# A REVIEW OF APPLICATION OF GFRP IN SHEAR AND FLEXURE TO STRENGTHEN THE REINFORCED CONCRETE BEAM

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***Abstract***- A numbers of research are being conducted for the use of frp in the repair and strengthening of reinforced concrete member. Repair and strengthening of concrete structure using such advanced material is a great revolutionary in the field of structural engineering. Research are being carried out on reinforced concrete beam of different shapes to check the behavior of fibre reinforced polymer on shear and flexural strength of beam. Many authors have performed certain experiment for different parameter and examined the change in property of beam or member. This paper presents review on the effect of different parameter such as type of FRP sheet, dimension of structure, no. of layers of FRP etc on the behavior of RCC beam in shear and flexure. For this analysis of numbers of research is being done and their results have been used here.

***Keywords- Flexure, GFRP sheets, RCC Beams, Shear, Strengthening***

## 1. INTRODUCTION

A structure once constructed does not remain as it is forever and it has to bear certain different load and their combination during it life span. These loads results in decrease in efficiency and hence strength of structures. Due to which the structure gets deteriorated such as cracks and bends appear in the structural member. Whenever a structure is affected by all such loadings we are left with two options i.e. either Repair or Reconstruction. But among these reconstruction proves to be very costly and that may be double to that of initial cost of structure. As structure built in past are not constructed as per our new codes of design which make them structurally unsafe and replacement of such structures require a huge amount and in the same time it destroys their antiquity if they are of ancient time. So at last we are left with Repairing or Retrofitting methods which are economical to us. But maintenance, rehabilitation and up gradation of structure is also a challenging task. For rehabilitation purpose Fibre Reinforced Polymer (FRP) have proved to be an efficient material. It can be used for providing strength to new as well as existing structures. At present different types of FRP materials are available such as Carbon Fibre( CFRP), Glass Fibre (GFRP), Aramid Fibre (AFRP ) etc. But from economy point of view GFRP sheets are mostly used and also previous researches have used them. These sheets of FRP are used externally so as to wound the member with these and the number of layers of FRP are decided on the basis of strength required. These application provide shear and flexural strength to beam. Both shear as well as flexure failure of beam are different from one another such as shear failure is brittle in nature and whereas flexural failure is ductile in nature. Making the use of above statement FRP sheets are applied on tension face of beam for flexural strengthening and on side face of beam for shear strengthening of beam.

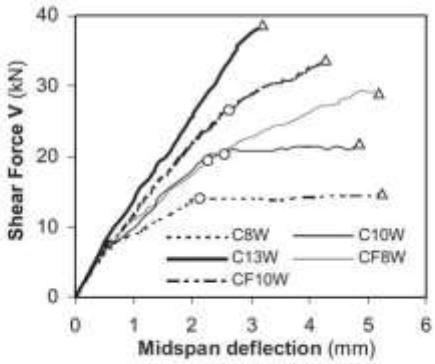
## 2. LITERATURE REVIEW

First developed in the mid 1930's, Glass Fiber Reinforced Plastic (GFRP) has become a staple in the building industry. Originally used merely for the construction of parts, in 1967, the architectural advantages were discovered with the attempted destruction of Disneyland's "House of the Future." Built in 1956-7, the futuristic house was built entirely of fiberglass, and when the attraction was no longer deemed necessary, it was scheduled to be destroyed in 1967. Amazingly, the wrecking ball merely bounced off the structure, and the possibilities for GFRP were recognized and began to grow. Here the work performed by different authors have been discussed along with their result. Hamid Saadatmanesh, and Mohammad R. Ehsani in 1991 performed experimental study on flexural strength of reinforced concrete beam by using GFRP. In their work five rectangular and one T-beam were tested under four point bending. They conclude their experiment by showing the result that flexural strength of beam can be significantly increased by bonding GFRP plates to the tension face of beams.

The gain in the ultimate flexural strength was more significant in beams with lower steel reinforcement ratio. They also showed that the epoxy bonded plates delayed the formation of cracks in beam and if they appear at high load level then their width was significantly reduced.

M.A. Saafan in 2006 performed experiment to find shear strengthening of beam with GFRP wraps on simply supported reinforced concrete beam designed with insufficient shear capacity and checked the efficiency of GFRP in strengthening of beam. In his work he used 20 beams of size 100 X 150 X 1050 mm with different shear strengthening methods like full wrapping of sides, U-jackets etc. and variable longitudinal reinforcement. The results indicated that significant increase in shear strength could be achieved by the application of GFRP to concrete beams deficient in shear capacity. When -jackets are properly applied over the shear span, the failure mode of the beam may be altered from that of a brittle shear failure to a ductile flexural failure mode. Also, the strengthened beams were able to achieve the strength and stiffness levels of web reinforced beams. The results also show that the serviceability performance of strengthened beams is expected to be superior with regard to increased cracking loads and the limited number of cracks and small cracking width.




Thomas E. Boothby[3] in 2005 used 28 specimens bonded with wet laid glass fibre reinforced polymer sheets to find the effect of GFRP on load, deflection, crack opening and strain. The experimental results showed that the GFRP sheet is the most ductile of the material system, allowing several secondary cracks to develop after repair, with a total elongation of 3mm over an initial length of 200mm. The specimens were precracked with a three point flexural load, subjected to a constant four point flexural load of about 25% of the initial ultimate moment, and placed into different environmental conditions like indoor laboratory, outdoor, elevated temperature/dry, and freeze/thaw. In this it was observed that the debonding of GFRP sheets from the concrete was the prime failure.

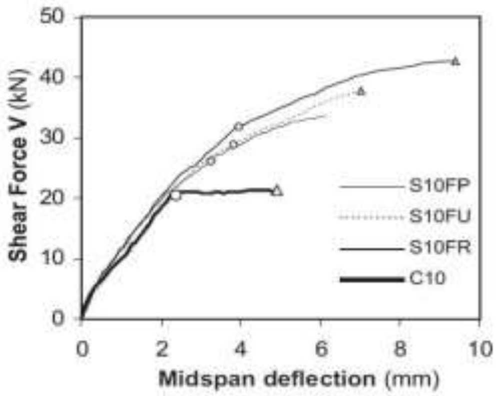



Figure1 Load deflection curve obtained by author for control beam with web reinforcement and shear strengthened beam

In 2006 Tarek H. Almusallam[4] tested 84 specimen to check the durability of reinforced concrete beams strengthened with glass fibre reinforced polymer laminates. He put the specimens in different environment for certain time period to find the change in flexural capacity and load deflection relationships of beams. The different environment conditions were maintained in laboratory and outside such as were controlled laboratory environment, outside environment, wet– dry normal water environment, wet–dry saline (NaCl) water environment, and wet–dry alkaline (NaOH) environment. The wet dry environment specimen were exposed to time cycle such that two week interval was adjusted for both the conditions. After that beams were tested on loading machine at 6, 12 and 24 months interval. It was found that there was no degradation in strength and stiffness of glass fibre reinforced sheets and also the performance of gfrp was not altered due to exposure to solar radiation. Hence we can say durability of structure is increased.

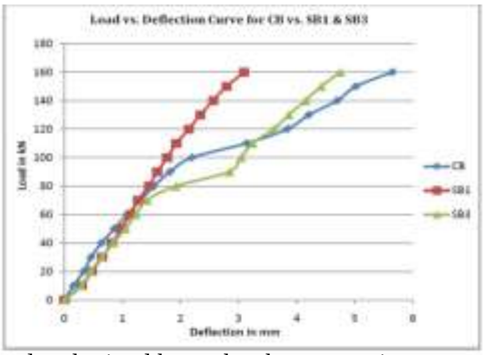
Bilal S. Hamad[5] in 2004 along with his colleagues examined the nature of fiber reinforced polymer (FRP) wraps to confine steel reinforcement in a tension lap splice region anchored in high-strength reinforced-concrete beams. Seven beam specimens were reinforced on the tension side with three deformed bars spliced at midspan Glass fiber reinforced polymer (GFRP) sheets were used. The main test variables were the GFRP configuration in the splice region (one strip, two strips, or a continuous strip), and the number of layers of the GFRP wraps placed around the splice region (one layer or two layers). All GFRP wraps were U-shaped. Except for the epoxy adhesive, no other anchorage mechanism or bonding procedure was applied for the GFRP wraps on the concrete beam. The test result showed that the GFRP can increase the bond strength and ductility of tension lap splices. They concluded that the GFRP wraps were effective in confining the tension splice region. The mode of failure in all beam specimens was a face-and-side split failure. The mode of failure as compared to beam without GFRP was more ductile and more gradual although the final mode of failure was splitting of the concrete cover. They also found strength increment ranging between 8% to 33% with respect to control beam. The use of GFRP wraps did not affect the cracking load. Overall conclusion of their research indicate that the use of GFRP wraps to confine bond critical regions in beams leads to change the nature of failure from brittle mode to a ductile one, allowing more bar lugs along the spliced bars to participate in the stress transfer between steel and concrete, and increasing the average splitting bond strength.

In 2008 N. Pannirselvam[6] and P.N. Raghunath study the structural behaviour of reinforced beams with externally bonded FRP reinforcements. They used 15 beams of 3 m length in total and having three different steel ratios, wrap thickness and wrap materials. Flexural test on beam was performed with two point loading to compare the FRP plated beams with unplated beams. Also the result flashes that strengthened beam have better performanceThe flexural strength and ductility increase with increase in thickness of GFRP plate. The increase in first crack loads was up to 88.89% for 3 mm thick Woven Rovings GFRP plates and 100.00% for 5 mm WRGFRP plated beams and increase in ductility interms of energy and deflection was found to be 56.01 and 64.69% respectively with 5 mm thick GFRP plated beam. It was found 28.57% to 40% increment of yield load for 3 mm thick GFRP sheet and 28.57% to 128.57% increment of yield load for 5 mm thick GFRP sheet

In 2009 M.C. Sundarraja[7] found the use of glass fibre reinforced polymer inclined strips on the web of beam for shear strengthening of beam. He carried out his work to obtain the effective width and spacing of strips for better shear capacity of beam. For his experimental purpose he used two point loading method. During his coursework various failure mode were observed such as shear failure due to FRP rupture, and also without FRP rupture, crushing of concrete at top and flexure failure. At last they got that use of GFRP can enhance strength of structure in shear and inhibit the development of cracks. The load deflection behavior of beam got better and also the load carrying capacity of beam got increased.

In 2012S. Deepa Raj[8]performed an experimental program to carry out to assess the effectiveness of the shear strengthening of concrete beams using Glass Fibre Reinforced Polymer (GFRP).She wanted to know the difference between two methods i.e. Near Surface method and Externally bonded reinforced. A number of beams were casted and tested to analyze the influence of the type of GFRP reinforcement, spacing and alignment of reinforcement on the structural behavior and failure mode. The various types of GFRP used in the study are GFRP rectangular strips, GFRP circular rods and GFRP sheets. It was found that GFRP sheets tend to be more effective than stiffer GFRP circular rods. The experimental study concluded that the shear strengthening of concrete beams using GFRP was effective in increasing ultimate load carrying capacity and improving the deflection characteristics. They also found that specimen strengthened with EBR showed an increase of 1.33 times in ultimate load, when compared to the control beam specimen Performance would increase with the provision of GFRP bidirectional strips rather than pultruded rods and sheets. Performance would again increase with the alignment of GFRP strips against the shear crack

A.K. Panigrahi[9] experimentally investigated the performance of reinforced concrete T-beams strengthened in shear using epoxy bonded bi-directional GFRP fabric. Total 12 beams were casted and tested under 4- point loading. Different parameters included in test are GFRP amount and distribution, bonded surface, numbers of layers and fiber direction. The results obtained showed that Externally bonded GFRP reinforcement can be used to enhance the shear capacity of RC T-beams. , but the efficiency of beam depends on the various parameters. It was also found that among all the GFRP strip configurations (i.e. vertical strips, strips inclined at 45º and strips inclined at +45º in one direction and +135º in another direction making an "X-shape"), the X-shape is more effective than the others. Application of GFRP to beam with end anchorage is better than without end anchorage. The p-Δ behavior for inclined GFRP strips was better than GFRP strips on sidesalone.The ultimate load carrying capacity of strengthened beam were found to be increased  from 6% to 65%. As per results it was found that U-wrap with end anchorage configuration was best among all and use of anchorage system eliminates the debonding of the GFRP sheet, which results in better utilization of the full capacity of the GFRP sheet.



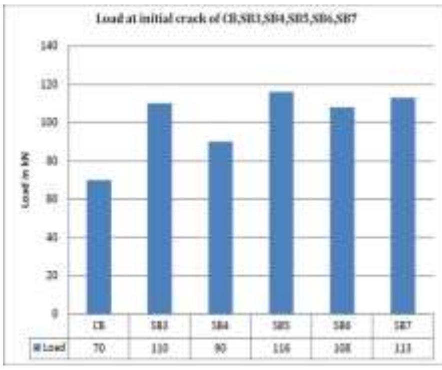



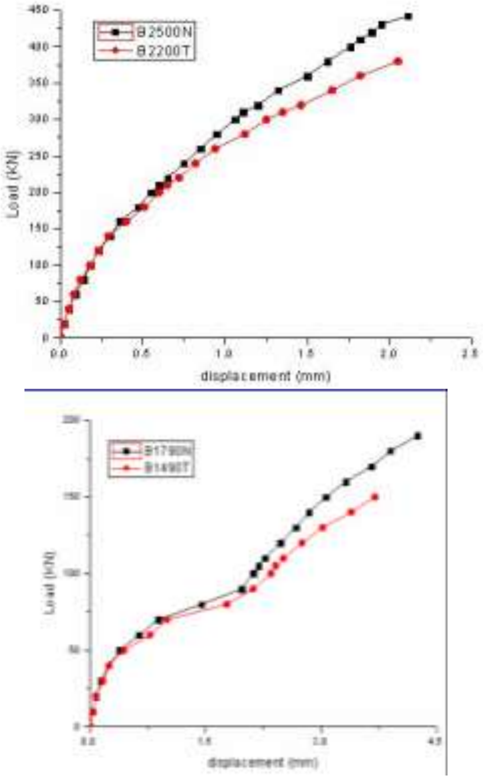

Figure: One of the results obtained by author by comparing control beam and strengthened beam

Figure : Result obtained by author showing the load at initial crack of control beam and strengthened beam

In 2013 AnumolRaju[10] and Liji Anna Mathew experimentally studied retrofitting of reinforced concrete beams strengthened with different types of fibres externally. Total 30 no. of beams of dimension 150mm X 150mm X 1000mm were casted for the research. Different types of fibre sheets used by them are Carbon, Glass, Steel, Polypropylene and Coir. As they used full wrapping technique so the deflection got minimized. Load carrying capacity as well as flexural strength of member increases due to application of FRP. The ultimate strength increment in carbon, glass, steel and coir fiber sheet strengthened beam by 125%, 89.6%, 45.02% and 37.9% respectively. Even though the beams retrofitted with CFRP sheets have the maximum ultimate load capacity, the cost of the material is high. Retrofitting using GFRP sheets prove to be economical since its cost is only Rs. 300/m2 and showed 89.6% increase in ultimate load capacity Kaushal Parikh[11] and

C.D.Modheraapplied GFRP on preloaded retrofitted beam for enhancement of flexural strength of beam by taking 17 specimen out of which two were control beam. During the application of load they have changed certain parameters such as no. of layer of GFRP, preload level at strengthening, arrangement of GFRP sheets and also checked the effect of traditional arrangement and New effective arrangement on beam. Finite element modeling was also used by them to carry out analytical results. At last they have compared the behavior of traditional arrangement and new effective arrangement of sheets and it was investigated that for traditional arrangement flexural load carrying capacity of preloaded beam increases by 80% but this increment was 104%in new effective arrangement of FRP. It was also observed that beams with traditional arrangement showed debonding phenomenon while beams with new effective arrangement showed shift of flexural crack away from flexural region and hence beam strengthened with new effective arrangement provide a good solution of retrofitting of beam. Another point found from that experiment study was that flexural strength of beam with new effective arrangement increasedby 20%, 16% and 18% for initially strengthened beam, retrofitted beam (preloaded of 40% of control beam) and retrofitted beam (preloaded of 90% of control beam) respectively with respect to traditional arrangement. On behalf of ductility also the new arrangement proved to be effective solution. When comes to toughness it was realized that increase in toughness of beam with new effective arrangement was 43%, 31% and 29% for initially strengthened beam, retrofitted beam (40% preloaded) and retrofitted beam (90% preloaded) respectively with respect to traditional arrangement.




`Figure: Beam strength

## 3. CONCLUSION

From the result obtained by different author shown in literature review we can establish following point in consideration with use of GFRP

1. The flexural strength of beam can be significantly increased in range of 40% to 125% by bonding GFRP sheet on tension face of reinforced concrete beam.[1, 4, 11]
2. Development of diagonal cracks can be inhibited by the use of inclined strips of GFRP[7]
3. It may be noted that the debonding of FRP reduces the effectiveness of FRP by not utilizing the strength of FRP [11]
4. The shear strength of beam can be increased by 50% to 60% by bonding GFRP sheets on side face of reinforced concrete beam.[9]
5. Beams strengthened SB with glass fibre reinforced polymer showed better load vs deflection characteristics than the control beam CB.
6. Application of GFRP gives positive effect on the ultimate strength and ductility of load deflection history.[13]
7. The use of GFRP is recommended instead of other FRP such as CFRP, PFRP etc as it is economical and gives the desired strength.[10]
8. The use of rectangular GFRP strips gave more strength than circular rods[8]
9. With the increase of no. of layers of GFRP the strength of beam increases but at decreasing rate.[14]
10. Application of FRP gives variation to certain structural aspects such as cracking, deformation level in shear reinforcement.[2]

11. Hence we can say that GFRP plays an important role in providing strength and retrofitting to structure.

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