



SHEAR BEHAVIOUR INVESTIGATION ON BFRP STRENGTHENED RCL-BEAM COMPARED WITH T-BEAM ANALYSIS

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ABSTRACT:

Since most recent couple of years, the request of reinforcing is continuing expanding because of assortment of reasons. The different purposes behind decay of auxiliary individuals incorporate change in stacking condition, ill-advised outline or execution, change of usefulness of building and so forth. Development of new structure post devastating old one won't just be uneconomical yet additionally it may have unfavorable impact on the bordering structures. In this manner, it is not fitting. Or maybe it is smarter to upgrade the heap bearing limit of the present weakening structure. Bars are the most critical individuals from any structure. They are intended for flexure and checked for shear. Notwithstanding, the flexural disappointment of pillar is favored against the shear disappointment which prompts disastrous disappointment. Different materials are currently accessible in the market for fortifying of RC Beams. An examination has been completed wherein 5 pillars were threw of 2000 mm length, 200 mm width and 270 mm profundity took after by testing in the wake of reinforcing. In the present test, materials utilized for fortifying are weaved work and welded work, utilizing component of Ferro-bond and Micro-Concrete. Additionally loads and redirections were measured and the outcomes indicate change in stack conveying limit of reinforced shaft when contrasted with non-fortified bar.

1.0 INTRODUCTION

The primary point of the planning of any structure is that it should serve for the period it has been intended to serve. Be that as it may, before the outline time frame is over the structure needs support due to reasons like change in stacking conditions, useful change, harms because of quakes and so forth. The structure developed amid antiquated time furthermore, which are as yet existing

interest more repair. Notwithstanding, a portion of the new structures likewise appear the indication of disintegration. Different system are accessible in the market for fortifying of RC pillars like Ferro Cement, Micro-Concrete, outer plate holding, shotcreting, splashed concrete and so forth. Strategy for showered cement can be utilized where the measurement addition is not an issue. Likewise, it is not financially savvy and expends additional time. Fortifying utilizing steel plate with epoxy is moreover a superior option however not in like manner hone because of issue of consumption and being uneconomic. Jacketing is utilized generally however the fundamental hindrance of this technique is that it builds the first measurements and along these lines weight of the structure. Ferro bond was characterized ferrocement as "a sort of thin divider fortified cement normally built of water driven concrete mortar, strengthened with firmly divided layers of consistent and generally little distance across mesh". Writing demonstrates that bunches of research has been done to ponder the impact of ferrocement method on various auxiliary individuals. Ferrocement system enhances the heap excepting limit of cement and can likewise use as coat in strengthened solid sections

1.1 Fibre Reinforced Polymer (FRP)

FRP composites are, as the name proposes, a composition of two or more materials which, when suitably united, form a different material with properties not available from the individual

ingredients. Fibre reinforced composite materials consist of fibers of high tensile strength and adhesive that binds the fibers together to produce the structural material. Commonly used fibers are aramid, basalt, carbon and glass in the civil engineering industry. The adhesive that is commonly used is epoxy which protects the fibres, providing durability and under the loading condition distributes the load to the fibres. The fibres are oriented in the direction(s) that utilize them most efficiently. The successful application of FRP in different fields like aerospace, sports, recreation and automobile industries is the reason for the increase in demand of FRP. The properties of FRP composites and their versatility have resulted in significant efficiency, reliability and cost effectiveness in rehabilitation.

Among various types of FRPs, mostly used FRP materials are carbon and glass fibres. Though the strength of carbon fiber is very high, but it is more expensive as compared to other types of fibres. Glass fiber is less expensive as compared to carbon fibre, but it was proven to be less effective and less durable against corrosive medium. Hence, to overcome all of these disadvantages basalt fibre have been used in the present research work. The cost of glass and basalt fibres is nearly same. Basalt fibre exhibits high corrosion resistant and chemical durability towards corrosive medium, such as salts, acid solutions and alkalis. It has also higher thermal ability as compared to glass fibres.

1.2 Strengthening using FRP

Concrete beams are the main element in structural engineering which are designed to carry both horizontal loads due to seismic or wind and vertical gravity loads. Like all other concrete elements they are susceptible for situations where there is an increase in structural loads. Generally reinforced concrete (RC) beams fail in two ways: flexure failure and diagonal tension (shear) failure. Flexural

failure is generally preferred to shear failure as the former is ductile while the latter is brittle. A ductile failure permits stress redistribution and gives prior notice to occupants, whereas a brittle failure is sudden and thus catastrophic. The use of external FRP reinforcement may be classified as: flexural and shear strengthening. Flexural strengthening using FRP for flexural strengthening the laminates of FRP are used and applied with epoxy to the tension zone of the RCC members which acts as external tension reinforcements to increase the flexural strength of the RCC members.

OBJECTIVE:

The main objectives of the present research work may be summarized as follows:

- To analyse the structural behaviour of T-section RC beams under static loading condition.
- To investigate the shear behaviour and modes of failure of shear deficient RC Tbeams strengthened with FRP composite sheets.
- To examine the effect of different parameters such as number of layers, bonding surface, different fibre orientation etc. on the shear capacity of the RC T-beams.
- To study the effect of strengthening with externally bonded FRP on the enhancement of strength in RC T-beams with web openings of different cross-section.
- To investigate the effect of an anchorage scheme on the improvement of shear capacity of the RC T-beams.

2.0 LITERATURE REVIEW

[1] Angelakos et al (2001).

In concrete beams the Shear transfer mechanism may occur by any of the following means:

- (1) Shear stress in the uncracked concrete,
- (2) Interface shear transfer,
- (3) Dowel action and arch action.

Failure due to cracking of beams occurs when the stresses in the beams exceed the tensile shear stress and the failure due to crushing occurs when the stresses exceed the compressive shear stress. As a result of compressive force being applied in the concrete strut portion between the loading point and support, the web portion of a beam carries biaxial stress.

[2] Task Committee 426 (1973).

The presence of the longitudinal reinforcement also influences the crack by reducing its size and modifies resistance performed by the aggregate interlock. The length and depth of the crack reduces considerably in the presence of larger amount of longitudinal reinforcement. The reduction in the size of cracks helps to prevent the beam from further crack propagation.

Thus by providing greater amount of longitudinal reinforcement, the shear capacity can be increased to an extent. When the shear resistance is more as in some cases, the flow of shear gets affected and a resistance in the form of arch action is developed. For this arch action to take place, the depth of the member should be sufficiently large enough which should be comparable to its span. If not, the structure will not be possible to develop the arch action. This type of arch action is common in deep beams, where the inclined cracks are formed from the point of loading to the support reaction.

[3] Nilson et al (2004)

The stirrups oppose widening of the cracks, which maintains the aggregate interlock within the concrete was explained in case of FRP RC beams. Moreover, stirrups are tied to the longitudinal reinforcement and due to this confinement effect the splitting of concrete along the longitudinal main bars is controlled more effectively. The extent and amount of shear resisted by the shear stirrups and concrete depends upon the design procedure which is being adopted.

[4] Kong (1990).

He has mentioned that the transition from ordinary beam behaviour to deep-beam behaviour is imprecise and is difficult to exactly predict the point of change in the behaviour. Reinforced concrete deep beams differ from other beams primarily in their behaviour to take up the load. Due to the geometry of deep beams, the failure in deep beams is totally governed by shear rather than flexural failure.

Before a deep beam could take up its full flexural strength, diagonal cracks are formed which tend to cause shear failure. Hence, shear strength is considered as an important factor in the design of concrete deep beams.

[5] Ashour et al (2002)

He proposed an empirical modelling obtained by using the genetic programming to predict the shear strength of reinforced concrete deep beam. The various parameters influencing the shear strength of RC deep beam was analysed using genetic programming. The following points were concluded in their model study:

- 1) The shear strength was found to increase as the shear-span to depth ratio was decreased, which indicates that the shear strength is inversely proportional to the 'shear span to depth' ratio.
- 2) The 'shear span to depth' ratio and amount of the main longitudinal reinforcement has a significant influence on the shear strength of RC deep beams.

3.0 METHODOLOGY

The purpose of the present research work is to study the effect of the externally bonded fiber

Reinforced polymer sheets on the shear capacity of the RC T-beams with and without T- Transverse openings under-static loading conditions. In this experimental programme a total of twenty two numbers of beams are cast and tested by applying symmetrical four point static loading system up to failure. The beams are grouped into two series designated as A and B. The first series of tests, series A,

dealt with the shear strengthening of the RC beams with T-shaped cross-section without transverse openings. The second series B, focused on the shear strengthening of the RC T-beams with transverse openings of different shapes. In each series, one of the beams is not strengthened with FRP and considered as control beam whereas other are strengthened with externally bonded unidirectional BFRP sheets in the shear zone of the beams. The variables selected for the experimental works are BFRP amount and distribution (i.e., wrap versus strips), bonded surface (i.e., lateral sides versus U-wrap), number of layers of BFRP, fiber orientation (i.e., 0° direction versus 90° direction versus 45° direction), Transverse web openings of different shape (i.e., circular versus square versus rectangular) and end anchor (i.e., U-wrap with and without end anchor).

3.2 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 2 numbers of 16 mm ϕ and 1 number of 12 mm ϕ HYSD bars as tension reinforcement. Four numbers of 10 mm ϕ bars are provided as hanger bars. The length and depth of the beam have been taken as 1300 mm and 175mm, respectively due to the limitation of the loading system available in the Structural Engineering laboratory, NIT Rourkela. The beams are overdesigned in flexure as per Indian code IS: 456-2000 in order to guarantee a shear failure. The effect of length parameter on the load carrying of beam has not been studied due to above limitation.

3.3 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 [30] and presented in Table 3.1. For mixing purpose, the concrete mixer is used and the water cement ratio is fixed at 0.55. Three numbers of 150x150x150 mm concrete cube specimens are cast along with each beam and cured for 28 days to determine the compressive strength of concrete.

The arrangement of reinforcement is same for all the beams. Two numbers of 16 mm ϕ and one number of 12 mm ϕ HYSD bars are provided as tension reinforcements and four numbers of 10 mm ϕ steel bars are used as hang-up bars. The cross-section and reinforcement details of the control beam are depicted in Figure 3.1. All the strengthened beams have same cross-section and reinforcement details as that of the control beam.

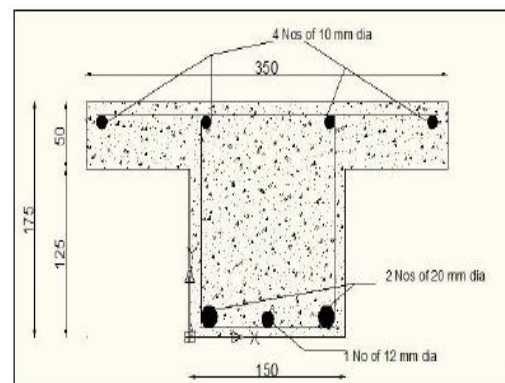


Figure All the strengthened beams have same cross-section and reinforcement details as that of the control beam.

The unidirectional tensile test is conducted to determine the ultimate stress, ultimate load and modulus of elasticity of the specimens. By using diamond cutter or hex saw the specimens are cut from the plates and is polished with the help of polishing machine. The mean of the three specimens is considered. The dimensions of the tested specimens are tabulated in Table

Table shows Dimension of the Specimens for tensile test

Orientation	No. of layers	Length of sample (cm)	Width of sample (cm)	Thickness of sample (cm)
0° orientation	2 Layers	25	2.5	0.56
	4 Layers	25	2.5	1.07
	6 Layers	25	2.5	1.53
	8 Layers	25	2.5	2.03
90° orientation	2 Layers	25	2.5	0.56
	4 Layers	25	2.5	1.07
	6 Layers	25	2.5 </td <td>1.53</td>	1.53
	8 Layers	25	2.5	2.03

The epoxy resin is mixed and applied on the required part of the concrete surface after the preparation of the concrete surface. The mixing is done in a plastic container by taking 10 percent of hardener (HY 951) with respect to the epoxy resin (Araldite LY 556) and is continued for some time to obtain a uniform mixture. Then the fabrics are cut as per the required size and the epoxy resin is applied to the concrete surface. After the application of epoxy resin coating, the BFRP fabric is employed at the top of the coating and a steel roller is used to eliminate the entrapped air bubbles at the interface of concrete/epoxy or fabric/epoxy for perfect bonding. Then over the first layer of BFRP the second layer of epoxy resin is applied and BFRP fabric is employed over the epoxy resin coating. Again a steel roller is used for eliminating the entrapped air and the above process is repeated until the required number of BFRP fabrics is obtained on the concrete surface. To avoid hardening of epoxy resin hardener mix this operation must be done very quickly. The excess epoxy resin is extruded by applying a constant uniform pressure on the composite fabric surface to achieve a good adherence between the concrete, the epoxy and the fabric. The operation is carried out at room temperature, cured for minimum 3 days before testing.



Application of epoxy and hardener on the beam



Fixing of BFRP sheets on the beam



Roller used for the removal of air bubble

4.0 TEST RESULTS AND DISCUSSIONS

the shear failure without strengthening. It is a shear deficient beam and is tested under the four point static loading system by applying the point loads gradually. The experimental setup for the control beam under four point static loading frame is shown in Figure 4.1(a). The first hair line crack appeared at a load of 60kN in the shear region of the beam as given in Figure 4.1(b). As the load increased, additional shear cracks are developed and the primary

visible crack undergoes widening and propagated as shown in Figure 4.1(c). With the further increase in load, the beam exhibited a wider diagonal shear crack and finally failed in shear a load of 158kN as illustrated in



Figure 4.1 (a) Experimental Setup of CB under four-point loading system, (b) Hair line crack started in shear region at a load of 60kN, (c) Crack pattern near Right support, (d) Crack pattern at ultimate failure

The failure of the beam SB1 is initiated due to the splitting of BFRP sheets over the principal shear crack in the same region as appeared in the control beam. Finally the beam failed by the debonding of BFRP sheets followed by a film concrete deposit adhered to them as given in Figure 4.2(b). The failure is followed by a diagonal shear failure with the increasing load and the beam failed at an ultimate load of 178kN as given in Figure

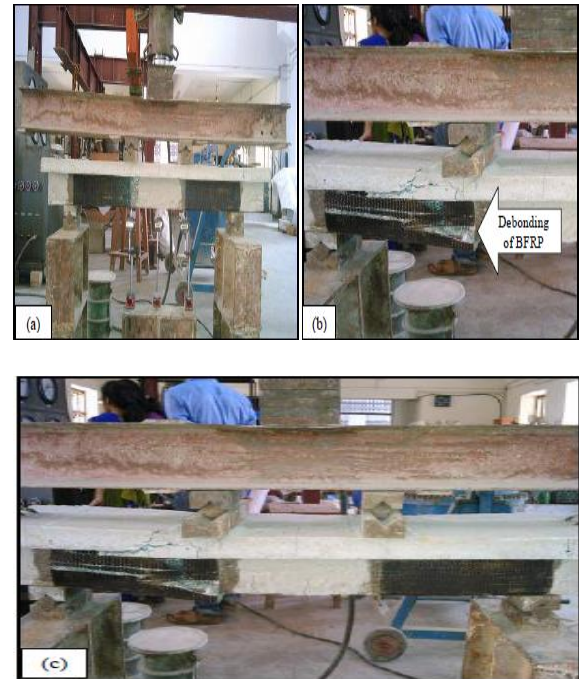


Figure 4.2 (a) Experimental Setup of beam SB1 under four-point loading system, (b) Debonding of BFRP sheet at ultimate load, (c) Ultimate failure of beam SB1 by debonding of BFRP sheet followed by diagonal shear crack

The beam SB4 is strengthened with 2 layers of BFRP strips in 00 orientation bonded only on the sides of the beam (i.e. on web portions) in the shear area (i.e. a length of 0 to L/3 and 2L/3 to L from the left support) with 3 strips of equal width of 50 mm and spacing between the strips is 50 mm bonded to both the shear spans of the beam. The experimental setup of the beam SB4 is given in Figure 4.5(a). The first hair line crack is observed on the concrete surface at a load of 65kN in the shear region of the beam as given in Figure 4.5(b). The ultimate shear failure of the beam SB4 occurred due to the debonding of the BFRP strips followed by a wider diagonal shear crack at an ultimate load of 163kN as illustrated in Figure 4.5(c). The strengthening of beam SB4 with BFRP side strips caused 3.16% increase in shear capacity over the control beam.



Figure 4.4 (a) Experimental Setup of beam SB4 under four-point loading system, (b) Hair line crack started in shear region at a load of 65kN, (c) Ultimate failure of beam SB4 by debonding of BFRP strip followed by diagonal shear crack

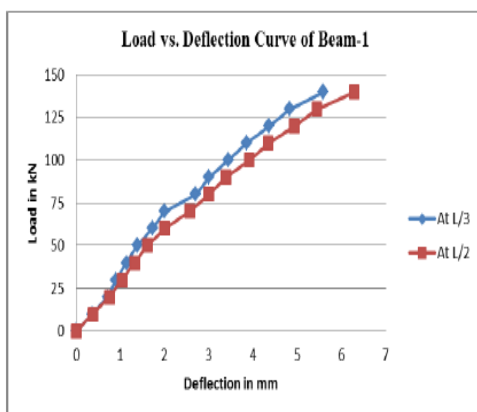


Figure 4.1 Load vs. Deflection Curve for CB

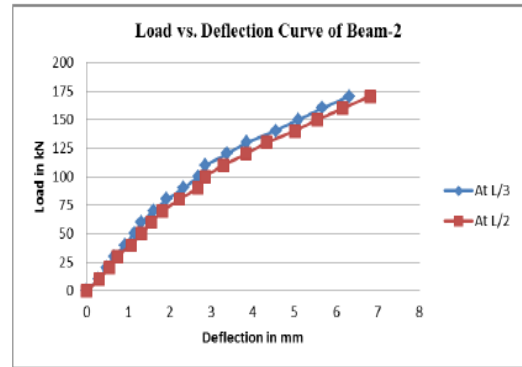


Figure 4.2 Load vs. Deflection Curve for SB

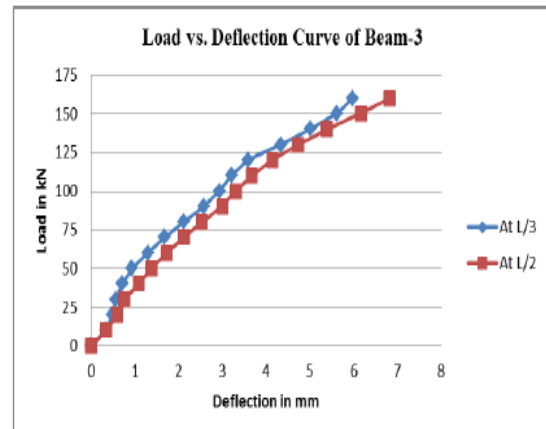


Figure 4.3 Load vs. Deflection Curve for SB2

ANALYSIS RESULTS

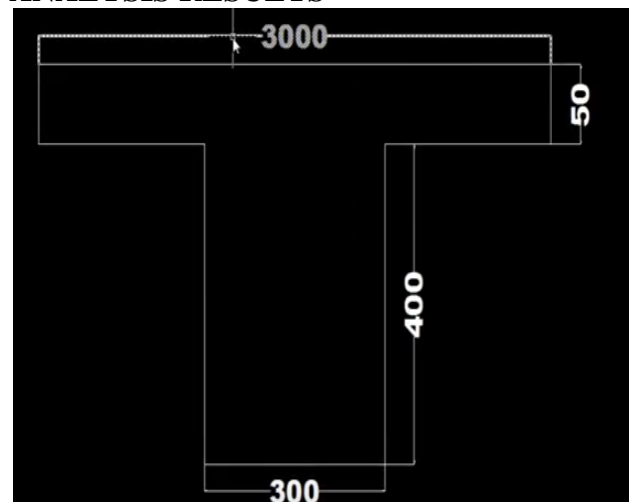


Figure 5.1 shows the T-beam section

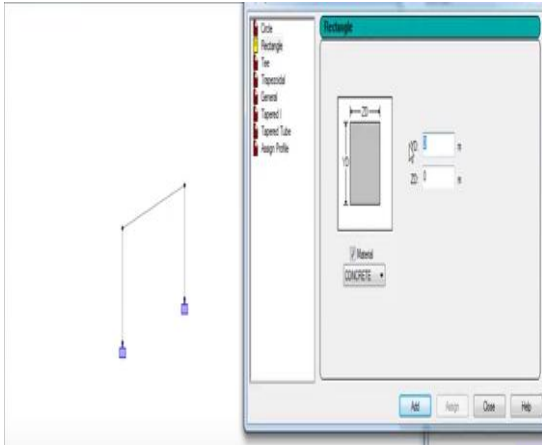


Figure 5.2 shows the beam selection in staad pro

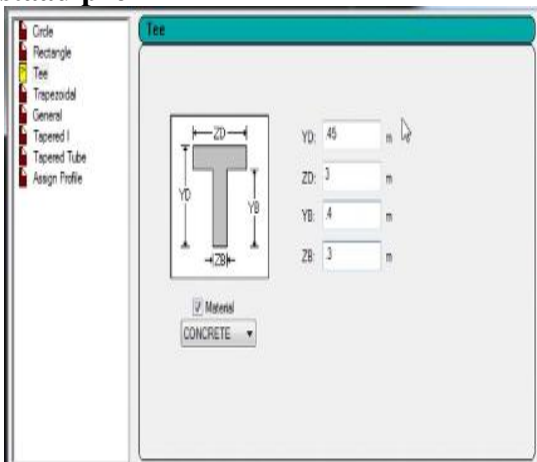


Figure 5.3 shows the T-beam selection

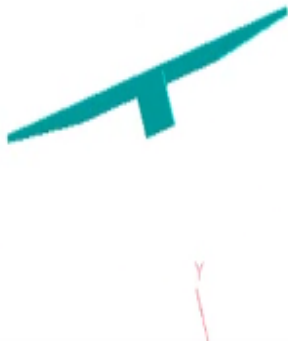
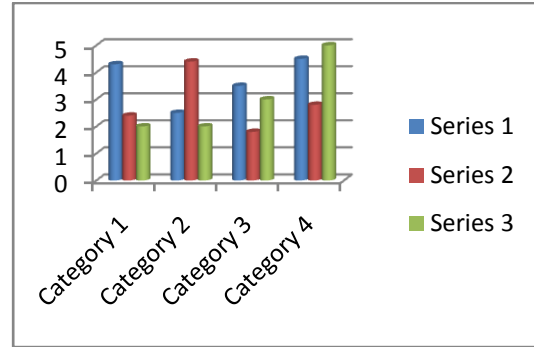


Figure 5.4 shows t beam creation



GRAPH SHOWS APPLIED LOADS

Conclusions

Based on the experimental investigation and analytical study of shear strengthening of RC T-beams with externally bonded unidirectional BFRP composites, the following conclusions are

Drawn:

- ❖ The shear capacity of RC beams with T-shaped cross-section can be enhanced
- ❖ Significantly by using BFRP composites as an external reinforcement.
- ❖ The initial cracks in the strengthened beams are formed at a higher load compared to the ones in the control beams.
- ❖ Strengthening with BFRP composites bonded to webs only are most susceptible to debonding with premature failure.
- ❖ The beam strengthened with BFRP sheets is found to have more shear capacity than
- ❖ The beam strengthened with BFRP strips.
- ❖ Strengthening of beams using U-wrap configuration is found to be more effective than
- ❖ The side-wrap configuration.
- ❖ Among all the BFRP strip configurations (i.e., horizontal stripes, vertical strips and Strips inclined at 450), the U-strip with 450 fiber orientations is more effective.
- ❖ The performance of externally bonded BFRP composites can be

improved significantly by using adequate anchoring system.

- ❖ A proportional increase in the shear capacity with the increasing BFRP amount cannot be achieved when debonding is not prevented.
- ❖ Anchorage system prevents the debonding of BFRP sheets/strips from the concrete surface, eliminating the premature failure, which consequently results in a better utilization of the full strength of the BFRP sheet/strip.
- ❖ Formation of crack gets delayed due to the use of BFRP sheets and also by introduction of end anchorage.
- ❖ U-wrap with end anchorage is found to be the most effective configuration among all the configurations.
- ❖ The load carrying capacity of the strengthened beams are found to be greater than that of the control beams, thus the externally bonded BFRP composites enhances the load carrying capacity.
- ❖ The shear strength of the T-beam strengthened with the U - wrap is found to be more in case of the beam without transverse web openings.
- ❖ The T-beam with transverse web openings strengthened with anchored U-wrap performs superior than the beam without anchorage.
- ❖ Among different shapes of transverse web openings, square hole is found to be more effective as compared to other ones.
- ❖ The analytical model based on ACI guidelines and Chen and Teng's model predicts conservative results compared to experimental ones.
- ❖ Finally, BFRP composite is proven to be a promising material for shear strengthening of RC T-beams with or without opening.

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