IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

ISO 3297:2007 Certified ⋇ Impact Factor 7.105 ⋇ Vol. 9, Issue 6, June 2022

DOI: 10.17148/IARJSET.2022.9640

The Study of Shear and Flexural Behavior of RC Beam Retrofitted With GFRP

Prasad C. Shinde[1], U. S. Ansari[2], Y. B. Gawande[3]

PG Student, Department of Civil Engineering, SND College of Engineering & Research Center, Nashik, India[1]

Professor & Head, Department of Civil Engineering, SND College of Engineering & Research Center, Nashik, India[2]

Professor, Department of Civil Engineering, SND College of Engineering & Research Center, Nashik, India[3]

Abstract: RCC structural members are retrofitted to restore the strength of aged structural concrete elements and prevent additional concrete distress. During their service lives beams can deteriorate due to poor construction, environmental influences, causing a reduction in the beam's strength. As a result, strengthening the weakened Beam is essential for its proper performance, and GFRP wrapping has been demonstrated to provide acceptable strengthening in prior studies. In this study, experiment is carried out on M25 grade concrete beams. Total 6 beams were casted of Standard size (200mm x 250mm) and 2.3 m in length in two groups which were Group A and Group B. In both the groups A and B there were 3 beams in each group. In group A, beams were casted flexure weak intentionally out of which 1 was control specimens and 2 beams of M25 concrete were wrapped with GFRP. Similarly In group B, beams were casted shear weak intentionally out of which 1 was control specimens and 2 beams of M25 concrete were wrapped with GFRP. Flexural and shear testing of beams was done on Universal Testing Machine (UTM) after 28 days of curing. At the time of Casting of beams the 6 no of cubes of M 25 Grade of standard size (150mm x 150mm x 150mm) were casted and tested under Compressive Strength Testing Machine after 7 days and 28 days of curing period. After testing of cubes, the results were extracted for Compressive Strength of cubes of 7 and 28 days and plotted on graph. After testing of both groups beams the results were extracted like deflection, failure modes, ultimate load carrying capacity and Compressive Strength and results were tabulated and plotted on graph. According to the results obtained conclusion was concluded.

Keyword: Glass fiber reinforced polymer (GFRP) sheets, Shear Strength, Flexural Strength, Strengthening.

I. INTRODUCTION

Buildings are one of the most important aspects of urban environments. They are the epicenter of human influence and contribute to the population's well-being. Because of the high proportion of existing buildings to new construction, governments, technicians, and engineers are aware of recent techniques for strengthening old structures in order to preserve and safeguard existing structures. Existing structures that have lost their strength due to deterioration or that have beyond their expected life period may require strengthening. When a structure is displaced or yields, however, strengthening the structure is a must. In recent years, the requirement to improve the strength and ductility of degraded beams has risen exponentially. Glass fiber reinforced polymer (GFRP) is one of the composite materials which is used in both repairing and strengthening of reinforced concrete structures. The fibers are extremely stiff, strong, and light, and are used in many processes to create excellent building materials. Glass fiber material comes in a variety of uni-directional, weaves, sheets, strips and several others. The properties of a Glass fiber are close to that of steel and the weight is close to that of plastic. Thus, the strength to weight ratio (as well as stiffness to weight ratio) of a Glass fiber part is much higher than either steel or plastic. Hence various rehabilitation and retrofitting methods like Steel Jacketing, Concrete Jacketing, Fiber Reinforced Polymer (FRP) Jacketing, etc. are used from which GFRP are considered in our work due to its advantages like high strength to weight ratio, high corrosion and fatigue resistance, ease in application and handling, with respect to other methods.

II. LITERATURE REVIEW

A. Abdelhak Bousselham and Omar Chaallal (2006), a) In this experimental study, CFRP retrofitting method used for strengthening of T beams in shear as CFRP is having high tensile strength and ductility. b) The study is based on the number of CFRP wraps and configuration of CFRP. The experiment carried out on T beams in shear from which results gets extracted by performing the experiments on the beams.

DOI: 10.17148/IARJSET.2022.9640

B. **Milan Surana, Dr. M. N. Bajad (2018),** a) In this research paper analytical study performd on Beam with GFRP, for this 5 numbers of beams considered from which one beam is not retrofitted with GFRP b) GFRP used in this study because of its high strength and ductility and also it is cost effective material for retrofitting. Analytical study done by GFRP wrapping of beams and results gets extracted by compairing with the Retroffited and unstrengthen beams by creating models.

C. **Hasim Ali Khan, Radhikesh Prasad Nanda, Biplab Behera, Subhrasmita Majumder (2018),** a) In this paper, the current research is based on an experimental analysis of retrofitting of structural component with GFRP. The experimental research approach helps in analyzing with varied patterns of GFRP composites. b) It determines how GFRP composites can improve shear strength, stiffness, load carrying capability, and ductility.

D. **Catherine Mohanji Gera and Prof. J. Jose Franklin (2016),** a) Retrofitting is the process of improving the resistance of present construction to external forces. b) Most of the solutions are based on previous successful experience. All most every time structural component may be restored to normalcy with minimal restoration measures, and in these cases, GFRP retrofitting is preferable**.**

III. OBJECTIVE OF WORK

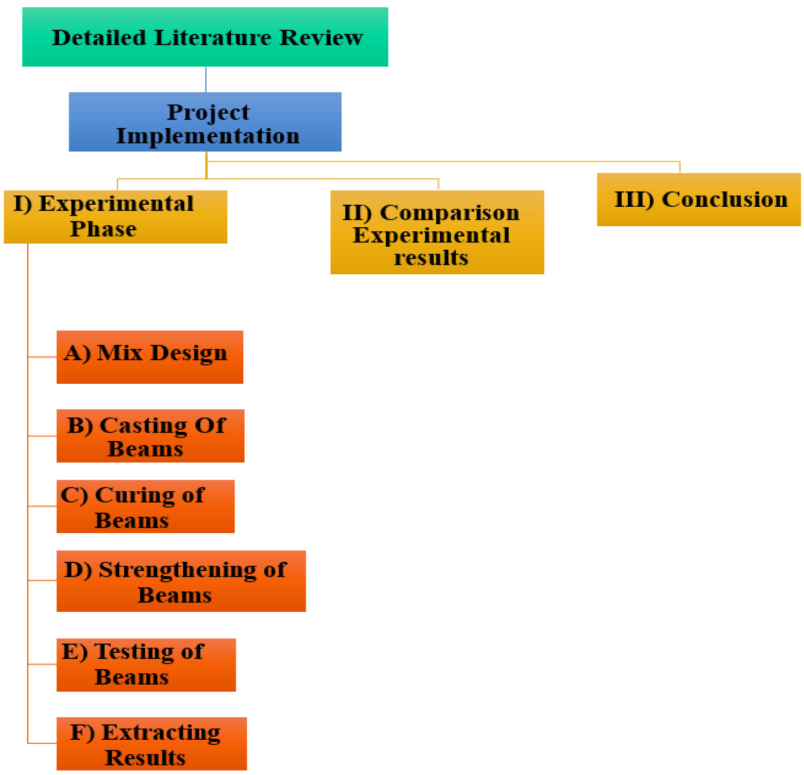
A. To increase the load carrying capacity of RC Beam using GFRP wrapping by studying flexural and shear behavior.

B. To increase the strength and toughness of RC Beam using GFRP.

C. To study the effect of loading on strength of RC Beams wrapped with GFRP.

D. To identify the most effective GFRP wrapping method.

IV. METHODOLOGY



IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

ISO 3297:2007 Certified ⁜ Impact Factor 7.105 ⁜ Vol. 9, Issue 6, June 2022

DOI: 10.17148/IARJSET.2022.9640

V. EXPERIMENTAL STUDY:

In this study, experiment is carried out on M25 grade concrete beams. Total 6 beams were casted of Standard size (200mm x 250mm) and 2.3 m in length in two groups which were Group A and Group B. In both the groups A and B there were 3 beams in each group. In group A, beams were casted flexure weak intentionally out of which 1 was control specimens and 2 beams of M25 grade were wrapped with GFRP. Similarly In group B, beams were casted shear weak intentionally out of which 1 was control specimens and 2 beams of M25 grade were wrapped with GFRP. For both Groups Flexural and shear testing of beams was done on Universal Testing Machine (UTM) after 28 days of curing. At the time of Casting of beams the 6 no of cubes of M 25 Grade of standard size (150mm x 150mm x 150mm) were casted and tested under Compressive Strength Testing Machine after 7 days and 28 days of curing period. After testing of cubes, the results were extracted for Compressive Strength of cubes of 7 and 28 days and plotted on graph. After testing of both groups beams the results were extracted like deflection, failure modes, ultimate load carrying capacity and Compressive Strength and results were tabulated and plotted on graph. According to the results obtained conclusion was concluded. The reinforcing steel for Group A and Group B as per following:

Table 1. Details of Reinforcing Steel

Reinforcing Steel	**Group A**		**Group B**	
Main Steel	Top Steel	Bottom Steel	Top Steel	Bottom Steel
	2, 8mm Día	2, 12mm Día	2, 8mm Día	3, 12mm Día
Stirrups	8 mm Día @ 75mm c/c		No Stirrups	

A. Materials Used

- **Cement:** For the investigation (OPC) – 53 Grade (ACC Cement) used. Physical properties were examined in line with IS specifications.
- **Fine aggregate:** In this experiment aggregate was taken from a riverbed and after passing through a 4.75 mm sieve specific gravity was 2.75% as per IS Code.
- **Coarse aggregate:** The 20 mm metal used as Coarse aggregate which was locally available and the specific gravity was 2.69% as per IS Code.
- **Water:** All concrete mixes contain ordinary tap water.
- **Reinforcing steel:** The main reinforcement was TMT bars and shear reinforcement was also TMT bars of 12mm and 8mm Respectively.
- **Glass Fiber Sheet:** For this study, E glass Fiber was used which was 15 inch wide and bi directional.

Fig.1 Glass Fiber Sheet

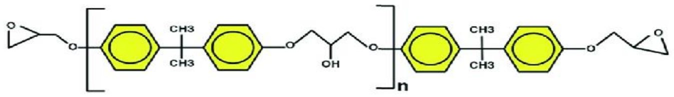
- **Epoxy Resin:** For this study LY 5 5 6 used as an epoxy resin and araldite HY 9 5 1 used as a hardner.

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

ISO 3297:2007 Certified ⁜ Impact Factor 7.105 ⁜ Vol. 9, Issue 6, June 2022

DOI: 10.17148/IARJSET.2022.9640



(a) Epoxy Resin (LY556)

(b) Epoxy Hardener - Araldite (HY951)

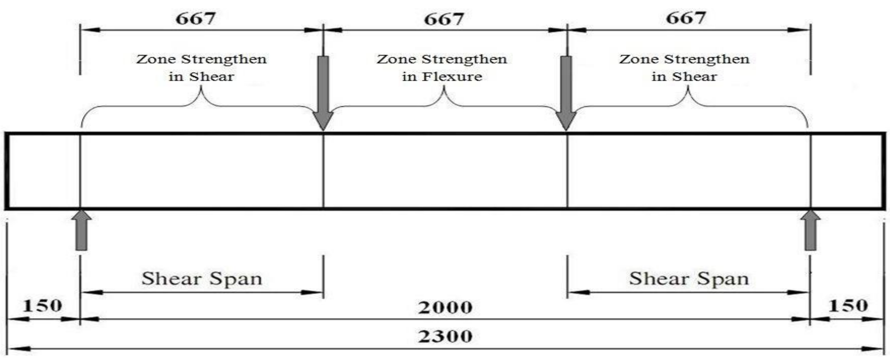
Fig.2 Chemical Structure of Epoxy Resin

- **Cube Casting:** For concrete cube compression testing, 150mmx150mmx150mm size cubes were casted. Using a compression testing machine, 3 cubes tested for 7 days and 3 cubes tested for 28 days.

Fig.3 Casting Of Cubes

B. Retrofitting of Beams

Retrofitting of both Group A and Group B was done after the 28 days of curing of beams. For Group A, as we intentionally casted the flexure weak beams and A1 was controlled beam so, A1 beam not strengthened and other 2 beams were strengthened in flexure. In this A2 beam strengthened at soffit only and A3 beam strengthened in U shape wrapping. Similarly For Group B, as we intentionally casted the shear weak beams and B1 was controlled beam so, B1 beam not strengthened and other 2 beams were strengthened in shear. In this B2 beam strengthened only on the two vertical sides of beam in shear zone and B3 beam strengthened in all sides in shear zone. For this GFRP wrapping of beams 1st of all beams surface scratched with sand paper and clean properly. In one plastic tub the mixing of epoxy resin and hardner done until the proper mix appear. Then epoxy resin coat was applied properly on the surface to be strengthened. The GFRP sheets were cut to the proper size and applied on the surface where epoxy was applied. For the proper bonding between fiber, epoxy and concrete surface the rolling with pressure was done. By the rolling air bubbles present in the GFRP also gets removed. After that 2nd coat of epoxy applied and process repeated. After strengthening, all beams were cured for 24 hrs. before testing.



IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

ISO 3297:2007 Certified ⁜ Impact Factor 7.105 ⁜ Vol. 9, Issue 6, June 2022

DOI: 10.17148/IARJSET.2022.9640

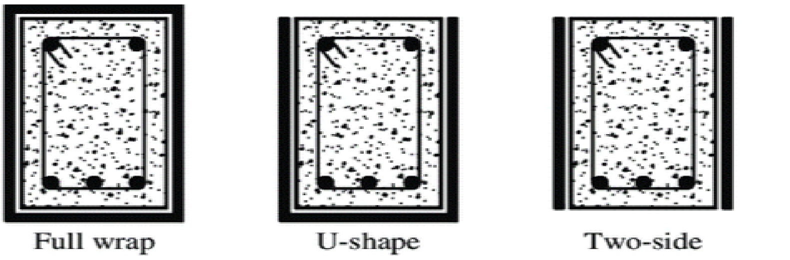


Fig.4 Strengthening of Beams

C. Testing Of Beams

Testing of all beams were done on Universal Testing Machine (UTM) after GFRP wrapping of beams. The beams tested under the symmetrical two-point loading system till the failure of specimens. All 6 beams were tested in which A1 and B1 were controlled beams. The results of ultimate load and deflection of controlled beams A1, B1 were extracted and compare with the other beams A2, A3 and B2, B3 Respectively.

Fig.5 Compressive Strength Testing Machine

Fig.6 Compressive Strength of Cubes

Fig.7 Universal Testing Machine

Fig.8 Loading Set up

VI. RESULTS AND FINDINGS

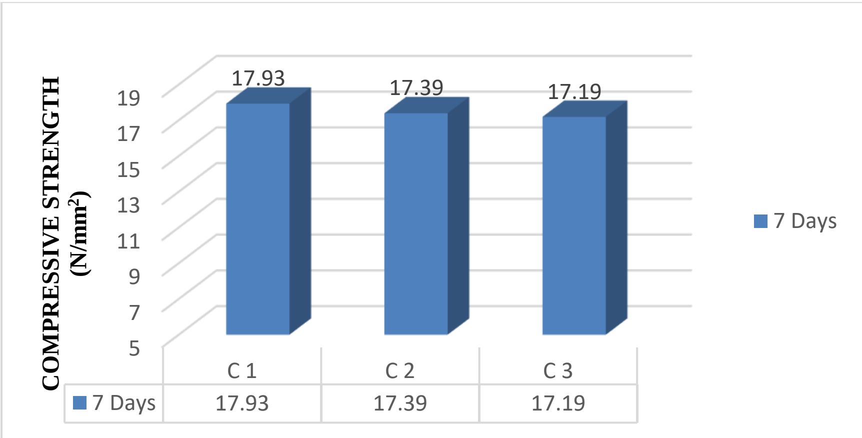
A. Compressive Strength of Cubes after 7 Days

Table 2. Compressive Strength of Cubes after 7 days

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
ISO 3297:2007 Certified ⁜ Impact Factor 7.105 ⁜ Vol. 9, Issue 6, June 2022
DOI: 10.17148/IARJSET.2022.9640

Sr. No.	ID MARK	COMPRESSIVE STRENGTH (N/mm^2)	AVERAGE COMPRESSIVE STRENGTH (N/mm^2)
1.	C1	17.93	17.50
2.	C2	17.39	
3.	C3	17.19	

Graph 1: Compressive Strength of Cubes after 7 days

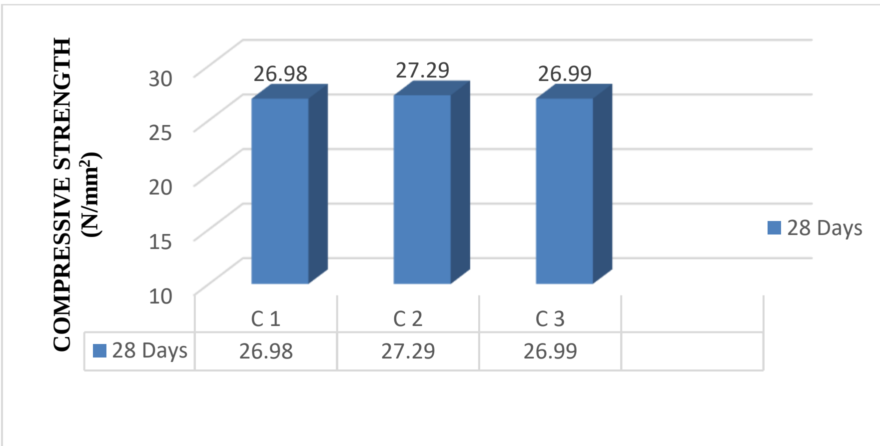


B. Compressive Strength of Cubes after 28 Days

Table 3. Compressive Strength of Cubes after 28 days

Sr. No.	ID MARK	COMPRESSIVE STRENGTH (N/mm^2)	AVERAGE COMPRESSIVE STRENGTH (N/mm^2)
1.	C1	26.98	27.08
2.	C2	27.29	
3.	C3	26.99	

Graph 2: Compressive Strength of Cubes after 28 days



C. Comparison of load at 1st Crack and Ultimate Load for Group A and Group B

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

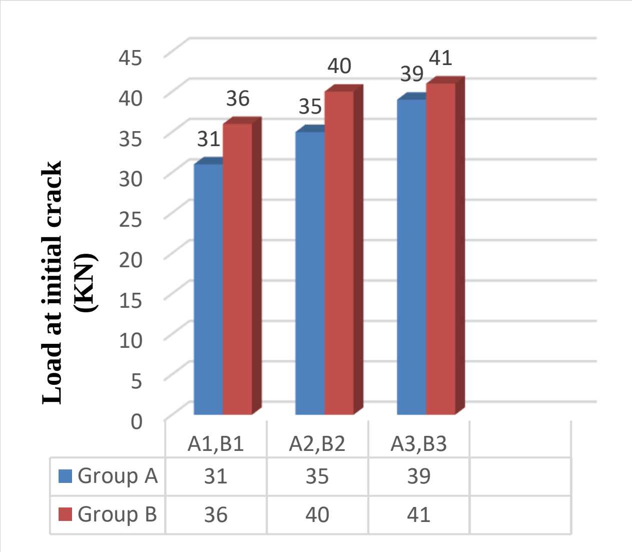
ISO 3297:2007 Certified ⁜ Impact Factor 7.105 ⁜ Vol. 9, Issue 6, June 2022

DOI: 10.17148/IARJSET.2022.9640

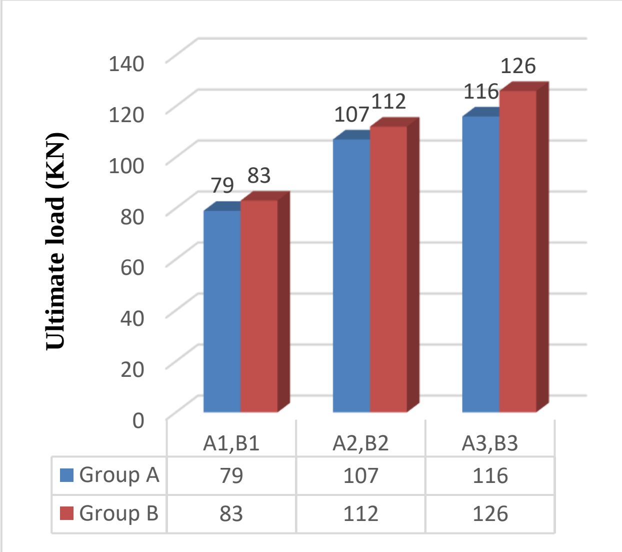
Table 4. Comparison of load at 1st Crack and Ultimate Load

Type of Group	Group A			Group B		
Initials of Beam	A1	A2	A3	B1	B2	B3
Load at 1st crack (KN)	31	35	39	36	40	41
Ultimate Load (KN)	79	107	116	83	112	126

Graph 3: Comparison of Load at 1st crack (KN)



Graph 4: Comparison of Ultimate load (KN)



VII. CONCLUSION

In this experimental Study, the shear and flexural behavior of RC beam retrofitted with GFRP examined. Total 6 beams were casted in two groups which were Group A and Group B. Based on results of experimental study, The important conclusions derived can be enlisted as:

1. As shown in Table 2 and Graph 1, Average compressive strength of 3 cubes after testing of 7 days curing noted as 17.50 N/mm^2 Hence, follows the IS specifications. It should be 65% of M25 grade for 7 days curing as per IS specifications.

2. As shown in Table 3 and Graph 2, Average compressive strength of 3 cubes after testing of 28 days curing noted as 27.08 N/mm^2 Hence, follows the IS specifications. It should be 100% of M25 grade for 28 days curing as per IS specifications.

3. Comparison of load at 1st Crack and Ultimate Load for Group A and Group B are shown in Table 4. As shown in Graph 3, load at 1st crack for GFRP retrofitted beams of both Groups A and B are more than controlled beams A1, B1. Also, as per the Graph 4, ultimate load carrying capacity for GFRP retrofitted beams of both Groups A and B are more than controlled beams A1, B1.

4. In group A, as the A1 is controlled beam which is intentionally made weak in flexure it fails in flexure and A2 beam is GFRP strengthen only at bottom so the ultimate load carrying capacity of A2 increases 35% as compared to A1.

5. Similarly, the A3 beam also GFRP strengthen in U shape so, the ultimate load carrying capacity of A3 increases 46% as compared to A1 beam and 8% as compared to A2 beam. In U shape GFRP wrapping of A3 beam the cracks are not visible until it fails so as compared to A2 beam which is strengthen only at bottom A3 gives less warning.

6. As per results, U shaped GFRP wrapped A3 beam increases the ultimate load carrying capacity about 8% than A2 beam strengthen only at bottom which is more costly and not significant.

7. In group B, as the B1 is controlled beam which is intentionally made weak in shear it fails in shear and B2 beam is GFRP strengthen only on the two vertical sides of beam in shear zone so the ultimate load carrying capacity of B2 increases 34% as compared to B1 beam.

DOI: 10.17148/IARJSET.2022.9640

8. Also, the B3 beam also GFRP strengthen in all sides in shear zone only so, the ultimate load carrying capacity of B3 increases 51% as compared to B1 beam and 12% as compared to B2 beam.

9. So, the GFRP retrofitting of beams can increases the ultimate load carrying capacity, ductility and toughness of the RC beam as per results.

ACKNOWLEDGMENT

I would like to express a deep sense of gratitude and thanks to **Dr. U. S. Ansari**, my guide and Head of department, **Prof. Y. B. Gawande**, my Co-guide and our principal **Dr. P. M. Patil**, whose contribution in stimulating suggestion, encouragement, giving necessary advice and every possible help in the overall preparation of this project. I would like to express deepest appreciation to all those who provided me the possibility to complete this project.

REFERENCES

[1] 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

[2] 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

[3] 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

[4] Abdelhak Bousselham and Omar Chaallal “Behavior of Reinforced Concrete T- Beams Strengthened in Shear with Carbon Fiber-Reinforced Polymer—An Experimental Study” ACI Structural Journal/May-June 2006. 339-347

[5] Milan Surana, Dr. M. N. Bajad “Behavior of RC Beams Strengthened with Glass Fiber Reinforced Polymer” International Journal of Research and Scientific Innovation (IJRSI) | Volume V, Issue V, May 2018 | ISSN 2321–2705

[6] Radhikesh Prasad Nanda, Biplab Behera, Subhrasmita Majumder, Hasim Ali Khan “RC Beam Strengthening by Glass Fiber Reinforced Polymer” International Journal of Engineering Technology Science and Research IJETSR 2394 – 3386 Volume 5, Issue 3 March 2018

[7] Prof J. Jose Franklin, Catherine Mohanji Gera “Retrofitting of RC Beam using Glass Fiber Reinforced Polymer Composite” International Journal of Engineering Research & Science (IJOER) ISSN: [2395-6992] [Vol-2, Issue-5 May- 2016]

[8] E. Priyadarshini, R. Veera Kumar, P. Selvam ani and S. Kaveri “An Experimental Study on Strengthening of Reinforced Concrete Beam using Glass Fiber Reinforced Polymer Composites” Indian Journal of Science and Technology, Vol 9(2), DOI: 10.17485/ijst/2016/v9i2/86358, January 2016

[9] Sameer Shrivastava, A. Tiwari “Strengthening of Beams Using Glass Fiber Reinforced Polymer (GFRP)Laminate” IJEDR 2018 Volume 6, Issue 3 ISSN: 2321-9939

