EXPERIMENTAL STUDY ON RETROFITTING OF RC BEAMS USING GLASS FIBER REINFORCED POLYMER SHEETS

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Abstract—Retrofitting the Reinforced Concrete (RC) framed structures have been magnifying these days globally. In order to have the upgradation towards the strength of the structural elements which are bounded externally using GFRP along with epoxy resin and hardener. The performance of conventional and retrofitted beams under weak in flexure condition are experimentally have been studied in this investigation. Total six beams were cast and in which three conventional and three retrofitted by reducing main reinforcement from 100% to 70% and 50%, to assess the flexural strength and damage level of the beams under weak in flexure condition. The symmetrical two-point loading arrangements have been applied along with span at a distance of L/3 on the beam. The results which are obtained in which the ultimate load carrying capacity of retrofitted beams are compared to conventional beams. The comparisons will made according to the experimental test results and the failure mechanism of beams.

Keywords—Glass fiber Reinforced polymer sheets, Retrofitting, Flexural Beam, two-point loading, Ultimate load carrying capacity of retrofitted beams.

I. INTRODUCTION

Retrofitting of existing Reinforced Concrete (RC) framed structures are become the major prominence in the construction domain these days. Many Reinforced Concrete (RC) framed structures located in zones of high seismicity in India are constructed without considering the seismic codal provisions. The vulnerability of inadequately designed structures represents seismic risk to occupants and this fact explains a strong social need to retrofit the existing building and upgrade the seismic code provisions. Hence, these structures need upgradation or retrofitting, which have become one of the thrust areas in structural engineering globally.

Retrofitting with Fiber Reinforced Polymers (FRP) to strengthen and repair damaged structures is a relatively new technique. Extensive researches are going on in the areas of application of FRP in concrete structures for its effectiveness in enhancing structural performance both in terms of strength and ductility.High strength fibers of glass, aramid and carbon are used as primary means of carrying load, while the polymer matrix protects the fibers and bind them into a cohesive structural unit. These are commonly called fiber – reinforced polymer composite materials. Now they are available in the form of rods, grids, sheets and winding strands.

II. METHODOLOGY

The material used for the retrofitting of RC beams was selected, collected. The resin and hardener used in this study were araldite LY 556 and hardener HY 917 were collected. The preliminary tests for cement, sand and coarse aggregate is done. The casting of beam is done as per the mix design with weak in flexural condition. After the curing process the specimen is retrofitted by using glass fiber reinforced polymer sheets. The symmetrical two-point loading arrangements have been applied along with span at a distance of L/3 on the beam. The results which are obtained in which the ultimate load carrying capacity of retrofitted beams are compared to conventional beams. The comparisons will made according to the experimental test results and the failure mechanism of beams.

III. MATERIAL SELECTION

3.1. Glass fiber reinforced polymer

Glass fibers are basically made by mixing silica sand, limestone, folic acid and other minor ingredients. The mix is heated until it melts at about 1260°C. The molten glass is then allowed to flow through fine holes in platinum plate. Glass is generally a good impact resistant fiber but weighs more than carbon or characteristics equal to or better than steel in certain forms.

PROPERTY	UNIDIRECTIONAL
Glass content (%)	60 – 90
Specific gravity	1.7 – 2.2
Tensile strength (MN/m^2)	530 – 1730
Tensile modulus (GN/m^2)	28 – 62
Compressive strength (MN/m^2)	310 – 480
Flexural strength (MN/m^2)	600 – 1800

Table 1.Properties of GFRP Sheets

3.2Adhesives and Properties

The Success of the strengthening technique critically depends on the performance of the epoxy resin used. The resin and hardener used in this study were araldite LY 556 and hardener HY 917.The purpose of the adhesive is to attach the composites to concrete surface.

Epoxy resin properties

Table 2.Properties of epoxy resin

SI NO	Properties	Araldite LY 556	Hardener HY 917
1	Aspect	Clear, pale yellow liquid	Clear liquid
2	Density at 25°C	1.15 – 1.20 (g/cm^3)	1.20 – 1.25 (g/cm^3)
3	Flexural strength	120 – 135 (Mpa)	

IV. BEAM PREPARATION

4.1 Mould preparation

Mix design is done as per IS: 10262 – 2009**.** The moulds are prepared with length of beam was 1000mm and the cross sectional dimensions were 160 mm x 150 mm. The dimensions of all the specimens were identical.

4.2 Mixing of concrete

After material procurement the next step is the process is to weigh the materials of the required quantity per meter cube. The volume of the beam is obtained as 0.024 m^3. Raw materials were weighed according to the design mix and poured into the tray.10% extra cement was used because of hand mixing. Firstly materials were mixed without water for some time till uniform texture was obtained. After that water was added slowly. Cement and sand mortar was used for finishing the top surface of beam.

4.3 Details of reinforcements:

The conventional beam designated as beam weak in flexure control specimen with 100% flexural reinforcement (BWFC100) and Retrofitted beam designated as beam weak in flexure retrofitted specimen with 100% flexural reinforcement (BWFR100). Two beams are casted one as controlled specimen and one for retrofitting with two numbers of 20 mm diameter bar at bottom and two bars of 16mm diameter bar as hanging bars with two legged stirrups of 8mm diameter bar at95mm c/c.

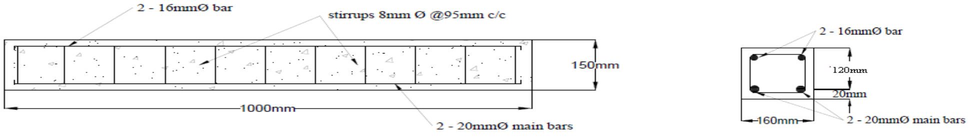


Figure 2. Detailing of BWFC100

The conventional beam designated as beam weak in flexure control specimen with 70% flexural reinforcement (BWFC70) and Retrofitted beam designated as beam weak in flexure retrofitted specimen with 70% flexural reinforcement (BWFR70). Two beams are casted one as controlledspecimen and one for retrofitting with two numbers of 16 mm diameter bar at bottom and two bars of 12mm diameter bar as hanging bars with two legged stirrups of 8mm diameter bar at 95mm c/c.

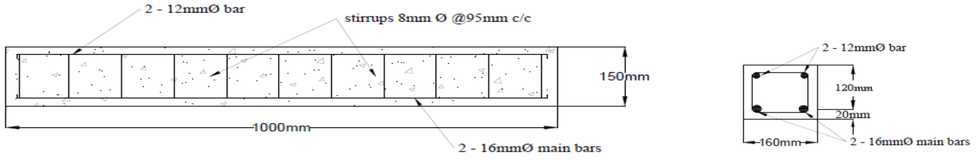


Figure 3. Detailing of BWFC70

The conventional beam designated as beam weak in flexure control specimen with 50% flexural reinforcement (BWFC50) and Retrofitted beam designated as beam weak in flexure retrofitted specimen with 50% flexural reinforcement (BWFR50). Two beams are casted one as controlled specimen and one for retrofitting with two numbers of 12 mm diameter bar at bottom and two bars of 10mm diameter bar as hanging bars with two legged stirrups of 8mm diameter bar at 95mm c/c.

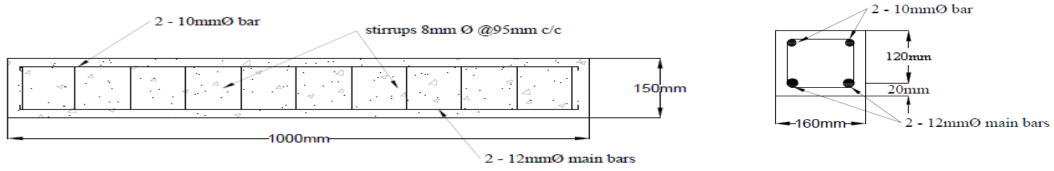


Figure 4. Detailing of BWFC50

4.4 Casting of beam

First the entire mould was oiled. So that the beams can be easily de-moulded from the mould after 24 hours. After placing the beam reinforcement cage in to the beam mould, the concrete mix which is mixed thoroughly need to be poured in to the beam mould in the form of layers.After filling of first two layers we need to place the vibrator or tamp by tamping rod inside the concrete in order to avoid air voids. And after filling the next layer of concrete mix again it is required to tamp to avoid the air voids. At last we need to level the top surface of the beam with the help of a trowel. The beams are needed to be demoulded within 24 hours. And after demould all the control and retrofitted specimens need to be covered with the help of gunny bags in order to perform curing up to 28 days.

4.5 Detailed process for fixing of GFRP

After the curing period is over. The concrete surface is made rough using a wire brush and then cleaned with water to remove all dirt. The beams are allowed to dry for 24 hours. The GFRP has to cut as per dimensions required for retrofitting. After cutting the GFRP sheet, the next step of the process is the mixture of epoxy resin and hardener with ratio of 1:5 have to be mixed thoroughly around for 10 to 15 minutes. Then applying on the cleaned surface of the beam at place where the GFRP have to be attached.

As per specifications and guidelines of the supplier of epoxy resins after application on the surface, pot life should be maintained around 30 minutes and then ensure that the epoxy solution is formed into sticky form. Then the GFRP need to be attached over the surface and roll the GFRP sheet with the help of steel roller in order to observe no air voids. All the three retrofitted beams were kept for 3 days at room temperature in order to gain the bonding strength.

Figure 5. Application of GFRP sheets

V. TESTING OF BEAMS

5.1 Experimental setup of beam

The control beams and the retrofitted beams were tested for the flexural strength. The testing procedure for the all the specimens was same. The surface of control beams is cleaned and washed for clear visibility of cracks. The two-point loading arrangement is used for testing of beams.. The test beam was supported on roller bearings acting as supports. The specimen was placed over the two steel rollers bearing leaving 50 mm from the ends of the beam. The remaining 900 mm was divided into three equal parts of 300 mm. Loading was done by hydraulic jack. Dial gauge was used for recording the deflection of the beams. The dial gauge was removed after the appearance of the crack and the load was further applied till fracture load. The ultimate load or fracture load was taken as the load at which the needle of load dial on the UTM returned back.

5.1.1Failure mechanism of conventional beams

5.1.1.1 Failure mechanism for BWFC100

The BWFC100 has been tested, and the ultimate load carrying capacity of beam was obtained as 120.78 kN and maximum deflection was 16.2 mm. The cracks were generated from the bottom surface of the beam and the major crack were obtained at the middle portion of the beam and it was observed that some of the shear cracks were also encountered, hence it can be stated that BWFC100 consists a failure mechanism of both flexural and -shear failure.

5.1.1.2Failure mechanism for BWFC70

The BWFC70 has been tested and the ultimate load carrying capacity was obtained as 98 kN and the maximum deflection was obtained as 14.54 mm. In this case, the beam was affected majorly due to flexural cracks and shear cracks. Also, the shear cracks were noticed near to the supports and propagates at an angel of 45^0 towards the compression zone, hence it can be stated that BWFC70 is obtained a combined failure of flexure and shear failure.

5.1.1.3 Failure mechanism for BWFC50

BWFC50 has been tested, and the ultimate load carrying capacity of beam was obtained as 78 kN and maximum deflection was obtained as 16.5 mm. As a parameter the percentage of main steel reinforcement has been reduced in this specimen from 100% to 50% to assess the flexural strength deficiency. The observed failure pattern of this specimen was purely flexural.

5.1.2 Failure mechanism of retrofitted beams

5.1.2.1 Failure mechanism for BWFR100

BWFR100 has been tested and the ultimate load carrying capacity was obtained as 165 kN and the maximum deflection was obtained as 12.5 mm. The beam was affected majorly due to shear cracks and fewer amounts of flexural cracks have been observed. Since, the BWFR100 was designed to resist flexural strength. It has been clearly observed that the retrofitting was helped to enhance the flexural strength.

5.1.2.2 Failure mechanism for BWFR70

BWFR70 has been tested and the ultimate load carrying capacity is obtained as 145 kN and maximum deflection was obtained as 11.66 mm. The beam was affected majorly due to shear cracks rather than flexural cracks because the beam was retrofitted at the tension surface of the beam in order to get resistance over flexure.

5.1.2.3 Failure mechanism for BWFR50

BWFR50 has been tested and ultimate load carrying capacity was obtained as 120 kN and the maximum deflection was obtained as 14.89 mm. Since the main reinforcement was reduced to 50% in this specimen. It can be observed that the GFRP was delaminated from the surface of the beam. Also, it can be observed that the sheet was tearing horizontally along the length. Few shear cracks were also observed.

VI. RESULTS AND DISCUSSIONS

. The comparison of conventional and retrofitted specimens is analyzed from the results.

6.1 LoadVs Deflection ResponseforBWFC100 andBWFR100

The Fig shows the comparison of flexural strength of BWFC100 and BWFR100. The load carrying capacity of BWFR100 is 36.7% greater than BWFC100 and the deflection was comparatively less with control beam having 100% main reinforcement. It indicates that the retrofitted beam has shown significant strength and stiffness with less magnitude of deflection.

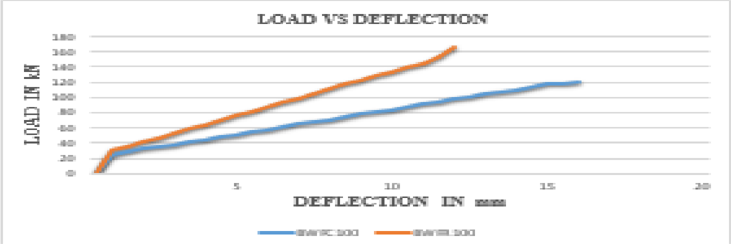


Figure 7.load v_s deflection for BWFC100 and BWFR100

6.2 Load Vs Deflection Response for BWFC70 AND BWFR70

The comparison of flexural strength of BWFC70 and BWFR70 is shown in Fig. The load carrying capacity of BWFR70 is 47.9 % greater than BWFC70 and the deflection was comparatively less with control beam having 70% main reinforcement. It shows that the retrofitted beam has significant strength and stiffness with less magnitude of deflection.

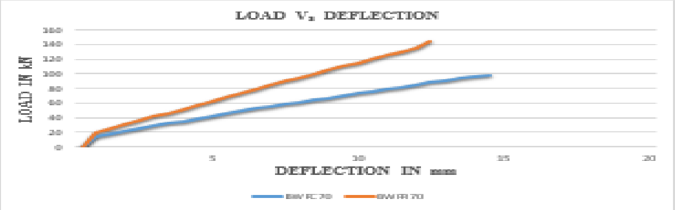


Figure 8.Loadvs deflection for BWFC70 and BWFR70

6.3 Load Vs Deflection Response for BWFC50 AND BWFR50

The comparison of flexural strength of BWFC50 and BWFR50 is shown in Fig. The load carrying capacity of BWFR50 is 53.84 % greater than BWFC50 and the deflection was comparatively less with control beam having 50% main reinforcement. It shows that the retrofitted beam has significant strength and stiffness with less magnitude of deflection.

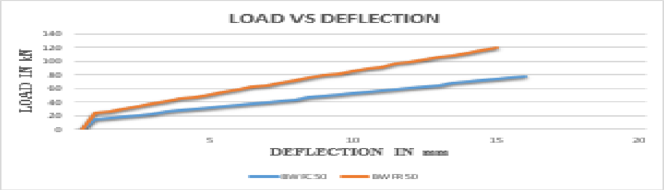
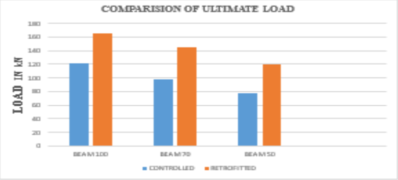


Figure 9. Load vs deflection for BWFC50 and BWFR50

6.4 Load Vs Deflection Response for Retrofitted specimen

The comparison of flexural strengths of three retrofitted specimen has been shown in Fig. The load carrying capacity of BWFR100 is greater than BWFC70 and BWFC50. The deflection was higher when compared to the BWFC70 and BWFC50**.**



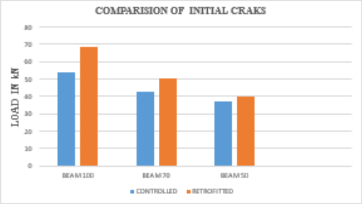


Figure 11.Comparison of Initial cracks Figure 12. Comparison of Ultimate loads

VII. CONCLUSION

The experimental study on control and retrofitted reinforced concrete beams using GFRP Sheets. As a parameter all beams made weak in flexure by reducing the main reinforcement from 100% to 70% and 50% have been studied and the beam failure mechanism also observed. From the rest results and calculated strength values, the following conclusions are drawn:

The load carrying capacity of retrofitted beams is significant when compared with control beams. The enhancements of flexural strength of retrofitted beams have been increased due to externally bonded GFRP.The visibility of flexural cracks has been noticed much higher in conventional beams when compared to the retrofitted beams at early intervals of load application. Few shear cracks were also noticed.The major shear cracks have been observed in BWFR100 at an ultimate load of 165kN.The delamination and flexural rupture of GFRP sheet was occurred in BWFR50 at an ultimate load of 120 kN.The ultimate load carrying capacity of BWFR100 was increased by 36.7% compared with BWFC100. The beam was affected majorly due to shear cracks and fewer amounts of flexural cracks have been observed. Since, the BWFR100 was designed to resist flexural strength. It has been clearly observed that the retrofitting was helped to enhance the flexural strength.The ultimate load carrying capacity of BWFR70 was increased by 47.9% compared with BWFC70.The ultimate load carrying capacity of BWFR50 was increased by 53.84% compared with BWFC50.The flexural strength and ultimate load carrying capacity of the retrofitted beams improved due to the external strengthening of beamsRetrofitting using GFRP sheets has been recommended in order to enhance the flexural strength of beams.

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