International Journal of Research
Available at https://edupediapublications.org/journals
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 12
April 2018

Study of Strengthening Rc Continuous Beam Using Fiber Reinforced Polymer Under Static Loading

Ch. Amarnadh[1], V. Kanaka Durga[2]
[1]M.Tech Student, [2]Asst.Professor
M.Tech Structural Engineering,
AMRITA SAI INSTITUTE OF SCIENCE AND TECHNOLOGY,
NH-9, Amrita Sai Nagar, Paritala (Post), Kanchikacherla Mandal, 521180

Abstract— The beams area unit reinforced with outwardly warranted optical fiber bolstered compound (GFRP) sheets. Totally different theme of strengthening is utilized. The program consists of fourteen continuous (two-span) beams with overall dimensions up to (152×305×2300) metric linear unit. The beams area unit classified into 2 series labeled S1 and S2 and every series have totally different proportion of steel reinforcement. One beam from every series (S1 and S2) wasn't reinforced and was thought of as an impression beam, whereas all alternative beams from each the series were reinforced in varied patterns with outwardly warranted GFRP sheets. This study examines the responses of RC continuous beams, in terms of failure modes, sweetening of load capability and cargo deflection analysis. The results indicate that the flexural strength of RC beams may be considerably hyperbolic by gluing GFRP sheets to the strain face. Additionally, the epoxy warranted sheets improved the cracking behavior of the beams by delaying the formation of visible cracks and reducing crack widths at higher load levels.

Index Terms—GFRP, high strength, low weight, corrosion resistance, high fatigue resistance, simple and fast installation.

INTRODUCTION

The most fashionable techniques for strengthening of RC beams have concerned the utilization of external epoxy-bonded steel plates. it's been found through an experiment that flexural strength of a support will increase by victimization this system. Though steel bonding technique is easy, efficient and economical, it suffers from a heavy downside of degradation of bond at the steel and concrete interphone as a result of corrosion of steel. Different common strengthening technique involves construction of steel jackets that is sort of effective from strength, stiffness and malleability concerns. However, it will increase overall cross-sectional dimensions, resulting in increase in self-weight of structures and is labor intensive. To eliminate these issues, plate was replaced by corrosion resistant and lightweight FRP Composite plates. FRPCs facilitate to extend strength and malleability while not excessive increase in stiffness. Further, such material might be designed to fulfill specific demand by adjusting placement of fibers. Therefore concrete members will currently be simply and effectively strong victimization outwardly secure 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. FRP systems can also be used in areas with limited access where traditional techniques would be impractical. However, due to lack of the proper knowledge on structural behavior of concrete structures, the use of these materials for retrofitting the existing concrete structures cannot reach up to the expectation. Successful retrofitting of concrete structures with FRP needs a thorough knowledge on the subject and available user-friendly technologies/ unique guidelines.

EXPERIMENTAL STUDY

The experimental study consists of casting of fourteen large scale continuous (two-span) rectangular reinforced concrete beams. All the beams weak in flexure are casted and tested to failure. The beams were grouped into two series labeled S1 and S2. Each series had different longitudinal and transverse steel reinforcement ratios which are mentioned in Table 3.5 and Table 3.6 for S1 and S2 respectively. Beams geometry as well as the loading and support arrangements are illustrated in Figure 3.6. All beams had the same geometrical dimensions: 152 mm wide × 305 mm deep × 2300 mm long.

One beam from each series (S1 and S2) was not strengthened and was considered as a control beam, whereas all other beams from both the series were strengthened with externally bonded GFRP sheets. Experimental data on load, deflection and failure modes of each of the beams are obtained. The change in load carrying capacity and failure mode of the

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 12
April 2018

beams are investigated for different types of strengthening pattern.

Detailing of Reinforcement:
For the same series of continuous reinforced concrete beams, same arrangement for flexure and shear reinforcement is made.

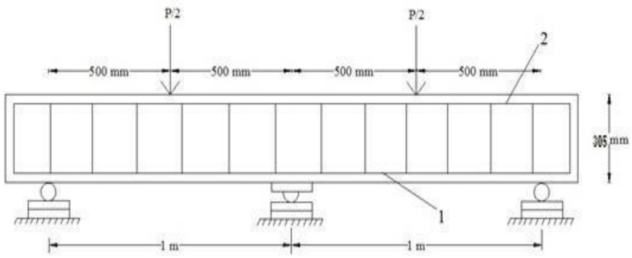

Fig. 3.1 Detailing of reinforcement1, 2 – top and bottom steel reinforcement

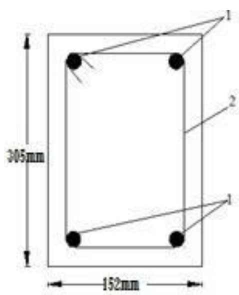

Fig. 3.2 Cross section: 1 – Longitudinal rebar's, 2 – close stirrups

Fig. 3.3 Steel Frame Used For Casting of Beam

Strengthening of Beams: At the time of bonding of fiber, the concrete surface is made rough using a coarse sand paper texture and then cleaned with an air blower to remove all dirt and debris. The fabrics are cut according to the size and after that the epoxy resin is mixed in accordance with manufacturer's instructions. The mixing is carried out in a plastic container (100 parts by weight of Araldite LY 556 to 10 parts by weight of Hardener HY 951). After the uniform mixing, the epoxy resin is applied to the concrete surface. Then the GFRP sheet is placed on top of epoxy resin coating and the resin is squeezed through the roving of the fabric with the roller. Air bubbles entrapped at the epoxy/concrete or epoxy/fabric interface are eliminated. This operation is carried out at room temperature. Concrete beams strengthened with glass fiber fabric are cured for at least 7 days at room temperature before testing.

Fig. 3.4 Application of epoxy and hardener on the beam.

Fig. 3.5 Roller used for the removal of air bubble

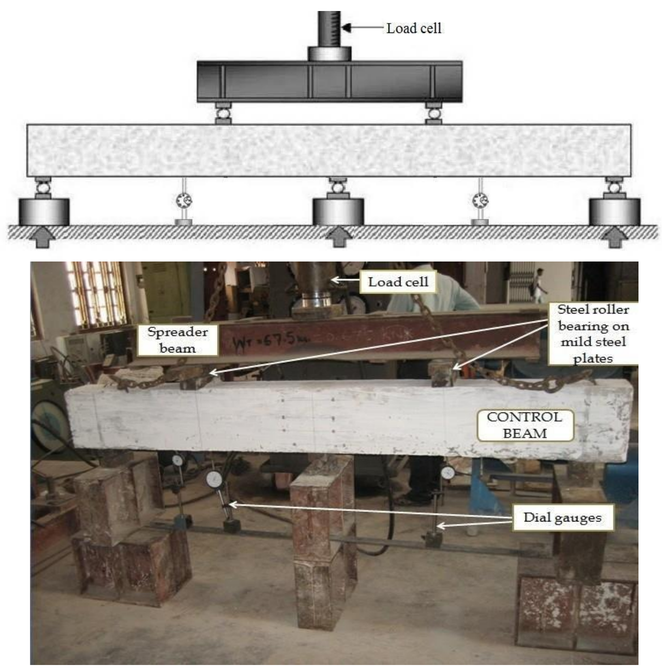

Fig. 3.6 Experimental setup

International Journal of Research
Available at https://edupediapublications.org/journals
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 12
April 2018

I. FABRICATION OF GFRP PLATE:

There are two basic processes for molding: hand lay-up and spray-up. The hand lay-up process is the oldest and simplest fabrication method. The process is most common in FRP marine construction. In hand lay-up process, liquid resin is placed along with FRP against finished surface. Chemical reaction of the resin hardens the material to a strong light weight product. The resin serves as the matrix for glass fiber as concrete acts for the steel reinforcing rods.
The following constituent materials were used for fabricating plates:

1. Glass Fiber
2. Epoxy as resin
3. Damien as hardener as (catalyst)

Polyvinyl alcohol as a releasing agent

A plastic sheet was kept on the plywood platform and a thin film of polyvinyl alcohol was applied as a releasing agent by the use of spray gun. Laminating starts with the application of a gel coat (epoxy and hardener) deposited in the mould by brush, whose main purpose was to provide a smooth external surface and to protect fibers from direct exposure from the environment. Steel roller was applied to remove the air bubbles. Layers of reinforcement were applied and gel coat was applied by brush. Process of hand lay-up is the continuation of the above process before gel coat is hardened. Again a plastic sheet was applied by applying polyvinyl alcohol inside the sheet as releasing agent. Then a heavy flat metal rigid platform was kept top of the plate for compressing purpose. The plates were left for minimum 48 hours before transported and cut to exact shape for testing.
Plates of 2 layers, 4 layers, 6 layers and 8 layers were casted and six specimens from each thickness were tested.

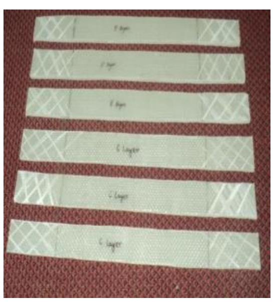

Fig. 3.8 Specimens for tensile testing

Fig. 3.9 Experimental set up of INSTRON 1195

Figure 3.10 Specimen failure after tensile test

Fig. 3.11 Experimental Setup of the CB1

Fig. 3.12 Flexural failure of CB1

Fig. 3.13 Control Beam, CB2 after failure

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 12
April 2018

Fig. 3.14 Experimental Setup of the Beam

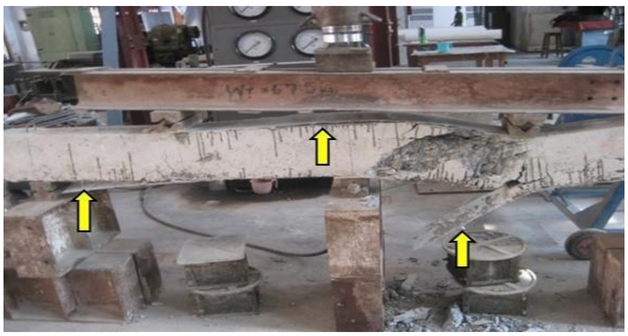

Fig. 3.15 Deboning failure of FRP

Fig. 3.16 Magnified view of the failure of the beam

Strengthened Beams (Sb2):

Single layer of U-wrap was applied on the beam to prevent flexural failure. Tensile rupture of FRP occurred at the mid section of both left and right

Span at lower loads and as the load increased, the beam failed in deboning with concrete cover as shown in Figure 3.17 and shear crack was developed below the FRP layer as shown in Figure 3.18.

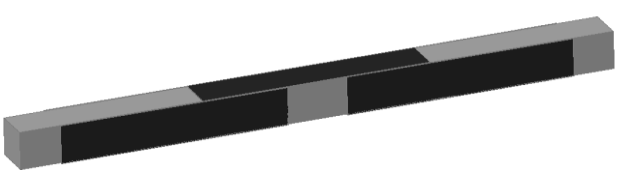

Figure 3.17 Tensile rupture of FRP at mid section of right span at lower value of load

Figure 3.18 Ultimate failure of beam by deboning of FRP with concrete Cover

IV. EXPERIMENTAL RESULTS

Failure Modes Control Beam

The control beam CB1 and CB2 failed completely in flexure. The failure started first at the tension zone and then propagated towards the compression zone and finally failed in flexure.

Strengthened Beam

Generally, the rupture of FRP sheet was sudden and accompanied by a loud noise indicating a rapid release of energy and a total loss of load capacity. For all the strengthened beams, the failure modes for Series S1 and S2 are described in Table 4.1 & 4.2.

The following failure modes were examined for all the tested beams:
Flexural failure
Deboning failure (with or without concrete cover)
Tensile rupture

Rupture of the FRP laminate is assumed to occur if the strain in the FRP reaches its design rupture strain before the concrete reaches its maximum usable strain. GFRP deboning can occur if the force in the FRP cannot be sustained by the substrate. In order to prevent deboning of the GFRP laminate, a limitation should be placed on the strain level developed in the laminate.

Table 4.1 Experimental Results of the Tested Beams for Series S1

	Failure Mode	*Pu* (KN)	$\lambda =$ Pu(strengthened beam)/ Pu(Control beam)
CB1	Flexural failure	260	1.00
SB1	Debonding failure without concrete cover	320	1.23
SB2	Tensile rupture	325	1.25
SB3	Debonding failure	334	1.28

International Journal of Research
Available at https://edupediapublications.org/journals

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 12
April 2018

	without concrete cover		
SB4	Tensile rupture	370	1.42
SB5	Tensile rupture	380	1.46
SB6	Debonding failure without concrete	415	1.59
SB7	Debonding failure	332	1.27
SB8	Debonding failure without concrete	345	1.32
SB9	Debonding failure	421	1.61

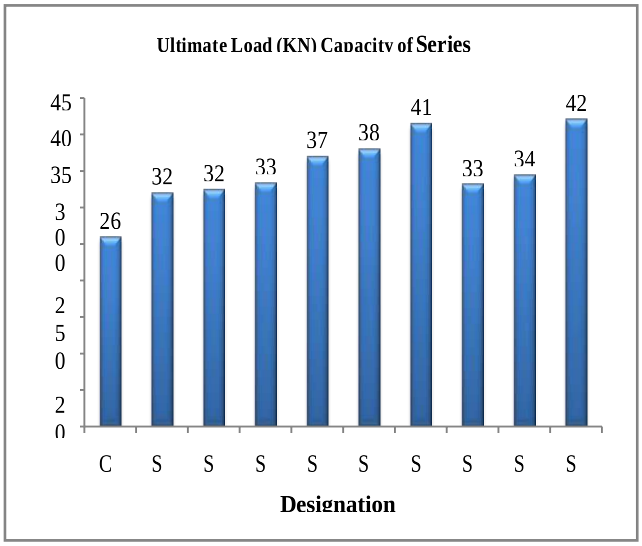

Fig. 4.16 Ultimate Load Capacity of Series S1 beams

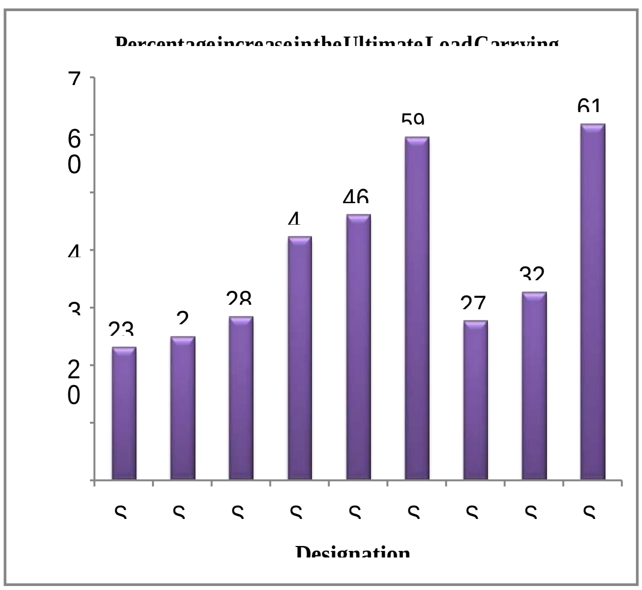

Figure 4.17 Percentage increase in the Ultimate Load Carrying capacity of strengthened beams of S1 w.r.t CB1

V. CONCLUSION

The present experimental study is carried out on the flexural behavior of reinforced concrete rectangular beams strengthened by GFRP sheets. Fourteen reinforced concrete (RC) beams weak in flexure having different set of reinforcement detailing are casted and tested. The beams were grouped into two series labeled S1 and S2. Each series had different longitudinal and transverse steel reinforcement ratios. From the test results and calculated strength values, the following conclusions are drawn:

- The ultimate load carrying capacity of all the strengthen beams is higher when compared to the control beam.
- The initial cracks in the strengthened beams are formed at higher load compared to control beam.
- From series S1, beam SB9 which was strengthened by U-wrap and was anchored by using steel plate and bolt system, showed the highest ultimate load value of 415 KN. The percentage increase of the load capacity of SB9 was 61.92 %.
- The load carrying capacity of beam SB6, which was strengthened by two layers of U- wrap of length 88 cm in positive moment zone and two layers of U-wrap of length 44 cm over first two layers, was 415 KN which was nearer to the load capacity of beam SB9. The percentage increase of load carrying capacity was 59.61 %, from which it can be concluded that applying FRP in the flexure zone is quite effective method to enhance the load carrying capacity.
- TB3 beam from Series S2, which was strengthened by two layers of U-wrap in positive moment zone and two layers of U-wrap in flexure zone above first two layers, was having maximum ultimate load value of 326 KN, than the other strengthened beams of same category. The percentage increase of this beam was 63 % which was highest among all strengthened beams.
- Using of steel bolt and plate system is an effective method of anchoring the FRP sheet to prevent the deboning failure.
- Strengthening of continuous beam by providing U-wrap of FRP sheet is a new and effective way of enhancing the capacity of load carrying.
- Flexural failure at the intermediate support section can be prevented by application of GFRP sheets.

SCOPE OF THE FUTURE WORK

It promises a great scope for future studies. Following areas are considered for future research:

- Experimental study of continuous beams with opening.
- Non linear analysis of RC continuous beam.
- FEM modeling of unanchored U-wrap.
- FEM modeling of anchored.

VI. REFERENCES

[1] ACI Committee 440, "Starte-of-the-art report on fiber reinforced plastic reinforcement for concrete structures", Report ACI 440R-96, USA: *American Concrete Institute*, 1996.

[2] Aiello MA, Valente L, and Rizzo A, "Moment redistribution in continuous reinforced concrete beams strengthened with carbon fiber-reinforced polymer laminates", *Mechanics of Composite Materials*, vol. 43, pp. 453-466, 2007.

[3] Aiello MA, and Ombres L, "Cracking and deformability analysis of reinforced concrete beams strengthened with externally bonded carbon fiber reinforced polymer sheet", *ASCE Journal of Materials in Civil Engineering*, vol. 16, No. 5, pp.292-399,2004.

[4] Akbarzadeh H, and Maghsoudi AA, "Experimental and analytical investigation of reinforced high strength concrete continuous beams strengthened with fiber reinforced polymer", *Materials and Design*, vol. 31, pp. 1130-1147, 2010.

[5] Arduini M, and Nanni A, "Behavior of pre-cracked R. C.

Beams strengthened with carbon FRP sheets", *ASCE Journal of Composites for Construction*, vol. 1, No. 2, pp. 63- 70, 1997.

[6] Ashour AF, El-Refaie SA, and Garrity SW, "Flexural strengthening of RC continuous beams using CFRP laminates", *Cement and Concrete Composites*, vol. 26, pp. 765-775, 2003.

[7] Bank LC, and Arora D, "Analysis of RC beams strengthened with mechanically fastened FRP (MF-FRP) strips", *Composite Structures*, vol. 79, pp. 180–191, 2006.

[8] Bousselham A and Chaallal O, "Behavior of reinforced concrete T-beams strengthened in shear with carbon fiber reinforced polymer- an experimental study", *ACI Structural Journal*, vol. 103, pp. 339–347, 2006.