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# Experimental Investigation on Geopolymer Concrete with Class 'F' Fly Ash

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***Abstract* - This experimental study was undertaken to study the strength characteristics of Geopolymer concrete. This experiment involves study to reduce the greenhouse gas emissions by implementing use of alternative material to cement. Five to eight percent of the world's man- made greenhouse gas emissions is from the cement industry itself. It is an established fact that the greenhouse gas emissions are reduced by 80% in Geopolymer concrete compared to conventional Portland cement manufacturing, as it does not involve carbonate burns etc. Thus Geopolymer based Concrete is highly environment friendly and the same time it can be made a high-performance concrete. In the present study, 100% replacement of conventional ordinary Portland cement is made by using ASTM class F fly ash, Ground granulated blast furnace slag and catalytic liquids (or AAS) to prepare Geopolymer concrete mixes. In our present study we evaluated strength characteristics of Geo polymer concrete by varying the molar concentration (6M, 8M, and 10M) and varying percentage of binding material. The work has been done to structural specimen like cylinders and cubes and evaluated compressive, split tensile strength for different binding material proportions and solution concentration.**

***Keywords:*** Geopolymer concrete, Fly ash, Ground Granulated Blast Furnace Slag (GGBS), alkaline activator, compressive strength, Split tensile strength.

## I. INTRODUCTION

The emission of $CO_2$ coupled with non absorption of the same on account of deforestation has tremendous environmental pollution leading to global warming and other bad effects. It is estimated that about 7% of green house is being emitted into the atmosphere annually on account of production of OPC alone. Therefore to reduce the emission of the $CO_2$ into atmosphere by reducing the cement production and consumption.

The demand for Portland cement is increasing day by day and hence, efforts are being made in the construction industry to address this by utilizing supplementary materials and developing alternative binders in concrete; the application of geo-polymer technology is one such alternative. The abundant availability of fly ash worldwide creates opportunity to utilize this by-product of burning coal, as a substitute for OPC to manufacture concrete. When used as a partial replacement of OPC, in the presence of water and in ambient temperature, fly ash reacts with the calcium hydroxide during the hydration process of OPC to form the calcium silicate hydrate.

Palomo et al (1999) suggested that pozzolans such as blast furnace slag might be activated using alkaline liquids to form a binder and hence totally replace the use of OPC in concrete. Hence, in this paper 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.

### 1.1 Scope of Geoppolymer Concrete

The research utilized low-calcium (ASTM Class F) fly ash as the base material for making geopolymer concrete. The fly ash was obtained from only one source. As far as possible, the technology and the equipment currently used to manufacture OP concrete were used to make the geopolymer concrete.

The concrete properties studied included the compressive and indirect tensile Strengths, the elastic constants, the stress-strain relationship in compression, and the workability of fresh concrete.

- Proper utilization of fly ash geopolymer is necessary to know about the characteristics and possible effects on the properties of concrete.
- Design mix for M20 and M25 concrete with different percentage of replacement of Cement with geopolymer concrete.
- To study the effects of fresh concrete properties (slump test and compaction factor Test) with different percentage of replacement of cement with geopolymer concrete.
- To study the effect of hardened concrete properties (i.e. compressive strength, split Tensile strength, flexural strength, modulus of elasticity and water absorption) with different percentage of replacement of cement with fly ash geopolymer.

 

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### 1.2 Aim and Objectives

The aim of the research is to evaluate the performance and suitability of fly ash and slag based geopolymer as an alternative to the use of ordinary Portland cement (OPC) in the production of concrete.

To evaluate the different strength properties of geopolymer concrete mixture with G.G.B.S replaced in percentage to fly ash. Making workable, high strength and durable geopolymer concrete containing G.G.B.S (Slag) without usage of ordinary Portland cement. The primary objective of this project is to study the strength characteristics of geo polymer concrete using fly ash& sodium silicate, sodium hydroxide. To determine the effect of fly ash and GGBS as a replacement for cement Concrete. Evaluation of the performance of FA-based Geopolymer and AAS concrete with respect to the strength properties.

## II. MATERIALS AND METHODOLOGY

Class F fly ash collected by electrostatic precipitator, obtained from Thermal Power Corporation at raichuru, Karnataka, used in the present study. It may be observed that they appear as plain spherical particles of varying diameters. The surface of fly ash particles appears smooth and clean. Specific gravity= 2.21.

**Table 1: chemical Properties of fly ash**

| chemical Properties of fly ash | | |
|---|---|---|
| **Parameters** | **Experimental value (%)** | **Requirements as per IS 3812- 2003** |
| Silica | 64.11 | $SiO_2$ >35% |
| Aluminum oxide | 18.58 | Total - >70% |
| Iron oxide | 4.32 | Total - >70% |
| Calcium oxide | 1.21 | - |
| $Na_2o$ | 0.21 | <1.5% |
| Potassium oxide | 1.02 | <1.5% |
| Magnesium oxide | 0.24 | <5% |
| Loss of ignition | 0.64 | <12% |

**GGBS (Ground granulated blast furnace slag)** Many researchers confirmed that GGBS had the ability to reduce the deleterious expansion caused by alkali aggregate reaction (AAR), especially when GGBS was used to replace Portland cement of high alkali content. Specific gravity= 2.20.

**Table 2: chemical Properties of GGBS**

| chemical Properties of GGBS | | |
|---|---|---|
| **Parameters** | **Experimental value (%)** | **Requirements as per IS 3812- 2003** |
| silica | 32.78 | |
| Calcium oxide | 34.8 | (CaO + MgO + Al2O3) / SiO2 1.94>1 |
| Magnesium oxide | 8.0 | (CaO + MgO + Al2O3) / SiO2 1.94>1 |
| Aluminum oxide | 20.8 | - |
| Iron oxide | 1.10 | - |
| Loss of ignition | 0.62 | - |
| silica | 32.78 | |
| Loss of ignition | 0.64 | <12% |

### 2.1 Fine aggregate

The sand used in this investigation is ordinary river sand. The sand passing through 4.75 mm size sieve is used in the preparation of specimens. The sand conforms to grading ZoneII as per IS: 383- 1970. The properties of sand such as fineness modulus, water absorption and specific gravity were determined as per IS: 2386-1963. The sand used for the experimental program is locally procured and confirming to zone- The specific gravity of fine aggregate is found to be 2.60.The water absorption test on coarse aggregate is found to be 0.45%.

### 2.2 Natural coarse aggregate

The coarse aggregate used in the investigation is 20 mm down size locally available crushed stone obtained from quarries. Specifications for coarse aggregate are included in IS: 383-1970. The physical properties have been determined as per IS: 2386- 1963.The specific gravity of coarse aggregate is found to be 2.65. The water absorption test on coarse aggregate is found to be 0.29%.

### 2.3 Alkaline activators

A mixture of sodium hydroxide and sodium silicate solution was chosen in the present study as alkali activators. Commercial grade sodium hydroxide in pallets (purity 97%; specific gravity 2.13) and sodium silicate solution ($Na_2O$=18.2%, $SiO_2$=36.7%, water=45.14%; specific gravity=1.53) were used to prepare the solution. The mass of NaOH pallets in a solution varied according to molar strength M.

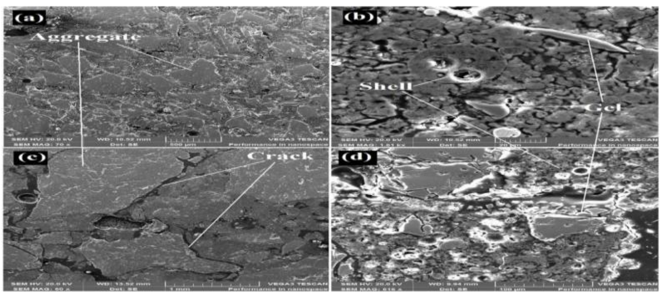


**Figure 1: Fly Ash Geopolymer Concrete**

 

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### 2.4 Tests on hardened concrete and Results

*2.4.1 Compressive strength test*

Specimens of dimensions 150x150x150mm were prepared. They are tested on 2000kN capacity compression testing machine as per IS 516-19.

The comparison graph shows in Fig.1the compressive strength of cubes shows for different molarities. For water curing of specimens 6M which gives more strength compare to the other 8M and 10M solutions. The maximum strength achieve within 7 days curing. The comparison graph shows the Fig. 2 compressive strength of cubes shows for different molarities for 20-80% FA and GGBS. By increasing GGBS quantity we can achieve more strength. For water curing of specimens 6M which gives more strength compare to the other 8M and 10M solutions. The maximum strength achieve within 7 days curing.

*2.4.2 Split tensile strength test*

Cylindrical specimens of diameter 150mm and length 300mm were prepared. Split tension test was carried out on 2000 kN capacity compression testing machine as per IS 5816-1999.

The comparison graph shows in Fig. 3 the tensile strength of cylinder shows for different molarities. For water curing of specimens 6M which gives less strength compare to the other 8M solutions. The maximum strength achieve within 7 days curing. The comparison graph shows the Fig. 4 tensile strength of cylinders shows for different molarities for 20-80% FA and GGBS. By increasing GGBS quantity we can achieve more strength. For water curing of specimens 8M which gives more strength compare to the other 6M solutions. The maximum strength achieve within 7 days curing.

## III. CONCLUSIONS

The experimental work carried out and analysis of the results the following is concluded:

- Minimization of the cost of the fly ash to the Portland cement.
- Geopolymer concrete is a low cost concrete.

It attains the maximum strength at the within the days of curing.

- As the GPCs do not contain any Portland cement, they can be considered as less energy intensive (i.e., low Embodied energy') apart from less energy intensiveness the GPCs utilize the industrial waste for producing the binding system in concrete.
- Compressive strength for 6M is more, compared to 8M and 10M.(Fig. 1and 2) While Molarity of solution decreases the strength is increases for water curing.
- The increase in GGBS quantity increases the strength. The split tensile strength is more in 8M compared to 6M. (Fig. 3 and 4) User-friendly geopolymer concrete can be used under conditions similar to those suitable for ordinary Portland cement concrete.
- The production of versatile, cost-effective geopolymer concrete can be mixed and hardened essentially like Portland cement.

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