Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 50(5) (2018) 287-290
DOI: 10.22060/ceej.2017.12793.5270

Flexural Behavior of RC Beams Strengthened by CFRP Sheets in the Beams with low and high Reinforcement Ratios

J. Sabzi, M. R. Esfahani*

Faculty of Engineering, Ferdowsi University of Mashhad, Mashhad, Iran

ABSTRACT: Externally Bonded Reinforcement (EBR) is known as a conventional method for flexural strengthening of concrete beams with Fiber Reinforced Polymer (FRP) composites. The present study has been conducted to investigate the flexural behavior of RC beams strengthened by CFRP sheets. Eight beam specimens strengthened by EBR method having the cross sectional dimensions of 250*300 mm and length of 2200 mm with two different reinforcement ratios (low and high) were evaluated under four point bending test. The compressive strength of four specimens was 25 MPa and other four specimens were made using high strength concrete with the compressive strength of 55 MPa. Additionally, the tensile reinforcement arrangement varied in different specimens with two bar sizes. In order to strengthen the specimens, two CFRP layers with dimensions of 160*1700 were used. Based on the results of the present study, in the case of low reinforcement ratio while maintaining the total reinforcement ratio constant, by decreasing the bar size and increasing the number of bars, the load carrying capacity of the specimen increases. In contrast, in the case of high reinforcement ratio, this results in the decrease of load carrying capacity. Finally, utilizing the smaller bar size in the tensile region of the specimens with low reinforcement ratio results in a more uniform distribution of cracks in the beam.

Review History:

Received: 19 April 2017
Revised: 11 June 2017
Accepted: 9 August 2017
Available Online: 19 August 2017

Keywords:

RC Beams
Flexural Strengthening
EBR, Debonding
CFRP

1- Introduction

Utilizing FRP sheets has several beneficial effects on strengthening, retrofitting and rehabilitation of structural elements. In the past few decades, FRP sheets have been widely used for strengthening of RC beams because of their superior mechanical properties. Various experimental studies have been carried out on FRP strengthened RC beams and different failure modes have been reported. Esfahani et al. [1] manufactured 12 RC beam specimens with dimensions of 2000×200×150 mm^3 in order to evaluate the flexural strengthening of beams with various levels of tensile reinforcement (low, medium and high reinforcement ratios). Nine specimens were strengthened in flexure by FRP sheets and three other were used as control specimens. Based on the result of this study, it was concluded that the FRP strengthening improves strength and stiffness of the specimens. The experimental results were different with the predictions of ACI [2] and ISIS [3] with respect to the effects of the FRP sheets on improving the flexural strength of the beams. The flexural strength calculated by the analytical relations for specimens with low steel ratios are higher than the experimental results, but for the medium and high tensile steel ratios, the difference is less.

In the present study, the flexural behavior of RC beams with low and high reinforcement ratios strengthened by CFRP sheets has been evaluated. Several variables such as tensile reinforcement arrangement, tensile reinforcement ratio and compressive strength of the concrete are investigated in this study.

2- Methodology

In the present study, eight specimens strengthened by EBR method with the cross sectional dimensions of 250*300 mm^2 and length of 2200 mm were manufactured and evaluated under flexural test. In order to investigate the effectiveness of the reinforcement ratio, 2 different reinforcement ratios (low and high) were used. The concrete utilized in four specimens was normal concrete having compressive strength of 25 MPa and the concrete used in the other four specimens was high strength concrete having compressive strength of 55 MPa. Table 1 illustrates the Characteristics of the EBR strengthened specimens. For strengthening the specimens, two CFRP layers with the dimensions of 160*1700 mm^2 were used. Cross sectional dimensions and arrangement of longitudinal and transverse reinforcement are presented in Figure 1.

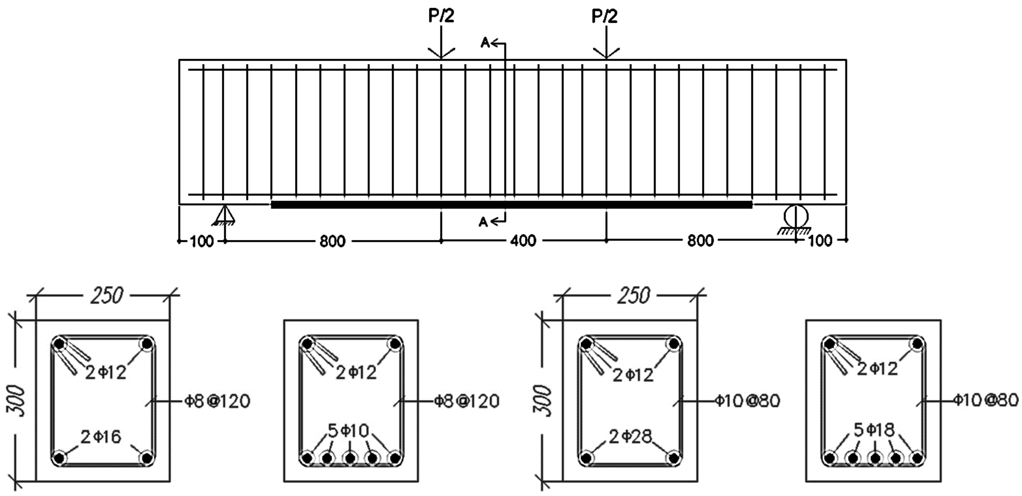
Corresponding author, E-mail: esfahani@um.ac.ir

Table 1. Characteristics of the EBR strengthened specimens

Specimens	Compressive Strength of concrete (MPa)	Tensile bars arrangement	Yield stress of bars (MPa)	Cross section of the tensile bars (mm^2)	Stirrup diameter (mm)	C^1_x	C^2_y	ρ/ρ_{max}
2D16-F25-E	25	2Ø16	453	402	8	30	20	0.36
5D10-F25-E	25	5Ø10	462	393	8	30	20	0.35
2D28-F25-E	25	2Ø28	379	1232	10	25	30	0.98
5D18-F25-E	25	5Ø18	367	1272	10	25	30	0.96
2D16-F55-E	55	2Ø16	453	402	8	30	20	0.21
5D10-F57-E	57	5Ø10	462	393	8	30	20	0.20
2D28-F54-E	54	2Ø28	379	1232	10	25	30	0.57
5D18-F53-E	53	5Ø18	367	1272	10	25	30	0.56

1. Bar's side cover 2 .Bar's bottom cover

The specimens of this type were named aDb-Fc-E, in which a, b and c are the number of tensile bars, the diameter of tensile bars, and the concrete compressive strength in MPa, respectively. E shows that EBR method is used for application of the FRP sheets.



Specimens with low reinforcements ratio   Specimens with high reinforcements ratio

Figure 1. Cross sectional dimensions of beam specimens, longitudinal and transverse reinforcement arrangement and loading arrangement

Tensile side of the specimens was pulverized using a grinder machine. This process was continued until the weak layer of the concrete was removed and the aggregates were observed. Upon achieving the smooth and appropriate surface of concrete for mounting the CFRP sheets, any dust was removed using an air jet. Afterwards, an epoxy adhesive was used to attach the CFRP sheets to the surface. Finally, an over-coating resin was applied onto the sheets. After the specimens were prepared, the flexural test was carried out. The beams were loaded statically and uniformly. A load cell and a Linear Variable Displacement Transducer (LVDT) mounted at the mid-span were installed to read load and mid-span deflections. The load cell and LVDT were connected to a data logger. The experimental load-deflection curves, specimen deflections and load carrying capacity of the beams were derived from bending test. In addition, observations of the crack propagation were recorded during the experiment.

3- Results and Discussions

Test results of the specimens with low reinforcement ratio are presented in Table 2. As seen in this table, in the case of specimens with larger diameter bars, the flexural strengths predicted by ACI-440 equation are higher than the experimental values. In the case of specimens with smaller diameter bars, the flexural strength predicted by ACI-440 equation is lower for specimens made with normal concrete and higher for the specimens made with high strength concrete compared to the flexural strength based on test results.

Test results for the specimens with high reinforcement ratio are depicted in Table 3. As presented in this table, in the case of specimens with larger diameter bars, the flexural strength predicted by ACI-440 equation is lower than the flexural strength based on the experimental results. In the case of specimens with smaller diameter bars, the flexural strength predicted by ACI-440 equation is higher than the experimental values.

Table 2. Experimental results in case of low reinforcement ratio

Specimens	Ultimate midspan deflection (mm)	Ultimate load (kN)	Predicted by ACI-440 (kN)
2D16-F25-E	12.7	148	190
5D10-F25-E	15.9	179	192
2D16-F55-E	18.4	164	196
5D10-F57-E	19.0	212	199

Table 3. Experimental results in case of high reinforcement ratio

Specimens	Ultimate midspan deflection (mm)	Ultimate load (kN)	Predicted by ACI-440 (kN)
2D28-F25-E	20.1	309	302
5D18-F25-E	19.5	289	309
2D28-F54-E	17.6	363	334
5D18-F53-E	15.9	311	340

4- Conclusion

Based on the result of the present study, while maintaining the total reinforcement ratio constant, decreasing the cross section and increasing the number of bars in the specimens with low reinforcements ratio leads to the enhancement of load carrying capacity. In the case of high reinforcement, by decreasing the bar size and increasing the number of bars, the load carrying capacity of the specimens decrease. Additionally, utilizing the bars with smaller diameter in the tensile region of the specimens with low reinforcement ratio causes a more uniform distribution of cracks in the beam.

References

[1] M.R. Esfahani, M.R. Kianoush, A.R. Tajari, Flexural behavior of reinforced concrete beams strengthened by CFRP sheets, 29(10) (2007) 2428-2444.

[2] ACI 440.2R-02, Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures, Reported by ACI Committee 440, (2002).

[3] ISIS Canada, Strengthening Reinforced Concrete Structures with Externally-Bonded Fiber Reinforced Polymers, ISIS Canada, (2001).

Please cite this article using:
J. Sabzi, M. R. Esfahani, Flexural behavior of RC beams strengthened by CFRP sheets in the beams with low and high reinforcement ratios, *Amirkabir J. Civil Eng.*, 50(5) (2018) 907-918.
DOI: 10.22060/ceej.2017.12793.5270