International Journal of Engineering Science Invention
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org || Volume 3 Issue 10 || October 2014 || PP.71-75

# Effect of width and layers of GFRP strips on deflection of Reinforced Concrete – GFRP Composite Beam

Ayad S. Adi[1], B. S. Karkare[2]and Mohammad Makki Abbass[3]
[1](Department of civil Engineering, Al Anbar university, Al Anbar, Iraq, PhD student Sinhgad Collage of Engineering, Pune University, Pune, Mh, India)
[2](Principal, Vishwakarma Institute of Information Technology, Pune, Mh, India)
[3](Department of Highway and Transportation, Collage of Engineering, Al-Mustansiriya University, Baghdad, Iraq)

***ABSTRACT :*** *This paper presents the experimental results on Reinforced Concrete (RC) beams strengthened by GFRP wraps in the tension-zone of reinforced concrete (RC) beams. The beam dimensions were 150mm x 150mm x 620mm span lengths (center to center between supports with full length 700mm). The GFRP laminates were applied length beams. The specimens of RC beams were tested in four points bending to failure. The width and layers of GFRP strips were varied in the tests. The paper provides information on behavior on the degree of GFRP enhancement of the reinforced concrete members due to GFRP strips and increase in load capacity with and without GFRP wrapping. A total number of 12 such specimens along with control RC beams were used in this experimental study. Consequently it has been noted that the GFRP materials enhance both strengthening and ductility of reinforced concrete beam sections because of the tensile strength increased in the tension zone due to the presence of GFRP. Tests results indicated that the load capacity for two layers of 25 mm width giving capacity higher than for one layer of 50 mm width with same thickness, because of for two layers increased in arm depth between GFRP center and the center of compression zone. Also, in case of two layers the number of longitudinal strand become stiffer and increased the capacity of beam because of increasing in reinforcement in tension zone and become more ductile, so that the time and load required to cause cracks become more. The results of tests have been evaluated and compared with international codes.*

***KEYWORDS -*** *Reinforced Concrete, Flexural Strength, GFRP, Strengthening and Composite Beam.*

## I. INTRODUCTION

A lot of in-service civil structures are either structurally deficient or functionally obsolete due to different reasons such as environmental deterioration, increase in design load, original construction faults, earthquake or external damage or changes in use. To ensure satisfactory and safe performance, such structures need repair and strengthening. To meet this demand, external bonding of glass fiber-reinforced plastics (GFRP) to tension surface of the member has been proven to be an effective strengthening method and has seen wide-spread applications. However, unlike the cold worked steel, GFRP composites remain elastic in nature until failure but fail in a noticeably brittle way. Externally bonded GFRP systems were developed as alternatives to traditional external reinforcing techniques such as steel plate bonding and steel. Consequently, GFRP-strengthened concrete structures can fail suddenly due to the GFRP rupture or de-bonding of GFRP sheets. The load capacity of such structural members depends on the mode of failure. The failure of GFRP strengthened RC flexural members may occur due the rupture of GFRP and crushing of concrete, after or before yielding of reinforcing steel.

In 2011, A. Hasnat et.al [1], investigated the factors influencing the enhancement of the moment capacity of flexural members strengthened with GFRP considering the primary modes of failure and analyzed them with respect to available codes and literature. Compressive strength of concrete, substrate strains, modulus of elasticity and tensile strength of GFRP, effective depth of concrete, width of GFRP strip were logically varied to understand respective contributions in the enhancement of moment capacity. The enhancement of moment capacity is existing compressive strength of concrete and the modulus of elasticity of FRP.In 2014, Ki-Nam Hong et.al [2], investigated improvement of flexural stiffness/strength of concrete members reinforced with externally bonded, aluminum -glass fiber composite beams. It was observed that the strengthened beams led to increase the initial cracking load, yielding load of tension steel and peak load. On the other hand, the ductility of some strengthened specimens was reduced by more than 50%.

In 2013, Anthony J. Lamanna et.al [3], investigated bonding of GFRP strips with reinforced concrete beams by mechanical fasteners. It was observed that the load capacity of the beams increased due to GFRP strips. In 1995, Hamid and Hamelin [4], tested small RC beams strengthened with different fiber-composite material consisted of glass or carbon bonded together with an epoxy matrix (Four types of plates) on the tension face and the lateral of the specimen, these beams were tested to failure under four point bending to measure load versus deflection and load capacity. It was found that the load capacity increased and the deflection decreased for reinforced concrete beams strengthened with FRP plates.In 2002, S.T. Smith and J.G. Tenget [5], studied comprehensive assessment of the strengths and weaknesses of large test database containing the test results reported to have failed by plate end de-bonding were first presented. Both statistical and graphical comparisons between test results and the predictions of the de-bonding strength models were shown. The authors claim that a simple de-bonding strength model suggested by them is superior to existing models.In 2012, S. Hashemi and R. Al-Mahaidi [6], investigated the flexural behavior of FRP-strengthened reinforced concrete beams using cement-based adhesives. It was concluded that the use of FRP increased the capacity of the beam and reduced deflection.The present paper aims at investigation of behavior and enhancement of load capacity of RC beams strengthened by GFRP strips with different widths and layers under static loading. Three different widths of GFRP strips are used with one and two layers, for strengthening the RC beams to find out most efficient distribution of GFRP strip area.

## II. EXPERIMENTAL PROGRAM

A series of twelve RC composite beams along with addition two reference RC beams (without GFRP), were used in this experimental study to find out flexural capacity.

### 1. Specimens details

Reinforced concrete beams of cross section 150mm x 150mm x 620mm were cast using two bars of 8mm diameter tension reinforcement and 6mm diameter stirrups at 80mm spacing. Grade of steel used was Fe 500 was used in this study. GFRP strips of 580mm length were used with three different widths of 25mm, 50mm and 100mm in one and two layers. These strips were bonded to the reinforced concrete beams in middle 580mm length using epoxy resin. Dial gauges were fitted at the center of beam to record the deflection. Details of the test schematic specimens are shown in Figure (1).

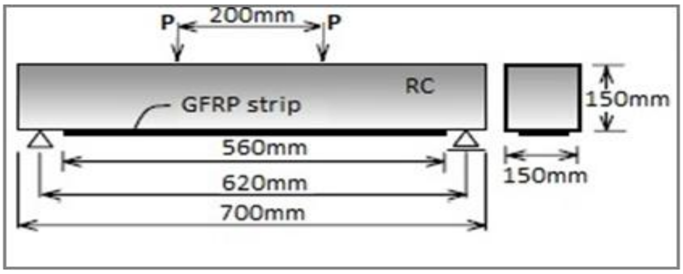


Fig. 1. Details of the test specimens.

### 2. Material Properties

**2.1. Concrete:** Concrete mix was designed according to BS5282 and IS10262:2009. The mix proportions with (W/C) ratios of 0.4 was used for grade M35, using Ordinary Portland Cement (OPC) 43 Grade.

**2.2. GFRP Sheets*:*** GFRP strip layers were fixed to the tension face of RC beams along the axial direction and the width were 25, 50 and 100 mm, GFRP according "ACI 440.2R-08"[8], Properties of GFRP strips are given in table(1). Because FRP materials are linear elastic until failure, the design modulus of elasticity for unidirectional FRP can be determined from Hooke's law.

Table 1. Properties of GFRP Sheets

| | |
|---|---|
| Specific Gravity | 2.56 |
| Effective Fibre Strip Thickness | 0.43 mm |
| Strain | 0.0146 |
| Young's Modulus of Elasticity. | 75,900 MPa |
| Tensile modulus | 60,000 MPa |
| Tensile Strength | 875 MPa |

**2.3. Adhesive:** GFRP sheets were bonded to RC beams with a flexible type of Epoxy resin. The brand of adhesive used in this study is Goldbond® 1893. The epoxy has a compressive strength 55 MPa.

## III. INSTRUMENTATION AND TESTING PROCEDURE

During each test, the deflection was measured using dial gauge having accuracy of 0.01mm that was attached on bottom side of the beam on GFRP strip, Figure (2) show the GFRP layout. Loading is applied with rate 1 kN per minute until failure. Table 2 summarizes observation of the test.

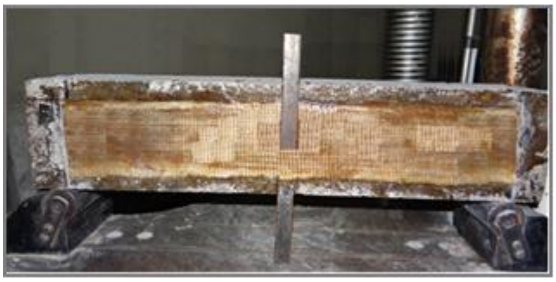

Fig. 2. GFRP layout fixed at the bottom soffit of beam.

## IV. LOAD-DEFLECTION BEHAVIOR

Figure (3), show a typical load-deflection relationships of RC beam without GFRP. The deflection of each specimen is plotted separately. Figure (4), shows the behavior of composite beams under static loading. The curve was linear up to 50% of the failure load and then become nonlinear.it was observed that due to strengthening with GFRP strips the deflection was reduced. Figure (5), shows the behavior of composite beams with two layers of GFRP. The curve was linear up to 50% of the failure load and after that become nonlinear. Figure (6), shows the comparison of composite beams with one and two layers. The load capacity increased and the deflection decreased when the width and number of layers increased. Table (2) gives theoretical and experimental load as well as deflection.

Table 2. Results obtained in Experimental test.

| Width of GFRP strip in mm | No.of layers | Area of GFRP mm2 | mark | $P_{cr}$ (kN) Load at observed first Crack Expt. | $P_u$ kN | $\Delta_u$ mm# | $P_{cr}/P_{u \cdot Exp}$. | $\Delta$ @ P=44kN |
|---|---|---|---|---|---|---|---|---|
| | | | | | Expt. | Expt. | | |
| 25 | 1 | 10.75 | D1 | 31.0 | 46 | 0.78 | 0.67 | 0.68 |
| 50 | 1 | 21.5 | D3 | 33.0 | 54 | 0.78 | 0.61 | 0.56 |
| 100 | 1 | 43 | D5 | 37.0 | 72 | 1.2 | 0.51 | 0.41 |
| 25 | 2 | 21.5 | D2 | 32.0 | 58 | 0.94 | 0.55 | 0.52 |
| 50 | 2 | 43 | D4 | 35.5 | 72 | 1.22 | 0.49 | 0.41 |
| 100 | 2 | 86 | D6 | 40.5 | 69* | 1 | 0.58 | 0.30 |
| Reference control Specimen | - | - | DR | 26.0 | 44 | 0.85 | 0.59 | 0.85 |

# Deflection at centre at failure (mm)

*Unexpected failure.

## V. DISCUSSION

It was seen that the cracking pattern observed affected the nature of Load – deflection curve. It was also observed that the area of GFRP used for strengthening of the RC beam affected the cracking pattern and controlled the deflection at the center.

1. When same GFRP area is provided in two layers, first crack is observed at a lower load. (GFRP area is 21.5mm$^2$ for specimens $D_3$ and $D_2$ whereas the load at first observed crack is 33kN and 32kN resp. GFRP area is 43.0 mm$^2$ for specimens $D_5$ and $D_4$ whereas the load at first observed crack is 37kN and 35.5kN resp.) From load-deflection curve (fig 4, 5) it is observed that actual cracking starts at a load lower than that for the first

observed crack which is evident from the load – deflection curve deviation from theoretical deflection line for $I_g$.

2. As the GFRP area used for strengthening was increased the nature of load – deflection curve changed from multi-linear to curvilinear shape as follows:

2.1. For control specimen (No GFRP Area) four to five flexure cracks were observed in central zone. The load – deflection curve was seen as multi-linear curve for this specimen due to these flexural cracks.

2.2. Single layer of GFRP:

2.2.1. Specimen D1 (Small GFRP Area) -One large flexural crack near midspan and 2-3 minor flexural-shear crack were observed. The load – deflection curve was trilinear in shape.

2.2.2. Specimen D3 (Medium GFRP Area) - One large flexural crack near midspan and one minor flexural-shear crack were observed. The load – deflection curve was trilinear in shape.

2.2.3. Specimen D5 (Large GFRP Area) – Minor flexural cracks near midspan and a major shear crack nearer support were observed. The load – deflection was curvilinear in shape.

2.3. Double layers of GFRP:

2.3.1. Specimen D2 (Medium GFRP Area) - One large flexural crack near midspan and one minor flexural-shear crack was observed. The load – deflection curve was bilinear in shape.

2.3.2. Specimen D4 (Large GFRP Area) - Minor flexural cracks near midspan and a major shear crack nearer support were observed. The load – deflection was curvilinear in shape.

2.3.3. Specimen D6 (Very large GFRP Area) – One major shear crack nearer to support was observed. The load – deflection was curvilinear in shape.

## VI. CONCLUSIONS

[1] GFRP strengthening increased cracking load with increase in GFRP strip width and number of layers. It is observed that at the load value of 44kN (equal to ultimate load of control sample), the deflection reduced with increase in GFRP area.

[2] As the area of GFRP increased the ratio of cracking load to ultimate load decreases, it is also observed that the ultimate load increased with increase in the GFRP area.

[3] From the load–deflection curve it was observed that the actual cracking load was same for single layer and double layer of GFRP with same area.

[4] It was observed that increased GFRP area provided better control on cracking of concrete in flexure and hence on deflection.

[5] It is observed that the increase in GFRP area changed the nature of Load – Deflection curve. This may be because of better control on cracking due to strengthening effect of larger GFRP area.

[6] As the total GFRP area increased, the difference in deflection due to single and double layer with same GFRP area reduced as seen from fig 6.

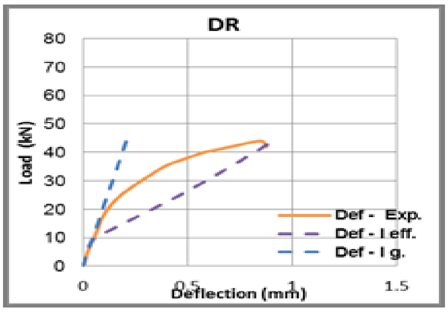


Fig.3. Load – deflection behavior of referenced beam without GFRP

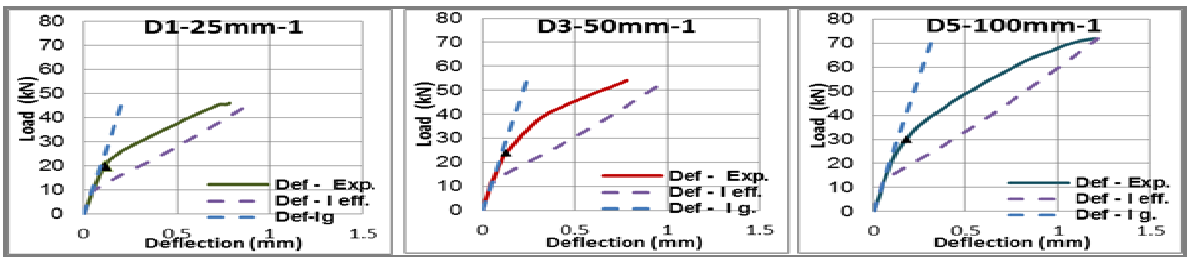


Fig.4. Load – deflection behavior of RC beams with one layer of GFRP

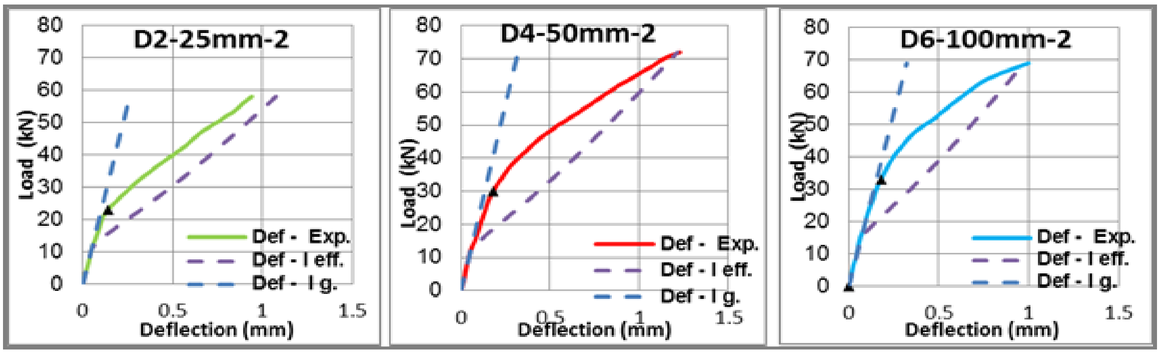


Fig.5. Load – deflection behavior of RC beams with two layer of GFRP

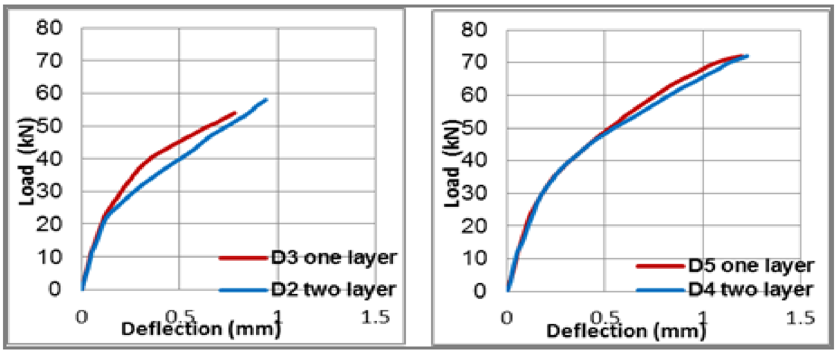


Fig.6. Compared of Load – deflection behavior of RC beams with one and two layers of GFRP

## VII. ACKNOWLEDGEMENTS

The authors would like to thank everyone, just everyone.

## REFERENCES

[1] A. Hasnat M.M. Islam A. F.M.S. Amin, Parameters affecting the flexural capacities of reinforced concrete members strengthened with FRP strip: A critical comparison, *4th Annual Paper Meet and 1st Civil Engineering Congress*, 2011, December 22-24, Dhaka, Bangladesh.

[2] Ki-Nam Hong, Chang- Geun Cho, Swoo-Heon Lee and Yeonho Park, Flexural Behavior of RC Members Using Externally Bonded Aluminum-Glass Fiber Composite Beams, *Polymers (6*), 2014, 667-685.

[3] Anthony j. lamanna, Lawrence C. Bank, David T. Borowicz and Dushyant Arora, Strengthening of concrete beams with mechanically fastened frp strips, *university of wisconsin, madison, wi*, 2001, USA.

[4] Hamid Varastehpour et, al, External reinforcement of concrete beams using fiber reinforced plastics, *Ein Dienst der ETH-Bibliothek Rämistrasse* ,1995,101, 8092 Zürich, Schweiz.

[5] S.T. Smith, J.G. Teng, FRP-strengthened RC beams. II: assessment of de-bonding strength models, *Engineering Structures (24)*, 2002, 397–417.

[6] S. Hashemi and R. Al-Mahaidi, Experimental and finite element analysis of flexural behavior of FRP-strengthened, RC beams using cement-based adhesives, *Construction and Building Materials*, *(26)*, 2012, 268–273.

[7] Building Code Requirements for Structural Concrete (ACI 318M-11), *an ACI Standard and Commentary American Concrete Institute*, 2011.

[8] ACI 440.2R-08,Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures, *Reported by ACI Committee 440 American Concrete Institute*, 2008.