# Impact Resistance of Geopolymer Concrete With GFRP Rebar

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**Abstract –** This study experimentally investigates the impact response of ambient cured GPC beams reinforced with steel and Glass fibre reinforced polymer (GFRP) bars. For this purpose, two different beams were studied. GPC beam reinforced steel bars and GPC beam reinforced with glass-fiber reinforced polymer (GFRP) bars with steel ratio of 0.83%. All the beams were subjected to impact load test and analysis is carried out under a drop weight of 10Kg.According to the results, the ultimate load deflection varied from 9-10%. According to experimental results, for GPC beam reinforced with GFRP bars had ultimate load deflection of 30% and 10% ultimate load deflection was obtained for the GPC beam reinforced with steel bars. When the results were compared, the total deflection of a GPC beam reinforced with both steel and GFRP bars is reduced by 20%. Both analytical and experimental methods have produced successful outcomes.

**Key Words** - ultimate load deflection, Geopolymer concrete (GPC), Glass fiber reinforced polymer (GFRP) bars, ANSYS 2020

## I. INTRODUCTION

Regular The engineering and construction sectors have paid substantial attention to geopolymer, an innovative and ecologically friendly substance. In contrast to conventional cement-based materials, geopolymer is created by a chemical reaction between an aluminosilicate source and an alkaline activator, producing a long-lasting and high-strength substance. In comparison to OPC, GPC emits 64% less carbon dioxide during the course of manufacture. These two separate materials, Geopolymer Concrete (GPC) and Ordinary Portland Cement (OPC), each have their own properties and manufacturing techniques. Cement produces large carbon dioxide emissions from this process also add to environmental worries. While GPC uses silica and alumina-rich natural resources or industrial waste products that have been activated by alkaline solutions, it is a more environmentally friendly option. GPC used at higher temperature and hence an attempt is made to cure GPC beam at ambient temperature by using nano silica. GPC have an advantages of Reduced carbon footprint, Greater strength and durability, water conservation and improved workability, utilization of industrial by-products and fire resistance. Nano silica has made a significant breakthrough in the field of civil engineering by enhancing the performance of cement and concrete-based composites and ushering in a new age of design for construction materials. which has particle sizes ranging from 1 to 100 nanometers. The properties of nano silica are Improved mechanical properties, enhanced durability, cost, greater flexural and compressive strength and reduced cracking and shrinkage. In structural engineering and construction, two materials that are often utilized are steel and fiber-reinforced polymer (FRP). Steel is a conventional material that has been widely used in many applications because of its strong strength and durability. Steel is nonetheless prone to corrosion, particularly in harsh settings, which need routine maintenance and might raise lifespan costs. FRP composites are made of high-strength fibers, such carbon, glass, or aramid, inserted in a polymer matrix. FRP is ideal for a variety of applications, notably in maritime and corrosive conditions because to its outstanding strength-to-weight ratio and corrosion resistance. It is simpler to transport and construct FRP structures since they frequently weigh less than steel and don't need anti-corrosion coatings. FRP may also be customized to meet unique needs and has great fatigue resistance.

## II. METHODOLOGY

*1. Description of Beams*

A total of two GPC beams with steel reinforced and GFRP rebar were designed with the following configuration: width (b) of 230 mm, depth (D) of 300 mm and length (L) of 1200 mm. Two 10-mm diameter GFRP bars corresponding to reinforcement ratio $\rho f = 0.83\%$ were employed with two 10 mm diameter at the top and three 12 mm diameter at bottom.

*2. Properties of beams*

### Material properties

In this investigation ordinary Portland cement concrete (OPCC) and nano silica based geopolymer concrete (GPC) were used. The GPC mix was composed of fine and coarse aggregate, Commercial grade-Class-F Fly ash, nano silica, 12M sodium hydroxide (NaoH), sodium silicate ($Na_2Sio_3$) is used in the work. The material properties were studied and satisfied as per codal provisions. The mix design for the M25 grade for GPC is shown in below Table 1. The mechanical properties of GPC for 28 days are shown in [Table 2]. GFRP bars and steel bars are used in the study. GFRP bar is manufactured by E-glass impregnated in vinyl ester resin. The nominal diameter of the GFRP bars and steel bars that are employed are 10 and 12 mm respectively and 8mm dia steel stirrups are used. The manufacturer provided information about the GFRP bars characteristics

**Table 1.** Mix design of GPC and OPCC.

| Mix proportion for GPC | | | | | | |
|---|---|---|---|---|---|---|
| Particular | Fly ash | Nano silica | FA | CA | NaoH | $Na_2Sio_3$ |
| $Kg/m^3$ | 468.18 | 11.92 | 628.193 | 1166.65 | 65.158 | 162.895 |

**Table 2.** Properties of GPC

| Concrete type | fc | ft | E | ff |
|---|---|---|---|---|
| GPC ($N/mm^2$) | 33.72 | 3.61 | 19523.8 | 5.12 |

*3. Experimental investigation*

The beams measuring 1200mm in length, 300mm in depth, and 230mm in breadth. GPC beam reinforced with Steel bars and GPC beam reinforced with GFRP bars are studied with reinforcement ratio of 0.83% which is under reinforced section and details are shown in Table 3.

Table 3. Tested beam details

| Specimen | Type of concrete | Type of reinforcement bar | Top bar dia (mm) | Bottom bar dia (mm) | Reinforcement Section | Reinforcement Ratio (%) |
|---|---|---|---|---|---|---|
| GEO_SR | GPC | Steel | 2#10 | 3#12 | Under reinforced | 0.83 |
| GEO_GR | GPC | GFRP | 2#10 | 3#12 | Under reinforced | 0.83 |

**Experimental setup**

After 28 days of curing at ambient temperature, all of the beams are subjected to impact loading until the failure of the beam. A loading pattern was setup as showed in the figure 1. A load is set on the beam using a simple support system. The drop weight of 10kg is dropped at the mid span of the beam from the height of 1.25m. The test beam is kept on the two simple supports by leaving 50mm on either side of the specimen's ends. 1100mm is divided equally which measures 550mm at each side. The drop weight is measured has no of blows by knowing the blows the first crack and the crush of the specimen is calculated. After noting the blows, the deflection of the beam is calculated by using the formula Ϭ=(mg)$L^3$/48 EI, I=$bh^3$/12 $mm^4$ = 517.5x$10^6$ $mm^4$, Velocity (v) = sqrt of 2gh m/s = 4.952 m/s. To conduct the test, the set was constructed as illustrated in the Figure 1.

**Figure 1**. Test setup for beams

*4. Analytical investigation using ANSYS 2020 Software*

To examine the dynamic performance of the beam, models in ANSYS 2020 were built using the same dimensions and properties as the actual data. The beam models are detailed in Table 3 and were created using the same configuration as in the experimental work. The beam model is subjected to an impact load as seen in Figure 2. The model is analyzed under impact load and results are extracted.

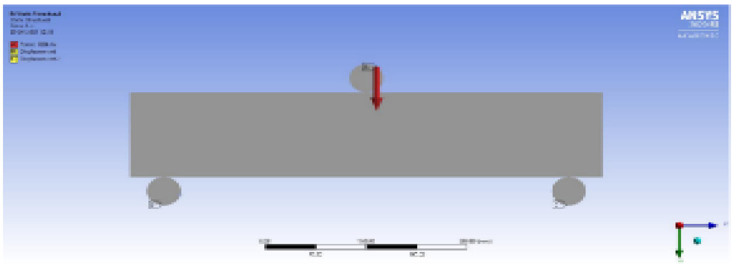

**Fig 2.** Model of beam in Ansys.

## III. RESULTS AND DISCUSSIONS

### Experimental results

It is noticed that, in fig 3 Geo_GR beam have less deflection of 1.26 mm and more load carrying capacity when compared to Geo_SR. Over all, the GPC beams reinforced with GFRP bars i.e., Geo_GR-7 has least deflection with more load carrying capacity. The GFRP bars has greater tensile strength than steel bars and this may be the reason for decreasing the deflection.

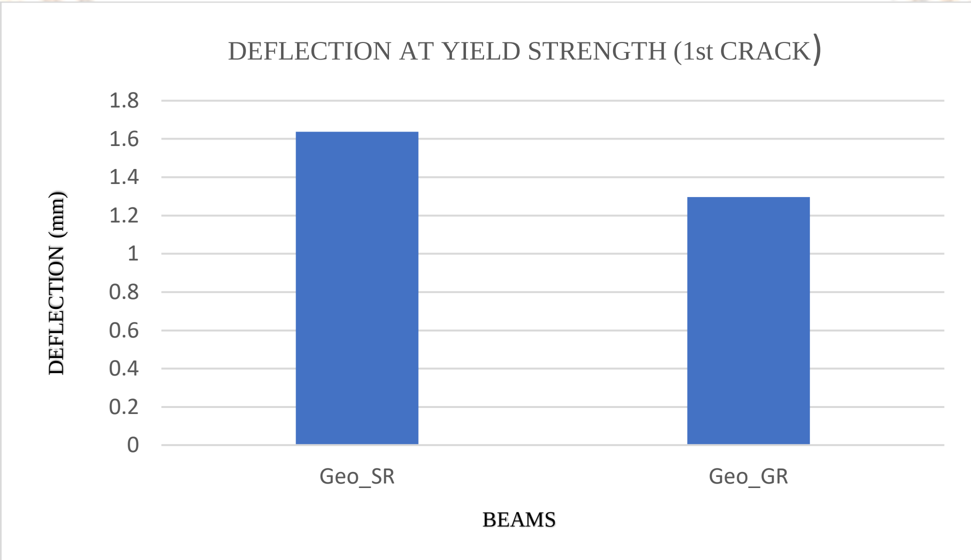


**Fig.3** ***Bar graph representing beam v/s deflection for yield strength***

The same observations were made at ultimate load i.e., Geo_SR had maximum deflection of 2.55 mm when compared to Geo_GR had least deflection of 2.32mm is shown in fig 4.

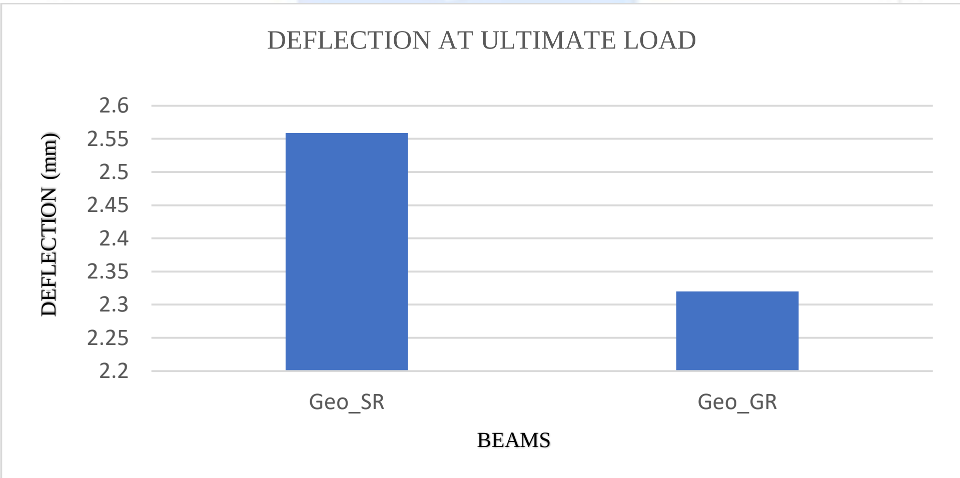


***Fig 4. Bar graph representing beam v/s deflection for ultimate load***

**Analytical results**

A total of two beams sized 1200 mm X 230 mm X 300 mm were reinforced with steel rebar and GFRP rebar are modelled in the Ansys 2020 workbench. The minimum deflection was observed in beam reinforced with GFRP when compared to the beam reinforced with steel rebar. It is noticed that, in fig 5 Geo_GR beam have less deflection of 1.18 mm and more load carrying capacity when compared to Geo_SR had 1.63 mm. Over all, the GPC beams reinforced with GFRP bars i.e., Geo_GR has least deflection with more load carrying capacity. The GFRP bars has greater tensile strength than steel bars and this may be the reason for decreasing the deflection.

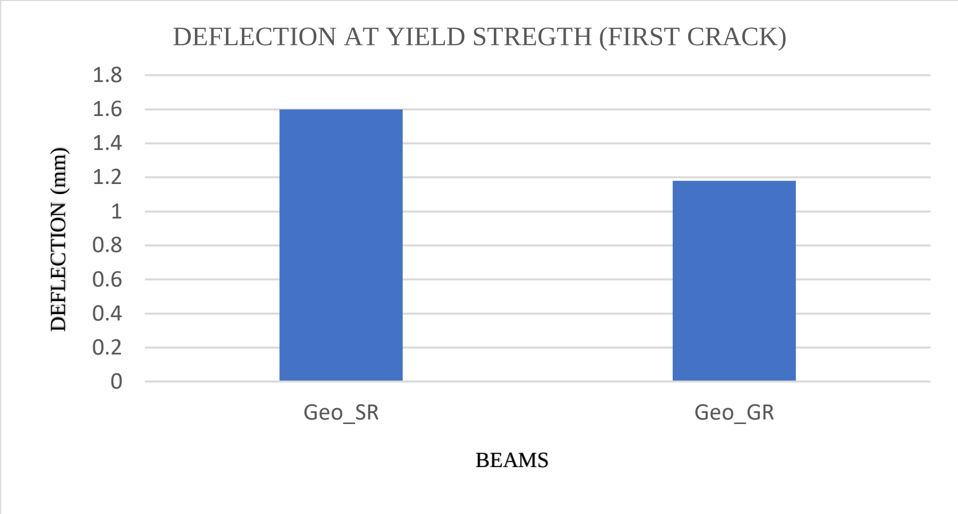


**Fig.5** Bar graph representing beam v/s deflection for yield strength

The same observations were made at ultimate load i.e., Geo_SR-4 had maximum deflection of 1.63 mm at 28 kN when compared to Geo_GR had least deflection of 1.18 mm at 70 kN is shown in Fig 6.

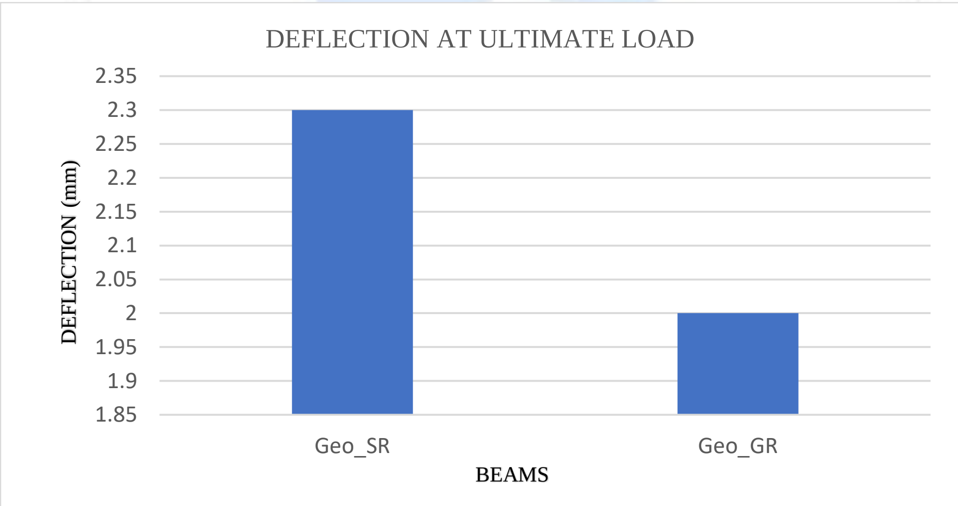


**Fig.6** Bar graph representing beam v/s deflection for ultimate load

**Comparison of experimental and analytical results**

In the beam reinforced with GFRP rebar has total maximum deflection of 2.32 mm and 2.2 mm experimental and analytical analysis respectively. In the beam reinforced with steel rebar has total maximum deflection of 2.59 mm and 2.3 mm experimental and analytical analysis respectively.

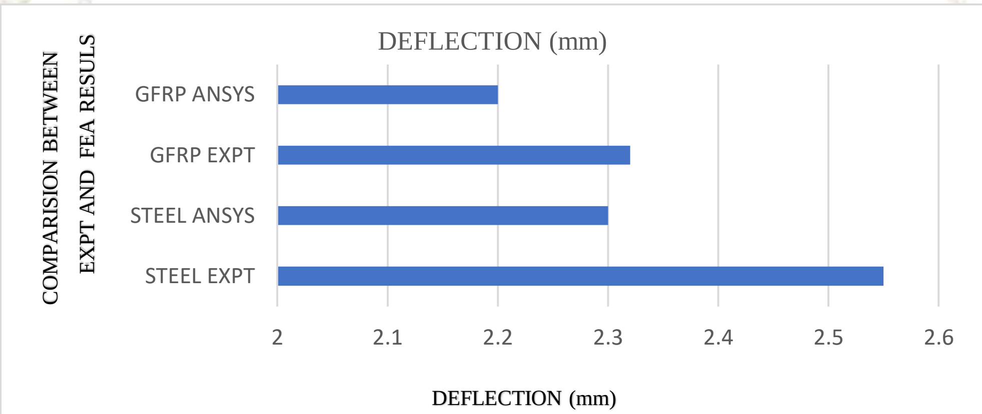


*Fig 7 Graph represents comparison of load and deflection between experimental and analytical results*

## IV. CONCLUSIONS

In the present work, experimental and analytical work is carried out for all the beams. For this research work impact load technique was considered for experimental purpose and for Analytical validation ANSYS 2020 software was utilized. The comparison was made for experimental and analytical work. By Comparing all the beams with steel ratios of 0.83, Ultimate load deflection was found to be increased by 10% for GPC beams with GFRP bars than Geo_SR. The ultimate load deflection of GPC beam reinforced with GFRP bars was found to be increased by 30% and 10% increase was found in GPC beam reinforced with steel bars, the increase was due to the tensile strength of the GFRP bars. The percentage difference between experimental and analytical varied by 9-10% for ultimate load deflection. By comparing both experimental and analytical results, the GPC with GFRP reinforced beam had a good strength when compared to GPC with steel bars.

## V. REFERENCES

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