A Review On Reinforced Concrete Beams Using Glass Fiber Reinforced Polymer

Pradnyesh Hitendra Sakhare [1],Madhur Arun Tichkule [2],Suraj Digambar Raut [3],Sushil Ishwar Rane [4],Dhananjay Hemraj Lanjewar [5],Akash Vinodrao Barde [6], V.Yerpude [7]
[1,2,3,4,5,6] Student Final Year, Civil Engineering Department , Suryodaya College of Engineering and Technology , Nagpur
[7] Asst. Prof. Civil Engineering Department , Suryodaya College of Engineering and Technology , Nagpur

Abstract

The maintenance, rehabilitation and upgrading of structural members, is perhaps one structures constructed in the past using the older design codes in different parts of the world are structurally unsafe according to the new design codes. Since replacement of such deficient elements of structures incurs a huge amount of public money and time, strengthening has become the acceptable way of improving their load carrying capacity and extending their service lives. Infrastructure decay caused by premature deterioration of buildings and structures has lead to the investigation of several processes for repairing or strengthening purposes. One of the challenges in strengthening of concrete structures is selection of a strengthening method that will enhance the strength and serviceability of the structure while addressing limitations such as constructability, building operations, and budget.

Keyword- *fiber reinforced polymers, concrete structures, design*

INTRODUCTION

Only a few years ago, the construction market started to use FRP for structural reinforcement, generally in combination with other construction materials such as wood, steel, and concrete. FRPs exhibit several improved properties, such as high strength-weight ratio, high stiffness-weight ratio, flexibility in design, non-corrosiveness, high fatigue strength, and ease of application. The use of FRP sheets or plates bonded to concrete beams has been studied by several researchers. Strengthening with adhesive bonded fiber reinforced polymers has been established as an effective method applicable to many types of concrete structures such as columns, beams, slabs, and walls. Because the FRP materials are non-corrosive, non-magnetic, and resistant to various types of chemicals, they are increasingly being used for external reinforcement of existing concrete structures. From the past studies conducted it has been shown that externally bonded glass fiber-reinforced polymers (GFRP) can be used to enhance the flexural, shear and torsional capacity of RC beams. Due to the flexible nature and ease of handling and application, combined with high tensile strength-weight ratio and stiffness, the flexible glass fiber sheets are found to be highly effective for strengthening of RC beams. The use of fiber reinforced polymers (FRPs)

LITERATURE REVIEW

The history of bonded external reinforcement in the UK goes back to 1975 with the strengthening of the Quinton Bridges on the M5 motorway. This scheme followed a number of years of development work by the Transport and Road Research Laboratory (TRRL), (now TRL), in association with adhesive manufacturers and the Department of Transport. In terms of testing programmes, research and development work continued at the TRRL and at several academic institutions in the UK, most notably at the University of Sheffield. Theoretical investigations and the evaluation of suitable adhesives were allied to the extensive beam testing programmes which were undertaken. Preliminary studies were conducted by Irwin (1975). Macdonald (1978) and Macdonald and Calder (1982) reported four point loading tests on steel plated RC beams of length 4900mm. These beams were used to provide data for the proposed strengthening of the Quinton Bridges (Raithby, 1980 and 1982), and incorporated two different epoxy adhesives, two plate thicknesses of 10.0mm and 6.5mm giving width-to-thickness (b/t) ratios of 14 and 22, and a plate lap-joint at its centre. In all cases it was found that failure of the beams occurred at one end by horizontal shear in the concrete adjacent to the steel plate, commencing at the plate end and resulting in sudden separation of the plate with the concrete still attached, up to about mid-span. The external plate was found to have a much more significant effect in terms of crack control and stiffness. The loads required to cause a crack width of 0.1mm were increased by 95%, whilst the deflections under this load were stimulated further research work. Eberline et al. (1988) present a literature review on research 105% depending upon the type of adhesive used and the plate dimensions. The features of this work became the subject of a more detailed programme of research at the TRRL (Macdonald, 1982; Macdonald and Calder, 1982), in which a series of RC beams of length 3500mm were tested in four point bending. The beams were either plated as-cast or plated after being loaded to produce a maximum crack width of 0.1mm. The effect of widening the plate whilst maintaining its cross-sectional area constant was studied. It was found that the plated as-cast and the pre-cracked beams gave similar load/deflection curves, demonstrating the effectiveness of external plating for strengthening purposes.

EXPERIMENTAL SETUP

All the specimens were tested in the loading frame of the “Structural Engineering” Laboratory of National Institute of Technology, Rourkela. The testing procedure for the entire specimen was same. After the curing period of 28 days was over, the beam as washed and its surface was cleaned for clear visibility of cracks. The most commonly used load arrangement for testing of beams will consist of two-point loading. This has the advantage of a substantial region of nearly uniform moment coupled with very small shears, enabling the bending capacity of the central portion to be assessed. If the shear capacity of the member is to be assessed, the load will normally be concentrated at a suitable shorter distance from a support.

Two-point loading can be conveniently provided by the arrangement shown in Figure. The load is transmitted through a load cell and spherical seating on to a spreader beam. This beam bears on rollers seated on steel plates bedded on the test member with mortar, high-strength plaster or some similar material. The test member is supported on roller bearings acting on similar spreader plates. The loading frame must be capable of carrying the expected test loads without significant distortion(Ashtashil Bhambulkar et al., 2013,2015,2018,2020,2019). Ease of access to the middle third for crack observations, deflection readings and possibly strain measurements is an important consideration, as is safety when failure occurs. The specimen was placed over the two steel rollers bearing leaving 150 mm from the ends of the beam. The remaining 2000 mm was divided into three equal parts of 667 mm as shown in the figure. Two point loading arrangement was done as shown in the figure. Loading was done by hydraulic jack of capacity 100 KN. Three number of dial gauges were used for recording the deflection of the beams. One dial gauge was placed just below the center of the beam and the remaining two dial gauges were placed just below the point loads to measure deflections.

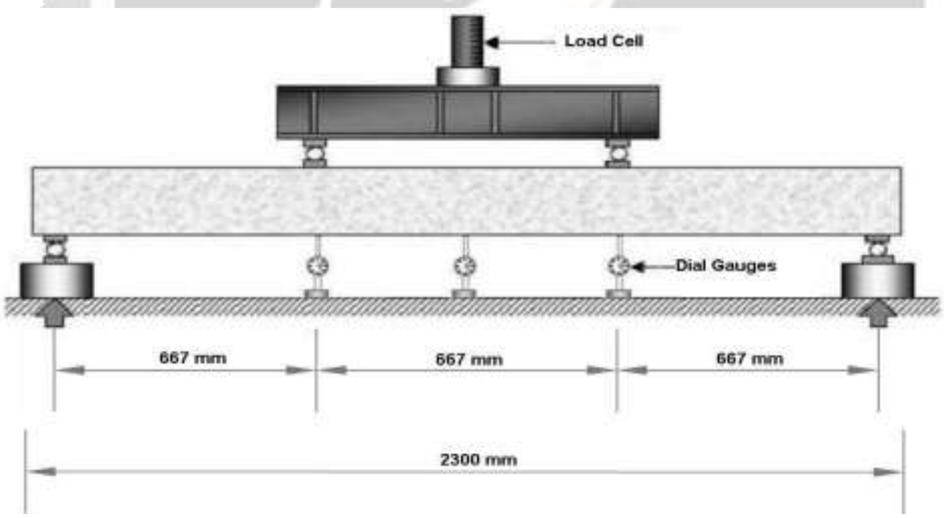

Fig. - Two point loading experimental setup

Flexural Strengthening Of Beams

To increase flexural strength, FRP fabrics are bonded as an external reinforcement on the tension side of steel-reinforced concrete beams with fiber orientation along the member length. Depending on the ratio of FRP reinforcement area to the beam's cross- sectional area and the area of internal steel reinforcement, the increase in flexural strength can be more than 100%. However, a flexural strength increase up to 50% would be more realistic, which depends on practical considerations such as the concrete member dimensions, serviceability limits, ductility, and effective thickness of FRP fabric reinforcement. The design philosophy of strengthening rectangular RC beams, is equally applicable to other shapes such as T- and I-sections having non-prestressed reinforcement.

RESULT AND DISCUSSION

Load Deflection History

From the load and deflection of data of set i beams f1, f2 and f3, load vs deflection curve is ploted for all the three beams. From this load vs deflection curve, it is clear that beam f1 has lower ultimate load carrying capacity compared to beams f2 and f3. Beam f1 had also undergone higher deflection compared to beams f2 and f3 at the same load. Beam f2 had higher ultimate load carrying capacity compared to the controlled beam f1 but lower than beam f3. Beam f3 had higher ultimate load carrying capacity compared to the beams f1 and f2. Both the beams f2 and f3 had undergone almost same deflection upto 65 kn load. After 65 kn load beam f3 had undergone same deflection as beam f2 but at a higher load compared to beam f2. The deflection undergone by beam f3 is highest. Beam f2 had undergone higher deflection than beam f1.

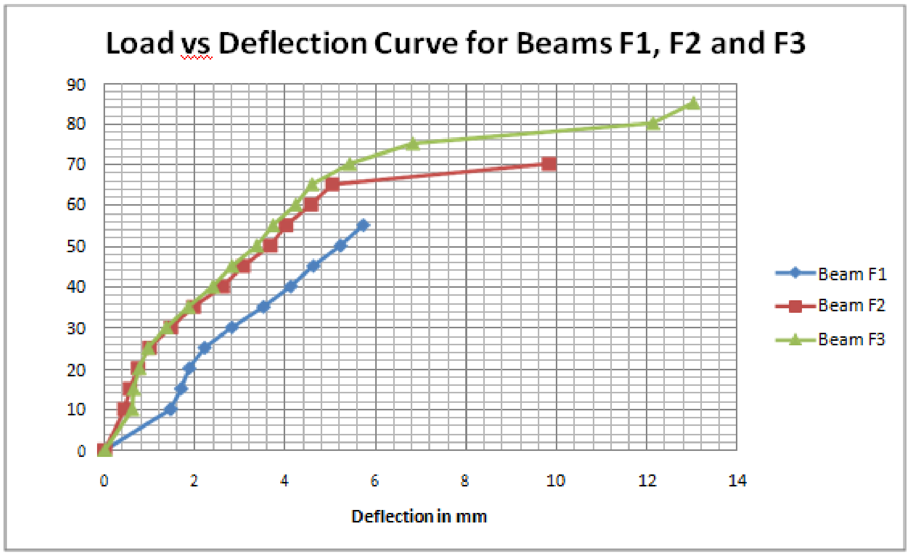

Fig. 5.4 Load vs deflection curves for beams f1, f2 and f3.

From the load and deflection of data of set ii beams s1, s2 and s3, load vs deflection curve is ploted for all the three beams. From this load vs deflection curve, it is clear that beam s1 has lower ultimate load carrying capacity compared to beams s2 and s3. Beam s1 had also undergone higher deflection compared to beams s2 and s3 at the same load. Beam s2 had higher ultimate load carrying capacity compared to the controlled beam s1 but lower than beam s3. Beam s3 had higher ultimate load carrying capacity compared to the beams s1 and s2. Both the beams s2 and s3 had undergone almost same deflection upto 70 kn load. After 70 kn load beam s3 had undergone same deflection as beam s2 but at a higher load compared to beam s2. The deflection undergone by beam s3 is highest. Beam s2 had undergone higher deflection than beam s1.

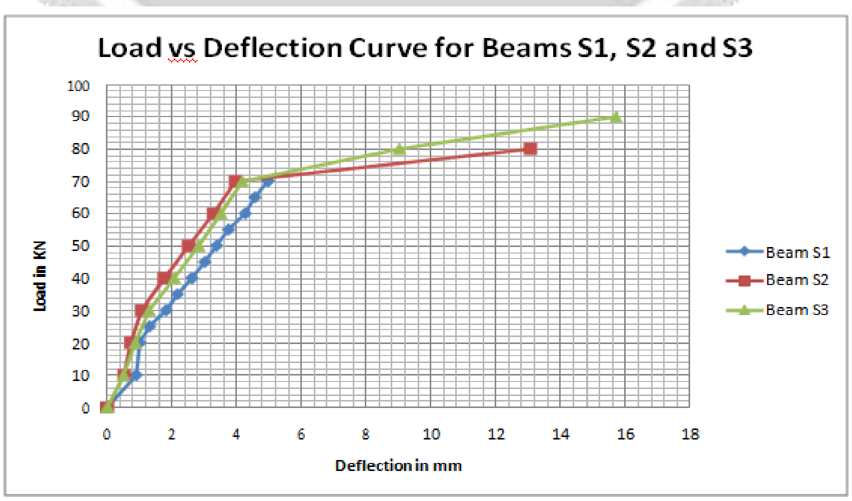

Fig. 5.8 Load vs deflection curves for beams s1, s2 and s3

Load At Initial Crack

Two point static loading was done on both set i and set ii beams and at the each increment of the load, deflection and crack development were observed. The load at initial cack of all the beams was observed, recorded and is shown in figure 5.9 and 5.10.

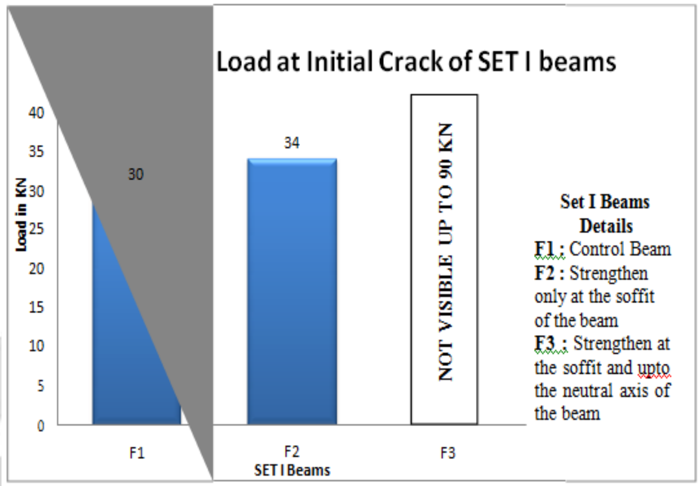

Fig. 5.9 Load at initial crack of beams f1, f2 and f3.

Under two point static loading of set i beams, at each increment of load, deflection and crack development were observed. In beam f1 initiation of the crack takes place at a load of 30 kn which is lower than beam f2 in which crack initiation started at 34 kn. The crack initiation of beam f3 was not visible due to application of gfrp sheet up to then eutral axis of the beam. The cracks were only visible after a load of 90 kn. Under two point static loading of set ii beams, at each increment of load, deflectionAnd crack development were observed. In beam s1 initiation of the crack takes place at aLoad of 35 kn which is lower than beam f2 in which crack initiation started at 39 kn and Further lower than beam f3 in which crack initiation started at 40 kn. There was not much Difference in load for crack initiation in beam s2 and s3.

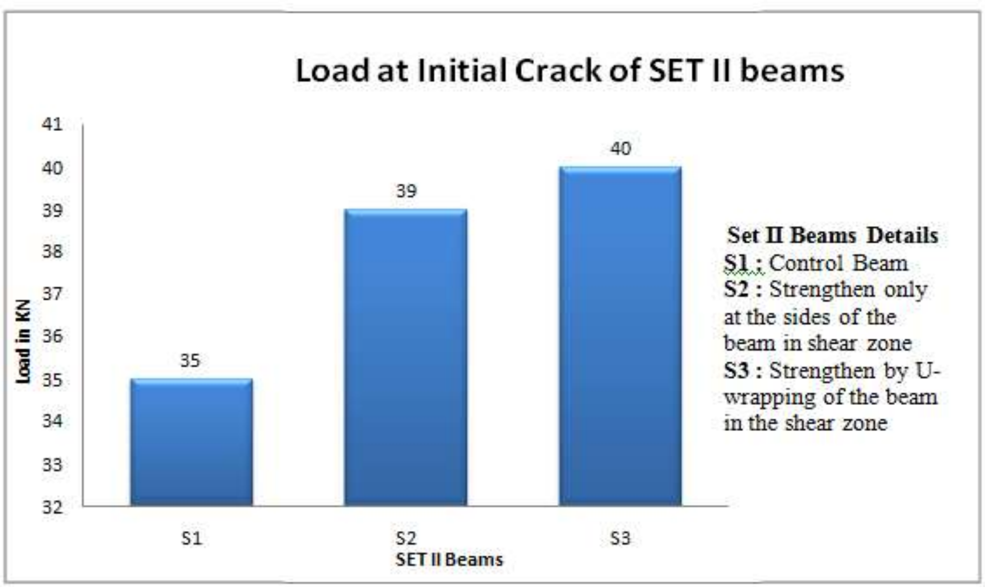

Fig. 5.10 Load at initial crack of beams s1, s2 and s3.

Ultimate Load Carrying Capacity

The load carrying capacity of the control beams and the strengthen beams were found out and is shown in fig. 5.11 and 5.12. The control beams were loaded up to their Ultimate loads. It was noted that of all the beams, the strengthen beams f2, f3 and s2, s3 ad the higher load carrying capacity compared to the controlled beams f1 and s1. An Important character to be noticed about the usage of gfrp sheets is the high ductile behaviour of the beams. The shear failure being sudden can lead to huge damage to the Structure. But the ductile behaviour obtained by the use of GFRP can give us enough warning before the ultimate failure. The use of frp can delay the initial cracks and further development of the cracks in the beam. Set i beams f1, f2 and f3 were loaded under two point static loading. As the load was increased incrementally development of cracks takes place and ultimately the beam failed. The ultimate load of f1 beam was 78 kn which is lower than f2 beam which carried an ultimate load of 104 kn and further lower than f3 beam which carried an ultimate load of 112 kN

Conclusions

1. Initial flexural cracks appear at a higher load by strengthening the beam at soffit. The ultimate load carrying capacity of the strengthen beam f2 is 33 % more than the controlled beam f1.
2. Analytical analysis is also carried out to find the ultimate moment carrying capacity and compared with the experimental results. It was found that analytical analysis predicts lower value than the experimental findings.
3. When the beam is not strengthen, it failed in flexure but after strengthening the beam in flexure, then flexure-shear failure of the beam takes place which is more dangerous than the flexural failure of the beam as it does not give much warning before failure. Therefore it is recommended to check the shear strength of the beam and carry out shear strengthening along with flexural strengthening if required.

References

1) Ahmed khalifa, antonio nanni “improving shear capacity of existing rc t-section beams using cfrp composites” cement & concrete composites 22 (2000) 165-174.
2) Ahmed khalifa, antonio nanni “rehabilitation of rectangular simply supported rc beams with shear deficiencies using cfrp composites” construction and building materials 16 (2002) 135–146.
3) Ahmed khalifa, william j. Gold, antonio nanni, and abdel aziz m.i. “contribution of externally bonded frp to shear capacity of rc flexural members” journal of composites for construction, vol. 2. No. 4, november,1998. 195-202
4) Alex li, cheikhna diagana, yves delmas “crfp contribution to shear capacity of strengthened rc beams” engineering structures 23 (2001) 1212–1220.
5) Ashtashil Bhambulkar et al., A Review on Eco Material Concrete” International Journal of Management, Technology And Engineering , Volume IX, Issue III, 2019, 5505-5508.
6) Ashtashil Bhambulkar et al., “A Review On Building By Manually Method And Softwear”, JETIR,Volume 7, Issue 5, 2020, 139-143.
7) Ashtashil Bhambulkar et al., “A Review Technique in Structure Health” International Journal of Management, Technology And Engineering , Volume IX, Issue III, 2019, 5509-5511.
8) Ashtashil Bhambulkar et al., “Analysis and Design of Falre Bridge” , International Journal Of Innovative Technology And Research, Volume No. 1, Issue No. 6, 2013, 588 - 590.
9) Ashtashil Bhambulkar et al., “Comparative Analysis On Various Properties Of Pervious Concrete With Conventional Concrete”, JETIR,Volume 7, Issue 5, 2020, 144-147
10) Ashtashil Bhambulkar et al., “Cost Optimization in Wastewater Treatment by Aquaculture”,International Journal of Advance Research in Science and Engineering, Vol 7, Issue 01, 2018, 627-629.
11) Ashtashil Bhambulkar et al.,“A Review Technique in Structure Audit” International Journal of Management, Technology And Engineering , Volume IX, Issue III, 2019, 5512-5514.
12) Ashtashil Bhambulkar et al.,“Application Of Gis In Transportation Engineering”, International Journal of Engineering Research and Applications (IJERA), Vol. 3, Issue 2, 2013, 540-542.
13) Ashtashil Vrushketu Bhambulkar ,“Effects of Leachate Recirculation on a Landfill” International Journal Of Advanced Engineering Sciences And Technologies, Vol No. 11, Issue No. 2, 286 – 291.
14) Ashtashil Vrushketu Bhambulkar ,“Municipal Solid Waste Collection Routes Optimized With Arc GIS Network Analyst”, International Journal Of Advanced Engineering Sciences And Technologies , Vol No. 11,

Issue No. 1, 202 – 207.

15) B. Taljsten and l. Elfgren "strengthening concrete beams for shear using cfrp- materials: evaluation of different application methods" composites: part b 31 (2000) 87–96.
16) Bjorn taljsten "strengthening concrete beams for shear with cfrp sheets" construction and building materials 17 (2003) 15–26.
17) D. Kachlakev and d.d. Mccurry "behavior of full-scale reinforced concrete beams retrofitted for shear and flexural with frp laminates" composites: part b 31 (2000) 445-452.
18) G. Spadea, f. Bencardino and r. N. Swamy "structural behavior of composite rc beams with externally bonded cfrp" journal of composites for construction vol. 2, no. 3. August, 1998. 132-137.
19) J. F. Bonacci and m. Maalej "behavioral trends of rc beams strengthened with externally bonded frp" journal of composites for construction, vol. 5, no.2, may, 2001, 102-113
20) Koji takeda, yoshiyuki mitsui, kiyoshi murakami, hiromichi sakai and moriyasu nakamura "flexural behaviour of reinforced concrete beams strengthened with carbon fibre sheets" composites part a 27a (1996) 981-987.
21) M. A. Shahawy, m. Arockiasamy, t. Beitelman, r. Sowrirajan "reinforced concrete rectangular beams strengthened with cfrp laminates" composites: part b 27b (1996) 225-233
22) N. F. Grace, g. A. Sayed, a. K. Soliman and k. R. Saleh "strengthening reinforced concrete beams using fiber reinforced polymer (frp) laminates" aci structural journal/september-october 1999. 865-875.
23) Thanasis c. Triantafillou and costas p. Antonopoulos "design of concrete flexural members strengthened in shear with frp" journal of composites for construction, vol. 4, no. 4, november, 2000. 198-205.
24) V.p.v. Ramana, t. Kant, s.e. Morton, p.k. Dutta, a. Mukherjee and y.m. Desai "behavior of cfrpc strengthened reinforced concrete beams with varying degrees of strengthening" composites: part b 31 (2000) 461-470.
25) Victor n. Kaliakin, michael j. Chajes and ted f. Januszka "analysis of concrete beams reinforced with externally bonded woven composite fabrics" composites: part b 27b (1996) 235-244.