

# Durability Aspects of Flyash Based Geopolymer Concrete

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**Abstract:** Geopolymer concrete contain no cement in concrete gains the popularity globally towards the sustainable development .It is a type of amorphous alumino-silicate cementations material which can be synthesized by polycondensation reaction of geopolymeric precursor and alkali polysilicates. Beside fly ash, alkaline solution is used to prepare geopolymer paste which binds the aggregates to form geopolymer concrete. Some studies can be seeing in literature on geopolymer concrete, not more work has been reported in the development of mix design procedure. In the addition, some of the conclusions are contradictory. In this paper an attempt is makes to develop the mix design for Geopolymer concrete in medium grade and relative comparison has been prepared with relative mix proportions of grade of OPC Concrete in both heat cured and sunlight cured conditions. Different mixes for each grade is casted, tested and calculated .The design parameters like alkaline liquid to fly ash ratio and water to Geopolymer solids ratio are proposed to develop the Geopolymer concrete of standard grade. Geopolymer concrete results from the reaction of a source materials that is rich in silica and alumina with alkaline liquid. A summary of the extensive studies conducted on fly ash-based geopolymer concrete is presented. We calculated the split tensile strength and flexural strength in this paper and testing the specimen in CPM at the age of 7 and 28 days. For the molarities 8M, 12M,16M calculation of these above two strengths are carried out. Test data are used to identify the effects of salient factors that influence the properties of the geopolymer concrete and to propose a simple method for the design of geopolymer concrete mixtures. Test data of various short-term and long-term properties of the geopolymer concrete and the results of the tests conducted on large-scale reinforced geopolymer concrete members show that geopolymer concrete is well-suited to manufacture precast concrete products that can be used in infrastructure developments. The paper also includes brief details of some recent applications of geopolymer concrete.

**Keywords:** Compressive strength, flyash, geopolymer, molarity

## 1. Introduction

The main component of preparing concrete, contributes significant amount of greenhouse gas, because the production of one ton of Portland cement releases about one ton of carbon dioxide gas into the atmosphere. Therefore, the introduction of a novel binder called 'geopolymer' by Davidovits promises a good prospect for application in the concrete industry as an alternative binder to Portland cement. In terms of decreasing the global warming, the geopolymer technology can be decrease the CO<sub>2</sub> emission to the atmosphere caused by cement and aggregates industries by 80%. Inspired by this novel technology and the fact that fly ash is a waste material and fully available, an attempt has been taken to develop an alternative concrete binder by applying the geopolymer technology and utilizing fly ash as the source material to prepare the Fly Ash-Based Geopolymer Concrete. the early work on fly ash-based geopolymer concrete concerning with the manufacturing process and the effect of curing time, curing temperature and the age of concrete on the compressive strength of fly ash-based geopolymer concrete. Moreover, the effect of alkaline ratio and the ratio of alkaline to water was also studied. the results on the factors affecting the compressive strength and other properties of fresh and hardened fly ash-based geopolymer concrete Attempts to apply this material as a structural material have geopolymer concrete beams and columns been taken by studying the behavior and strength of reinforced fly ash-based geopolymer concrete beams and columns. This paper presents the study on fly ash-based geopolymer concrete, mix design is focused for three grades i.e. low, medium and higher grades have been arrived and

tested for compressive strength.

## 2. Geo-Polymer Concrete

An alkaline liquid could be used to react with the silicon (Si) and the aluminum (Al) in a source material in by-product materials like fly ash and rice husk ash to produce binders. Because the chemical reaction that takes place in this case is a polymerization process.

Geopolymers are like the family members of inorganic polymers. The chemical composition of the geopolymer material is same as to natural zeolitic materials, but the microstructure is amorphous. The polymerization process involves a substantially speed chemical reaction under alkaline condition on Si-Al minerals, those results in a three-dimensional polymeric chain and ring structure consisting of Si-o-Al-o bonds. The Literature (2-4),tels that water is released during the chemical reaction that occurs in the formation of geopolymers. This water, expelled from the geopolymer mixture during the curing and other drying periods, releases behind discontinuous nano-pores in the matrix, which gives benefits to the performance of geopolymers. The water in a geopolymer mixture, therefore, plays no role in the chemical reaction that takes place, it merely provides the workability to the mixture during handling. This is in contrast to the chemical reaction of water in a Portland cement concrete mixture during the hydration process.

### 3. Fly Ash Based Geo-Polymer Concrete

Geopolymer concrete is prepared by using source materials that are rich in silica and alumina. While the cement-based concrete utilizes the formation of calcium-silica hydrates (CSHs) for matrix formation and strength, geopolymers enters the chemical reaction of alumino-silicate oxides with alkali polysilicates yielding polymeric Si-O-Al bonds.

The manufacture of geopolymer concrete is carried out by using the usual concrete technology methods. As in the Portland cement concrete, in fly ash-based geopolymer concrete, the aggregates occupy the largest volume, i.e. about 75-80% by mass.

Sodium-based activators were chosen because they were cheaper than Potassium-based activators. The sodium hydroxide is used, in flake or pellet form. It is recommended that the alkaline liquid is made by mixing both the solutions together at least 24 hours prior to use. The mass of NaOH solids in a solution varied depending on the concentration of the solution presented in terms of molar, M. The concentration of sodium hydroxide solution can vary in the range between 8 Molar and 16 Molar. The mass of water is the major component in both the alkaline solutions. For improving the workability, a melamine based super plasticizer is mixed to the mixture.

### 4. Mix Proportions of Geopolymer Concrete:

The primary difference between Geopolymer concrete and Portland cement concrete is the binder. The silicon and aluminium oxides in low-calcium flyash reacts with the alkaline liquid to prepare the geopolymer paste that binds the loose coarse and fine aggregates and other un reacted materials to form the geopolymer concrete. As in the case of Portland cement concrete the coarse and fine aggregates occupy about 75% to 80% of the mass of Geopolymer concrete. This component of Geopolymer concrete mixture can be made by using the tools currently available for Portland cement concrete. The compressive strength and workability of geopolymer concrete are effected by the proportions and properties of the constituent materials that make the geopolymer paste.

Experimental results have shown the following (4-6):

- As the H<sub>2</sub>O- Na<sub>2</sub>O molar ratio increases, the compressive strength of Geopolymer concrete decreases.
- Higher the concentration of Sodium hydroxide solution results in higher compressive strength of geo polymer concrete.
- Higher the ratio of Sodium silicate to Sodium hydroxide by mass, higher the compressive strength depends on the above guide lines the trial mixture is designed as follows.

### 5. Experimental Program

The sodium hydroxide flakes were dropped in distilled water to make a solution with a desired concentration at least one day prior to use. The fly ash and the aggregates were first

mixed together in a pan mixer for about three minutes.

The sodium hydroxide and the sodium silicate solutions were mixed together with super plasticizer then added to the dry materials and mixed about four minutes. The fresh concrete was cast into the moulds immediately after mixing, in three layers and compacted with manual strokes and vibrating table. After casting, the specimens were cured at 60°C for 24 hours. Two types of curing were made, Heat curing and Ambient curing. For heat curing, the specimens were cured in an oven and for Ambient curing the specimens were left to air for desires period. The heat cured specimens were left to dry-air in the laboratory for the next six days until testing on the 7th day and 28<sup>th</sup> day.

For the denoted grade of Geopolymer concrete mix about 7 mixture proportions were tested and optimized by taking the mix which obtains maximum compressive strength at 28 days under Heat curing (Oven curing) and Ambient cured conditions.

### 5.1 Compressive Strength

The effect of various factors such as the source of fly ash, the concentration of NaOH solution in terms of molarity, the curing temperature namely room temperature curing and heat curing at 60°C and the age of concrete at the time of testing, on the compressive strength of geopolymer concrete has been investigated and presented. Test results of compressive strength are presented in Table 1

The effect of source of fly ash on the compressive strength of geopolymer concrete is discussed in terms of compressive strength index. The compressive strength index is the ratio between the compressive strength of geopolymer concrete prepared by using Mettur fly ash and the compressive strength of geopolymer concrete prepared from Tuticorin fly ash for the same concentration of NaOH, identical curing temperature and at the same age of concrete.

It was observed that, in case of ambient curing at room temperature, the compressive strength index is greater than one for all the three molarities of NaOH solution both at 7 days and 28 days age of concrete as shown in Figure 1 This indicates that the compressive strength of geopolymer concrete prepared by using Mettur fly ash is higher than that of geopolymer

**Table 1:** Average Compressive strength of specimen at 28 days

Specifications	Avg. Ultimate Load in KN	Avg. Compressive Strength MPa
F <sub>T</sub> M <sub>8</sub> C <sub>a</sub> A <sub>28</sub>	405.65	20.85
F <sub>T</sub> M <sub>8</sub> C <sub>h</sub> A <sub>28</sub>	440.50	25.30
F <sub>T</sub> M <sub>12</sub> C <sub>a</sub> A <sub>28</sub>	505.23	29.52
F <sub>T</sub> M <sub>12</sub> C <sub>h</sub> A <sub>28</sub>	645.20	33.52
F <sub>T</sub> M <sub>16</sub> C <sub>a</sub> A <sub>28</sub>	580.25	29.65
F <sub>T</sub> M <sub>16</sub> C <sub>h</sub> A <sub>28</sub>	660.50	35.22

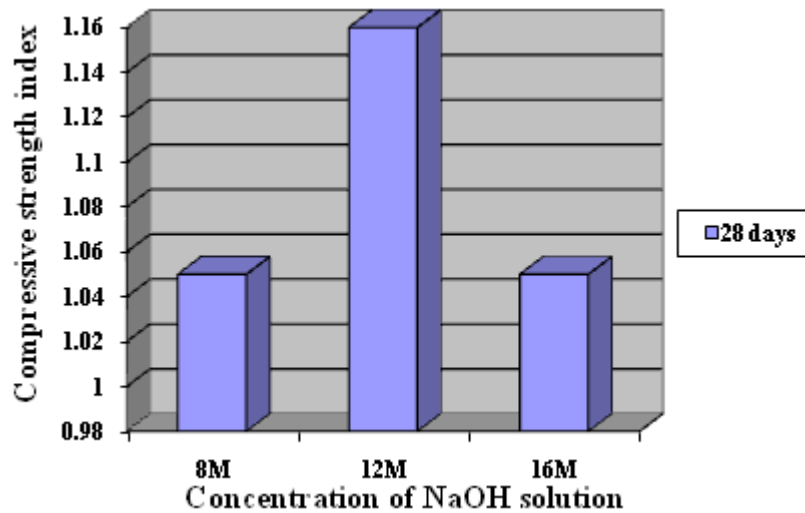


Figure 1: Compressive strength index

### 5.2 Split Tensile Strength Of Geo Polymer Concrete

The effect of different factors such as the source of fly ash, the concentration of NaOH solution, the curing temperature and the age of concrete on the split tensile strength of geopolymer concrete has been optimised and presented. Test results of split tensile strength are represented in below Table 2.

The effect of source of fly ash on the split tensile strength of geopolymer concrete is discussing in terms of split tensile strength index. Split tensile strength index is the ratio between the split tensile strength of geopolymer concrete made by using thermal fly ash and the concentration of NaOH at different curing temperature and at the same age of concrete. It was identified that, in case of ambient curing at room temperature, the split tensile strength index is greater than one for all the three molarities of NaOH solution both at 7 days and 28 days. This indicates that the split tensile strength of geopolymer concrete prepared by using thermal fly ash is better for curing at room

temperature. Similarly in heat curing, split tensile strength indices for most of the cases is greater than one which denotes that the split tensile strength of geopolymer concrete prepared by using thermal fly ash is good for split tensile strength and gives good compressive strength.

Table 2: split tensile strength index for 7 and 28 days

Specification	Avg. Ultimate load in KN	Split tensile strength index
$f_t m_8 c_a a_7$	17.25	0.25
$f_t m_8 c_h a_7$	65.65	0.95
$f_t m_8 c_a a_{28}$	70.45	0.99
$f_t m_8 c_h a_{28}$	90.25	1.30
$f_t m_{12} c_a a_7$	21.52	0.32
$f_t m_{12} c_h a_7$	80.25	1.15
$f_t m_{12} c_a a_{28}$	84.5	1.22
$f_t m_{12} c_h a_{28}$	97.55	1.36
$f_t m_{16} c_a a_7$	27.62	0.42
$f_t m_{16} c_h a_7$	105.25	1.65
$f_t m_{16} c_a a_{28}$	101.25	1.44
$f_t m_{16} c_h a_{28}$	110.23	1.74

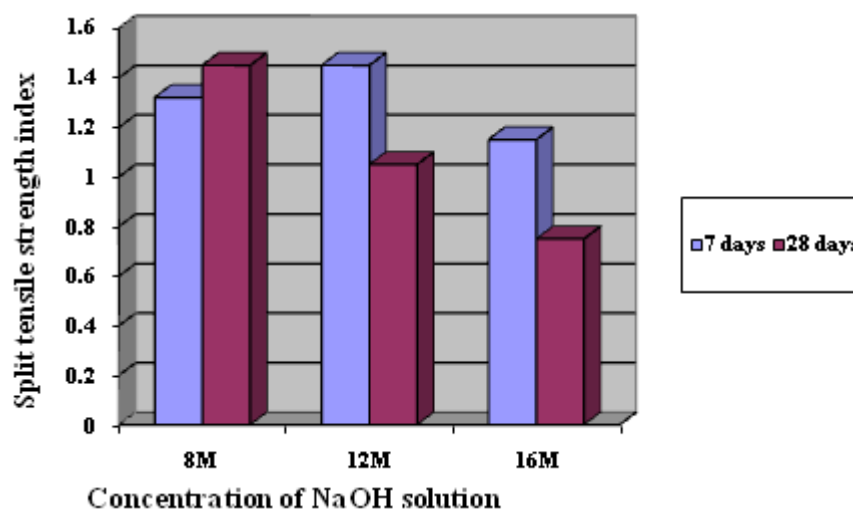


Figure 2: Split tensile strength index-Ambient Curing

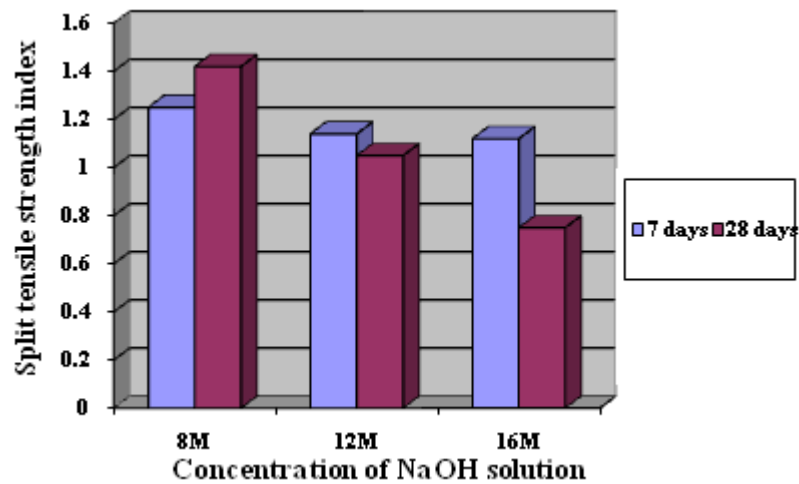


Figure 3: Split tensile strength index-Heat Curing

### 5.3 Flexural Strength

The effect of different factors such as the source of fly ash, the concentration of NaOH solution and the curing temperature on the flexural strength of geopolymer concrete has been investigated and presented. Test results of flexural strength are presented. The effect of source of fly ash on the flexural strength of geopolymer concrete is discussed in terms of flexural strength. This indicates that the flexural strength of geopolymer concrete prepared by using thermal fly ash is good in flexural strength.

The effect of concentration of NaOH solution on the flexural strength of geopolymer concrete is presented in Figure. From the test results, it was found that flexural strength of geopolymer concrete increased when the concentration of NaOH solution increases for all the cases. For geopolymer concrete prepared by using thermal fly ash, increasing the concentration of NaOH solution from 8 M to 12M results in an improvement of flexural strength at about 16% for heat curing conditions. The flexural strength also increases by about 42% as the concentration of NaOH solution is further increased from 12 M to 16 M. Similarly for ambient curing conditions, the increasing concentration of NaOH from 8 M to 12M resulted in increasing of flexural strength by 25%. When the concentration of NaOH solution is then increased from 12 M to 16 M, the flexural strength gets increased by 20%.

Table 3: Flexural strength index

Specifications	Avg. Ultimate load in kN	Flexural strength index
F <sub>T</sub> M <sub>8</sub> C <sub>a</sub> A <sub>7</sub>	15.25	5.52
F <sub>T</sub> M <sub>8</sub> C <sub>h</sub> A <sub>28</sub>	17.32	6.12
F <sub>T</sub> M <sub>12</sub> C <sub>a</sub> A <sub>7</sub>	19.50	7.25
F <sub>T</sub> M <sub>12</sub> C <sub>h</sub> A <sub>28</sub>	20.25	8.15
F <sub>T</sub> M <sub>16</sub> C <sub>a</sub> A <sub>7</sub>	22.65	9.60
F <sub>T</sub> M <sub>16</sub> C <sub>h</sub> A <sub>28</sub>	25.2	10.25

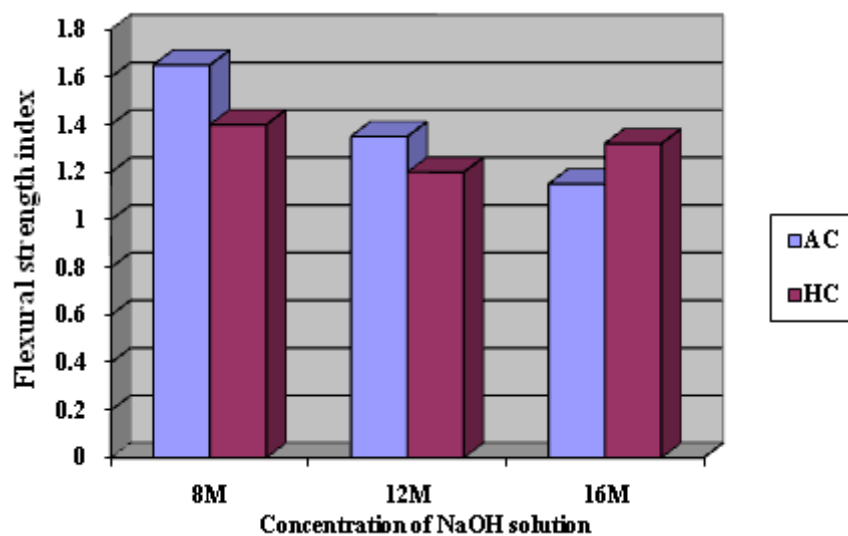


Figure 3: Flexural strength index

## 6. Conclusion

From the investigation it is clear that for Water/binder ratio & alkaline liquid/Flyash ratio are the factors of governing in designing of the Geopolymer mix design for different grades. The Water/binder ratio 0.35 and Alkaline liquid to flyash ratio of 0.50 are recommended for the development in compressive strength of geopolymer concrete can be gained by decreasing the water binder ratio.

The compressive strength attains at 28 days for Geopolymer concrete under the ambient curing is nearly equal to compressive strength achieved by Geopolymer concrete at 7 days. Because of the slow reactivity of flyash at ambient temperature, heat must be applied as considerable to increase the geo polymerization process.

- 1) The decrease in water content is recommended to the formation of geo polymerization process, which offers for increase of concentration of Sodium hydroxide and sodium silicate silicates. Hence the concentration of NaOH increases then the compressive strength increases. Hence it is recommended 16M concentrations for medium grade.
- 2) It is recommended to adding the Super plasticizers for high strength Geopolymer concretes, which is analogous to Conventional concrete of higher grades to secure required workability.
- 3) It also reported that unlike in the past literature, inclusion of high alkaline solution content to the mix not need to increase the strength which can be seen from reported Geopolymer mixes in the present work.
- 4) for the same concentration of NaOH, the different curing temperature and the age of concrete, split tensile strength and is higher in case of thermal fly ash based geo polymer concrete.

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