International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 9
September 2017

Shear behaviour of BFRP Strengthened RC T Beams

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Abstract:-

Several classical methods for strengthening have been used in the past such as jacketing for reinforced columns, addition of steel plates at locations of tensile stresses and pre-stressing certain locations to improve the strength of the member. Recently fibre reinforced polymers have replaced steel plates and emerged as a better material for externally applied strengthening material for beams to increase their shear and flexural capacity and for columns as best material for warping and confinement. ACI committee 440-R-08 [1] has presented a guideline for design and construction of externally FRP method for strengthening of concrete structures. The most recent advanced strengthening technique is near surface mounted fibre reinforced polymer. NSM FRP is applied to the tension region of the beams inside pre prepared grooves. Debonding failure modes which restrict the full exploitation of FRP are the most occurring type of failure for externally bonded FRP. While in NSM technique, the existence of bars or the strip inside grooves would provide better bond between the FRP and the concrete. In this paper methods of strengthening RC beams are reviewed with emphasis on the latest development of NSM FRP as the best emerged technology for strengthening reinforced concrete members for shear and flexure. Recommendation for future trend of research in this area is also given.

1.0. Introduction:

The main aim of the designing of any structure is that it should serve for the period it has been designed to serve. But before the design period is over the structure needs maintenance due to reasons like change in loading conditions, functional change, damages due to earthquakes etc. The structure constructed during ancient time and which are still existing demand more repair. However, some of the new structures also show the sign of deterioration. Various mechanism are available in the market for strengthening of RC beams like Ferro Cement, Micro-Concrete, external plate bonding, shotcreting, sprayed concrete etc.

Method of sprayed concrete can be used where the dimension increment is not a problem. Also, it is not cost effective and consumes more time. Strengthening using steel plate with epoxy is also a better alternative but not in common practice due to problem of corrosion and being uneconomic. Jacketing is used widely but the main disadvantage of this method is that it increases the original dimensions and thus weight of the structure.

Ferro cement was defined ferrocement as “a type of thin wall reinforced concrete commonly constructed of hydraulic cement mortar, reinforced with closely spaced layers of continuous and relatively small diameter mesh”[1]. Literature shows that lots of research has been done to study the effect of ferrocement technique on different structural members. Ferrocement technique improves the load barring capacity of concrete and can also use as jacket in reinforced concrete columns [2–4]. Nassif[5] conclude that by adding a thin layer of ferrocement to a concrete it enhances its ductility

Some of the existing reinforced concrete structures may require strengthening or stiffening in order to increase their structural performance. Strengthening with adhesive bonded fiber reinforced polymer (FRP) has been established as an effective method applicable to many types of such structures.

Several studies have been focused on the potential use of FRP for flexural strengthening of concrete beams, but relatively little research has been done on the use of FRP in shear strengthening [1-12]. In addition to that the current understanding of the shear behaviour of RC beam strengthened with FRP is limited and much further research is still needed. Therefore, the aims of this study were to gain a better understanding and enhance the experimental database of shear behaviour of RC beams, without internal shear reinforcement, strengthened externally with bonded CFRP–U strips, and to develop a simple accurate model to predict the contribution of CFRP–U strips to the shear capacity of such beams at the complete debonding of the critical CFRP strips. The main variables investigated were, effective height (depth) of CFRP–U strips, number and width of strips for the same amount of fiber shear reinforcement, and spacing or amount of strips.

This system increases the load carrying capacity and the flexural ductility compared to EBR reinforcement alone. This system requires more work and still vulnerable to environmental conditions. Eftekhar and Yaqubi [6] introduced a new method for surface preparations which was named Holing method (HM FRP) Fig.(5). In this technique holes of definite depth, diameter, and spacing are drilled into the tension side of the beam where the sheets are to be bonded, the holes are filled with epoxy during sheets installation. This technique also increases the flexural capacity and ductility, however it is costly and time consuming and also exposed to environmental conditions.

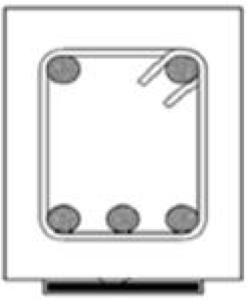

Fig.1 EBR method [2]

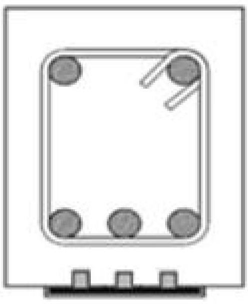

Fig.2 EBORG method [2]

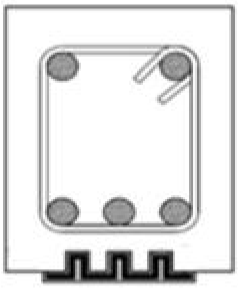

Fig. 3 EBRIG method [2]

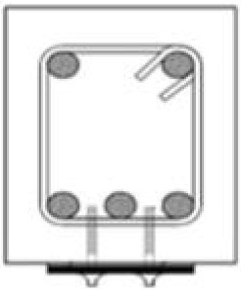

Fig. 4 MF-EBR method [2]

Fig. 5 HM FRP method [2]

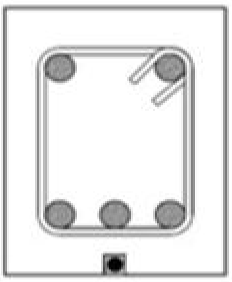

Fig. 6 NSM FRP method [2]

The discovery of NSM FRP method, Fig.(6) made the trend of research and engineering community to be toward this recent technique. NSM idea was first applied on retrofitting a bridge deck in Europe in the early 1950s using steel bars. But nowadays steel is less preferred for strengthening due to its draw backs compared with FRP such as exposure to corrosion, heavy weight and less tensile strength.

As far as comparison of NSM FRP with externally FRP is concerned, NSM technique proceeds the latter by several advantages: (1) Debonding of NSM FRP materials is less likely to occur, as the FRP is grouted inside the concrete and can be easily bonded into adjacent concrete members. (2) The NSM technique enables the FRP to be protected from environmental impact. (4). No change aesthetically required in strengthened structure.

The above factors can be enough to make the NSM technique more attractive and encourage engineers worldwide to accelerate the research on the area. Critical review is presented in this paper on research work on flexure and shear strengthening of NSM FRP for RC beams. This work is an extension of a work carried out by the first author [7] with the addition of new research on beam flexure and beam shear strengthening using NSM FRP technique.

2.0. Problem Formulation

The experimental programme carried out for this research work consist of total five reinforced concrete beams with a size of 2000 x 200 x 270 mm. Nomenclature of all the tested beam is describe in Table 1. Beam section (2000 x 200 x 270 mm) was design such that it fails in shear only. It comprised of 5 bars of 12 mm diameter Fe-415 as tension steel and 2 anchor bars of 10 mm diameter. 6 mm 2-legged MS stirrups (150 mm x 220 mm out to out) at a spacing of 300 mm center to center distance were used as shear reinforcement. All the beams were casted in mould of size 2000 mm x 200 mm x 270 mm (in to in Dimensions). The moulds were fabricated from MS sheets of 4 mm thickness.

Table 1Nomenclature of Beams

Sr. No.	Name of Specimen	Nomenclature
1.	Non-Strengthened Beam	NSB
2.	Ferrocement with welded wire mesh	SFC-Weld
3.	Ferrocement with weaved wire mesh	SFC-Weave
4.	Micro-Concrete with welded wire mesh	SMC-Weld
5.	Micro-Concrete with weaved wire mesh	SMC-Weave

2.1. Materials

- Concrete mix design was made to produce normal strength concrete having a 28 day cubic compressive strength of 30 MPa. Ordinary Portland cement, local natural sand and gravel of 20 mm maximum size were used.
- Two diameters of high strength deformed bars 22 and 12 mm of 440 and 470 MPa proof strength respectively were used for longitudinal reinforcement.
- Uniaxial Carbon Fiber Reinforced Polymer (CFRP) laminates were used to externally strengthen the shear spans of the beam, under a commercial name of SikeWarp. Hex–230C. CFRP is available in rolled of 0.12 mm effective thickness, 300 mm width, and of about 5000 mm length. According to the data provided by the CFRP supplier, the fabrics had an elastic modulus of 231000 MPa, tensile (rupture) strength of 4100 MPa, and rupture strain of 1.7%.
- An epoxy mortar of about 2 mm thickness was applied to all strengthened beams as a substratum to the CFRP sheets

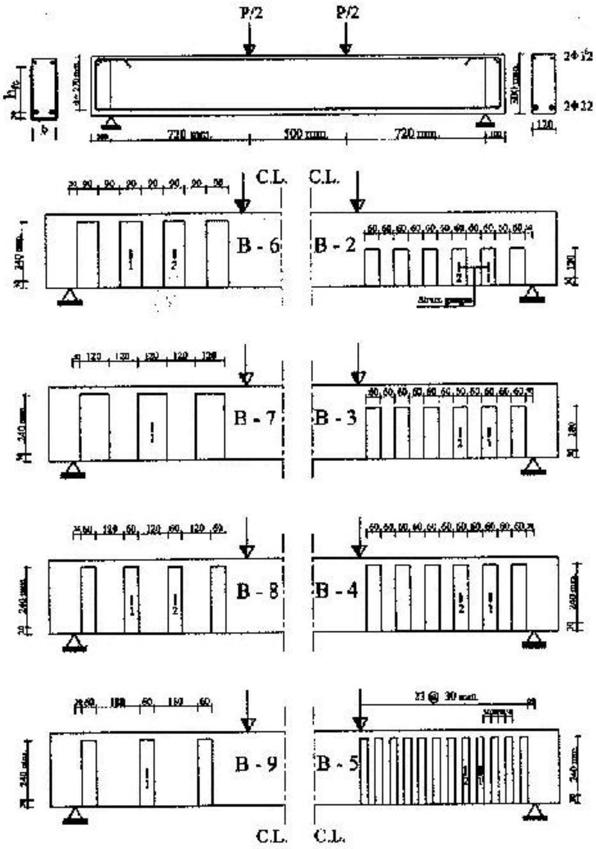

Fig : Details of test specimens

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IJETSR
www.ijetsr.com
ISSN 2394 – 3386
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3.0. TEST RESULTS

In general, and as expected all test specimens failed mainly as a result of diagonal tension cracking (shear failure). Cracking pattern at ultimate load and failure modes of all beams are shown in **Fig(Crack patterns of tested beams).** Each specimen exhibited an initial flexural crack in the region of pure bending and subsequent additional flexural cracks formed in the central region. As the applied load was increased a number of flexural shear and shear cracks were developed along the shear spans and one of them extended diagonally upward toward the loading point. Failure of control beam (B–1) was sudden and by diagonal tension. In case of strengthened beams, the diagonal tension failure was preceded by CFRP strips bond failure and/or CFRP rupture, and the diagonal crack occurred at a relatively higher load than for the control beam. All strengthened beams failed by concrete splitting and crushing behind the fiber strips. The splitting of concrete behind the strips caused these fiber strips to be ruptured or pushed out wards (debonding). In case of beam B–5 with 30 mm strip width, rupture of fiber strips along the path of the main diagonal crack was observed and there was no debonding of the fiber strips.

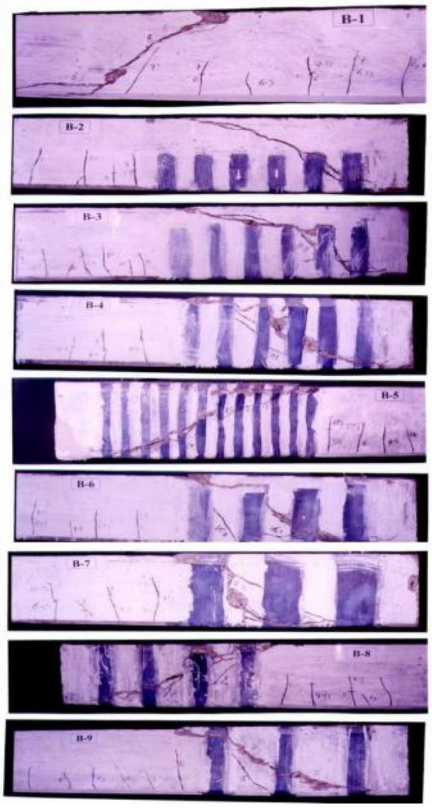
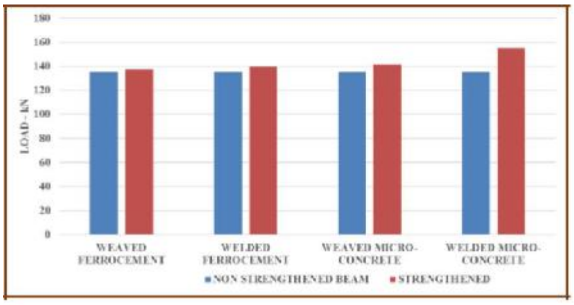


Fig : Crack patterns of tested beams.

3.1. Ultimate Load carrying capacity

The ultimate load carrying capacity of SFC-Weave and SFC-weld increases by 1.6% and 3.03% respectively as compared to Non- Strengthened beam. In case of Micro-concrete maximum load carrying capacity of beam SMC-Weave and SMC-Weld increases by 4.62% and 14.69% respectively compared to Non-Strengthened beam. The graphical representation of the comparison is shown in the following figure.



3.2. First Crack Load v/s Deflection

In this current research work load at first crack and deflection at this corresponding load was also observed as shown in Figure 5.

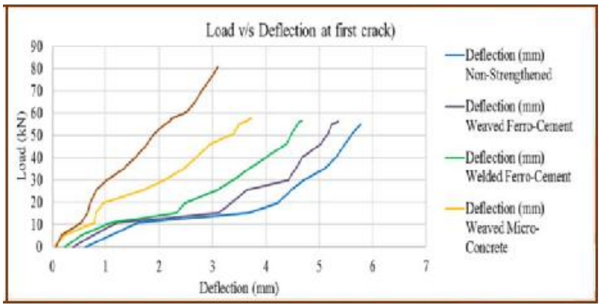


Fig : Load v/s Deflection at First crack

In the load v/s deflection curve for the Strengthened (SFC-Weave, SFC-Weld, SMC-Weave, SMC-Weld) beam was higher than the Non-Strengthened Beam (NSB). Load at first crack in non-strengthened beam was 55.07 kN. At this load the deflection in SFC-Weave, SFC-Weld, SMC-Weave and SMC-Weld were 5.23 mm, 4.59 mm, 3.62 mm and 2.19 mm respectively, which is less than the deflection in NSB (5.77 mm).

3.3. Ultimate Load v/s Deflection

In the present manuscript load v/s deflection at ultimate load was also measured as shown in Figure 6. NSB was failed at the load of 135.21 kN and deflection at ultimate load was 15.12 mm. But at this ultimate load deflection in SFC-Weave, SFC-Weld, SMC-Weave and SMC-Weld were 14.44 mm, 14.83

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ISSN 2394 – 3386
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mm, 12.87 mm and 9.24 mm respectively. It is clearly observed that the strengthened beam give the least deflection compared to non-strengthened beam. SMC-Weld was give the least deflection of 5.88 mm compared to non-strengthened beam (15.12 mm).

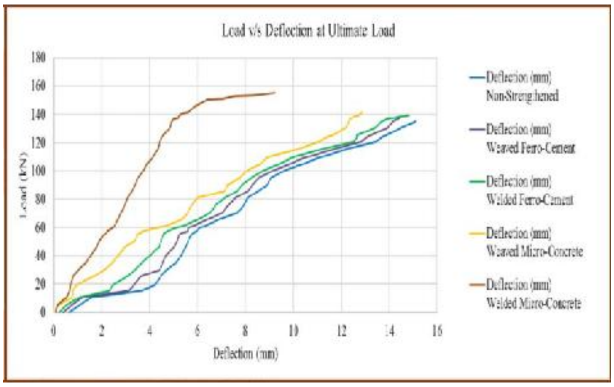

Figure Load v/s Deflection at Ultimate Load

3.4. Failure Pattern

The non-Strengthened Beam (NSB) was failed in shear because it was designed to fail in shear only.

Figure Failure Pattern of Beam

4.0. Conclusions

1. All the four mechanism adopted in the study shall be recommended since all the strengthened beams failed in flexure instead of shear.

2. The de-bonding of the strengthened part took place.

3. Strengthening of beam carried with welded wire mesh and Micro-Concrete shows the least deflection even at first crack and at ultimate load.

4. The maximum increase in the ultimate load carrying capacity of beam strengthened with Welded Mesh and Micro-concrete is found to be 14.69 %.

5. The deflection of beam strengthened with Welded Mesh and Micro-Concrete was reduced to about 38.88 % at the ultimate loading.

5.0. References:

1. Eslami & H. R. Ronagh, “Experimental Investigation of an Appropriate Anchorage System for Flange-Bonded Carbon Fiber–Reinforced Polymers in Retrofitted RC Beam–Column Joints”, Journal of Inst. Eng. India Ser., 2013
2. S.V. Grelle & L.H. Sneed, “An Evaluation of Anchorage Systems for Fiber-Reinforced Polymer (FRP) Laminates Bonded to Reinforced Concrete Elements”, Structures Congress 2011, 1157 – 1168
3. Mitra Nilanjan & Samui Pijush, “Prediction of Inelastic Mechanisms Leading to Seismic Failure of Interior Reinforced Concrete Beam–Column Connections”, Structural Design Construction, 2012, 110 - 118
4. X.K. Zou, J.G. Teng, L. De Lorenzis, S.H. Xia, “Optimal performance-based design of FRP jackets for seismic retrofit of reinforced concrete frames”, Journal of Composite Part B, 2007, 584 - 597