mm IS sieve and retained on 75mm micron sieve are known as fine aggregate. In this investigation locally available river sand is used. Properties of fine aggregates were determined as per IS: 2386-1963.

Table -2: Physical properties of Fine aggregate

Physical properties Fine Aggregate	
Specific gravity	2.57
Bulk Density (Kg/m3)	1715
Water Absorption	0.9%

2.3 Coarse Aggregate

The coarse aggregate which passes through 16mm IS sieve and retained on 12.5mm micron is used. . Properties of coarse aggregates were determined as per IS: 2386-1963.

Table -3: Physical properties of Coarse aggregate

Physical properties Coarse Aggregate	
Specific gravity	2.64
Bulk Density (Kg/m3)	1622
Water Absorption	1%

2.4 Copper Slag

Copper slag is an irregular, black, glassy and granular in nature and its properties are similar to the river sand. In this investigation copper slag is obtain from SARASWATI TRADING CO. MUMBAI. The copper slag used in this study have glassy appearance and black in color. The particle size of the copper slag and river sand is similar to each other i.e. sieve size from 4.75mm to 75 micron. The tests which conducted on river sand is also carried on copper slag.

Fig -1: Copper slag

Table -4: Physical properties of Copper Slag

Physical properties Copper slag	
Specific gravity	3.64
Color	Black
Appearance	Glassy
Bulk Density (Kg/m3)	1920
Water Absorption	0.4%

Table -5: Chemical properties of Copper slag

Chemical properties Copper slag	
Iron (Fe2O3)	68.29%
Silica dioxide (SiO2)	25.84%
Calcium oxide (CaO)	0.15%
Aluminum oxide(Al2O3)	0.22%

2.5 Alkaline Solution

In this study alkaline solution is used in the combination of Sodium silicate (Na2SiO3) and Sodium Hydroxide (NaOH) in the ratio of 0.35. The laboratory grade sodium hydroxide was used having 97-98 % purity and in form of flakes which is brought from SAHMARTH CHEMICAL INDUTRY KHAMGAO .For instance, NaOH solution with a concentration of 14M consisted of 14x40=560 grams of NaOH solids (in flake or pellet form) for 1 liter of the solution, where 40 is the molecular weight of NaOH. The mass of NaOH solids was measured as 560 grams per kg of NaOH solution of 14M.

Fig -2: Sodium Hydroxide

The sodium silicate solution with SiO2, Na2O by mass, i.e. (Na2O = 14.25%, SiO_2-33.90% and water 51.85% by mass) was used. The ratio of sodium silicate solution to sodium hydroxide solution by mass was fixed as 2.

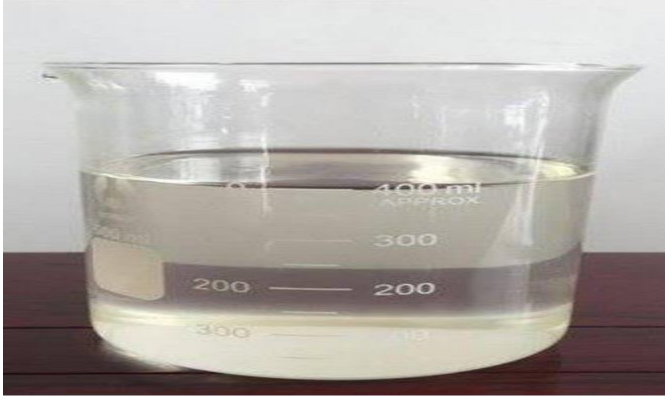

Fig -3: Sodium Silicate

3. METHODOLOGY

3.1 Mix Proportion

Table -6: Designation of concrete

Designation of concrete	% Copper Slag
M1	0
M2	20
M3	40
M4	60
M5	80
M6	100

Table -7: Fine aggregate, coarse aggregate, copper slag & alkaline solution content in mix.

MIX	Fine aggregate(kg/m³)	Copper Slag (kg/m³)	Coarse aggregate(kg/m³)	Fly ash(kg/m³)	Alkaline solution (kg/m³)
M1	608.63	0	1130.3	450	157.5
M2	487.35	121.72			
M3	365.18	243.45			
M4	243.45	365.18			
M5	121.72	486.90			
M6	0	608.63			

3.2 Specimen Preparation

The mixing time of the materials is greatly affect the strength and workability of the Geopolymer concrete.

Initially the source materials and aggregate is thoroughly mixed for 4-5 minutes in the pan. After mixing of source materials and aggregate alkaline solution is mixed and continued mixing for another 5 minutes to get stiffer paste. Longer mixing time gives lower sump value and increase density of concrete. The concrete cubes of size100 x 100x 100 mm size and cylinders of size 150 mm diameter and 300 mm length were casted for each mix proportion. The prepared concrete is then poured in to the moulds in three layers and then each layer was compacted with 25 No. of blows using 16 mm diameter tamping rod.

3.3 Curing Of Geopolymer Concrete

After casting of geopolymer concrete the specimen is left for one day to set concrete properly. After one days the concrete specimen is demoulded and left for curing at room temperature or at ambient temperature.

3.4 Results and Discussion

3.4.1 Dry Density Test

Table -8: Dry Density (N/mm2)

Sr.No	Copper Slag (%)	Dry Density (kg/m3)
1	0	2362
2	20	2364
3	40	2372
4	60	2382
5	80	2393
6	100	2402

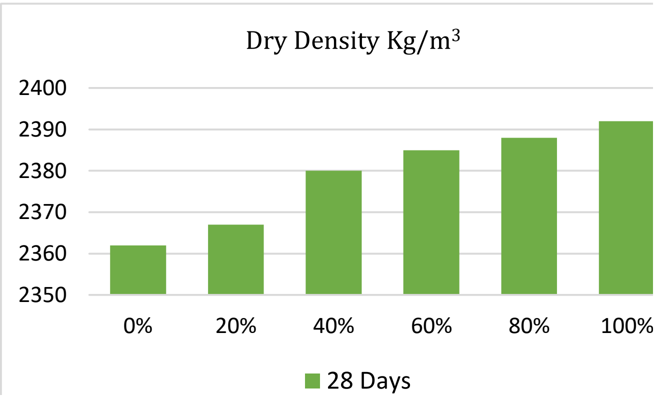

Chart -1: Dry Density

The density of fly ash based geopolymer concrete partially fine aggregate is replaced by copper slag of the mixes at 28 days ranges from 2362 kg/m³ to 2402 kg/m³ for ambient cured concrete.

3.4.2 Workability Test

Table -9: Workability (mm)

Sr.No	Copper Slag (%)	Slump
1	0	42
2	20	39
3	40	38
4	60	36
5	80	33
6	100	31

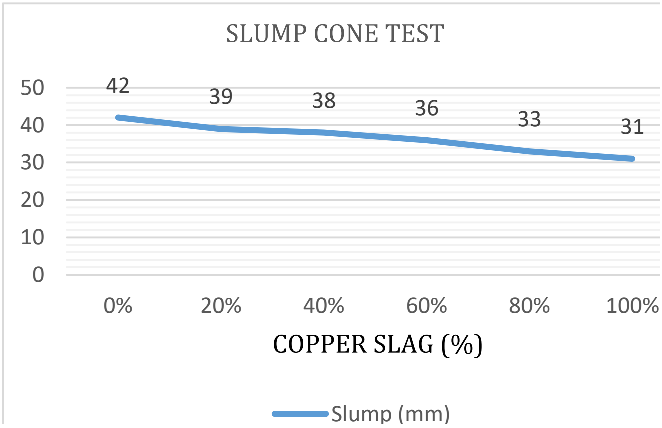

Chart -2: Slump cone

The workability of fly ash based geopolymer concrete partially fine aggregate is replaced by copper slag of the mixes is ranges from 31mm to 42mm. As the percentage of copper slag in geopolymer concrete is increasing the workability is decreases.

3.4.3 Compressive Strength Test

Table -10: Compressive Strength Test (N/mm²)

Sr.No	Copper Slag (%)	7 Days	28 Days
1	0	23.32	33.45
2	20	24.75	35.89
3	40	27.15	38.90
4	60	25.38	36.20
5	80	23.27	33.60
6	100	21.38	32.80

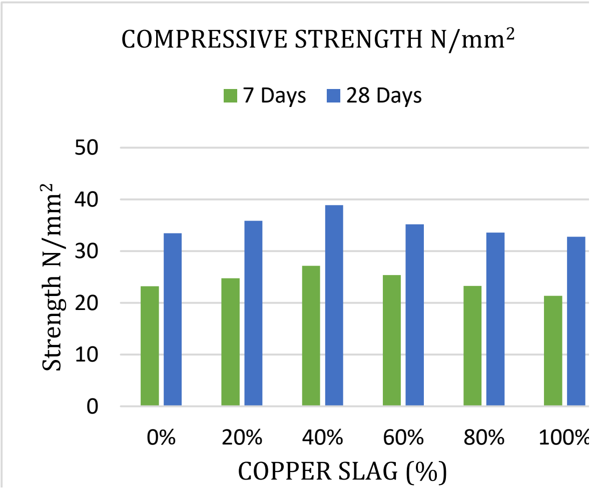

Chart -3: Compressive Strength

The maximum compressive strength at 7 days and 28 days is 27.15 N/mm² and 38.90 N/mm² respectively. The optimum percentage of compressive strength in fly ash based geopolymer concrete partially fine aggregate is replaced by copper slag is 40%.

3.4.4 Split Tensile Strength Test

Table -11: Split Tensile Strength (N/mm²)

Sr.No	Copper Slag (%)	28 Days
1	0	3.35
2	20	3.98
3	40	4.01
4	60	3.80
5	80	3.65
6	100	3.45

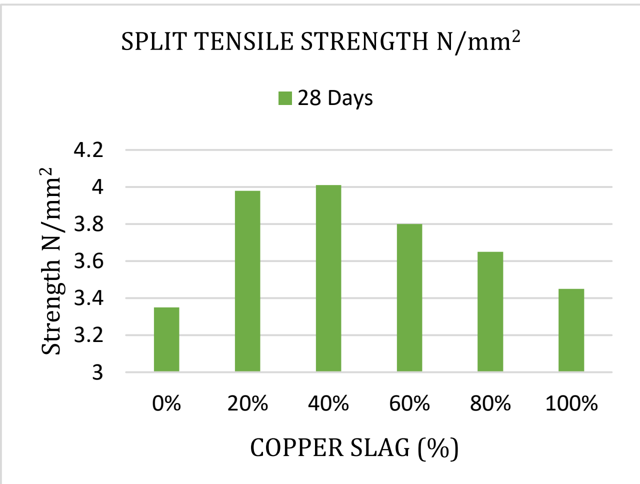

Chart -4: Split Tensile Strength

The maximum split tensile strength at 28 days was 4.01 N/mm². The optimum percentage of split tensile strength in fly ash based geopolymer concrete partially fine aggregate is replaced by copper slag is 40%.

4. CONCLUSIONS

- Low calcium fly ash based Geopolymer concrete with 14M sodium hydroxide concentration and copper slag as a partial replacement for natural river sand shows compressive strength and split tensile strength of 38.90 N/mm² and 4.01 N/mm² ambient cured concrete.
- As increasing the percentage of copper slag in place of sand, strength of concrete increases this may be influenced by presence of higher amount of silica in copper slag compared to the sand.
- Up to 40% replacement, geopolymer concrete gain more strength. Beyond 40% replacement the strength started to reduce.
- Based on this experimental investigation we can say that the optimum percentage of copper slag replacement as fine aggregate in geopolymer concrete is 40%.
- Partial replacement of copper slag in fine aggregate reduces the cost of making concrete due to copper slag is waste material.

REFERENCES

[1] K.Mahendran1, N.Arunachelam2 "Study on Utilization of Copper Slag as Fine Aggregate in Geopolymer Concrete" International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.53 (2015).
[2] Xu H, Van Deventer JSJ. The geopolymerisation of alumino-silicate minerals. International Journal of Mineral Processing. 2000; 59(3):247–66.
[3] M.I. Abdul Aleem, P.D. Arumairaj "Optimum mix for Geopolymer concrete" Indian Journal of Science and Technology, Vol. 5, No. 3 March 2012, pp. 2299-2301.
[4] Ambrish et al.(2017). "Partial Replacement of Copper Slag as Fine Aggregate"SSRG International Journal of Civil Engineering.
[5] Anuradha R, Sreevidya V, Venkatasubramani R, Rangan BV. Modified guidelines for geopolymer concrete mix design using Indian standard. Asian Journal of Civil Engineering (Building and Housing). 2012; 13(3):353–64.
[6] Ryua GS, Leeb YB, Koha YT, Chung YS. The mechanical properties of fly ash-based geopolymer concrete with alkaline activators. Construction and Building Materials. 2013; 47:409–18.
[7] Al-Jabri K.S., Taha R.A., Al-Hashmi A. and Al-Harthy A.S. "Effect of copper slag and cement by-pass dust addition on mechanical properties of concrete", Construction and building materials, Vol. 20, pp. 322-331, 2006.
[8] John L. Provis and Susan A. Bernal. (2014) "Geopolymers and Related Alkali- Activated Materials"

[9] M.I.Abdul Aleem1,P.D. Arumairaj2, "Geopolymer concrete- a review" International Journal of Engineering Sciences & Emerging Technologies, ISSN: 2231 – 6604,(2012).
[10] Sahoo S, Das BB, Rath AK, Kar BB. Acid, alkali and chloride resistance of high volume fly ash concrete. Indian Journal of Science and Technology. 2015; 8(19):1–12.
[11] Guo, X., et al. (2010). "Compressive strength and microstructural characteristics of class C fly ash geopolymer." Cement and Concrete Composites **32**(2): 142-147.
[12] Hardjito, D., et al. (2004). "On the development of fly ash-based geopolymer concrete." ACI Materials Journal-American Concrete Institute **101**(6): 467-472.
[13] Puertas, F., et al. (2000). "Alkali-activated fly ash/slag cements: strength behaviour and hydration products." Cement and Concrete Research **30**(10): 1625-1632.
[14] D.Hardjito and B.V. Rangan, "Developlment and properties of low-calcium fly ash-based geopolymer concrete" Research report GC 1, Curtain university of Technology, Australia.
[15] G.S. Manjunath, Radakrishna, C.Gridhar, Mahesh Jadhav. "Compressive strength develeopment in ambient cured geo-polymer mortar" . International Journal of Earth science and Engineering, Vol 04, No 06 SPL, Octobar 2011, pp.830-834.
[16] Washington Almeida moura, Jardel Pereira Gonclaves and Monica Batista Leite Lima, "Copper slag waste as a supplementary cementing material to concrete," Journal of Material Science 42 (7), 2226, 2007.
[17] Khalifa S Al-Jabri, Abdullah H Al-Saidy, Ramzi Taha, "Effect of copper slag as a fine aggregate on the properties of cement mortars and concrete," Construction and Building Materials 25 (2), 933-938,2011.