# Analysis of Geo Polymer Concrete Behaviour with GGBS

**Padmanaban M .S**

Central Polytechnic College, Chennai, Tamil Nadu, India

**Abstract:** ***The major problem the world is facing today is the environmental pollution. In the construction industry mainly the production of Portland cement will causes the emission of pollutants results in environmental pollution. We can reduce the pollution effect on environment, by increasing the usage of industrial by-products in our construction industry. Geo-polymer concrete is such a one and in the present study, to produce the geo-polymer concrete the Portland cement is fully replaced with GGBS (Ground granulated blast furnace slag) and alkaline liquids are used for the binding of materials. The alkaline liquids used in this study for the polymerization are the solutions of Sodium-hydroxide (NaOH) and sodium silicate (Na2Sio3).. This study investigates the use of GGBFS (ground granulated blast furnace slag) in 100% replacements by mass in cement. Harden concrete properties like compressive strength, Spilt tensile, flexural strength of concrete are be determined for Geoplymer concrete and Normal concrete. Finally the test results were compared from the test results, it has been observed that the geo-polymer concrete possess better result than the normal concrete.***

**Keywords:** GGBS, geopolymer concrete, alkaline liquid, compressive strength. Spilt tensile, Flexural strength

## 1. Introduction

Masonry is the building of structures from individual units that are usually bound together by means of mortar [1]. Concrete block masonry is a common construction material in India because of its abundance, low cost and availability of skilled labour [2]. The main drawback of cement concrete blocks is consumption of cement which is a major contributor to the greenhouse effect and the global warming, it is necessary to consider this with very severe regulations and limitations [3]. At the same time the demand for industrial and domestic energy results in the production of a large volume of fly ash from solid coal fuel, which may increase in the world on an unprecedented scale in future [4]. Therefore, fly ash should not only be disposed of safely to prevent environmental pollution, but should be treated as a valuable resource. Production of building materials, particularly bricks/blocks using fly ash is considered to be one of the solutions to the ever increasing fly ash disposal problem in the country [5]. All the three methods of utilizing fly ash are considered in construction in different forms. Cement can be replaced partly with fly ash, Geopolymer and FaL-G can be used in the form of masonry blocks for better and strength and durability [6] r to understand and evaluate the results of the present study

## 2. Experimental Part

### Mix design procedure for conventional cement concrete and geopolymer concrete

Geo polymer concrete (GPC) represents a rather recent development in concrete materials technology and its GGBS based concrete, possessing the most desirable properties during fresh as well as hardened concrete stages. GPC is superior to conventional cement concrete (CCC)as the ingredients of GPC contribute most optimally and efficiently to the various properties. To produce GPC mix it is essential that it requires careful selection and proportioning of the ingredients which are almost the same as that CCC. There is no standard code or specified IS code for geo polymer mix design. Based on references only we need to design.

### Mix Design for M30 as per IS 10262-2009 for Normal Concrete

The specimens are to be caste with concrete of characteristic strength 20N/mm2. The physical properties of constituent materials are investigated and presented as follows.

a) Grade designation: M30
b) Maximum nominal size of aggregate: 20mm (angular)
c) Degree of quality control: good
d) Type of exposure: mild
e) Degree of supervision: good
f) Maximum water-cement ratio: 0.45
g) Minimum cement content: 320 kg/m3
h) Maximum cement content : 450 kg/m3

#### 1) Test Data for Materials

a) Type of cement used: OPC43 grade
b) Specific gravity of cement: 3.15
c) Specific gravity
i) Coarse aggregate: 2.67
ii) Fine aggregate: 2.44

#### 2) Target Mean Strength of Concrete

f ’ck = fck + 1.65 x S
where
f ’ck = target average compressive strength at 28 days,
fck = characteristic compressive strength at 28 days,
S = standard deviation.
S = 5, from table-1(IS 10262:2009)
Therefore, f ’ck = 20 + 1.65 x 5
= 38.25 N/mm2

#### 3) Selection of Water Cement Ratio

From table-5 of IS 456, maximum water-cement ratio = 0.45
Adopt w/c = 0.45,
0.45≥ 0.45, hence ok.

#### 4) Selection of Water Content

From table-2, of IS10262:2009
Maximum water content = 186 litre (for 25 to 50mm slump range)

Estimated water content for 100 mm slump=186+((6/100)x186).=197litre.

**5) Determination of Cement Content**
Water cement ratio = 0.45
Cement content = 192/ 0.45= 437.78 kg/m3
From table-5(IS 456), the minimum cement content =320 kg/m3.
437.78 kg/m3>320 kg/m3.hence ok

**6) Calculation of Aggregate**
From table-3 (IS 10262)
For 20mm aggregate,
Volume of coarse aggregate = 0.65
Volume of fine aggregate = 1- 0.62= 0.35

**7) Calculation Cement and Water Content**
Volume of cement = mass of cement / (specific gravity x 1000)= 0.139 m3
Volume of water = mass of water / (specific gravity x 1000)= 0.197 m3

**7) Determination of Coarse and Fine Aggregete Content**
1m3 concrete = volume cement + volume of water +volume of aggregate
Volume of total aggregate = 1 – (volume of cement + volume of water)= 0.664m3
Volume of fine aggregate = 0.35
Volume of coarse aggregate = 0.65

**8) Calculation of Weight Per Cubic Meter**
Weight of water = 1 x 1000 x 0.197 = 197 kg/m3
Weight of fine aggregate = 0.664 x 0.35 x 1000 x 2.44= 569.38 kg/m3
Weight of coarse aggregate= 0.664 x 0.65 x 1000 x 2.67= 1102.40 kg/m3

**9) Mix Proportion**
Cement = 427 kg/m3
Water = 197 kg/m3
Fine aggregate = 569.38 kg/m3
Coarse aggregate = 1102.40 kg/m3
C : F.A : C.A 1: 1.33 :2.58

**Design of Geopolymer Concrete Mixtures**

Studies have been carried out on fly ash-based geo polymer concrete. The compressive strength and the workability of geo polymer concrete are influenced by the proportions and properties of the constituent materials that make the geo polymer paste. Research results [Hardjito and Rangan, 2005] have shown the following:
Higher concentration (in terms of molar) of sodium hydroxide solution results in higher compressive strength of geo polymer concrete.

Higher ratio of sodium silicate solution-to-sodium hydroxide solution ratio by mass, results in higher compressive strength of geo polymer concrete.

The slump value of the fresh geo polymer concrete increases when the water content of the mixture increases. Super plasticizers may assist in improving workability.

As the H2O-to-Na2O molar ratio increases, the compressive strength of geo polymer concrete decreases.

Assume that normal-density aggregates in SSD condition are to be used and the unit-weight of concrete is 2400 kg/m3.

Take the mass of combined aggregates as 77% of the mass of concrete,
i.e. 0.77x2400= 1848 kg/m3.
Coarse aggregate=0.64x1848=1183 kg/m3.
Fine aggregate=0.36x1848=665.28 kg/m3.
The mass of GGBS alkaline=2400-1848 kg/m3.=552 kg/m3.
Assume alkaline/GGBS=0.47
Mass of GGB S= 552/(1+0.47) =375.51 kg/m3.
Mass of alkaline = 552-375.51 =176.49 kg/m3.
Assume sodium silicate/NAOH=3
Mass of NAOH=176.49/(1+3) =44.12 kg/m3.
Mass of sodium silicate=176.49-44.12 kg/m3.=132.37 kg/m3.
Calculation of water to geo polymer
1)NAOH,
Solid =0.25 x44.12 =11.03kg.
Water =0.75 x44.12 =33.09kg.
2) NA2SIO3,
Water=0.559*132.37 =74 kg/m3.
Solid=58.37 kg/m3.
Total mass of water=74+33.09 =107.09 kg/m3.
Total mass of geo polymer solids=11.03+58.37+375.51 =444.91 kg/m3.
Water/geo polymer ==0.24

**Table 1:** Guideline of selecting geo polymer mix design

| Water-to-geo polymer solids ratio, by mass | Workability | Design compressive strength (MPa) |
|---|---|---|
| 0.16 | Very stiff | 60 |
| 0.18 | Stiff | 50 |
| 0.20 | Moderate | 40 |
| 0.22 | High | 35 |
| 0.25 | High | 30 |

Mix design for geo **polymer**
GGBS 394.29 kg/m3
Fine aggregate 591 kg/m3
sodium silicate solution 112.65 kg/m3
Sodium hydroxide solution 45.06kg/m3 (8M)

**Preparation of Geopolymer Concrete**
To prepare sodium hydroxide solution of 8 molarity (8M), 320 grams (8x40 i.e., molarity x molecular weight) of sodium hydroxide flakes was dissolved in one litre of water. The mass of NaOH solids in a solution will vary depending on the concentration of the solution expressed in terms of molar, M. The mass of NaOH solids was measured as 248 grams per kg of NaOH solution of 8M concentration. The sodium hydroxide solution thus prepared is mixed with sodium silicate solution one day before mixing the concrete to get the desired alkaline solution. The solids constituents of the geo polymer concrete, i.e. the aggregates and the GGBS, were dry mixed in the pan mixer for about three minutes. After dry mixing, alkaline solution was added to the dry mix and wet mixing was done for 4 minutes. Nine cubes, three cylinder, three prism were cast and compaction was done by hand compaction.

## 3. Experimental Investigation

**Table 2:** Properties of OPC

| S. No. | Property of Cement | Values |
|---|---|---|
| 1 | Fineness of Cement | 306 |
| 2 | Normal Consistency (%) | 44% |
| 3 | Grade of Cement | 43 |
| 4 | Specific Gravity | 3.15 |
| 5 | Initial Setting time | 55 min |
| 6 | Final Setting Time | 100 min |

**Physical properties for fine aggregate**

**Table 3:** Sieve Analysis of Fine Aggregate

| Sieve size (mm) | Weight Retained (g) | Cumulative Weight Retained (g) | Cumulative % retained | % Passing | IS:383-1970– Zone III requirement |
|---|---|---|---|---|---|
| 4.75 | 0 | 0 | 0 | 100 | 100 |
| 2.36 | 4 | 4 | 0.21 | 100 | 90-100 |
| 1.18 | 352 | 356 | 18.53 | 99.79 | 85-100 |
| 0.6 | 869 | 1225 | 63.77 | 81.46 | 75-100 |
| 0.3 | 676 | 1901 | 98.96 | 55.87 | 60-100 |
| 0.15 | 20 | 1921 | 100 | 16.54 | 12-40 |

Fines value of fine aggregate=2.87

River Sand conforming to **grade Zone III** of IS: 383-1970 is selected

**Specific Gravity**

**Table 4:** Specific Gravity of Fine Aggregate

| Sl. No. | Observations | Trial 1 | Trial 2 | Trial 3 |
|---|---|---|---|---|
| 1. | Weight of the specific gravity bottle (W1), g | 652 | 652 | 652 |
| 2. | Weight of bottle + 1/3rd filled sand(W2), g | 852 | 848 | 845 |
| 3. | Weight of bottle + 1/3rd filled sand + water(W3), g | 1643 | 1647 | 1650 |
| 4. | Weight of bottle + water (W4), g | 1524 | 1524 | 1524 |
| 5. | Value | 2.46 | 2.68 | 2.88 |

$$\text{Specific gravity} = \frac{(w2-w3)}{(w2-w1)-(w3-w4)}$$

**Average specific gravity of sand = 2.44**

**Table 5:** Water absorption test for fine aggregate

| S.no | Observations | Trial-2 | Trial-1 |
|---|---|---|---|
| 1. | Sand + water(W1) | 1.444 | 1.092 |
| 2. | After one day(W2) | 1.46 | 1.1078 |
| 3. | Different(W3) | 0.016 | 0.0158 |
| 4. | Value | 1.40% | 1.45% |

Water absorption= (w3/w1) * 100

Water absorption=1.42%

**Physical Properties for Coarse Aggregate**

**Table 6:** Specific Gravity of Coarse Aggregate

| Sl. No. | Observations | Trial 1 | Trial 2 | Trial 3 |
|---|---|---|---|---|
| 1. | Weight of the specific gravity bottle (W1), g | 652 | 652 | 652 |
| 2. | Weight of bottle + 1/3rd filled sand(W2), g | 852 | 848 | 845 |
| 3. | Weight of bottle + 1/3rd filled sand + water(W3), g | 1643 | 1647 | 1650 |
| 4. | Weight of bottle + water (W4), g | 1524 | 1524 | 1524 |
| 5. | Value | 2.46 | 2.68 | 2.88 |

$$\text{Specific gravity} = = \frac{(w2-w3)}{(w2-w1)-(w3-w4)}$$

**Average specific gravity of C.A = 2.67**

**Table 7:** Water absorption test for coarse aggregate

| S. No | Observations | Trial-2 | Trial-1 |
|---|---|---|---|
| 1. | Coarse + Water(W1) | 2.608 | 2.456 |
| 2. | After one day (W2) | 2.618 | 2.466 |
| 3. | Difference (W3) | 0.0099 | 0.0103 |
| 4. | Value | 0.38% | 0.42% |

**Water absorption= (w3/w1) * 100**

**Water absorption==0.40%**

Physical Properties for GGBS

**Table 8:** Properties of GGBS

| S. No. | Property of slag | Values |
|---|---|---|
| 1 | Fineness | 387 |
| 2 | Specific Gravity | 2.75 |
| 3 | Initial Setting time | 170 min |
| 4 | Final Setting Time | - |

**Water Absorption Test for Geo Polymer**

**Table 9:** Table water absorption test for geo polymer and nominal concrete

| S. No | Observation | Normal | | Geo polmer | | Difference in absorption |
|---|---|---|---|---|---|---|
| | | Trial-1 | Trial-2 | Trial-1 | Trial-2 | |
| 1. | Dry oven wt. | 8.340 | 8.340 | 8.290 | 8.300 | - |
| 2. | Absorption after one hr.(11am) | 8.490 | 8.490 | 8.500 | 8.510 | 0.62 |
| 3. | Absorption after one hr.(12pm) | 8.510 | 8.530 | 8.520 | 8.500 | 0.034 |
| 4. | Absorption after one hr.(1pm) | 8.520 | 8.540 | 8.510 | 8.500 | 0.305 |
| 5. | Absorption after one hr.(2pm) | 8.520 | 8.550 | 8.520 | 8.510 | 0.255 |
| 6. | Absorption after one hr.(3pm) | 8.530 | 8.550 | 8.510 | 8.510 | 0.25 |

Minimum absorption difference is 0.25%

Maximum absorption difference is 0.62%

## 4. Results

**Table 10:** Compressive Strength for Geo Polymer Concrete

| S.no | Curing age | Ultimate load | | | Mean | Compressive strength (N/sq.mm) |
|---|---|---|---|---|---|---|
| | | Trial-1 | Trial-2 | Trial-3 | | |
| 1 | 7 days | 1040 kN | 940kN | 980kN | 960 kN | 42.67 |
| 2 | 21 days | 1189kN | 1176kN | 1150kN | 1172kN | 52.08 |
| 3 | 28 days | 1430kN | 1245kN | 1339kN | 1292kN | 57.42 |

**Table 11:** Compressive Strength for Standard Concrete

| S.no | Curing age | Ultimate load | | | Mean | Compressive Strength (N/sq.mm) |
|---|---|---|---|---|---|---|
| | | Trial-1 | Trial-2 | Trial-3 | | |
| 1. | 7 days | 570Kn | 570kN | 550kN | 560 kN | 24.89 |
| 2. | 21 days | 740kN | 660kN | 625kN | 675kN | 30 |
| 3. | 28 days | 850kN | 750kN | 1050kN | 800kN | 39.42 |

**Table 12:** Split Tensile Strength for Geo Polymer Concrete

| S. No | Curing Age | Standard | | Geopolymer | | Different (Mpa) |
|---|---|---|---|---|---|---|
| 1 | 21 | 200kN | 2.89N/sq.mm | 300kN | 4.24N/sq.mm | 2.09 |
| 2 | 28 | 300.34kN | 4.24 N/sq.mm | 423kN | 5.98N/sq.mm | 2.65 |

**Table 13:** Flexural strength for geo polymer concrete

| S. No | Curing Age | Standard | | Geopolymer | | Different (Mpa) |
|---|---|---|---|---|---|---|
| 1 | 21 | 10.24kN | 1.51N/sq.mm | 12kN | 1.68 N/sq.mm | 0.17 |
| 2 | 28 | 12kN | 1.77 N/sq.mm | 17 kN | 1.92 N/sq.mm | 0.15 |

## 5. Discussions

- Fibre reinforced Geo polymer composites may be considered a solution to improve flexural strength and fracture toughness.
- Since there is demand for natural sand, the fine aggregate shall be replaced partially by quarry dust.
- Different structural elements like Geo polymer Concrete Beam, Reinforced Geo polymer Concrete Beam, Reinforced Geo polmer Concrete Columns, Reinforced Beam Column joints shall be cast for the above mentioned concentrations of Sodium Hydroxide solution and curing conditions and tested.

## 6. Concusions

Based on the experimental investigation the following conclusions are listed below:

1) Water absorption property is lesser than the nominal concrete**.**
2) The compressive strength and split tensile strength, flexural strength of geopolymer concrete higher than the normal concrete.
3) For a given proportion of a mix, the compressive strength and split tensile strength increase with age.
4) The rate of gain in compressive strength and split tensile strength of geopolymer concrete is very fast at 7 days curing period and the rate gets reduces with age.
5) Geo polymer concrete can be recommended as an innovative construction material for the use of construction.
6) Apart from less energy intensiveness, the GPCs utilize the industrial wastes for producing the binding system in concrete. There are both environmental and economical benefits of using GGBS.

## References


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