SHEAR STRENGTHENING OF REINFORCED AND PRESTRESSED CONCRETE BEAM USING FRP

Prajakta Rajendra Mane[1], Prof. M. N. Shirsath[2], Prof. Shweta S. Tikotkar[3]

[1]M.E.(Structures)Student, Department of Civil Engineering, G. H. Raisoni College of Engineering and Management, Ahmednagar-414008, Maharashtra, India.
[2]Vice-Principal and Professor, Department of Civil Engineering, G. H. Raisoni College of Engineering and Management, Ahmednagar-414008, Maharashtra, India.
[3] Assistant Professor, Department of Civil Engineering, G. H. Raisoni College of Engineering and Management, Ahmednagar-414008, Maharashtra, India.

Abstract - *This analysis explores the consequence of an experimental investigation for improving the shear capability of reinforced concrete (RC) T beams with shear inadequacies, strengthened with Basalt Fiber Reinforced Polymer (BFRP) sheets that are an economic and new relatively substitute for more expensive fibers widely used around strengthening of RC beams. A maximum of twenty-two numbers of concrete T beams are analyzed as well as different sheet configurations as well as designs are analyzed to determine the effects of theirs along the shear capability of all the beams. One beam of the beams is viewed as control beam, while some other beams are strengthened with externally bonded BFRP sheets/strips. The experimental outcomes evidenced the* usage of latest mechanical anchorage pattern containing laminated composite plates enhances the shear capability of the beams considerably by stopping the debonding of BFRP sheets, such the total strength on the BFRP sheets become used.

Key Words*: *FRP Composites, Properties of FRP composites, Structural design, Repair of structures

1. INTRODUCTION

The traditional design approaches on the market are steel-jacketing and concrete-jacketing. The concrete jacketing creates the current portion big and therefore gets better the load hauling capacity of all the framework. Though the strategies have a few demerits including construction of completely new formworks, extra weight because of enlargement of aisle, higher set up cost etc. The steel jacketing has found to become a good method to improve the overall performance of components, though this process calls for tough welding work within the area as well as have possible problem of corrosion that increases the cost of upkeep. Now-a-days, FRP composite substances are a fantastic choice being utilized as outside reinforcement due to the high specific stiffness of their substantial weight, higher tensile strength, light in weight, opposition to corrosion, excessive longevity as well as simplicity of set up.

1.1 Strengthening Using FRP

Concrete beams tend to be the primary aspect in structural engineering that are created to transport both horizontal a lot because of seismic or maybe vertical gravity and wind loads. Like any other concrete elements, they are vulnerable for situations in which there is a rise within structural a lot. Typically, reinforced concrete (RC) beams fail within two ways: diagonal tension and flexure failure (shear) disappointment. Flexural disappointment is frequently desirable to shear malfunction while the former is ductile while latter is brittle. A ductile disaster not only enables stress redistribution but also provides previous discover to occupants, whereas a brittle failure is sudden and therefore catastrophic. The utilization of outside FRP reinforcement might be categorized as: flexural as well as shear strengthening.

1.2 Shear Strengthening Using FRP

If the RC beam is deficient for shear, or perhaps when the shear capacity of it is under the flexural capacity right after flexural strengthening, shear strengthening must be thought about. It is significantly crucial that you look at the shear capacity of RC beams that are suggested to become strengthened.

In order to boost the shear capacity of the beams, each composite sheet as well as plates may be consumed, however the former one of them is much more appreciable due to the flexible nature of theirs as well as simplicity of handling and application. Different FRP bonding systems might be utilized to enhance the shear capacity of RC beams. These contain (1) aspect bonding (bonded towards the sides on the beams only) (2) U jacketing (bonded to the sides as well as tension face on the beam) as well as (3) wrapping (bonded around the entire cross segment on the beam). As RC T section is considered the most preferred form of girders and beams in bridges and buildings, total wrapping is not an achievable option. Fibers might be bidirectional or unidirectional as revealed within figure 1.3. The utilization of fibers within 2 instructions may clearly be favourable with value to shear opposition even though strengthening for turned around loading isn't necessary, aside from not likely situation whereby one of many fibre paths is roughly parallel towards the shear cracks.

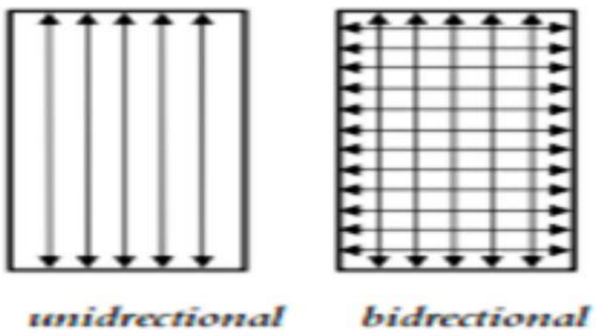

Fig 1: Fiber directions in composite materials

1.3 Advantages of FRP

- Corrosion Resistance.
- Lightweight.
- Ease of installation
- Less Finishing and maintenance.
- High fatigue resistance.
- Ductility of FRP wrapped members improves extensively.
- They are perfect for external application.
- They are durable both environmentally and from service point of view.
- They are available in various forms: sheets, plates, fabric, etc.
- They are available in long lengths that eliminate joints.
- They cure within 24 hours.
- Versatile in nature.

1.4 Problem Statement

Most of the analysis works were made investigating flexural as well as shear behaviour of RC rectangular beams strengthened with fiber reinforced polymer (FRP) composites. Till date absolutely no work has been found studying the shear behaviour of RC T beams making use of externally bonded Basalt fiber reinforced polymer (BFRP) composites. A small work continues to be found about the strengthening of RC T-beams with no study and web openings has become reported on the strengthening of beams with transverse opening by using BFRP composites. A lot of scientists are from the viewpoint which the prior design methods do not have detailed comprehension of the shear behaviour of RC T-beams.

1.5 Objective

- To study the structural behaviour of reinforced concrete (RC) T beams under static loading condition. To study the structural behaviour of reinforced concrete (RC) T beams under static loading condition.
- In order to look at the outcome of various details like quantity of layers, bonding surface, various fiber orientation etc. over the shear capacity on the RC T-beams.
- In order to take a look at the outcome of an anchorage pattern over the enhancement of shear capability on the RC T-beams.
- In order to investigate the outcome of a new anchorage scheme over the shear capacity on the beam.

1.6 Scope

- In order to evaluate the shear behaviour of T section RC beams below fixed loading time quality.
- In order to look at the shear behaviour as well as modes of failure of RC shear deficient T beams externally strengthened with basalt fiber reinforced polymer (BFRP) sheets.
- In order to take a look at the impact of various test details including fiber amount as well as distribution bonded surface area, quantity of layers, fiber orientation and also end anchorage process over the shear capacity of RC T beams strengthened with externally bonded BFRP composites.
- To calculate analytically the shear capability on the RC T beams.

2. METHEDOLOGY

2.1 Test Specimens

- Twenty-two reinforced concrete T beams are considered in this study with dimensions as follows:
- Span= 1300mm Width of web= 150mm Depth of web= 125mm Depth of flange= 50mm Effective depth= 125mm. The steel reinforcement in the beams consists of two numbers of sixteen mm φ and one number of twelve mm φ HYSD bars as tension reinforcement. 4 numbers of ten mm φ bars are provided as hanger bars.
- The depth and length of the beam have been taken as 1300 mm and 175mm, respectively because of the limitation of the loading system obtainable in the Structural Engineering laboratory, NIT Rourkela. The beams are overdesigned in flexure as per Indian code IS: 456 2000 to be able to guarantee a shear

failure. The effect of length parameter on the load carrying of beam has not been studied because of above limitation.

2.2 Casting of Specimens

The beam specimens are made from the nominal mix of the concrete of grade M20 with mix proportions as per IS: 456 2000. For mixing purpose, the concrete mixer is used, and the water cement ratio is fixed at 0.55. 3 numbers of 150x150x150 mm concrete cube specimens are cast along with each beam and cured for twenty-eight days to decide the compressive strength of concrete.

2.3 Fabrication of BFRP plate for tensile test

The following component materials are used for fabricating the BFRP plate:

- Unidirectional basalt FRP (BFRP)
- Resin (Epoxy)
- Catalyst (Hardener)
- Releasing agent (Polyvinyl alcohol)

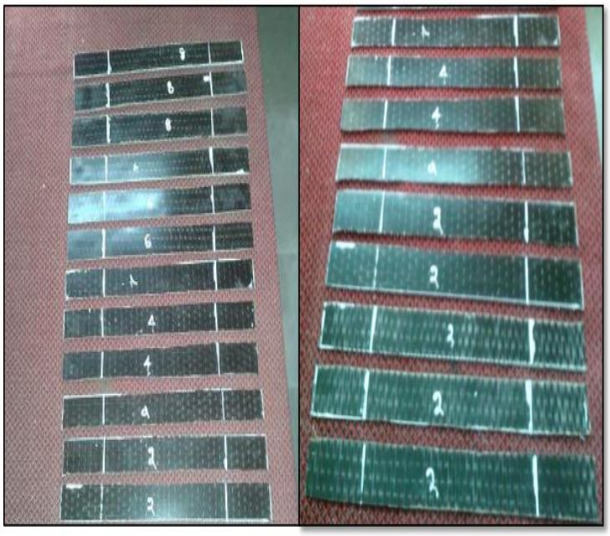

Fig 2: Specimens for tensile testing of unidirectional BFRP composite

2.4 Determination of Ultimate stress, Ultimate Load & Modulus of Elasticity of BFRP

The unidirectional tensile test is performed to determine the primary stress, ultimate load, and modulus of elasticity of the specimens. By using hex or diamond cutter saw the specimens are cut from the plates and is polished with the help of polishing machine.

Orientation	No. of layers	Ultimate Stress (MPa)	Ultimate Load (N)	Young's Modulus (MPa)
0^0 orientation	2 Layers	13.86	202	4588
	4 Layers	14.07	577	5561
	6 Layers	19.53	883	5607
	8 Layers	23.57	1010	6395
90^0 orientation	2 Layers	328	5808	11920
	4 Layers	391	11870	12870
	6 Layers	421	22110	13130
	8 Layers	469	25480	13920

Table 1. Result of the specimens from tensile test

2.5 Strengthening of Beams with FRP fabrics

Of the process of strengthening, the FRP fabrics are bonded to the concrete surface using a good resin and hardener. First the bottom surface area of the beam is cleaned by removing all of the loose particles. Then by means of course sandpaper, the required part of the concrete surface is made uneven and most of the dirt and debris particles are removed with an air blower. The epoxy resin is mixed and applied on the necessary part of the concrete surface after the planning of the concrete surface. The blending is done in a clear plastic container by taking 10 percent of hardener with respect to the epoxy resin and is continued for some time to get a uniform mixture.

Fig 3: Application of epoxy and hardener on the beam

Fig 4: Fixing of BFRP sheets on the beam.

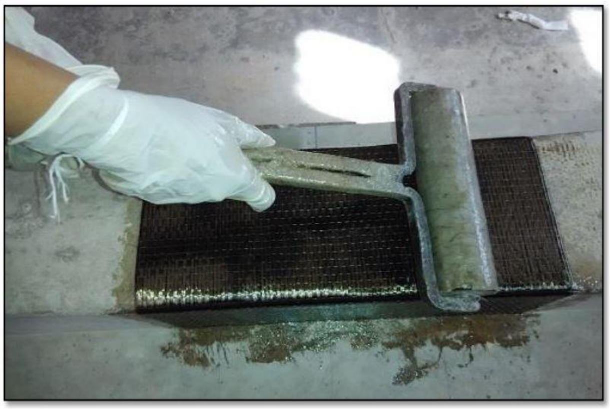

Fig 5: Roller used for the removal of air bubble.

2.6 Experimental Set-up for Testing of Beams

The arrangement of the 4-point static loading system is provided in Figure 3.9. The load is transferred to a spreader beam by means of a load cell. The spreader beam is placed above the test specimen by means of steel rollers placed on steel plates bedded on cement to pay for an even levelled surface. The expected test loads should be carried by the loading frame for all of the specimens without any distortion. The beam specimen to be tested is placed on steel rollers placed between 2 steel plates bearing leaving 150mm from the ends of the specimen. The rest of the 1000mm is divided into 3 identical parts of 333mm as presented in the Figure 3.9. The lines are drawn on the specimens to be tested at distances of L/3, L/2, & 2L/3 from the left support (L=1300mm). The deflection of the specimens is recorded with the assistance of 3 dial gauges. 2 dial gauges are positioned under 2 concentrated loads, i.e., at L/3 and 2L/3 distances as well as the other dial gauge is positioned under the Centre of the specimen, i.e., at L/2 distance to measure the deflections.

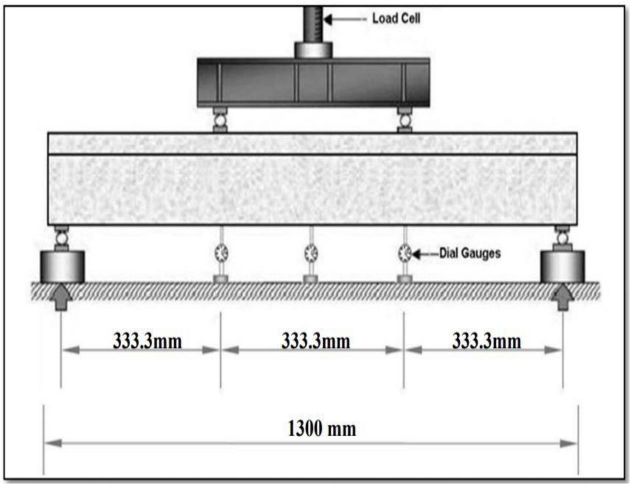

Fig 6: Details of the Test setup with location of dial gauges

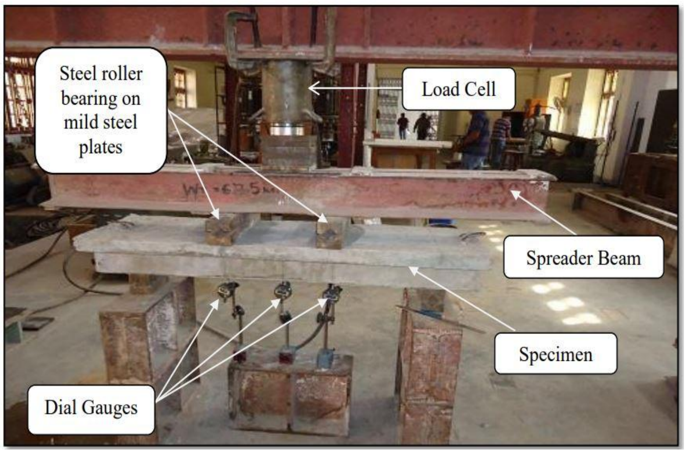

Fig 7: Experimental Setup for testing of beams

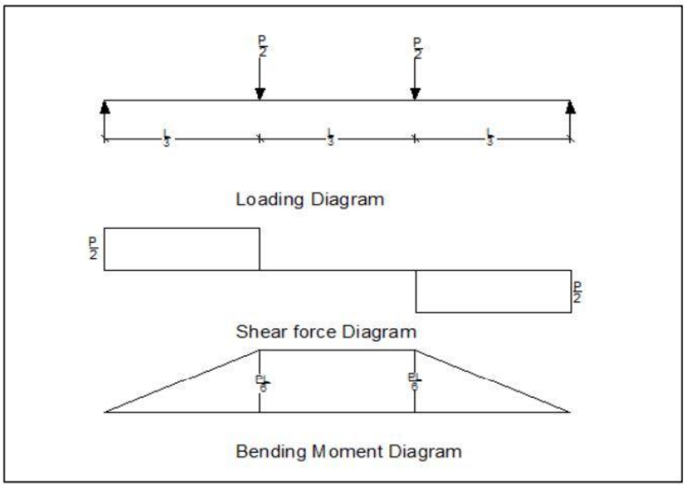

Fig 8: Shear force and bending moment diagram for four-point static loading.

3. RESULT

This analysis interprets the results obtained from the experimental investigation. The series A comprises of the shear strengthening of the RC beams with T shaped cross-section with no transverse openings, the behaviour of the RC T beams with respect to initial crack load, ultimate load carrying capacity, crack pattern, deflection is studied throughout the test and their failure modes are described. Except the control beams, all the beams are strengthened with different configurations of unidirectional BFRP sheets/strips. All the beams are made as shear deficient ones.

Crack Behaviour and Failure Modes

The twenty-two numbers of RC T-beams are tested under four-point static loading system and their cracking behaviour and modes of failure are reported below.

1. **Strengthened Beam 1 (SB1)**

The failure is followed by a diagonal shear failure with the increasing load and the beam failed at an ultimate load of 178kN. The strengthening of beam SB1 with BFRP sheets in 00 orientation having U wraps caused 12.66 % increase in shear capacity over the control beam.

2. **Strengthened Beam 2 (SB2)**

The beam failed by the debonding of BFRP sheets, the ultimate failure is followed by a diagonal shear failure with the increasing load and the beam failed at an ultimate load of 167kN.

3. **Strengthened Beam 3 (SB3)**

The failure of the beam SB3 occurred at an ultimate load of 170kN, and the ultimate shear failure is because of the debonding of the BFRP strips followed by a wider diagonal shear crack. The strengthening of beam SB3 with BFRP U strips caused 7.59 % increase in shear capacity over the control beam.

4. **Strengthened Beam 4 (SB4)**

The ultimate shear failure of the beam SB4 occurred as a result of the debonding of the BFRP strips followed by a wider diagonal shear crack at an ultimate load of 163kN. The strengthening of beam SB4 with BFRP side strips caused 3.16 % increase in shear capacity over the control beam.

5. **Strengthened Beam 5 (SB5)**

The debonding failure is followed by a diagonal shear failure with the increasing load and also the beam finally failed at an ultimate load of 200kN. The strengthening of beam SB5 with BFRP sheets in 900 orientation having U wraps caused 26.58 % increase in shear capacity over the control beam.

6. **Strengthened Beam 6 (SB6)**

The debonding failure is followed by a diagonal shear failure with the increasing load and also the beam finally failed at an ultimate load of 175kN. The strengthening of beam SB6 caused 10.76 % increase in shear capacity over the control beam.

7. **Strengthened Beam 7 (SB7)**

The failure of the beam SB7 occurred as a result of the debonding of the BFRP strips at an ultimate load of 185kN followed by a wider diagonal shear crack. The strengthening of beam SB7 with BFRP U strips caused 17.09 % increase in shear capacity over the control beam.

8. **Strengthened Beam 8 (SB8)**

The ultimate shear failure of the beam SB8 occurred as a result of the debonding of the BFRP strips followed by a wider diagonal shear crack at an ultimate load of 166kN. The strengthening of beam SB8 with BFRP side strips caused 5.06 % increase in shear capacity over the control beam.

9. **Strengthened Beam 9 (SB9)**

The ultimate shear failure of the beam SB9 occurred as a result of the debonding of the BFRP strips followed by a wider diagonal shear crack at an ultimate load of 192kN. The strengthening of beam SB9 with BFRP U strips caused 21.52 % increase in shear capacity over the control beam.

10. **Strengthened Beam 10 (SB10)**

The ultimate failure of the beam SB10 is because of the tearing of the BFRP sheets below the anchorage plate at an ultimate load of 219kN. The strengthening of beam SB10 with BFRP sheets in 900 orientation having U wraps with end anchorage system caused 38.61 % increase in shear capacity over the control beam.

11. **Strengthened Beam 11 (SB11)**

The failure of the beam SB11 occurred on account of the tearing of the BFRP sheets below the anchorage plate followed by a wider diagonal shear crack at an ultimate load of 232kN. An increase in the shear strength is observed as compared with beam SB10. The strengthening of beam SB11 with 4 layers of BFRP sheets in 900 orientation having U wraps with end anchorage system caused 46.83 % increase in shear capacity over the control beam.

12. **Strengthened Beam 12 (SB12)**

The ultimate failure of the beam SB12 occurred at an ultimate load of 200kN because of the tearing of the BFRP strips followed by a wider diagonal shear crack in an equivalent region as in case of CB. The strengthening of beam SB12 with BFRP U strips in 900 orientation.

4. CONCLUSION

Based on the experimental investigation and analytical study of shear strengthening of RC Tbeams with externally bonded unidirectional BFRP composites, the following conclusions are drawn:

- shear capacity of RC beams with T shaped cross section can be increased significantly by using BFRP composites as an external reinforcement The. The first cracks in the strengthened beams are formed at a greater load compared to the ones in the control beams.
- Strengthening with BFRP composites bonded to webs only are most prone to debonding with premature failure. The beam strengthened with BFRP sheets is found to have a lot more shear capacity compared to the beam strengthened with BFRP strips strengthening of beams using U wrap configuration is found to be better than the side wrap configuration. Among all the BFRP strip configurations (i.e., horizontal strips, vertical strips and strips inclined at 450), the U strip with 450 fiber orientations is more effective Formation of crack gets delayed because of the use of BFRP sheets as well as by introduction of end anchorage.
- The load carrying capacity of the strengthened beams can be found to be in excess of that of the control beams, thus the externally bonded BFRP composites enhance the load carrying capacity.

5.Future Work

- FRP strengthening of RC T beams using carbon and aramid composites.
- Strengthening of RC T beams using woven basalt fiber.
- Strengthening of RC L section beams with FRP composites.
- Strengthening of RC L section beams with transverse web openings.
- Effect of transverse web openings of different size and shape on the shear behaviour of RC L section beams.
- Effects of shear span to effective depth ratio on the shear capacity of beams.
- Numerical modeling of RC T & L beams strengthened with FRP sheets with end anchorage.

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