Journal of Civil Engineering and Environmental Technology
Print ISSN: 2349-8404; Online ISSN: 2349-879X; Volume 2, Number 8; April-June, 2015 pp. 649-653

http://www.krishisanskriti.org/jceet.html

Flexural Strengthening of Reinforced Concrete Beams Using Glass Fibre

N. Gokulnath[*1], G. Harri[2] and V. Hariharan[3]

[1,2]Student, Department of Civil Engineering, Dhirajlal Gandhi College of Technology, Salem, India
[3]Department of Civil Engineering, Dhirajlal Gandhi College of Technology, Salem, India
E-mail: [1]ngokul35@gmail.com, [2]sudharsann.92@gmail.com [3]hari.nayaky@gmail.com

Abstract—*This paper reveals the work associated with the behaviour of strengthening the pre-damaged reinforced concrete beams by using glass fibre reinforced polymer. The study presented here elaborates the mechanical properties of glass fibre with three different layers of reinforcements. GFRP ("E" glass fibre - chopped strand mat) laminates are introduced to enhance the overall performance of reinforced concrete beams. In this study eight beams of size 100mm width, 150mm depth and 1600mm overall length were cast and tested for flexure. Out of eight beams two beams were treated as control beams and the remaining six beams were loaded to a predetermined damage level, and strengthened by fastening GFRP laminates. Fastening of GFRP laminates onto the surface of the pre-damaged beam was done by using epoxy resin adhesive. The strengthened beams were again tested for ultimate load carrying capacity by conducting flexural test. A comparative study was made between the control beam and the pre-damaged beams strengthened by GFRP laminates. From the test results it could be seen that glass fibre reinforced polymer can be used as an alternative strengthening material for the reinforced concrete beams damaged due to overloading.*

Keywords: *CSM, GFRP, concrete beams, laminates, strengthening and epoxy resin.*

1. INTRODUCTION

Concrete is the most widely used construction material today. The constituents of concrete are coarse aggregate, fine aggregate binding material and water. The mixture of the materials results in a chemical reaction called hydration and a change in the mixture from plastic to a solid state occurs over a period of time. Rapid increase in construction activities leads to acute shortage of conventional construction materials. It is conventional that sand is being used as fine aggregate in concrete.

In any given nation major share of wealth is put into the construction of the infrastructures and buildings. It is economical to repair and rehabilitate the structures in distress after a considerable life span or damage due to faulty design or faulty construction or poor material or poor maintenance or due to other unforeseen causes than demolition and reconstruction. Rehabilitation of the structures is necessary either to stop deterioration or to arrest degradation. Rehabilitation program is a job of expert from the beginning and it should be carried out in a planned way and selection of repair program must be based upon full assessment of condition of the structure and facilities available. There is still a demand for large and full scale testing of structures. Physical testing plays a major role in the development of design methods. Distress in any structure whether it is a masonry or concrete or steel is inevitable due to various reasons such as weather, cyclones, earthquake and other natural calamities.

The deterioration of the material may take place over long periods of time and the durability of the material gets affected. To keep our heritage alive, these structures have to be maintained well for which repairs and rehabilitation play a dominant role. Epoxy resin is used as adhesive material.

Chopped strand mat is a non-woven reinforced material. It is manufactured by spreading continuous filament roving of 50mm in length, distributed it at random uniformly held together with powder or emulsion binder.

2. OBJECTIVE

The objective of this investigation is to study the effectiveness of GFRP sheets and the increase of the flexural strength of concrete beams by the Fibre-reinforced polymer (FRP). This study includes flexural testing of concrete beams strengthened with different layers of GFRP sheets.

- Calculating the effect of different layers of GFRP sheets on the flexural strength.
- To find whether chopped strand mat fibre is capable for use as a strengthening material.

The aim of the present investigation is limited to Small-scale beams of the particular size of 100 x 150 x 1600 mm length rectangular beam for strengthening purpose. The two point loading pattern is used to achieve the pure bending. The external bonding is made for the full length of the beam and it covers three faces of it (U wrapping).

3. MATERIALS USED FOR CASTING OF BEAMS

3.1 Cement

The cement used in this study was Ordinary Portland Cement of 53 grade with specific gravity of 3.12 as per (IS: 12269, 1987). The initial and final setting time was tested in laboratory at room temperature was 89 minutes and 410 minutes respectively.

Table 1: Properties of Cement

S No	Description	Result
1	Specific gravity	3.12
2	Fineness Modulus	4%
3	Consistency	34%
4	Water Absorption	0.5%

3.2 Fine Aggregate (FA)

Nearby available river sand is taken for using in this study, which is tested for specific gravity and fineness modulus is founded to be 2.58 and 2.62 respectively. The sand used in this study have to be pass through the IS sieve of size 4.75 mm and zone confirming zone II as per as per IS:383-1970.

Table 2: Properties of Fine Aggregate

S No	Description	Result
1	Specific gravity	2.613
2	Water Absorption	2.0%
3	Fineness modulus	2.72

3.3 Coarse Aggregate (CA)

The material were collected and cleaned for impurities. Particles of nominal size 20 mm were used and tested in the laboratory as per specifications recommended by IS:383-1970.

Table 3: Properties of Coarse Aggregate

S No	Description	Result
1	Specific gravity	2.625
2	Water Absorption	0.5%
3	Fineness modulus	6.15

3.4 Form Work

Steel mould of beam size is 100mm x 150mm and 1600mm long. The mould is thoroughly cleaned and all the corners and junctions were properly sealed to avoid leakage of concrete through small openings.

Fig. 1: Mould for beam with reinforcement

Shuttering oil was then applied to the inner face of the mould. The reinforcement cage is then placed in position inside the mould carefully keeping in view a clear cover of 20 mm for the top and bottom bars as shown in Fig.1

3.5 Chopped Strand Mat Fibre (CSM)

Chopped strand mat is a non-woven reinforced material. It is manufactured by spreading continuous filament roving of 50mm in length, distributed it at random uniformly held together with powder or emulsion binder.

Fig. 2: Chopped strand mat fibre

Table 4: Properties of CSM

S No	Description	Result
1	Specific gravity	1.4
2	Tensile strength	100MPa
3	Compressive strength	150MPa
4	Moisture content	=<0.2% (Emulsion binder)

4. DETAILS OF TEST PROCEDURE

In this test program eight rectangular reinforced concrete beams of dimensions 100mm width, 150mm depth and 1600mm overall span were cast and tested. The beams were reinforced with two numbers of 10mm diameter bars at the tension face, two numbers of 8mm diameter bars at the compression face and 6mm diameter bars as stirrups at 120 mm centre to centre.M20 grade concrete mix satisfying the ratio 0.48:1.0:1.68:2.89 was adopted for all the eight beams.Out of the eight beams two beams (CB1 and CB2) were designated as control beams and were tested for the ultimate load carrying capacity (Pu). The remaining six beams (BOL1 to BOL6), were pre damaged to a load of 60% of the ultimate load carrying capacity Pu of the perfect beams and were strengthened with glass fibre reinforced polymer laminates having three different layers reinforcements were used.

4.1 Procedure to bond GFRP

The surface was first cleaned to remove any dust particles. Then the surface was applied withthe mixed solution of epoxy resin, Then the properly cut Chopped Strand Mat was placed over thesurface and another coating of the mix was applied and then the specimen was left to dry for 10 hours,before testing.

Fig. 4: Wrapping of chopped strand mat

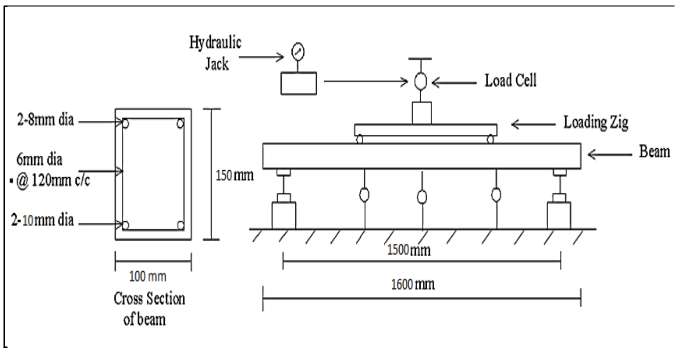


Fig.3 Loading Arrangement for beam

5. CASTING OF BEAMS

For casting of beams steel moulds satisfying the beam dimensions were used. The inner surface of the mould was spread with machine oil. The measured quantity of cement, fine aggregate and coarse aggregate were mixed thoroughly to obtain a uniform colour in the laboratory concrete mixer. The measured quantity of water was added to the dry mix and mixing was done properly. The steel reinforcement was placed inside the mould with proper cover. The concrete was poured into the mould in layer by layer. Each layer of concrete was compacted well using damping rod. The top surface of the concrete was finished well. The beam specimen was removed from the mould after 24 hours of casting and cured using wet gunny bags for28 days. The beams B1 and B2 were loaded up to failure Pu by subjecting the beam for two points loading and the general arrangement for testing the control beams and the pre-damaged rehabilitated beams were shown in Fig.1.The other six beams were damaged to the predetermined load of 60% of Pu. The pre-damaged beams were again strengthened using GFRP laminates.

6. TESTING OF BEAMS

Before testing the member was checked dimensionally and visual inspection made with all information carefully recorded. After setting the beam in the loading frame the load was increased up to the failure of beam and deflection was recorded at each stage and a load/deflection plot was prepared.

Fig. 5: Experimental setup for testing of beam

7. EXPERIMENTAL PROGRAMME

Eight beams were cast for flexural test, and are grouped into four series.The first series of two beams were designated as control beams (CB1 and CB2) and tested for ultimate failure load (Pu) and was observed as 32kN. The second, third and fourth series of beams were designated as BOL1, BOL2 and BOL3, BOL4 and BOL5, BOL6 respectively. They were tested for a pre-determined load of 60%Pu and rehabilitated with GFRP laminates of different layers are arranged in a standard manner.

Table 5: Experimental results

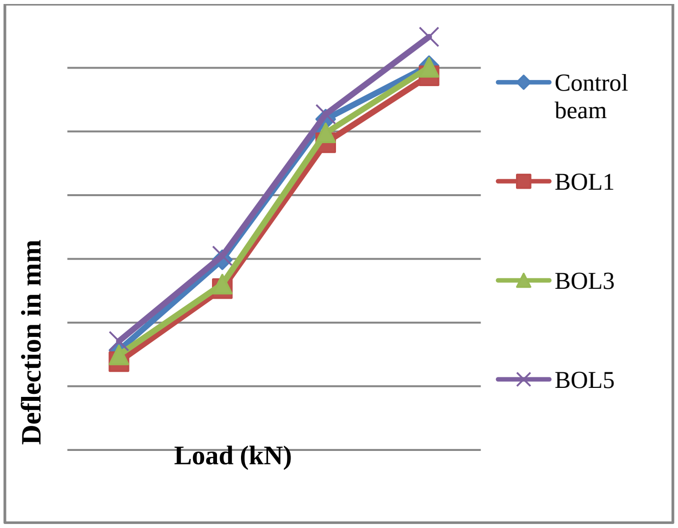
S No	Beam code	Beam designation	Pre-damaged level	First crack load	Ultimate load
1	CB1 & CB2	Control	----	13	32
2	BOL1 & BOL2	Pre-damaged	60%Pu	15	34
3	BOL3&BOL4	Pre-damaged	60%Pu	14	33
4	BOL5&BOL6	Pre-damaged	60%Pu	14	33

Two-point loading system was adopted to test the control beams and also for the pre-damaged rehabilitated beams as shown in Figure 4. The first crack load and the ultimate load were observed and entered in Table 5. For each load increment of 2.0 kN, the central deflection was carefully observed, and the deflection at 10kN, 20kN, 30kN, the deflection corresponding to the ultimate load of the perfect beam Pu, and the deflection corresponding to the ultimate load of the pre-damaged rehabilitated beams were recorded and tabulated in Table 5.

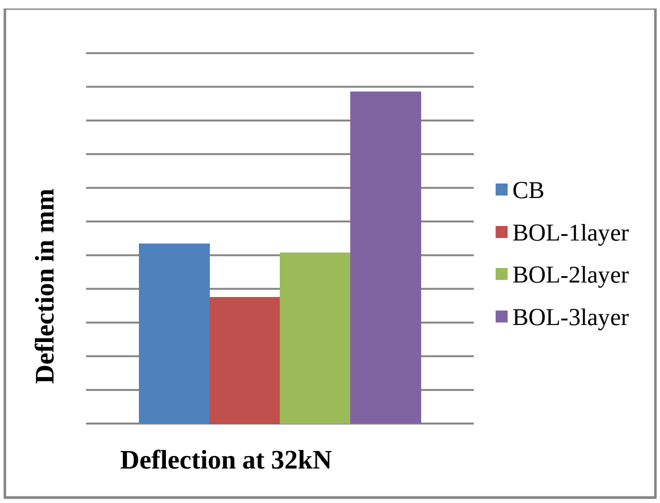
Table 6: Deflection at various stages of loading

S No	Beam code	Beam designation	Deflection in mm at various stages of loading				
			10kN	20kN	30kN	Pu = 32kN	Ultimate
1	CB1 & CB2	Control	7.82	14.93	25.97	30.17	-----

2	BOL1 & BOL2	Pre-damaged	6.93	12.67	24.12	29.38	34.24
3	BOL3& BOL4	Pre-damaged	7.46	13.02	24.89	30.04	36.47
4	BOL5& BOL6	Pre-damaged	8.54	15.24	26.36	32.43	39.80



Graph 1: Load Deflection Curve



Graph 2: Deflection at ultimate load

A comparative study on the load carrying capacity was made on the performance of all the pre-damaged rehabilitated beams with the performance of the control beam. The deflection performance of the control beam, and the pre-damaged rehabilitated beams were grouped according to the amount of volume fraction at different stages of loading are observed and entered in Table.6. Graph 1 shows the comparative representation of deflection of rehabilitated beams with control beams at different stages of loading. Graph 2 shows the comparative representation of deflection of rehabilitated beams with the ultimate load.

8. DISCUSSION

The test results are summarized in Table 5, Table 6 and graphically represented in Graph 1 and Graph 2. It shows the comparative representation of all the eight beams grouped in series, distressed by 60%P_u and rehabilitated by GFRP laminates having three different layers of reinforcement. From the graph it was observed that the load carrying capacity of the rehabilitated beams at the initial cracking stage and the ultimate stage increases by 13% and 10% with respect to control beams, particularly for the beams rehabilitated with GFRP laminates of single layer. Similarly there was a good reduction of 18.4% in deflection of the pre-damaged rehabilitated beams with respect to control beams at the ultimate stage. The beams rehabilitated by GFRP laminates of single layer exhibits good performance in load carrying capacity as well as showed good reduction in deflection in comparison with beams rehabilitated with GFRP laminates of two and three layer.This increase in load carrying capacity and reduction in deflection is due to the addition of GFRP laminate which increases the cross sectional area, thereby increasing the moment of inertia and stiffness of the beam sections.

9. CONCLUSION

The application of GFRP layer has given adequate confinement for the reinforced concrete beams. Hence during testing of beams, splitting of concrete did not occur for the beams rehabilitated by bonding of different layer. The addition of GFRP laminate in pre-damaged beams increases the stiffness of the beam and hence increases in load carrying capacity and reduction in deflection. Moreover the bonding of GFRP laminate by plate bonding technique has less labour involvement and is cheaper compared to other methods of strengthening the distressed beams available.

REFERENCES

[1] K L Muthuramu., A Chandran., S Govindarajan, and S Karunanidhi, (2010), ‘Strengthening Of Reinforced Concrete Elements Using Glass Fibre’, 35thConference on Our World In Concrete & Structures: 25 - 27 August 2010, Singapore.

[2] NamasivayamAravind., Amiya K. Samanta., D. K. Singha Roy and Joseph V. Thanikal (2013), ‘Retrofitting Of Reinforced Concrete Beams Using Fibre Reinforced Polymer (FRP) Composites – A Review’, Journal of Urban and Environmental Engineering, vol.7, n.1, p.164-175.

[3] ShoeibSoliman Ata Elkareim. and Osman Moustaf (2011), ‘Experimental Analysis Of R.C. Beam Strengthened With Discrete Glass Fiber’, Architecture and Civil Engineering Vol. 9, No 2, 2011, pp. 205 – 215.

[4] N. ATTARI., S. AMZIANE. and M. CHEMROUK (2008), ‘Strengthening Reinforced Concrete Beams Using Hybrid FRP Laminates’, Fourth International Conference on FRP Composites in Civil Engineering (CICE2008) 22-24 July 2008, Zurich, Switzerland.

[5] Murali G. and Pannirselvam N. (2011), 'Flexural Strengthening Of Reinforced Concrete Beams Using Fibre Reinforced Polymer Laminate: A Review', ARPN Journal of Engineering and Applied Sciences, Vol. 6, No. 11, ISSN 1819-6608.
[6] Ahmad Abdel Hamid., HanyElshafie., El-Sayed Nasr. andEzatFahmy. (2007), 'Retrofitting Of Reinforced Concrete Beams Using Advanced Composite Overlays'.
[7] Ma'en S. Abdel-Jaber., Ani]s S. Shatanawi and Mu'tasim S. Abdel-Jaber (2007), 'Guidelines for Shear Strengthening of Beams Using Carbon Fibre-Reinforced Polymer (FRP) Plates', Jordan Journal of Civil Engineering, Volume 1, No. 4, 2007.
[8] Revathy J. and Sriraman M. (2014), 'Structural Response of FRP Strengthened Post-Tensioned Concrete Beams', Research Journal of Recent Sciences, Vol. 3(ISC-2013), 198-202 (2014).
[9] N. Pannirselvam., P.N. Raghunath and K.Suguna (2008), 'Strength Modeling of Reinforced Concrete Beam with Externally Bonded Fibre Reinforcement Polymer Reinforcement', American J. of Engineering and Applied Sciences 1 (3): 192-199, 2008.
[10] Sandeep G. Sawant, A. B. Sawant, M. B. Kumthekar (2013), 'Strengthening of R.C.C. Beam- Using Different Glass Fiber', International Journal of Inventive Engineering and Sciences (IJIES) ISSN: 2319–9598, Volume-1, Issue-2, January 2013.
[11] R.S.Ravichandran., K. Suguna and P.N. Raghunath (2012), 'Flexural Behaviour of Composite High Strength Concrete – Fibre Reinforced Polymer Beams', IJCSET, January 2012, Vol.2, Issue 1,839-842.