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EXPERIMETAL STUDY ON TORSIONAL BEHAVIOR OF RC BEAMS STRENGTHENED WITH FRP

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Abstract - *Environmental degradation, increased service loads, reduced capacity due to aging, degradation owing to poor construction materials and workmanships and conditional need for seismic retrofitting have demanded the necessity for repair and rehabilitation of existing structures. Fiber reinforced polymers has been used successfully in many such applications for reasons like low weight, high strength and durability. The objective of present study is to evaluate the effectiveness of the use of epoxy-bonded FRP fabrics as external transverse reinforced to reinforced concrete beams subjected to torsion. Torsional results from strengthened beams are compared with the experimental result of the control beams without FRP application. The study tends to shows remarkable improvement in torsional behavior of all the FRP strengthen beams.*

Key Words: **Torsion, GFRP Fabrics, Torsional Strength, Universal testing Machine, Epoxy Resins.**

1.INTRODUCTION

Modern civilization depends upon the performance of its infrastructure ranging from industrial buildings to power stations and bridges. For the satisfactory performance of the existing structural system, the need for maintenance and strengthening is inevitable. During its whole life span, nearly all engineering structures undergoes degradation or deteriorations. This problem needs development of successful structural retrofit technologies. Hence upgrading the structure has two options, repair/retrofit or demolition/reconstruction. Demolition or reconstruction means complete replacement of an existing structure may not be a cost-effective solution and it is likely to become an increasing financial burden. Therefore, repair and rehabilitation of the structures is very often chosen over reconstruction for the damage caused due to degradation, aging, lack of maintenance, and severe earthquakes and changes in the current design requirements. However, with the introduction of new advanced composite materials such as fiber reinforced polymer (FRP) composites, concrete members can now be easily and effectively strengthened using externally bonded FRP composites Retrofitting of concrete structures with wrapping FRP sheets provide a more economical and technically superior alternative to the traditional techniques in many situations because it offers high strength, low weight, corrosion resistance, high fatigue resistance, easy and rapid installation and minimal change in structural geometry. The results obtained from different investigations regarding enhancement in basic parameters like strength/stiffness, ductility and durability of structural members retrofitted with externally bonded FRP composites, though quite encouraging.

1.1 Torsional strengthening of RC beams

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 typical examples of the structural elements subjected to torsional moments and torsion cannot be neglected while designing such members. Structural members subjected to torsion are of different shapes such as T-shape, inverted L–shape, double T-shapes and box sections. In addition, torsion is usually associated with bending moments and shearing forces, and the interaction among these forces is important. Thus, the behavior of concrete elements in torsion is primarily governed by the tensile response of the material, particularly its tensile cracking characteristics.

Spandrel beams, located at the perimeter of buildings, carry loads from slabs, joists, and beams from one side of the member only. This loading mechanism generates torsional forces that are transferred from the spandrel beams to the columns. Similar to the flexure and shear strengthening, the FRP fabric is bonded to the tension surface of the RC members for torsion strengthening. In the case of torsion, all sides of the member are subjected to diagonal tension and therefore the FRP sheets should be applied to all the faces of the member cross section. However, it is not always possible to provide external reinforcement for all the surfaces of the member cross section. In cases of inaccessible sides of the cross section, additional means of strengthening must be provided to establish the adequate mechanism required to resist the torsion.

1.2 GFRP & Epoxy Resin

Textile glass fibres begin as varying combinations of SiO_2, Al_2O_3, B_2O_3, CaO, or MgO in powder form. These mixtures are then heated through direct melting to temperatures around 1300 degrees Celsius, after which dies are used to extrude filaments of glass fibre in diameter ranging from 9 to 17 µm.

Table -1: Properties of GFRP Sheets

Tensile strength	3800 N/mm2
Modulus of elasticity	240 KN/mm2
Density	1.7

The success of the strengthening technique primarily depends on the performance of the epoxy resin used for bonding of FRP to concrete surface. Numerous types of epoxy resins with a wide range of mechanical properties are commercially available in the market. These epoxy resins are generally available in two parts, a resin and a hardener. The resin and hardener used in this study are both manufactured by Huntsman.

Table -2: Properties of Epoxy

Araldite LY 556	Aspect (visual)	clear liquid
	Viscosity at 25 °C (ISO 12058-1)	10000 –12000 (mPa s)
	Density at 25 °C (ISO 1675)	1.15 - 1.2 (g/cm3)
	Epoxide index (ISO 3001)	5.30 – 5.45 (Eq/kg)
Hardener XB 3473	Aspect (visual)	clear blue to brown
	Viscosity at 25 °C (ISO 12058-1)	80 – 125 (mPa)
	Density at 25 °C (ISO 1675)	0.99 - 1.02 (g/cm3)
	Epoxide index (ISO 3001)	11.20 – 12.10 (Eq/kg)

Mixing Ratio: Huntsman Resin: Huntsman hardener = 100:23

2. EXPERIMENTAL SETUP

In the experimental program total twenty-seven rectangular RC beams were casted, out of which three are controlled specimens and remaining twenty-four are grouped in two GFRP coated categories one Pre loading and another coated after loading up to first.

2.1 Specimen characteristics

The twenty-seven Reinforced Concrete rectangular beam of cross section of 150 × 300 mm and 1200 mm long were casted by using, 2 No's-10 mm and 1 No-12 mm diameter reinforcing bar at bottom and 2 No's-10 mm diameter bars at top (Fe500) with 8mm stirrups at spacing 150 mm c/c. (Fe500)

2.2 Concrete properties

All the RC beams were casted using M20 grade of concrete with 53 grade Ultra tech OPC cement, 20 mm maximum size of coarse aggregate with sp. Gravity 2.74 and river sand having sp. gravity 2.65 with water cement ratio of 0.5 mix proportion ratio by using I.S 10262-2009 is 1: 1.87:2.95. The clear concrete cover to the outer side of stirrup was 20 mm. And these beams were cured in water for 28 days. As the size of beams is considerably bulky, beams are cured in the artificially prepared tank at the site where all beams were casted.

3. TESTING SETUP

A torsion test setup was attached to universal testing machine is shown in Fig. 3.1 Channel section is used to form a bracket. This bracket is attached to RC beam by bolted connection and lever arm of 0.66 m is created by bracket at farther end. Torsional moment is created by an I Section flange beam laid diagonally on the lever arms. A twist is created at the both ends with the middle part of RC beam in pure torsion. The RC beam is supported by roller support at both the ends. As each lever arm is superimposing with equal load, moment is calculated by product of force and perpendicular distance.

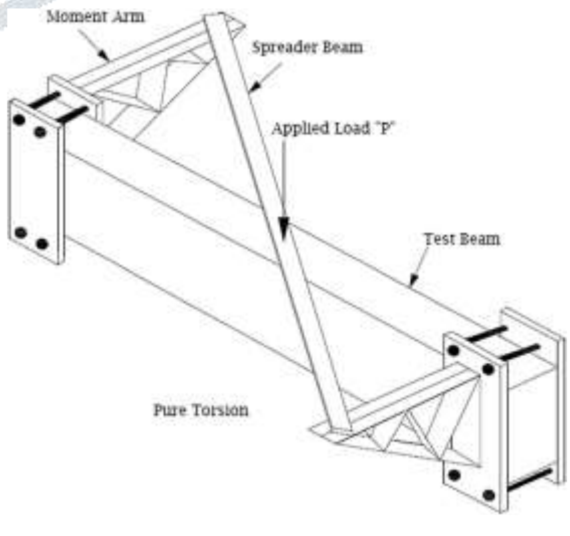

Fig -1: Loading Assembly diagram

4. TEST RESULTS AND DISCUSSION

4.1 Test results

Table -3: Test result for RC beams

SR NO	TEST SPECIMEN	FIRST CRAKING LOAD	DEFLECTION (MM)	CRAKING MOMENT (KN.M)	UTIMATE LOAD (KN)	DEFLECTION (MM)
1	Control beam CB1	20.31	6.72	13.40	32.71	7.20
2	Control beam CB2	19.40	5.10	12.80	25.24	6.80
3	Control beam CB2	18.52	6.10	12.40	23.30	6.85
4	Pre coated: Fully wrapped PFB1	41.69	7.60	27.93	48.89	8.20
5	Pre coated: Fully wrapped PFB2	38.70	7.80	25.90	44.36	8.10
6	Pre coated: Fully wrapped PFB3	39.13	7.20	26.21	43.90	8.1
7	Pre coated: 150mm strip @ 100 mm c/c PFB4	25.20	6.20	16.89	34.40	6.45
8	Pre coated: 150mm strip @100 mm c/c PFB5	27.40	6.34	18.35	35.85	6.74
9	Pre coated: 150mm strip @ 100 mm c/c PFB6	25.90	6.11	17.35	35.23	6.80
10	Pre coated: 150mm strip @ 75 mm c/c PFB7	35.33	6.71	23.67	39.84	7.57
11	Pre coated: 150mm strip @ 75 mm c/c PFB8	34.56	6.20	23.15	35.67	7.83
12	Pre coated: 150mm strip @ 75 mm c/c PFB9	33.85	6.63	22.67	36.74	7.63
13	Pre coated: 150mm strip @ 100 mm c/c with45° PFB10	25.20	6.10	16.88	36.80	7.30
14	Pre coated: 150mm strip @ 100 mm c/c with45°PFB11	25.63	6.30	17.17	34.74	6.80
15	Pre coated: 150mm strip @ 100 mm c/c with45°PFB12	25.42	6.10	17.03	33.38	6.75

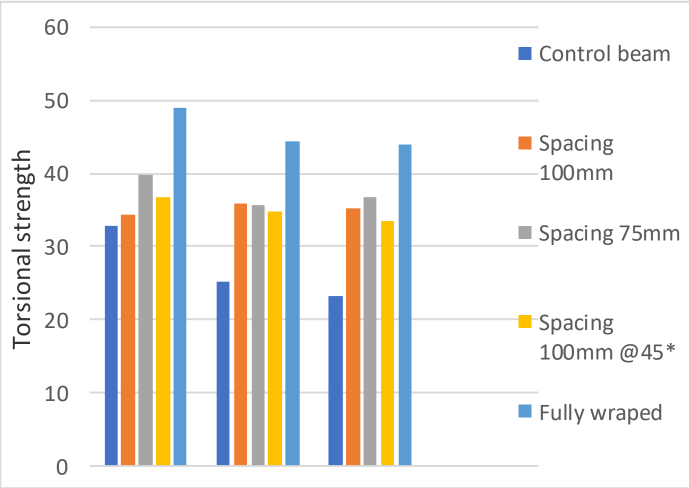

Figure-2: Ultimate torsional strength comparison for pre coated beams

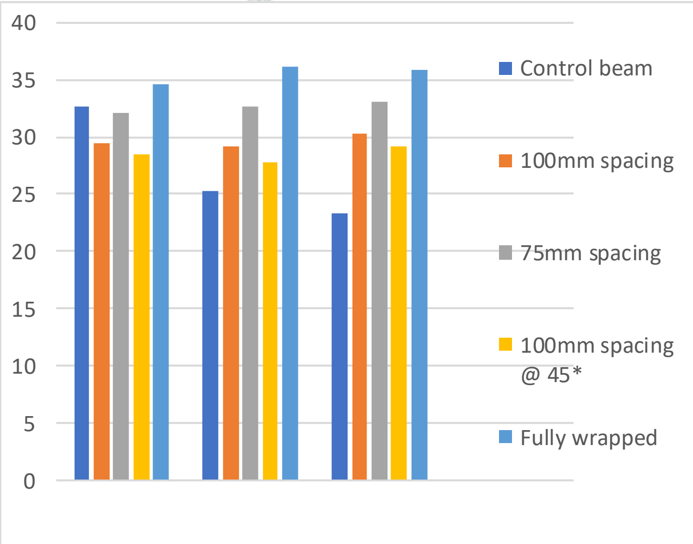

Figure-3: Ultimate torsional strength comparison between beam coated with 150 mm strip at 100 mm c/c beam fully FRP coated.

5. DISCUSSION

1. Torsional load carrying capacity of FRP coated beams goes increasing as the spacing between the FRP band (150mm) decreases and shows maximum for fully wrapped beams.
2. Ultimate load carrying capacity of beam loaded up to first crack and then coated with 150mm FRP strip at 100 mm c/c increases by 23% and with full wrapping it is increased by 28%.
3. The cracking load of the pre coated beam increase in the range of 27% with respect to the control beam with the same configuration of concrete grade and steel reinforcement.
4. For fully wrapped beam strength increase up to 34% with respect to control beam.

6. CONCLUSION

It has been observed that torsional load carrying capacity of beam increases up to 30% to 40% as compared to control beams by use of FRB coating on beams. Some beams were treated with FRP after giving the 20% of load from total load carrying capacity of beams and the torsional moment was regained by 20% which represents the improved torsional moments resisting capacity of a beam. The beams in actual service condition goes deteriorates during their life, reduces the torsional resistance this beam is undergone under some loading condition. Hence the beams pre-loaded and tested after FRP coating gives similar results like beams which are in actual service condition.

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