Rotational Behaviour of Reinforced Concrete Beam Wrapped with Different Fibers

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Abstract—
FRP is an excellent option for external reinforcement due its non-corrosive and nonmagnetic nature of the materials along with its resistance to chemicals made. This study has been carried out to determine the properties of fiber reinforced polymer and reinforced concrete structures wrapped with fiber reinforced polymer is studied and torsional behaviour of Reinforced Concrete (RC) structure since it increases flexural strength and improves torsional behaviour of RC beam. Hence various research papers were studied based on experimental study on torsion on concrete structures wrapped with FRP. Analytical study torsion on concrete structures wrapped with FRP and Modelling using Ansys software for torsion on concrete structures wrapped with FRP. From the literature review it is clear that, no models predicted the complete behavior of RC beams wrapped with FRP because FRP was not bonded to all beam faces. Also prediction of failure mode, Experimental study of beam strengthened with FRP under torsion is to be worked since less information is available

Index Terms—FRP, CFRP, GFRP, RC, AFRP, Beam, Polymer,

1 INTRODUCTION

In 1940 FRP were used in defense industries for aerospace and aeronautic engineering [1]. Most widely in the world as retrofitting concrete structures and china has developed specification for FRP material [2, 3]. Around the world repair and strengthening of structural concrete members is done by externally bonding FRP sheets. In civil engineering construction industry strengthening with Fiber Reinforced Polymers (FRP) is commonly used. FRP an excellent option for external reinforcement due its non-corrosive and nonmagnetic nature of the materials along with its resistance to chemicals made. Also different advantages of FRP are: (a) FRP is low weight because it is less dense. And its equivalent volume is lesser than equivalent volume of steel; hence these properties helps in construction work for handling all types of work, (b) FRP has more material stiffness than steel, (c) FRP can be applied to any shape of the concrete surface, (d) fibre material is almost nil or less re-active to chemical, where structures are exposed to chemical. Hence it is safe for construction of tanks pipes etc. hence FRP are used chemical and other industries for concrete structures, (e) fibre material is safe because it is non-conductive to electricity and fire resistant, hence essential used in power industry and structure[4]. It conform to BS476 or ASTM-E-84, (f) fibre material are less affected by changes in temperature in atmosphere, especially fiberglass gives almost no change to temperature changes, and (g) all fibre material requires no or less maintenance.
Applications of AFRP and FRP are in civil engineering new construction, repair and rehabilitation applications, and architectural applications. Aramid fibre reinforced polymer AFRP and FRP design and application is lacking because no guidelines are developed till date. Data related AFRP is protected by military due which it becomes difficult for structural engineer for wrapping of FRP or AFRP materials for strengthening concrete structures. Structural engineer either uses ACI guidelines or experience of different researchers. However many guidelines are given by concrete society ACI, ISIS Canada for designing FRP as strengthening in concrete structure [22]

2 LITERATURE REVIEW

All around the world wrapping of FRP, Externally bonding are used for strengthening of structural concrete members by retrofitting, repair and also in new construction. Fiber Reinforced Polymers (FRP) composite materials are basically used as external reinforcement for various concrete structures.
2.1 Experimental Study on torsion on concrete structures

Kandekar and Talikoti (2019) investigated RC beam wrapped by Aramid fibre for increasing torsional strength. Size of beam used for study was 150mmX300mm in cross section and of 1m in length. Experimental result showed that torsional strength of RC beam wrapped by Aramid fibre was more as compared with controlled or normal RC beam with normal RC beam without wrapping of any FRP.

Shengqiang Ma et al., (2018) performed experimental study of Torsion on reinforced concrete beams with box-section wrapped with CFRP carbon fibre reinforced polymer. From investigation U-jacketing strips of CFRP showed better result to the ultimate torque. Comparison of ultimate torque was made by Shengqiang Ma model with Ghobarah and Chinese model. However, Ghobarah and Chinese model was observed that best for calculating the ultimate torsional capacity of strengthened beams with rectangular or box-section by FRP entirely wrapping or U wrap.

### Table- I: Cracking and Ultimate Torque and the Increase of Torque (Shengqiang Ma et al., 2018)

<table>
<thead>
<tr>
<th>Beam</th>
<th>Concrete compressive strength Mpa</th>
<th>Cracking torque Tcr (kN.m)</th>
<th>Increase in Tcr</th>
<th>Twist angle at cracking torque (°)</th>
<th>Ultimate torque Tu (kN.m)</th>
<th>Increase in Tu</th>
<th>Twist angle at ultimate torque (°)</th>
<th>Increase in torsional stiffness (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TBC</td>
<td>38.9</td>
<td>10.3</td>
<td>0.25</td>
<td>22.9</td>
<td>-</td>
<td>2.47</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>TBS</td>
<td>40.4</td>
<td>10.25</td>
<td>-0.4%</td>
<td>0.40</td>
<td>26.7</td>
<td>16.6%</td>
<td>2.85</td>
<td>1</td>
</tr>
<tr>
<td>TBS L1</td>
<td>35.0</td>
<td>12.5</td>
<td>21.7%</td>
<td>0.45</td>
<td>26.5</td>
<td>16%</td>
<td>2.71</td>
<td>5.6</td>
</tr>
<tr>
<td>TBS L2</td>
<td>37.6</td>
<td>12.0</td>
<td>16.6%</td>
<td>0.26</td>
<td>27.6</td>
<td>20.5%</td>
<td>2.83</td>
<td>5.1</td>
</tr>
</tbody>
</table>

Notation for Strengthening Configuration: (a) Bonded with One-layer Strips (TBS), (b) Bonded with One-layer Strips and One-layer Lateral Strip (TBSL1), (c) Bonded with Two-layer Strips and One-layer Lateral Strip (TBSL2)(Unit: mm)

Prasad and Kumar (2017) performed experimental work on L shaped RC beam to study the torsional strength. Result showed that beam designed for 106.68kn-m bending moment resist 33.52 kN-m torsional moment. Also when 30% of reinforcement was provided in beam it resis it 30.48 kN-m.

Saadatmanesh (1994) and Shahawy (2000) presented experimental work showed that rectangular columns wrapped with FRP gave better strength than nor rectangular column without wrapping FRP in terms of torsion.
Obaidat et al., (2010) investigated torsional strengthening of RC members by wrapping CFRP with different length, position at which location retrofitting done internal reinforcement ratio.9 experimental studies predicted that torsional strength more when member wrapped with CFRP than conventional concrete structure. Ductility and confinement of concrete structures were studied.

Ghobarah et al., (2002) predicted that 45° orientations of glass and carbon fibers wrapped around RC beam showed better result and confirms the efficient use of wrapped material. Glass and carbon fibers wrapping design guidelines were suggested.

Panchacharam and Belarbi (2002) investigated Torsional behaviour of RC beam wrapped with GFRP by performing experimental work. Torsional strength of RC beam wrapped with GFRP was increased compared to normal beam. Also theoretical model of RC beam wrapped with GFRP results predicted same results as showed by experimental work.

Jing et al. (2005) performed experimental investigation by wrapping carbon fiber reinforced polymer to concrete box beam to study torsional behavior, cyclic torque and bending moment. Prediction was made that by wrapping carbon fiber reinforced polymer to concrete box beam increases a seismic capacity of capacity of box. Restoring force model of concrete box beam wrapped with CFRP under torsional cyclic torque and bending moment was developed in present work.

Ameli et al., (2007) in present work various configuration of wrapping FRP to strength then concrete beam was done. It was found that ultimate torque of fully wrapped beams increase as compared to normal concrete beam.

Hii and Al-Mahaidi (2007) performed experimental work on solid and box-section RC beam wrapped with CFRP. Results showed that torsional strength was more when member wrapped with CFRP than conventional concrete structure.

Behera et al., (2008) investigated experimental study on RC beam with U wrapping and results shows that U wrapping on three sides increases ultimate torque and twist in RC beam.

Mahmood and Mahmood (2011) experimental work was performed on prestressed concrete beams wrapped with CFRP to study torsional behaviour of beam. Size of beam was 150mmx250mm cross section and 2500mm in length. Result of experiment showed that fully wrapped prestressed beams gave better strength then partial wrapping. Also prestressed concrete beams wrapped with CFRP showed more torsional strength then reference beam. Nonlinear finite element analysis of tested beam was predicted by this study.

2.2 Analytical study for reinforced concrete beams strengthened in torsion

Deifalla and Ghobarah (2010) investigated study of RC beam model wrapped with different configuration and different failure mode. The analytical model of RC beam predicted that the strength of RC beam was more than previous model investigated by researcher. Also analytical model gave good agreement with results from experimental work.

Chalioris et al., (2007) applied analytical method to study the behaviour of RC beams wrapped with CFRP under torsion. Crack analysis for plain concrete in torsion model and modified softened truss theory model were used for predicting the torsional behaviour of RC beam. Analytical results showed that torsional moment calculation, torque curves were almost same as that of experimental method.

A.R.Zojaji, M.Z.Kabir (2012) studied the torsional behaviour of RC beam wrapped with FRP computational method is adopted. It is observed that agreement of torque test curves when compared with experimental result of solid and hollow rectangular sections RC beam.

![Graphical representation of torsional strength analysis](image)

Figure 3: In plane stresses of an element from shear flow zone when RC beam wrapped with FRP undergo torsion.

2.3 Modelling and analysis of externally bonded reinforced beam under torsion

Al-Mahaidi and Hii (2006) studied the torsional behaviour of box-section reinforced concrete beam wrapped with CFRP using photogrammetry and numerical method was used for finite element modeling. Total 11 analytical model were used for torsional capacity of beam. The result of analytical method for torsional strength, effect wrapping of CFRP and cracks showed great accuracy as compared with experimental result.

Santhakumar et al., (2007) investigated numerical and finite
element method using ANSYS on RC beam wrapped with CFRP. Study was performed on retrofitted and unretrofitted (write correct word) RC beam. Result showed that CFRP orientation with ±45° and 90° showed better strength compared to other orientation. Also beam RC beam wrapped with CFRP showed better result than RC beam without any FRP.

3. CONCLUSIONS

3.1 The design codes and specification for FRP is not developed completely.

3.2 The complete behaviour of reinforced beam wrapped with FRP is not predicted completely with respect to wrapping orientation, torsional resistance.

3.3 More experimental results are required to study the complete behaviour of reinforced beam wrapped with FRP.

REFERENCES


