# A STUDY ON STRENGTH PROPERTIES OF GEOPOLYMER CONCRETE WITH ADDITION OF COPPER SLAG

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**ABSTRACT:** Geopolymer concrete is an innovative, environment friendly, sustainable and green technology in modern construction industry. Recycling the industrial by-products in the construction industry and utilizing this product significantly complements the sustainable technology and development. Nowadays conventional Portland cement binders was replaced by geopolymer concrete which an ecofriendly alternative for binder. In this paper, an experimental investigation on Geopolymer Concrete was done copper slag an industrial by-products as a replacement of fine aggregates. And also Mechanical properties were studied by varying mix proportions with different replacement levels in copper slag as a replacement of fine aggregate were studied. The properties of six different proportions with control mix concrete and others were 10 %, 20 %, 30 %, 40 % and 50 % fine aggregate were replaced with copper slag are compared and discussed briefly. The oven temperature at 60˚C for a period of 24 hours and ambient curing conditions are considered. Each specimen tested on the compressive strength, split tensile strength and flexural strength of concrete. The test results show that the compressive strength increases with the increase of the copper slag content. Improvements: These results, thereby substantiates the fact that the copper slag is an alternative material for sand.

***Keywords: Compressive Strength, Copper Slag, Fly Ash, Geopolymer, Sodium Hydroxide, Sodium Silicate, GGBS, Alkaline Liquid.***

## 1. INTRODUCTION

Concrete is the most widely used construction material in world .Water and ordinary Portland cement (OPC) is the major ingredient used in concrete. The production of cement releases large amount of carbon dioxide (CO2) to the atmosphere that will affect the environment. In order to rectify these problems an alternative to be found for cement and fine aggregate in concrete will help us to reduce the environmental impact. Using alkali- activated binder or inorganic alumina-silicate polymer called “Geopolymer” which is used to replace the cement in concrete. Geopoymer is from materials rich in Silica and alumina either it might be naturally available or by-products from the industries. Fine aggregate will be replaced by steel slag, copper slag and blast furnace slag from the metallurgical industries. Geopolymer concrete has many advantages over normal concrete. It gives high strength, more resistant to chemicals and corrosion, when compared to the concrete prepared from OPC. It has a property of gaining High-early strength either when cured at dry heat or in steam, this character can be best utilized in precast industry to increases the rate of production of elements.

Curing temperature and durations are the most important factors which influence the strength of the geopolymer concrete. As the presence of sodium silicate in gel form delays the setting time of the concrete at ambient temperature, concrete is cured at 60˚C for about 24 hours to 48 hours. To overcome this problem, the effect of curing time on the compressive strength of the geopolymer concrete cannot be generalized within 5 to 6 hours. However, 21 hours of curing is observed to be very effective for the development of the compressive strength beyond which there is no considerable increase in the strength of concrete. The present study investigates the possibilities of using copper slag as a fine aggregate in geopolymer concrete in ambient curing and hot air oven 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. The copper slag is procured from Hindustan Industries Ltd, for the replacement of sand in geopolymer concrete. The slag appears as black glassy particle and granular. The particle sizes are similar to the sand. Copper slag is a by-product material obtained from copper extraction by smelting. The mineralogical composition and morphology of the slag show that it can be used in the construction industry. If CaO content increases, in the slag it can induce cementatious properties under the activation of NaOH and also improves the strength of the concrete.

## 2. MATERIALS USED:

### Fly ash

Fly ash is collected from Tuticorin Thermal Power Plant. It contains 80 to 85% of silica and alumina.

### Fine aggregate

The sand was tested as per the given procedure in BIS: 2386-1968

### Coarse aggregate

The coarse aggregate was tested as per the given procedure in BIS: 2386-1963.The coarse aggregate meeting the requirements of BIS: 383-1970 is suitable for making GPC.

### Copper slag

Copper slag is a by-product obtained from the smelting and refining of copper. The slag is collected from Hidalgo, Hindustan .Production of one tone of copper is generated approximately 2.2-3.0 tones copper slag

### Alkaline liquid

Alkaline solutions are mainly composed of sodium silicate and sodium hydroxide solution. Generally NAOH is available in market in the form of pellets or flakes with 96% to 98 % purity.

## 3. MATERIAL PROPERTIES

### Fly ash

**Table 1. Chemical composition of class F fly ash**

| chemicals | %composition |
|---|---|
| $Sio_2$ | 50.18 |
| $Al_2O_3$ | 26.31 |
| $Fe_2O_3$ | 13.68 |
| $MgO_3$ | 1.29 |
| $SO_3$ | 0.02 |
| $Na_2O$ | 0.32 |
| $K_2O$ | 0.53 |
| TiO | 1.66 |
| SrO | 0.30 |
| $P_2O_5$ | 1.55 |
| $Mn_2O_3$ | 0.09 |

The specific gravity test result of fly ash=2.2

**Aggregate**

**Table 2. properties of coarse aggregate**

| Sieve (mm) | Specific gravity | Bulk density (kg/m³) | Fineness modulus |
|---|---|---|---|
| 20 | 2.96 | 1649 (compacted) 1545 (loose) | 7.55 |
| 12.5 | 2.83 | 1668 (compacted) 1542 (loose) | 6.76 |
| sand | 2.66 | 1633 (compacted) 1536 (loose) | 2.32 |
| Copper slag | 3.77 | 1962 (compacted) 1802 (loose) | 4.48 |

## 4. MIX DESIGN

In the design of geopolymer concrete mix, assume the unit-weight of concrete is 2400kg/$m^3$ By assuming the ratio of alkaline liquid to fly ash as 0.315.The ratio of sodium silicate to sodium hydroxide solution was fixed as 2.43.in the present investigation, concentration of NAOH solution is taken as 8M.Water binder ratio 0.55 for M20 grade.

**Table 3. Mix proportion for geopolymer concrete**

| Mix | Binder | F.A (kg/m³) | | | C.A (kg/m³) | | M | 6% Alkaline | | Water |
|---|---|---|---|---|---|---|---|---|---|---|
| | 17% Fly ash | Copper slag % | | 30% Fine sand | 20mm | 12mm | | NAOH | $Na_2Si_{O_3}$ | |
| 1 | 408 | 0 | - | 554 | 776 | 517 | 8 M | 42 | 102 | 224 |
| 2 | 408 | 10 | 55 | 498 | 776 | 517 | | 42 | 102 | |
| 3 | 408 | 20 | 110 | 443 | 776 | 517 | | 42 | 102 | |
| 4 | 408 | 30 | 166 | 387 | 776 | 517 | | 42 | 102 | |
| 5 | 408 | 40 | 221 | 332 | 776 | 517 | | 42 | 102 | |

**PREPARATION OF ALKALINE SOLUTION:**

The concentration of NAOH solution is taken as 8M. 320g of sodium hydroxide flakes dissolved in one liter of water to prepare sodium hydroxide solution of 8M.

## 5. TEST RESULT

**Slump cone test**

The slump cone test is measured the workability of concrete done as per IS Code.

**Table 4. slump values**

| Mix proportion | % of copper slag | Slump values mm |
|---|---|---|
| Mix 1 | 0 | 100 |
| Mix2 | 10 | 110 |
| Mix3 | 20 | 115 |
| Mix4 | 30 | 125 |
| Mix5 | 40 | 130 |

The slump values goes on increasing by addition of copper slag (increasing) do not absorbs water to certain thus the workability of concrete slightly increased.

**Compressive strength test:**

The mould of 150×150×150 can be used and tested at the age of 7, 28 days using400 tone capacity.

**Table 5 .Compressive strength on cube (Mpa)**

| Binders | 7 Days | AVG | 28 Days | AVG |
|---|---|---|---|---|
| MIX 1 | 6.104 | 6.394 | 6.976 | 7.848 |
| | 6.54 | | 7.848 | |
| | 6.54 | | 8.72 | |
| MIX 2 | 15.26 | 13.516 | 15.26 | 16.42 |
| | 13.08 | | 16.568 | |
| | 12.208 | | 17.44 | |
| MIX 3 | 23.98 | 23.98 | 27.468 | 27.468 |
| | 21.8 | | 27.032 | |
| | 26.16 | | 27.904 | |
| MIX 4 | 28.34 | 27.32 | 30.52 | 31.392 |
| | 27.468 | | 31.392 | |
| | 34.88 | | 38.94 | |
| MIX 5 | 34.88 | 33.86 | 38.94 | 39.24 |
| | 34.008 | | 39.93 | |
| | 32.70 | | 38.85 | |

The above table shows that the compressive strength varies by 5 to 10 N/$mm^2$. The compressive strength increases while increasing copper slag content. The max compressive strength is obtained at Mix5 in 7 days.

**Split tensile test**

Split tensile test were carried out on 150×300mm cylinder. The strength can be calculated using the following formula

$$F_{sp}=2p/3.14dl$$

P-max load in N,
d-diameter of the specimen in mm,
l -length of the specimen in mm.

**Table 6. Split tensile strength test on cylinder (Mpa)**

| Binders | 7 Days | AVG | 28 Days | AVG |
|---|---|---|---|---|
| MIX 1 | 0.97 | 0.924 | 1.013 | 1.236 |
| | 0.832 | | 1.002 | |
| | 0.97 | | 1.693 | |
| MIX 2 | 2.08 | 2.22 | 2.943 | 2.766 |
| | 2.22 | | 2.669 | |
| | 2.36 | | 2.687 | |
| MIX 3 | 2.638 | 2.726 | 2.892 | 2.949 |
| | 2.77 | | 2.978 | |
| | 2.77 | | 2.978 | |
| MIX 4 | 3.33 | 3.343 | 3.653 | 3.547 |
| | 3.469 | | 3.512 | |
| | 3.23 | | 3.476 | |
| MIX 5 | 3.905 | 3.845 | 3.918 | 3.952 |
| | 3.830 | | 3.969 | |
| | 3.800 | | 3.97 | |

It is observed that the split tensile strength goes on increasing an addition of copper slag. The max strength is obtained for Mix5.It is also observed that the value of split tensile strength goes on increasing with increase in curing period.

**Flexural tensile strength test**

For a rectangular sample under a load in a four-point bending setup where the loading span is one-third of the support span.

$$\text{Flexural tensile strength}=PL/BD^2$$

Where,

P –load at the fracture point
L-length of the support span
B-width
D-thickness

**Table 7. Flexural tensile strength on beam (Mpa)**

| Binders | 7 days | AVG | 28 Days | AVG |
|---|---|---|---|---|
| MIX 1 | 0.46 | 0.47 | 0.76 | 0.75 |
| | 0.48 | | 0.74 | |
| MIX 2 | 1.00 | 1.03 | 1.18 | 1.17 |
| | 1.06 | | 1.16 | |
| MIX 3 | 1.564 | 1.580 | 2.26 | 2.254 |
| | 1.66 | | 2.23 | |
| MIX 4 | 1.73 | 1.77 | 2.66 | 2.76 |
| | 1.81 | | 2.86 | |
| MIX5 | 2.28 | 2.29 | 3.23 | 3.25 |
| | 2.30 | | 3.27 | |

It is observed that the flexural strength value is increasing while increasing the % of copper slag and curing period.

## CONCLUSION

The sample of Geopolymer concrete for various proportions of copper slag and fly ash were casted and evaluation of mechanical properties of hardened concrete was done.

In this study the mechanical properties of GPC increase in copper slag content.

The maximum compressive strength is obtained for mix-5 proportion was 39.24 Mpa, so it can be recommended in place of M20 grade concrete in future.

Similarly the other mix proportion of GPC also has higher strength when compared to conventional concrete (M30, M40)

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