Flexural and Shear Strengthening Of Geopolymer Concrete Beams With Externally Bonded GFRP Sheet

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***Abstract*—Geopolymer concretes are new category of building materials that have emerged as an alternative to ordinary portland cement concrete. It synthesis from industrial by-products or wastes and posess low energy demand during their production. Fibre Reinforced polymer (FRP) has been widely applied in several functions in civil engineering fields. Especially, FRP sheet is extreamly suitable for strengthening of the prevailing structures, due to its advantages of light weight, high strength, corrosion resistance, and ease to application. This paper presents an experimental investigation on the performance of geopolymer concrete beams strengthened in flexure and shear using GFRP sheets. Test parameters are GFRP sheet orientation and number of layers .The objective of this study is to clarify the role of glass fibre reinforced polymer sheet epoxy bonded to the beam for flexural and shear strengthening of plain geopolymer concrete beams and additionally to study the strengthening effect on ultimate force and load deflection behaviour of the beam. The load carrying capacity of the GFRP strengthened specimens was found to be increased when compared to control beam.**

***Index Terms*— Geopolymer concrete, Fly ash, GFRP, Load carrying capacity, load deflection behavior.**

I. INTRODUCTION

As the construction sector continues its move towards the concept of sustainable development, geopolymer concrete (GPC) can eventually be utilized in many applications as an alternative for ordinary portland cement (OPC) concrete, whose continued use is confronted with environmental and energy intensity problems. To reduce the environmental impact of concrete manufacture, it's been advised that alternatives to OPC requiring the utilization of fewer natural resources and fewer carbon dioxide emitting sources of energy are required. It synthesis from industrial by-products or wastes and possess low energy demand during their production. Geopolymer concretes have received substantial research attention recently, with comprehensive studies being meted out at the material level specializing in quantifying the fresh and hardened material properties and long term durability. There is; but, a comparatively limited number of studies available on the structural behaviour of strengthened geopolymer concrete members. Glass fibre reinforced polymers (GFRP) sheets are being progressively used in rehabilitation and retrofitting of concrete structures as an alternative to steel in concrete because of their high strength-to-weight ratio and corrosion and fatigue resistance and ease of handling and application at site are other benefits.

II. EXPERIMENTAL STUDY

This project work consists of an experimental investigation on the flexural and shear behaviour of plain geopolymer concrete beams strengthened in shear and flexure with GFRP sheet in different configurations. The ultimate load for the specimens is determined using three point bending test in the Flexural Testing Machine (FTM) and the increase in ultimate load is determined with respect to the control specimen to find out the effectiveness of each configuration. Tests were carried out on 100mm x 100mm cross section and 500mm long beams without reinforcement to investigate and compare the results on the load carrying capacity, ultimate load, flexural strength and maximum deflection.

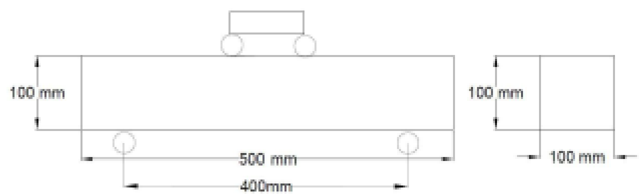

Fig -1: Details of beam specimen

The beam specimens were tested under two-point bending test with load point spacing of 100 mm. The effective span for the beam is taken as 300 mm. The details of specimens are shown in Table 1

Table 1 Specimen Details

Sl no.	Specimen ID	No.of layers	GFRP sheets provided
1	CB	---	None
2	GPC 1	1	1 layer of GFRP - 0^0 orientation
3	GPC 2	1	1 Layer of GFRP - 45^0 orientation
4	GPC 3	2	1 layer of GFRP – 45^0 and 1 layer of GFRP 45^0 in other direction- ‘X’ shape orientation
5	GPC 4	2	1 inner layer of GFRP - 0 Degree and 1 outer layer with 45^0 orientation
6	GPC 5	3	1 inner layer of GFRP -0 ^{0} and 1 outer layer with ‘X’ shape orientation
7	GPC 6	4	2 number of GFRP in ‘X’ shape orientation

III. Preparation Of Alkaline Solution

Locally available silicates and hydroxides of sodium are used to prepare alkaline liquid. Sodium hydroxide pellets were mixed with distilled water and then sodium silicate were added.

Fig -2: Prepared alkaline solution

IV. PREPARATION OF THE SPECIMEN

Steel moulds are used for the casting of beams of size 100 x 100 x 500 mm. Concrete was mixed and placed in the mould in layers and tamped thoroughly. The top surface is levelled and finished. The same procedure continued for all 7 specimens. After 4 days, the specimens were demolded and subjected to heat curing for 7 days and then cured at ambient temperature for remaining 21 days.

V. GLASS FIBER REINFORCED POLYMER WRAPPING AND RESIN SYSTEM

The resin system used in this work was made of two parts namely resin and hardener. The components were thoroughly manually mixed for 5 minutes. The concrete beams were cleaned and completely dried before the resin was applied.

VI.TEST SETUP

The beams loading test under two-point loading were performed in a flexural testing machine with 100 kN capacity. The load was applied at a uniform rate till failure. The beams were loaded at centre at a distance of 167 mm from the support of the beam. The specimens were arranged with simply supported conditions. The load was applied without shock and increasing continuously at a rate such that the extreme fiber stress increases approximately 7 $kg/cm^2/min$. Deflection of the beam was measured using a dial gauge of least count 0.01 mm at end of specimen.

VII.TEST RESULTS

Influence Of Orientation Of GFRP In Single Layer On Beams

The load vs deflection curve for the control beam (CB) and beams strengthened with GFRP (GPC 1 & GPC 2) were shown in Fig. 5.1. From the above study, it is observed that U-wrap strengthening with GFRP fabric in flexural zone of beam GPC 1 gives better results for single layer with 0^0 orientation.

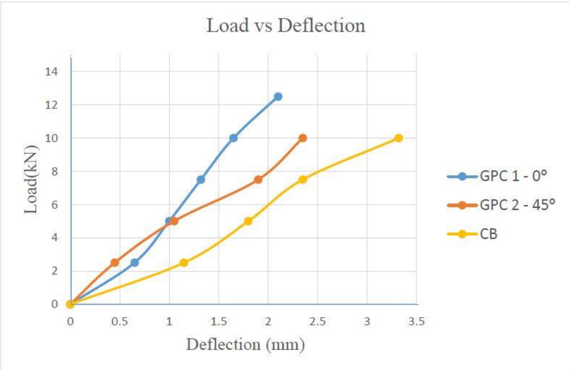

Fig 3: Load vs deflection curve for control beam and beams with different orientation of GFRP sheets

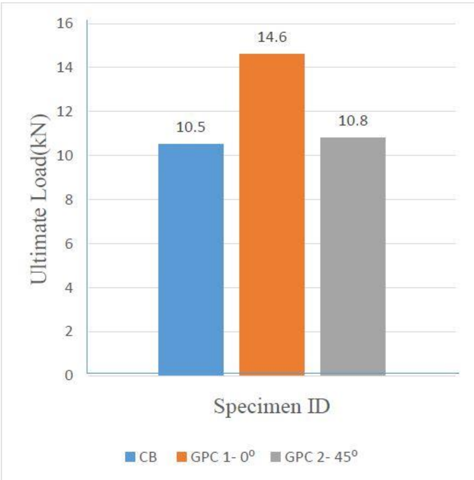

Fig 4: Ultimate load for control beam and beams with different orientation of GFRP sheet

The ultimate load of the specimens bonded with GFRP sheets (GPC 1 & GPC 2) were increased when compared to the control beam (CB). The ultimate load of the specimens bonded with single layer of GFRP sheets with different orientations were increased when compared to the control beam (CB). The ultimate load of the specimens with 0^0 orientation is increased by 39.04% when compared with the control beam. The percentage increase in maximum load carrying capacity of GPC 1 with 0^0 orientation and 45^0 orientation are found to be 39.04% and 2.85% respectively as compared to that of control beam. Similarly the load carrying capacity of GPC 1 with 0^0 orientation, is increased by 35.18% when comparing to GPC 2 with 45^0 orientation.

The ultimate deflection of the beams GPC 1 and GPC 2 were reduced compared to the control beam CB. The ultimate load for the control beam was obtained as 10.5 kN. The value of deflection obtained for beams GPC 1 and GPC 2 for a load of 10.5 kN were reduced in comparison with CB. The deflection of GPC 1 and GPC 2 is reduced by 50.3 and 29.21 % respectively when compared with the control beam specimen.

Influence Of Orientation Of GFRP In Double Layer On Beams

The load vs. deflection curve for the control beam (CB) and beams strengthened with GFRP (GPC 3 & GPC 4) were shown in Fig. 5.3. The ultimate load of the specimens bonded with GFRP sheets (GPC 3 & GPC 4) were increased when compared to the control beam (CB).

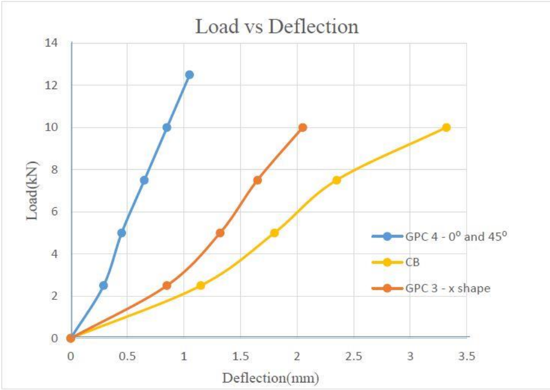

Fig 5 : Load vs deflection curve for control beam and beams with double layers of GFRP sheets

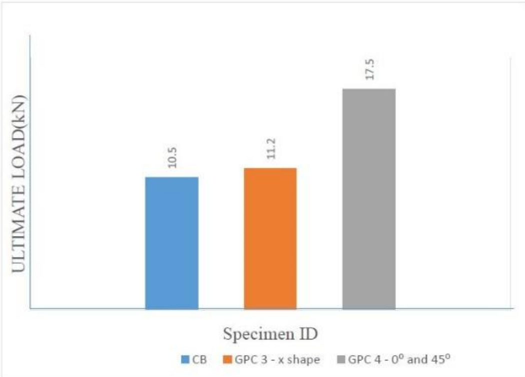

Fig 6: Ultimate load for control beam and beams with double layers of GFRP sheet

The percentage increase in maximum load carrying capacity of GPC 3 and GPC 4 are found to be 6.67% and 66.67%, respectively as compared to that of control beam.The beams strengthened with GFRP sheets have reduced the percentage deformation on comparison with the control specimen. The increase in the number of layers of GFRP also increased the percentage reduction in deformation. The deflection of GPC 3 and GPC 4 is reduced by 38.25 % and 74.39 % respectively when compared with the control beam specimen.

Influence Of Number Of GFRP Layers On Beams

The load-deflection curve for the control beam (CB) and beam strengthened with single layer of GFRP sheet in 0^0 orientation (GPC 1), beam strengthened with double layer of GFRP sheet in combination of 0^0orientation and 45^0orientation (GPC 4), beam with 0^0 and 45^0 in one direction and 45^0 in other direction making an x shape (GPC 5) and two numbers of x shape orientation (GPC 6) were shown in Chart 5.

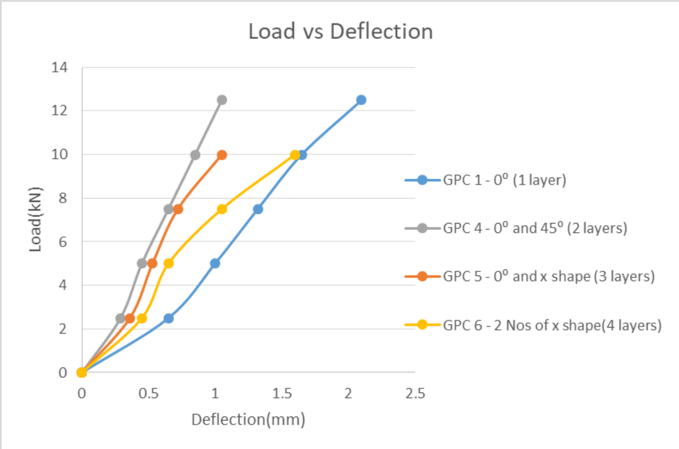

Fig 7: Load vs deflection curve for control beam and beams with varying no. of layers of GFRP (GPC 1), (GPC 4), (GPC 5) and (GPC 6)

Ultimate load for control beam and beams strengthened with single layer of GFRP sheet in 0^0 Orientation (GPC 1), beam strengthened with double layer of GFRP sheet in combination of 0^0 and 45^0 orientation (GPC 4), beam strengthened with 3 layers of GFRP sheet in 0^0 and x shape orientation (GPC 5) and beam strengthened with 4 layers of GFRP sheet in 45^0 in one direction and 45^0 in other direction making an x shape (GPC 6) were shown in **Fig. 8**

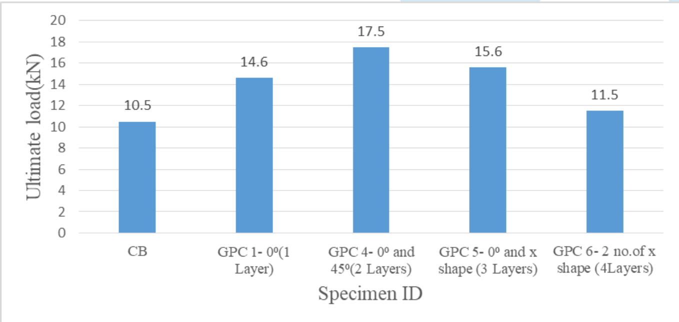

Fig 8: Ultimate load for control beam and beams strengthened with GFRP sheet

VIII. CONCLUSIONS

The following salient conclusions were drawn from the present investigations:

- The flexural and shear performance of GPC beams strengthened with GFRP as external reinforcement was studied based on the ultimate load carrying capacity of the beam and it was found that the load carrying capacity of beams showed an increase of maximum by 39.04% and 66.67% when compared to control beam in single layer and double layer scheme respectively. This shows that this method can enhance the flexural and shear performance of geopolymer concrete beams. In 3 layered and 4 layered condition, the load carrying capacity of beams showed an increase by 47.61% and 9.52% respectively when compared to control beam.
- The utilization of geopolymer as cementitious material provides additional environmental as well as technical benefits.
- In single layer orientation, greatest improvement in strength is attained for 0° orientation, 0°- 45°orientation in double layer strengthening schemes.
- In single layer orientation scheme, beam GPC 1 increased its load carrying capacity by 39.04% in comparison with CB and beam GPC 1 increased its load carrying capacity by 35.18% in comparison with GPC 2.
- In double layer orientation scheme, beam GPC 4 increased its load carrying capacity by 66.67% in comparison with CB and beam GPC 3 increased its load carrying capacity by 6.67% in comparison with CB.
- Considering the number of layers of GFRP sheet, the optimum ultimate load is obtained for GPC 4 with 1 layer of GFRP in 0^0 orientation and 1 outer layer in 45^0 orientation.

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