EXPERIMENTAL STUDY ON EXTERNAL STRENGTHENING OF RC BEAMS USING CFRP COMPOSITES UNDER FLEXURAL LOADING

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ABSTRACT: *In our country an impressive parcel of the current sustained strong structures are requiring fix or entertainment, rebuilding, considering disintegrating due to various components like utilization, nonattendance of indicating, frustration of holding between bar, section, lump, etc… Strengthening of existing invigorated strong structures is critical to get a typical future and achieve unequivocal necessities. The prerequisite for beneficial recuperation and bracing systems of existing strong structures has realized inventive work of composite fortifying structures. Progressing exploratory and orderly research have demonstrated that the use of composite materials for existing helper parts is all the more monetarily smart and requires less effort and time than the standard strategies. Fiber Reinforced Polymer (FRP) composite has been recognized in the improvement business as a gifted substitute for fixing and invigorating of RCC structures. During ongoing decades, much research has been done on flexural sustaining of invigorated strong shafts using different sorts of fiber reinforced polymers and pastes. A positive Literature review reliant on the past exploratory and efficient research on invigorated strong shafts is presented. Proposed procedure for invigorating the RC shaft is picked subject to the past preliminary and analytic research. Practices of fortified strong columns with remotely strengthened CFRP with various sorts of gums is inspected. Static weight responses of the significant number of bars under two-point load procedure had surveyed similarly as flexural quality, break recognition, compositeness between CFRP surface and concrete, and the related dissatisfaction modes.*

Keywords: Reinforced Polymer & Beam flexural behavior

1. INTRODUCTION:

The development of external bonding of High-strength Carbon fiber reinforced polymer (CFRP) composites is the potential technique over the steel plates in structural strengthening and upgrades of damaged or deteriorated members. One such technique is adding CFRP as external bonded reinforcement to the structure for upgrading reinforced concrete beams was the use of externally epoxy-bonded steel plates. Another advantage of using CFRP wraps to repair corrosion damaged members is the external confining pressure provided by the CFRP that enhance the bond at the deteriorated concrete cover zone. To externally bond CFRP sheets on the tension and also lateral sides of RC beams and columns is a widely used method for repairing and strengthening of the RC structures. Such reinforcing technique is an effective way to improve the flexural and or shear performance of the RC structures.

1.1 SCOPE

The beams are strengthened with externally bonded FRP sheets in single, two and three layer which are fully and partial wrapping in beam axis at the bottom side.

1.2 OBJECTIVES:

Investigate the Failure modes of the each strengthened and un-bonded beams, the load and the corresponding deflection and also the enhancement in moment carrying capacity and reduction in mid-span deflection, Comparisons are made between the controlled beam and retrofitted beam experimental results.

2. LITERATURE REVIEW

Henrik Thomsen, Enrico Spacone, Suchart Limkatanyu and Guido Camata (2004) presented a paper on analyzing the failure mode of reinforced concrete beam strengthened in flexure region with externally bonded FRP. A nonlinear RC beam element model with bond-slip between the concrete and the FRP plate was used to study how the failure mechanism of simply supported strengthened RC beams is affected with the following parameters: plate length, plate width, plate stiffness, and loading type. But the beam geometry was kept constant. The parametric studies confirmed the experimentally observed results according to which the most commonly observed failure modes due to loss of composite actions are affected by the plate geometric and material properties.

Tom Norris, Hamid Saadatmanesh and Mohammad R. Ehsani (1997) presented a paper and dealt with the results of an experimental and analytical study of the behavior of damaged or under strength concrete beams retrofitted with thin CFRP sheets are presented. The CFRP sheets were epoxy bonded to the tension face and web of concrete beams to enhance their flexural and shear strengths. CFRP sheets can provide increase in strength and stiffness to existing concrete beams when bonded to the web and tension face.

Nanni A (2001) has received remarkable attention on strengthening of concrete members with externally bonded FRP laminates or near surface mounted (NSM) bars. FRP materials have been used in small projects and some multi-million dollar projects for strengthening parking garages, multi-purpose convention centers, office buildings and silos. This paper reports on shear and flexural upgrades for five applications in bridges and buildings. The drivers for this technology are several, but perhaps the most relevant one is the ease of installation.

Pedro R. Salom, Janos Gergely and David T. Young (2004) have done a research which shows that fiber-reinforced polymer composites can increase flexural, axial, and shear capacity of beams, columns, and walls. The present paper describes both experimental and analytical programs, focussing on the torsional strengthening of reinforced concrete beams using composite laminates. The variables considered in this study included fiber orientation, composite laminate, and effects of a laminate anchoring system. The study proved that the FRP laminates could increase the torsional capacity of concrete beams by more than 70%.

3. TESTING AND RESULT:

3.1 FIBRE REINFORCED CEMENT CONCRETE BEAMS WITH AND WITHOUT CFRP WRAPPING

3.1.1 Description of Specimens:

Among the seven beams, six beams were fabricated using fibre reinforced concrete and they were externally strengthened by CFRP composites with one, two and three layers. The remaining three beams were fabricated using conventional concrete and they were externally strengthened by CFRP composites with one, two and three layers. The entire strengthened beams. The size and length of the beams were 180 x 200 mm and 1800 mm respectively. To identify the specimens easily, the beams were designated with the names such as FRC-FWB-1, FRC-FWB-2, FRC-FWB-3, FRC-PWB-1, FRC-PWB-2, FRC-PWB-3, NC-FWB-1, NC-FWB-2 and NCFWB-1. For example, the beams FRC-FWB-1 and FRC-PWB-1 indicate that the RC beams fabricated using fibre reinforced concrete were strengthened by full and partial wrapping, respectively with one layer. The control beams were designated as FRC-CB. Strengthened beams before testing

3.2 Beam Strengthened by Full Wrapping:

3.2.1 Failure modes of conventional and fully wrapping beams:

All the specimens were kept at the supports and centered to ensure symmetric loading and also the specimens were loaded until failure so as to understand the influence of CFRP on their flexural behaviour of RC members fabricated using conventional and fibre reinforced concrete.

Fig: 1 Strengthened beams before testing

4. Beam Strengthened by Full Wrapping:

4.1 Failure modes of conventional and fully wrapping beams:

All the specimens were kept at the supports and centered to ensure symmetric loading and also the specimens were loaded until failure so as to understand the influence of CFRP on their flexural behaviour of RC members fabricated using conventional and fibre reinforced concrete.

Fig: 2 Failure pattern of FRC-FWB-1

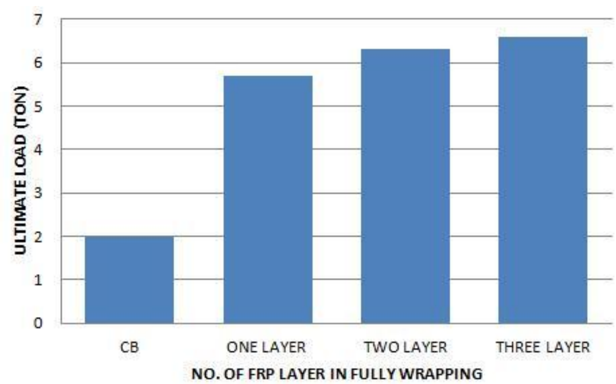
4.2 Flexural strength of CB & FWB:

The failure load and the percentage of increase in flexural strength capacity of CFRP strengthened beams compared to the control beam. It can be understood that the external bonding of FRP composite enhanced the strength capacity of the beam in both cases, in addition to that, the increase in number of FRP layers enhanced the strength capacity of the RC beam further. For instance, in comparison with control beam, the specimens FRC-FWB-1, FRC-FWB-2 and FRC-FWB-3. The enhancement in flexural strength of FRC beams strengthened with CFRP than that of RC beams fabricated using conventional concrete is attributed to the high tensile strength, post cracking behaviour and flexural toughness of the FRC concrete. It can be inferred that the flexural strength capacity of the FRP strengthened beam can be by the type of the concrete used to fabricate.

Table: 1 Experimental test result Ultimate load and nature of failure for CB and FWB beams

Si. No.	Type of Beam	Beam designation	Load at initial crack (TON)	Ultimate load (TON)	Type of failure modes
1	Control beam	CB	1	2	Flexural failure cum yielding of concrete with multiple narrow cracks
2	FWB Single layer	FWB - 1	2.7	5.7	Rupture failure of FRP composites occurred at the mid-span of the section.
3	FWB Two layer	FWB - 2	3.3	6.3	Rupture failure of FRP composites occurred at the mid-span of the section.
4	FWB three layer	FWB -3	3.6	6.6	Rupture failure of FRP composites occurred at the mid-span of the section.

Graph: 1 Flexural strength of FRC beam strengthened by fully wrapping – comparison



4.3 Failure modes of partially wrapping beams:

The typical failure mode and the ultimate failure load and maximum deflection of all beams externally strengthened by partial wrapping. The failure mode of the FRC beams strengthened by partial wrappings was very similar to FRC beams strengthened by full wrapping. The beams strengthened with one and two layers of CFRP composites, failed by the rupture failure of FRP composites, observed at the mid-span of the section, furthermore the origin point of the rupture was in the place of vertical cracks.

Fig: 3 Failure pattern of FRC-PWB-1

Fig: 4 Failure pattern of FRC-PWB-2

The beams strengthened by three layers of CFRP failed by rupture of fibre cum de-lamination observed at the end of the CFRP composites. The de-lamination of CFRP composites may be due to the creation of peeling stress at the end of the CFRP composites.

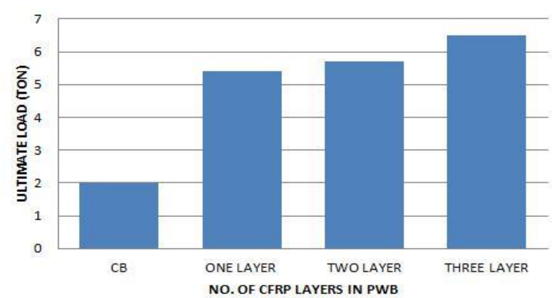
4.4 Flexural strength of CB & PWB:

The failure load and the percentage of increase in flexural strength capacity of CFRP strengthened beams compared to the control beam. It can be understood that the external bonding of FRP composite enhanced the strength capacity of the beam in both cases; in addition to that, the increase in number of FRP layers enhanced the strength capacity of the RC beam further. For instance, in comparison with control beam, the specimens FRC-PWB-1, FRC-PWB-2 and FRC-PWB-3. The enhancement in flexural strength of FRC beams strengthened with CFRP than that of RC beams fabricated using conventional concrete is attributed to the high tensile strength, post cracking behavior and flexural toughness of the FRC concrete.

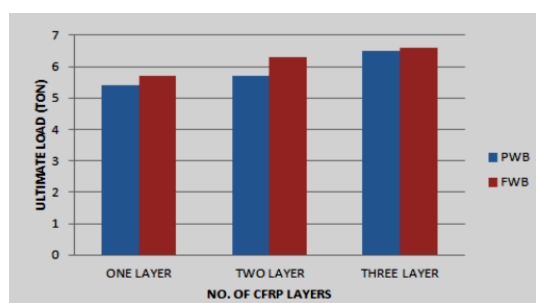
Table: 2 Experimental test result Ultimate load and nature of failure for CB and PWB beams

Si. No.	Type of Beam	Beam designation	Load at initial crack (TON)	Ultimate load (TON)	Type of failure modes
1	Control beam	CB	1	2	Flexural failure cum yielding of concrete with multiple narrow cracks
2	PWB Single layer	PWB - 1	2.7	5.4	Rupture failure of FRP composites occurred at the mid-span of the section.
3	PWB two layer	PWB - 2	3	5.7	Rupture failure of FRP composites occurred at the mid-span of the section.
4	PWB three layer	PWB - 3	3.3	6.5	Rupture failure of FRP composites occurred at the mid-span of the section.

Graph: 2 Flexural strengths of FRC beam strengthened by fully wrapping – comparison



Graph: 3 Flexural strengths of FRC beam strengthened by full and partial wrapping – comparison



5. CONCLUSION:

The external bonding of CFRP fabrics offers an externally effective means of strengthening Reinforced Concrete (RC) beams flexure. CFRP fabric property bonded to the tension face of RC beams can enhance the flexural strength substantially the strengthened beams exhibit an increase in flexural strength for 40 to 45 percent for three layers' static loading respectively. A flexible system will ensure that bond line three layers CFRP strengthened beam does not break before failure and participate fully in structural resistant of the strengthened beams. In flexural (FB) beams, the use of CFRP on the RC beam increased its ultimate load capacity. In this investigation CFRP strengthened beam gives appreciable strength and stability when compared to control beam.

6. REFERENCES:

1. **Alaa Morsy and EI Tony Mahmoud (2013)** Bonding Techniques for Flexural Strengthening of RC beams using CFRP laminates. Ain Shams Engineering Journal (2013) 4, 369 – 374.

2**. Alferjani.M.B. S et al (2013)** Use of Carbon Fiber Reinforced Polymer Laminate for strengthening reinforced concrete beams in shear.

3. **Barros. J and Dias. S (2002)** Shear strengthening of reinforced concrete beams with laminate strips of CFRP. Journal of Mechanics of Composite Materials and Structures.

4. **Concrete Technology by A.M. Neville & J.J. Brooks**, ADDISON-WESLEY, Concrete Technology by M.S. Shetty, S. CHAND & COMPANY LTD.

5. **Ehsani and Saadatmanesh (1991)** Extensive study into the reactions of RC beams strengthened with FRP under static loading. ASCEJ. Struct. Eng., vol.117 no. 11, pp.3417-3433.

6. **Elchaiakani.M and Bambach.M. R (2007)** Plastic mechanism analysis for circular hollow section (CHS) tubes strengthened using CFRP.

7. **IS 456, (2000) Code** of practice for reinforced concrete design, New Delhi: Bureau of Indian Standards, 2000.

8. **IS 10262- 2009** Code of practice for Concrete Mix Proportioning, New Delhi: Bureau of Indian Standards, 2009.