EFFECT OF GFRP WRAPPING ON FLEXURAL BEHAVIOUR OF REINFORED CONCRETE BEAMS

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Abstract - *Strengthening of RC beams is necessary to obtain the expected life span of structures. Strengthening of RC beams using steel plates and FRP composites are most common globally. In order to minimize the disadvantages of steel , many researchers have tried various FRP composites such as Aramid, Glass and Carbon. Advantages given by this material is such as resistance against corrosion, high tensile strength, superior ductility, light weight, and absence of heavy additional equipment in application. Strengthening the structural members of old buildings using advanced materials is a contemporary research in the field of repairs and rehabilitation. The strengthening of the beams is done with different amount and configuration of GFRP sheets. This investigation deals with experimental study of retrofitted reinforced concrete beams using Glass Fiber Reinforced Polymer (GFRP). The effect of number of GFRP layers and its orientation on ultimate load carrying capacity and failure mode of the beams are investigated. Rectangular corrugated GFRP laminates are used for strengthening RC beams to achieve higher flexural strength and load carrying capacity.*

Key Words: Glass Fibre Reinforced Polymer, Epoxy Resin, Control Beam, Wrapping, Strengthening, Deflection

1.INTRODUCTION

All over the world there are structures intended for living and transportation. The structures are of varying quality and function. A structure is designed for a specific period and depending on the nature of the structure, its design life varies. Some of these structures are in such a bad condition that they need to be replaced. There is also a need for upgrading existing structures. As complete replacement or reconstruction of the structure will be cost effective, strengthening or retrofitting is an effective way to strengthen the same. The most popular techniques for strengthening of RC beams have involved the use of external epoxy-bonded steel plates, but it suffers from a serious problem of deterioration of bond at the steel and concrete interphase due to corrosion of steel. To eliminate these problems, steel plate was replaced by corrosion resistant and light-weight FRP Composite plates. FRPCs help to increase strength and ductility without excessive increase in stiffness. Beams are the critical structural members subjected to bending, torsion and shear in all type of structures. Similarly, columns are also used as various important elements subjected to axial load combined with/without bending and are used in all type of structures. concrete members can now be easily and effectively strengthened using externally bonded FRP composites. By wrapping FRP sheets, retrofitting of concrete structures provide a more economical and technically superior alternative to the traditional techniques in many situations because it offers high strength, low weight, corrosion resistance, high fatigue resistance, easy and rapid installation and minimal change in structural geometry. Fiber Reinforced Polymer(FRP) systems can also be used in areas with limited access where traditional techniques would be impractical.

2. METHODOLOGY

- Collection of the materials required for conducting the experiment.
- Testing of the materials to determine their properties.
- Concrete mix design.
- Curing of the beam specimen for 28 days.
- Testing of control beam under two-point loading with simply supported end conditions.
- Bonding of the GFRP strips to the sides of the beams varying the number of layers, type and wrapping styles of the strips.
- Testing of the GFRP bonded beams under two-point loading with simply supported end conditions.
- Analysis of the test results.

3.MATERIALS AND PROPERTIES

3.1 Cement

Ordinary Portland Cement (OPC) – 53 grade (Malabar Cement) was used for the investigation.

Table -1:

CEMENT PROPERTIES	
Grade	OPC 53 Grade
Manufacturer	Malabar Cements
Specific gravity	3.15
Fineness	8 %
Initial setting time	120 minutes
Final setting time	247 minutes
Standard consistency	27 %
Compressive strength	
7 days	35 N/mm^2
28 days	53 N/mm^2

3.2 Fine Aggregate

M- Sand was used through out the experiment. As per IS 2386-1963, the fine aggregate passing through 4.75 mm sieve and had a specific gravity of 2.6 was used. The grading zone of fine aggregate was zone II as per Indian Standard specifications.

3.3 Coarse Aggregate

Coarse aggregate are the crushed stone is used for making concrete. The maximum size of coarse aggregate was 20 mm and specific gravity of 2.65 subjected to as per IS 2386 -1963.

3.4 GFRP Sheet and Epoxy Resin System

The beam strengthening was conducted by using Chopped Strand Mat (300gsm). It's a type of glass fiber reinforced polymer(GFRP) and Isothalic resin was used as the bonding agent, because of its high mechanical property and chemical resistance.

3.5 Water

Potable water was considered for this experiment.

4.EXPERIMENTAL INVESTIGATION

4.1 Specimen Details

A total of Seven specimens of size (1800 x120x200)mm is used in this experiment. Out of seven beam specimen, one beam specimen served as control beam and the rest of six beam were strengthened in flexure by bonding with GFRP Sheet. The control beam was used to find the ultimate load carried and hence to compare the flexural capacity of GFRP bonded beams. Among the six beams the experimental variables considered were the number of layers of wrapping and type of wrapping.

Table -2:

GFRP WRAPPING CONDITIONS		
Sl.No	Condition	Abbreviation
1	U warpping	
	Single Layer	U1
	Double Layer	U2
	Tripple Layer	U3
2	Bottom wrapping	
	Single Layer	B1
	Double Layer	B2
	Tripple Layer	B3

Fig -1: Reinforced concrete beam specimen

Fig -2: Application of Epoxy Resin layer on specimen

Fig -3: Testing of U wrapped specimen (U3)

4.2 Reinforcement Details

Seven set of beams were casted for this experimental test program. In all set of beams, 10 mm φ bars are provided as the main longitudinal reinforcement and 8 mm φ bars are provided at top longitudinal reinforcement and 8 mm φ bars as stirrups at a spacing of 135 mm center to center.

Fig -4: Reinforcement details of the beam

4.3 Test Procedure

Before testing the member cured will be dried in the sun and will be white washed and kept for 24 hours prior to testing. The member will then be checked dimensionally, and a detailed visual inspection made with all information will be carefully recorded. After setting and reading all gauges, the load will be increased incrementally up to the calculated working load, with the loads and deflections recorded at each stage. Loads will then normally increased again in similar increments up to the failure, with deflection gauges replaced by a suitably mounted scale as that the failure approaches. This is necessary to avoid damage to gauges and although accuracy is reduced, the deflections at this stage will usually be large and easily measured from the distance. Similarly, cracking and manual strain observations must be suspended as failure approaches unless special safety precautions are taken. If it is essential then that precise deflection readings are taken up to collapse. Cracking and failure mode was checked visually, and a load v/s deflection plot was prepared.

5.RESULT AND DISCUSSIONS

It was observed that the Beam had less load carrying capacity when compared to that of the externally strengthened beams using GFRP sheets. Beam specimen of size (1800 x120x200)mm is used in the experiment, When the load was applied development of cracks was visible after applying load of 10 kN. The ultimate load carried by the control beam was 40 kN and deflection at ultimate load was 56 mm.

Beams wrapped with GFRP along the flexural span of the beam, by bonding along the bottom and U wrapping of beam cross-section was studied. Load deflection behaviour of the specimen were studied. The energy absorption capacity which is area under load deflection curve was also observed and the ductility factor which is ratio of deflection of at ultimate load to the yield load were studied. Comparison of results were made between all GFRP wrapped beam and control beam. GFRP beams showed better performance.

The improvement of ultimate load for bottom wrapping was more for three layers than that of double layer than that of single layer. The improvement in ultimate load was 25% for three layers than 12.5% that of double layer than 5% that of single layer respectively. Energy absorption capacity for bottom wrapping was more for three layers than that of double layer than that of single layer.

The improvement of ultimate load for U wrapping was more for three layers than that of double layer than that of single layer. The improvement of ultimate load was 42.5% for U wrapping for three layers than 22.5% that of double layer than 12.5% that of single layer respectively. Energy absorption capacity for U wrapping was more for three layers than that of double layer than that of single layer.

Among the bottom wrapped specimen and U wrapped shows better improvement in properties compared to controlled beam. The improvement in ultimate load was 14% for U wrapping compare bottom wrapped specimen. Energy absorption capacity, ductile factor and first crack load were higher for U wrapping. It was observed that deflection corresponding to ultimate load of controlled of

GFRP specimen and U specimen has lesser deflection compared to bottom wrapping. Deflection behaviour and the ultimate load carrying capacity of the beams were noted.

Table -3:

Details of Tested Beam Specimens			
Name of specimen	Ultimate Load (kN)	First Crack (kN)	Deflection (mm)
C.B	40	8	5.62
B1	42	11	5.75
B2	45	14	6.65
B3	50	18	6.88
U1	45	13	6.28
U2	49	16	6.76
U3	57	20	7.68

The results showed that the flexural capacity of GFRP wrapped beams increased as the number of layers of the GFRP sheets increased.

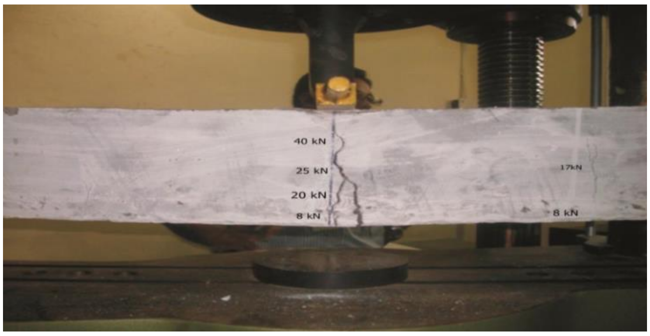

Fig -5: Flexural cracks for control beam specimen (CB)

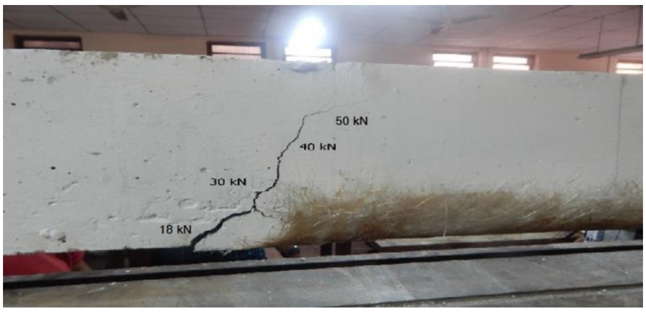

Fig -6: Flexural cracks for bottom wrapped layered specimen (B3)

5.1 Load Deflection Behaviour of Specimens

Using the data obtained from the experiment the load deflection plots were drawn. All the plots shows linear behaviour up to the formation of first crack. This is termed as pre cracking load. Beyond this point slope of the graphs decreases. This indicate the formation of multiple cracks and hence reduction in flexure rigidity of specimen. In this stage, deflection increases non linearly with load. The first batch of cracks was flexural cracks occurring in the mid span zone and as the load is increased a series of flexural cracks was formed in the shear span region. It then inclines to form flexural shear cracks joining the loading zone and zone outside the flexural strengthened region. The failure is mostly occurring due to debonding of the GFRP from concrete surface with disintegration of concrete attached to it.

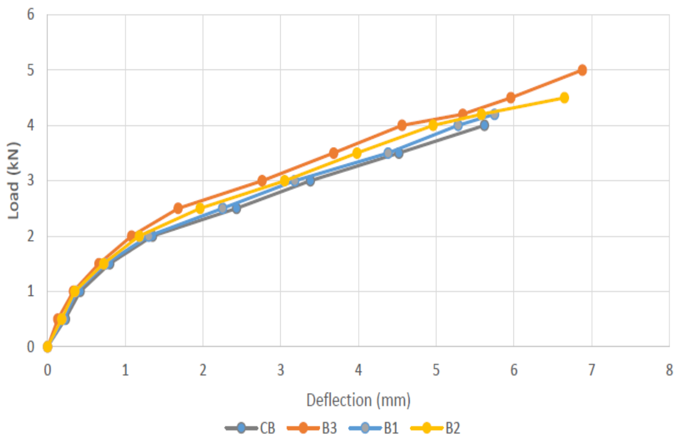

Chart -1: Load deflection curve for bottom wrapped specimen

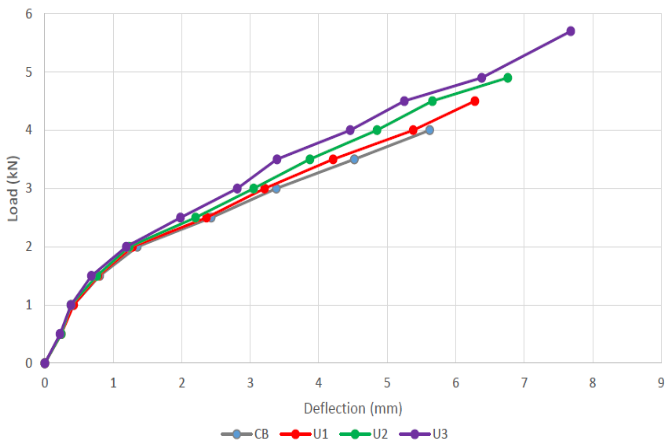

Chart -2: Load deflection curve for U wrapped specimens

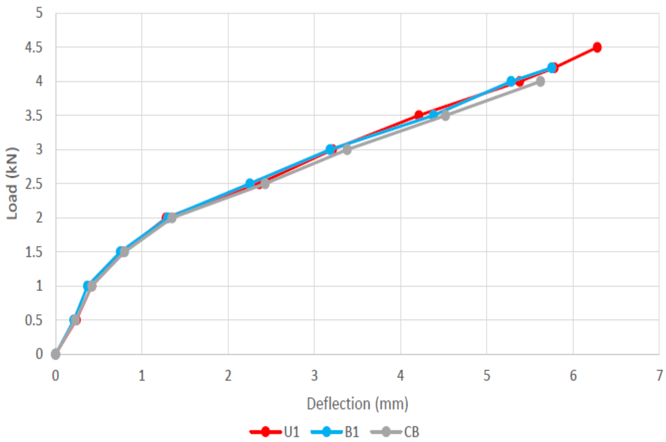

Chart -3: Load deflection curve for bottom wrapped and U wrapped single layered specimens

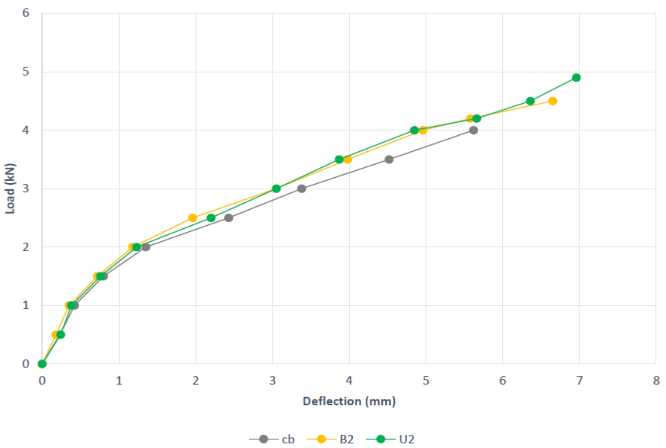

Chart -4: Load deflection curve for bottom wrapped and U wrapped double layered specimens

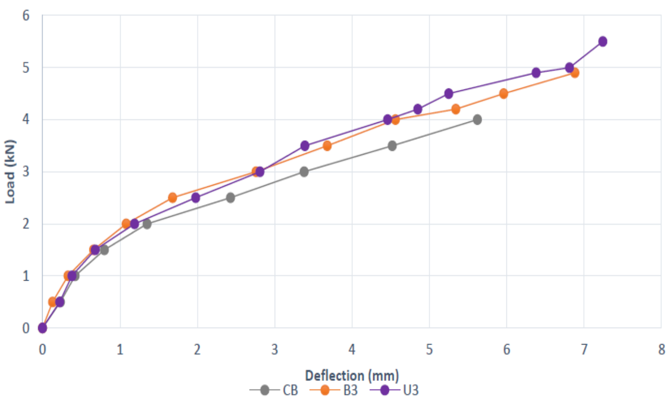

Chart -5: Load deflection curve for bottom wrapped and U wrapped three layered specimens

In the case of wrapped specimen, at the failure there was rupture and rebounding of glass fiber from the beam. The glass fiber reinforced polymer sheets inhibited the crack propagation, thereby improving the load carrying capacity of the specimen. The comparison of ultimate loads for the U wrapped and bottom wrapped specimen for single layer, double and triple layer.

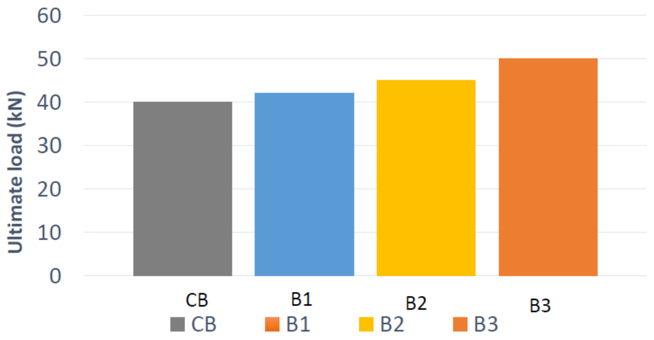

Chart -6: Comparison of ultimate loads for bottom wrapped specimen

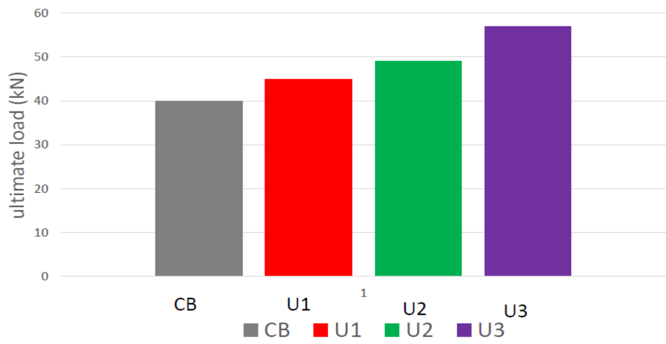

Chart -7: Comparison of ultimate loads for U- wrapped specimen

6.CONCLUSIONS

The major conclusions derived from this study are given as follows:

- The results obtained from this study indicate that there is a significant increase in the flexural strength which can be achieved by bonding GFRP sheets to the tension face of reinforced concrete beams.
- The extreme compressive strain of concrete fiber in the strengthened beams with increased number of GFRP layers remains more or less linear, up to failure of the beam and is not significantly affected by concrete cracking or yielding of the tension steel.
- The ultimate load carrying capacity of all the strengthen beams were enhanced as compared to the control beams where as in all, the ultimate deflection for control beam was found to be more than GFRP wrapped beam specimens.

- None of the beams except control beams showed flexure failure i.e. the beams showed increased strength in flexure. The failure pattern for strengthened beams was noticed in shear failure of the section along with delamination of GFRP below the crack towards support.

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