International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.10 No.8, pp 320-325, 2017

# Analytical Study on Fibre Reinforced Geopolymer Concrete

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**Abstract :** This paper focuses on the Experimental and Analytical Investigation carried out on fibre reinforced Geopolymer concrete with Flyash and GGBS, glass fibre and steel fibre. Geopolymer concrete is proven to have excellent engineering properties with a reduced carbon footprint[1]. It not only reduces the greenhouse gas emissions (compared to Portland cement based concrete) but also utilizes a large amount of industrial waste materials such as fly ash and slag.In addition to geopolymer, fibre addition was seen to enhance the tensile strength. The experimental investigation of steel fibre reinforced concrete and glass fibre reinforced concrete was done by compression test and young's modulus was calculated. An Analytical study was done using ANSYS V12.0 with the modulus of elasticity found from the experimental result.
**KeyWords :** Analytical investigation, fibre reinforced Geopolymer Concrete, Flyash, GGBS, Glass and Steel Fibre, Greenhouse emissions, Tensile strength, ANSYS V12.0.

## 1.0 Introduction:

Concrete is the commonly used construction material. Its usage by the continuities across the globe is second only to water. Customarily, concrete is produced by Ordinary Portland cement as the binder. The usage of OPC is on the increase to meet infrastructure developments. The world-wide demand for OPC would increase further in the future[3]. It is well-known that the cement production depletes significant amount of natural resources and releases large volumes of carbon-di-oxide. Cement production is also highly energy-intensive, after steel and aluminum. On the other hand, coal-burning power generation plants produce huge quantities of fly ash. The volume of fly ash would increase as the demand for power increases. Most of the fly ash is considered as waste and dumped in landfills. In order to address the issues mentioned above, it is essential that other forms of binders must be developed to make concrete[6,7]. Hence we have used the concept of fibre reinforced geo-polymer concrete. The addition of fibres increases the tensile strength, toughness and energy absorbing capacities.

### 1.1 Need For Fibre Reinforced Geopolymer Concrete:

Fibre-reinforced geopolymer concrete has highly desirable structural engineering properties, which can lead to significant environmental and economic benefits[2]. Its use is, however, limited by concerns regarding an increased brittleness compared to Ordinary Portland Cement concrete. Cementitious materials are generally brittle in behavior and are inherently weak in resisting tensile forces. Low amounts of tensile force can cause a sudden failure which is usually caused by the proliferation of cracks. Steel reinforcement is a common method of reinforcing the tensile strength of Cementitious materials. The addition of fibres to cementitious materials works on a similar theory whereby fibres act to transmit tensile forces across a crack. Fibres in general and polypropylene fibres in particular have gained popularity in recent years for use in concrete, mainly owing to their low price and excellent characteristics, but also because they reduce the shrinkage, and improve cracking resistance and toughness of plain concrete.

## 2.0 Literature Study:

### 2.1 Geopolymer Concrete with Fly Ash:

A Lloyd and B V Rangan, they concluded that geopolymer concrete results from the reaction of a source material that is rich in silica and alumina with alkaline liquid. Test data are used to identify the effects of salient factors that influence properties of the geopolymer concrete and to propose a simple method for the design of geopolymer concrete mixtures.

### 2.2 Mechanical Properties of Steel Fiber-Reinforced Concrete:

Job Thomas and AnanthRamaswamy[8]**,** they concluded that the various strength properties studied are cube and cylinder compressive strength, split tensile strength, modulus of rupture and postcracking performance, modulus of elasticity, Poisson's ratio, and strain corresponding to peak compressive stress. The variables considered are grade of concrete, namely, normal strength 35 MPa, moderately high strength 65 MPa, and high-strength concrete 85 MPa, and the volume fraction of the fiber$V_f$=0.0, 0.5, 1.0, and 1.5%.

### 2.3 Physical Properties of Steel Fiber Reinforced Cement Composites Made with Fly Ash:

Falah A. Almottiri[10]**,** in this paper the structural behaviour of steel fibre reinforced flyash concrete under compression and flexure was studied by conducting tests on standard control specimens. The use of steel fibres in fly ash concrete improves its structural properties, especially the flexural tensile strength. Increasing the percentages of fly ash up to 30% and steel fibres up to 1.5% in concrete enhances the flexural tensile strength as well as the compressive strength. Finally, the use of fibre reinforced fly ash concrete is recommended as an alternative to fibre reinforced plain concrete.

## 3.0 Materials Used:

**3.1 FLY ASH:** Class C Fly ash conforming to IS 3812 (Part 1:2003) was used in this study.

**3.2 GGBS: Ground-granulated blast-furnace slag** conforming to IS 12089:1987 was used.

**3.3 Alkaline Activator Solution:** Sodium silicates and sodium hydroxides were added besides distilled water to form the alkaline activator solution.

**3.4 Fine Aggregate:** Locally available river sand conforming to grading zone II of IS 383 –1970. Sand passing through IS 4.75mm Sieve will be used with the specific gravity of 2.65.

**3.5 Coarse Aggregate:** Locally available blue metal was used. Crushed granite stones of size of 15 mm aggregate which passing through 20 mm sieve and retained on 10 mm sieve as per IS: 383-1970 was used for experimental purpose.

**3.6 Water:** Ordinary portable water without acidity and alkanet available in pump.

**3.7 Super Plasticizer:** Conplast SP 430 is based super plasticizer was used to obtain the desired workability, Sivakumar and Manu Santhanam (2007).

**3.8 Fibre:**

**Steel Fibre:** Crimped steel fibrewas used shown in Fig.1 and properties are tabulated in Table 1.

**Glass Fibre:** Glass fibre also called fibre glass. It is material made from extremely fine fibre of glass fibre is a lightweight, extremely strong, and robust material was shown in Fig.2 properties are tabulated in Table 2.

**Table1. Properties of Steel Fibre**

| Property | Steel |
|---|---|
| Length | 50mm |
| Diameter | 1mm |
| Aspect ratio | 50 |

**Table2. Properties of Glass Fibre**

| Property | Glass |
|---|---|
| Diameter | 8-15µm |
| Specific gravity | 2.68 |

## 4.0 Methodology:

Collection of raw materials was done after preparing of Mix Proportion has been arrived and charted in Table 3. By the literature study it was concluded that volume fraction of 1.0% will achieve good strength and the molarity M10 of produce good workability in fresh concrete and the reliable on strength. Totally 3 no's of cylinders for Steel fibre Geopolymer concrete and 3 no's of cylinders for Glass fibre Geopolymer concrete were casted shown in Fig.3. From that the stress strain analysis had been done for the optimized load was shown in Fig.4. Finally the analytical model has been worked out by ANSYS V12.0 software using the Young's Modulus arrived from the Cylinder test.

**Table 3 Mix Proportion**

| | |
|---|---|
| Cylinder dimension (nos.3) | 0.3m x 0.15m |
| Fly ash | 5.8kg |
| GGBS | 0.63kg |
| Fine aggregate | 8.88kg |
| Coarse aggregate | 20.67kg |
| Water(10%) | 631ml |
| Superplasticizer(3%GGBS+Fly ash) | 190ml |
| Sodium hydroxide(NaoH) | 241gms |
| Sodium silicate($Na_2Sio_3$) | 3626.9 gms |
| Glass fibre and steel fibre in same proportion(1%) | 97gms |

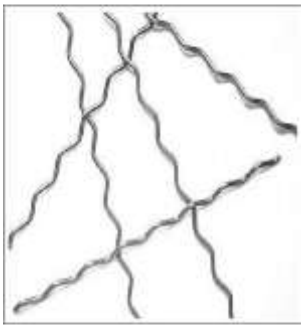


**Fig. 1 Steel Fibre** **Fig.2 Glass Fibre** **Fig. 3 Specimens** **Fig.4 Testing**

## 5.0 Result:

**Table 4 Steel Fibre Reinforced Geopolymer Concrete**

| S.No | Deform Ation | Length | Area | Load | SFGPC | | Load | GFGPC | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Strain | Stress KN/m$^2$ | | Strain | Stress KN/m$^2$ |
| 1 | 0 | 300 | 0.018 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0.01 | 300 | 0.018 | 20 | 3.33E-05 | 1111.11 | 30 | 3.33E+5 | 1666.67 |
| 3 | 0.02 | 300 | 0.018 | 30 | 6.67E-05 | 1666.67 | 40 | 6.67E+5 | 2222.22 |
| 4 | 0.03 | 300 | 0.018 | 55 | 0.0001 | 3055.56 | 50 | 0.0001 | 2777.78 |
| 5 | 0.04 | 300 | 0.018 | 70 | 0.00013 | 3888.89 | 70 | 0.000133 | 3888.89 |
| 6 | 0.05 | 300 | 0.018 | 90 | 0.00017 | 5000 | 80 | 0.000167 | 4444.44 |
| 7 | 0.06 | 300 | 0.018 | 110 | 0.0002 | 6111.11 | 90 | 0.0002 | 5000 |
| 8 | 0.07 | 300 | 0.018 | 130 | 0.00023 | 7222.22 | 100 | 0.000233 | 5555.56 |
| 9 | 0.08 | 300 | 0.018 | 150 | 0.00027 | 8333.33 | 105 | 0.000267 | 5833.33 |
| 10 | 0.09 | 300 | 0.018 | 165 | 0.0003 | 9166.67 | 115 | 0.0003 | 6388.89 |
| 11 | 0.1 | 300 | 0.018 | 190 | 0.00033 | 10555.6 | 140 | 0.000333 | 7777.78 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 12 | 0.11 | 300 | 0.018 | 210 | 0.00037 | 11666.7 | 140 | 0.000367 | 7777.78 |
| 13 | 0.12 | 300 | 0.018 | 235 | 0.0004 | 13055.6 | 150 | 0.0004 | 8333.33 |
| 14 | 0.13 | 300 | 0.018 | 250 | 0.00043 | 13888.9 | 155 | 0.000433 | 8611.11 |
| 15 | 0.14 | 300 | 0.018 | 275 | 0.00047 | 15277.8 | 170 | 0.000467 | 9444.44 |
| 16 | 0.15 | 300 | 0.018 | 335 | 0.0005 | 18611.1 | 180 | 0.0005 | 10000 |
| 17 | 0.16 | 300 | 0.018 | 390 | 0.00053 | 21666.7 | 190 | 0.00053 | 10555.6 |

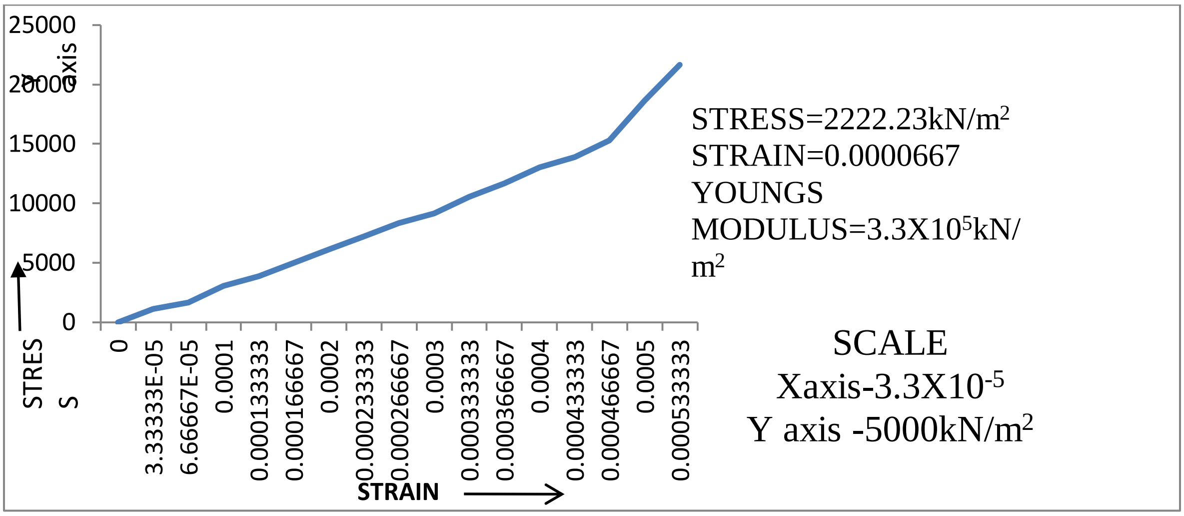


**Fig. 5 Stress-Strain Curve for Steel Fibre Reinforced Geopolymer Concrete**

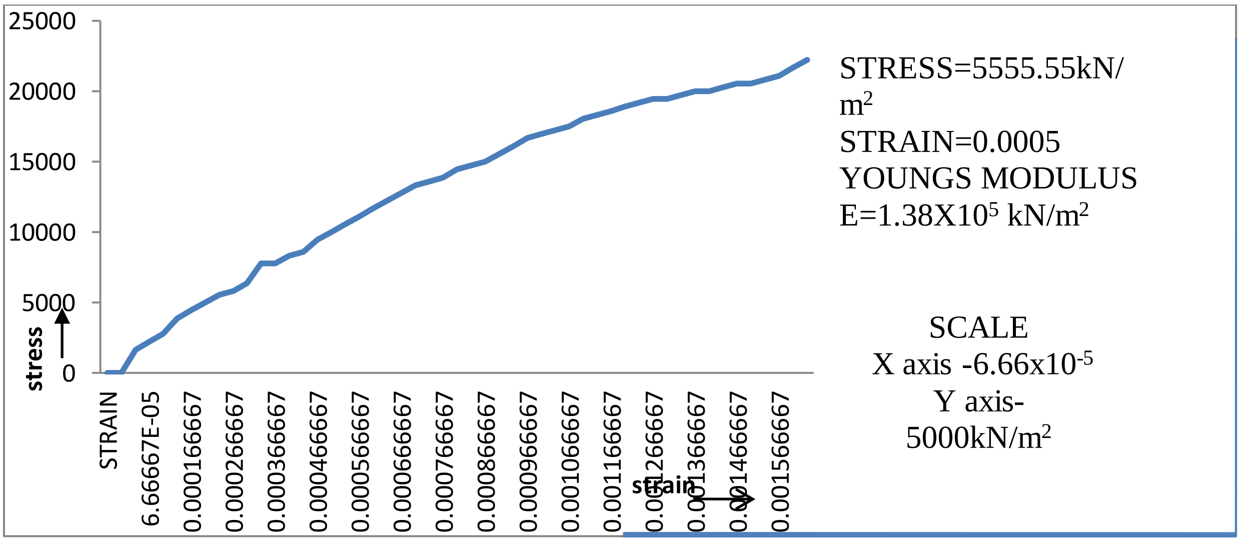


**Fig.6 Stress-Strain Curve for Glass Fibre Reinforced Concrete**

**Table 5 Modulus of Elasticity**

| S.No | Type Of Concrete | Modulus of Elasticity(E) |
|---|---|---|
| 1 | Steel fibre reinforced geopolymer concrete | $3.3\times10^5$KN /m$^2$ |
| 2 | Glass fibre reinforced geopolymer concrete | $1.38\times10^5$KN /m$^2$ |

**Finete Element Analysis**

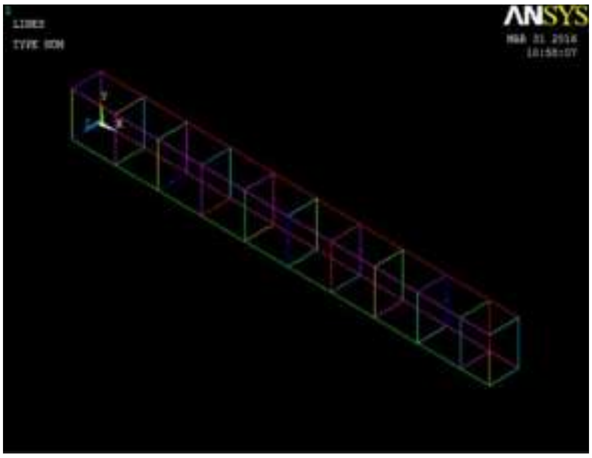


**Fig.7Reinforcement detailing of fibre reinforced geopolymer concrete**

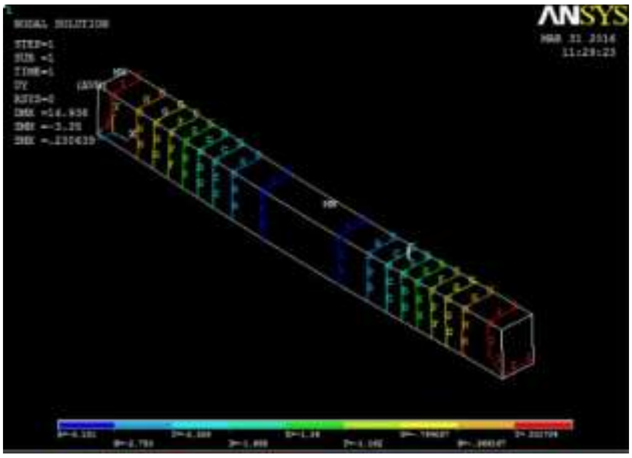


**Fig.8 Analysis report of steel fibre reinforced geopolymer concrete**

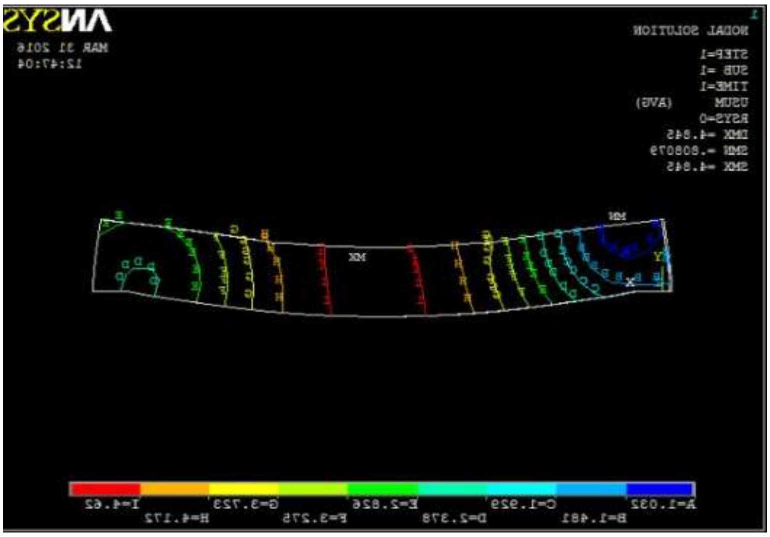

**Fig.9Analysis report of glass fibre reinforced geopolymer concrete**

**Table 6 Deformation observed**

| Specimen Description | Deformation in Experimental | Deformation in Analytical |
|---|---|---|
| Glass fibre reinforced geopolymer concrete | 0.49 mm | 14.936 mm |
| Steel fibre reinforced geopolymer concrete | 0.16 mm | 4.845 mm |

## 6.0 Conclusion

The conclusions drawn from experimental and analytical study

- During casting work there is no segregation or bleeding of concrete.
- The modulus of elasticity of steel fibre reinforced geopolymer concrete 58.18% higher than the glass fibre reinforced geopolymer concrete.
- The steel fibre reinforced geopolymer concrete shows 67.56% variation in deformation than glass fibre reinforced geopolymer concrete.

- From the percentage variation of modulus of elasticity and deformation steel fibre reinforced geopolymer concrete if found to have high strength.
- Steel fibre reinforced geopolymer concrete shows less crack propagation than the glass fibre reinforced geopolymer concrete.
- The comparative result gives 21% difference for experimental and ANSYS 12.0.

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