International Journal of Innovative Research and Advanced Studies (IJIRAS)
Volume 4 Issue 4, April 2017

ISSN: 2394-4404

Flexural Behaviour Of R.C. Beams Wrapped With G.F.R.P. Laminates

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***Abstract:** Repair and strengthening of R.C beam is now becoming more and more important in the field of structural strengthening and retrofitting. Fiber reinforced polymer (FRP) externally bonding with epoxy resin is recently widely used in construction industry to increase the ultimate strength of structures. This paper presents the result of experimental studies carried out to get the effect of side bonded GFRP laminates to RC beams.*

The result indicates the strengthened beam by GFRP significantly increases more and more load carrying capacity as compared to reference GFRP to concrete surface. From this work, it is concluded that as deflection goes on increasing that is ultimate load directly varies with deflection. All strengthened beam gives sufficient warning compared to normal beam failure.

***Keywords:** Repairs GFRP (Glass Fiber Reinforced Polymers), Load Carrying Capacity, Side Bonded Beams, Flexural Strength, Configuration.*

I. INTRODUCTION

Civil Engineering structures are an important part of infrastructures and provide good service to the user; they experience distresses on account of reason and need of strengthening and retrofitting to bring them back to their originally intended service condition. Deterioration of concrete structures is one of the major problems of the construction industry today. Also a large numbers of structures constructed in the olden days using old design codes in different parts of world are structurally unsafe compared to today's codes. As replacement of total structure or part of the structure is uneconomical, time consuming therefore strengthening has become possible way of improving the load carrying capacity and extending life of structure. If the effective method is used for strengthening and retrofitting it is possible to bring structures back to their originally intended service usage, many modern techniques are involved to proper effective strengthening and retrofitting methods.

There is large need of strengthening of concrete structures all around the world. Strengthening of structures is often necessary under various circumstances such as loss of strength in structural members due to deterioration over time, changes in codal provisions, changes in earthquake zones, human errors in the initial construction, and increase in the applied loads. Strengthening of concrete members is usually accomplished by construction of external reinforced concrete or shot-Crete jackets, by post-tensioning, or by epoxy bonding of steel plates to the tension face of structural members.

This paper presents overview of currently used fiber materials, their properties, and techniques which are applicable for strengthening of R. C. beams and to study the flexural behavior of the reinforced concrete beams strengthening with side bonded configuration of glass fiber polymer and also effect of same on M20 concrete. The strengthening work includes assessment of the existing strength of the beams, enhancement required in strength, selection of the appropriate strengthening scheme.

A. OBJECTIVE OF PROPOSED WORK

- ✓ To calculate the flexural strength of RC beams using different configuration of externally bonded GFRP laminates.
- ✓ To find the effectiveness of externally bonded GFRP laminates on the strength of RC beams.
- ✓ Comparative study of strengthened beams.

B. PROPERTIES OF FRP

The main properties of Carbon, Aramid and E-Glass fibers as per manufacturer are given in Table 1.

Sr. No.	Property	Type of fiber		
		Carbo	Aramid	E-
1	Tensile Strength (MPa)	4300-4900	3200-3600	600-1800
2	Modulus of Elasticity	230 - 240	124 - 130	55 - 70
3	Strain at failure (%)	1.9 - 2.0	2.5 - 2.8	3.2 - 3.6
4	Specific gravity	1.76 - 1.78	1.44 - 1.46	2.56- 2.58
5	Poisson's ratio	0.2	0.35	0.2
6	Density	1800	1440	2560

Table 1: Properties of FRP

In the recent years, there have been considerable worldwide attentions among engineers for the fiber reinforced polymer (FRP) material in construction industry. These materials have high strength to weight ratio, excellent resistance to corrosion, chemical resistance, and non-magnetic, electrically non-conducting, light-weight and twice to four times as strong as steel in tension. It is relatively easy to use, fast, and results in small changes in structural size generally in the order of millimeters. These materials can be applied while the structure is in use and therefore it is expected to replace most of previous existing repairs and strengthening techniques.

II. EXPERIMENTAL SETUP

Beams were designed, so they are failed in flexure and strong in shear. To improve the capacity or performance level of a beam, it is necessary to strengthen or retrofit the beam in flexure. To improve the flexural strength, beams were retrofitted by side bonded GFRP laminate. To achieve the required aim, the experimental program has been made. Total 06 beams were cast. These beams were classified into three groups (two beams in each group). Out of these three groups, first group was made of reference beams. The remaining two groups were classified on the basis of different configuration of side bonded GFRP. bonded GFRP laminate. To achieve the required aim, the experimental program has been made. Total 06 beams were cast. These beams were classified into three groups (two beams in each group). Out of these three groups, first group was made of reference beams. The remaining two groups were classified on the basis of different configuration of side bonded GFRP.

Sr. No.	Configuration of G.F.R.P	Abbreviations	No. of beams	Tested for
1	Reference Beam(Without GFRP)	RB	02	Flexural strength & deflection
2	Tension Side bonded beam (100mm wide)	TB	02	Flexural strength & deflection
3	Both side Face bonded beam (150mm wide)	SB	02	Flexural strength & deflection

Table 3: Properties pf Materials

Sr. No.	Material	Cement	Aggregate		Steel	
	Property		Coarse	Fine	Mild	Tor
1	Specific Gravity	3.15	2.6	2.9	----	----
2	Compressive strength at 7 days (MPa)	51.2	----	----	----	---
3	Consistency	28%	----	----	----	---

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3	Consistency	28%	----	----	----	---
4	Initial setting time Final setting time	200min 275min	----	----	----	---
5	Water absorption	----	1.0 %	3.5 %	----	----
6	Free (Surface) Moisture	----	----	0.5 %	----	----
7	Yield Stress (MPa)	----	----	----	250	415

Table 3: Properties of Materials

Sr. No.	Property	Design standard
1	Characteristics compressive strength required in the field at 28 days	20 MPa
2	Maximum size of aggregate	12 mm
3	Degree of workability	0.90 Compacting factor
4	Degree of quality control	Good
5	Type of exposure	Mild

Table 4: Design Stipulation of Mix Design

A. DETAILS OF BEAM SPECIMEN

Four groups of specimens, each one of them consisting 1500mm long simply supported reinforced concrete beams with an effective span of 1300mm, were designed, constructed in the laboratory and tested under monotonic two point bending loading. The group of reference beams (RB) was designed to fail in flexure. The shear failure was avoided by reinforcing the beams with dense stirrups,

Φ6mm steel bars at 50mm centers at shear spans, all specimens were provided with this adequate transverse reinforcement to prevent shear failure.

Sr. No.	Content	Weight	Proportion
01	Water	196.5 lt	0.52
02	Cement	377.88 kg	1.00
03	Sand	740.18 kg	1.95
04	Aggregate	1045.20	2.77

Table 5: Proportions of Materials

B. TESTING PROCEDURE

The beam specimen setup is shown in the figure 2, beam was kept on loading frame for loading. The dial gauge was fixed at mid-span and 1/3 span from both ends of beam specimen and initial readings are noted.

The beam was then loaded to check the effectiveness of test setup. The beam is then subjected to loading through the 5 KN incremental loading stages up to the failure. Dial gauge readings were taken for all stages. Cracks formed on the faces of the beams were marked and identified.

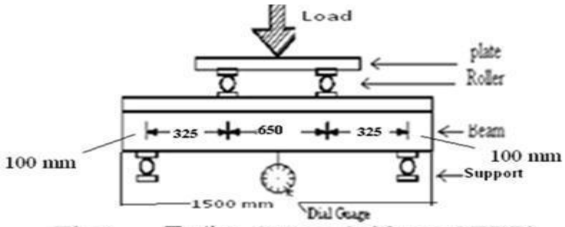

Fig.1 Testing Set up (without GFRP)

C. EXPERIMENTAL RESULTS

The experimental results and load deflection curves of reference and different GFRP configuration of side boned RC beams is as follows. The details are shown in Table 6 to 11 and figures 2 to 7.

Load	0	5	10	15	20	25	30	35	40	45	50
Avg. Defl	0.0	0.12	0.28	0.43	0.57	0.68	0.89	1.07	1.3	1.44	1.62
Load	55	60	65	70	75	80	85	90	95	100	
Avg. Defl	1.83	2.05	2.31	2.61	2.9	3.11	3.46	3.84	4.09	4.57	

Table 6: Reference Beam (RB)

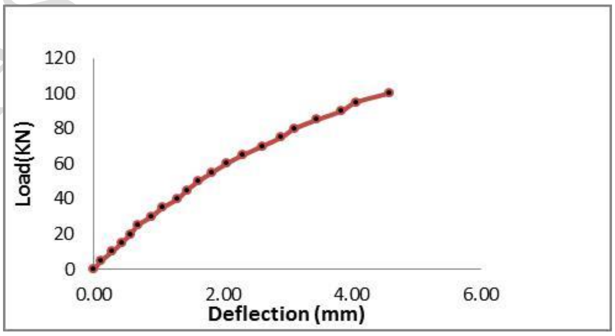

Figure 2: Load Vs. Deflection Curve For Reference Beam (RB)

Load	0	5	10	15	20	25	30	35	40	45	50	
Avg. Defl	0.0	0.08	0.33	0.61	0.95	1.2	1.44	1.79	2.14	2.52	2.82	
Load	55	60	65	70	75	80	85	90	95	100	105	110
Avg. Defl	3.21	3.67	4.17	4.60	5.05	5.5	5.9	6.29	6.75	7.2	7.6	8.03

Table 7: Tension Side Bonded Beam (Tb)

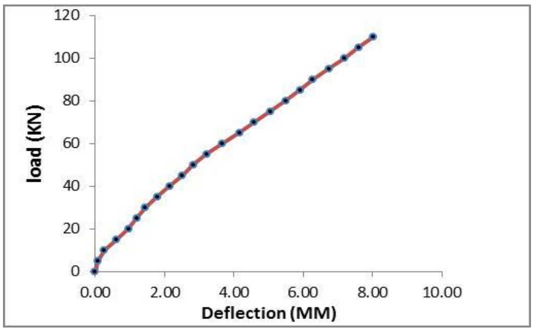

Figure 3: Load Vs. Deflection Curve for Tension Side Bonded Beam (Tb)

International Journal of Innovative Research and Advanced Studies (IJIRAS)
Volume 4 Issue 4, April 2017
ISSN: 2394-4404

Load	0	5	10	15	20	25	30	35	40	45	50	55
Avg. Defl	0.0	0.04	0.20	0.53	0.69	1.1	1.47	1.86	2.25	2.81	3.4	3.84
Load	60	65	70	75	80	85	90	95	100	105	110	
Avg. Defl	4.26	4.82	5.38	6.07	6.74	7.34	7.96	8.68	9.43	10.43	11.55	

Table 8: Both Side Face Bonded Beam (SB)

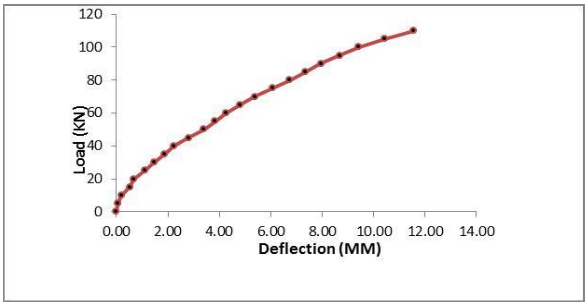

Figure 4: Load Vs. Deflection Curve For Both Side Face Bonded Beam (Sb)

Sr. No.	Configuration of G.F.R.P	Abbr.	Max. load KN	Avg. defl. In mm	Modeof failure
1	Reference Beam (Without GFRP)	RB	100	4.57	Flexural failure
2	Tension side bonded beam (100mm wide)	TB	110	8.03	Flexural failure+ Debonding
3	Both side face bonded beam (150mm wide)	SB	110	11.55	Flexural failure +Separation of GFRP

Table 12: Experimental Results of Different Configuration of GFRP Bonded Beam

III. RESULT COMPARISON

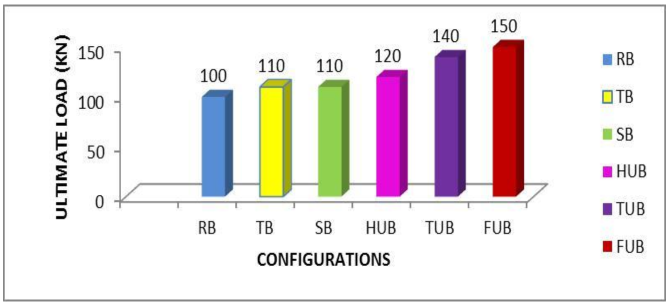

Figure 8: Variation in Ultimate Load for Different Configuration of GFRP Bonded Beams

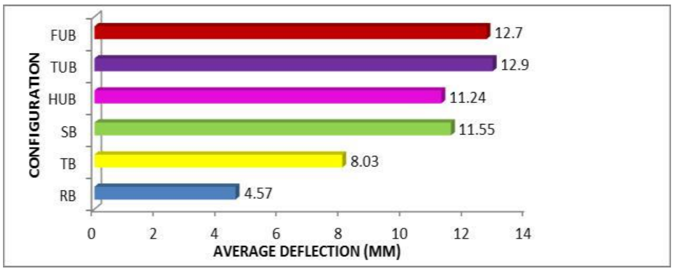

Figure 9: Variation in Average Deflection for Different Configuration of GFRP Bonded Beams

Sr. No	Configuration	Average deflection in mm	Percentage increase in Average deflection %
1	Reference beam	4.57	-
2	Tension side bonded beam	8.03	75
3	Side bonded beam	11.55	152

Table 13: Percentage Increase in Average Deflection

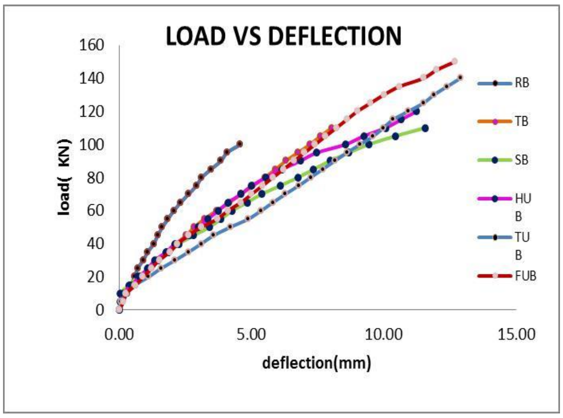

Figure 10: Load Vs Deflection Behaviour for Different Configuration of GFRP

IV. DISCUSSION AND CONCLUSION

A. DISCUSSION

The failure mode of the strengthened beams was observed due to GFRP debonding, concrete crushing and flexural failure. In each beam which is failed by GFRP debonding, the final crack pattern is similar to reference beam. The failure is mostly occur due to debonding of the GFRP from concrete surface with disintegration of concrete attached to it. The location of debonding area varied according to the type of configuration. Fig 10 shows ultimate load of all type of different side bonded configuration of GFRP.As compare to reference beam, ultimate load for failure of tension side bonded beam and side face bonded beam is increased by 10%.

B. CONCLUSIONS

- ✓ The load carrying capacity for the M20 grade concrete beams is increased by 50 % after strengthened with full U wrapping of GFRP compared with the reference beam.
- ✓ The deflection in 2/3 U and full wrapped beam is increased by 182 % and 177% respectively with respect to reference beam.
- ✓ From the experimental results it is observed that the increase in load carrying capacity and performance of concrete (deflection) is strongly depends upon the configuration of GFRP.
- ✓ The results of the experiments are very encouraging. It is concluded that bonding GFRP laminates is feasible method of upgrading the strength of reinforced concrete beams.

ISSN: 2394-4404

Experimental values of ultimate load of GFRP are more than theoretical values. As the load carrying capacity and deflection of full U wrapped GFRP beam is more than that of other configuration. It is most favorably accepted configuration for retrofitting.

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