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# AN EXPERIMENTAL INVESIGATION ON THE MECHANICAL PROPERTIES OF GEOPOLYMER CONCRETE WITH GLASS FIBRES

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**Abstract**— *Geopolymer concrete is a concrete with a non organic alumina-silicate binder system corresponding to the hydrated calcium silicate binder system of concrete. It acquires the advantage of rapid strength gain, worthy mechanical and durability properties, averted water curing. In addition to these aspects they are eco-friendly and competent of being sustained substitute to the ordinary Portland cement but it exhibits the failure nature homologous to brittle solids. This restriction may be overcome by fibre reinforcement to intensify their flexural strength. This paper determining the experimental examination conducted on mechanical properties of geopolymer concrete (GPC) and ordinary Portland cement concrete (OPCC). A total of twelve mixes were cast, in which six mixes were of GPC and six mixes were of OPCC with varying percentages of glass fibres from 0,0.5,1,1.5,2 and 2.5 by weigh fraction of binder. The present paper illustrates the relative study on the mechanical properties of OPCC and GPC accompanied with glass fibres.*

***Keywords*** — *Glass fibres, compressive strength, split tensile strength, flexural strength, GPC and OPCC.*

## I. INTRODUCTION

Concrete is one of the most extensively used construction material it is mostly accompanied with Portland cement as the predominant constituent for producing concrete, OPCC is traditionally used as the leading binder to produce concrete. However, Portland cements are highly internal-energy-demanding and cause the giving off of green house gas, $CO_2$ during their production. Cement production is also highly energy- demanding next to steel and aluminium. On the other hand, coal burning power generation plants generate massive quantities of fly ash. Most of the fly ash is not completely used, and a large part of it is disposed in landfills which affects aquifers and surface bodies of fresh water. In order to address environmental the effects there is a demand for development of substitute concretes. In such case, geopolymer concrete (GPCs) can be considered as potential substitute material for conventional concrete.

**B. Vijaya Rangan et al** investigated on reinforced geopolymer concrete beams and columns and concluded that the behaviour of these members are similar to the reinforced conventional cement concrete and also showed better acid resistance, sulphate attack, suffers very diminutive drying shrinkage and undergoes small creep[1]. **Mohd Mustafa Al Bakri Abdullah et al** gave a review on chemical reaction and mechanism of flyash based geopolymer concrete and he named binders as alkali-activated binders instead of geopolymer, and most of the authors accord that mechanism comprises in 3 sequential manners such as orientation, hardening and dissolution[2]. **Aanal Shah**, was conducted a research on the effect of flyash on replacement of GGBS up to 50% on strength properties and durability of the concrete. And he also concluded that on replacement of GGBS up to 30% in flyash gave the finest results[3].**James Aldred** did a research on GPC and concluded that it has heat of hydration,, shrinkage and high tensile strength this leads to have more technical benefits than conventional concrete, specially in structural elements subjected to external constraints[4]. **Kim Hung mo** did a review on beams, columns and slabs using geopolymer concrete and then he concluded that using using geopolymer concrete in beams and columns there is no detrimental effect on structural memebers and also he says standard code should be used to safely design the beams and columns, as the behaviour and failure mode on structural members are similar to conventional concrete [5]. **Faiz U.A. Shaikhhad** did a research on inducing chloride to both OPC(Ordinary Portland Cement Conrete)) & GPC(Geo Polymer Concrete) specimens. In case of GPC with varying concentrations of NaoH of molarity 14 and 16, with the ratio ( 2.5,3,3.5) of sodium silicate to sodium hydroxide. At first the specimens are placed in Sodium chloride salt solution for 4days and then the specimens are shifted to ambient temperature for 3days, it was a part of dry cycle and then did half cell potential method as per ASTM C-876. He made a conclusion that by increasing the concentration of NaoH and Na2Sio3, the performance of GPC is better than OPC and also GPC specimens are excelling corrosion resistance than OPC specimens [6]. **P. Nath et al** has investigated on eight GPC mixes with varying percentages of flyash and GGBS, varying solution to binder ratio from 0.35 to 0.45 and varying ratios of sodium silicate to sodium hydroxide. He concluded that combination of slag in the flyash based GPC decreases the initial setting time and increases the strength properties of concrete, as the binder ratio increased from 0.35 to 0.45 then the strength of the concrete is decreased and the setting time of concrete is increased[7]. **R. B. Khadiranaikar et al**, investigated on reinforced geopolymer concrete with the strength of concrete M50, M40 and M30, 12 molarity of NaoH solution, 2.5 ratio of sodium silicate to sodium hydroxide. He concluded that the load deflection of beams in GPC and OPC are similar, provisions made in the code IS: 456-2000 has a better accord with the geopolymer concrete[8].**Y. D. Deore et al** did investigation on the fractured behaviour of GPC(geo polymer concrete) based on compressive strength, and he concluded that by adding carbon fibers and glass fiber, the workability of the concrete reduces. And also he concluded that by using glass fibres gives high strength in cracking propagation compared to carbon fibres[9]. **Shrikant**

 

**Harle et al** did research by adding glass fibres to conventional concrete and geo polymer concrete and he concluded that split tensile strength has more in conventional than GPC, flexural strength has more in geo polymer concrete than conventional concrete[10].

## II. EXPERIMENTAL PROGRAMME

The aim of the present experimental investigations is to study the effect of glass fibres on the compressive strength, split tensile strength and flexural strength of ordinary Portland cement concrete and geopolymer concrete with varying percentages of glass fibres such as 0, 0.5, 1, 1.5,2 and 2.5 with compressive strength of 25 MPa. The experimental programme involves of procuring of materials, testing of materials, casting of specimens and testing of specimens.

### *2.1 Materials used:*

#### *2.1.1Fly Ash*

Fly ash is a by-product from pulverized coal in electric power generating plants. For the present work fly ash used was confirming to class F, obtained from Rayalaseema thermal power plant (RTPP), kadapa, Andhra Pradesh.

#### *2.1.2 Ground granulated blast slag (GGBS)*

Ground Granulated Blast Furnace slag (GGBS) is the granular material shaped when liquid iron blast furnace slag (a by-result of iron and steel making) is quickly chilled (extinguished) by inundation in water. For the present investigation GGBS was obtained from JSW cements Ltd, Bilakalaguduru village, gadivemula mandal, Kurnool district, Andhra Pradesh.

#### *2.1.3 Alkaline liquid:*

In the present research work we used sodium silicate and sodium hydroxide solutions. Sodium silicate which was available in the local market as a liquid gel and it is used 2.5 times of NaoH, while sodium hydroxide is available as flakes or pellets from the local market, these pellets are dissolved into water to form sodium hydroxide solution with a concentration of 10M. It consists of 10x40 = 400 grams of sodium hydroxide per liter volume of water, and to reduce the heat the solution was prepared before one day of casting the specimens.

#### *2.1.4 Aggregates:*

In this investigation the coarse aggregate and fine aggregate was used, and the physical properties of aggregates were tested according to IS 2386-1963. The coarse aggregate was used in two sizes viz. 20mm and 10mm of nominal size, these aggregates of different size and crushed angular shape are brought from the local crushing plant and measured the specific gravity of aggregate as 2.76. The fine aggregate was brought from the locally available and it conforming to IS 383-1970 of table 4 of grading zone-II.

#### *2.1.5 Cement:*

In this investigation I used Zurai brand of Ordinary Portland Cement (OPC) was used, which was brought from the locally available market, it was fresh and free from lumps, measured the specific gravity, consistency, fineness and compressive strength of cement was 3.13, 33% , 2% and 54.7mpa respectively.

#### *2.1.6 Glass fibres:*

In the present investigation glass fibres are brought from Buddha building technology, Shree Shashwat, Hatkesh, MiraBhaynder Road, Mira Road (East), Thane, Maharashtra, which has a length of 12mm, diameter is 14 microns, aspect ratio is 857 and tensile strength of glass fiber 1700mpa, and the characterstics of glass fibers are, it achieve high strength, corrosion resistance and good temperature resistance.

 

**Fig 1 – Glass fibres**

### *2.2 Mix Proportions*

#### *2.2.1 Ordinary Portland cement concrete*

The mix proportions for M 25 grade of concrete were obtained in accordance with the IS 10262:2009 guidelines.

**Table 2.1: Mix Proportions of OPCC**

| Specimen ID | Cement (kg/m$^3$) | Coarse aggregate (kg/m$^3$) | Fine aggregate (kg/m$^3$) | Water (kg/m$^3$) | Glass fibres (kg/m$^3$) (by weight of cement) |
|---|---|---|---|---|---|
| **OPCCG0** | 383.16 | 1174.76 | 686.12 | 191.58 | 0 |
| **OPCCG0.5** | 383.16 | 1174.76 | 686.12 | 191.58 | 1.92 |
| **OPCCG1** | 383.16 | 1174.76 | 686.12 | 191.58 | 3.83 |
| **OPCCG1.5** | 383.16 | 1174.76 | 686.12 | 191.58 | 5.75 |
| **OPCCG2** | 383.16 | 1174.76 | 686.12 | 191.58 | 7.66 |
| **OPCCG2.5** | 383.16 | 1174.76 | 686.12 | 191.58 | 9.58 |

#### *2.2.2 Geopolymer concrete*

For the purpose of mix proportioning the following were considered:

- The density of geopolymer concrete as 2400 kg/m$^3$.
- The mass of coarse aggregate and fine aggregate together are taken as 75% of entire concrete by mass.
- The mass of fine aggregate is taken as 30% of the total aggregates.

Design procedure of M 25 grade GPC:
1. Density of GPC =2400 kg/m$^3$
2. Mass of combined aggregate =0.75*2400 =1800 kg/m$^3$
3. Mass of alkaline liquid and binder =2400-1800=600 kg/m$^3$
4. The ratio of alkaline liquid to binder ratio =0.45
5. Mass of binder = 600/(1+0.45) =413.79 kg/m$^3$
6. Mass of Fly ash (70%) =0.70*413.79 = 289.66 kg/m$^3$
7. Mass of GGBS (30%) =0.30*413.79 = 124.14 kg/m$^3$
8. Mass of Alkaline liquid = 600-413.79 = 186.21 kg/m$^3$
9. Let the ratio of Sodium silicate solution to Sodium hydroxide solution =2.5
10. Mass of Sodium hydroxide solution = 186.21/(1+2.5) = 53.2 kg/m3
11. Mass of Sodium silicate solution = 186.21-53.2 = 133.01 kg/m$^3$

**Table 2.2: Mix Proportions of GPC**

| **Specimen ID** | **Fly ash (kg/m$^3$)** | **GGBS (kg/m3)** | **NaOH Solution (kg/m$^3$)** | **$Na_2SiO_3$ Solution (kg/m$^3$)** | **Coarse aggregate (kg/m$^3$)** | | **Fine aggregate (kg/m$^3$)** | **Glass fibres (kg/m$^3$)** |
|---|---|---|---|---|---|---|---|---|
| | | | | | **10mm** | **20mm** | | |
| **GPCG0** | 289.6 | 124.1 | 53.2 | 133.01 | 882 | 378 | 540 | 0 |
| **GPCG0.5** | 289.6 | 124.1 | 53.2 | 133.01 | 882 | 378 | 540 | 2.07 |
| **GPCG1** | 289.6 | 124.1 | 53.2 | 133.01 | 882 | 378 | 540 | 4.14 |
| **GPCG1.5** | 289.6 | 124.1 | 53.2 | 133.01 | 882 | 378 | 540 | 6.21 |
| **GPCG2** | 289.6 | 124.1 | 53.2 | 133.01 | 882 | 378 | 540 | 8.27 |
| **GPCG2.5** | 289.6 | 124.1 | 53.2 | 133.01 | 882 | 378 | 540 | 10.34 |

***2.3 Casting:***

For casting the test specimens, standard size of cubes (150 × 150 × 150 mm),beams (100 × 100 × 500) mm and cylinders (150 mm × 300 mm) made with cast iron moulds were used. The moulds (cubes, cylinder and beams) were cleaned to get rid of the dust particles and mineral oil was applied to all sides of the mould before concrete is poured into the mould. Thoroughly mixed concrete is filled into the mould in three layers of equal height followed by compaction, the left over part on the moulds are removed with trowel and top surface is levelled and smoothened.

***2.4 Curing:***

After 24 hours of casting, specimens are demoulded and kept in curing tank for 28days in case of a ordinaty Portland cement concrete. Whereas in case of a geopolymer concrete specimens are placed at ambient curing.

## III. RESULTS AND DISCUSSIONS

In this chapter, we are discussing about strength properties of concrete such as Compressive strength, Split tensile strength and Flexural strength of various concrete mixes with addition of glass fibers of varying percentages viz. 0,0.5,1,1.5,2 and 2.5 by weigh fraction of binder.

***3.1Compressive Strength of concrete:***

Compressive strength of M 25 grade of ordinary Portland cement concrete and geopolymer concrete were studied with varying percentages of glass fibres such as 0, 0.5, 1, 1.5,2 and 2.5.

**Table 3.1-Compressive strength of OPCC and GPC with Glass fibres**

| Mix Designation | Compressive strength ($N/mm^2$) | % increase in strength compare to mix of 0% glass fibres |
|---|---|---|
| OPCG0 | 31.3 | - |
| OPCG0.5 | 35.7 | 14.05 |
| OPCG1 | 37.9 | 21.08 |
| OPCG1.5 | 40.2 | 28.43 |
| OPCG2 | **42.8** | 36.74 |
| OPCG2.5 | 40.6 | 29.71 |
| GPCG0 | 34.6 | - |
| GPCG0.5 | 41.3 | 19.36 |
| GPCG1 | 46.3 | 33.81 |
| GPCG1.5 | 48.2 | 39.30 |
| GPCG2 | 49.7 | 43.64 |
| GPCG2.5 | **51.7** | 49.42 |

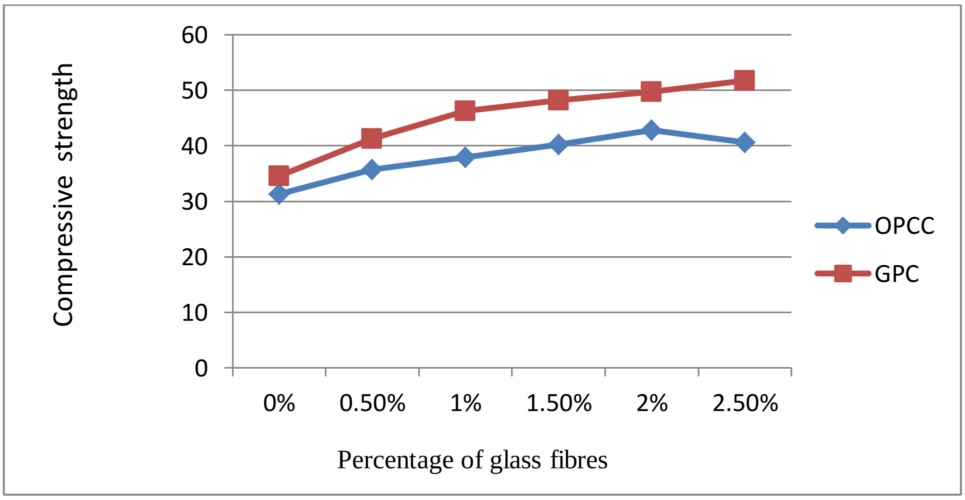


**Fig 3.1 Variation of compressive strength of ordinary Portland cement concrete and geopolymer concrete with glass fibres**

It was observed that compressive strength was increased up to 2 % of glass fibres in case of a ordinary Portland cement concrete and 2.5% of glass fibres in case of geo polymer concrete, the compressive strength achieved for 2% of glass fibers was 42.8 N/mm2 to the OPCG2 mix and 36.74% more compared with OPCGO mix. The maximum strength achieved for 2.5% of glass fibres was 51.7 N/mm2 to the GPCG2.5 mix and 49.42% more compared with GPCGO mix.

***3.2Tensile strength of concrete***

Split tensile strength of M 25 grade of ordinary portland cement concrete and geopolymer concrete were studied with varying percentages of glass fibres such as 0, 0.5, 1, 1.5,2 and 2.5.

**Table 3.2-Split tensile strength of OPCC and GPC with Glass fibres**

| Mix Designation | Split tensile strength ($N/mm^2$) | % increase in strength compare to mix of 0% glass fibres |
|---|---|---|
| OPCG0 | 3.04 | - |
| OPCG0.5 | 3.64 | 19.73 |
| OPCG1 | 3.86 | 26.97 |
| OPCG1.5 | 4.31 | 41.77 |
| OPCG2 | **4.85** | 59.53 |

| | | |
|---|---|---|
| OPCG2.5 | 4.42 | 45.39 |
| GPCG0 | 3.54 | - |
| GPCG0.5 | 4.03 | 13.84 |
| GPCG1 | 4.50 | 27.11 |
| GPCG1.5 | 4.85 | 37.00 |
| GPCG2 | 5.02 | 41.80 |
| GPCG2.5 | **5.38** | 51.97 |

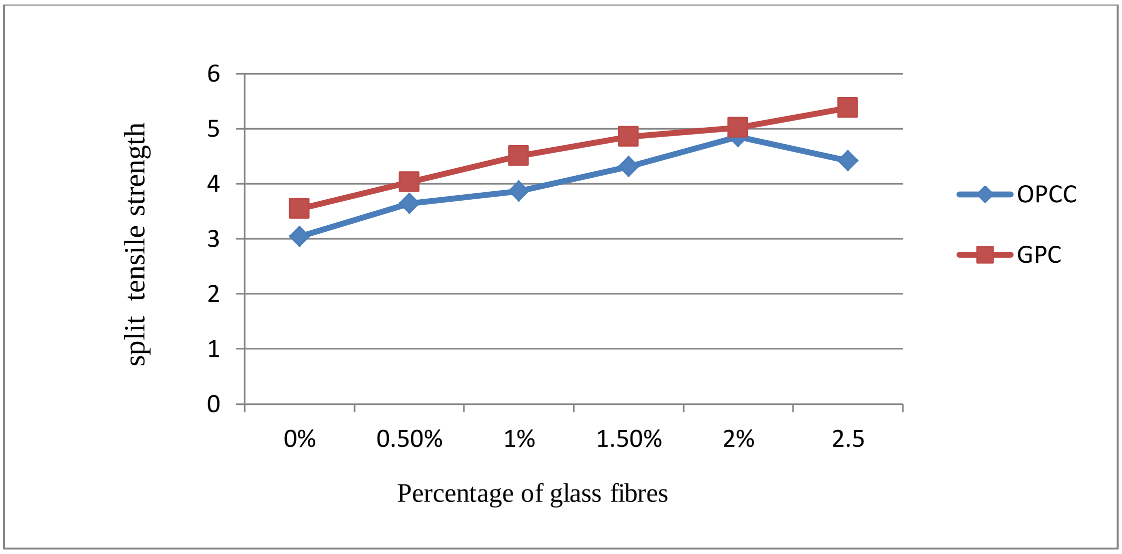


**Fig 3.2 Variation of split tensile strength of ordinary portland cement concrete (OPCC) and geopolymer concrete (GPC) with glass fibres**

It was observed that split tensile strength was increased up to 2 % of glass fibres in case of a ordinary portland cement concrete and 2.5% of glass fibres in case of geo polymer concrete, the split tensile strength achieved for 2% of glass fibers was 4.85 N/mm2 to the OPCG2 mix and 59.33% more compared with OPCGO mix. The maximum tensile strength achieved for 2.5% of glass fibers was 5.38 N/mm2 to the GPCG2.5 mix and 51.97% more compared with GPCGO mix.

***3.3Flexural strength of concrete***

Flexural strength of M 25 grade of ordinary portland cement concrete and geopolymer concrete were studied with varying percentages of glass fibres such as 0, 0.5, 1, 1.5,2 and 2.5.

**Table 4.3-Flexural strength of OPC and GPC with Glass fibres**

| **Mix Designation** | **Flexural strength ($N/mm^2$)** | **% increase in strength compare to mix of 0% glass fibres** |
|---|---|---|
| OPCG0 | 3.79 | - |
| OPCG0.5 | 4.08 | 7.65 |
| OPCG1 | 4.25 | 12.13 |
| OPCG1.5 | 4.37 | 15.30 |
| OPCG2 | **4.45** | 17.41 |
| OPCG2.5 | 4.36 | 15.03 |
| GPCG0 | 4.34 | - |
| GPCG0.5 | 5.22 | 20.27 |
| GPCG1 | 5.81 | 33.87 |
| GPCG1.5 | 6.06 | 39.63 |
| GPCG2 | 6.22 | 43.31 |
| GPCG2.5 | **7.32** | 68.66 |

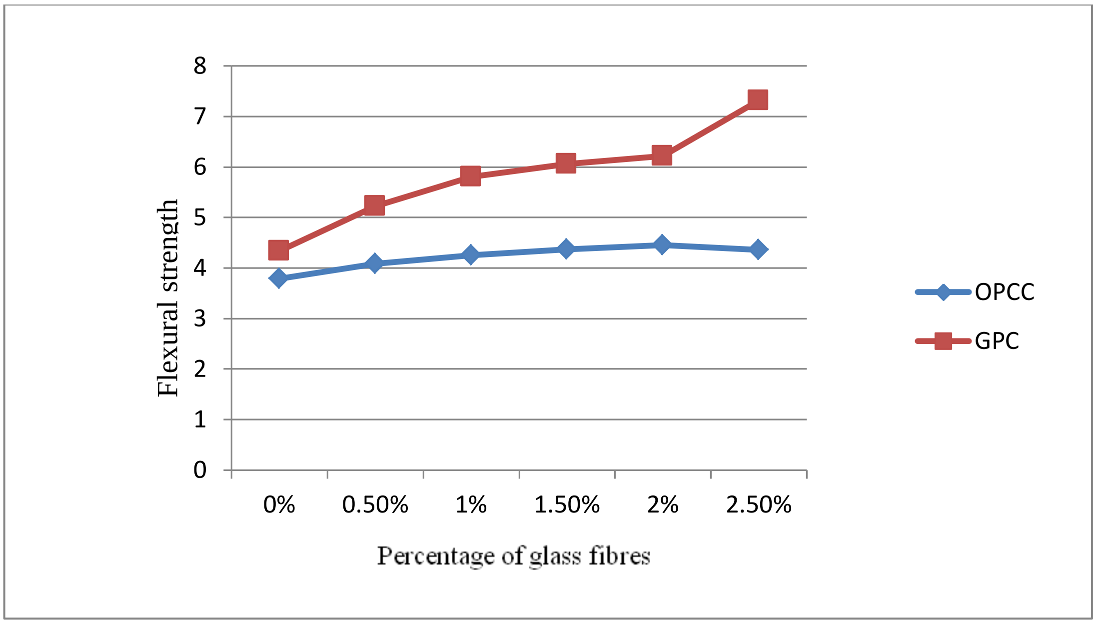


**Fig 3.3 Variation of Flexural strength of ordinary portland cement concrete and geopolymer concrete with glass fibres**

It was observed that Flexural strength was increased up to 2 % of glass fibres in case of a ordinary portland cement concrete and 2.5 % of glass fibres in case of a Geopolymer concrete. The optimum flexural strength obtained for 2% of glass fiber was 4.45 $N/mm^2$ to the OPCG2 mix and 17.41% more compared to that of OPCGO mix. The maximum strength obtained for 2.5% of glass fibres was 7.32 $N/mm^2$ to the GPCG2.5 mix and 68.66% more compared to that of GPCGO mix.

## IV.CONCLUSIONS

Based on the experimental investigations carried on the mechanical properties of ordinary portland cement concrete and geopolymer concrete with glass fibres the following conclusions are drawn.

- The compressive strength of concrete is increased by 36.74% and 49.42% in case of a ordinary portland cement concrete and geopolymer concrete at 2% and 2.5% of glass fibres respectively when compared to the corresponding mixes with 0% glass fibres.
- The split tensile strength of concrete is increased by 59.53% and 51.97% in case of a ordinary portland cement concrete and geopolymer concrete at 2% and 2.5% of glass fibres respectively when compared to the corresponding mixes with 0% glass fibres.
- The flexural strength of concrete is increased by 17.41% and 68.66% in case of a ordinary portland cement concrete and geopolymer concrete at 2% and 2.5% of glass fibres respectively.
- Geopolymer technology does not only contribute to the minimization of greenhouse gas emissions but also reduces disposal costs of industrial waste.
- Geopolymer technology encourages the recycling of waste and surely it will be an paramount footprint towards viable concrete industry.

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