STATE OF THE ART ON TORSION BEHAVIOR OF FLANGE BEAM WITH GFRP STRENGTHENED RC SLABS

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Abstract
Rehabilitation and strengthening of concrete structures with FRP (Fibre Reinforced Polymers) has been a useful technique since last few years. FRP sheets or plates are very suitable for strengthening not only because of their strength, but also due to the simplicity in the application. Fiber reinforced polymers has been utilized effectively as a part of numerous applications such as low weight, high quality and capacity to last. Numerous past examination chips away at torsion strengthening were centered on strong rectangular RC Beams with distinctive strip designs and diverse sorts of fiber. Distinctive models were produced to torsion test for strengthening of RC beams and effectively utilized for approval of the test works.In the present work test study was done with a specific end goal to have a superior comprehension the conduct of torsion reinforcing of strong RC flanged T-Beam. A RC T-beam is deliberately examined and intended for torsion like a RC rectangular beam; the impact of cement on flange is disregarded by codes. In the present study impact of width in changing so as to oppose torsion is concentrated on flange width of controlled bars. It can be concluded from the literature review that FRP is one of the efficient option for strengthening in either of the case like increasing the load carrying capacity of structures or to restore the original capacity of the structure after distress due to any means. In this paper, different strengthening techniques using FRP and other materials are reviewed.

Key words*: *FRP, strengthening, Glass Fiber reinforced Polymers; Torsion Strengthening.

I. INTRODUCTION

Early efforts for comprehension the reaction of plain concrete subjected to unadulterated torsion uncovered that the material fails at shear. Structural members curved in plan, members of a space frame, eccentrically loaded beams, curved box girders in bridges, spandrel beams in buildings, and spiral stair-cases are average illustrations of the basic components subjected to torsional members and torsion can't be disregarded while planning such individuals. Auxiliary individuals subjected to torsion are of distinctive shapes, for example, T-shape, modified L–shape, twofold T-shapes and box segments. These distinctive designs make the comprehension of torsion in RC beams from complex assignment. Likewise, torsion is generally connected with twisting moments and shearing stress, and the communication among these strengths is critical. Consequently, the conduct of solid components in torsion is principally administered by the tractable reaction of the material, especially its malleable breaking qualities. Spandrel beams, situated at the border of structures, convey loads from pieces, joists, and beams from one side of the part just. This stacking component creates torsion powers that are exchanged from the spandrel shafts to the segments. Reinforced concrete (RC) beams have been observed to be lacking in torsion limit and needing reinforcing. FRPs are commonly used in the aerospace, automotive, marine, and construction industries. The applicability of FRPs for strengthening of concrete structures as an efficient option has been actively studied in numerous research laboratories and professional organizations around the world. Like the flexure and shear fortifying, the FRP fabric is attached to the strain surface of the RC individuals for torsion reinforcing. On account of torsion, all sides of the part are subjected to askew pressure and hence the FRP sheets ought to be connected to every one of the characteristics of the part cross area. Be that as it may, it is not generally conceivable to give outer support to every one of the surfaces of the part cross segment. In instances of out of reach sides of the cross area, extra method for reinforcing must be given to build up the satisfactory system required to oppose the torsion. The viability of different wrapping setups demonstrated that the completely wrapped pillars performed superior to anything utilizing FRP as a part of strip.

II. EXPERIMENTAL PROGRAMS

A. Materials:

1) Cement:

Finely sieved cement which passes through 90 micron IS sieve is taken for experimental with specific gravity of 3.12 and surface area of cement is observed as 300 kg/ mm2 to 320 Kg/mm2.

2) Fine aggregate:

Locally available sand which passes through 4.75 mm IS sieve with specific gravity of 2.6 is taken in account for making concrete to avoid shrinkage.

3) Coarse aggregate:

The coarse aggregates are brought from quarry are used which retained on 4.75 mm IS sieve and having specific gravity of 2.8

4) Water:

Ordinary tap water is used for concrete mix.

5) Steel Reinforcement:

High-Yield Strength Deformed (HYSD) bars confirming to IS 1786:1985 (FE 415). The longitudinal steel reinforcing bars were deformed, high-yield strength, with 20φ mm 10φ and 8 mmφ diameter. The stirrups were made from deformed steel bars with 6 mm φ diameter.

6) Glass Fiber reinforced polymer composites:

Continuous fiber reinforced materials with polymeric matrix (FRP) can be considered as composite, heterogeneous, and anisotropic materials with a prevalent linear elastic behavior up to failure. Normally, Glass and this study, GFRP sheet was used during the tests i.e., a bidirectional FRP with the fiber oriented in both longitudinal and transverse directions, due to the flexible nature and ease of handling and application, the FRP sheets are used for torsion strengthening.

B. Compressive strength:

The concrete is a mixture of cement, sand and gravel. The mix proportions are calculated as IS: 10262 1980, the mix proportions are 1:1.67:3.22:0.5 (cement : fine aggregate : coarse aggregate : water).The cubes are casted as per moulds dimension of T beams mentioned above with mix proportions 1:1.67:3.22:0.5 and require reinforced details.

C. T beam mould:

Overall span=2000 mm
Width of web= 150 mm
Depth=270 mm
Width of flange=250 mm
Depth of flange=80 mm

D. Strengthening of beams:

At the time of bonding of fiber, the concrete surface is made rough using a coarse sand paper texture and then cleaned with an air blower to remove all dirt and debris. After that the epoxy resin is mixed in accordance with manufacturer's instructions. The mixing is carried out in a plastic container (100 parts by weight of Araldite LY 556 to 10 parts by weight of Hardener HY 951). After their uniform mixing, the fabrics are cut according to the size then the epoxy resin is applied to the concrete surface. Then the GFRP sheet is placed on top of an epoxy resin coating and the resin is squeezed through the roving of the fabric with the roller. Air bubbles entrapped at the epoxy/concrete or an epoxy / fabric interface are eliminated. During hardening of the epoxy, a constant uniform pressure is applied to the composite fabric surface in order to extrude the excess epoxy resin and to ensure good contact between the epoxy, the concrete and the fabric. This operation is carried out at room temperature. Concrete beams strengthened with glass fiber

E. Use of FRP's:

Strengthening of concrete structures must be considered when the existing structure deteriorates or any alteration to the structure has to be made due to which the structure may fail to serve its purpose. In some cases it can also be difficult to reach the areas that need to be strengthened. When strengthening is going to be undertaken all failure modes must be evaluated. The strengthening should be designed with consideration to minimize the maintenance and repair needs.

F. Advantages of FRP's:

FRP materials have very good durability. They are available in long lengths and hence eliminate the problems of joints and splices. The curing period for FRP's is very less, i.e. they cure within 24 hours. Light-weight construction is possible with such materials. The resistance against corrosion is also one of the fruitful advantages of such materials. The installation process is also simple and it requires minimum maintenance even after construction. FRP's are ideally suited for any external application.

G. Structural Applications of FRP's:

FRP can be applied to strengthen beams, columns and slabs of buildings and bridges. It is possible to increase the strength of structural members even after they have been severely damaged due to loading conditions. In the case of damaged reinforced concrete members, this would first require the repair of the member by removing loose debris and filling in cavities and cracks with mortar or epoxy resin. Once the member is repaired, strengthening can be achieved through wet, hand lay-up of impregnating the fibre sheets with epoxy resin then applying them to the cleaned and prepared surfaces of the member.

III. VARIOUS STRENGTHENING TECHNIQUES

The most common used flexural strengthening techniques with FRP composites are:

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1) Externally bonded reinforcement (EBR) using FRP sheets and strips, &
2) Near surface mounting (NSM) method using FRP strips.

The Externally Bonded Reinforcement (EBR) is most commonly used due to its simple installation. Different systems of externally bonded FRP reinforcement (FRP EBR) exist, related to the constituent materials, the form and the technique of the FRP strengthening. In general, these can be subdivided into "wet lay-up" (or "cured in-situ") systems and "prefab" (or "pre-cured") systems.

1) Wet Lay-Up Systems:

Dry unidirectional fibre sheet and semi-unidirectional fabric (woven or knitted), where fibres run predominantly in one direction partially or fully covering the structural element. Installation on the concrete surface requires saturating resin usually after a primer has been applied. Two different processes can be used to apply the fabric:

2) Prefabricated Elements:

Pre-manufactured cured straight strips, which are installed through the use of adhesives, are used. They are typically in the form of thin ribbon strips that may be delivered in a rolled coil. Normally strips are pultruded. In case they are laminated, also the term laminate instead of strip may be used

Fig. 1 : Wet lay-up of CFRP sheets

B. Near Surface Mounted (NSM) Reinforcement:

The Near-surface mounted reinforcement technique is developed for strengthening concrete structures. The technique was developed as an alternative to externally bonded fibre composite materials. The process involves cutting a series of shallow grooves in the concrete surface in the required direction. The depth of the groove must be less than the cover so that the existing reinforcement is not damaged. The grooves are then partially filled with epoxy mortar into which pultruded carbon fibre composite rods or strips are pressed. The remainder of the groove is then filled with epoxy mortar and the surface is being levelled. The approach can be used to increase the flexural (bending) of beams and slabs, or the shear capacity of beams. It can also be used for strengthening concrete masonry walls.

IV. YIELD LINE THEORY

The yield line theory is an ultimate load theory for design of R.C slabs. The yield line theory is a powerful tool in analysis as it enables determination of failure moment in slabs of rectangular as well as irregular shapes for different support conditions and loadings. In this theory, the strength of slab is assumed to be governed by flexure alone; other effects such as shear and deflection are only required to be . checked, if necessary. The yield line is defined as a line in the plane of the slab across which reinforcing bars have yielded and about which excessive deformation under constant ultimate moment, continues to occur leading to failure.

A. Behaviour Of One Way Slab Up To Failure

When a uniformly loaded one-way simply supported under-reinforced slab is designed, a plastic hinge is developed at the point of maximum bending moment on loading, at ultimate state (for a specific strip). When all the points (plastic hinges) of strips of slabs are connected they form a yield line. And at this time, we can say that collapse mechanism has formed

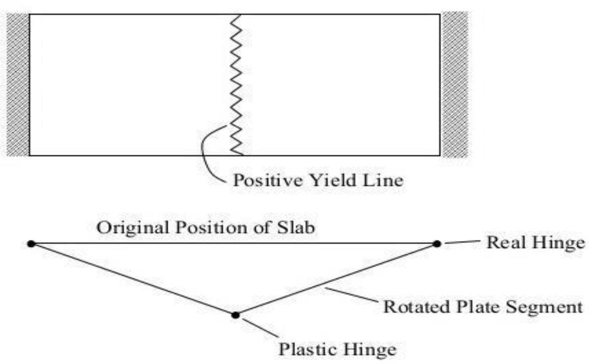

Fig. 2: Positive Yield Line for One-way simply supported slab

B. Assumptions of Yield Line Theory:

The failure mode is arrived at on the basis of following assumptions:

1. The failure is due to complete yielding of reinforcing steel along the yield lines.
2. The bending moments and twisting moments at ultimate state are uniformly distributed along the yield line.
3. At failure, the yield line divides the slabs into individual segments.
4. The plastic deformations are much greater than the elastic deformations which can be considered as negligible.

C. Guidelines for Predicting Yield-line Patterns:

The following guidelines can help to determine the yield line:

1) Yield lines are straight lines.
2) Yield lines end at the slab boundary.
3) Yield lines pass through the intersection of axes of rotations of adjacent elements.
4) Axes of rotations generally lie along lines of supports and pass over the columns.

V. RESULT and CONCLUSION

Five specimens of strengthened T beams are casted to check deflection and strength by three point load method. One beam was control beam without any bond of glass fiber and remaining four beams are bonded with glass fiber.

Beam 1:

0.00	0.000	0.000	
1.83	0.004	0.002	
3.45	0.006	0.004	
5.13	0.007	0.005	
7.20	0.005	0.007	
9.08	0.008	0.013	
11.15	0.007	0.012	
13.14	0.011	0.015	First Hair line Crack appeared
15.12	0.011	0.019	@70kN
16.87	0.014	0.024	Ultimate load @ 95 kN
18.21	0.017		

Table. 1: Reading of speciman1

Beam with U-wrap with flange anchorage system of GFRP

Fig. 3: Cracks on Flange of Beam

Figure 4. Beam after cracking

The experimental program of this study consists of five numbers of reinforced concrete T- beams with different flange widths tested under torsion. The main objective of this study is to investigate the effectiveness of the use of epoxy-bonded FRP fabrics as external transverse reinforcement. Based on conducted experimental measurements and analytical predictions, the following conclusions were concluded.

1) Experimental results shows that the effect of flange width on torsion capacity of GFRP strengthened RC T-beams are significant.
2) Torsion strength increases with increase in flange area irrespective of beam

strengthening with GFRP following different configurations schemes.

3) The cracking and ultimate torque of all strengthen beams were greater than those of the control beams.
4) The increase in magnitude depends on the FRP strengthening configurations.
5) Beams fully wrapped with 45^0 oriented GFRP stripes showed next highest torsion resisting capacity.

Increase of 111.11% to 91.667% in first cracking and 81.03% to 95.39% in ultimate torsion were recorded for series B beams and series C beams respectively. Beams U wrapped with 90^0 oriented GFRP stripes showed lowest torsion resisting capacity. Since shear flow stresses take a close path during torsion loading, torsion would not be well resisted in case of U-jacketing strengthening.

For U wrapped beams increase of 22.22% to 33.33% in first cracking and 23.27% to 36.84% in Ultimate torsion were recorded for series B beams and series C beams respectively. Beams strengthen with U jacketing in web and top of flange and anchored with bolts exhibited increase of 11.11% to 55% in first cracking and 28.33% to 61.84% in ultimate torsion were recorded for series B beams and series C beams respectively.

Figure 5. concrete beam flange cracking

The use of continuous FRP strips that wrapped around the cross-section of T-beams caused a significant increase on the ultimate torsion strength. It is concluded that full wrapping with continuous strips is far more efficient for torsion upgrading than the use of wrapping with the discrete strips.

1) Based on the previous studies and the above literature review the following conclusions can be made:
2) EB-FRP laminates increases the flexural strength of slab with cut-outs and it also enhances its stiffness.
3) FRP sheets are more effective in strengthening systems as compared to FRP strips as there is premature de-bonding failure due to higher stiffness in FRP strips.
4) FRP sheets increase the load carrying capacity of slab with opening by applying different positioning of FRP sheets.
5) The cracking pattern found in the opening shows a high concentration of stress being occurred at the corner of the opening when vertical load is applied.

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