BEHAVIOUR OF REINFORCED CONCRETE CONTINUOUS RECTANGULAR AND T-BEAMS IN NEGATIVE MOMENT REGION

S.Sukrithi[1], Dr.P.Easwaramoorthi[2]
[1]Assistant Professor, Department of Civil Engineering,
Dr.N.G.P.Institute of Technology, Coimbatore, Tamil Nadu
[2]Professor, Department of Civil Engineering, Kumaraguru College of Technology
Coimbatore, Tamil Nadu

ABSTRACT
Fiber-reinforced polymer (FRP) application is a very effective way to repair and strengthen structures that have become structurally weak over their life span. FRP repair systems provide an economically viable alternative to traditional repair systems and materials. In this study Experimental and Analytical Investigation on Behaviour of Reinforced concrete Continuous T-beams in Negative Moment Region strengthened using Glass Fiber Reinforced Polymer (GFRP) sheets are carried out. Reinforced concrete T-beam externally bonded with GFRP sheets were tested to failure using a symmetrical two point static loading system. Two RC T-beams and One Rectangular beam were cast for this experimental test. One beam was used as a control beam and one beams is strengthened using Glass Fiber Reinforced Polymer (GFRP) sheets. Experimental data on load, deflection and failure modes of each of the beams were obtained. The effect of different amount and configuration of GFRP on ultimate load carrying capacity and failure mode of the beams were investigated.The experimental results showed that the externally strengthened reinforced concrete beam with bonded GFRP sheet showed significant increase in ultimate load.A series of comparative studies on deflection between T-beam and Rectangular beam were made. Future areas of research are being outlined.

Keywords: Reinforced Concrete Rectangular, T-beams, Negative Moment region, Glass Fiber Reinforced Sheets

INTRODUCTION

While many methods of strengthening structures are available, strengthening by applying GFRP laminate has become popular. For strengthening purposes, application of GFRP laminate is more advantageous than other materials. Teng et al. (2002) pointed out that, there is increased demand for extensive research work to improve the characteristic behavior of FRP materials to establish their application acceptability in RC structures, beams, slabs and columns. In particular, their practical implementations for strengthening civil structures are numerous. Several researchers pointed out that most of the pragmatic works consist mainly of the rectangular beams. Furthermore, the design methodologies as well as guidelines are evolved mainly for the simply supported rectangular beams. Generally, the research works were conducted on RC rectangular sections which are not truly representative for the fact that most RC beams would have a T Section due to the presence of a top slab.

Although many research studies had been conducted on the strengthening and repairing of simply supported RC beams using external plates, there is little reported work on the behavior of strengthened RC-T beams. Especially, works relating to the application of GFRP laminate for strengthening the tension zone of RC T- beams in the presence of column are very few. The negative moment region or the support region of continuous reinforced concrete (RC) beams is a critical one due to the simultaneous occurrence of maximum moment and shear.

In addition, there are few difficulties arise due to the presence of columns and other components such as electric and plumbing lines or HVAC ducts.

BEAM NAME	CONCRETE STRENGTH (MPa)	LENGTH (m)	APPLYING ZONE
B0- RECTANGULAR BEAM	25	2.6	--
B1- T-BEAM	25	2.6	--
B2- T-BEAM	25	2.6	FLEXURE

Table 1 : Test Matrix

These columns and components hinder the process of applying CFRP laminate in this region using conventional techniques. Another important point is that, the use of thick steel plates for strengthening will raise the floor level, which might be undesirable. An exhaustive literature review has revealed that, a little amount of research works had been done to address the possibility of strengthening the tension zone of RC T- beam in presence of column using FRP materials. In this context, due its low profile and ease of installation, composite materials such as carbon fiber reinforced polymer (CFRP) can be used to provide an economical and versatile solution for extending the service life of structures. CFRP laminates may provide strengthening solutions for all types of structural elements such as beams, columns, walls and slabs (Nanni, 1999).

EXPERIMENTAL PROGRAM

Reinforced concrete Rectangular beam of size 2.6x0.1x0.175m is cast. For all the two reinforced concrete T beams, the same arrangement for flexure and shear reinforcement is made. The tension reinforcement consists of 2 nos of 10 mm diameter and 2 nos of 8 mm diameter HYSD bar and 6mm diameter rings are placed @150mm c/c. In flange 8mm diameter main rods and four bars of 6 mm diameter HYSD bars are provided as distributors. The Rectangular beam is reinforced with 2 nos of 10 mm diameter and 2 nos of 8 mm diameter HYSD bar and 6mm diameter rings are placed @150mm c/c. The detailing of reinforcement of the beam is shown in Fig. All the beams were cast with M_{25} grade concrete and tested after 28days. One of the T beam and Rectangular beam was tested without FRP reinforcement, and was identified as Beam B0 and B1. The other T beam is identified as Beam B2, was strengthened in both flexure and shear.

Fig 1.Beams With Their Moulds

For flexural strengthening of Beam B2, two plies of 0.8mm thick GFRP laminates were applied on the flanges.The strengthening system was applied to the surface ofthe beam using standard procedure specified by the manufacturer. The surface treatment of concrete prior to the installation of strengthening system was done using water jetting, which proved to be very effective and environmentally friendly.

Fig 2.Fixing Of Gfrp Sheets On The Beam

The beams were tested as simply supported T-beams under two point bending. The purpose of the test setup was to obtain tension on the flanges, as in the case of the negative moment region of a continuous beam. The supports represented the points of inflection of a continuous beam, where the bending moment is zero. Linear Variable Differential Transformers (LVDTs) were placed at mid span and quarter span to monitor the deflection of the beam and at the supports to measure settlement. The test setup is shown in Figure

Fig 3.Test Setup Of Rectangular Beam

Fig 4.Test Setup of T-Beam

RESULTS AND DISCUSSION

Beam B0 failed in the classical flexural failure mode, which is characterized by yielding of the tension steel followed by the crushing of concrete in the compression zone. Beam B1 failed in the flexural failure mode, which is characterized by yielding of the tension steel followed by the crushing of concrete in the compression zone. The strengthened beams also exhibited flexural failures. All beams cracked at practically the same level of load, at about 40Kn. After cracking, the decrease in stiffness in Beam B0 was larger than in Beams B1 and B2. The ultimate strength of Beams B1 and B2 were higher than that of the Rectangular beam, respectively.

Fig 5.Final Failure In Beams By Crushing Of Concrete

Fig 6.Failure Modes Of Rectangular Beam

Fig 7.Final Failure In Beams By Crushing Of Concrete

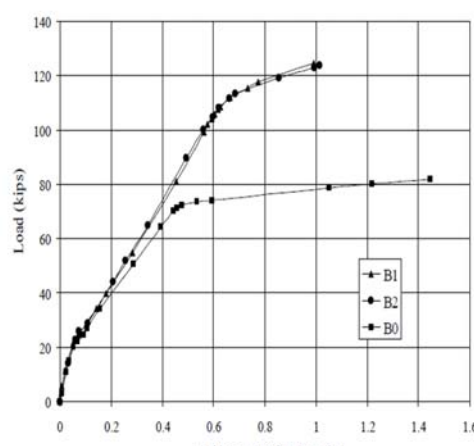

Fig 8.Load Deflection Diagram

CONCLUSION

The present experimental study is done on the behavior of reinforced concrete continuous T-beams in negative moment region strengthened by GFRP sheets. From the test results and calculated strength values, the following conclusions are drawn:

1. The ultimate load carrying capacity of the strengthened beam is enhanced as compared to the Control Beam.

2. Initial flexural cracks appear for higher loads in case of strengthened beams.

3. The load carrying capacity of the strengthened Beam was found to be maximum of all the beams. It increased up to 37.5 % more than the control beam

4. Externally bonded GFRP laminates are very effective in enhancing the strength, in both flexural and shear, and stiffness of the negative moment region of T-beams.

REFERENCES

1. ACI Committee 440 (1996) State Of Art Report On Fiber Reinforced PlasticReinforcement For Concrete Structure ,ACI 440R-96, American Concrete Institute,
2. Alam, M.A.; Jumaat, M.Z. (2015) Preventi on of debonding failure of intermediate anchor to eliminate premature shear failure of flexurally strengthened reinforced concrete beams. Arabian Journal for Science and Engineering, 40 (8). pp. 2219-2232. ISSN 1319-8025
3. Grace, N. F., “Strengthening of Negative Moment Region of Reinforced Concrete Beams Using Carbon Fiber-Reinforced Polymer Strips” ACI Structural Journal, V.98, N0.3, May-June 2001, pp. 347-358.
4. Grace, N. F., Soliman, A. K., Abdel-Sayed, G., and Saleh, K. R. (1999), “Strengthening ofcontinuous beams using fibre reinforced polymer laminates”, Proceedings of 4thInternational Symposium on Fibre Reinforced Polymer Reinforcements for ReinforcedConcrete Structures,

   SP-188, American Concrete Institute, Farmington Hills, Michigan,USA, pp.647-657.
5. Muhammad MukhlesurRahman and Md. WaliurRahman (2013), Simplified method of strengthening RC continuous T beam in the hogging zone using carbon fiber reinforced

   polymer laminate – A numerical investigation.
6. M.F. Petrou, J. Aidoo, K.A. Harries, and C.G. Papakonstantinou, "Fatigue Behavior of Reinforced Concrete Beams/Slabs Strengthened with GFRP/CFRP Sheets", Proceedings of the Fifth NSF National Workshop on Bridge Research in Progress, Minneapolis, Minnesota, Oct. 8-10, 2001, pp 51-54.
7. M. Z. Jumaat, M. M. Rahman* and M. A. Alam(2013), “Flexural strengthening of RC continuous T beam using CFRP laminate”- Journal of Civil Engineering Construction Technology.
8. Nanni, A ,Khalifa A (2000) “Improving shear capacity of existing RC T-section beamsusing CFRP composites” Cement & Concrete Composites 22 (2000) 165-174.
9. ObaidatYasmeenTaleb , Susanne Heyden , Ola Dahlblom , Ghazi Abu-FarsakhYahia Abdel-Jawad (2010) “Retrofitting of reinforced concrete beams using composite laminates” Construction and Building Materials
10. Papakonstantinou, C. G., Petrou, M. F., andHarries, K. A. (2001), “Fatigue of reinforcedconcrete beams strengthened with GFRP sheets”, ASCE Journal of Composites forConstruction, Vol. 5, No. 4, pp. 246-253.
11. M.F. Petrou, J. Aidoo, K.A. Harries, and C.G. Papakonstantinou, "Fatigue Behavior of Reinforced Concrete Beams/Slabs Strengthened with GFRP/CFRP Sheets", Proceedings of the Fifth NSF National Workshop on Bridge Research in Progress, Minneapolis, Minnesota, Oct. 8-10, 2001, pp 51-54.
12. Raoof, M., dan Davies, T. J. (2001). “Simple Determination Of The Axial Stiffness For Large Diameter Independent Wire rope Core Or Fibre.” The Journal Of Strain Analysis For Engineering Design, Vol. 38: 577
13. Ross, C. A., Jerome, D. M., Tedesco, J. W., and Hughes, M. L. (1999), “Strengthening ofreinforced concrete beams with externally bonded composite laminates”, ACI StructuralJournal, Vol. 96. No. 2, pp. 65-71

14. Sinaph M. Namboorimadathil, J. Gustavo Tumialan, Antonio Nanni, Behavior of RCT-beams strengthened in the negative moment region with CFRP laminates, San Francisco Tanarslan, H.M. and S. Altin, "Behavior of RC T-section beamsstrengthened with CFRP strips, subjected to cyclic load." Materials and Structures, 2010.43(4): pp. 529-542
15. The Concrete Society, UK :2002, “Design Guidance for Strengthening ConcreteStructures using Fibre Composite Materials”, Technical Report No. 55, January 26, 2002
16. Wines, J. C., et al. (1966), “Laboratoryinvestigation of plastic glass fi bre Reinforcementfor reinforced and prestressed concrete”, United States Army Crops. Of Engineers, WES,Vol. 1 & 2, Vicksburg, MS, pp. 228