Intensification of Non-Breakable Material Ray with Glass Fiber Reinforced Polymer

Jeedi Vennela[1], Dr.MD.Subhan[2]
[1]M.Tech Student, Dept of Civil Engineering, [2]Professor & HOD, Dept of Civil Engineering
[12]AVN College of Engineering and Technology, Hyderabad, T.S, India.

Abstract- Experimental investigations on the flexural and shear behaviour of RC beams strengthened using continuous glass fiber reinforced polymer (GFRP) sheets are carried out. Externally reinforced concrete beams with epoxy-bonded GFRP sheets were tested to failure using a symmetrical two point concentrated static loading system. Two sets of beams were casted for this experimental test program. In SET I three beams weak in flexure were casted, out of which one is controlled beam and other two beams were strengthened using continuous glass fiber reinforced polymer (GFRP) sheets in flexure. In SET II three beams weak in shear were casted, out of which one is the controlled beam and other two beams were strengthened using continuous glass fiber reinforced polymer (GFRP) sheets in shear. The strengthening of the beams is done with different amount and configuration of GFRP sheets.

Experimental data on load, deflection and failure modes of each of the beams were obtained. The detail procedure and application of GFRP sheets for strengthening of RC beams is also included. The effect of number of GFRP layers and its orientation on ultimate load carrying capacity and failure mode of the beams are investigated.

Keywords- GFRP; flexure; shear; strengthened; symmetrical two point concentrated static loading system.

I. INTRODUCTION

The rehabilitation of infrastructures is not new, and various projects have been carried our around the world over the past two decades. One of the techniques used to strengthen existing reinforced members involves external bonding of steel plates by means of two-component epoxy adhesives. It is possible to improve the mechanical performance of a member. The wide use of this method for various structures, including building and brides, has demonstrated its efficiency and its convenience. In spite of this fact, the plate bonding technique presents some disadvantages due to the use of steel as strengthening material. The principal drawbacks of steel are its high weight which causes difficulties in handling the plates on site and its vulnerability against corrosive environments. Moreover, steel plates have limited delivery lengths and, therefore, they require joints.

II. RELATED STUDY

In this report three beams were tested for flexure, controlled beam and other two beams were casted and strengthened by applying GFRP on two beams in flexure mode. Further study continues by testing more number of beams includes various kinds of fiber materials. A further study includes the strengthening of beam is done by different amount and different configurations of GFRP sheets provided. The various concrete mix proportions and also cross sectional dimensions of the beam and analysis also consider for further study. Strengthening of the beam is also depends on matrix materials like epoxy resin (adhesives). The matrix materials have mechanical properties such as strength, shear and compression. So we have a scope for further study that by using different kind of matrix materials to strengthen the reinforced concrete beams.

III. METHODOLOGY AND TASTING

Two sets of beams were casted for this experimental test program. In SET I three beam (F1, F2 and F3) weak in flexure were casted using same grade of concrete and reinforcement detailing. In SET II there beams (S1, S2 and S3) weak in shear casted using same grade of concrete and reinforcement detailing. The dimensions of all the specimens are identical. The cross sectional dimensions of the both the set of beams is 150 mm by 150 mm and length is 700 mm. in SET I beams 2, 10 mm ϕ bars are provided as the main longitudinal reinforcement and 6 mm ϕ bars as stirrups at a spacing of 100 mm center to center where as in SET II beams 3, 10mm ϕ bars are provided as the main longitudinal reinforcement and without any stirrups.

A. ERFORMANCE BASED OBJECTIVE

An objective of performance based objective targets like the flexural behavior of reinforces concrete beams. To study the effect of GFRP strengthening on ultimate load carrying capacity and failure pattern of reinforced concrete beams. Another objective is based on the shear behavior of reinforced concrete beams. To study the effect of GFRP strengthening on the shear behavior of reinforce concrete beams.

TESTING:

The flexural and shear strength of a section depends on the controlling failure mode. The following flexural and shear failure modes should be investigated for an FRP strengthened section.

- Crushing of the concrete in compression before yielding of the reinforcing steel
- Yielding of the steel in tension followed by rupture of the FRP laminate
- Yielding of the steel in tension followed by concrete crushing

Fig.1: Application of epoxy and hardener on the beam

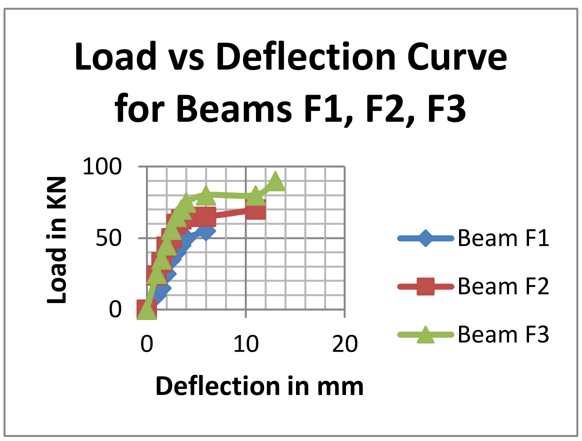
A member of failure modes have been observed in the experiments of RC beams strengthened in flexure and shear by GFRPs. These include flexure failure; shear failure, flexural failure due to GFRP rupture and crushing of concrete at the top. Rupture of the FRP laminate is assumed to occur if the strain in the FRP reaches its design rupture strain before the concrete reaches its maximum usable strain cover delimitation or FRP debonding can occur if the force in the FRP cannot be sustained by substrate. The GFRP strengthened beam and the control beams were tested to find out their ultimate load carrying capacity. It was found that the control beams F1 and S1 failed in flexure and shear showing that the beams were deficient in flexure and shear respectively. In SET I beams F2 failed due to fracture of GFRP sheet in two pieces and then flexure-shear failure of the beam took place. Beam F3 failed due to delamination of the GFRP sheet after that fracture of GFRP sheet took place and then flexure- shear failure of the beam. In SET1 beams F2 and F3, GFRP rupture and flexural shear kind of failure was prominent when strengthening was done using both the wrapping schemes. In SET II beams S2 and S3 failed due to flexural failure and crushing of concrete on the top of the beam. The SET II beams S2 and S3 developed major flexural cracks at the ultimate loads. In SET II beams S2 and S3 the flexural kind of failure was prominent when strengthening was done using both the wrapping schemes.

S.No.	Type of beam	Beam designation	Load at initial crack (KN)	Ultimate load (KN)	Nature of failure
1	Beams weak in flexure (SET-1)	F1 F2 F3	30 34 Not visible	62 94 97	Flexural failure GFRP rupture + flexure-shear failure GFRP rupture + flexure-shear failure
2	Beams weak in flexure (SET-II)	S1 S2 S3	33 37 39	82 96 98	Shear failure Flexural failure + crushing of concrete Flexural failure + crushing of concrete

Table 3.1 Ultimate load and nature of failure for SET-1 and SET-II beams

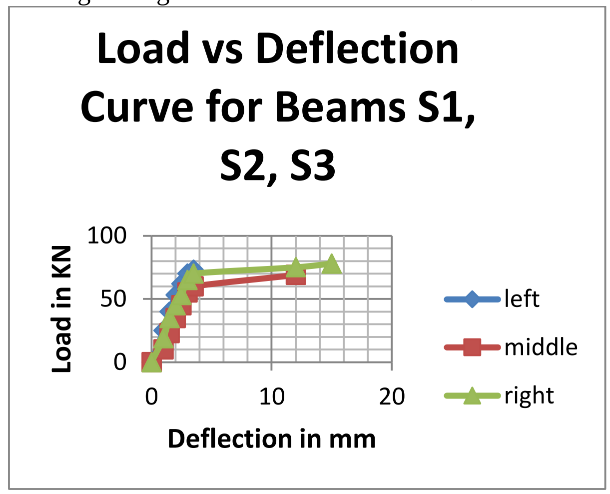
IV. RESULTS AND DESCUSSIONS

The mid span deflection of each beam was compared with that of their respective control beams. Also the load deflection behavior was compared between two wrapping schemes having the same reinforcement it was noted that the behavior of the flexure and shear deficient beams when bonded with GFRP sheets were better than their corresponding control beams The graphs comparing the mid span deflection of flexure and shear deficient beams and their corresponding control beams are shown. The use of GFRP sheet had effect in delaying the growth of crack formation. In SET-1 when both the wrapping schemes were considered it was found that the beam F3 with GFRP sheet up to the neutral axis along with the soffit had a better load deflection behavior when compared to the beam F2 with GFRP sheet only at the soffit of the beam



Load vs. Deflection Curve for Beams F1, F2, F3

From the load and deflection of data of SET-I beams F1, F2, F3 load vs. deflection curve is plotted for all three beams. From this load vs. deflection curve, it is clear that beam F1 has lower ultimate load carrying capacity compared to beams F2 and F3. Beam F1 had also undergone higher deflection compared to beams F2 and F3 al the same load. Beam F2 had higher ultimate load carrying capacity compared to controlled beam F1 but lower than beam F3. Beam F3 had higher ultimate load carrying capacity compared to the beams F1 and F2. Both the beams F2 and F3 had undergone almost same deflection up to 60 KN load. After 60 KN load beam F3 had undergone same deflection as beam F3 is highest. Beam F2 had undergone higher deflection than beam F1.

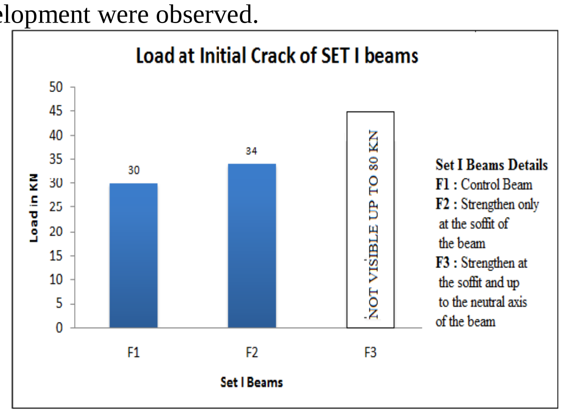


Load vs Deflection Curves for Beam S1, S2, S3

From the load and deflection of SET II beams S1, S2, S3, load vs. deflection curve is plotted for all the three beams. From the load vs. deflection curve, it is clear that beam S1 has lower ultimate load carrying capacity compared to beams S2 and S3. Beam S1 had also undergone higher deflection compared to beams S2 and S3 at the same load. Beam S2 had higher ultimate load carrying capacity compared to the controlled beam S1 but lower than beam S3. Beam S3 had higher ultimate load carrying capacity compared to the beams S1 and S2. Both the beams S2 and S3 had undergone almost same deflection up to 70 KN load. After 70 KN load beam S3 had undergone same deflection as the beam S2 but at a higher load compared to beam S2. The deflection undergone by beam S3 is higher. Beam S2 had undergone higher deflection than beam S1.

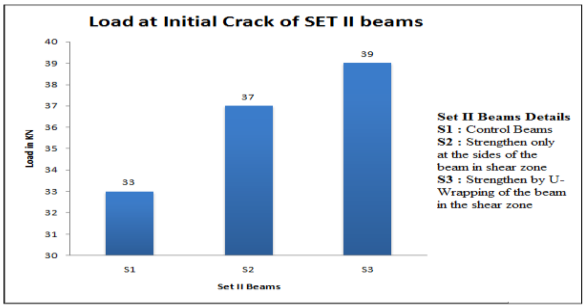
B.LOADS AT INITIAL CRACK

Two point loading was done on both SET I and SET II beams and at the each increment of the load, deflection and crack development were observed.



Load at initial crack of beams F1, F2, and F3

Under two point static loading of SET I beams, at each increment of load, deflection and crack development were observed. In beam F1 initiation of the crack takes place at a load of 30 KN which is lower than beam F2 in which crack initiation started at 34 KN. The crack initiation of beam F3 was not visible due to application of GFRP sheet up to the neutral axis of the beam. The cracks were only visible after a load of 80 KN.

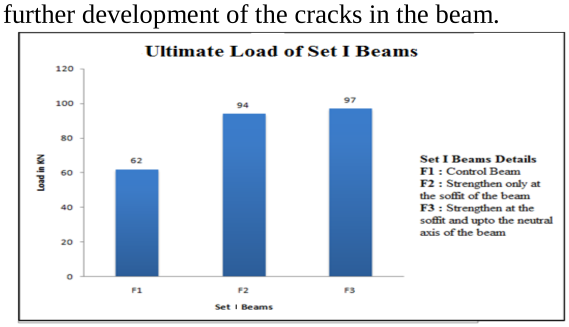


Load at initial crack of beams S1, S2, and S3

Under two point static loading of SET II beams, at each increment of load, deflection and crack development were observed. In beam S1 initiation of the crack takes place at a load of 33 KN which is lower than beam F2 in which crack initiation started at 37 KN and further lower than of beam F3 in which crack initiation started at 39 KN. There was not much difference in load for crack initiation in beam S2 and S3.

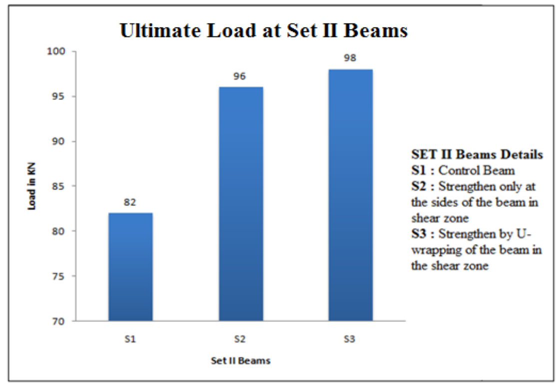
C.ULTIMATE LOAD CARRYING CAPACITY

The load carrying capacity of the control beams and the strengthen beams were found out and is shown. The control beams were loaded up to their ultimate loads. It was noted that of all the beams, the strengthen beams F2, F3 and S2, S3 had the higher load carrying capacity compared to the controlled beams F1 and S1. An important character to be noticed about the usage of GFRP sheets is the high ductile behavior of the beams. The shear failure being sudden can lead to huge damage to the structure. But the ductile behavior obtained by the use of GFRP can give us enough warning before the ultimate failure. The use of FRP can delay the initial cracks and further development of the cracks in the beam.



Ultimate load of beams F1, F2, and F3

SET I beams F1, F2, F3 were loaded under two point static loading. As the load was increased incrementally development of cracks takes place and ultimately the beam failed. The ultimate load of F1 beam was 62 KN which is lower than F2 beam which carried an ultimate load of 94 KN and further lower than F3 beam which carried an ultimate load of 97 KN.



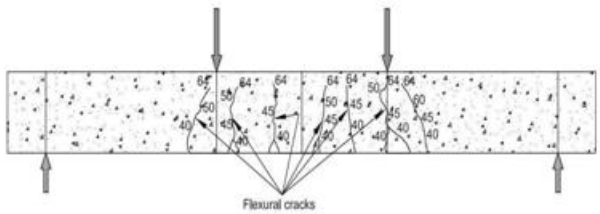
Ultimate load of beams S1, S2, and S3

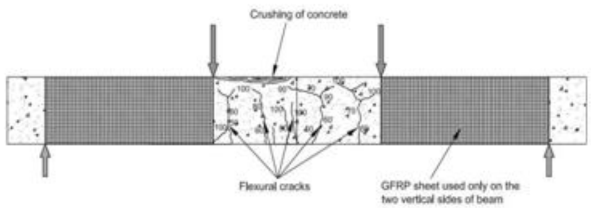
SET II beams S1, S2, S3 were loaded under two point static loading. As the load was increased incrementally development of cracks takes place and ultimately the beam failed. The ultimate load of S1 beam was 82 KN which is lower than S2 beam which carried an ultimate load of 96 KN and further lower than S3 beam which carried an ultimate load of 98 KN.

D.CRACK PATTERN

The crack patterns at collapse for the tested beams of SET I and SET II are shown in fig. 5.13 to 5.18. In SET I the controlled beam F1 exhibited widely spaced and lesser number of cracks compared to strengthened beams F2 and F3. The strengthened beams F2 and F3 have also shown cracks at relatively the close spacing. This shows the enhanced concrete confinement due to the GFRP strengthening. This composite action has resulted in shifting of failure mode from flexural failure (steel yielding) in case of controlled beam F2 to peeling to GFRP sheet in case of strengthened beams F2 and F3. THE DEBONDING of GFRP sheet has taken place due to flexure-shear cracks by giving cracking sound. A crack normally initiates in the vertical direction and as the load increases it moves in inclined directions due to the combined effect of shear and flexure. If the load is increased further, cracks propagate to top and the beam splits. This type of failure is called flexure-shear failure.

The SET II beam S1 the shear cracks started at the center of short shear span. As the load increased, to widen and propagated towards the location of loading. The cracking patterns show that the angle of critical inclined crack with the horizontal crack axis is about 45o. For strengthened reinforced concrete beams S2 and S3, the members of vertical cracks were increased compared to controlled beam S1.





V. CONCLUSION

1. In this experimental investigation the flexural and shear behavior of reinforced concrete beams strengthened by GFRP sheets are studied. Two sets of reinforced concrete (RC) beams, in SET I three weak in flexure and in SET II three beams weak in shear were casted and tested. From the test results and calculated strength values, the following conclusions are drawn:
2. A) SET I Beams (F1, F2, F3)
3. Initial flexural cracks appear at a higher load by strengthening the beam at soffit. The ultimate load carrying capacity of the strengthen beam F2 is 33% more than the controlled beam F1.
4. Load at initial cracks is further increased by strengthening the beam at the soffit as well as on the two sides of the beam up to the neutral axis from the soffit. The ultimate load carrying capacity of the strengthen beam F3 is 43 % more than the controlled beam F1 and 7 % more than the strengthen beam F2.
5. Analytical analysis is also carried out to find the ultimate moment carrying capacity and compared with the experimental results. It was found that analytical analysis predicts lower value than the experimental findings.
6. When the beam is not strengthen, it failed in flexure but after strengthening the beam in flexure, then flexure-shear failure of the beam takes place which is more dangerous than the flexure failure of the beam as it does not give much warning before failure. Therefore it is recommended to check the shear strength of the beam and carry out shear strengthening along with flexural strengthening if required.
7. Flexural strengthening up to the axis of the beam increase the ultimate load carrying capacity, but the cracks developed were not visible up to higher load. Due to invisibility of the initial cracks, it gives less warning compared to the beams strengthen only at the soffits of the beam.
8. By strengthening up to neutral axis of the beam, increase in the ultimate load carrying capacity of the is not significant and cost involvement is almost three times compared to the beam strengthen by GFRP sheet the soffit only.
9. B) SET II Beams (S1, S2, S3)
10. The control beam S1 failed in shear as it was made initially weak in shear.
11. The initial cracks in the strengthen beams S2 and S3 appears at higher load compared to the un-strengthen beam S1.
12. After strengthening the shear zone of the beam the initial cracks appears at the flexural zone of the beam and the crack widens and propagation towards the neutral axis with increase of the load. The final failure which indicates that the GFRP sheets increase the shear strength of the beam. The ultimate load carrying capacity of the strengthen beam S1 is 31 % more than the controlled beam S1.
13. When the beam is strengthen by U-wrapping in the shear zone, the ultimate load carrying capacity is increased by 48 % compared to the control beam S1 and by 13 % compared the beam S2 strengthen by bonding the GFRP sheets on the vertical sides alone in the shear zone of the beam.
14. When the beam is strengthen in shear, then only flexural failure takes place which gives sufficient warning compared to the brittle shear failure which is catastrophic failure of beams.
15. The bonding between GFRP sheet and the concrete is intact up to the failure of the beam which clearly indicates the composite action due to GFRP sheet.
16. Restoring or upgrading the shear strength of beams using GFRP sheet can result in increased shear strength and stiffness with no visible shear cracks. Restoring the shear strength of beams using GFRP is a highly effective technique.

VI. REFERENCES

[1]. M. A. Shahawy, M. Arockiasamy, T. Beitelman, R. Sowrirajan “Reinforced concrete rectangular beams strengthened with CFRP laminates” Composites: Part B 27B (1996) 225-233.

[2]. Victor N. Kaliakin, Michael J. Chajes and Ted F. Januszka “Analysis of concrete beams reinforced with externally bonded woven composite fabrics” Composites: Part B 27B (1996) 235-244.

[3]. Koji Takeda, Yoshiyuki Mitsui, Kiyoshi Murakami, Hiromichi Sakai and Moriyasu Nakamura “Flexural behaviour of reinforced concrete beams strengthened with carbon fibre sheets” Composites Part A 27A (1996) 981-987.

[4]. G. Spadea, F. Bencardino and R. N. Swamy "Structural Behavior of Composite RC Beams with Externally Bonded CFRP" Journal of Composites for Construction Vol. 2, No. 3. August, 1998. 132-137

[5]. Ahmed Khalifa, William J. Gold, Antonio Nanni, and Abdel Aziz M.I. "Contribution of externally bonded FRP to shear capacity of RC flexural members" Journal of Composites for Construction, Vol. 2. No. 4, November,1998. 195-202.

[6]. N. F. Grace, G. A. Sayed, A. K. Soliman and K. R. Saleh "Strengthening Reinforced Concrete Beams Using Fiber Reinforced Polymer (FRP) Laminates" ACI Structural Journal/September-October 1999. 865-875.

[7]. Taljsten and L. Elfgren "Strengthening concrete beams for shear using CFRP-materials: evaluation of different application methods" Composites: Part B 31 (2000) 87-96

[8]. Ahmed Khalifa, Antonio Nanni "Improving shear capacity of existing RC T-section beams using CFRP composites" Cement & Concrete Composites 22 (2000) 165-174

[9]. Thanasis C. Triantafillou and Costas P. Antonopoulos "Design of concrete flexural members strengthened in shear with FRP" Journal of Composites for Construction, Vol. 4, No. 4, November, 2000. 198-205

[10]. V.P.V. Ramana, T. Kant, S.E. Morton, P.K. Dutta, A. Mukherjee and Y.M. Desai "Behavior of CFRPC strengthened reinforced concrete beams with varying degrees of strengthening" Composites: Part B 31 (2000) 461-470

[11]. D. Kachlakev and D.D. McCurry "Behavior of full-scale reinforced concrete beams retrofitted for shear and flexural with FRP laminates" Composites: Part B 31 (2000) 445-452

[12]. Alex Li, CheikhnaDiagana, Yves Delmas "CRFP contribution to shear capacity of strengthened RC beams" Engineering Structures 23 (2001) 1212-1220

[13]. J. F. Bonacci and M. Maalej "Behavioral trends of RC beams strengthened with externally bonded FRP" Journal of Composites for Construction, Vol. 5, No.2, May, 2001, 102-113

[14]. Ahmed Khalifa, Antonio Nanni "Rehabilitation of rectangular simply supported RC beams with shear deficiencies using CFRP composites" Construction and Building Materials 16 (2002) 135-146

[15]. Bjorn Taljsten "Strengthening concrete beams for shear with CFRP sheets" Construction and Building Materials 17 (2003) 15-26

[16]. C. Diagana, A.Li, B. Gedalia, Y. Delmas "Shear strengthening effectiveness with CFF strips" Engineering Structures 25 (2003) 507-516

[17]. M.N.S. Hadi "Retrofitting of shear failed reinforced concrete beams" Composite Structures 62 (2003) 1-6

[18]. Sergio F. Brena, Regan M. Bramblett, Sharon L. Wood, and Michael E. Kreger "Increasing Flexural Capacity of Reinforced Concrete Beams Using Carbon Fiber-Reinforced Polymer Composites" ACI Structural Journal/January-February 2003. 36-46

[19]. BimalBabuAdhikary, Hiroshi Mutsuyoshi, and Muhammad Ashraf "Shear Strengthening of Reinforced Concrete Beams Using Fiber-Reinforced Polymer Sheets with Bonded Anchorage" ACI Structural Journal/September-October 2004. 660-668

[20]. Zhichao Zhang and Cheng-Tzu Thomas Hsu "Shear Strengthening of Reinforced Concrete Beams Using Carbon-Fiber-Reinforced Polymer Laminates" Journal of Composites for Construction, Vol. 9, No.2, April 1, 2005. 158-169

[21]. Viswanathan, P. V. And Gangadharan, T. K. "Environmental and waste manipulate in iron and metallic company", NML, Jamshedpur, pp.199-207, 1996

[22]. Waligora, J., Bulteel, D., Degrugilliers, P., Damidot, D., Potdevin, J. L., and Measson, M. "Chemical and mineralogical characterizations of LD converter metal slags: A multi-analytical strategies technique." Materials characterization 61.1 (2010): 39-48.

[23]. Wang, Q., and Yan, P. "Hydration residences of easy oxygen furnace metallic slag." Construction and Building Materials 24.7 (2010): 1134-1140.