JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

# Review of Properties of Geo-Polymer Concrete (GPC) with Addition of Fly Ash

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*Abstract :* Usage of cement as binder of aggregates has been a standard practice in any construction site since cement can be conveniently used for in situ concreting with good strength. Manufacture of concrete is an energy-demanding process and causes pollution. Geopolymer Concrete (GPC) is an advanced eco-friendly concrete manufactured by activating source material rich in alumina and silica by alkaline liquids to form aluminosilicates based inorganic polymers.Adopting GPC to replace cement concrete can solve the problem of unsustainable usage of limestone and pollution related to the manufacturing process of cement since the ingredients utilized are waste products such as fly ash and GGBS. Sustained and effective polymerization reaction between source materials and alkaline liquids is possible at elevated temperatures around 90°C. Due to this factor, GPC has limited usage for in situ application. Ambient cured GPC exhibited average strength and increased setting time. To achieve high strength and curing at ambient temperature, GPC needs to be modified with replacement and addition of certain ingredients, this influences strength and curing conditions. The addition of OPC as admixture amplifies the binding process and improves the strength. The combined effect of adding OPC and GGBS facilitates ambient curing for the GPC with high strength. Gujcon CFR fibre was added to the mix to constrain the formation of shrinkage cracks and prevent the effects of thermal variation. Ultimate strength was achieved through this modification with improved elastic properties due to the influence of fiber reinforcement. The experimental program was intended for examining mechanical and durability characteristics of modified GPC. The modified GPC was aimed at producing high strength, ambient cured concrete for the in situ application. A sequence of tests to check the key properties of GPC in the fresh and solid state was performed in accordance with relevant standards and procedures. Compressive strength was checked for each mix by testing cubes of standard size. In this investigation, it was found that strength increased gradually with GGBS replacing fly ash. Further increment in strength was achieved by the addition of OPC as admixture and Gujcon CRF fibre as secondary reinforcement. The investigation on strength characteristics and durability of GPC resulted in a hybrid concrete which was superior in strength and durability attributes. Adoption of geopolymer technology ensures sustainable and eco-friendly manufacturing process without the need of high temperature for curing which makes the concrete ideal for in situ application.

***IndexTerms*** **– Fly-Ash, GPC, GGBS**

## I. INTRODUCTION

The requirement for concrete as a building material has seen a consistent increment in usage owing to in situ adaptability, ease of usage, durability, fire resistance, and high strength. However, cement, the binders of aggregate in concert is expensive and causes pollution during the manufacturing process.Production of cement emits a huge amount of CO2 into the atmosphere. A rough estimate of greenhouse gases emitted due to the production of cement is about 7% annually. Another estimate suggests that around 900 kilograms of carbon dioxide is released with every ton of cement produced. The carbon dioxide produced during cement

manufacturing is due to both chemical process and burning of fossil fuels. To aggravate the problem, deforestation, pollution due to power generation and other means cause an irreplaceable depletion of ozone layer.

Unsustainable uses of limestone, the raw material for cement manufacturing has caused landscape depletion and other associated problems. The consumption of cement for manufacturing of concrete needs to be controlled by taking suitable measures. Some of the methods to control or avoid the consumption of cement are by economical mix design, replacement of cement by fly ash or materials similar to cement, using alternate binding materials for concrete such as GPC.The perfect substitute to conventional cement concrete is GPC., with good mechanical properties and exceptional durability, GPC is a new range of eco-friendly, inexpensive construction material which would be ideal to replace cement concrete.Geopolymer utilizes inorganic aluminosilicate polymer synthesized from source materials such as fly ash which is rich in aluminium and silicon as binders. The alkaline solution is used to dissolve the silicone and Aluminium molecules to form a gel-like amorphous compound which binds the aggregate in the presence of heat. By adopting geopolymer technology we can reduce the consumption of cement for manufacturing concrete.Fly ash is a by-product of coal burning process is disposed of in landfills which increased the landfill cost as millions of tons of fly ash was disposed of. Disposal in landfills also caused many environmental impacts. By adopting geopolymer technology for manufacturing concrete, we can utilize the industrial waste product like fly ash and GGBS as source material which in combination with alkaline solution acts as a Binder of aggregates.

## II. OBJECTIVES OF THE STUDY

The main objective of the study is as follows:

- To reduce the consumption of cement by including fly ash and GGBS as replacement this will lead to less impact on the environment and cost effective.
- To do experimental investigation this aims to develop a modified GPC for in situ application.
- To conduct Experimental investigation of durability in terms of acid attack, thermal shock, and fire attack.
- To study the effect of mixing superplasticizer in Geopolymer concrete and cement paste.

## GEOPOLYMER

Geopolymers are synthetic materials formed by the aqueous alkali-activation of aluminosilicate solid particles. Joseph Davidovits first coined the term ‘geopolymer’ and inthe year 1978, he projected that polymerization of alumino-silicate source materials and the alkaline solution would produce binders like cement.

The formation of a binder by using alkali solution and aluminosilicates is broadly referred to ‘geopolymer’. Thus, it is known as alkali-activated cement and inorganic polymer concrete. Polymerization is the fast chemical reaction between silicon and aluminum that results in a three-dimensional polymeric chain and ring structure consisting of Si-O-Al-O. This later combined with fly ash gives binders.

## GEO-POLYMERIZATION REACTION

Geopolymer reveals an amorphous microstructure and is similar to zeolites in chemical composition. In Geo-polymerization alumino-silicate materials is transformed in a wide range of into building materials. Thus the new composition has phenomenal chemical and physical properties such as acid and fire resistance. Geo-polymerization reaction takes place in three different processes. Geo- polymerisation consists of 15 natural Al-Si minerals as shown in Figure 1.1.

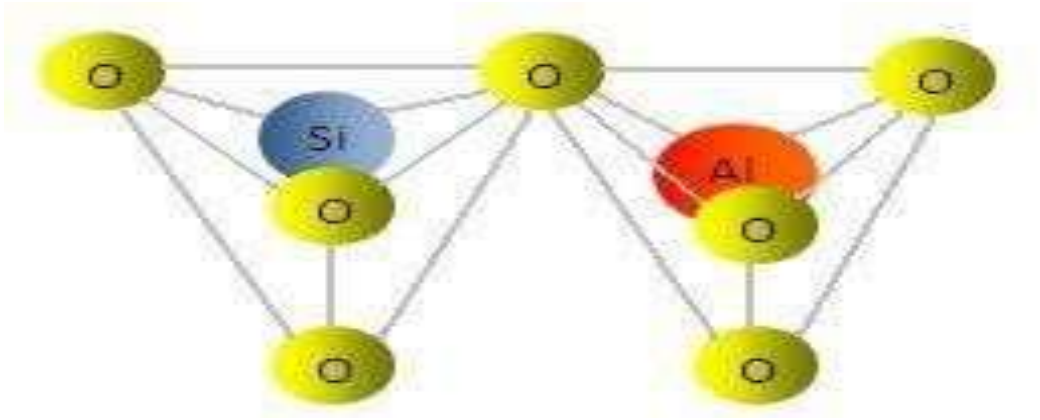



**Fig1.1 Structure of Geo-polymer Concrete(GPC)**

In alkaline solution, all these minerals are soluble with a greater extent of dissolution in NaOH than in KOH and silicates in alkaline solution. After geo-polymerization, minerals with a higher extent of dissolution demonstrate better compressive strength. During the initial mixing, the silicon and aluminium ions in the raw materials like fly ash, GGBS, silica fume, bentonite, etc. are dissolved in the alkaline solution. Here, oxygen bond is formed by condensation reaction of the silicon and aluminium hydroxide which links the water molecules. The oxygen bond formed due to the condensation bonds the neighbouring Si and Al tetrahedral. A clear representation of the reaction is given in the Figure 1.2.

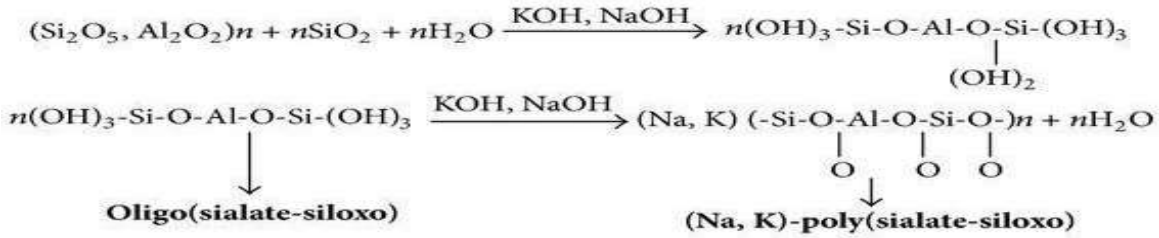



**Figure 1.2 Geo-polymerization Reaction**

This polymerization reaction takes place at elevated temperatures, and it produces stronger geopolymers. Geopolymers can harden rapidly at room temperatures and gain compressive strength up to 20MPa in 1 day.

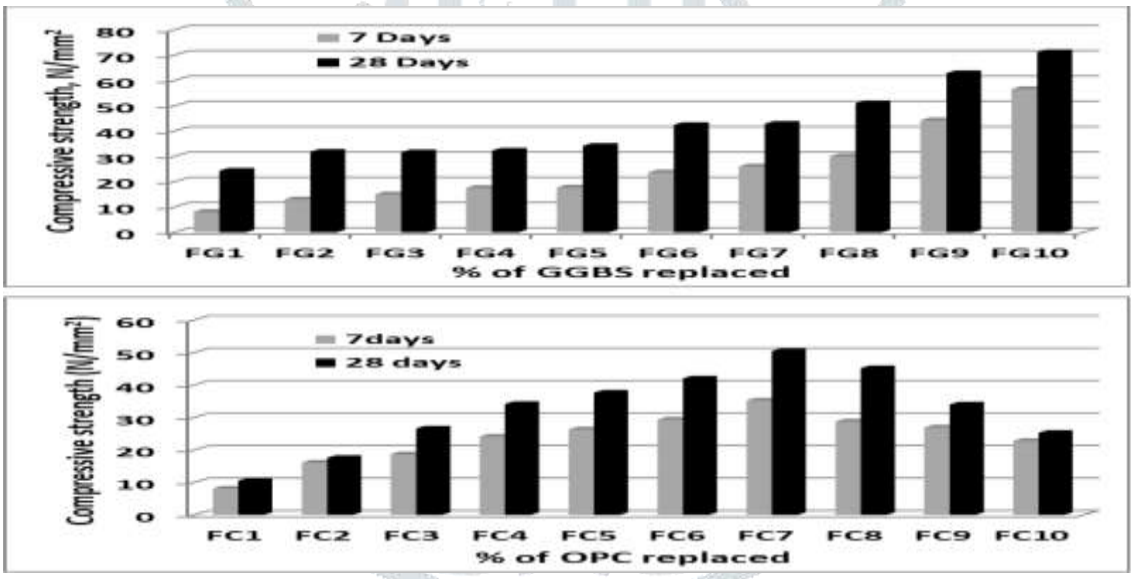
**INGREDIENTS OF GPC**

In the synthesis of geopolymers, there are two types of essential raw materials, solids containing aluminosilicate and alkali-silicate solution. In alkali-silicate medium, aluminosilicate solids function as sols. A sol-gel matrix is formed by sol-liquid and is usually done in sol-gel methodology. The commonly used kaolinite and calcined kaolinite or metakaolinite are the sources of aluminosilicate. Others include natural aluminosilicate minerals and industrial waste-based materials, such as blast furnace slags and fly ashes. By diluting alkali-hydroxide solids in commercial silicate solutions, water alkali-silicate solutions were made to obtain certain silicates and alkali concentrations, expressed as SiO2/M2O and H2O/M2O ratios.

**ADVANTAGES OF GPC**

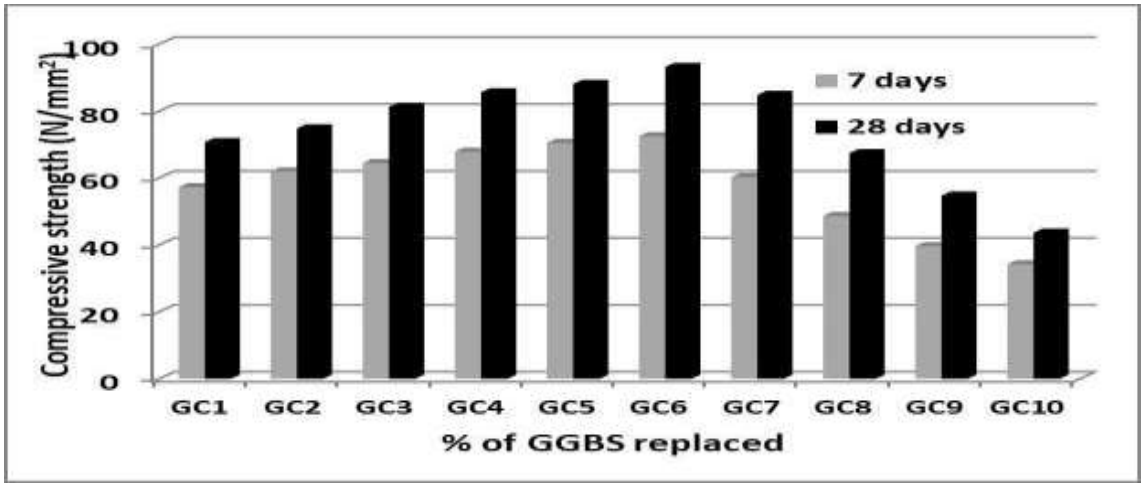
- **High strength:** GPC are strong both in compression and tension. They are an excellent option for rapid builds because of their rapid strength gaining and curing property. They can withstand more movements as they are less brittle than normal portland concrete.
- **Low creep:** The tendency of concrete to deform permanently due to the constant forces applied to it is known as creep. Here, for GPC, the creep is low.

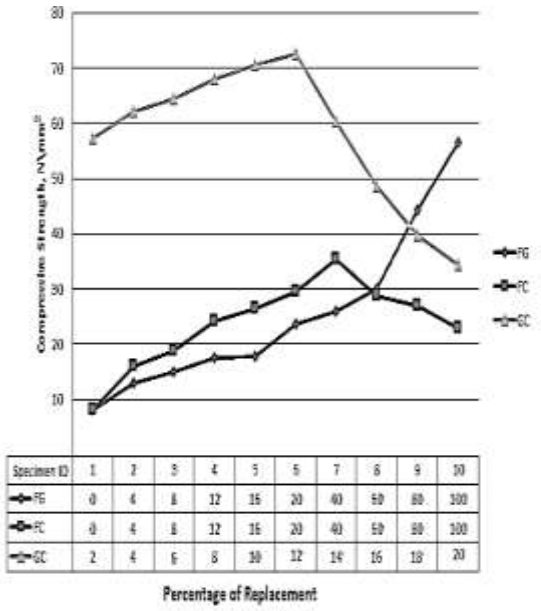
- **Low shrinkage:** GPC has low shrinkage since hydration is not required during polymerization. Shrinkage can cause severe cracks which will be dangerous due to the drying and heating of the concrete or even the evaporation of water.
- **Strong chemical resistance:** Geopolymers are highly alkaline in nature and generally not affected by acids, toxic chemicals, and salts which make it highly chemical resistant. Since limestone is not used as an ingredient for manufacturing GPC, problems related to chemical attack in both acidic and saline environment are prevented effectively.
- **Resistant to heat and cold:** GPC does not experience thermal cracks as it has the ability to stay stable even at high temperatures. Presence of pozzolanic materials like GGBS and fly ash provides protection against temperature variations.
- **Ideal for repair works:** GPC has the potential to be the ideal repair materials for concrete structures as it has a quick setting ability and high strength with excellent durability.
- **Economical:** The overall cost of fly ash based GPC is 10 to 30% less than that of ordinary Portland cement concrete. Hence the use of GPC in the construction industry is economical.



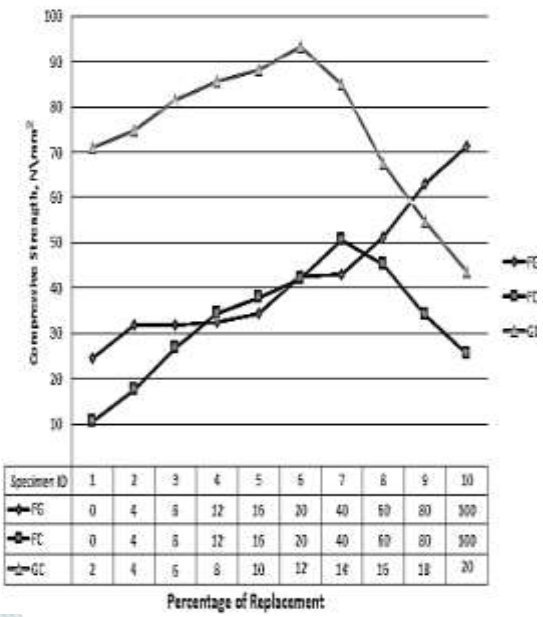









| Specimen ID | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| FG | 0 | 4 | 8 | 12 | 16 | 20 | 40 | 60 | 80 | 100 |
| FC | 0 | 4 | 8 | 12 | 16 | 20 | 40 | 60 | 80 | 100 |
| GC | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 |

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# CONCLUSION

Cement, the binder of aggregate in concrete is expensive and releases an equal amount of carbon dioxide during production, On the other hand, concrete offers exceptional strength and fire resistance without losing its strength, But the depleting raw materials and polluting nature of the production process show the negative side of cement concrete. Precise combinations of proportions of GGBS and OPC have an outcome of ambient-cured, high strength GPC which can also be used for in situ applications. In GPC, the addition of OPC and a constant amount of 7g/m$^3$of Gujcon CRF fiber as secondary reinforcement are responsible for the significant improvement in the mechanical properties.

- Trial mix was adopted with modification to achieve high strength and durability. The optimum mix proportions having satisfactory levels of workability lead to effective casting process and improvement of strength.
- Heat due to the exothermic reaction between alkaline solution and water during the dissolving process was exploited by reducing the resting time from 24 hours to 6 hours in order to utilise the heat for polymerization reaction which made ambient curing possible.
- From the experimental investigation of slump cone test it was evident that the ingredients of GPC influenced the workability to a great extent. GGBS being pozzolanic in nature improves the workability and adding ordinary Portland cement decreased the workability. However, workability of all the mix proportions including the optimum mix proportion had satisfactory slump value.
- Compressive strength of ambient cured modified GPC for all trial mix proportion was experimentally analysed. An incremental improvement of strength was observed when fly ash was replaced with GGBS. By reaching 100% fly ash with GGBS, it results in the maximum compressive strength of 71.24 N/mm$^2$.
- By using fly ash based Geo Polymer Concrete with 40% replacement of OPC resulted in the maximum compressive strength of 54.90 N/mm$^2$.

  Samples of GPC with GGBS replaced with 20% cement which produced the minimum strength was analyzed, and the microstructure revealed the presence ofnumerous micro cracks and micro pores throughout the surface of the specimen. Moreover, the presence of unreacted cement and GGBS particles were also visible due to poor workability and quick setting.
- The effect of fibre reinforcement on microstructure of modified GPC was studied with samples of Gujcon CRF fibre reinforced modified GPC with fly ash replaced with cement. The microstructure showed crack free formation of amorphous solids with randomly dispersed Gujcon CRF fibre. The Gujcon CRF fibre acted as a reinforcement between shrinkage cracks and improved the integrity of the structure.

## FUTURE SCOPE

The following are a few areas for the future investigation.

- As the modified geopolymer developed is for in situ applications under ambient curing, self-compacting modified geopolymer can be developed by adopting suitable admixtures and aggregates.
- Analysis and design of structural of beam-column connections, slabs and other structural members can be investigated.
- Buckling performance of modified GPC can be investigated.
- The structural performance of modified GPC beams can be broadened by performing torsional analysis of beams.
- Nano admixtures can be introduced as admixtures to improve the strength and durability of the modified GPC.

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