Behaviour of RC Beams Strengthened with Glass Fiber Reinforced Polymer

Milan Surana[1], Dr. M. N. Bajad[2]

[1]*Research Scholar, Department of Civil Engineering, Sinhgad College of Engineering, Pune, Maharashtra, India*

[2]*Associate Professor, Department of Civil Engineering, Sinhgad College of Engineering, Pune, Maharashtra, India*

Abstract: **Several studies have been conducted to investigate the strength of RC members with fiber reinforced polymers (FRPs). Concrete structural members such as beams, columns, walls are a part of various buildings. Understanding the response of these members of structures strengthened with FRP is crucial for the development of an efficient and safe structure. The problem of accurately determining the shear capacity of structural concrete members appears rather difficult to solve, despite many studies carried out in recent decades. In particular, glass-fiber-reinforced polymer (GFRP) is being used in a growing number of applications because of their superior performance at a relatively competitive cost. In this study, a set of 5 control beams namely C1, C2, C3, C4 and C5 with different reinforcements were taken. C1 beam was designed as fully strengthened beam so it was not retrofitted with GFRP. The reinforcement of the other four beams was changed so they were deficient in strength. These deficient beams were retrofitted with GFRP strips (inclined and U wrap fashion). The shear stress and strain parameters of the control beams and the retrofitted beams were observed and noted. Also, the stress strain curve of the beams was studied. It was found that the strength of beams improved with the addition of GFRP.**

Keywords: **FRP, Shear stress - strain, Strength, RC beam, resin epoxy**

I. Introduction

Enhancement of concrete structures may be required for a wide range of reasons. The concrete structures may have turned out to be fundamentally in sufficient for instance, because of material deterioration, poor configuration or development, maintenance absence, redesigning of outline burdens, for example, natural causes like earthquakes. The strength of a corroding steel reinforcing bar is reduced because of a reduction in the cross-sectional area of the steel bar. While the steel reinforcing bars are corroding, the concrete integrity is impaired because of cracking of the concrete cover caused by the expansion of the corrosion products. Replacement of such deficient structures incurs a huge amount of public money and time. So, strengthening has become the acceptable way of improving their strength and serviceability [1]. Glass fibers are significantly cheaper than carbon fibers and aramid fibers. Therefore, Glass Fiber Reinforced Polymer (GFRP) composites have become prevalent in many applications. Shear failure is disastrous and occurs generally without advance warning. Thus, it is required that the beam fails in flexure rather than in shear. Deficiencies for shear occur for numerous reasons, including insufficient shear reinforcement or reduction in steel area because of corrosion, increased service load, and construction defects. To increase the shear resistance of concrete beams, sheets and laminates of FRP are generally applied on the faces of the elements to be strengthened, using an externally bonded reinforcing technique. Several researchers have proved that the shear resistance of concrete beams can significantly be increased by adopting the external reinforced bonding technique with GFRP and solid epoxy paste which can strengthen the structures. From the past studies conducted by [2-6] it has been shown that externally bonded glass fiber-reinforced polymers (GFRP) can be used to enhance the shear capacity of RC beams. Due to the flexible nature and ease of handling and application, combined with high tensile strength and stiffness, the flexible glass fiber sheets are found to be highly effective for shear strengthening of RC beams.

II. Literature Review

Chaallal O. et al [3] studied RC beams strengthened with diagonal side CFRP strips, which produced premature failure as a result of concrete peeling off at a strip in tension stressed zone. Therefore, it was suggested that U wrap would be more appropriate.

Robert R. S. and Prince A. G. [7] studied finite element modelling on behaviour of reinforced concrete beam-column joints retrofitted with carbon fibre reinforced polymer. The Finite element modelling (FEM) has turned to be recreating the physical conduct of complex building frameworks. The (FEA) programs have increased normal acknowledgment among architects in industry and analysts. The examination of retrofitted with carbon Fibre reinforced polymer sheets (CFRP) utilizing ANSYS have been exhibited in this paper. Three different strengthened sheet of CPRF on solid shaft were displayed utilizing ANSYS. Both the ends of the beam in investigation have been kept pivoted. Static load was connected at the free end of the cantilever bar. The analyses have been conducted for the retrofitted beam and the outcomes have been exhibited.

More R. U. and Kulkarni D. B. [8] studied flexural behavioural study on RC beam with externally bonded aramid fibre reinforced polymer. They represent the flexural manner of Aramid fibre reinforced polymer (AFRP) with RC beams of M25 grade cement. Results have been conducted for beam (simply supported) of cross-section

100mm×150mm×1200mm with laminated by aramid fibre polymer sheets. The impacts of reinforcing on burden conveying limit and impact of harm degree are talked about in subtle element. The outcomes demonstrate that the heap conveying limit of bars was essentially expanded as the quantity of layer expanded. The acceptance of the trial results was finished by utilizing ANSYS programming. To concentrate on the flexural conduct of the pillar, the examples were just subjected to two-point stacking system just. The bars were wrapped with AFRP sheets in single layer and twofold layers along the length at the base face of the bar. The present work incorporates Effect of harm level of the pillar and impact of number of layers. In this manner it is an achievable technique for fortifying and retrofitting of RC pillars.

Jayajothi P. et al [9] studied finite element analysis of FRP strengthened RC beams using ANSYS. Remotely fortified FRP sheet can be utilized to increase flexural quality of strengthened solid pillars. Strengthened solid bars remotely fortified with fibre strengthened polymer sheets utilizing limited component strategy embraced by ANSYS. The precision of the limited component model is checked with help of correlation its outcomes with the trial results. The heap redirection bends acquired from the limited component investigation holds great with the trial results.

Khalifa et al. [10] studied the shear performance and the modes of failure of reinforced concrete (RC) beams strengthened with externally bonded carbon fiber reinforced polymer (CFRP) wraps experimentally. The experimental program consisted of testing twenty-seven, full-scale, RC beams. The variables investigated in this research study included steel stirrups (i.e., beams with and without steel stirrups), shear span-to depth ratio (i.e., a/d ratio 3 versus 4), CFRP amount and distribution (i.e., Continuous wrap versus strips), bonded surface (i.e., lateral sides versus U-wrap), fiber orientation (i.e., 90°/0° fiber combination versus 90° direction), and end anchor (i.e., U-wrap with and without anchor). As part of the research program, they examined the effectiveness of CFRP reinforcement in enhancing the shear capacity of RC beams in negative and positive moment regions, and for beams with rectangular and T-cross section. The experimental results indicated that the contribution of externally bonded CFRP to the shear capacity is significant and dependent upon the variable investigated. For all beams, results show that an increase in shear strength of 22 to 145% was achieved.

III. Problem Statement

In the program, five control beams were taken (C1, C2, C3, C4, and C5) with two different retrofitting cases. In one set of beams, the retrofitting was done by using inclined side GFRP strips whereas in the next case, retrofitting was done by providing inclined U-strips of GFRP. Among these five beams, C1 was fully strengthened. But the other four beams were so designed such that they were shear deficient. The two sets of beams had the same reinforcements as that of the shear deficient control beams. A R.C. beam 100 mm x 150 mm, span 1000 mm is supported at both the ends. Calculate shear stress and shear strain on the RC beam with (inclined and U-wrap fashion) and without GFRP for the following data. Use M20 grade concrete with different steel and fiber.

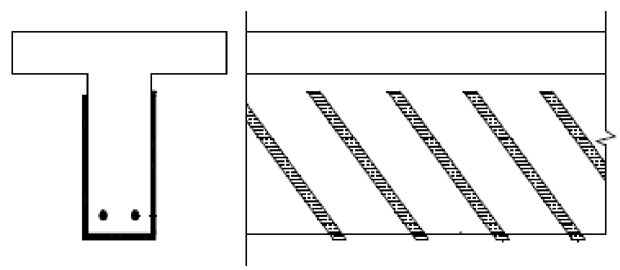

Figure 1 Side view and front view of the GFRP strips on RC beam

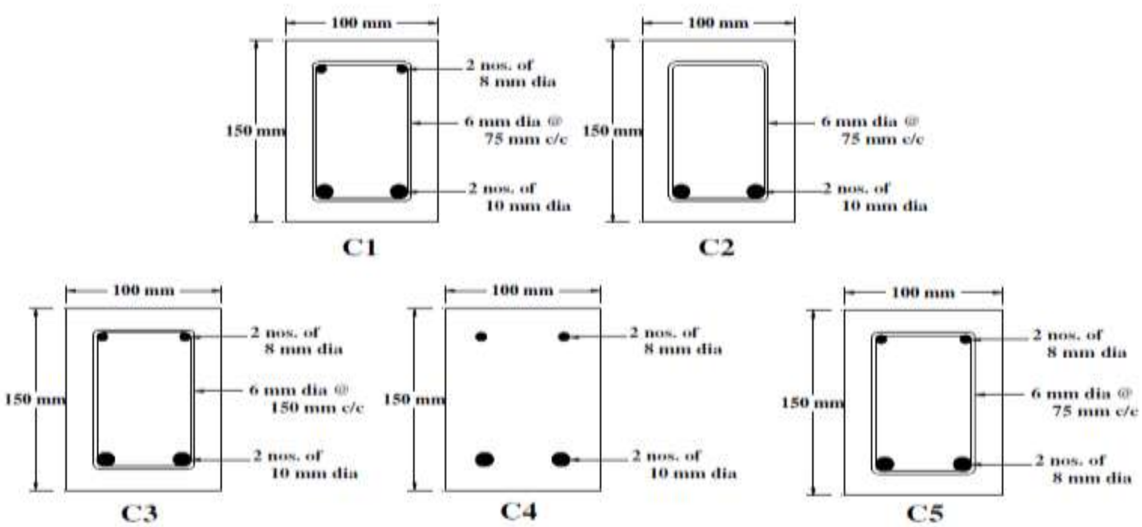

Figure 2 Reinforcement details of the RC beams

3.1 Material Specifications

Various material properties and specifications were used in the project work. The materials and specifications used are listed below:

3.1.1Specifications of The Beam Studied

The specifications of the beam used in the project work is shown below:

Table 1. Specifications of the beam used in project work

Length of beam	1000 mm
Depth of beam	150 mm
Width of beam	100 mm

3.1.2 Concrete Properties

For concrete, the compressive strength of 20 N/mm^2 was used. Following are the properties used for concrete:

Table 2. Concrete Properties used in project work

Compressive strength (N/mm^2)	20 N/mm^2
Poisson's ratio	0.2
Modulus of Elasticity (MPa)	22360

3.1.3 Properties of Steel Reinforcement

The longitudinal reinforcements used were bars of 10 mm and 8 mm diameter. The stirrups were of 6 mm diameter. The yield strength of steel reinforcements used in this project work were 390 N/mm^2, 375 N/mm^2 and 240 N/mm^2 for 10 mm, 8 mm, and 6 mm diameter bars, respectively.

Table 3. Steel Properties used in project work

Steel Material	**Yield stress**	**Diameter**
Longitudinal bar 1	390 N/mm^2	10 mm
Longitudinal bar 2	375 N/mm^2	8 mm
Stirrups	240 N/mm^2	6 mm

3.1.4 Properties of GFRP

Glass fiber polymer composites are among the oldest and least expensive of all composites. Glass fiber was used in this investigation. The principal advantages of E-glass are low cost, high tensile and impact strengths and high chemical resistance.

Table 4. GFRP Properties used in project work

Properties of glass fiber	**Value**
Density of fiber	2.6 g/cm^3
Fiber layer thickness	1 mm
Tensile strength	3400 N/mm^2
Tensile modulus	73000 N/mm^2

IV. METHODOLOGY

The RC beams were analyzed with and without GFRP and are shown be the following sample models below:

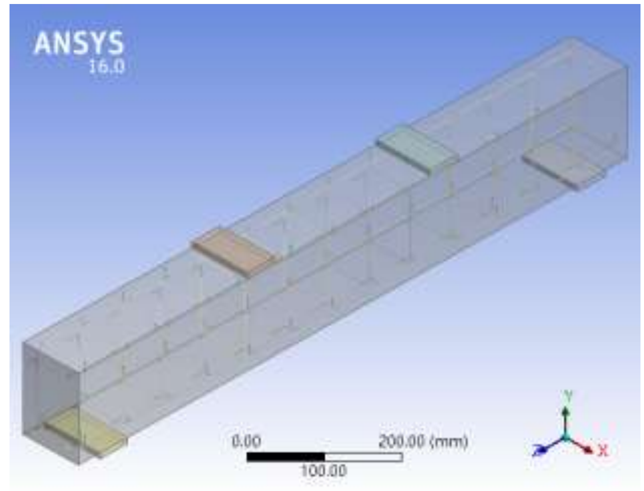

Figure 3. Control beam 3D view

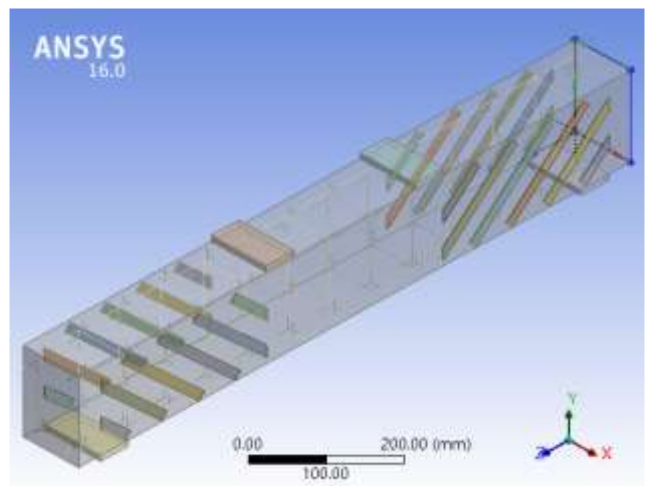

Figure 4 Beam with inclined side GFRP 3D view

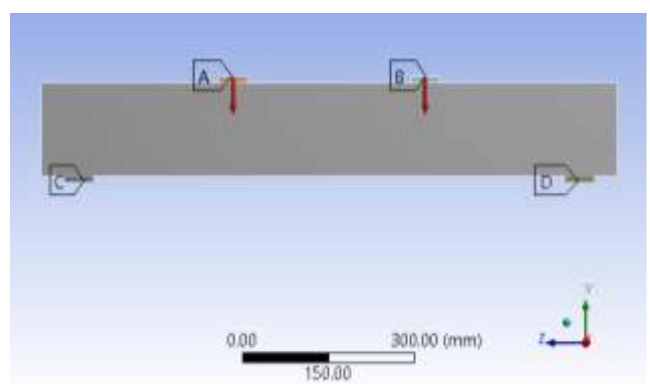

Figure 5. Loading details on control beam

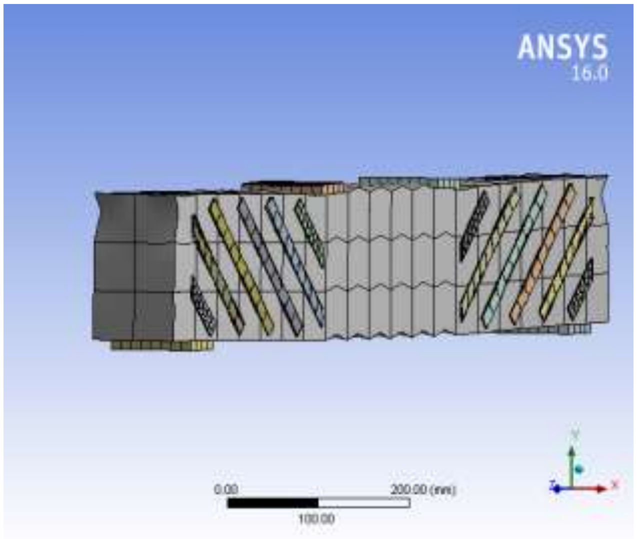

Figure 6 Analyzed Beam model (3D view)

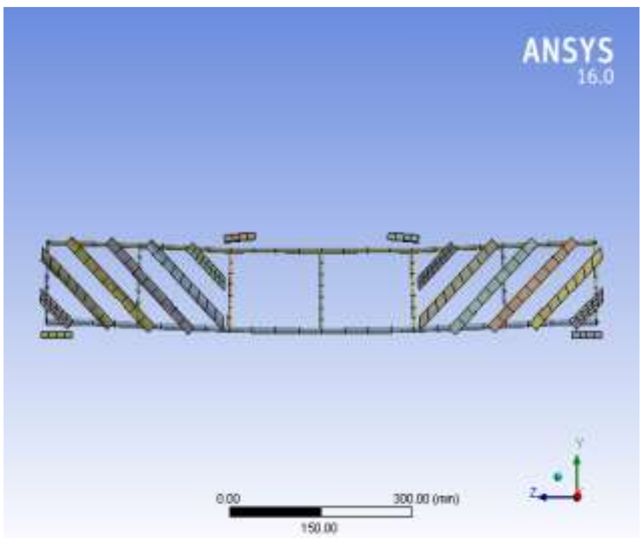

Figure 7 Analyzed Beam model (Reinforcement view)

V. Results and Discussions

Stress Strain analysis

The shear stress strain behaviour was evaluated and observed. All the beams (with and without GFRP) were analyzed and the stress strain values were compared. During the shear stress and strain analysis, the values of stress and strain at various steps were noted. The results obtained after the shear stress and strain analysis showed that glass fiber reinforced polymer decreased the shear stress of RC beams at similar loads that were applied to control beams. The maximum stress for beam C2 decreased from 52.23MPa to 42.74MPa, beam C3 decreased from 54.49MPa to 42.61MPa, beam C4 decreased from 57.24MPa to 42.55MPa and beam C5 decreased from 55.39MPa to 42.78MPa with the inclusion of GFRP. Similarly, maximum shear strain for beam C2 decreased from 5.08E-03 to 9.22E-04, beam C3 decreased from 3.29E-03 to 1.16E-03, beam C4 decreased from 1.93E-03 to 1.00E-03 and beam C5 decreased from 3.23E-03 to 1.53E-03 with the inclusion of GFRP. Also, the shear stress and strain curves were plotted for the RC beams with and without GFRP. The stress strain curves for the RC beams with and without GFRP are shown below:

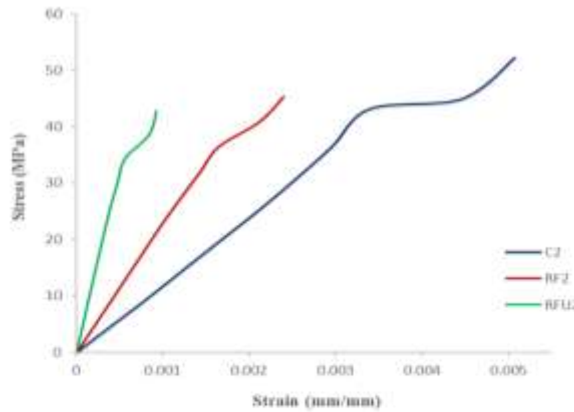

Figure 12 Analytical stress strain graph (Beam C2, RF2 and RFU2)

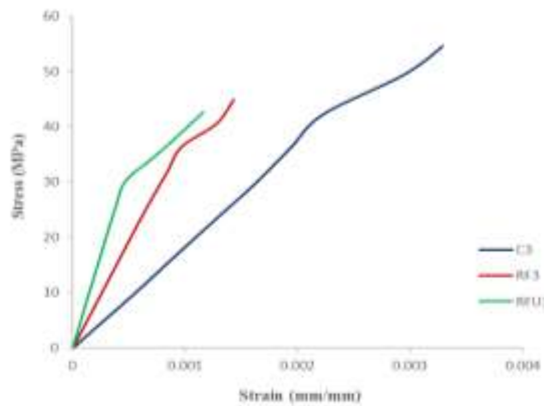

Figure 13 Analytical stress strain graph (Beam C3, RF3 and RFU3)

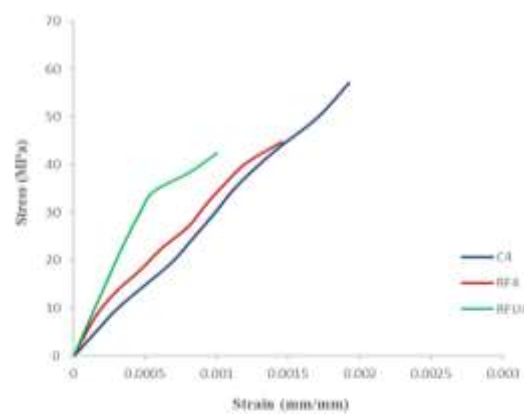

Figure 14 Analytical stress strain graph (Beam C4, RF4 and RFU4)

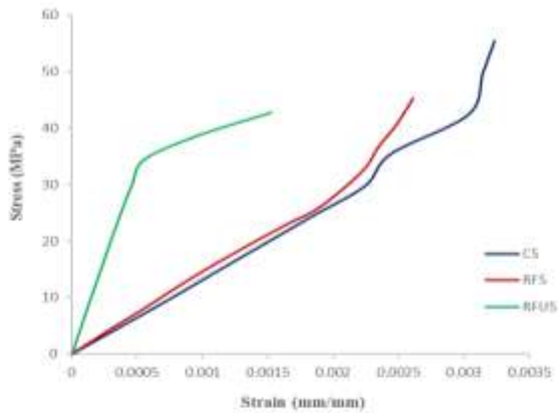

Figure 15 Analytical stress strain graph (Beam C5, RF5 and RFU5)

V. CONCLUSIONS

Based on the current analytical results of RC beams with strengthened by GFRP, the following conclusions can be drawn:

1. To evaluate the shear strength of reinforced concrete beams wrapped with GFRP, ANSYS based analytical program was adopted.
2. The strengthening of the RC control beams with GFRP improves the shear strength of the beams against higher loads.
3. The results obtained after the shear stress and strain analysis showed that glass fiber reinforced polymer decreased the shear stress of RC beams at similar loads that were applied to control beams. The shear stress and shear strain behaviour for all the RC beams improved significantly with the inclusion of GFRP.
4. Therefore, the retrofitting of glass fiber reinforced polymer on RC beams is efficient and beneficial as it gives more strength to the shear deficient beams.

REFERENCES

[1] Mettu Bhaskara Rao, P.J. Rao, M.V.S. Rao, K.J. Rao, "Study of the behaviour of GFRP – RC beams under shear" in *International Journal of Engineering Trends and Technology (IJETT)*, vol. 4, Issue 7, July 2013.

[2] Al-Sulaimani GJ, Sharif A, Basunbul IA, Baluch MH, Ghaleb BN, "Shear repair for reinforced concrete by fiberglass plate bonding.", *ACI Struct*, 1994, pp. 458–464.

[3] Chaallal O, Nollet MJ, Perraton D, "Shear strengthening of RC beams by externally bonded side CFRP strips.", *J Compos Construct*, 1998, pp. 111–113.

[4] Miyauchi K, Inoue S, Nishibayashi S, Tanaka Y, "Shear behaviour of reinforced concrete beam strengthened with CFRP sheet.", *Trans Jpn Concr Inst*, 1997, pp. 97–104.

[5] Norris T, Saadatmanesh H, "Shear and flexural-strengthening of R/C beams with carbon fiber sheets.", *J Struct Eng*, 1997, pp. 903–911.

[6] Sato Y, Tanaka T, Ueda T, Ono S, "Shear behaviour of RC beams reinforced with carbon fiber sheets." *Trans Jpn Concr Inst*, 1996, pp. 137–142.

[7] Robert R. S. and Prince A. G., "Finite Element Modelling on Behaviour of reinforced concrete beam-column joints retrofitted with carbon fibre reinforced polymer", *International Journal of Civil and Structural Engineering*, 1(3), 2010, pp. 576-582.

[8] More R. U. and Kulkarni D. B., "Flexural Behavioural Study on RC Beam with Externally Bonded Aramid Fibre Reinforced Polymer", *International Journal of Research in Engineering and Technology*, 3(7), 2014, pp. 316-321.

[9] Jayajothi P., Kumutha R. and Vijai K., "Finite Element Analysis of FRP Strengthened RC Beams Using Ansys", *Asian Journal of Civil Engineering*, 14(4), 2013, pp. 631-643.

[10] Khalifa A., Lorenzis L. D., and Nanni A., "FRP composites for shear strengthening of RC beams", Proceedings, 3rd International Conference on Advanced Composite Materials in Bridges and Structures, 2000.

[11] M.C. Sundarraja, and S. Rajamohan, "Strengthening of RC beams in shear using GFRP inclined strips – An experimental study", Construction and Building Materials, 2009, pp. 856-864.