JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

ENHANCING THE STRUCTURAL PERFORMANCE OF RC CONTINUOUS BEAMS USING GLASS FIBRE REINFORCED POLYMER (GFRP) STRENGTHENING TECHNIQUES

Nagesh Singh Baghel[1], Mr.Akhand Pratap Singh[2],
M.Tech Scholar[1], Assistant Professor[2],
Shri Rawatpura Sarkar University Raipur Chhattisgarh

Abstract

"Over the last decade, advances in strengthening structures through external bonding of advanced fiber-reinforced polymer (FRP) composites have gained significant popularity worldwide." This technology is a more cost-effective and technically superior alternative to traditional procedures, delivering improved strength, great fatigue resistance, low weight, corrosion resistance, easy and speedy installation, and little structural geometry changes. Despite the widespread use of in-situ reinforced concrete (RC) continuous beams in construction, there has been little research into FRP strengthening of continuous beams.

This paper describes an experimental research of the behaviour of continuous RC beams under static loading conditions. Externally bonded glass fiber-reinforced polymer (GFRP) sheets and unbonded GFRP with a steel bolt system are used to reinforce the beams, with various strengthening schemes. Six continuous (two-span) beams with diameters of (1502502300) mm, all with similar longitudinal and transverse steel reinforcing, comprise the experimental setup. One beam is used as the control specimen and receives no strengthening, while the others are strengthened in various patterns with externally bonded GFRP sheets and unbonded GFRP employing end anchorage with the steel bolt system.

The research looks into the reactions of RC continuous beams, with an emphasis on failure modes, load capacity enhancement, and load deflection analysis. The results show that connecting GFRP sheets to the shear face significantly increases the shear strength of RC beams. Furthermore, using unbonded GFRP sheets with end anchorage improves cracking behaviour by delaying the emergence of visible cracks and reducing crack widths at higher load levels.

Keywords: Continuous beam; reinforcement; GFRP; debonding failure; end anchorage.

1. Introduction

1.1 General

Concrete structures might, for a mixture of reasons, be found to perform unacceptably. This could show itself by poor execution under static loading, as cracking or excessive deflections, or there could be insufficient extreme quality or strength. A structure is designed for a specific period and depending on the nature of the structure, its design life varies. Decay in solid structures is a noteworthy test confronted by the foundation and scaffold commercial ventures around the world. The degradation could be mainly due to nature's effects, which includes gradual loss of strength with ageing, corrosion in steel, high intensity loading, freeze-thaw cycles, temperature variation, or exposure to chemicals or saline water and due to ultra-violet radiations. As complete replacement or reconstruction of the structure will be cost effective, strengthening or retrofitting is an effective way to strengthen the same.

Reinforced concrete structures regularly need to face adjustment and change of their execution amid their administration life. The primary contributing components are change in their utilization, new plan guidelines, weakening because of consumption in the steel brought about by introduction to a forceful situation and mischance occasions, for example, seismic tremors. In such circumstances there are two conceivable arrangements: substitution or retrofitting. Full structure substitution may have determinate disservices, for example, high expenses for material and work, a more grounded natural effect and drawback because of interference of the capacity of the structure, e.g. activity issues.

1.4 Suitability of FRP for Uses in Structural Engineering

The quality properties of FRPs on the whole make up one of the essential purposes behind which structural designers select them in the configuration of structures. A material's quality is represented by its capacity to manage a heap without unnecessary twisting or disappointment. At the point when a FRP example is tried in hub strain, the connected power every unit cross-sectional zone (anxiety) is relative to the proportion of progress in an example's length to its unique length (strain). At the point when the connected burden is evacuated, FRP comes back to its unique shape or length. At the end of the day, FRP reacts straight flexibly to pivotal anxiety.

1.6 Current Research on FRP

A genuine matter identifying with the utilization of FRPs in common applications is the absence of configuration codes and details. For about 10 years now, scientists from Europe, Canada and Japan have been working together their endeavors in any expectation of growing such reports to give direction to designers planning FRP structures.

2.2 Objective and Scope of the Present Work

The objective of the present work is to study the behavior of continuous beams strengthened with bonded and unbonded GFRP sheets under static loading condition.

In the present work, behavior of RC continuous rectangular beams strengthened with externally bonded or unbonded GFRP is experimentally studied. The beams have same longitudinal and transverse steel reinforcement ratios. All beams have the same geometrical dimensions. These beams are tested up to failure by applying two points loading to evaluate the enhancement of its strength due to strengthening.

2. Experimental Study

The experimental part comprises of casting six two-span continuous rectangular reinforced concrete beams. All the beams had same longitudinal and transverse steel reinforcement ratios and were cast and tested to failure. The beams were strong in flexure and shear reinforcement was not strong. Beams geometry as well as the loading and support arrangements are illustrated in the figure below. All beams had the same geometrical dimensions: 150 mm wide × 250 mm deep × 2300 mm long.

One of the six beams was not strengthened by GFRP and was considered as a control or reference beam, whereas other five beams were strengthened with unbonded or externally bonded GFRP sheets. Experimental data on load, deflection and failure modes of each of the six beams were obtained. The change in the load carrying capacity and the failure modes of the beams are investigated for different types of strengthening pattern.

3.1 Casting of Specimen

A proportion of **1: 1.6: 3.2** is taken for cement, fine aggregate and course aggregate for casting of beams. The mixing of these materials is done by using concrete mixture. The beams are cured for 28 days. Six concrete cube specimens of dimensions 150mm cube were made at the time of casting of every beam and were kept for curing. The uni-axial compressive tests on the concrete produced were performed and the average compressive strength (fcu) of the beams after 28 days for each beam was recorded.

Table 3.1 Design Mix Proportions

Description	Cement	Sand (Fine Aggregate)	Course Aggregate	Water
Mix Proportion (by Weight)	1	1.6	3.2	0.55
Quantities of Materials (Kg/m^3)	368.4	589.44	1178.88	202.62

3.4 Testing of Beams

All the six beams were tested one by one. All of them were tested in the same arrangement. The deformation readings in the dial gauge for each 10KN of load were recorded throughout the test. The load at which the first visible crack is developed is recorded as cracking load. Then the load is applied till the ultimate failure of the beam. The dial gauges placed at mid- spans measured the deflections at different loads (multiples of 10KN) for all beams with and without GFRP. The data furnished in this chapter have been interpreted and discussed in the next chapter to obtain a conclusion.

3.4.1 Beam -1

Control Beam (CB1)

Fig 3.2 Test Setup for Control Beam

The control beam, CB1, failed in the RC shear failure mode. The wide diagonal shear cracks were observed. The cracks were well extended from mid support to the left centre span. The first crack of CB1 was obtained at 80KN load and the ultimate failure of the beam occurred at 240KN load.

Fig 3.3 First Crack On the Beam

Fig 3.4 Ultimate Failure of the Beam

3. Test Results And Discussions

The loadings on the beams were a concentrated load at each mid-span and the experimental results thus obtained are discussed in terms of the failure mode observed and the load vs deflection curve. The crack patterns and the mode of failure of each beam are also described in this chapter. All the beams are tested for their ultimate strengths and it is observed that the control beam had less load carrying capacity than the strengthened beam. One beam from the series was tested as un-strengthened control beam and rest beams were strengthened with various patterns of FRP sheets. The different failure modes of the beams were observed for different beams.

4.1 Experimental Results

4.1.1 Failure Modes

4.1.1.1 Control Beam

The control beam failed completely in shear. The failure started first at the center span areas and then propagated towards the central support and finally failed in shear.

4.1.1.2 Strengthened Beam

Generally, the rupture of FRP sheet was very quick and sudden, and a loud noise was audible indicating a sudden energy release and thus loss in load-carrying capacity. For all the strengthened beams, the failure modes are described as below.

The following failure modes were examined for all the tested beams:

- Shear failure
- Debonding failure (with or without concrete cover)
- Debonding along with shear cracks at the span

Table 4.1 Experimental Results of the Tested Beams

Designation of Beams	**Failure Mode**	**Pu(KN)**	**λ=Pu(strengthened beam) Pu(Control beam)**
CB1	Shear Failure	240	1
SB1	Debonding Failure Along with Shear Cracks	288	1.2
SB2	Debonding Failure	310	1.29
SB3	Debonding Failure	340	1.42
SB4	Shear Failure	270	1.125
SB5	Shear Cracks Along With Cracks at Vertical Support	318	1.325

The ultimate failure load for all the tested beams are summarized in the above table. The ratio of load enhancement (λ), which is the ratio of the ultimate load of the strengthened beam to that of the control beam, is also presented in the table. From the table it is found that, addition of GFRP layers increased the load-carrying capacity and by introducing the anchoring system, the enhancement of load capacity can be done.

4.1 Load Deflection and Load Carrying Capacity

The GFRP strengthened beams and the control beams are tested to find out their ultimate load carrying capacity. The deflection of each beam under the load point i.e. at the midpoint of each span position is analyzed. Mid-span deflections of each strengthened beam are compared with the control beam. It is noted that the behavior of the beams when unbonded or bonded with GFRP sheets are better than the control beams. The mid-span deflections of the beams are lower when bonded externally with GFRP sheets. The strengthened beams were found to have higher stiffness than the control beams. Increasing the numbers of GFRP layers generally reduced the deflection at mid span and increased the beam stiffness for the same value of load. The use of GFRP sheet had effect in slowing the growth of cracks.

4.1.1 Load-Deflection Curves for All Beams

The deflections at the mid-spans were recorded at various loads for control as well as the strengthened beams and the load-deflection curves of the strengthened beams were contrasted with the control beams and the conclusions were drawn for each beam.

Strengthened Beams

Load-Displacement Curve For SB 1 Vs CB

To strengthen SB1, single layer of glass FRP was applied at the surfaces to prevent shear failure. And it was observed that the deflection values were less than that of the control beam for the same load value. At lower load value, debonding of FRP without concrete cover occurred and SB1 finally failed in shear. At the load of 110 KN initial cracks appeared. Later on increasing the load values, the cracks propagated further and the beam failed with an ultimate load of 288 KN

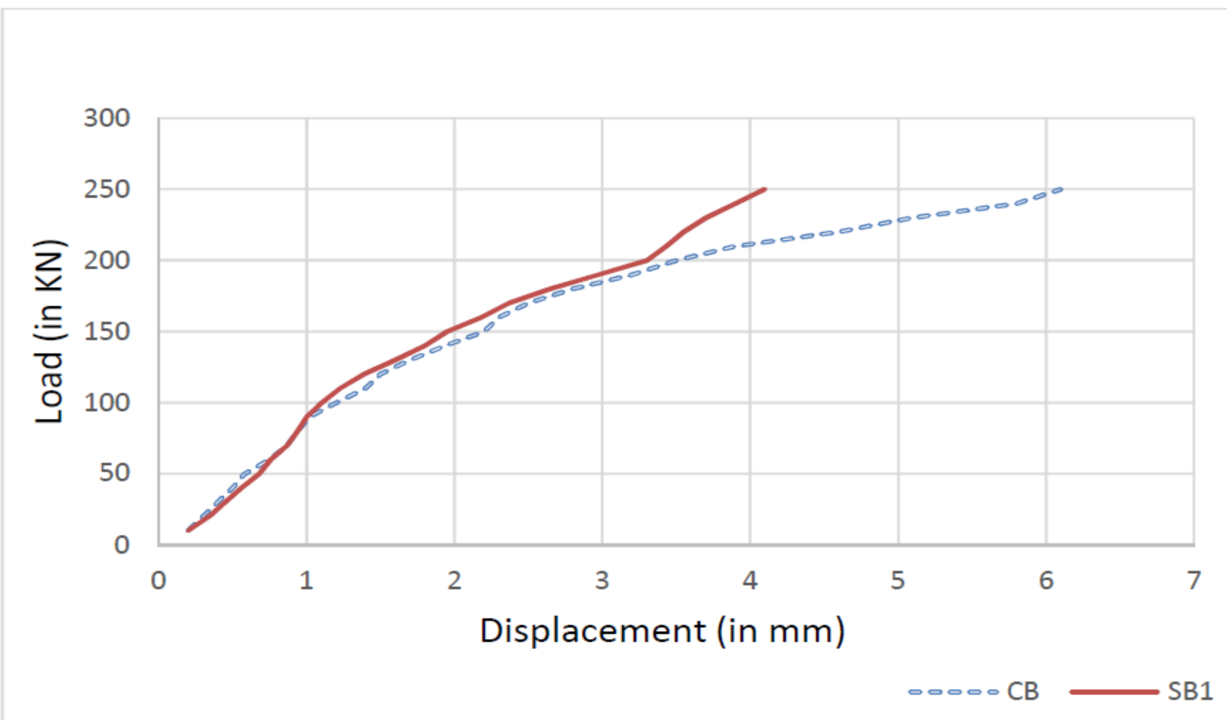

Fig 4.1 Load-Displacement Curve For SB 1 Vs CB

Load-Displacement Curve For SB 2 Vs CB

SB2 was strengthened with two layers of glass FRP applied at the surfaces similar to SB1 to prevent shear failure. And from Fig 4.2, it is clear that the deflection values of SB2 are less than that of the control beam for the same load value. At the load of 130 KN initial hairline cracks appeared. Later on increasing the load values, the cracks propagated further and the beam failed with an ultimate load of 310 KN.

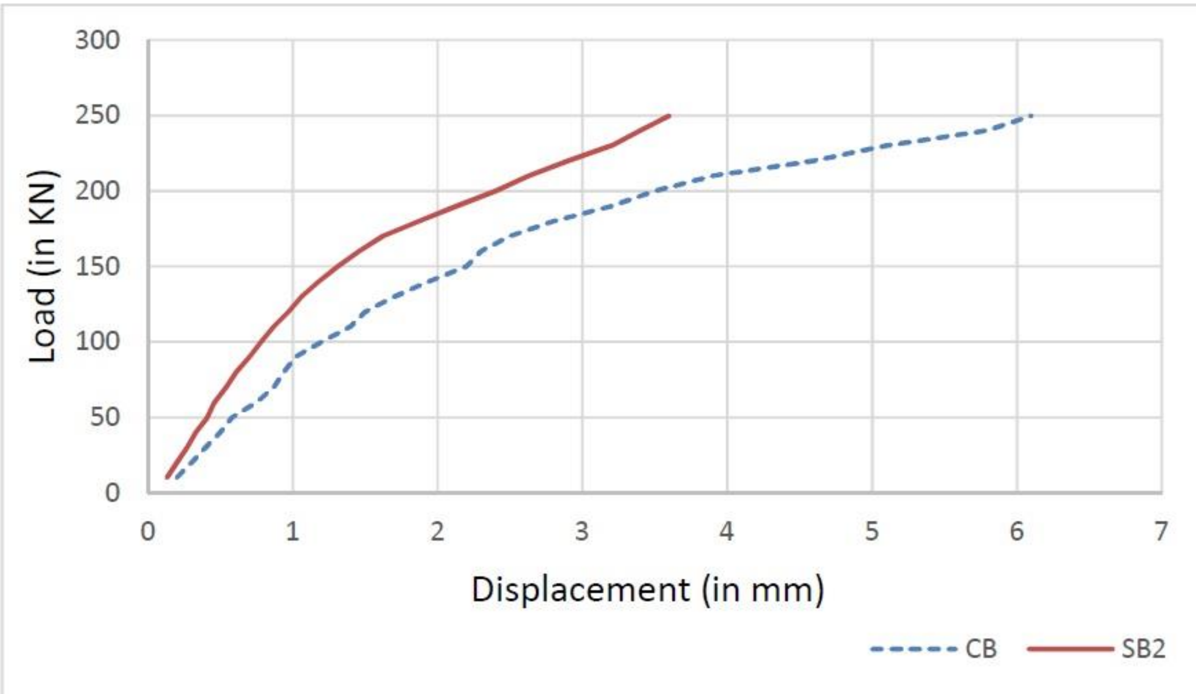

Fig 4.2 Load-Displacement Curve For SB 2 Vs CB

Load-Displacement Curve For SB 3 Vs CB

Similarly, SB3 was strengthened with four layers of glass FRP. And, from the graphs in Fig 4.3 it is clear that the deflection values are much less compared to the control beam for the same load value. Moreover, the beam failed due to debonding of glass FRP sheets from the concrete cover and flexural cracks were found at the central support due to negative bending moment (hogging) at the central support. The ultimate load of SB3 was found out to be as high as 340 KN.

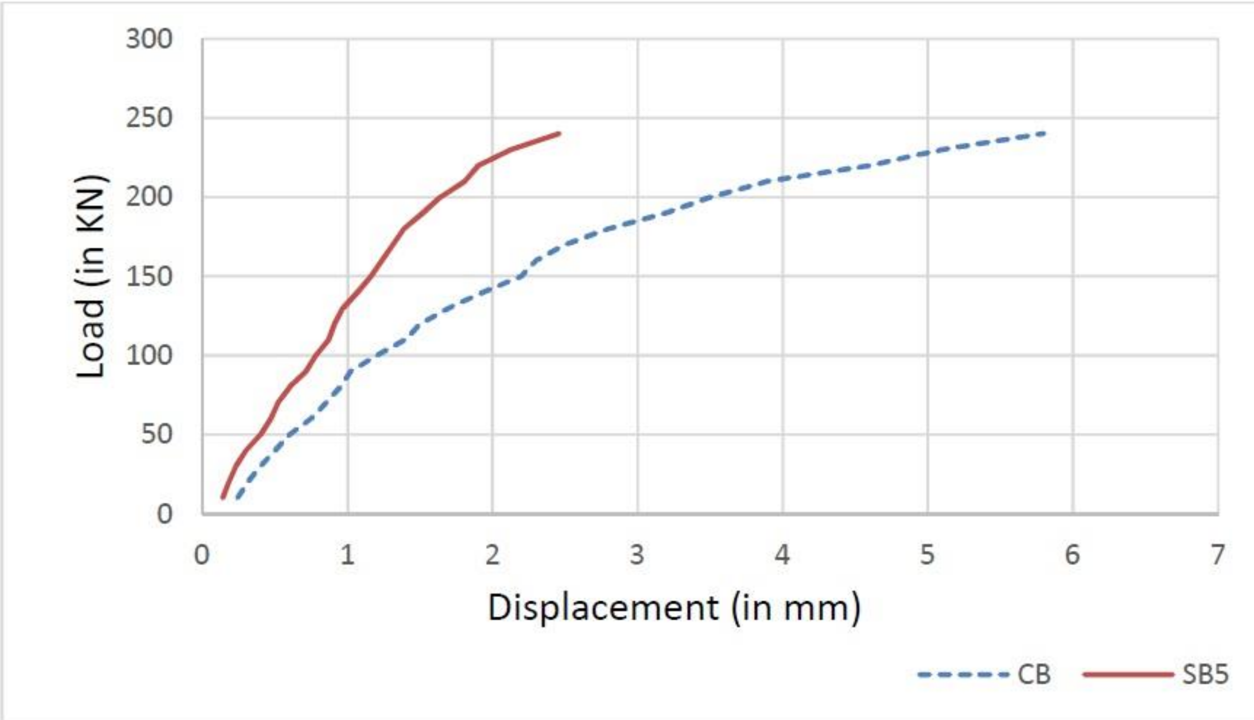

Fig 4.3 Load-Displacement Curve For SB 3 Vs CB

Load-Displacement Curve For SB 4 Vs CB

The technique of strengthening the beams with unbonded glass FRP was used. End anchorage was provided using steel bolts and plates. In SB4, one layer of glass FRP was U-wrapped just under the loading points. The ultimate failure of the beam was in shear at 270 KN. And it was observed that the displacement values were nearer to that of the control beam.

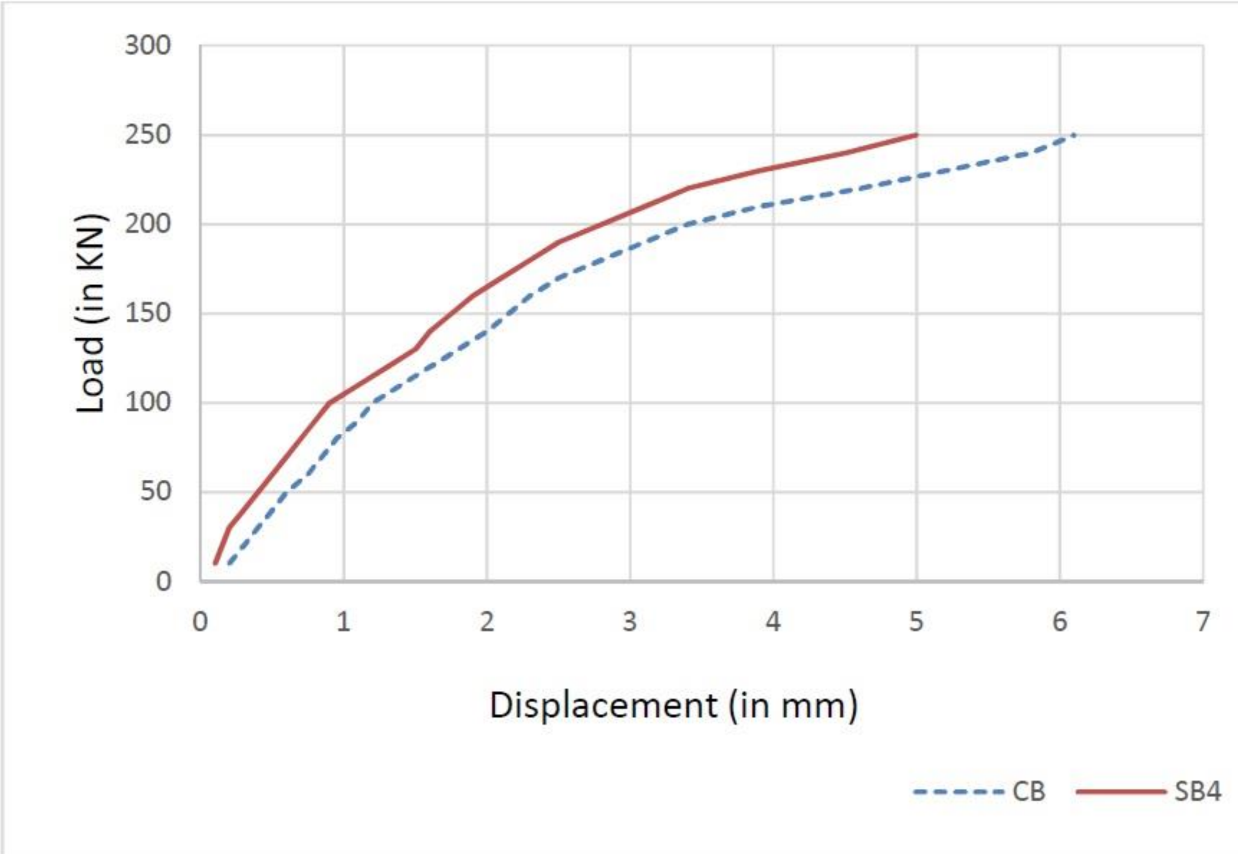

Fig 4.4 Load-Displacement Curve For SB 4 Vs CB

Load-Displacement Curve For SB 5 Vs CB

SB5 was also strengthened with unbonded glass FRP provided with end anchorages using steel bolts and plates. In SB5, one layer of glass FRP each was U-wrapped from loading point to central support .And expectedly, the beam showed much resistance to shear failure. Interestingly, the beam developed cracks due to shear from the right mid-span to the end support and also cracks were found at the central support. The ultimate failure occurred at 318 KN.

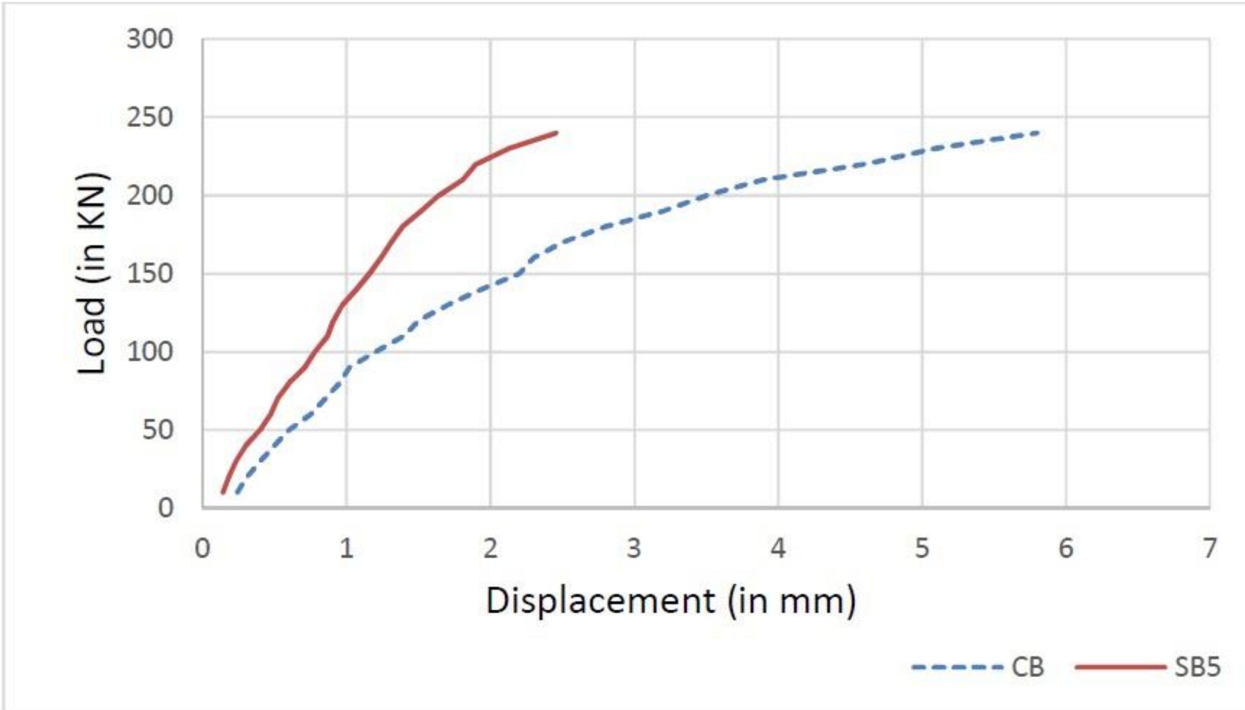

Fig 4.5 Load-Displacement Curve For SB 5 Vs CB

Thus, the load carrying-capacity of all the strengthened beams are discussed here, and it is found that beam SB3 has the maximum load capacity of 340 KN and maximum percentage increase of load carrying capacity, i.e., 41.67%. Moreover, the ultimate shear capacities of all the strengthened beams are higher than that of the control beam.

5.1. Conclusions

The present experimental study is carried out on the behavior of reinforced concrete rectangular beams strengthened by GFRP sheets. Six reinforced concrete (RC) beams weak in shear are casted and tested. All the beams had same longitudinal and transverse steel reinforcement ratios. The conclusions drawn from the experimental results are as follows:

1. The strengthened beams had higher load-carrying capacity as compared to the control beam.
2. The initial cracks in the strengthened beams appeared at higher loads compared to the control beam.
3. The test results show that on strengthening the beams using FRP technique, the shear capacity can be increased.
4. Strengthened beam SB3, which was strengthened by four layers of FRP showed the highest ultimate load value of 340 KN and the percentage increase in the load capacity of SB3 was 41.67 %.
5. On increasing the number of layers of glass FRP, the load carrying capacity of the beams also increases.
6. Unbonded FRP system with end anchorage using steel bolts and plates is a very new, time and cost-effective technique

5.2 Scope of the Future Work

It promises a great scope for future studies. Following areas are considered for future research:

1. Experimental study of continuous beams with opening
2. Non-linear analysis of RC continuous beam
3. FEM modeling of unanchored U-wrap
4. FEM modeling of anchored U-wrap

References

1. Aiello MA, Valente L, and Rizzo A, “Moment redistribution in continuous reinforced concrete beams

strengthened with carbon fiber-reinforced polymer laminates", Mechanics of Composite Materials, vol. 43, pp. 453-466, 2007.

2. Aiello MA, and Ombres L, "Cracking and deformability analysis of reinforced concrete beams strengthened with externally bonded carbon fiber reinforced polymer sheet", ASCE Journal of Materials in Civil Engineering, vol. 16, No. 5, pp.292-399,2004.
3. Arduini M, and Nanni A, "Behaviour of pre-cracked R. C. beams strengthened with carbon FRP sheets", ASCE Journal of Composites for Construction, vol. 1, No. 2, pp. 63- 70, 1997.
4. Ashour AF, El-Refaie SA, and Garrity SW, "Flexural strengthening of RC continuous beams using CFRP laminates", Cement and Concrete Composites, vol. 26, pp. 765-775, 2003.
5. Ceroni F, "Experimental performances of RC beams strengthened with FRP materials", Construction and Building Materials, vol. 24, pp. 1547-1559, 2010.
6. Grace NF, "Strengthening of negative moment region of reinforced concrete beams using carbon fiber-reinforced polymer strips", ACI Structural Journal, vol. 98, No. 3, pp. 347- 358, 2001.
7. Grace NF, Sayed GA, and Saleh KR, "Strengthening of continuous beams using fibre reinforced polymer laminates", American Concrete Institute, Farmington Hills, Mich, pp. 647-657, 1999.
8. Grace NF, Wael R, and Sayed AA, "Innovative triaxailly braided ductile FRP fabric for strengthening structures", 7th International Symposium on Fiber Reinforce Polymer for Reinforced Concrete Structures, ACI, Kansas City, MO, 2005.
9. Grace NF, Abdel-Sayed G, Soliman AK, and Saleh KR, Strengthening of reinforced concrete beams using fibre reinforced polymer (FRP) laminates", ACI Structural Journal, vol. 96, No. 5, pp. 865-874, 1999.
10. Maghsoudi AA, and Bengar H, "Moment redistribution and ductility of RHSC continuous beams strengthened with CFRP", Turkish Journal of Engineering and Environmental Sciences, vol. 33, pp. 45-59, 2009.
11. Obaidat YT, Susanne H, Ola D, Ghazi A, Yahia A, "Retrofitting of reinforced concrete beams using composite laminates", Construction and Building Materials, vol. 25, pp. 591-597, 2010.
12. Smith ST, and Teng JG, "Debonding failures in FRP-plated RC Beams with or without U strip end

anchorage" FRP Composites in Civil Engineering, vol. 1, pp. 607–615, 2001.

13. Ross CA, Jerome DM, Tedesco JW, and Hughes ML, "Strengthening of reinforced concrete beams with externally bonded composite laminates", ACI Structural Journal, vol. 96. No. 2, pp. 65-71, 1999.
14. Sebastian WM, "Significance of mid-span de-bonding failure in FRP-plated concrete beams", ASCE Journal of Structural Engineering, vol. 127, No. 7, pp.792-798, 2001.
15. Smith ST, and Teng JG, "FRP-strengthened RC beams I: Review of debonding strength models", Engineering Structures, vol. 24, No. 4, pp. 385-395, 2002.
16. Teng JG, Smith ST, Yao J, and Chen JF, "Intermediate crack-induced debonding in RC beams and slabs", Construction and Building Materials, vol. 17(6–7), pp. 447–462, 2003.