REVIEW ON SHEAR STRENGTH OF RC BEAM USING FIBER REINFORCED POLYMER (FRP)

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***Abstract* — This paper present a literature review related to role of Fibre reinforced polymer (FRP) reinforcement in RC beam. Several investigators carried out experimental and theoretical investigations on concrete beams and columns retrofitted with various fibre reinforced polymer (CFRP, GFRP, etc.) composites in order to study their effectiveness. Many practical applications worldwide now confirm that the technique of bonding FRP laminates or fabric to external surfaces is a technically sound and practically efficient method of strengthening and upgrading of reinforced concrete load-bearing members that are structurally inadequate, damaged or deteriorated.**

***Keywords* — CFRP, Shear strengthening, RC beams, Retrofit methods, FRP strengthening.**

I. INTRODUCTION

FRP composite materials are comprised of high strength continuous fibers, such as glass, carbon, or steel wires, embedded in a polymer matrix. The fibers provide the main reinforcing elements while the polymer matrix (epoxy resins) acts as a binder, protects the fibers, and transfers loads to and between the fibers

FRP systems have been successfully used to strengthen buildings, bridges, silos, tanks, tunnels, and underground pipes. The higher cost of FRP materials is offset by reduced costs of labour, use of equipment, and downtime during installation, making them more cost-effective than traditional strengthening techniques. There are different types of FRPs are available in industry amongst which mainly using in strengthening are Glass Fiber(GFRP), Kevlar Fiber (KFRP), Carbon Fiber(CFRP) and Aramid Fiber(AFRP).

II. LITERATURE REVIEW

[1] Alex li et al. Carried out an experiment research on shear strengthening of rc beams with externally bonded cfrp sheets and found that it is not necessary to strengthen the entire concrete beam surface. The general and regional behaviour of concrete beams with bonded carbonfiber–reinforced plastic sheets are studied with the help of strain gauges. The appearance of the first cracks and the crack propagation in the structure up to the failure is monitored and discussed for five different strengthened beams. For the strengthened beam, the ultimate strength can have a significant increase in comparison with the normal beam. The crack modes were greatly influenced by the dimension and the position of the strengthened CFRP sheet. The experimental results indicated that the beam strengthened in both flexure and shear had a slight advantage, in ultimate strength, in comparison with the beam strengthened in flexure. The maximum gain in the ultimate flexural strength was only 11%.

[2] Barbara G. Charalambidi et al have studied on Fatigue Behaviour of Large-Scale Reinforced Concrete Beams Strengthened in Flexure with Fiber-Reinforced Polymer Laminates. In their study Ten reinforced concrete beams of rectangular and T-shaped cross-sections were strengthened with two different FRP techniques. The first concerned the use of externally bonded CFRP laminates and the second the use of NSM CFRP laminates. To prevent shear failure, CFRP sheets were placed on the shear spans. Seven specimens were subjected to fatigue loading up to failure, whereas three specimens were subjected to static loading. To prevent shear failure, CFRP sheets were placed on the shear spans. Load–deflection curves were illustrated for all specimens. There was recorded a proportional increase in deflection with the number of cycles. All specimens experienced the highest increase in deflection during the last decades of thousands of cycles of fatigue loading until failure. FRP strengthened beams subjected to low-level loading, exhibited far more upgraded behaviour.

[3] D. V. Reddy et al have examined the effect of fire on structural elements retrofitted by carbon fiber reinforced polymer composites. They found that Due to low temperature resistance, the CFRP systems are not capable of safely and adequately enduring fire for any substantial period of time. The similitude analysis performed in his study justifies the time duration reduction to compensate for the increased interior temperature of the specimen due to its reduced cross-section. Though CFRP systems have proven to be a technically efficient and sound method of strengthening and improving structurally inadequate, or otherwise damaged, or failing load-bearing members but due to low temperature resistance, the CFRP systems are not capable of safely and adequately enduring fire for any substantial period of time.

[4] D. V. Reddy et al. Studied fire resistance of structural concrete retrofitted with carbon fiber–reinforced polymer composites. Their paper presents an experimental investigation for evaluating the effects of fire exposure on properties of structural elements retrofitted by carbon fiber–reinforced polymers (cfrp). Mechanical properties of CFRP-strengthened reinforced concrete (RC) members, protected with secondary insulation, were investigated, before and after (residual)direct fire exposure. Direct fire contact resulted in a reduction in capacity of 9% to 20% for CFRP-strengthened RC beams and 15% to 34%for CFRP-strengthened RC columns. This study proved that because of its low temperature resistance, the CFRP system is not capable of safely and adequately enduring a fire for any substantial period of time. Passive fire protection applied to the exterior of the CFRP system is capable of improving the fire endurance of the strengthened member. CFRP systems have proved to be a technically efficient and sound method of strengthening and improving structurally insufficient or otherwise damaged or failing load-bearing members.

[5] Davood Mostofinejad et al. investigated on influence of different bonding and wrapping techniques on performance of beams strengthened in shear using CFRP reinforcement. Promising results have been obtained from flexural strengthening of concrete elements

using the grooving method in its special form of externally bonded reinforcement in grooves (EBRIG) to postpone CFRP debonding and load carrying capacity enhancement. Drawing upon that results, they studied to investigate the influence of the EBRIG and EBR methods used for shear strengthening of structural members when used with different techniques of installing CFRP sheets to provide sufficient bonding between CFRP sheets and the concrete substrate. In their study, seven concrete beam specimens, 120 × 160 × 1400 mm in size, were cast and subjected to the 4-point loading test. External shear anchorages were provided for each span of the beams separately, therefore, each specimen was tested in two rounds and a total of 14 tests were performed. They found that using the EBR method for strengthening RC beams increased their load capacity by up to an average percentage value of 110% relative to the control beam; however, this increase was about 126% when the EBRIG method was employed. The three-full wrapping, U-shape wrapping, and 2-side wrapping techniques increased the average values for the load capacity of the specimens by about 79%, 30%, and 13%, respectively, when the EBR method was employed; and by 89%, 59% and 31%, respectively, when the EBRIG method was used.

[6] Hamidreza Tahsiri et al. investigated experimental study of RC jacketed and CFRP strengthened RC beams. In their paper, they presented the results of an experimental study on retrofitting RC beams using FRP strengthening and RC jacketing. Three-point loadings were applied to twelve strengthened beams and three reference specimens to put the two techniques into perspective. Formation of first cracks, FRP debonding, and onset of concrete crushing were compared and discussed. Use of U-wraps nearby the CFRP laminates postpones the concrete cover delamination. Post-yield strength of the RC jacketed beams is noticeably higher than the CFRP strengthened beams. The FRP method triggers premature debonding failure at the mid-span leading to loss of sufficient ductility.

[7] M.R. Esfahania et al. experimentally studied on flexural behaviour of reinforced concrete beams strengthened by CFRP sheets. They investigated the flexural behaviour of reinforced concrete beams strengthened using Carbon Fibre Reinforced Polymers (CFRP) sheets. The effect of reinforcing bar ratio on the flexural strength of the strengthened beams is examined. Twelve concrete beam specimens with dimensions of 150 mm width, 200 mm height, and 2000 mm length were manufactured and tested. Beam sections with three different reinforcing ratios, were used as longitudinal tensile reinforcement in specimens. Nine specimens were strengthened in flexure by CFRP sheets. The other three specimens were considered as control specimens. The width, length and number of layers of CFRP sheets varied in different specimens. The flexural strength and stiffness of the strengthened beams increased compared to the control specimens. The flexural strength and stiffness of the strengthened beams increased compared to the control specimens.

[8] Mahbube Subhani et al. Studied on Assessment of bond strength in CFRP retrofitted beams under marine environment. In their study, the bond between carbon fibre reinforced polymer and concrete is improved by modifying the property of commercial epoxy and compared against normal epoxy. Also, a model is proposed to determine the bond strength from flexural test and compared against the available bond strength models which are typically obtained from pull out test. This proposed model shows promising results in terms of predicting the bond strength from flexural test. In addition, a strength reduction factor is introduced to incorporate the effect of wet dry cycles to predict the long term behaviour. They found that the modified epoxy enhances the ductile property and bond strength. The maximum load carrying capacity is not affected too much under short term exposure, the ductility is affected greatly by it. The degradation rate in bond strength is less in modified epoxy adhered CFRP with concrete compared to the normal epoxy attached concrete beams. A strength reduction factor to predict the bond strength under the marine environment is introduced.

[10] Ratan Kharatmol et al. had investigated strengthening of beams using carbon fiber reinforced polymer. An experiment study is carried out by them to study the change in the structural behaviour of R.C.C. beams wrapped with carbon fiber of different thickness, orientation and length to enhance the flexural and shear capacity of the beams along with the existing practice of doing the repair work. CFRP wrapped at tension side gives better strength as compared to CFRP wrapped at two parallel sides but gives less strength as compared to CFRP wrapped at three sides. CFRP wrapped at three sides gives higher strength but as the CFRP composite is costly it increasing the cost of construction so from an economic point of consideration CFRP wrapped at tension side to the beam is desirable.

[12] R.A. Hawileh et al. have experimentally investigated effect of flexural CFRP sheets on shear resistance of reinforced concrete beams. He experimented on Thirteen beams were cast without transverse reinforcement in the shear span and were divided into three groups with different longitudinal steel reinforcement ratios. The tested specimens failed in shear as a result of a diagonal-tension crack. The increase in the concrete shear capacity of strengthened specimens was in the range of 10–70% compared to the control specimens. They have concluded that flexural longitudinal reinforcement ratio has a significant effect on the shear strength of RC beams. The shear strength of the tested specimens was also predicted using different codes guidelines and standards. Diagonal shear cracks become steeper and post cracking stiffness also increased as the amount of longitudinal reinforcement ratio increased. As the number of layers of longitudinal CFRP sheets increased, the shear strength of the tested RC beams also increased.

[13] Shraddha B. Tibhe et al. took comparative experimental study on torsional behavior of RC beam using CFRP and GFRP Fabric Wrapping. In present experimental study deals with the torsional strengthening of Reinforced Concrete beams using epoxy bonded FiberReinforced Polymer (FRP) fabric. Total Thirty-nine rectangular beams of size 150mm × 300 mm and 1200 in length are casted. Out of which, three beams are control beam and remaining thirty-six beams are classified into two groups. One with CFRP fabric wrapping and another with GFRP fabric wrapping. With various wrapping patterns. The applied CFRP and GFRP configurations are U-jacketed, vertical strips with spacing, and edge strips along with vertical strips along its entire length. Torsional capacity of beams of two groups is compared with control specimen with respect to torsional moment, angle of twist and ductility factor and it was observed that CFRP fabric bonded beam shows more torsional strength than the GFRP bonded beam. As we compare CFRP bonded RC beam with GFRP bonded RC beam then experimentally it proved that CFRP fabric having maximum torsional strength than GFRP fabric. CFRP and GFRP failure may be due to debonding of CFRP and GFRP or crushing of concrete. We can say that crack width decreases due to use of CFRP and GFRP fabric. The torsional strength, angle of twist, ductility factor is having maximum value for CFRP bonded beam than GFRP bonded beam.

[14] Tom Norris et al. worked on shear and flexural strengthening of RC beams with carbon fiber sheets. They presented result of their experimental and analytical study of behaviour of damaged or understrength concrete beams retrofitted with thin carbon fiber reinforced polymer sheets. The CFRP sheets are epoxy bonded to the tension face and web of the concrete beam to enhance their flexural and shear strengths. Nineteen beams were fabricated, loaded beyond concrete cracking strength, and retrofitted with three CFRP systems. CFRP sheet can provide increase in strength and stiffness to existing concrete beams when bonded to the web and tension face. The magnitude of increase and mode of failure are related to the direction of the reinforcing fibres. The result of his study showed that CFRP may be

used to increase the strength and stiffness of beams without causing catastrophic brittle failures associated with this strengthening technique.

[15] Thong M. Pham et al. studied on review of concrete structures strengthened with FRP against impact loading. Their study reviewed the dynamic properties of FRP materials. From their study FRP materials can be used to improve the impact resistance of RC structures including beams, slabs, columns and masonry walls. They lead to an increase in the load carrying capacities, ductility and energy absorption. They found Debonding mechanism of FRP and its rupture strain under impact loads are still unclear. The tensile strength of FRP materials increases as the strain rate increases while a conclusion on the failure strain and stress–strain relation could not be made. FRP material would be recommended for strengthening structures against impact events but further studies are still needed.

III. CONCLUSIONS FROMLITERATURES

1. The significant increase in the shear strength up to 50% can be achieved by bonding CFRP sheets to the sides of the RC beams.
2. FRP application leads to a variation of some of the significant structural aspects like the cracking pattern and deformation levels in shear reinforcing systems.
3. Diagonal shear cracks become steeper and post cracking stiffness also increases as the amount of longitudinal reinforcement ratio increases.
4. The result of this study shows that CFRP may be used to increase the strength and stiffness of beams without causing catastrophic brittle failures associated with this strengthening technique.
5. CFRP wrapped at tension side gives better strength as compared to CFRP wrapped at two parallel sides but gives less strength as compared to CFRP wrapped at three sides.
6. Due to low temperature resistance, the CFRP systems are not capable of safely and adequately enduring fire for any substantial period of time.
7. The FRP method triggers premature debonding failure at the mid-span leading to loss of sufficient ductility.
8. With increasing numbers of layers of CFRP sheets, there was increment in strength but in decreasing manner.
9. It is seen that the failure mode of debonding of CFRP, reduces the effectiveness of CFRP by not utilizing the strength of CFRP.
10. Overall, there is lack of comparison of different configuration other than full side wrapping and U- wrapping for beams strengthened in shear.
11. For the strengthened beam, the ultimate strength can have a significant increase in comparison with the normal beam.
12. Crack width decreases due to application of CFRP sheet.

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