Strength Study of RCC Beams Retrofitted Using Different Fiber Reinforced Polymer (FRP)

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***Abstract*—Throughout the world many existing reinforced concrete structure are under need of repair or rehabilitation due to the various deterioration factors like environmental effects, revision in loading standards, seismic retrofitting, corrosion, lack of reinforcement detailing etc leading to failure of bonding between beam-column, increase in deflection limits. As Fiber Reinforced Polymer (FRP) composite incrementing the strength of RCC structures due to its outstanding properties such as high strength to weight ratio, resistance to corrosion and fire, higher fatigue strength and impact energy absorption capacity. This paper focuses exclusively on behaviour of RCC beams strength using the Vinyl-Ester bonded GFRP and Epoxy bonded GFRP wrapped retrofitting. Ultimate load carrying capacity, deflection and cracking are analysis experimental. An effort has been made in this paper to represent the collective contributions of researchers and to focus on the type of beam gaining maximum enhancement in shear strength with use of FRP laminates. The paper also represents the effect of different parameters on the strength of beams strengthened externally with FRP sheets or strips. It was concluded that the wrapping of FRP sheets increases the ultimate load carrying capacity of RCC beams.**

Keywords—FRP; Vinyl Ester Bonded GFRP; Epoxy bonded GFRP; Shear Strength; RCC Beams

I. INTRODUCTION

This Retrofitting of shear concrete elements are accomplished by externally bonding or wrapping steel plates or wires to concrete. This technique has proved to be effective in increasing ultimate strength and stiffness of reinforced concrete elements. In the last decade, the development of strong epoxy glue has led to a technique which has great potential in the field of retrofitting structures. Basically the technique involves pasting steel plates or fiber reinforced polymer (FRP) to the surface of the concrete. These plates then act monolithically with the concrete. FRP can be convenient compared to steel for a number of reasons. These materials have higher ultimate strength and lower density than steel. The installation is easier and temporary support for fixing is not required due to the low weight. They can be formed on site into complicated shapes and can also be easily cut to length on site. FRP composites are different from traditional construction materials such as steel or aluminum. FRP composites are anisotropic (properties apparent in the direction of the applied load) whereas steel or aluminum is isotropic (uniform properties in all directions, independent of applied load). Therefore, FRP composite properties are directional, meaning that the best mechanical properties are in the direction of the fiber placement. Composites are similar to reinforced concrete where the rebar is embedded in an isotropic matrix called concrete. FRP composites possess some outstanding properties such as: resistance to corrosion, good fatigue and damping resistance, high strength to weight ratio, and electromagnetic transparency. FRP has found an increasing number of applications in construction either as internal or as external reinforcement for concrete structures. Civil structures made of steel reinforced concrete are normally susceptible to environmental attacks that lead to the initiation of an electrochemical process which leads to the corrosion of steel reinforcement. Constant maintenance and repairing is needed to enhance the life cycle of those structures.. The use of FRP bars as an internal reinforcement for concrete bridge decks and also girders provides a potential for increased service life, economic and environmental benefits. In this paper beams were retrofitted with 1.2 mm Epoxy bonded GFRP sheets and 0.9 mm Vinyl-Ester bonded GFRP sheets using epoxy resins. In all a total of 6 beams were tested and the respective readings were recorded. The beams were full-wrapped and tested for shear behavior analysis. [1]

II. MATERIAL COMPOSITION

Polymer composites are heterogeneous materials resulting from the combination of different constituents, including high-performance fibers, polymer matrix and various fillers and additives. Fibers exhibit high tensile strength and stiffness and are the main load carrying element. Resin offers high compressive strength and binds the fibers into a firm matrix. Additives help to improve the mechanical and physical properties as well as the workability of composites. Glass fiber reinforced polymer (GFRP) is used for investigation purpose of retrofitting beam. Following are some of the characteristics of this versatile fiber. Glass fiber reinforced polymer (GFRP), also known as glass fiber reinforced plastic is a fiber made of a plastic matrix reinforced by fine fibers made of glass. The plastic matrix used is epoxy or thermoplastic. The GFRP is the least expensive but has lower strength and significantly lower stiffness compared to other alternatives. The glass fibers are divided into three classes -- E-glass, S-glass and C-glass. The E-glass is designated for electrical use and the S-glass for high strength. The C-glass is for high corrosion resistance, and it is uncommon for civil engineering application. Out of the three fibers, the E-glass is the most common reinforcement material used in civil structures. It is produced from lime-alumina-borosilicate, which can be easily obtained from abundance of raw materials like sand. The fibers are drawn into very fine filaments with diameters ranging from 0.002 to 0.013mm. The glass fiber strength and modulus can degrade with increasing temperature. Although the glass material creeps under a sustained load, it can be designed to perform satisfactorily. The fiber itself is regarded as an isotropic material and has a lower thermal expansion coefficient than that of steel.

TABLE-II FRP Materials

S.no	Constituents	Characteristic
1	Vinyl ester bonded fiber reinforced polymer	Plastic matrix
2	Unsaturated Polyesters	Polymerization of dicarboxylic acid
3	Epoxies	Glycidyl ethers and amines.
4	Vinyl Esters	Workability of the epoxy resins and the Fast curing of the polyesters
5	Polyurethanes	Polyisocyanate and Polyol
6	Phenolics	Phenols and Formaldehyde

III. SPECIMEN AND TEST SET-UP

A. *Casting of test Beams*

A total of six simply supported beams were tested. All beams were of rectangular cross section 100mm wide and 500mm deep with 2 bars of 8 mm diameter as longitudinal reinforcement at top and 2 bars of 10 mm diameter as longitudinal reinforcement at bottom of beam section. The test specimens were divided into three series, namely, series A for controlled beam, series B for Vinyl Ester Bonded GFRP upto length of L/4 from both ends and at center length of L/2 Epoxy bonded GFRP and series C for Vinyl Ester Bonded GFRP at center length of L/2 from both ends and Epoxy bonded GFRP upto length of L/4 from both ends. Each series consisted of two beams as testing specimens. The material chosen are concrete compressive strength Fck=20 N/mm^2 and the grade of steel chosen is Fe 415 N/mm^2.As to study the increase in the shear strength of the beams after retrofitted with Vinyl Ester bonded Glass Fiber Reinforced Polymer beams are designed in such a manner that they are deficient in shear and hence fail in shear therefore detailing of the shear Reinforcements is done as each 2 Legged 6mm dia stirrups at 90 mm C/C. (Figure-1)

B. *Experimental Arrangement*

Use All the Six beams are tested under simply supported end conditions .Two point loading is adopted for testing. The testing of beams is done with the help of hydraulic operated jack connected to load cell. The load is applied to the beam with the help of hydraulic jack and the data is recorded from the data acquisition system which is attached with the load cell. The value of deflection is also obtained from the data acquisition system. Out of these six beams 2 are control beam which are tested after 28 days of curing to find out the safe load which is taken as load corresponding to deflection of L/250 i.e. 15 mm. When the beams are tested, shear cracks are seen over the beam which shows that they are failing in shear. Two beams of series A as Controlled Specimens, two beam of series B as Vinyl Ester Bonded GFRP upto length of L/4 from both ends and at center length of L/2 Epoxy bonded GFRP and two beams of series C as Vinyl Ester Bonded GFRP at center length of L/2 from both ends and Epoxy bonded GFRP upto length of L/4 from both end tested for shear. (Figure-2)

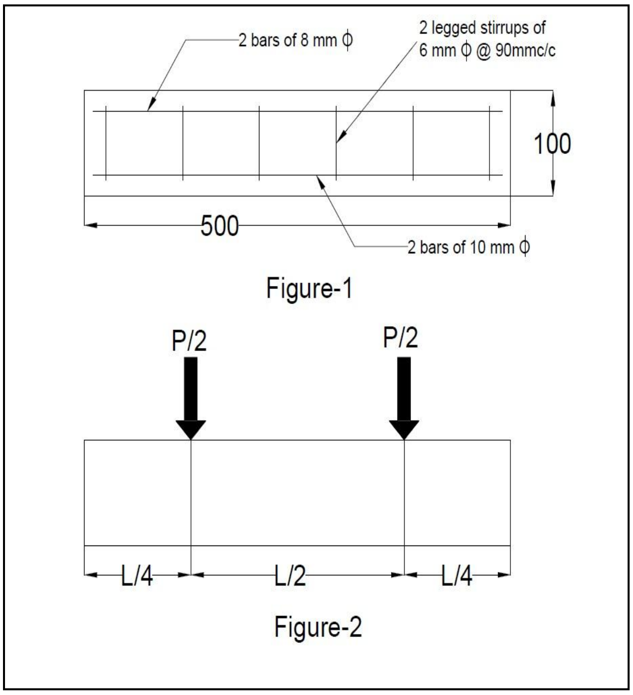


Figure-1:- detailing of beam section

Figure-2:- loading Set-up of beam

C. *Retrofitting of the beams*

For proper bonding between the beam and the sheets, the surface of the sheets is roughened using brush or using some other roughening materials such as sand paper or hard brush or small chisel. Once the beam surface is roughened, the Vinyl Ester resin is prepared. The Vinyl Ester is prepared in the ratio of 1:5 (1 part of hardener is used with 5 parts of resin). The mixture is then mixed thoroughly. After the Vinyl Ester is mixed complete, the Vinyl Ester is applied to be roughened

end of the sheets using brushes. After the Vinyl Ester is properly applied in the sheets, the sheets are fixed on all the sides of the beams, whose surface was cleaned using a brush. Some pressure is given on the surface for proper fixing of the sheets. Similarly sheets are wrapped on all the faces of the beam for the full wrapping technique. And the same procedure is repeated for applying epoxy bonded GFRP sheets to RCC beams for both full wrapping. After the beam is completely retrofitted, the beams are kept for drying and setting properly for 24 hours. Figure-3(a), Figure-3(b)

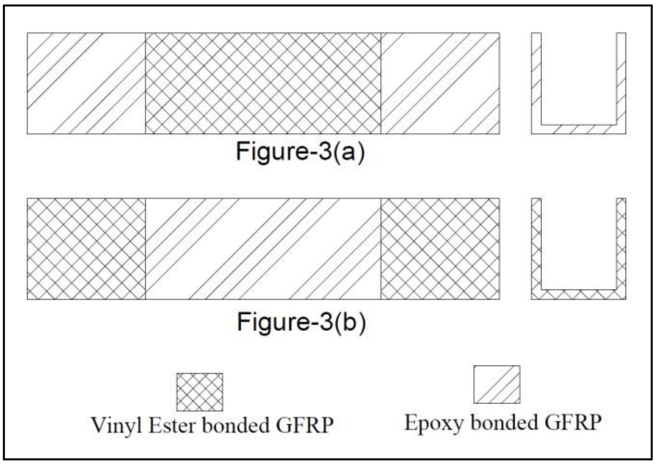


Figure-3(a):-Detailing FRP for Series-B beam

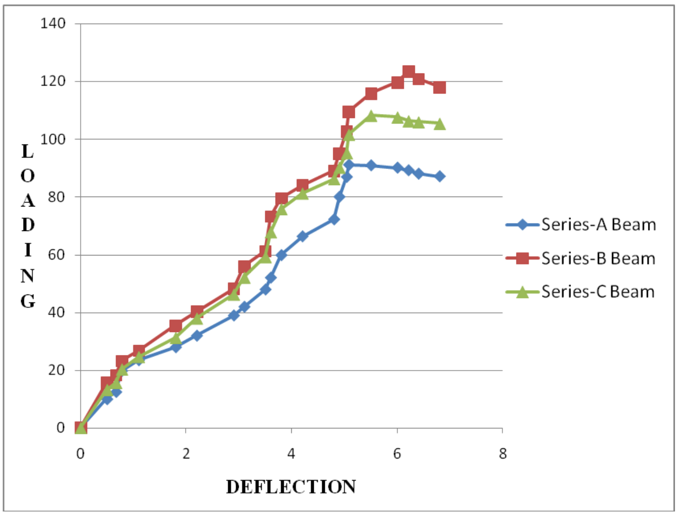
Figure-3(b):- Detailing FRP for Series-C beam

IV. TEST RESULTS AND DISCUSSION

Retrofitted RCC beams, retrofitted using the full wrapping technique has shown an increase by about 15% over the shear strength of normal RCC Beams. The shear strength of the Epoxy bonded GFRP at center and Vinyl ester bonded GFRP retrofitted at both ends of RCC beams; retrofitted using the mix wrapping technique has shown an increase by about 9.47% over the shear strength of normal RCC. The shear strength of the Vinyl ester bonded GFRP at center and Epoxy bonded GFRP retrofitted at both ends of RCC beams; retrofitted using the mix wrapping technique has shown an increase by about 14.2% over the shear strength of normal RCC. First crack strength of the Vinyl ester bonded GFRP retrofitted at center of RCC beams in Shear retrofitted using the mix wrapping technique has shown an increase by about 56.2% over the shear strength of normal RCC Beams. The first crack strength of the Epoxy bonded GFRP retrofitted at center RCC beams in Shear retrofitted using the mix wrapping technique has shown an increase by about 50.2% over the shear strength of normal RCC Beams. It can be concluded that Vinyl Ester bonded GFRP sheets at center and Epoxy bonding GFRP at ends when used for retrofitting performs better in enhances the shear carrying capacity and cracking resistance of the structure as compared to structure retrofitted using Epoxy Bonded GFRP at center and Vinyl ester bonded GFRP at both ends. Generally Vinyl Ester Bonded GFRP at center and Epoxy bonded at both ends gives about 11% of more strength as compared to beam retrofitting using Epoxy bonded GFRP at center.

TABLE-II Percentage increase in load carrying Capacity (%)

Specimen	Load at First Crack (kN)	Failure Load (kN)	Deflection at failure (mm)	Percentage increase in load carrying Capacity (%)
Series-A beam-1	57.5	91.2	5.08	--
Series-A beam-2	62	89.4	5.94	--
Series-B beam- 1	54.5	123.7	6.21	4.98
Series-B beam-2	59.8	120.1	6.16	16.21
Series-C beam-1	64	108.2	5.51	13.24
Series-C beam-2	62	104.2	4.88	9.45



Graph-I Load- Deflection Curves

V. CONCLUSIONS

Based on the test results presented in this study the following conclusions can be drawn.

1. The inclusion of FRP on concrete surface provides better crack control and deformation characteristic of beams.

2. Both the first crack strength and ultimate strength in shear increase in both series of setups. More significant increase was found for the Vinyl Ester Bonded GFRP fiber reinforced beams i.e. series-B because of their increased resistance to propagation of cracks.

3. Shear strength increases with increasing of fiber content
4. The theoretical prediction of ultimate shear strength on the basis of methods used in the study gives results close to the observed values in most of the beams tested.

5. Maximum increase of 56 percent in first cracking load for beam containing 1.25 percent of fibers was observed when compared with beam containing no GFRP.

Also for all the beams tested in this program maximum shear strength was attained in beams reinforced with GFRP

These results support the use of different fiber reinforcement polymer on same beam here Vinyl Ester Bonded GFRP and Epoxy bonded GFRP.

REFERENCES

[1] Tara Sen , H.N.Jagannatha Reddy, Shubhalakshmi B.S "Shear Strength Study of RC Beams Retrofitted Using VinylEster Bonded GFRP and Epoxy Bonded GFRP" *National Institute of Technology, Agartala, Barjala, Jirania, Tripura (West), India, Bangalore Institute of Technology, K.R. Road, Bangalore, India, Dayanand Sagar College of Engineering, Bangalore, India** E-mail of the corresponding author: tara.sen@rediffmail.com (*references*)

[2] Michele BARBATO, Giorgio MONTI, Federico Santinelli," Fiber-Section Fe Of FRP-Strengthened RCCBeam For Seismic Analysis", Structural Engineering Department, UCSD, 9500 Gilman Dr La Jolla, CA, USA ,Dipartimento di Ingegneria Strutturale e Geotecnica, Università La Sapienza di Roma,Via A. Gramsci, 53 – 00197 Roma, Italy

[3] Mohammad Reza Mohammadizadeh, Mohammad Javad Fadaee, And Hamid Reza Ronagh," Improving Torsional Behaviour Of Reinforced Concrete Beams Strengthened With Carbon Fibre Reinforced Polymer Composite", *Iranian Polymer Journal* 18 (4), 2009, 315-327, Received 11 September 2008; Accepted 16 March 2009

[4] Nabil F. Grace," Strengthening Of Negative Moment Region Of Reinforced Concrete Beams Using Carbon Fiber-Reinforced PolymerStrips", *Title No. 98-S33*

[5] J.G. Dai, T. Ueda, Y. Sato1 And T. Ito ,Division Of Built Environment, School Of Faculty Of Engineering,Hokkaido University, Japan, Email: Daijg@Eng.Hokudai.Ac.Jp, P.S. Mitsubishi Construction Co., Ltd., Japan,"

[6] Flexural Strengthening Of Rc Beams Using Externally Bonded FRP Sheets ThroughFlexible Adhesive Bonding", *Proceedings Of The International Symposium On Bond Behaviour Of FRP InStructures (BBFS 2005)* Chen And Teng (Eds) © 2005 International Institute For FRP In Construction

[7] H.C. Wu And P. Sun," Fiber Reinforced Cement Based Composite Sheets For Structural Retrofit",*Proceedings Of The International Symposium On Bond Behaviour Of FRP In Structures (BBFS 2005)* Chen And Teng (Eds) © 2005 International Institute For FRP In Construction.

[8] Robert Ravi.S , Prince Arulraj.G," Experimental Investigation On Behavior Of Reinforced Concrete Beam Column Joints Retrofitted With GFRPAFRP Hybrid Wrapping", *International Journal Of Civil And Structural Engineering,* Volume 1, No 2, 2010

[9] C.A. Zeris," Experimental Investigation Of Strengthening Of Non Ductile Rc Beams Using FRP",*Proceedings Of The 8th U.S. National Conference On Earthquake Engineering*, April 18-22, 2006, SanFrancisco, California, USA. Paper No. 853

[10] M. Z. Jumaat, M. M. Rahman And M. A. Alam, "Flexural Strengthening Of RC Continuous T Beam Using CFRP Laminate: A Review", *International Journal Of The Physical Sciences* Vol. 5(6), Pp. 619-625, June 2010. Available Online At Http://Www.Academicjournals.Org/IJPS. ISSN 1992 - 1950 ©2010 Academic Journals