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Critical Investigations on Shear and Flexural Behaviour of RCC Beam Retrofitted with Various Fibre Reinforced Polymer (FRP) Composites

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Abstract: *Experimental investigations on retrofitting of RC beams over the past thirty-five years using FRP techniques have been clearly developed the potential use of different fibre reinforced polymer fabric for improving the flexural strength, toughness index and shear strength of reinforced cement concrete beams. In recent years among the different techniques of rehabilitation of existing structures, Basalt Fibre Reinforced Polymer (BFRP) as an external bonding has been considered as a popular one. This review paper is mainly to used on several features of RC retrofitted concrete beams such as strengthening of concrete beams by suitable retrofitting techniques, to extend the fatigue life of the structural element and eliminates the crack growth rate.*

Keywords: Retrofitting-Fibre reinforced polymer (FRP) -Adhesives-Failure mode- Flexural and shear behaviour

I. INTRODUCTION

Fibre reinforced polymer (FRP) has become one of the most popular methods in the repair and rehabilitation of concrete structures due to various application and the special physical characteristics. Both the destructive and non-destructive assessment have been used to test the durability of FRP in order to investigate the condition of the structure.FRP, a relatively non-corrosive, high strength, lightweight material, have over the past 25 years emerged as practical materials.

FRP bars are used as internal reinforcement for concrete structures. FRP bars, sheets and strips are used for strengthening of various structures constructed from concrete masonry, Timber etc.FRPs employed for seismic retrofitting. Most recently, the performance characteristics of FRP strengthening have become increasingly popular in construction and retrofit applications, specifically in aging, damaged or overloaded concrete structures. Traditionally, FRP has been used in the Civil, Aerospace and Automotive industries for applications requiring high strength to weight ratios and rigidity.

II. SHEAR AND FLEXURAL BEHAVIOUR OF RCC BEAM RETROFITTED WITH VARIOUS FIBRE REINFORCED POLYMER COMPOSITES

2.1 Pello Larrinaga et.al investigated that

- The effect of reinforced concrete slab used as a flexible reinforcing material tied out of low-grade reinforced concrete beams from ancient buildings.
- Concluding that textile has strengthened concrete in terms of increasing its flexibility and load-bearing capacity under flexure loads.

2.2 Faisal M. Muktar et.al investigated that

- The shear behavior and binding characteristics of ductile RC beams initially at the end of the transition to breakage breakdown failures when reinforced using a reinforced outer carbon fiber polymer (CFRP).

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- The test system can serve as a bond test philosophy in the sense that this method of brittle boundary failure provides a more logical operation for crack debonding performance of FRP reinforced beams.

2.3 Lianheng Cai et.al investigated that

- The cutting behavior of rectangular reinforced concrete (RC) reinforced CFRP grid with epoxy mortar was investigated.
- The result showed that the shear volume and split RC patterns reinforced with CFRP grid in shear can be successfully improved.

2.4 Yasmin Murad et.al reported that

- The shear behavior of RC beams made of steel and pvc electric plastic wire fibers.
- The result of a high-rise test of + 47.44% in the estimated deformity occurs when a large percentage of plastic wires are inserted into the concrete mix. Finished models are also developed into ABAQUS to mimic the numerical behavior of the templates.

2.5 Subhrasmita Majumder et.al calculated that

- The shear strength behavior of missing reinforced concrete (RC) beams reinforced with geosynthetic materials.
- Comparing the performance of geogrid models enclosed in these parameters is better compared to closed RC geotextile beams and higher in closed specimens.
- It is guaranteed that geogrid and geotextile materials can be a very useful solution for reinforcing the RC beam by external or internal confinement at very low cost.

2.6 Haya H.Mhanna et.al examined that

- The effect of reinforced concrete shear reinforcement (RC) T-beams with modulus carbon fiber reinforced polymer (CFRP) laminates and anchors.
- The result shows that U-wraps led to a 61 percent increase in shear strength compared to the control model, but the failure was dominated by strong bonding of CFRP laminates, with no indication of ductility before failure.

2.7 Yasmin Murad et.al investigated that

- The cutting behavior of RC beams with basalt and polypropylene fibers.
- The result shows that the inclusion of 0.6% polypropylene fibers improved shear strength, peak deviation, ductility and initial stiffness up to 23.2%, 39.74%, 195% and 2.56% with reference
- beam prepared with ordinary concrete with a concentration of 2.5% basalt fibers up to 20%, 64%, 121% and 21.2% compared to beams prepared with ordinary concrete respectively.
- The study of the parameters were the basics of WWM, location, and high temperatures and the performance of the monitored structure in terms of retention capacity, resistance, durability and durability.

2.8 Rajai Z. AL-Rousan et.al concluded that

- The parameters were the basics of WWM, location, and high temperatures and the performance of the monitored structure in terms of retention capacity, resistance, durability and durability.
- The result showed that the embedded WWM showed significant performance in improving the cutting capacity exposed to high temperatures of RC beams, WWM is active in improving the internal shear reinforcement for the exposure of high-temperature RC beams.

2.9 EnassAlrajfi et.al investigated that

- The performance of the RC beam's structure made of natural composite, reconstituted composite concrete and asphalt concrete that has also been sought under normal and high temperatures.

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- The result showed that the temperature had a negative impact on the shear strength, load capacity, stretch strength, and deviation of the RC beams; the increase in RAP percentage has resulted in a decrease in their carrying capacity.

2.10 E.Ferrier et.al investigated that

- The flax fiber reinforced polymer (FFRP) using the external bonding method (EB) and near surface mounted method (NSM).
- The result indicates that the ultimate load increased by 10% to 35% for the reinforced beams, the shear strengthening analysis of concrete beam using a new natural material, the shear reinforcement of concrete beams.

2.11 Kagan Sogut et.al reported that

- The behavior of RC T- barbers reinforced with embedded FRP bars.
- Test results and FE showed that concrete and FRP contributions to shear shear and total shear strength all decreased with the increase in steel-to-FRP shear reinforcement ratio.

2.12 Emad E.Etman et.al examined that

- The shear strength of the reinforced concrete beams (RC) provided by pre-assembled steel trusses in the shear span area.
- The result showed that reinforced steel beams showed better shear performance and improved shear width compared to those reinforced beams with the same reinforced bars**.**

2.13 TrungKien Nguyen et.al concluded that

- The behavior of the RC deep beam structure without shear reinforcement.
- The result shows a large donation of a deep rusty rod with adequate gripping capacity of beam models and a shear span-to-depth measurement and corrosion degree and corrosion degree does not always result in adverse effects in failure mode, and resistance to shear, rusty beams.

2.14 ChalachewB.Hunegnaw et.al calculated that

- The effect of the orientation of stirrups on the shear capacity of RC beams as the shear- span-to-depth ratio.
- The results revealed that the shear capacity increases as the arrangement of stirrup changes from conventional vertical arrangement to inclined arrangement and Shear capacity also increases as concrete compressive strength increase, which shows that concrete contribution to the shear capacity of beams.

2.5 Ric Hughes et.al investigated that

- The shear reinforcement of RC beams with basalt fiber reinforced polymer (BFRP) composites.
- Equilibrium reinforced concrete slabs with basalt fiber reinforcement and reinforcing parts of the structure.
- The data show that the yield and strength of the end times of the beams have been increased and the re-installed beams also showed swelling and better performance.

2.16 Swapnasarit Kar et.al investigated that

- The shear reinforcement of RC beams with basalt fiber reinforced polymer (BFRP) composites.
- The result shows that reinforced concrete load failure increases by 17-50% and the efficiency of basalt fiber sheets in increasing shear capacity to 20% higher than that of glass fiber sheets.

2.17 ChittaranjanB.Nayak et.al calculated that

- The structural and cracking behaviour of RC T- beams is investigated experimentally and analytically strengthened with basalt fiber reinforced polymer (BFRP).

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- The result demonstrates that superficially bonded BFRP can enhance the flexural capacity and reduce the deflection of the beam and the most effective wrapping pattern was a 45° than 90° wrapping and without wrapping, it shows different cracking patterns and yield points of the beam with and without strengthening.

2.18 Abathar Al-Hamrani et.al reported that

- The shear behavior of basalt fiber reinforced concrete (BFRC) basalt-reinforced beams and glass fiber reinforced bars of polymers and stirrups.
- The result shows that increasing the longitudinal stiffness of the BFRP-FRC beams tested by 50 and 120% led to an increase in their final strength by 24 and 48%, the carrying capacity of the BFRP-FRC tested beams decreased significantly by 46 %, Reduction of stirrups space from 250 mm to 170 mm showed a 20% increase in tested load capacity.

2.19 Ali Saribiyik et.al examined that

- The shear strength of reinforced concrete beams (RC) with basalt fiber reinforced polymer (BFRP) composites.
- The result shows that the shear volume of RC beams reinforced with BFRP compounds increased between 43% and 100%.

2.20 R. Madotto et.al concluded that

- The effectiveness of BFRP in reinforcing reinforced concrete beams.
- The BFRP fabric has been shown to be effective in increasing both the shear strength and flexibility capacity of the tested beams.

2.21 Walid Mansour et.al investigated that

- The shear consolidation of continuous RC beams with web openings with FRP layers.
- The results showed that the continuous RC beams containing openness in the zone II group were the most affected among the analyzed areas and the group's load capacity decreased from 7.3 to 66.1% compared to the solid rod.

2.22 Bo Wang et.al investigated that

- The experimental results of four-point bending tests for reinforced concrete (RC) beams strengthened by carbon fiber reinforced polymer (CFRP) grids and sprayed polymer-cement-mortar (PCM).
- The result indicates that the shear strengthening effect of the CFRP grid-PCM reinforcing layers bonded along both sides of RC beams was sufficient.

2.23 Hiroshi Sasano et.al noticed that

- Improving plant life by allowing long-term performance, numerical model, which can detect changes in structural performance due to drying.
- The numerical method model can accurately assess the effect of drying on the members of the structure, although there are some remaining problems regarding brittle breakage.

2.24 Omar R.Abuodeh et.al investigated that

- The behavior of shear lacking reinforced concrete (RC) reinforced shear with side-bonded laminates and warped fiber-reinforced reinforced (FRP) laminates.
- The result showed that a strong neural propagating back-propagating network (RBPNN) with selected parameters was able to predict FRP severity more accurately (r2 = 0.885; RMSE = 8.1 kN) than that of RBPNN with the first 15 restrictions (r2 = 0.668; RMSE = 16.6 kN).

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2.25 Shervin K.Ghomi et.al investigated that

- The seismic activity of the internal GFRP-RC column joints.
- The result shows that the linear nature of the GFRP material led to lower residual damage to the joints of the GFRP-RC column compared to its corresponding RC metal counterparts and the GFRP-RC joints with multiple cyclic loads up to 8% without drifting rate strong failure.

2.26 Hiroshi Sasano et.al calculated that

- The performance of an older RC structure, a numerical model, taking into account the moisture transfer associated with shrinkage and the apparent changes in concrete material, is proposed.
- The result shows the distribution of rebar stress after drying, changes in diagonal fracture patterns, changes in diagonal fracture patterns, styles in load change relationships, especially with the strength of diagonal cracks.

2.27 Ade Lisantono et.al examined that

- The behavior of high fly ash cutting as replacing the Portland cement of reinforced concrete beams (RC).
- The result shows that that can be achieved by beams with 50% fly ash due to higher shaving power than 60% beam and 70% fly ash.

2.28 C. Pellegrino et.al reported that

- The behavior of reinforced concrete (RC) beams reinforced with shear with external bonds.
- The result shows an increase in shear strength of reinforced beams increasing with increasing axial strength of the composite and effective problems in composite compositions using available models that were much lower than the maximum weight measured with heavy gauges placed in the composites.

2.29 G. M. Chen et.al concluded that

- The Reinforced concrete (RC) beams can be strengthened in shear by externally bonded (EB) fibre reinforced polymer (FRP) composites in the forms of side-bonded FRP strips, FRP U-jackets or FRP wraps.
- The analytical solution is that the development of the FRP shear contribution by opening the shear crack and investigating the shear interaction between different components (FRP shear reinforcements, steel shear reinforcements, and concrete) in RC shear reinforced beams with FRP.

2.30 Liu Jin et.al investigated that

- Rc cantilever seismic shear failure behavior test with opposite stiffness under load for low fatigue.
- The result shows that the alleged cutting capacity of RC cantilever beams is significantly reduced as the size of the structure increases and the shear strength indicates a stronger size effect.

2.31 M. Breveglieri et.al investigated that

- Imitating crack shear pressure transfer in a concrete model of crack smeared concrete is essential to accurately predict the deterioration and cracking behavior of RC elements indicating shear failure.
- The result shows that the holes are drilled with a cross section, in the desired direction, and steel or FRP wires are inserted into these holes and fastened to the concrete substrate with adhesive materials.

2.32 Patrick Huber et.al concluded that

- The result shows that the opening of the crack and slide behavior are directly related to the shape of the critical shear crack, Although the effect of compacting is more pronounced at large fracture angles, the number of stirrups falling through the critical shear crack is reduced by beams and stirrups.
- Although crack kinematics was clearly dependent on organ depth and the presence of stirrups, especially with respect to crack opening behavior, it did not show dependence on the type of concrete regarding crack openness or slippery behavior.

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2.33 P. Bernardi et.al investigated that

- Behavioral representation of pre- and post-fragmentary behavior using a basic model for the analysis of reinforced concrete structures.
- Experimental results show that bare concrete panels are subject to biaxial pressure, as well as RC and SFRC beams without shear reinforcement and high fracture width due to appearance and durability problems.

2.34 Belal Almassri et.al examined that

- The key features of the FE numerical model developed using the FEMIX computer code to predict the contribution of surface-mounted polymer rods (NSM) carbon-fiber-reinforced polymer (CFRP) in the repair of RC beams of rusted concrete.
- The result shows that the efficiency of the NSM strategy is limited by the semi-conical impact of each NSM CFRP contribution of the rod and the unadulterated point span of the SB beams, which resulted in the appearance of cracks in the center. RC beams are fastened to the shaft.

2.35 R.Siva Chidambaram et.al reported that

- Exploratory studies are being conducted to evaluate the feasibility of geo-grid as an additional cutting edge in RC beam models.
- The result shows that significant improvements in the strength and post-harvest behavior of wooden models depend on%% reinforced concrete and the use of geo-grid sealing and the proper use of geo-grid reinforced concrete not only., helps to achieve ductile behavior but also transforms brittle failure mode.

2.36 Lei Wang et.al investigated that

- The shear behavior of rusty concrete (RC) beams with stirrups and inclined bars.
- It shows that the slightest loss of rust less than 10% on stirrups and sloping bars has little effect on the deformity of the shaft and rust of stirrups and sloping bars does not change the mode of shear pressure compression failure.

2.37 Christian Escrig et.al investigated that

- The reinforced concrete beams cut with a variety of reinforced mortar.
- The result suggests that the effectiveness of the reinforcement systems is limited by the performance of the TRM matrix bond with the concrete or substrate or by reinforcing fabric and comparisons between different TRM composites.
- It can be said that PBO fabrics (PXM750) showed excellent performance, increasing shear resistance as well as the flexibility of the reinforced beams, even on a non-linear stage.

2.38 A.Deifalla et.al author examined that

- A set of new experiments that were able to mimic the behavior of T-shaped curves under a combined shear and torsion was developed.
- The result shows that the flange stirrup is most effective in resisting the torsion moment over shear force, the amount of torque to the shear ratio significantly affects the behavior of the T-shaped beams modified according to the fracture pattern; failure mode; strut angle of inclination; cracking and final torque; post-cracking rigidity of torsional; fractures and high shear; flange and web stirrup strain.

2.39 G.Sakar et.al concluded that

- Experimental and numerical testing response to reinforced concrete (RC) loading concrete shear with Glass Fiber Reinforced Polymer (GFRP) rods using a nearby surface mounted (NSM) method.
- The result shows that the NSM GRRP screening program tested significantly improved the carrying capacity of the tested samples between 49% and 66%.

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- The ductility of the reinforced samples was more than that it controls the unconfirmed template and varies between 112% and -172% and increase GFRP web size from 6 mm to 10 mm and reduce space from 160 mm to 120 mm.

2.40 Georges EL-Saikaly et.al investigated that

- The fatigue performance of RC T-beams reinforced savings to increase service load using pre-made CFRP L-shaped lamps.
- The results confirmed the possibility of using CFRP L-shaped laminates to extend the service life of RC T-beams dealing with fatigue loading and the presence of flexible steel in reinforced beams led to a significant reduction in shear resistance due to CFRP, which ensures interchangeability between steel and steel-CFRP.

2.41 Omar A. Farghal et. al reported that

- The performance of shear reinforced concrete (RC) T-beams reinforced shear with a combination of Carbon Fiber Reinforced Polymer (CFRP).
- The result shows that reinforced beams can survive cycles of cyclic loading cycles (= 50% of very heavy load) without obvious signs of damage (premature failure) indicating the effectiveness of the CFRP reinforcement program in increasing the fatigue of structural fatigue and reinforced beams provided with U-jacket authorized sheets. An acceptable enhancement in structural ductility.

2.42 Sherif H.AL-Terasawyet.al examined that

- The performance of reinforced concrete (RC) beams reinforced beams.
- The result shows that CFRP folding that is tied to the outside has improved the cutting ability significantly and that the customized CFRP configuration is more effective than vertical.

2.43 Joaquim A.O. BARROS et.al investigated that

- The Experimental research has demonstrated the excellent performance of the near surface mounted (NSM) technique with carbon fiber reinforced polymer (CFRP) laminates for the shear strengthening of reinforced concrete (RC) beams.
- The result shows that the NSM laminates provided a large increase in terms of load carrying capacity after shear crack formation and the effectiveness level of the NSM technique was limited by the concrete tensile strength, Inclined laminates were more effective than vertical laminates and an increase of the percentage of laminates led to an increase of the shear capacity of the beams.

2.44 Sherif H. Al Tersawy et.al concluded that

- To analyze the performance of reinforced concrete (RC) beams strengthened in shear.
- The result indicates that externally bonded CFRP wraps enhanced the shear strength of beams significantly and that inclined CFRP configuration is more effective than vertical ones.

2.45 Jiangfeng Dong et.al investigated that

- Experimental research on reinforced concrete (RC) beams with external flexural and flexural–shear strengthening by fiber reinforced polymer (FRP) sheets consisting of carbon FRP (CFRP) and glass FRP (GFRP).
- The output shows that the flexural–shear strengthening arrangement is much more effective than the flexural one in enhancing the stiffness, the ultimate strength and hardening behavior of the RC beam.

2.46 Abdeldjelil Belarbi et.al concluded that

- The shear behavior of reinforced concrete slabs (RC) reinforced with fiber-reinforced polymer (FRP) composites.

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- The result showed that the increase in shear strength from about 23% to 26% compared to the corresponding control rod, FRP-reinforced beams with mechanical anchorage showed 7-48% higher shear strength than beams, FRP strengthens full shear- RC scale poles work just as well as those seen in low-level RC beams.

2.47 H. K. Lee et.al reported that

- The behavior and performance of reinforced concrete (RC) deep T-section beams reinforced with CFRP sheets.
- The test result shows that important variables of reinforcing length, combination of fiber direction, and anchorage have a significant impact on the performance of the hardened reinforcing beams.

2.48 Xiao-Hui Wang et.al investigated that

- An experimental investigation in the effect of corrosion damaged partial length in one shear span on the shear behaviour and load capacity of reinforced concrete (RC) beams.
- The result indicate that the mechanical behaviour and load capacity of the test specimens are greatly influenced by the bond characteristics and high corrosion induced damage within the partial length.

2.49 Mark G. Stewart et.al examined that

- To consider that the spatial and time dependent variability of pitting corrosion, structural resistance and load effects.
- The result indicates that the probability of failure assuming brittle reinforcement behaviour is up to 450% higher than assuming ductile behaviour.

2.50 Andrea Rizzo et.al investigated that

- Estimate the shear strengthening of reinforced concrete (RC) members is the use of near-surface mounted (NSM) fiber-reinforced polymer (FRP) reinforcement.
- The result shows shear strengthening of reinforced concrete (RC) members is the use of near-surface mounted (NSM) fiber-reinforced polymer (FRP) reinforcement the stiffer bond slip behavior of the joints induced larger peak bond stresses and accelerated the initiation debonding cracks in the concrete, the reduced distance between the bars accelerated the formation of a debonding failure pattern involving all the bars together.

III. CONCLUSION

In light of the above literature review, to provide knowledge reference for current and further studies on the FRP reinforcement, strengthening of RC beams by using different FRP. This review paper covered the adhesive curing, shear strengthening, fatigue performance and failure modes of RC beams with different FRP such as, basalt, glass and carbon etc… and surface preparation. FRP is considered as an important technology that displays great potential for rehabilitation application, repairing structural elements and in the construction industry

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