iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** V **Month of publication:** May 2025

DOI: https://doi.org/10.22214/ijraset.2025.71194

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue V May 2025- Available at www.ijraset.com

Experimental & Analytical study on Tee beams reinforced Concrete using FRP composites analysis

Chandan Kumar[1], Ankita Singhai[2], Rahul Kumar Satbhaiya[3]
[1]*M.Tech Scholar, Civil department, Infinity Management & Engineering College, Sagar (MP)*
[2]*Asst. Professor and Guide, Infinity Management & Engineering College, Sagar (MP)*
[3]*HOD, Infinity Management & Engineering College, Sagar (MP)*

Abstract: This study deals with experimental investigation for enhancing and strengthening structurally deficient T-beams by using an externally bonded fiber reinforced polymer (FRP). The rehabilitation of existing reinforced concrete (RC) bridges and building becomes necessary due to ageing, corrosion of steel reinforcement, defects in construction/design, demand in the increased service Loads, and damage in case of seismic events and improvement in the design guidelines. Fiber-reinforced polymers (FRP) have emerged as promising material for rehabilitation of existing reinforced concrete structures. The rehabilitation of structures can be in the form of strengthening, repairing or retrofitting for seismic deficiencies. RC T-section is the most common shape of beams and girders in buildings and bridges. Shear failure of RC T-beams is identified as the most disastrous failure mode as it does not give any advance warning before failure. The shear strengthening of RC T-beams using externally bonded (EB) FRP composites has become a popular structural strengthening technique, due to the well-known advantages of FRP composites such as their high strength-to-weight ratio and excellent corrosion resistance. This study assimilates the experimental works of glass fiber reinforced polymer (GFRP) retrofitted RC T-beams under symmetrical four-point static loading system. An innovative method of anchorage technique has been used to prevent these premature failures, which as a result ensure full utilization of the strength of FRP.

Shear collapse of reinforced concrete (RC) members is catastrophic and occur suddenly with no advance warning of distress. In several occasions existing RC beams have been found to be deficient in shear and in need of strengthening. Conventional shear strengthening method such as external post tensioning, member enlargement along with internal transverse steel, and bonded steel plates are very costly, requiring extensive equipment, time, and significant labour. Conversely, the relatively new alternative strengthening technique using advanced composite materials, known as fiber reinforced polymer (FRP), offers significant advantages such as flexibility in design, ease of installation, reduced construction time, and improved durability.

The overall objective of this study was to investigate the shear performance and failure modes of RC T-beams strengthened with externally bonded GFRP sheets. In order to achieve these objectives, an extensive experimental program consisting of testing eleven, full scale RC beams was carried out. The variables investigated in this study included steel stirrups, shear span-to-depth ratio, GFRP amount.

The experimental results indicated that the contribution of externally bonded GFRP to the shear capacity is significant and depends on the variable investigated. The failures of strengthened beams are initiated with the deboning failure of FRP sheets followed by brittle shear failure. However, the shear capacity of these beams has increased as compared to the control beam which can be further improved if the deboning failure is prevented. An innovative method of anchorage technique by using GFRP plates has been used to prevent.

Keywords: GFRP, Fiber-Reinforced Polymers, Externally Bonded, Reinforced Concrete, T-Beams.

I. INTRODUCTION

The knowledge of understanding of the earthquakes is increasing day by day and therefore the seismic demands imposed on the structures need to be revised. The design methodologies are also changing with the growing research in the area of seismic engineering. So the existing structures may not qualify to the current requirements[1]. Retrofitting is specially used to relate to the seismic upgrade of facilities, such as in the case of the use of composite jackets for the confinement of columns. Retrofitting is making changes to an existing building to protect it from flooding or other hazards such as high winds and earthquakes. The maintenance, rehabilitation and upgrading of structural members, is perhaps one of the most crucial problems in civil engineering applications. Moreover, a large number of structures constructed in the past using the older design codes in different parts of the world are structurally unsafe according to the new design codes.

To meet up the requirements of advance infrastructure new innovative materials/ technologies in civil engineering industry has started to make its way [2]. Any technology or material has its limitations and to meet the new requirements new technologies have to be invented and used. With structures becoming old and the increasing bar for the constructed buildings the old buildings have started to show a serious need of additional retrofits to increase their durability and life [3].

II. METHODOLOGY

Experimental program: For the experimental study total nine beams are cast. The concrete of M20 grade are designed with proportion 1:1.67:3.3 and water cement ratio of 0.5. HYSD bars of Fe415 grade are used. The beams are divided in three sets based on the flange width. Set T2, and T4 consist of flange width 250mm, 350mm and 450 mm respectively. The sections details and reinforcement details are shown in the First set has one beam T2. The beam is un-strengthened and cast to study the effect of width of flange. Set T3 and T4 consist of four beams. T3C and T4C are un-strengthen as control beams. T3SF and T4SF are strengthen with fully wrapped GFRP strips oriented at 90 , T3SU and T4SU are strengthen with U- wrapped GFRP strips oriented at 90 , T3S45 and T4S45 are strengthen with fully wrapped GFRP strips oriented at 45 Bi-directional woven GFRP fiber are used for retrofitting the beams. The epoxy resin is used for bonding GFRP fibers to the concrete surface. The resin and hardener used in this study are Araldite LY 556 and hardener HY 951 respectively. Four layers of 100mm wide strips of G FRP are used for strengthening. Three types of strengthening schemes are adopted in the study.

A. *Experimental Setup*

All the specimens except SBA3 and SBB3 are tested as simple RC T-beams using four-point static loading frame with shear span to effective depth ratio (a/d) equal to 2.66 and SBA3 and SBB3 are having a/d ratio equal to 2. The tests were carried out at the Structural Engineering" Laboratory of Civil Engineering Department, NIT Rourkela. The testing procedure for the entire specimen is same. After the curing period of 28 days are over, then the beam surface is cleaned with the help of sand paper for clear visibility of cracks. Fig. 1 shows the details of the test setup. A load cell with a capacity of 500 kN and attached to a hydraulic jack was used to measure the load during testing.

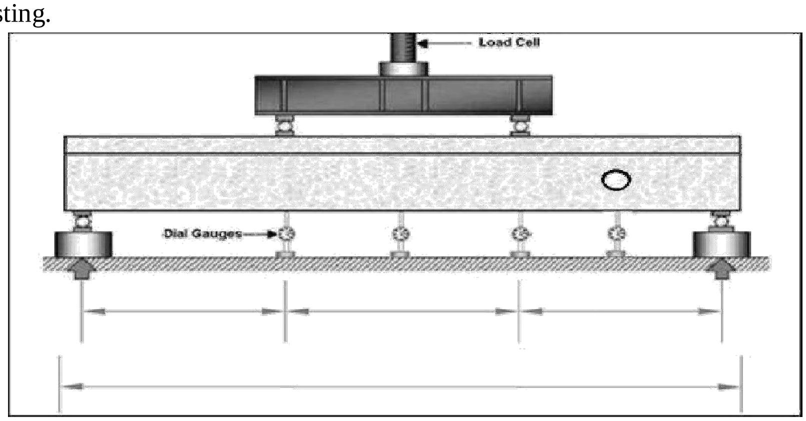

Fig 1 Details of the Test setup with location of dial gauges

III.RESULTS AND DISCUSSIONS

The results obtained from the testing of eleven number RC T-Beams for the experimental program are interpreted. Their behaviour throughout the test are described with respect to initial crack load and ultimate load carrying capacity, deflection, crack pattern and modes of failure. All the beams except the control beams (CB) and solid beams are strengthened with various patterns of GFRP sheets. All the beams except SBA2-3 and SBB2-3 were in both the groups having shear span of 333.33 mm and SB3 having shear span of 250 mm. Specimens of group-A were cast without stirrups and group-B casted with stirrups at 200mm spacing. In both the groups the beam designated as SBA2-1 and SBB2-1 were strengthened with two layers of bi- directional GFRP sheets having U-wrap on shear of the beam where the transverse hole is provided. The beam SBA2-2 and SBB2-2 were strengthened with two layers of bi-directional GFRP sheets having U-wrap on shear span (0 to L/3 and L/3 to 2L/3) of the beam with flange anchorage system. The beam SBA2-3 and SBB2-3 were strengthened with two layers of bi- directional GFRP sheets in the form of U-wrap on shear span for a width of 250 mm with flange anchorage system. SBA4-1 was strengthened with four layers of bi-directional GFRP sheets having U-wrap on shear span (0 to L/3 and L/3 to 2L/3) of the beam with flange anchorage system by using GFRP plates instead of steel plates.

A. Experiment Results

1) Group-A

The solid beam was cast with same reinforcement used for control beam but no transverse hole is provided. Fig 2 shows the experimental test setup of solid beam under four point loading. The first hair crack was visible in the shear span at a load of 110 kN as shown in Fig 3. With further increase in load, the beam finally failed in shear at a load of 208 kN exhibiting a wider diagonal shear crack as shown in Fig.4. The first shear crack became the critical crack for the ultimate failure of the solid beam. There is a 17.3% increase in shear capacity over the control beam.

Fig 2 Experimental Setup of beam Solid beam

Fig 3 Hair line crack started at 110kN

Fig 4 Widened crack at ultimate load

2) Group-B

The solid beam was cast with same reinforcement used for control beam but no transverse hole is provided. Fig 5 shows the experimental test setup of solid beam under four point loading. The first hair crack was visible in the shear span at a load of 110 kN as shown in Fig 6 With further increase in load, the beam finally failed in shear at a load of 240 kN exhibiting a wider diagonal shear crack as shown in Fig 7. The first shear crack became the critical crack for the ultimate failure of the solid beam. There is a 41.67% increase in shear capacity over the control beam.

Fig 5 Experimental Setup of beam Solid beam B

Fig 6 Hair line crack started at 110kN

Fig 7 Widened crack at ultimate load

B. Result Summary

The ultimate load carrying capacities of all the beams along with the nature of failure are summarized in Table 1. The ratio of ultimate load carrying capacity of strengthened beam to control beam are computed and presented in Table 1

TABLE I
RESULT SUMMARIES

Beam designation		Nature of failure	P_u(KN)	Λ
Group-A	Solid beam	Shear failure	208	1.2
	CB	Shear failure	172	-
	SB1	Shear failure	180	1.04
	SB2	Tearing and debonding of GFRP+ shear failure	220	1.28
	SB3	Tearing and debonding of GFRP+ shear failure	210	1.22
	SB4	Debonding failure +shear failure	230	1.33
Group-B	Solid beam	Shear cracks shifted to the non-strengthened zone of the shear span	240	1.71
	CB	Shear failure	140	-
	SB1	Tearing and debonding failure + shear failure	198	1.41
	SB2	Tearing of GFRP +shear failure	204	1.45
	SB3	Tearing of GFRP +shear failure	214	1.53

IV. CONCLUSIONS

In this experimental investigation the shear behaviour of RC T-beams strengthened by GFRP sheets are studied. The test results illustrated in the present study showed that the external strengthening with GFRP composites can be used to increase the shear capacity of RC T-beams, but the efficiency varies depending on the test variables such as fiber orientations, wrapping schemes, number of layers and anchorage scheme.

The present experimental program consisting of nine numbers of reinforced concrete T- beams with three different flange widths tested under torsion. The main objective is to exam line the effectiveness of epoxy-bonded GFRP fabrics used as external transverse reinforcement to resist torsion. Based on presented experimental results and analytical editions, the Following conclusions are drawn:

1) Experimental results show that the effect of flange width on torsional capacity of GFRP strengthened RC T-beams is significant.
2) Torsional strength increases with increase in flange area irrespective of beam strengthening with GFRP following different configurations schemes.
3) With 250 mm wide flange width increase in strength was 13%, with 350mm wide flange was 29% and for 450mm wide flange was found to be 69%. This is due to increase in area enclosed inside the critical shear path.

REFERENCES

[1] ACI 440.2R-02, "Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures", Reported by ACI Committee 440.
[2] Al-Amery R., and Al-Mahaidi R. (2006), "Coupled flexural-shear retrofitting of RC Beams using CFRP straps", Construction and Building Materials, 21, 1997-2006.
[3] Alex L., Assih J., and Delmas Y. (2001), "Shear Strengthening of RC Beams with externally bonded CFRP sheets", Journal of Structural Engineering, Vol. 127, No. 4, Paper No. 20516.
[4] Balamuralikrishnan R., and Jeyasehar C. A. (2009), "Flexural behaviour of RC beams strengthened with Carbon Fiber Reinforced Polymer (CFRP) fabrics", The Open Civil Engineering Journal, 3, 102-109.
[5] Bousselham A., and Chaallal O. (2006), "Behavior of Reinforced Concrete T-beams strengthened in shear with carbon fiber-reinforced polymer –An Experimental Study", ACI Structural Journal, Vol. 103, No. 3, pp. 339-347.
[6] Ceroni F. (2010), "Experimental performances of RC beams strengthened with FRP materials", Construction and Building materials, 24, 1547-1559.
[7] Chaallal O., Nollet M. J., and Perraton D. (1998), "Strengthening of reinforced concrete beams with externally bonded fibre-reinforced-plastic plates: design guidelines for shear and flexure", Canadian Journal of Civil Engineering, Vol. 25, No. 4, pp. 692-704
[8] Chen J. F., and Teng J. G. (2003), "Shear capacity of FRP-strengthened RC beams: FRP debonding", Construction and Building Materials, 17, 27-41.
[9] Chen J. F., and Teng J. G. (2003), "Shear capacity of Fiber-Reinforced Polymer- Strengthened Reinforced Concrete Beams: Fiber Reinforced Polymer Rupture", Journal of Structural Engineering, Vol. 129, No. 5, ASCE, ISSN 0733-9445, pp. 615-625
[10] Deifalla A., and Ghobarah A. (2010), "Strengthening RC T beams subjected combined torsion and shear using FRP fabrics Experimental Study", Journal of Composites for