AN EXPERIMENTAL INVESTIGATION ON THE TORSION BEHAVIOUR OF A FLANGE BEAM APPLYING GLASS FIBRE REINFORCED POLYMER

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ABSTRACT

The need for the repair and rehabilitation of existing structures is perpetuated by factors such as environmental deterioration, excessive service loads, the reduction of capacity attributed to aging, substandard construction materials and workmanship, and seismic retrofitting requirements. Among these innovations in structural strengthening, the introduction of fiber-reinforced polymers (FRPs) has proven to be very efficient because of their lightweight, high strength, and longevity.

Researchers have previously studied various strip arrangements and fiber types for torsional strengthening of solid rectangular RC beams. Yet more research into hybrid designs is needed. Various analytical models have been proposed to estimate the torsional response of reinforced rectangular beams, corroborating with experimental results. Not much work has been done on the torsional strengthening of RC T-beams.

This study will provide further insight into the torsional behavior exhibited by solid RC flanged T-beams using experimental investigations. Torsion of RC T-beams is analyzed and designed exactly the same way as it is done for RC rectangular beams 24, however, the contribution of the concrete flange is usually not considered in available design codes. The study investigates the contribution of flange dimensions in resisting torsion by altering flange width of beams in a controlled setup. Furthermore, a variety of strengthening configurations and fiber orientations of the RC T-beams were used to study their effect on the torsional performance of the beams.

This study examines the transverse reinforcement of textiles under torsion. Torsion data from the FRP strengthening beams are displayed and contrasted with the experimental results from the control beams, which did not use FRP. According to the study, the full-scale GFRP strengthened beams do exhibit a notable improvement in torsional behavior.

INTRODUCTION

Civil engineering infrastructure forms the backbone of our civilization at large where applications(e.g., pollution control plants, industrial buildings, power stations, bridges, etc.) are essential for fostering economic and social development. Regular maintenance and strengthening procedures are essential for these structures to function correctly and safely. All engineering structures regardless residential or facilitating deterioration over the years.

Structural integrity is primarily compromised due to external factors like intensity loading, chemical exposure, saline-water intrusion, and ultra-violet rays. Second we have that a lot of structural damage is to earthquakes. To overcome such challenges, valuable solutions in the form of advanced structural retrofitting technologies need to be developed.

In order to maintain the condition of civil engineering structures, they must be continually monitored for the best action to take. Parting counsel When to repair/retrofit vs demolish/reconstruct depends on many factors, particularly cost

and possibility. Although full reconstruction is one option, it is an expensive undertaking. Retrofitting, on the other hand, offers a more pragmatic and affordable solution in many situations, extending the durability and strength of existing buildings.
When structures such as bridges or buildings are found damaged as a result of degradation, aging, lack of maintenance, destructive earthquakes or by changing design criteria, repair and rehabilitation are often more desirable than total reconstruction. Conventional prefabricated reinforced concrete (RC) structural column and beam retrofitting transpired as an exercise during which low quality or partially damaged parts of concrete and steel reinforcement were excavated and replacement with stronger, more durable materials was instigated as made one easy, efficient, and economic externally bonded FRP sheets for strengthened RC structures. Some benefits of FRP-retrofitted concrete structures are higher strength, lightweight properties, corrosion resistance, high-fatigue resistance, easy installation, and fewer structural modifications. Additionally, FRP manufacturing enables the production of complex shapes and designs that are challenging or even impossible to replicate with conventional steel materials.

TORSIONAL STRENGHTENING OF BEAMS

Research on pure torsion behavior of plain concrete not surprisingly found that the mechanism of failure is tension-controlled compared to shear-controlled. In plain concrete, the mechanism of fragile failure is generated by tensile stresses, not shear forces. For example, the torsional moments in the design consideration for several structural members, e.g., curved beams in space frames.

The torsional effects in structural members such as T-shaped, inverted L, double T-shaped, or box- section are more complex due to the presence of bending moments and shear forces. The interaction of tensile and torsional forces is key because the tensile response of concrete—namely tensile cracking behavior—drives torsional performance.

Commonly, a spandrel beam is found along the perimeter of a building, supporting loads on their one side from slabs, joists, and beams. The loading method transmits the moments between the spandrel beams to the columns. Nonetheless, reinforcement concrete (RC) beams typically show limited torsional capacity, therefore they may need to be strengthened mainly due to insufficient stirrups (as a consequence of construction mistakes or design reasons), corrosion that significantly decreases effective steel area, or increased load requirements observed due to occupancy changes.

However, the design of torsional strengthening in RC members uses FRP fabric for bonding. As the torsion causes the diagonal tension in all directions, the FRPs must be applied to all facies of the cross-section. Where some surfaces are inaccessible, however, different methods of strengthening must be employed to provide an appropriate mechanism for torsional resistance. Moreover, the improvement rate of the fully wrapped beams in torsion was clearly higher than that of the beams with strip FRP configurations, indicating that complete wrapping is the most effective way to strengthen the torsion capacity of the beams.

REVIEW OF LITERATURE

In recent global research investigations and applications, externally bonded fiber-reinforced polymer (FRP) sheets have emerged as a means of strengthening and mending structural concrete elements. The civil engineering community finds the idea of external reinforcement with fiber-reinforced polymer (FRP) composite materials to be appealing. The benefits of FRP composite materials, such as their high strength and stiffness and ease of installation, have garnered significant interest in the civil engineering field as compared to traditional repair materials. Plus, it was discovered that FRP, when used as an exterior reinforcement solution, possesses a chemical resistance property in addition to being non-corrosive and non-magnetic.

The research of FRP composite material for concrete structures dates back to around 1950's in Europe by (Rubinsky and Rubinsky, 1954; Wines, J. C. et al., 1966). Meier (Meier 1987) is known to be the pioneer for bonded FRP system which was first bonded FRP on-site repair in Switzerland (Meier and Kaiser 1991). Early applications of FRP in Japan were designed for repairing concrete chimneys (ACI 440 1996) and were developed in the early 1980s. By 1997 external bonded FRP materials had been used to strengthen over 1500 concrete structures worldwide. More recently many types of FRP materials have been developed with various types of fibres. FRP products include bars, cables, sheet materials, laminates, and 2-D and 3-D grids. As the new materials of FRP composites, the growth in use of FRP composites have been considerable, many research, development works, and application trends in FRPs processing technology and other aspects has been conducted.

Despite a number of authors devoted to the study of strengthened concrete members with externally bonded FRP sheets/laminates/fabrics, there is not yet a national design code in any country available that includes design guidelines for the FRP strengthened concrete structures. Never the less national codes of practice have been issued (The Concrete Society, UK: 2004; ACI 440:2002; FIB: 2001; ISIS Canada: 2001; JBDPA: 1999) which provide current practices on FRP system selection and design and detailing of FRP-reinforced structures. In contrast, there is a difference of opinion over some of the aspects of the design and detailing guidelines. Such circumstances are only expected while the novel material is implemented on a global artist basis.

Various research continues at institutions worldwide, and the results of this research are expected to make design criteria ever better in the years to come.

Riyaz Syed et al, [12] Carbon nanotubes (CNTs) have gained a lot of attention in the field of building materials due to their exceptional mechanical, thermal, and electrical properties. Their influence can be seen in several ways across construction and civil engineering applications. Here's an overview of how CNTs are influencing building materials:

K Thirupathi Rao et al [13] Deficit irrigation is a strategic method that saves water while maintaining acceptable crop yields. Here's an overview and analysis on "Irrigation Scheduling Based on Soil Moisture Studies and Crop Yield Under Deficit Irrigation" that you can use for a report, research paper, or presentation.

K Thirupathi Rao et al [14] Sustainable concrete incorporates industrial waste (like fly ash, GGBS, silica fume, or slag) to reduce carbon footprint. Non-Destructive Testing (NDT) methods are used to evaluate the strength, durability, and integrity of concrete without damaging the structure. The objective of this is to assess how sustainable concrete made with industrial waste performs under NDT techniques compared to conventional concrete.

K Thirupathi Rao et al [15], Groundwater is a primary source for both drinking and agricultural irrigation in many regions. Overexploitation and contamination threaten its quality and sustainability. Evaluation of groundwater quality is essential to ensure: Human health safety, Sustainable agricultural productivity, Long-term resource planning

S Sunil Pratap Reddy [16] Concrete is the most widely used construction material in the world, yet it is inherently prone to cracking. These cracks compromise durability and lead to costly repairs, reduced structural integrity, and environmental impact over time. Self-healing concrete (SHC) addresses these issues by autonomously repairing cracks, extending service life and reducing maintenance.

Research Authors like, Saadatmanesh et al., (1994); Shahawy, (2000) have taken up FRP strengthened circular or rectangular columns studying Strength and ductility of these columns, Durability of these columns, Effect of confinement, Preparation of design guidelines, Experimental investigation.

OBJECTIVE AND SCOPE OF THE PRESENT WORK

This research aims to investigate the torsion performance of reinforced concrete beams with flanged cross sections (T-beams) that are strengthened by GFRP fabrics that are externally attached. The experimental results of three beams without the use of FRP were validated using eight reinforced beams under different torsional strains. We evaluate the following FRP configurations.

1. Wrapping of FRP strip around the cross section of fully wrapped T-beams with discrete 090 with longitudinal axis of beam
2. Discretized FRP strip around the cross section making it completely wrapped T-beams 045 with longitudinal axis of the beam
3. A T-beam that is U-jacketed and has bonded strips of FRP on the bottom edges of the flange and on the web of the beam.
4. A U-jacketed T-beam reinforced with FRP stirrs on top of the flange and point-bonded FRP strip on the web-bonded bottom sides of the flange.
5. An RC T-beam, which is referred to as an RC rectangular beam in this context, is analyzed and designed in Figure 1. Codes disregard how concrete affects the flange. This study investigates the effects of changing the flange width on the torsion resistance of the flange portion in controlled beams. Three beams with various
6. It is cast and tested to failure with variable widths of flanges designed to fail in torsion. The same web thickness and depth for a rectangular beam are taken into consideration to compare their performances.

EXPERIMENTAL STUDY

This study involves constructing an experimental program focused on the most effective strengthening parameters on torsional behavior capable of full-scale practical applications, where a total of eleven medium-scale reinforced concrete beams (1900 mm long) were constructed. T2, T3 and T4 are three types of T- shaped beams which are subjected to combined bending torsion. The control specimens were three beams without torsional reinforcement and eight specimens were strengthened in torsion with external transverse reinforcement consisting of epoxy-bonded glass FRP fabrics.

Within each group, it included one specimen is without transverse reinforcement (control specimen). Specimen T2C was control specimen of group-A, it contained only longitudinal reinforcement; four 20 mmφ deformed bars, and ten 10 mmφ, transverse bars of two legged stirrups at cross-section corners, and control specimen of T3C,and T4C of group- B, comprised six longitudinal deformed bars; one 20 mm diameter 10 mmφ, and four 8 mmφ and transverse bars of 8 mmφ two legged stirrups. All eight other specimens of the experimental program contained the same longitudinal steel reinforcement as the control specimens of their group, as well as transverse reinforcement (such as steel stirrups).

A naming scheme was established for the identification of test beams. The initial character in the name R (Rectangular), T (T-section) are used to classify the cross/section of beam. Character two is the length of the beam. The 3rd , is used to indicate the accentuation (U or UA) web or tessera or both. Character 4 in the name (90, 45) names the fiber orientation relative to the longitudinal axis of the beam

Reinforcing Steel

In accordance with IS 1786:1985, RHPHYSD bars. High-yield strength, deformed steel bars with a diameter of 20φ mm, 10φ mm, and 8mm were used as longitudinal reinforcing bars. With a diameter of 8 mm, the stirrups were made of distorted steel bars.

In order to ascertain the yield strength of the steel reinforcements utilized in this experimental program in accordance with ASTM requirements, uniaxial tension tests were conducted on three coupons of steel bars. The specimens' average proof stress or yield strength values are provided in

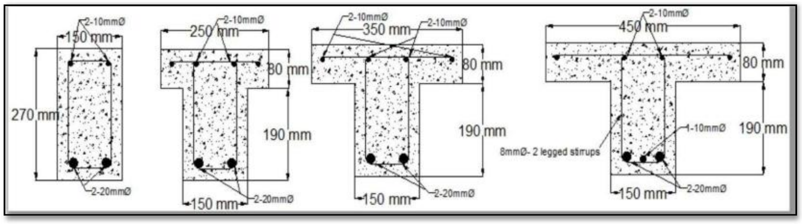
The values of the modulus of elasticity of steel bars are 2 × 10^5 Mpa

Table 3.3 Tensile Strength of reinforcing steel bars

Sl. no. of sample	Diameter of bar (mm)	0.2% Proof stress (N/mm^2)	Avg. Proof Stress (N/mm^2)
1	20	475	470
2	10	530	529
3	8	520	523

Detailing of Reinforcement

A Fiber Reinforced Polymer (FRP)



Materials made of continuous fiber reinforced plastic (CFRP) should be handled as composites, heterogeneous, and anisotropic materials having linear elastic characteristics that predominate until failure. The composition of FRP is typically composed of carbon fibers and glass, which serve as reinforcing materials. Epoxy serves as the binding agent for the fiber layers. GFRP sheet was used in this study as they are flexible, easy to handle, mix and apply, hence, FRP sheets have been used to provide torsional strengthening during testing. For the entire course of this study, Owens Corning manufactured E-glass was used

Epoxy Resin

FRP's ability to adhere to the concrete surface with epoxy resin mostly determines how efficient the strengthening method is. There are several different commercial formulations of epoxy resins with a variety of mechanical properties. The two components of these epoxy polymers are usually a hardener and a resin. Araldite LY 556 and HY 951 were the resin and hardener used in this investigation.

Casting of GFRP Plate for tensile strength

These are two of the basic processes to mold composites: hand lay-up and spray-up.

Hand Lay-Up: An old, simple fabricating method of composites that is very labor-intensive. The first technique is the most widely used in FRP marine construction. Stage 2: A layer of prerung woven glass fiber reinforcement is laid up on the finished surface of an open mold. Next, liquid resin is spread over the reinforcement. The resin then undergoes chemical reactions that cause it to heat and cure, resulting in a strong but lightweight final part. Just as concrete provides a matrix for reinforcing steel, the resin provides a binding matrix for the glass fibers. It keeps 50: 50 matrix to fiber weight ratio in this technique.

Hand lay-up in open mold contact molding was used to stack the woven roving plies in the correct order. A strong, flat plywood platform was the material of choice. Using a spray gun, a layer of polyvinyl alcohol was applied as a releasing agent over a plastic sheet that was placed over the plywood platform. First, a gel coat (epoxy and hardener) is brushed directly onto the mold to start the lamination process which serves the dual purpose of affording the outer shell a smooth finish and protecting the fibers from the environment. Woven roving build-up ply was cut from roll. The mould was prepared with reinforcing layers on the top of the gel coat and gel coat was brushed on. Serrated steel rollers were also used to remove away any air bubble that might had got entrapped. The above process was continued to form the hand lay-up before the gel coat had cured. Once more, PVA was applied inside the sheet as releasing agent, and a plastic The plate's top was covered with a covering. In order to ensure appropriate compression, a portion of our heavy flat metal rigid platform was then also included on top of the plate. After being left to dry for a minimum of two days, the plates were transported and sliced into the appropriate shape for testing. Plates with one, two, four, six, and eight layers were cast, and three layers of each thickness were used specimens were tested.

Test specimens for woven glass/epoxy composite tensile tests

INSTRON universal testing experimental configuration 600 kN capacity machine

FRP's Young's modulus, ultimate stress, and ultimate load determination

Prior to analyzing the ultimate stress of DGEBA resin, longitudinal and transverse samples were subjected to uniaxial tensile tests in order to determine the ultimate stress, ultimate load, and Young modulus. The specimens were then sliced with a hex saw or diamond cutter, polished on a polishing machine, and finally removed from the plates. At least three replicate specimens' mean values were found. These specimens' sizes are shown in the table. 3.4

Tensile strength and Youngs modulus were then measured upon loading the specimens with an INSTRON 600kN machine for 10kN increasing load within 1min between the specimens in the Production Engineering Lab, NITR, Rourkela. The test specimens were initially clamped into the fixed upper jaw followed by the movable lower jaw. A careful handling was performed, which kept each side with a grip length of 50 mm to avoid slippage. We started with zero strain. The data acted as an input to plot a stress-strain graph, and the first slope represents Youngs modulus. At the time of specimen failure, the ultimate load and ultimate stress were determined. Table 3.4 summarizes the average values over layers for each specimen.

Result of the Specimens

GFRP plate of	Length of sample (mm)	Width of sample (mm)	Thickness of sample (mm)	Ultimate Load (N)	Young's Modulus (MPa)	Ultimate Stress (MPa)
1 layer	250	25	0.7	2760	5658	137.9
2 layers	250	25	1	4190	9493	167.7
4 layers	250	25	1.7	9400	10020	210.1
6 layers	250	25	2.1	13840	11000	276.8
8 layers	250	25	3.1	17720	9253	228.7

STRENGTHENING OF BEAMS

The surface of the concrete is scarified with sandpaper or a coarse texture to which the fiber is bonded. This is later blown to blast the dirt and debris before bonding. The resin is mixed in proportions as specified by the manufacturer. The mixture was prepared in a plastic container in a ratio 100 wt.

After making sure the ink is evenly distributed throughout the fabric, it is trimmed to the required size. The prepared concrete surface is then covered with epoxy resin, and GFRP sheeting is placed on top of the epoxy resin coating. A roller is used to drive the resin into the fabric's roving and to release trapped air in the epoxy/fabric or epoxy/concrete interface. Uniform pressure is applied to the composite fabric surface during the epoxy-resin hardening process, which enables excess resin to be extruded from the surface to promote adhesion between the fabric, concrete, and epoxy. All of these steps are done at room temperature to apply the GFRP to the concrete.

roller for eliminating air bubbles

Form Work

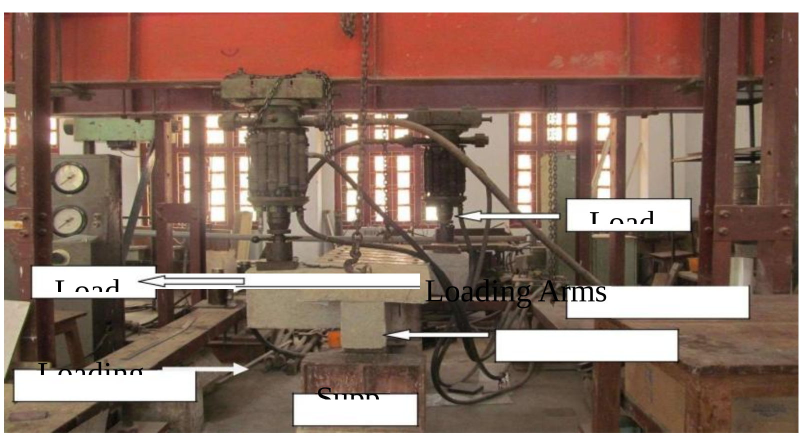
Since concrete is fresh and malleable, a quality form is necessary to mold it into the desired size and shape. Therefore, the form work has to be sturdy and rigid enough to support heavy, wet concrete without bulging anywhere. sealing the form work's joints to stop the cement slurry from leaking. Later, Mobil oil was applied to the form-work's interior facings. The lower lay on dense semipermeable plastic sheet contained by the inflexible socialize. Following this, concrete cover blocks were used to position the reinforcement cage in place well within the side work, where the cover was 20mm on sides and bottom, with a cover block.

The steel frame used to cast RC T-beams

EXPERIMENTAL SETUP

The beams were tested in the loading frame ofStructural Engineering Laboratory of National Institute of Technology, Rourkela. All the specimen has the same testing procedure. Initially the beams are cured for 28 days and cleaned with sand paper for better crack visibility. Two point loading set up is used for beams testing.

The benefit of this is that there is a large area of close to constant moment and very low shears, so that the capacity for bending of the central piece can be evaluated. The arrangement of the equipment in Figure 3.9 gives easy two-point loading. A spreader beam receives the load from a load cell and spherical seats. To provide a level and smooth surface, the spreader beam is set up on rollers that are supported by steel plates that are subsequently cemented onto the test member. The roller bearings that support the test member function on similar spreader plates. Directly beneath the specimen, 150 mm from the ends of the beam, are two steel roller bearing supports. Square plates are positioned on a beam flange 100 mm from the end, and a load cell applies the load through them. For loading, a 100-ton hydraulic jack was utilized. A clear view of the experimental setup is shown in.

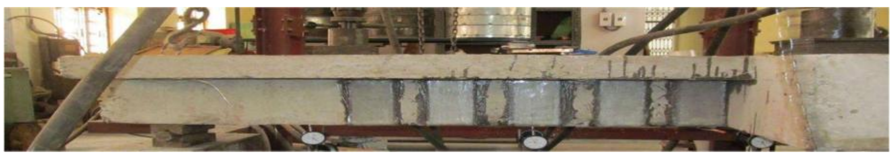


Loading Setup

T-beam with a 350mm flange width and no GFRP, control beam (T3C)

Strengthened T- beam (T3SU)

Fiber strips with a width of 100 mm and a center-to-center spacing of 175 mm are utilized to reinforce the third beam. The longitudinal axis of the beam is 90 degrees from the orientation of the fiber strips. Every strip is entirely wrapped around the beam and contains four layers of bidirectional GFRP cloth. Moreover, below displays the beam.



T-shaped beam strengthened with U-Wrap's GFRP

Strengthened T- beam (T3SUA)

The beam (T3SUA) is modeled using four layers, each measuring 75 mm in width.

U-RAP for Subsoil and Web/Bearing Longitudinal Directional Embedded Limit of Concrete Strain and Subsoil Surface DeformationUsing the mago for the magnitude, Web sections, flange anchorage system, and U-head spacing on the bottom are provided for control.

FRP debonding:

T-shaped beam reinforced with flange anchoring and GFRP of U- Wrap.

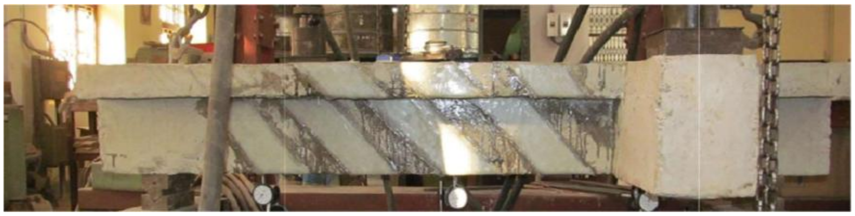
Strengthened T- beam (T3SF)

A model of the beams using (T3SF) is shown in four GFRP strips of 100mm width and 75mm trapping spacing around full circumference of beam sectional And the orientation of beam has 90º. Figure 3-13.

T-shaped beam strengthened using completely wrapped GFRP beams.

Strengthened T- beam (T3S45)

Four layers of 100mm wide, 75mm spaced and 45º inclination of GFRP strips are modelled on the beam (T3S45) as Fully Wrapped and shown in figure 3-14. The control beam is one of five beams in this group. This beam possesses For every beam, the flange width is 450mm and the reinforcement is 2-20mmφ, 3-10mmφ, and 2-8mmφ



T-shaped beams reinforced using 45º inclination-wrapped GFRP strips

T- BEAM (T4C)

The solid T-beam is not covered in GFRP. Its purpose is to comprehend how the beam behaves in a static loading test associated with plate bolt connections. The center of the span is largely slack in torsion. depicted in Figure 3.15.

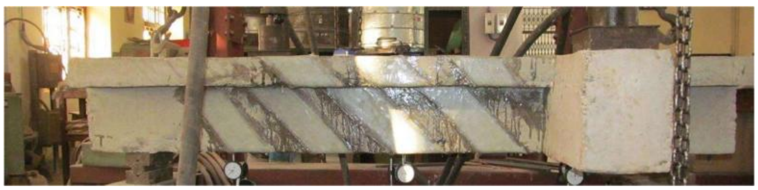
T-beam with a 450mm flange width and no GFRP, control beam

The same strengthening plans were taken into consideration for this group, which included four beams reinforced with GFRP. Figure 3.16-19

T-beam Strengthened with GFRP of U-Wrap

T-shaped beam reinforced with U-Wrap GFRP and flange anchoring.

T-shaped beam strengthened using completely wrapped GFRP beams.



T-shaped beam reinforced using 45º inclination-wrapped GFRP strips

CONCLUSIONS

The experimental program of this study aims to evaluate the performance of epoxy-bonded fiber- reinforced polymer (FRP) fabrics as external transverse reinforcement by testing eleven distinct reinforced concrete T-beams with different flange widths under torsion. Conclusions The following results were obtained based on the empirical findings and the analytical predictions.

- The following are a few significant conclusions from the experimental result: Increased torsional capacity is achieved by the greater flange width of the GFRP-strengthened RCT beams.
- The flange area was found to increase the torsional strength irrespective of the beam being strengthened with the GFRP applied in various configurations.
- ·With250mm wide flange increase in strengthwas13%for350mm wideflangewas29% andfor 450mm wideflangewas69%. This is owing to the net area enclosed inside the critical shear path.
- All strengthen beams had higher cracking and ultimate torsional moment compare with control beams. FRP strengthening configurations affect the increase in magnitude.

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