

# Study On Fly Ash Based Geo-Polymer Concrete Using Admixtures

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**Abstract**— Due to growing environmental concerns of the cement industry alternative cement technologies have become an area of increasing interest. One such thing is “GEOPOLYMER CONCRETE”. It utilizes an alternate material including fly ash as binding material in place of cement. This fly ash reacts with alkaline solution NaOH and sodium silicate ( $\text{Na}_2\text{SiO}_3$ ) to form a gel which binds fine and coarse aggregates. Since geopolymer concrete is an emerging field, the guide lines from the bureau of Indian standards are yet to be formulated. An attempt has been made to find out an optimum mix for geopolymer concrete. Concrete cubes of size 150\*150\*150 mm were prepared. The compressive strength was found out at 7 days and 28 days.. When compared with conventional concrete or any other concrete method it is more advantageous, economical and eco friendly.

**Keywords**— Fly Ash, Geopolymer Concrete, Sodium Hydroxide (NaOH), Sodium Silicate ( $\text{Na}_2\text{SiO}_3$ ).

## I. INTRODUCTION

Davidovits [1988] proposed that an alkaline liquid could be used to react with the silicon (Si) and the aluminium (Al) in a source material of geological origin or in by-product materials such as fly ash and rice husk ash to produce binders. Because the chemical reaction that takes place in this case is a polymerization process, he coined the term „Geopolymer“ to represent these binders. Geopolymer concrete is concrete which does not utilize any Portland cement in its production. Geopolymer concrete is being studied extensively and shows promise as a substitute to Portland cement concrete. Research is shifting from the chemistry domain to engineering applications and commercial production of geopolymer concrete.

There are two main constituents of geo polymers, namely the source materials and the alkaline liquids. The source materials for geo polymers based on alumina-silicate should be rich in silicon (Si) and aluminium (Al). These could be natural minerals such as kaolinite, clays, etc. Alternatively, by-product materials such as fly ash, silica fume, slag, rice-husk ash, red mud, etc could be used as source materials. The choice of the source materials for making geo polymers depends on factors such as availability, cost, type of application, and specific demand of the end users. The alkaline

liquids are from soluble alkali metals that are usually sodium or potassium based. The most common alkaline liquid used in geo polymerisation is a combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate or potassium silicate.

## II. MATERIALS USED

### A. Fly ash

Fly ash is defined in cement and concrete terminology as the finely divided residue resulting from the combustion of ground or powdered coal, which is transported from the firebox through the boiler by flue gases.”Fly ash is a by-product of coal-fired electric generating plants. Fly ash can be used in Portland cement concrete to enhance the performance of the concrete. Fly ash is one of the residues generated in combustion, and comprises the fine particles that rise with the flue gases.



Fig 1. Fly Ash

### B. Coarse aggregate

Coarse aggregate are a broad category particulate inert materials used in construction. Hard stones are crushed to the required size and are used as coarse aggregate. The material that is retained on as IS sieve of size 4.75 is called coarse aggregate.

Aggregate of essentially the same nominal maximum size and grading will produce concrete of satisfactory workability. These aggregates are bound together by the cement and fine aggregate in the presence of water to form concrete. Coarse aggregates of sizes 12mm and 20mm and fine aggregate taken from a local supplier are used in the present study and the properties as shown in Table 1.

*C. Fine aggregate*

Fine aggregate should consist of natural sand or crushed stone sand. It should be hard, durable and clean and be free from organic matter etc. fine aggregate should not contain any appreciable amount of clay balls and harmful impurities such as alkalis, salts, coal, decayed vegetation etc. The silt contents should not exceed 4%.

*D. Sodium hydroxide solution*

The most common alkaline activator used in geo polymerisation is a combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate or potassium silicate [3]. The type and concentration of alkali solution affect the dissolution of fly ash. Leaching of Al<sup>3+</sup> and Si<sup>4+</sup> ions are generally high with sodium hydroxide solution compared to potassium hydroxide solution. Therefore, alkali concentration is a significant factor in controlling the leaching of alumina and silica from fly ash particles, subsequent geo polymerization and mechanical properties of hardened geopolymer. Duchesne et al (2010) confirmed that in presence of NaOH in the activating solution the reaction proceeds more rapidly and the gel is less smooth. The gel composition analysed in the sample activated with the mixture of sodium silicate and NaOH is enriched in Na and Al[1].



Fig 2. Sodium Hydroxide flakes

*E. Sodium silicate solution*

Palomo et al (1999) concluded that the type of activator plays an important role in the polymerization process. Reactions occur at a high rate when the alkaline activator contains soluble silicate, either sodium or potassium silicate, compared to the use of only alkaline hydroxides. A study conducted by Xu and Van Deventer (2000) showed that the addition of sodium silicate solution to the sodium hydroxide solution as the alkaline activator enhanced the reaction between the source material and the solution. Tempest et al (2009) state that the sodium silicate activator dissolves rapidly and begins to bond fly ash particles. Open porosity can be observed and is rapidly filled with gel as soon as the liquid phase is able to reach the ash particles. The liquid phase is important as a fluid transport medium permitting the activator to reach and react with the fly ash particles.

TABLE 1. Properties of Aggregates

Property	Coarse Aggregate		Fine Aggregate
	20 mm	12 mm	
Fineness Modulus	8.14	8.14	3.45
Specific gravity	2.71	2.71	2.61
Bulk Density	1533.33 Kg/m <sup>3</sup>	1516 Kg/m <sup>3</sup>	1250.12 Kg/m <sup>3</sup>
Percentage of voids	45.21%	48.52%	50.98%

### III.METHODOLOGY

#### A. Preparation of Alkaline Solutions

In this paper the compressive strength of geopolymer concrete is examined for the mixes of varying molarities of Sodium hydroxide (3M, 5M, 7M and 9M). The molecular weight of sodium hydroxide is 40. To prepare 3M i.e. 3 molar sodium hydroxide solution, 120g of sodium hydroxide flakes are weighed and they can be dissolved in distilled water to form 1 litre solution. For this, volumetric flask of 1 litre capacity is taken, sodium hydroxide flakes are added slowly to distilled water to prepare 1liter solution. The weights to be added to get required molarity are given in Table 2.

TABLE 2. Weights of NaOH flakes

Required Molarity	Weight in gms of Sodium Hydroxide flakes
3M	120
5M	200
7M	280
9M	360

#### B. Mixing of Geopolymer concrete

The fly ash, fine aggregates and coarse aggregates were mixed in a container and then the alkaline solution was added to prepare the geopolymer concrete. The geopolymer concrete was placed in 100 mm cube moulds. The Geopolymer concrete was dark in colour with shiny appearance. The mix proportions were as given in Table 3. As there are no code provisions for the mix design of geopolymer concrete, the density of geo-polymer concrete is assumed as 2440 kg/m<sup>3</sup>. The other calculations are done by considering the density of concrete. The total volume occupied by the aggregates is assumed to be 65%. The quantities of all ingredients are kept constant as given Table 3 except the molarity of NaOH is changed in the each mix. The conventional method used in the making of normal concrete is adopted to prepare geopolymer concrete. First, the fine aggregate, coarse aggregate and fly ash are mixed in dry condition for 3-4 minutes and then the alkaline solution which is a combination of Sodium

hydroxide solution and Sodium silicate solution with super plasticizer is added to the dry mix. The mixing is done about 6-8 minutes for proper bonding of all the materials. After the mixing, the cubes are casted by giving proper compaction. The sizes of the cubes used are of size 100mmX100mmX100mm. For the curing geopolymer concrete cubes, two methods are used, one by placing the cubes in hot air oven and by placing the cubes in direct sun-light. For oven curing, the cubes are demoulded and kept in oven at 60°C for an hour. Then the cubes are demoulded and kept in oven at 50°C for 3 days and 7days. For the sun light curing, the cubes are demoulded after 1 day of casting and they are placed in the direct sunlight for 3 days and 7 days.

Ingredients in (kg/m <sup>3</sup> )		Different mixes			
		F1	F2	F3	F4
Fly Ash		670	670	670	670
Fine Aggregate		600	600	600	600
Coarse Aggregate	20 mm	320	320	320	320
	12 mm	650	650	650	650
Sodium silicate solution		120	120	120	120
Sodium hydroxide solution		80 (3M)	80 (5M)	80 (7M)	80 (9M)
Super-plasticizer		5	5	5	5

TABLE 3. Mixing proportions of geo-polymer concrete

### IV. RESULTS

The cubes are tested in compressive testing machine to determine their compressive strength at the age of 3 days and 7 days of curing. The figures 3 and 4 are showing the compressive strength increment with molarity of NaOH. (3M, 5M, 7M and 9M) for the specimens which were cured by hot air oven and by direct sun light at the age of 3 days and 7 days.

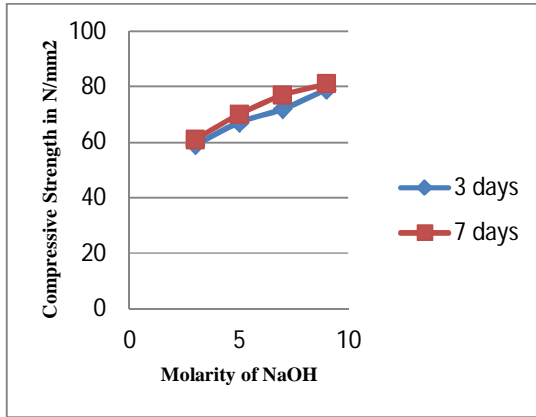


Fig 3. Comparison of compressive strength at age of 3 and 7 days in oven cured

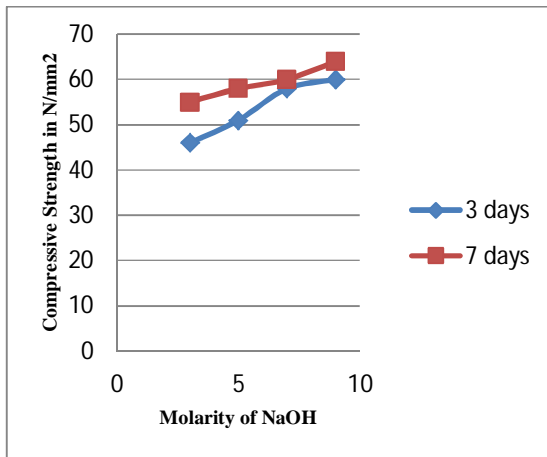


Fig 4. Comparison of compressive strength at age of 3 and 7 days in sun light cured

#### CONCLUSIONS

- We observed that the compressive strength is increased with the increase in the molarity of sodium hydroxide.
- After 3 days of curing the increase in the compressive strength is not significant.
- Compared to hot air oven curing and curing by direct sun light, oven cured specimens gives the higher compressive strength but sun light curing is convenient for practical conditions.

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