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An Experimental Study on Strength Behaviour of Fly Ash Based Geo Polymer Concrete

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***Abstract* - Construction is one of the fast growing fields orldwide. As per the present world statistics, every year around 260, 00, 00,000 Tons of Cement is required. This quantity will be increased by 25% within a span of another 10 years. Since the Lime stone is the main source material for the ordinary Portland cement an acute shortage of limestone may come after 25 to 50 years. More over while producing one ton of cement, approximately one ton of CO_2 will be emitted to the atmosphere, which is a major threat for the environment.**

The Thermal Industry produces a waste called fly ash which is simply dumped on the earth, occupies larger areas. The waste water from the Chemical Industries is discharged into the ground which contaminates ground water. By producing Geopolymer Concrete all the above mentioned issues shall be solved by Re-arranging them. Since Geopolymer concrete doesn't use any cement, the production of cement shall be reduced and hence the pollution of atmosphere by the emission of carbon di oxide shall also be minimized.

The study will be on geopolymer concrete prepared with a combination of fly ash, alkali activator solution and aggregates. The aim of the project is to replace cement completely with fly ash in reinforced concrete and to test the strength and durability properties. Thus, industrial byproducts and waste materials are effectively used to reduce the impact of these waste products on environment. Fly ash is locally available in abundance.

Keywords – Geo polymer concrete, Alkaline Solutions, Fly ash

1. INTRODUCTION

The name geopolymer was formed by a French Professor Davidovits in 1978 to represent a broad range of materials characterized by networks of inorganic molecules. The geopolymers depend on thermally activated natural materials like Meta kaolinite or industrial by-products like fly ash or slag to provide a source of silicon (Si) and alumina (Al). These Silicon and Aluminium is dissolved in an alkaline activating solution and subsequently polymerizes into molecular chains and become the binder. The reaction of Fly Ash with an aqueous solution containing Sodium Hydroxide and Sodium Silicate in their mass ratio, results in a material with three dimensional polymeric chain and ring structure consisting of Si-O-Al-O bonds.

Water is not involved in the chemical reaction of Geopolymer concrete and instead water is expelled during curing and subsequent drying. This is in contrast to the hydration reactions that occur when Portland cement is mixed with water, which produce the primary hydration products calcium silicate hydrate and calcium hydroxide. This difference has a significant impact on the mechanical and chemical properties of the resulting geopolymer concrete, and also renders it more resistant to heat, alkali–aggregate reactivity and other types of chemical attack

In the case of geopolymers made from fly ash, the role of calcium in these systems is very important, because its presence can result in flash setting and therefore must be carefully controlled. The source material is mixed with an activating solution that provides the alkalinity (sodium hydroxide or potassium hydroxide are often used) needed to liberate the Si and Al and possibly with an additional source of silica (sodium silicate is most commonly used).

The temperature during curing is very important, and depending upon the source materials and activating solution, heat often must be applied to facilitate polymerization, although some systems have been developed that are designed to be cured at room temperature

2. EXPERIMENTAL WORKS

2.1 Materials

2.1.1 Fly ash

Low Calcium Fly ash (class F)Fly ash is the main by product created from the combustion of coal in coal-fired power plants. There are two "classes" of fly ash, Class F and Class C. Each class of fly ash has its own unique properties. Class F Fly Ash contains calcium hydroxide content is less compared to class C.

Table 1 Physical Properties of Fly Ash

Parameters	Value
Appearance	Very Fine Powder
Particle Size	35 Microns -Mean
Colour	Grey to Black
Odour	Odourless
Specific Gravity	2.17

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Table 2. Chemical Properties of Fly Ash

Constituents	Fly Ash (%)
CaO	1-3
SiO_2	35-60
Al_2O_3	10-30
Fe_2O_3	4-10
MgO	0.2-5
MnO_2	-
Glass	20-30

2.1.2 Active Alkaline Solution

The solution of sodium hydroxide and sodium silicate are used as alkaline solutions in the present study. Commercial grade sodium hydroxide in pellets form and sodium silicate solution are used.

For preparation of alkaline solution, in this research work the compressive strength of Geo polymer concrete is examined for the mixes of 12M and 14M of sodium hydroxide. The molecular weight of sodium hydroxide is 40. To prepare 12M of solution 480 g of sodium hydroxide flakes are weighed and they can be dissolved in distilled water to form 1 litre solution. Volumetric flask of 1 liter capacity is taken, sodium hydroxide flakes are added slowly to distilled water to prepare 1liter solution. Sodium hydroxide solution is prepared before 24 hours of the casting of specimen. Sodium silicate solution (water glass) obtained from local suppliers was used. The mixture of sodium silicate solution and sodium hydroxide solution forms the active alkaline solution. Both these solution are mixed together at time of mixing of concrete

2.1.3 Aggregates

Locally available natural sand with 4.75 mm maximum size was used as fine aggregate, having specific gravity, fineness modulus and unit weight as given in Table 3 and crushed stone with 16mm maximum size having specific gravity, fineness modulus and unit weight as given in Table 3 was used as coarse aggregate.

Table 3. Physical Properties of Coarse and Fine Aggregates

Property	Fine Aggregate	Coarse Aggregate
Specific Gravity	2.57	2.68
Fineness Modulus	3.63	4.936
Surface Texture	Smooth	--
Particle Shape	Rounded	Angular

2.2 Mix Proportions

As there are no code provisions for the mix design of geopolymer concrete, the density of geo-polymer concrete is assumed as 2400 Kg/m^3. The rest of the calculations are done by considering the density of concrete. The total volume occupied by fine and coarse aggregate is adopted as 77%. The alkaline liquid to fly ash ratio is kept between 0.40 to 0.55. The ratio of sodium hydroxide to sodium silicate is kept as 2.5.The conventional method used in the making of normal concrete is adopted to prepare geopolymer concrete.

2.3 Casting and Curing

Firstly, the fine aggregate, coarse aggregate, fly are mixed in dry condition for 3-4minutes and then the alkaline solution which is a combination of Sodium hydroxide solution and Sodium silicate solution is added to the dry mix. Water is taken as 10 % of the Cementous material (fly ash). The mixing is done for about 6- 8 mins for proper bonding of all the materials. After the mixing is done, cubes, cylinders and beams are casted by giving proper compaction in three layers.

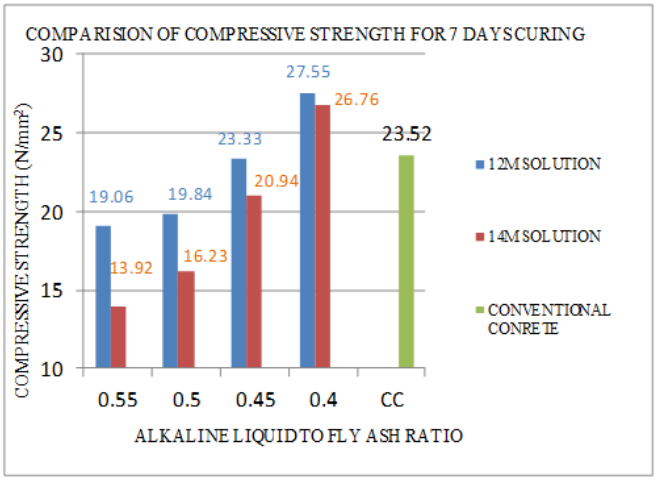
Table 4. Material Requirements for 1 m^3

	A L to F.A ratio	Alkaline liquid (litre/m^3)	Flyash (Kg/m^3)	Fine aggregate (Kg/m^3)	Coarse aggregate (Kg/m^3)
12M	0.55	194	353	718	1125
	0.50	183	365	714	1120
	0.45	172	383	724	1134
	0.40	158	395	721	1129
14M	0.55	195	355	716	1121
	0.50	184	367	721	1129
	0.45	172	383	724	1134
	0.40	157	394	718	1125

3. TEST RESULTS AND DISCUSSION

The cubes, cylinders and beams are tested to determine their compressive strength, split tensile strength at the age of 7 days and 28 days of curing and to determine the flexural behaviour of geopolymer concrete. The results have shown that the mix combination of 12M solution at 0.45 and 0.40 ratio of alkaline liquid to fly ash and 14M solution 0.45 of 0.40 ratio of alkaline liquid to fly ash gave maximum compressive strength compare to the rest. The results have shown that the mix combination of 12M solution at 0.45 and 0.40 ratio of alkaline liquid to fly ash and 14M solution of 0.40 ratio of alkaline liquid to fly ash gave maximum split tensile strength compare to the rest. It was found that as the alkaline liquid to fly ash ratio minimum and age of the concrete increases the compressive strength of geopolymer concrete is enhanced at ambient temperature without water curing.

3.1 Comparison of Compressive Strength Results of GPC and CC for 7 Days Curing



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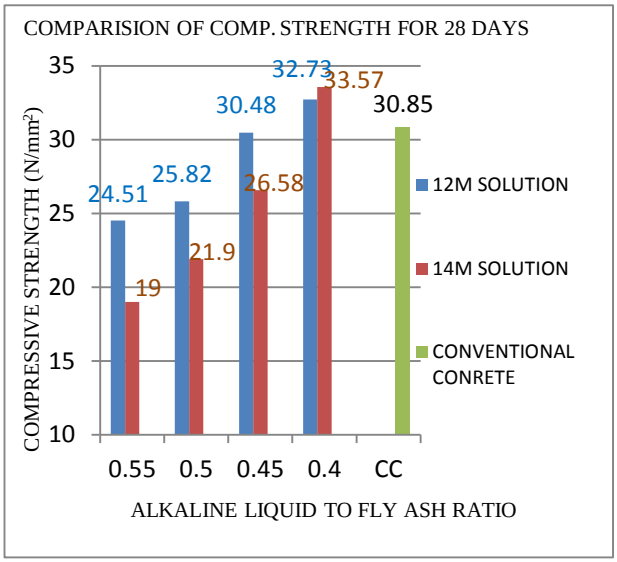
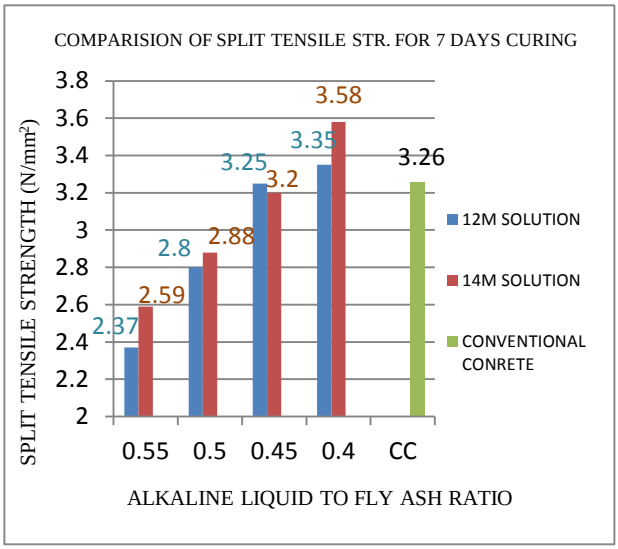
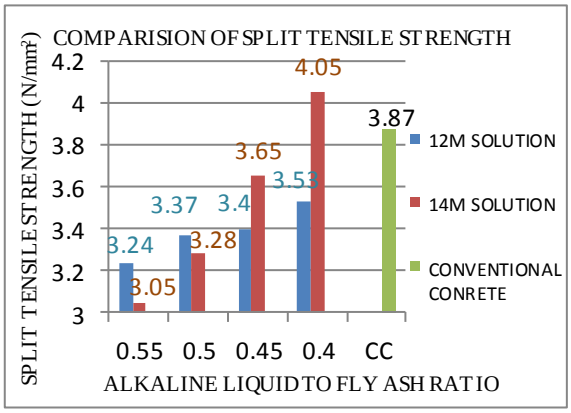
3.2 Comparison of Compressive Strength Results of GPC and CC for 28 Days Curing



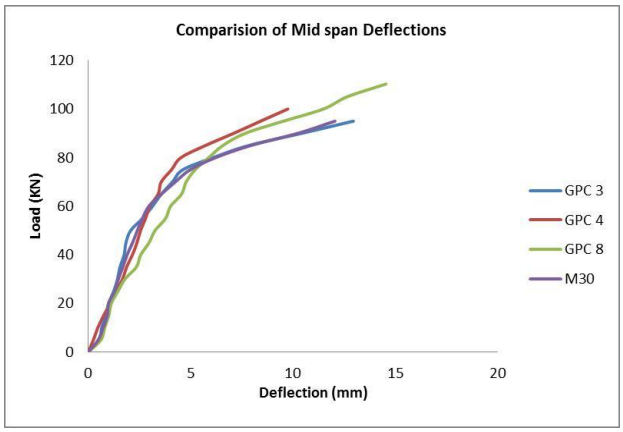
3.3 Comparison of Split Tensile Strength Results of GPC and CC for 7 Days Curing



3.4 comparison of Split Tensile Strength Results of GPC and CC for 28 Days Curing



3.5 Comparision of Mid Span Deflections of GPC Beams with C.C Beams



According to the results, an increase on compressive strength had been observed for 0.45 and 0.40 ratio of alkaline liquid to fly ash compared to conventional concrete. It was observed that the alkaline liquid to fly ash ratio increases the compressive strength and tensile strength are decreases. Flexural behaviour of geopolymer concrete beams has the maximum load carrying capacity compared to the conventional M30 mix. Using higher percent of flyash and lower percent of alkali activator solution as a cement replacement can obtain higher strength.

4. CONCLUSIONS

Flexural behaviour of geopolymer concrete beams has the maximum load carrying capacity compared to the conventional M30 mix. Using higher percent of flyash and lower percent of alkali activator solution as a cement replacement can obtain higher strength

User-friendly geopolymer concrete can be used under conditions similar to those suitable for ordinary Portland cement concrete. These constituents of Geopolymer

Concrete shall be capable of being mixed with a relatively low-alkali activating solution and must be curable in a reasonable time under ambient conditions.

The production of versatile, cost-effective geopolymer concrete can be mixed and hardened essentially like Portland cement. Geopolymer Concrete shall be used in repairs and rehabilitation works.

Due to the high early strength Geopolymer Concrete shall be effectively used in the precast industries, so that huge production is possible in short duration and the breakage during transportation shall also be minimized.

Geopolymer Concrete shall also be used in the Infrastructure works. In addition to that the Flyash shall be effectively used and hence no landfills are required to dump the fly ash

The government can make necessary steps to extract sodium hydroxide and sodium silicate solution from the waste materials of chemical industries, so that the cost of alkaline solutions required for the geopolymer concrete shall be reduced.

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