# PERFORMANCE OF GGBS BLENDED GEOPOLYMER CONCRETE WITH BASALT FIBRE

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## ABSTRACT

Concrete which is a vast used matrix in the construction field, is adding a global hinderence which emit $CO_2$ and absorb $O_2$. This experimental study intends to overcome this scenario and improves the susatainablity of the environment. Geopolymer are generally proved to be fire resistance, acid resistance and saline resistance. Thus the blending of GGBS and adding of basalt fibers elevates the hardened property and durability property of the geopolymer concrete. Basalt fibers also add fire resistance property and improves the flexural and tensile behaviour. The geoplymer was synthesized with flyash, GGBS, alkaline solution, M-sand and to which basalt fibers are added in bundle. The study perform strength and durability properties of geoplymer concrete. The specimen are casted and tested for compressive strength and split-tensile strength. These are also studied for its durability properties like water absorption, sorptivity, NaCl (saline property) and HCl (acid resistance). The results were discussed.

Keywords - Geopolymer, alkaline solution, flyash, GGBS, basalt fibre, strength, durability

## I. INTRODUCTION

In this modern age, Civil Engineering constructions have their own structural and durability requirements, every structure has its own intended purpose and hence to meet this purpose, modification in traditional cement concrete has become mandatory. The Portland Pozzolona Cement (PPC) is widely used binder in most of the concrete constructions. PPC takes the major contribution in emission of greenhouse gases. For each ton of cement one ton of $CO_2$ is being released into the atmosphere [1].

An alternative eco-friendly concrete binder called "GEOPOLYMER" is developed, an aluminosilicate material. Flyash (also known as flue-ash) is a residue generated by combustion of coal which is rich in alumina and silica. Geopolymer reduces about 80% of emission [2]. Geopolymer was synthesized with flyash, GGBS, alkaline solution, M-sand, and to which basalt fibres are added in bundles. Geopolymer exposes to a temperature of about 500ºC and showed a same resistance to hydrochloric acid when compared to conventional concrete[2].

Basalt an oldest solidified lava rock formed near the surface of earth's crust. It is rich in magnesium and iron. The basalt fiber enhances the flexure and tensile nature of concrete. A different fibre dosages of 0%, 0.5%, 1%, 1.5% and 2% are added in geopolymer concrete, to investigate the optimum strength of concrete. The compressive strength, split-tensile strength and flexural strength tests on the concrete specimens shows the percentage variation in strength and optimum value is obtained.

The acid attack test was conducted by immersing the specimen in acid water for 24 hours. Hydrochloric acid (HCl) with a pH range of about 2, is taken at 5% weight of water which constitutes the acid water[3]. Similarly, saline, sorptivity and water absorption property of the specimens are tabulated and studied.

## II. MATERIALS USED

### A. *Fly ash*

Fly ash, low calcium class F type is generally glassy with some crystalline inclusions of mullite and quartz. It is in form of fine powder which is a by-product from combustion coal (pulverized) in power plants supply, an excellent material used in blended cement, hollow blocks and mosaic tiles. Commonly, fly ash includes substantial amount of calcium oxide (CaO) and silicon dioxide ($SiO_2$), its being endemic ingredients in coal-bearing rock strata. It also known as flue-ash, which is cheap material for the replacement of Portland cement in concrete. It also improves the strength, segregation and ease of pumping concrete. Major step towards sustainable growth for fly ash is decay process is difficult. Specific gravity and fineness modulus is 2.30 & 7.86[4].

### B. *Water*

Specimen's casting was done with minimum quantity of water (potable) which is required to mix the geopolymer water. The pH of the water used is maintained in neutral at 7.

### C. *GGBS*

GGBS comprises of CaO, aluminium oxide, magnesium oxide, silicion di-oxide. The addition of GGBS in geopolymer concrete will boost the strength of the concrete and the curing of the concrete at normal room temperature is possible. The chemical content of ground granulated blast furnace slag remains the same as in normal PPC cement but proportion is different[7].

### D. *M-Sand*

The M-sand obtained from local source was used as fine aggregate used for preparing concrete specimens. The specific gravity of sand was 2.51. The sand was made

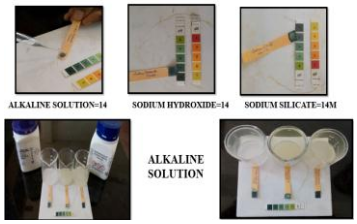
saturated surface dry (SSD) before using in the geopolymer mix to avoid water absorption from activator solution.

### *E. Coarse aggregate*

Coarse aggregate is a vast part of coarse particulate material used in construction. These small granite stone of size of 20mm was selected for this work. The specific gravity is 2.61 and fineness modulus is about 7.16[5]. Coarse aggregate properties have been tested.

### *F. Alkaline solution*

The alkaline activator consists of Sodium Hydroxide and Sodium Silicate. The Sodium Hydroxide solution of concentration 16M was taken. The solutions were taken in a ratio of 0.61. The alkaline solution is used after 24 hours for concrete mixing. pH of alkaline solution tested and found to not less than 6 as per IS code.




### *G. Basalt fibre*

The basalt has a well grained mineral texture due to rapid cooling of molten lava on the earth crust. This rock is also igneous rock which contains 45% to 60% of $SiO_2$ content in its volume. To prepare the basalt fibre, the basalt rock is heated up to 1000$^{o}$C. Basalt fibre of size 12mm in length and 36µm in diameter were used. The fibre dosage varied from 0.5% - 2% in bundles. Basalt composite can replace steel as 1kg of basalt reinforces equals 9.6kg of basalt [6].

## III. METHODOLOGY AND EXPERIMENTAL WORK

This chapter explains the method taken to carry out the experiment and to study the performance of the Geopolymer concrete. The basic properties of the materials are procured and tested. Mix proportioning is calculated and mixes are designed. To make alkaline solution, mix sodium silicate, sodium hydroxide and water in calculated in mix proportioning, one day prior to its use. Fly ash, basalt fibres and aggregates are blended in dry state vigorously whenever required. Alkaline activator is mixed with the dry blend for about10-15 minutes which makes a homogenous mix. Transfer the Geopolymer concrete to the moulds, after greasing. The moulds are vibrated for about 2-3 minutes to remove the entrapped air. For a fresh concrete specimen, 60 minutes is given as rest period. Then specimens are cured using ambient curing and the specimens are evaluated at 7$^{th}$ day for their properties.

### *A. Compressive strength test*

The strength is test by compressive strength, specimens of the cube dimensions 100x 100x100 mm casted for M35 grade of concrete. The specimen is kept for 7 days ambient curing, their testing is done with the help of compressive testing machine. The load was given to the specimen till the specimen get failed. The reading was noted. Three specimen were prepared for each test and tested and noted the final value. The compressive strength was calculated by following formula,

Compressive strength of concrete

$$= \frac{\text{Ultimate compressive load}}{\text{Area of cross section (mm}^2\text{)}}$$

### *B. Split Tensile Strength*

Usually concrete is weak in tension, so to improve the property of concrete basalt fibre is added.

Split tensile strength= $\mathbf{2P/\pi dl}$

where,

P=failure load
L=length of the cylinder
d= diameter.

### *C. Flexural strength test*

The beam specimen of the size 500mm X 100mm X 100mm, is used to find out the flexural strength of the concrete. The specimen is kept for 7 days ambient curing, their testing is done with the help of Universal testing machine. The load is applied to the upper most surface as cast in the mould, through1pt loads as indicated. The load is applied at the rate of 1.8KN/min. the load is increased until the specimen fails. Unlike crushing failure, flexure will be sudden and abrupt and hence a close watch on the dial gauge reading is made and failure load recorded accurately.

Flexural strength = $\mathbf{Pl/bd^2}$

Where,

P= load in N/mm2
d= depth of the beam
b= breadth of the beam
l= length of the beam

### *D. Durability tests*

***1) Water absorption test*** - This is to evaluate the water absorption property of concrete. The specimen of size 100x100x100 mm was immersed completely in water for about 24 hours. Before immersion, the weight of the cured specimens is noted. The final water absorption property value of the specimens is arrived by weighing the immersed specimens.

***2) Sorptivity*** – It is a simple and rapid test to determine the tendency of concrete to absorb water by capillary suction. The cured specimens of size 100x100x100mm were cleaned and initial mass to be noted. Then it is immersed in water at a depth of 5-10mm. At selected times as 5,10,15,20,25 & 30 minutes, the samples are removed from water and are weighed. The values are noted and tabulated. The gain in mass per unit area over the density of water is plottes versus the square root of the elapsed time. The slope of the line of best fit of these points (ignoring the origin) is taken as the Sorptivity.

***3) Acid Resistance test*** – The well cured specimens after 7 days of ambient curing are taken out and initial weight of the specimens are noted. For acid resistance test, HCl with a pH of 2 at 5% weight of water was added to water in which

the concrete cubes were stored. The pH is maintained for 24 hours and then the specimens were tested for colour variance and change in weight.

***4) Salinity*** – For Salinity test the well cured specimens are stored in water which contain 35 grams of Nacl for 24 hours. Before stored in water the initial weight of specimen was noted. Then the specimens are weighed for change in weight.

## IV. Result and Discussion

### *A. Compressive strength test*

The compressive strength test is used to see the capacity of concrete attaining at $7^{th}$ day test. It can be measured by the (Compressive Test Machine) by plotting the force obtained at the stage of crack occurred in the specimen. It was measured for 7 days of concrete specimen with various proportions of basalt fibre.

**Table 1 Compressive Strength**

| Mix no | % of basalt fibre | Compressive strength ($N/mm^2$) |
|---|---|---|
| M1 | 0% | 42.2 |
| M2 | 0.5% | 36.5 |
| M3 | 1% | 37 |
| M4 | 1.5% | 44 |
| M5 | 2% | 38.5 |

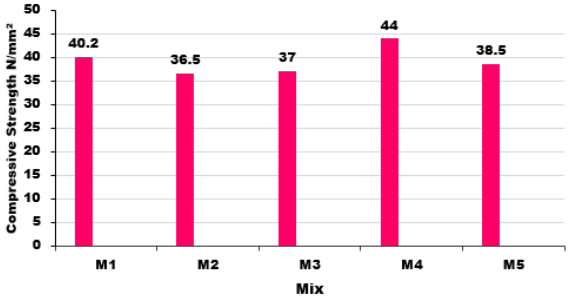



**Figure1 Compressive Strength**

The Fig1 indicates the comparison of result of compressive strength using cube specimen of $M_{35}$ grade concrete.It is observed that the strength obtained in 1.5% of basalt fibre gives high compressive strength than other volume fraction.

### *B. Split- tensile strength test*

The split tensile strength test is taken for specimen for grade $M_{35}$. In this we observer the strength obtaining for various proportions of basalt fibre after 7 days of ambient curing of concrete. The specimen has a length of 300mm and a diameter of 150mm. The specimen placed in the plane of its length , showed cracks which is tabulated as shown in table 2

**Table2 Split Tensile Strength**

| Mix no | % of basalt fibre | Split- tensile strength ($N/mm^2$) |
|---|---|---|
| M1 | 0% | 4.5 |
| M2 | 0.5% | 4 |
| M3 | 1% | 4.3 |
| M4 | 1.5% | 4.9 |
| M5 | 2% | 4.2 |

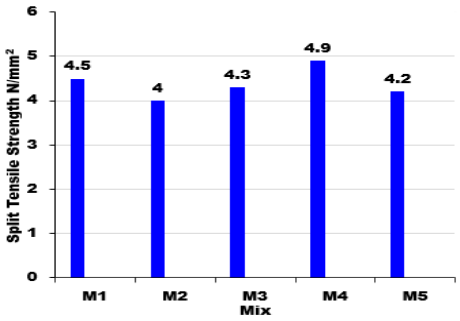



**Figure2 Split Tensile Strength**

This indicates the compression of result of split tensile strength using cylinder specimen of $M_{35}$ grade of concrete**.** It is observed that the strength obtained in 1.5% of basalt fibre gives high split-tensile strength than other volume fraction.

### *C. Flexural strength test*

The Flexural strength test is taken for specimen for grade $M_{35}$. In this we observer the strength obtaining for various proportions of basalt fibre after 7 days of ambient curing of concrete.

**Table3 Flexural Strength**

| Mix no | % of basalt fibre | Flexural strength ($N/mm^2$) |
|---|---|---|
| M1 | 0% | 4.6 |
| M2 | 0.5% | 4.3 |
| M3 | 1% | 4.5 |
| M4 | 1.5% | 5 |
| M5 | 2% | 4.4 |

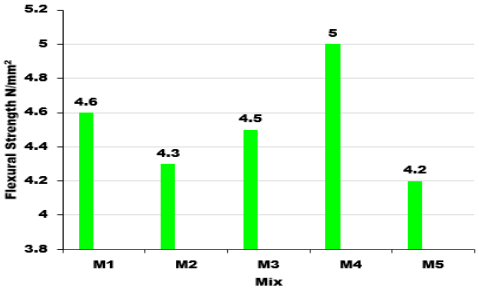



**Figure3 Flexural Strength**

This indicates the strength obtained in 1.5% of basalt fibre gives high Flexural strength than other volume fraction.

### *D. Durability tests*

#### *1) Water absorption test*

**Table4 Water absorption Test**

| Mix no | Initial weight of concrete(kg) | Final Weight of Concrete(kg) | % of water absorption |
|---|---|---|---|
| M1 | 2.420 | 2.452 | 1.13 |
| M2 | 2.456 | 2.487 | 1.26 |
| M3 | 2.435 | 2.467 | 1.31 |
| M4 | 2.468 | 2.495 | 1.11 |
| M5 | 2.498 | 2.540 | 1.64 |

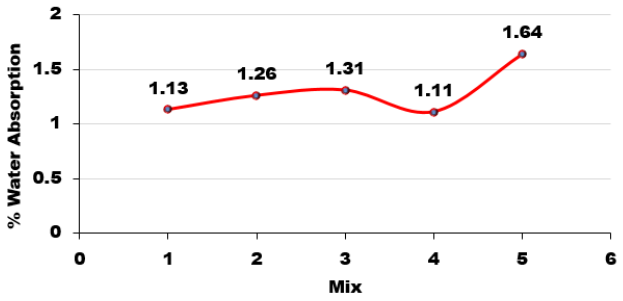



**Figure4 Water Absorption Test**

The concrete cube which has honey comb property, its causes deterioration due to absorption of more moisture. When this cube is exposed to the environment, which consists of moisture content will affect the concrete durability. So to know the absorption of moisture content the water absorption test is taken as per the code ASTM C642. The results are found to be satisfactory since it is less than 5% as per the codal provisions.

### *2) Sorptivity*

**Table 5.1(a) Mix design designation for M35 mix = M1**

| Test time (s) | $\sqrt{Time}$ $\sqrt{Time}$ ($S^{½}$) | Initial weight ,w(g) | Change in weight, $\Delta w \Delta w$ (g) | $I=\frac{\Delta W}{Ad}$ $\frac{\Delta W}{Ad}$ |
|---|---|---|---|---|
| 0 | 0 | 2400.20 | 0 | 0 |
| 300 | 17.32 | 2400.32 | 0.12 | 0.012 |
| 600 | 24.49 | 2400.38 | 0.18 | 0.018 |
| 900 | 30 | 2400.44 | 0.24 | 0.024 |
| 1200 | 34.64 | 2400.53 | 1.00 | 0.1 |
| 1500 | 38.72 | 2400.65 | 0.45 | 0.045 |
| 1800 | 42.42 | 2400.76 | 0.56 | 0.056 |

**Table 5.1(b) Mix design designation for M35 mix = M2**

| Test time (s) | $\sqrt{Time}$ $\sqrt{Time}$ ($S^{½}$) | Initial weight ,w(g) | Change in weight, $\Delta w \Delta w$ (g) | $I=\frac{\Delta W}{Ad}$ $\frac{\Delta W}{Ad}$ |
|---|---|---|---|---|
| 0 | 0 | 2400.11 | 0 | 0 |
| 300 | 17.32 | 2400.19 | 0.08 | 0.008 |
| 600 | 24.49 | 2400.26 | 0.15 | 0.015 |
| 900 | 30 | 2400.32 | 0.21 | 0.021 |
| 1200 | 34.64 | 2400.45 | 0.34 | 0.034 |
| 1500 | 38.72 | 2400.51 | 0.4 | 0.04 |
| 1800 | 42.42 | 2400.62 | 0.51 | 0.051 |

**Table 5.1(c) Mix design designation for M35 mix = M3**

| Test time (s) | $\sqrt{Time}$ $\sqrt{Time}$ ($S^{½}$) | Initial weight ,w(g) | Change in weight, $\Delta w \Delta w$ (g) | $I=\frac{\Delta W}{Ad}$ $\frac{\Delta W}{Ad}$ |
|---|---|---|---|---|
| 0 | 0 | 2400.01 | 0 | 0 |
| 300 | 17.32 | 2400.09 | 0.08 | 0.008 |
| 600 | 24.49 | 2400.11 | 0.1 | 0.01 |
| 900 | 30 | 2400.20 | 0.19 | 0.019 |
| 1200 | 34.64 | 2400.25 | 0.24 | 0.024 |
| 1500 | 38.72 | 2400.31 | 0.3 | 0.03 |
| 1800 | 42.42 | 2400.42 | 0.41 | 0.041 |

**Table 5.1(d) Mix design designation for M35 mix = M4**

| Test time (s) | $\sqrt{Time}$ $\sqrt{Time}$ ($S^{½}$) | Initial weight ,w(g) | Change in weight, $\Delta w \Delta w$ (g) | $I=\frac{\Delta W}{Ad}$ $\frac{\Delta W}{Ad}$ |
|---|---|---|---|---|
| 0 | 0 | 2400.00 | 0 | 0 |
| 300 | 17.32 | 2400.12 | 0.12 | 0.012 |
| 600 | 24.49 | 2400.20 | 0.20 | 0.02 |
| 900 | 30 | 2400.36 | 0.36 | 0.036 |
| 1200 | 34.64 | 2400.48 | 0.48 | 0.048 |
| 1500 | 38.72 | 2400.62 | 0.62 | 0.062 |
| 1800 | 42.42 | 2400.83 | 0.83 | 0.083 |

**Table 5.1(e) Mix design designation for M35 mix = M5**

| Test time (s) | $\sqrt{Time}$ $\sqrt{Time}$ ($S^{½}$) | Initial weight ,w(g) | Change in weight, $\Delta w \Delta w$ (g) | $I=\frac{\Delta W}{Ad}$ $\frac{\Delta W}{Ad}$ |
|---|---|---|---|---|
| 0 | 0 | 2401.00 | 0 | 0 |
| 300 | 17.32 | 2401.03 | 0.03 | 0.003 |
| 600 | 24.49 | 2401.15 | 0.15 | 0.015 |
| 900 | 30 | 2401.21 | 0.21 | 0.021 |
| 1200 | 34.64 | 2401.34 | 0.34 | 0.034 |
| 1500 | 38.72 | 2401.39 | 0.39 | 0.039 |
| 1800 | 42.42 | 2401.46 | 0.46 | 0.046 |

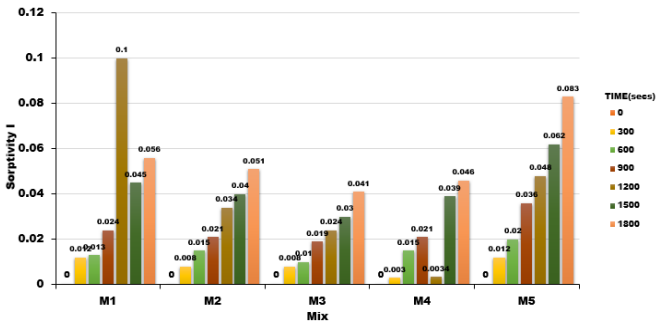



**Figure5 Sorptivity Test**

Sorptivity, which is also used to find absorption of water in concrete faster, then the water absorption test i.e. within half an hour. The above table shows the result in M4 which absorbs the less amount of water than other mix.

### *3) Acid resistance*

**Table 6 Acid Resistance Test**

| Mix no | Initial weight in grams(W1) | Final weight in grams(W2) | Acid Attack % |
|---|---|---|---|
| M1 | 2400.20 | 2395 | 0.22 |
| M2 | 2400.15 | 2392 | 0.34 |
| M3 | 2400.18 | 2394 | 0.26 |
| M4 | 2400.10 | 2397 | 0.13 |
| M5 | 2401.00 | 2394 | 0.29 |

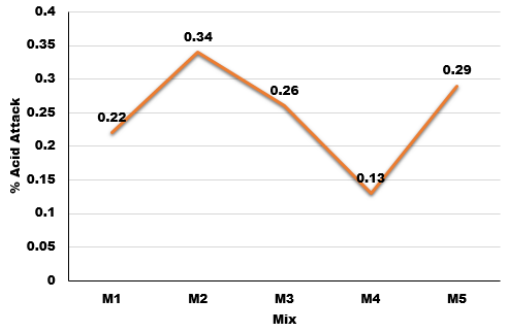



**Figure6 Acid Resistance Test**

Acid resistance test is for to check (colour change) corrosion in concrete. The above result shows the no colour change in all mix(M1-M5).

***4) Salinity***

**Table7 Salinity Test**

| S.No | Mix no. | Initial weight in grams(W1) | Final weight in grams(W2) | Salinity % |
|---|---|---|---|---|
| 1 | M1 | 2400.12 | 2397.1 | 0.12 |
| 2 | M2 | 2400.14 | 2396 | 0.17 |
| 3 | M3 | 2400.10 | 2391.36 | 0.364 |
| 4 | M4 | 2400.13 | 2398.2 | 0.074 |
| 5 | M5 | 2400.00 | 2389.2 | 0.45 |

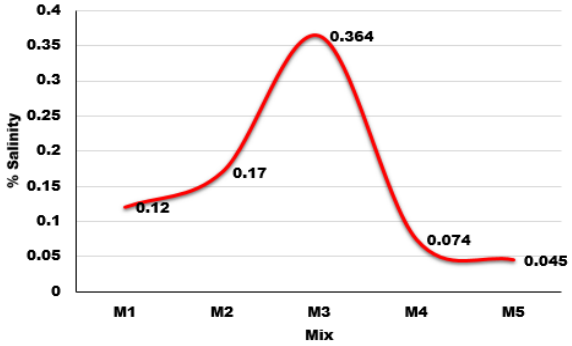



**Figure7 Salinity Test**

The salinity result shows the reaction of salt water with concrete is less in the above mix(M1-M5)

## V. Conclusion

1) The working ease of the geopolymer concrete prepared by blending GGBS with fly ash was found to be good.
2) Geopolymer concrete blended GGBS with basalt fibre, showed better performance in split tensile strength and flexural strength
3) With reference to the target mean strength, when compared with geopolymer concrete without basalt fibre, 1.5% basalt fiber added GGBS blended geopolymer concrete is having 9.4% increased compressive strength.
4) With reference to IS 5816:1997, the value must range between 1/8-1/10$^{th}$ of the fck and when compared with Geopolymer concrete without basalt fiber, 1.5% basalt fiber added GGBS blended Geopolymer concrete is having 8.8% increased split tensile strength
5) The Geopolymer concrete showed a minimal water absorption of 1.7% decrement in 1.5% of basalt when compared with geopolymer concrete without basalt.
6) The salinity value of geopolymer concrete with 1.5% basalt is 38.33% lower to basalt free geopolymer concrete.
7) The Geopolymer concrete with 1.5% basalt is decreased by 40.9% to geopolymer without basalt
8) It also shows low visibility of corrosion and colour change in acid environment
9) Addition of GGBS accelerated the earlier setting time and ambient curing helps in practical applications
10) This technique is an excellent alternative solution to the CO2 producing Portland cement concrete.

## VI. Scope For Future Work

1) Corrosion resistance test can be conducted for a long term duration.
2) Temperature resistance property can be tested and studied.
3) XRF, XRD tests can be done to show the radiation shielding property of basalt fibres.
4) Any product form of this experiment can be applied in future practical applications.

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