# An Effect of Alkaline Solution on Strength of Geopolymer Concrete

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## Abstract

"Geopolymer is a new development in the world of concrete in which cement is totally replaced by pozzoloanic materials like fly ash and activated by highly alkaline solutions ($NaOH/Na_2SiO_3$) to act as a binder in the concrete mix". Geopolymer concrete utilizes an alternate material including fly ash as binding material in replace of cement and As some of the surveys said one tone manufacturing of cement produces nearly one tone of carbon dioxide and which in turn produces greenhouse gases which cause global warming. Present work selects two l industrial by products such as fly ash and ground granulated blast furnace slag (GGBFS) to manufacture geo polymer concrete. Three Molarities of NaOH 6M, 8 M, 10 M, are considered with the replacement of fly ash with GGBFS and as per Indian Standard Specimens are casted and tested at room temperature curing.

**Keywords: Alkaline Solution Ratio, $NaOH/Na_2SiO_3$, Ground Granulated Blast Furnace Slag, compressive strength**

## I. INTRODUCTION

The term geopolymer was first Define by joseph Davidovits in 1978 to describe a family of mineral binders with chemical composition.

Concrete is second largest material used by people of in a world and as we know that cement is main binding component in concrete. Generally for each ton of Portland cement production, releases a ton of carbon dioxide in the atmosphere. Also cement production consumes significant amount of natural resources.

Geopolymer is a new development in the world of concrete in which cement can totally replace by pozzoloanic materials like fly ash and activated by highly alkaline solutions to act as a binder in the concrete mix. Therefore for complete replacement of cement by fly ash and to achieve the higher strength using alkaline activators. Fly ash when comes in contact with highly alkaline solutions forms inorganic alumina–silicate polymer product yielding polymeric bonds known as Geopolymer. The main binder is a C-S-H gel, as the result of a hydration process. In the later case, the main constituents to be activated with high alkaline solution are mostly the silicon and the aluminum present in the by-product material such as low calcium (Class F) fly ash. The binder produced in this case is due to polymerization. And Fly ash is partially replace with GGBFS.

## II. SCOPE

In present study the Ratio of Na2SiO3 to NaOH is 2 or 3. Three Molarities of NaOH 6M, 8 M, 10 M, and are considered. Partial replacement of flyash with GGBFS carried out 0%, 10%, 20%, 30%, 40% respectively and speciment of 150x150x150 mm cube and cylinder of 150 mm dia. and 300 mm in heights are tested.

## III. MATERIAL USED IN CONCRETE

Fly Ash
GGBFS
Aggregates
Alkaline activators
Water

### *A. Fly Ash:*

The finely divided residue that results from the combustion of ground or powdered coal and that is transported by flue gasses from the combustion zone to the particle removal system.

*1) Physical & Chemical Properties*

Fly ash particles are typically spherical, finer than Portland cement and lime, ranging in diameter from less than 1 μm to no more than 150 μm. The physical and chemical characteristics depend on the combustion methods, coal source and particle shape the colour of fly ash can be tan to dark grey, depending upon the chemical and mineral constituents. By the year 2010, the amount of

fly ash produced worldwide is estimated to be about 780 million tons annually. Thus we can also utilize fly ash in such application. Here Fly ash (F class) is used, obtained from Wanakbori Thermal Power Station-Kheda(Gujrat).

Table – 1
Fly ash characteristics

| *Chemical characteristics* | *F class flyash* |
|---|---|
| *Sio2 + $Al_2O_3$ + $Fe_2O_3$ Min.* | *49* |
| *$SiO_2$ Min.* | *25* |
| *Reactive silica Min.* | *19* |
| *MgO Max.* | *5* |
| *$SO_3$ Max.* | *3* |
| *$Na_2O$ Max.* | *1.5* |
| *Total chloride Max.* | *0.05* |
| *LOI Max.* | *5* |

### *B. GGBFS:*

Ground Granulated Blast Furnace Slag (GGBFS) is a by product of the steel industry. Blast furnace slag is the non-metallic product consisting essentially of calcium silicates and other bases that is developed in a molten condition simultaneously with iron in a blast furnace.

*1) Physical & Chemical Properties:*

The chemical composition of slag varies depend on composition of raw material. It consist Unreactive Crystalline material consisting of assemblage of Ca-Al-Mg silicates. The main components of GGBFS are CaO, $SiO_2$, $Al_2O_3$, MgO. The higher rate of Si & Al results the hieigher strength achived in concrete. It's colour is near white, Light Cream colour, Smooth and Fine particles. Content of GGBFS are written in Table.2

Table – 2
Content of GGBFS

| *Constituents* | *Value* |
|---|---|
| *CaO* | *30-35* |
| *$Al_2O_3$* | *18-25* |
| *$Fe_2O_3$* | *0.8-3.0* |
| *MgO* | *6-10* |
| *$SO_3$* | *0.1-0.3* |
| *$SiO_2$* | *30-36* |

### *C. Aggregates:*

Naturally available river sand used as fine aggregate. Sand is conducted as per IS:2386-Part 1-1963, and Locally available 20 mm course aggregate used, tested with sieve analysis, , Elongation index, Flakiness index, and Compressive strength, Specific Gravity IS:2386 part 3.

### *D. Alkaline Activators:*

In the present investigation, sodium based alkaline activators are used. Single activator either sodium hydroxide or sodium silicate alone is not much effective. So, the combination of sodium hydroxide and sodium silicate solutions are used for the activation of fly ash based geopolymer concrete.

Sodium silicate-to-sodium hydroxide ratio by mass maintained for better strength. Ratio of sodium silicate solution-to-sodium hydroxide solution by mass 2 OR 3. This ratio was at 2 or 3 for most of the mixtures because the sodium silicate solution is considerably cheaper than the sodium hydroxide solution. Both NaOH and Na2Sio3 are mixed before day of casting.

### *E. Sodium Hydroxide (NaOH):*

Solution of NaOH is available in market or it can be easily made with NaOH available in solid form by dissolve it in water. Sodium Hydroxide in solid form is obtained in 3 mm thick flakes having 2.21 specific gravity and 98% purity. Mass of NaOH in solution depend on concentration of solution expressed in terms of Molar.Here three type of solution is used as 6 M,8 M, 10 M.

### *F. Sodium Silicate ($Na_2Sio_3$):*

Sodium silicate is common name also known as Liquid glass or water glass. It is made of Na2CO3 and SiO2 and gives Na2SiO3 and $CO_2$.

$$Na_2CO_3 + SiO_2 \Rightarrow Na_2SiO_3 + CO_2$$

Table – 3
$Na_2SiO_3$ Constituents

| *Constituents* | *Value (%By Mass)* |
|---|---|
| *$Na_2O$* | *15.07%* |

| | |
|---|---|
| *$SiO_2$* | *32.13%* |
| *Water* | *52.80%* |

Density of Sodium silicate is 2.62 g/cm$^3$.

### *G. Water:*

General water is used for Cement concrete can be used for geopolymer concrete. No special water required for curing of this concrete. The minimum quantity of water required to achieve desired workability.

## IV. PROPOSED MIX DESIGN

There is no codal provision for the Mix Design of Geopolymer concrete. Based on the past research on geopolymer and literature review available following trial mix is adopted for current design:-

As stated in scope of work Ratio of Alkaline Activator to Fly ash is fixed as 0.45. Ratio of Na2SiO3 to NaOH is 2 or 3. Fly ash: Fine Aggregates: Coarse Aggregates is 1: 1.5: 3

Table – 4: represent the Mix design for 8 M of NaOH solution forming Geopolymer concrete.

Table – 4
Proposed Mix Design

| *Constituent* | *Unit* | *Quantity* |
|---|---|---|
| *Fly ash* | *Kg/m$^3$* | *383* |
| *Fine Aggregate* | *Kg/m$^3$* | *546* |
| *Coarse aggregate* | *Kg/m$^3$* | *1188* |
| *NaOH solution* | *Kg/m$^3$* | *80* |
| *Na2SiO3 sollution* | *Kg/m$^3$* | *120* |
| *Extra water* | *Kg/m$^3$* | *30* |

## V. EXPERIMENT METHODOLOGY

Here for each molarity and replacement of GGBFS 3 no. of specimens are casted. As per Indian Standard 150 x 150 x 150 mm cubes and cylinders of 150 mm in diameter and 300 mm in height are casted. Replacement of fly ash with GGBFS Is Carried Out At 10% Interval Upto 40%. Molarities of NaOH are 6M, 8 M, and 10 M used for solution. After mixing the liquids to the dry mix it is observed that it became viscous, dark in colour and cohesive.

After 24 hr. all cubes are demoulded from specimen and cubes are placed for curing at room temperature.

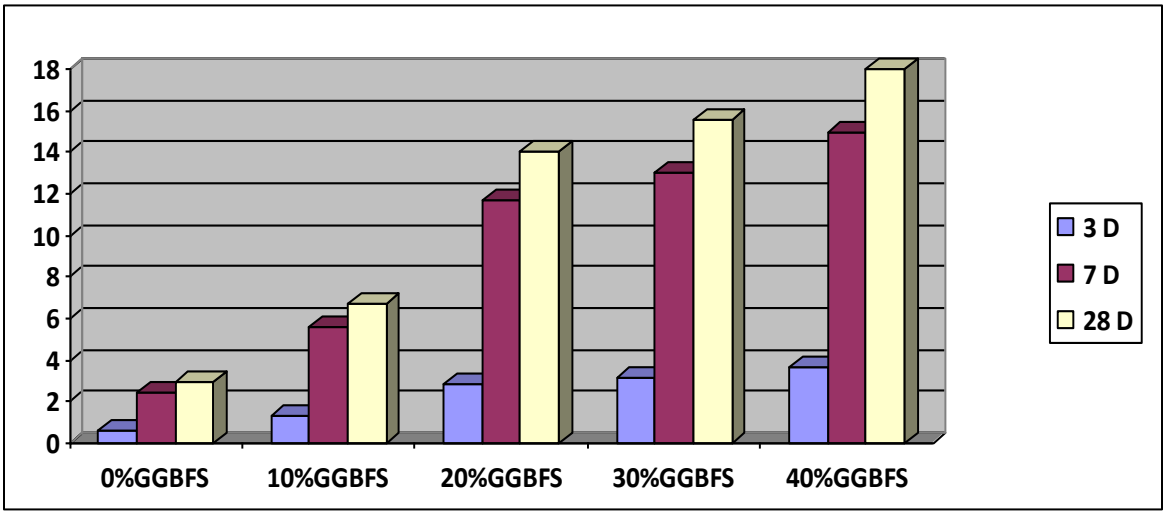
Ratio of $Na_2SiO_3$ to NaOH = 2

### *A. Compression Test Result:*

*1) For 6 M of NaOH:*

Table – 5
All values are in N/mm$^2$

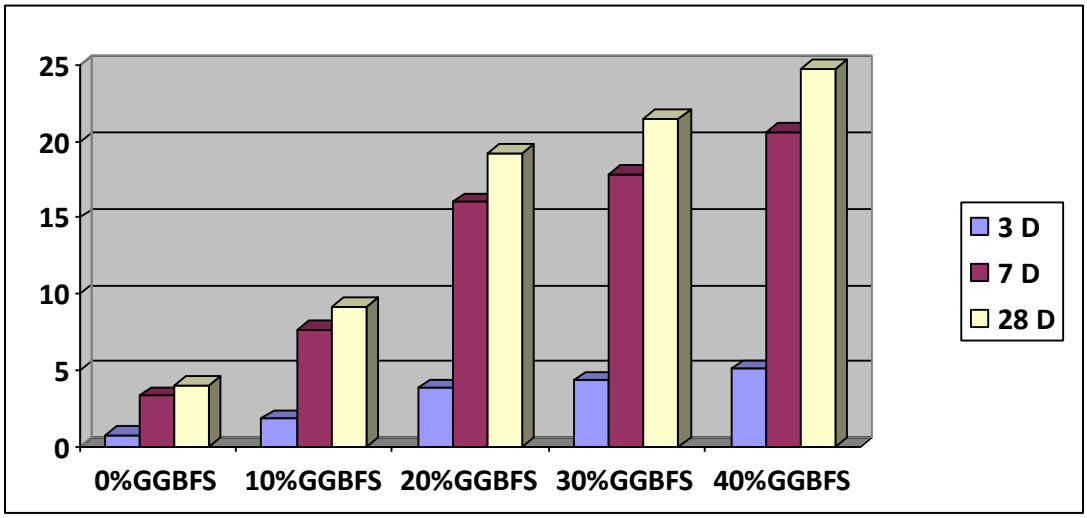
| *Days* | *0 % GGBFS* | *10 % GGBFS* | *20% GGBFS* | *30% GGBFS* | *40 % GGBFS* |
|---|---|---|---|---|---|
| *3 D* | *0.59* | *1.33* | *2.80* | *3.12* | *3.62* |
| *7 D* | *2.44* | *5.56* | *11.67* | *13.00* | *14.96* |
| *28 D* | *2.95* | *6.67* | *14.04* | *15.60* | *17.98* |



*2) For 8 M of NaOH:*

Table – 6
All values are in N/mm$^2$

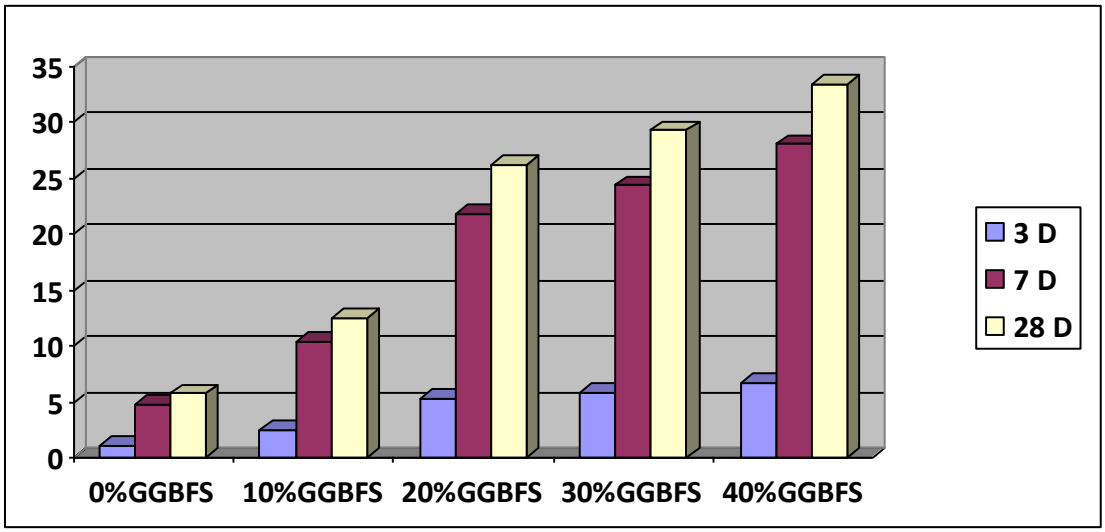
| *Days* | *0 % GGBFS* | *10 % GGBFS* | *20% GGBFS* | *30% GGBFS* | *40 % GGBFS* |
|---|---|---|---|---|---|
| *3 D* | *0.80* | *1.85* | *3.84* | *4.36* | *5.12* |
| *7 D* | *3.35* | *7.63* | *16.01* | *17.86* | *20.58* |
| *28 D* | *4.02* | *9.15* | *19.21* | *21.43* | *24.69* |




*3) For 10 M of NaOH:*

Table – 7
All values are in N/mm$^2$

| *Days* | *0 % GGBFS* | *10 % GGBFS* | *20% GGBFS* | *30% GGBFS* | *40 % GGBFS* |
|---|---|---|---|---|---|
| *3 D* | *1.14* | *2.51* | *5.24* | *5.85* | *6.67* |
| *7 D* | *4.76* | *10.42* | *21.84* | *24.36* | *28.06* |
| *28 D* | *5.72* | *12.53* | *26.20* | *29.28* | *33.37* |



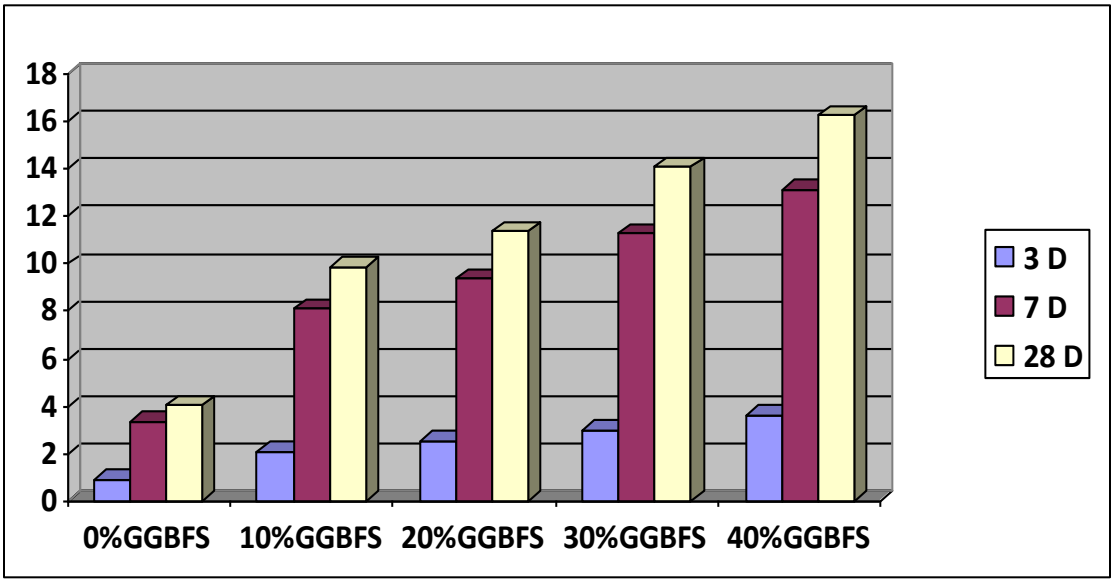

Ratio of $Na_2SiO_3$ to NaOH = 3

### *B. Compression Test Result:*

*1) For 6 M of NaOH:*

Table – 8
All values are in N/mm$^2$

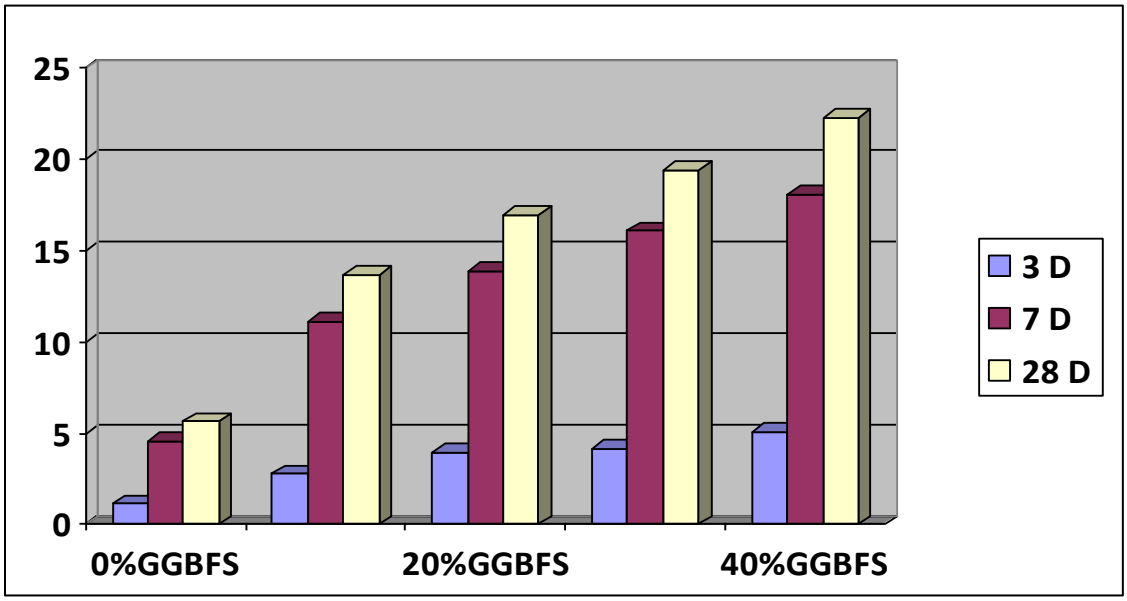
| *Days* | *0 % GGBFS* | *10 % GGBFS* | *20% GGBFS* | *30% GGBFS* | *40 % GGBFS* |
|---|---|---|---|---|---|
| *3 D* | *0.89* | *2.07* | *2.54* | *3.00* | *3.62* |
| *7 D* | *3.35* | *8.09* | *9.36* | *11.26* | *13.10* |
| *28 D* | *4.02* | *9.88* | *11.36* | *14.05* | *16.22* |




*2) For 8 M of NaOH:*

Table – 9
All values are in N/mm$^2$

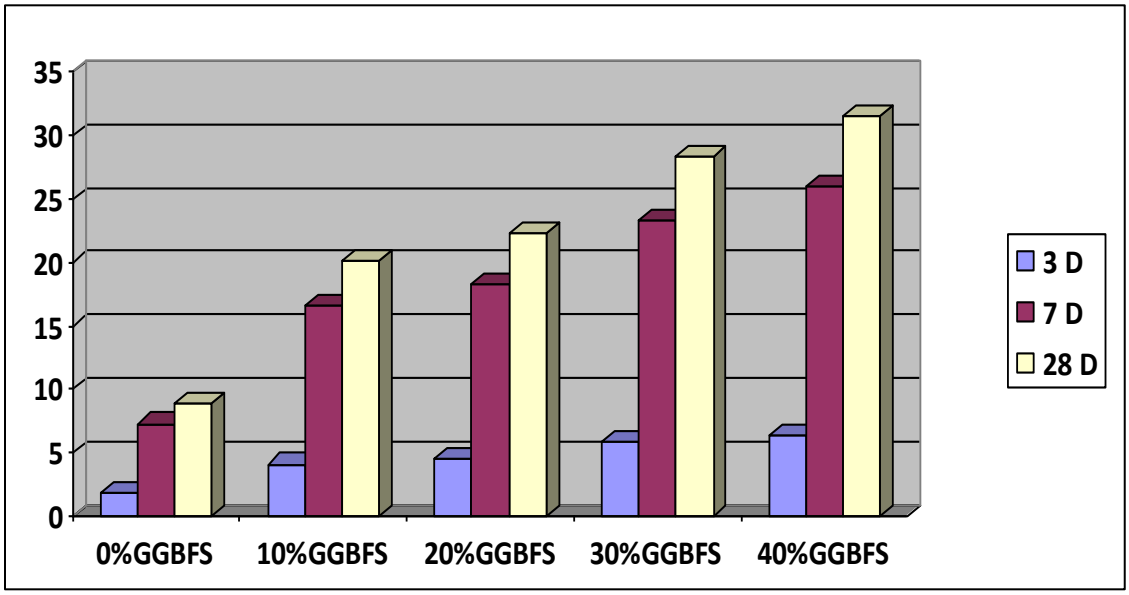
| *Days* | *0 % GGBFS* | *10 % GGBFS* | *20% GGBFS* | *30% GGBFS* | *40 % GGBFS* |
|---|---|---|---|---|---|
| *3 D* | *1.14* | *2.78.* | *3.92* | *4.14* | *5.07* |
| *7 D* | *4.60* | *11.13* | *13.86* | *16.08* | *18.10* |
| *28 D* | *5.63* | *13.68* | *16.94* | *19.44* | *22.28* |




*3) For 10 M of NaOH:*

Table – 9
All values are in N/mm$^2$

| *Days* | *0 % GGBFS* | *10 % GGBFS* | *20% GGBFS* | *30% GGBFS* | *40 % GGBFS* |
|---|---|---|---|---|---|
| *3 D* | *1.77* | *4.10* | *4.57* | *5.81* | *6.33* |
| *7 D* | *7.29* | *16.56* | *18.26* | *23.32* | *25.92* |
| *28 D* | *8.85* | *20.09* | *22.34* | *28.34* | *31.48* |




## VI. CONCLUSION

- Geopolymer concrete can obtained at room temperature
- GGBFS with flyash increase the strength of geopolymer concrete
- Workability of geopolymer concrete decrease with increase of molarity of NaOH
- Increment in strength is observed upto 30% of GGBFS. Increament is less at 40% of GGBFS
- GGBFS not effect on workability of geopolymer concrete

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