IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

AN EXPERIMENTAL STUDY ON FLYASH BASED GEOPOLYMER CONCRETE

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ABSTRACT
In the paper an experimental investigation was carried out to study the behaviour of geopolymer concrete. Geopolymer concrete prepared for the experimental study is based on the use of fly ash with cement and coarse aggregate with use of sodium silicate and sodium hydroxide. Results obtained from the experimental study shows that the effect of fly ash with in considered sodium silicate and sodium hydroxide results in good strength of M35 to M40 grade concrete. The strength of fly ash based geopolymer gave good results when curing time was increased. Compressive strength, split tensile strength, flexural strength were the tests considered for the proposed experimental study.

KEYWORDS: Geopolymer concrete, sodium silicate, sodium hydroxide, fly ash.

INTRODUCTION
Concrete is one of the most widely used construction material, it is usually associated with Portland cement as the main component for making concrete. Ordinary Portland cement (OPC) is conventionally used as the primary binder to produce concrete. the abundant availability of fly ash worldwide creates opportunity to utilize this by-product of burning coal, as a substitute for Ordinary Portland cement to manufacture concrete. When used as a partial replacement of Ordinary Portland cement, in the presence of water and in ambient temperature, fly ash reacts with the calcium hydroxide during the hydration process of Ordinary Portland cement to form the calcium silicate hydrate (C-S-H) gel. The development and application of high volume fly ash concrete, which enabled the replacement of Ordinary Portland cement up to 60% by mass, is a significant development.

In this respect, the geopolymer technology proposed by Davidovits shows considerable promise for application in concrete industry as an alternative binder to the Portland cement. In terms of reducing the global warming, the geopolymer technology could reduce the carbon-di-oxide emission to the atmosphere caused by cement and aggregates industries by about 80%.

LITERATURE SURVEY
Djwantoro Hardjito (2001) has developed the material and the mixture proportions, the manufacturing process, the fresh and hardened state characteristics, the influence of various parameters on the fresh and hardened state concrete, the utilization of the material in structural members, and the long-term behavior The geopolymer technology developed by Davidovits in the 1980s offers an attractive solution. In 2001, the authors embraced Davidovits original concept of geopolymers to make fly ash-based geopolymer concrete.

In the authors' experimental work (9-16), low-calcium ASTM Class F dry fly ash obtained from a local power station was used as the source material. Most of the fly ash comprised oxides of silicon (50% by mass), aluminium (25% by mass), and iron (10 to 18% by mass). The calcium content of the fly ash was about 2% by mass. About 80% of the fly ash had particles of less than 38 to 55 micrometer in size.

Fly ash-based geopolymer concrete offers several economic benefits over Portland cement concrete. The cost of one ton of fly ash is only a small fraction, if not free in some parts of the world, of the cost of one ton of Portland cement. Therefore, after allowing for the cost of activator liquids needed to the make the geopolymer concrete, we have estimated that the cost of fly ash-based geopolymer concrete may be about 10 to 30 percent cheaper than that of Portland cement concrete. In addition, we have learnt that the appropriate usage of one ton of fly ash earns one carbon-credit that has a redemption value of about 10 to 20 Euros. Based on the data given in this paper, one ton low-calcium fly ash can be utilised to manufacture approximately 2.5 cubic metres of fly ash-based geopolymer concrete, and hence earn monetary benefits through carbon-credit trade. Furthermore, the very little drying shrinkage, the low creep, and the excellent resistance to sulfate attack offered by the fly ash-based geopolymer concrete may yield additional economic benefits when it is utilised in infrastructure applications.

A summary of the extensive studies carried out by the authors on the fly ash-based geopolymer concrete. Low-calcium fly ash is used as the source material, instead of the Portland cement, to make concrete.

Fly ash-based geopolymer concrete has excellent compressive strength and is suitable for structural applications. The salient factors that influence the properties of the fresh concrete and the hardened concrete have been identified.

The elastic properties of hardened concrete and the behavior and strength of reinforced structural members are similar to those of Portland cement concrete. Therefore, the design provisions contained in the current standards and codes can be used to design reinforced fly ash-based geopolymer concrete structural members.

The fly ash-based geopolymer concrete also shows excellent resistance to sulfate attack, undergoes low creep, and suffers very little drying shrinkage. The paper has identified several economic benefits of using fly ash based geopolymer concrete.

Ammar Motorwala (2013) proposed the feasibility of alkali activated geo-polymer concrete, as a future construction material. The main objective of this study involves observation of structural behaviours of the fresh fly ash-based geo-polymer concrete, understanding the basic mixture proportioning of fly ash-based geopolymer concrete and evaluating various economic considerations an effort is made to identify and study the effect of salient parameters that affects the properties of low-calcium fly ash-based geo- polymer concrete and the properties of concrete at varied concentrations of alkali solutions and how the change in temperature affects the strength characteristics.

MATERIALS AND METHODS

MATERIALS

The materials used for making fly ash-based geopolymer concrete specimens are high-calcium dry fly ash as the source material, aggregates, alkaline liquids, water, and super plasticizer.

Fly Ash

Fly ash is the residue from the combustion of sub-bituminous coal collected by mechanical or electrostatic separators from the flue gases of lignite power plants.

There are about 75 thermal power plants in India and the total production of fly ash is nearly as much as that of cement (75 tons). But our utilization of fly ash is only about 5% of the production.

Most of the fly ash available globally is high-calcium fly ash formed as a by-product of burning anthracite or bituminous coal. Although coal burning power plants are not considered to be eco-friendly, the extent of power generated by these plants is on the increase due to the huge reserves of good quality coal available worldwide and the low cost of power produced from these sources. Therefore, huge quantities of fly ash will be available for many years in the future.

Since fly ash is produced by rapid cooling and solidification of molten ash, a large portion of components comprising fly ash particles are in amorphous state. The amorphous characteristic greatly contributes to the pozzolanic reaction between cement and fly ash. One of the important characteristics of fly ash is the spherical form of the particles. This shape of particle improves the flow ability and reduces the water demand.

ASTM broadly classifies fly ash into two classes.

Class F: Fly ash normally produced by burning anthracite of bituminous coal, usually has less than 5% CaO. Class F fly ash has pozzolanic properties only.

Class C: Fly ash is normally produced by burning lignite or sub-bituminous coal. Some Class C fly ash may have Calcium oxide content in excess 10%. In addition to pozzolanic properties Class C fly ash also possesses cementitious properties.

In this experimental work, high calcium, Class C (American Society for Testing and Materials) dry fly ash obtained from the lignite of Neyveli Lignite Power Station, Cuddalore, was used as the base material.

Alkaline Liquid
A combination of sodium silicate solution and sodium hydroxide solution was chosen as the alkaline liquid. Sodium-based solutions were chosen because they were cheaper than Potassium-based solutions.

he sodium hydroxide solids were of a laboratory grade in pellets form with 99% purity, obtained from local suppliers. The sodium hydroxide (NaOH) solution was prepared by dissolving the pellets in water. The mass of sodium hydroxide solids in a solution varied depending on the concentration of the solution expressed in terms of molar, M. For instance, sodium hydroxide solution with a concentration of 8M consisted of 8x40 = 320 grams of sodium hydroxide solids (in pellet form) per litre of the solution, where 40 is the molecular weight of sodium hydroxide. Note that the mass of sodium hydroxide solids was only a fraction of the mass of the sodium hydroxide solution, and water is the major component.

Sodium silicate solution (water glass) obtained from local suppliers was used. The chemical composition of the sodium silicate solution was Na_2O=8%, SiO_2=28%, and water 64% by mass. The mixture of sodium silicate solution and sodium hydroxide solution forms the alkaline liquid.

Aggregates
Local aggregates, comprising 20 mm, and less than 20 mm coarse aggregates and fine aggregates, in saturated surface dry condition, were used. The coarse aggregates were crushed granite-type aggregates and the fine aggregate was fine sand. Coarse aggregates were obtained in crushed form majority of the particles were of granite type. The quality is tested using the crushing and impact test. The fine aggregate was obtained from the sand dunes in uncrushed form. These are purchased from local suppliers.

Superplasticizer
The sulphonated naphthalene-formaldehyde (superplasticizer), obtained from local supplier is used.

Cement
Cement is the important binding material in concrete. Portland cement is the common form of cement. It is the basic ingredient of concrete, mortal, and plaster.

Coarse Aggregate
A maximum size of 20mm is usually selected as coarse aggregates up to 20mm may be used in concrete.

MANUFACTURE OF TEST SPECIMENS

MIX DESIGN
The mix design for M40 grade concrete is designed below
Mix design for 3 number of cube:
Volume of 4 cube= $(4\times15^3) / 100^3 = 0.0101\ m^3$
Wt of the batch (4 cubes)= 0.0101 × 2400=24.24 kg
Total weight of the batch = 24.24 + 2.424 kg (10% excess)
= 26.664 kg

Combined aggregate = 75% – 80%
We take it as 77%.
Weight of combined aggregate= 26.664 × 77/100 = 20.53 kg
We take fine aggregate as 6.84 kg and coarse aggregate as 13.69 kg.
Weight of alkaline and fly ash = 26.664 – 20.53 = 6.134 kg

ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

$$\frac{\textbf{Alkaline solution}}{\textbf{Fly ash}} = \mathbf{0.30 - 0.45}$$

We take it as 0.35
Weight of fly ash = 6.134 / (1+0.35)= 4.544 kg
Weight of alkaline solution = 6.134 – 4.544 =1.59 kg

$$\frac{\textbf{Sodium silicate}}{\textbf{Sodium hydroxide}} = \mathbf{2.5}$$

Weight of sodium hydroxide solution = 1.59 / (1+2.5) = 0.454 kg
Weight of sodium silicate solution = 1.59 – 0.454 = 1.136 kg

On manufacture of the geopolymer concrete in the laboratory, the major problem we faced is the workability, so we added extra water during the manufacture process.

The mix was prepared as per the presented geopolymer mix design and was then subjected to test such as compressive strength, split tensile strength, flexural strength and slump cone test for workability.

The results are tabulated below.

Tab:4.1.Compressive Strength of Geo-polymer Concrete

100 Percentage of fly ash in concrete	**Concentration of NaOH in 8M**	**7 days (N/mm^2)**	**14 days (N/mm^2)**	**28 days (N/mm^2)**
		25	31.5	33
		24	30	34.5
		26	29.5	32.5
Average compressive strength in (N/mm^2)		25	30	33

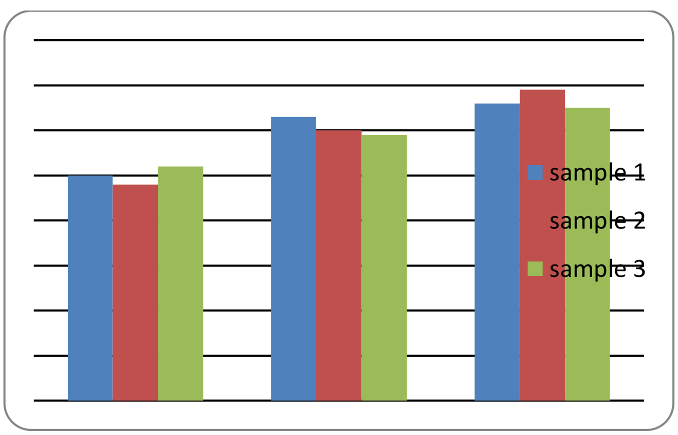

Figure 4.1: Compressive Strength of Geo-Polymer Concrete

Tab.4.2: Compressive Strength of Normal Concrete

Conventional concrete	**7 days (N/mm^2)**	**14 days (N/mm^2)**	**28 days (N/mm^2)**
	37	40.5	43.5
	38	40	41.5

ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

	39	39.5	42
Avg compressive strength in (N/mm^2)	38	40	42

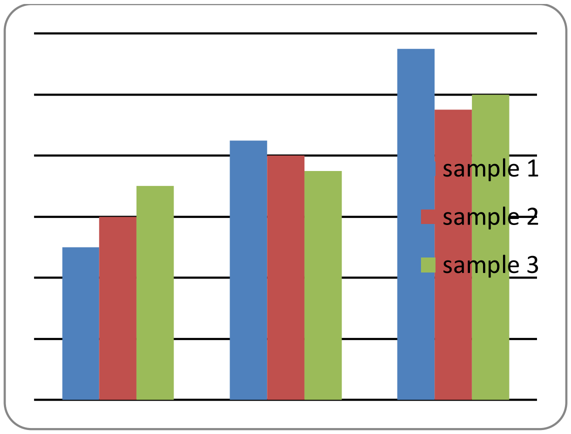

Figure 4.2: Compressive Strength of Normal Concrete

Tab:4.2 Split Tensile Strength of Geopolymer Concrete

100 Percentage of Fly Ash in Concrete	**Concentration of NaOH in 8M**	**7 days (N/mm^2)**	**14 days (N/mm^2)**	**28 days (N/mm^2)**
		1.00	1.56	2.06
		1.10	1.47	2.10
		1.00	1.50	2.12
Average Split Tensile Strength in (N/mm^2)		1.03	1.51	2.12

Table 4.3: Split Tensile Strength of Normal concrete

	7 days (N/mm^2)	**14 days (N/mm^2)**	**28 days (N/mm^2)**
Conventional Concrete	1.28	2.1	2.5
	1.25	2.20	2.67
	1.24	2.00	2.56
Average Split Tensile Strength in (N/mm^2)	1.25	2.10	2.57

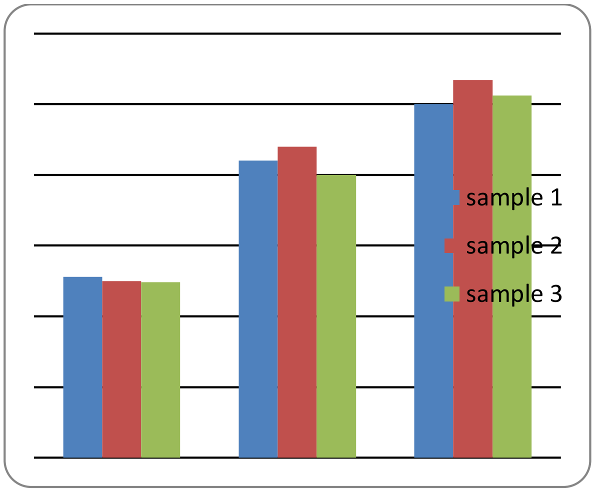

Figure 4.4: Split Tensile Strength of Normal Concrete

CONCLUSIONS

Based on the experimental work, the following conclusions are drawn:

- The slump value of the fresh fly-ash based geo-polymer concrete increases with the increase of water added beyond 0.35.
- The slump of the normal concrete is 30 mm is relatively less than fly ash class C based geo-polymer concrete with the concentration of NaOH in 8 M is 28 mm.
- The fresh fly ash-based geopolymer concrete is easily handled up to 120 minutes without any sign of setting.
- Longer curing time produces higher compressive strength of fly ash-based geopolymer concrete.
- However, the increase in strength beyond 24 hours is not much significant.
- The compressive strength of the fly ash based geopolymer concrete decreases with the increase in water content.
- This shows when temperature increased the strength too increased.
- The compressive strength of fly ash class C based geo-polymer concrete with the concentration of NaOH in 8M is 33 N/mm^2 at 28 days strength is less than the compressive strength of normal concrete is 42 N/mm^2 at 28 days strength.
- The split tensile strength of fly ash class C based geo-polymer concrete with the concentration of NaOH in 8M is 2.12 N/mm^2 at 28 days strength is less than the split tensile strength of normal concrete is 2.57 N/mm^2 at 28 days strength.
- During the split tensile strength the above condition prevailed.
- During the durability tests on concrete such as water absorption and fire resistance, the geo-polymer concrete gives better results.

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