American Journal of Engineering and Applied Sciences

Original Research Paper

Numerical Study on Coupling Beam Retrofitted Using CFRP and GFRP Sheets

Saeideh Hakimi and Rahmat Madandoust

Department of Civil Engineering, University of Guilan, Rasht, Iran

Article history
Received: 02-04-2018
Revised: 11-04-2018
Accepted: 04-08-2018

Corresponding Author:
Rahmat Madandoust
Department of Civil Engineering, University of Guilan, Rasht, Iran
Email: Rmadandoust@yahoo.com

Abstract: One of the most useful way to resist against earthquake is using coupling beam of steel shear walls. The steel shear wall's behavior depends on several factors such as stiffness, ductility, strength and so on. But, it has the shear cracks in coupling beam. In this paper, the effect of Carbon Reinforced Fiber Polymer (CFRP) on coupling beams has been evaluated to find out the improvement in ductility, stiffness and its strength. In order to do this research, the commercial edition of ABAQUS software is used. The results show that, using CFRP sheets can improve the load capacity of coupling beams.

Keywords: Coupling Shear Wall, Finite Element Method, Diagonal Cracks, CFRP Sheets

Introduction

Steel shear wall is one of the most effective way to resist from earthquake. The opening on the shear wall not only can be important in the architecture point of view, but also it can improve ductility. Moreover, the shear wall behavior can be different in compressive area of the coupling beam. Figure 1 indicated the behavior of coupling beam in the shear wall.

On the other hand, there are two different ways to improve shear wall behavior with coupling beam. The first method which is an old method is using steel jackets. Barnes *et al*. (2001) studied on the behavior of strengthening reinforced concrete shear wall with coupling beam using different plates and bolts which the results indicate improving in shear and flexural performance of coupling beam. The second and most common method is using fiber reinforced polymer (FRP) to strength and retrofitted RC structures. Chen and Teng (2003) evaluated shear failure of RC beam retrofitted by FRP and its stress distribution. Generally, El-Sokkary (2012) Layssi and Mitchell (2012) and Woods (2014) evaluation about the deterioration of poor concrete quality on the existing reinforced concrete shear wall. They found out that the RC shear walls had been affected by poor confinements, inappropriate longitudinal reinforcements, reinforcement layout in coupling beam and so on which caused reduction in load capacity of shear walls and necessity of repairing or retrofitting. Moreover, Fallahi *et al*. (2018) did analytical study on walls retrofitted by FRP. Their results showed that load capacity of the wall increases in comparison with wall without FRP. Moreover, Soleimani and Roudsari, 2015 (2015) did numerical study on the RC beams under extreme loading using ABAQUS software. He evaluated these beams under quasi-static and impact loading condition and retrofitted two of the beams with GFRP sheet. The results declared that using GFRP increase the ductility and load capacity even under dynamic loading conditions.

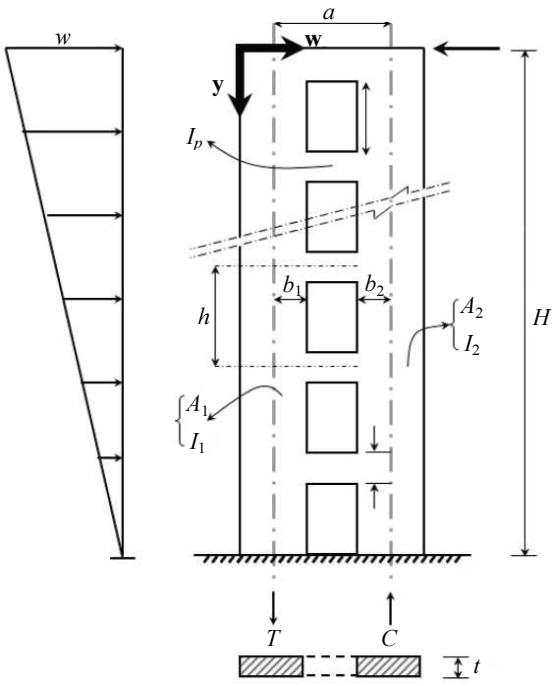

Fig. 1: Coupling beam behavior in shear wall (El-Tawil and Kuenzli 2002)

Model Development

In this research, numerical study of coupling beam in RC wall is conducted using ABAQUS finite element software. For this reason, the experimental study by Riyazi *et al*. (2007) have been used to validate the numerical model with experimental ones. Table 1 Shows the detail of longitudinal and transvers bars and the compressive strength of concrete. Also, Fig. 2 and 3. show the geometry details, load cell and LVDT location.

Table 1: Experimental reinforcing details

Sample ID	Compressive strength (MPa)	Longitudinal main bars	Longitudinal middle bars	Stirrups
P4	20	4Φ16	4Φ12	6Φ8

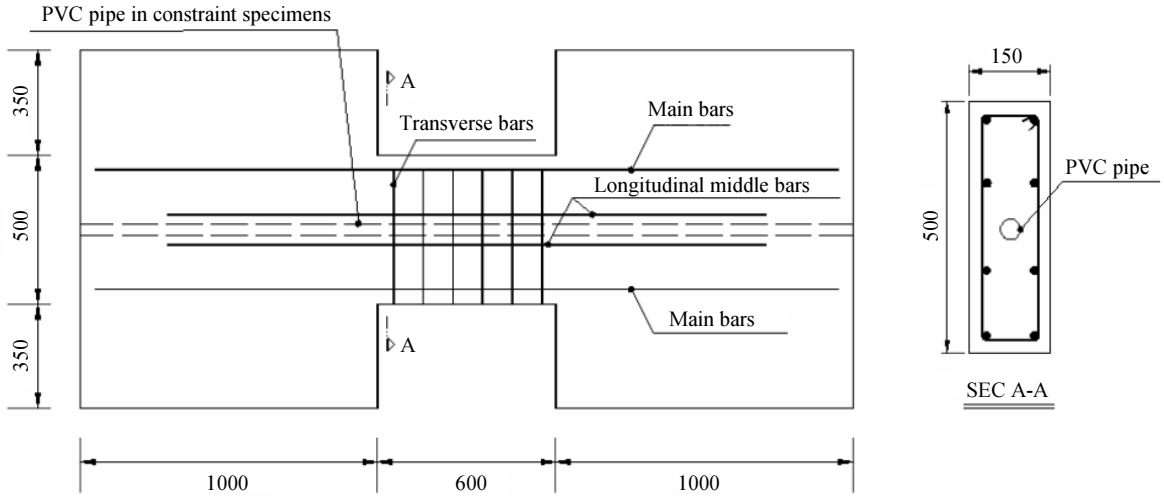

Fig. 2: Experimental Sample details (2007)

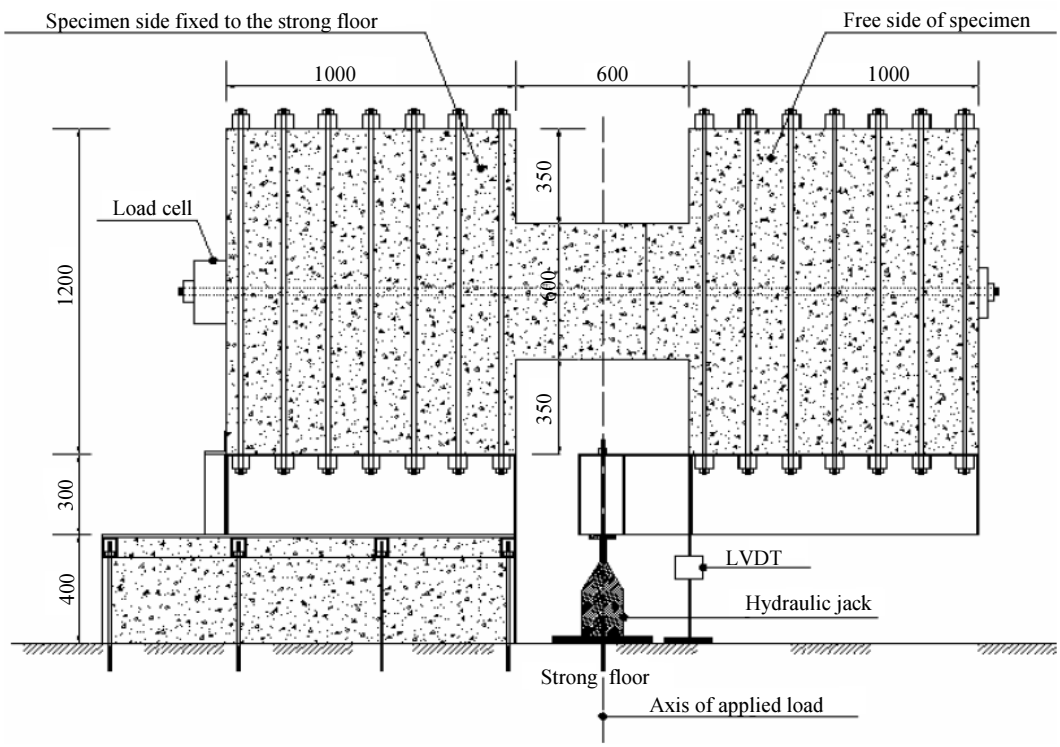

Fig. 3: Experimental set up details (2007)

DOI: 10.3844/ajeassp.2018.1125.1129

In order to model RC wall in ABAQUS, the wall is defined as solid part and both longitudinal and transvers bars are modeled as beam and to model CFRP sheet, shell element is deployed. Also, it should be noted that reinforced concrete wall is as C3D8R which R is reduced integration method to increase the speed of analyses and composite material (FRP) S4R and finally beam is defined as B31 mesh family. The bottom line here is to define the concrete behavior. In this case, the model investigated by Roudsari *et al*. (2017; 2018) is used in which he used the theoretical method as concrete damage plasticity model to define different parts of concrete behavior using MATLAB toolbox. In this section, compressive and tensile behavior of concrete and its damages have been taken from MATLAB as an input file of ABAQUS software. Then, he validated the MATLAB code with another theoretical method and also experimental test with ABAQUS software in order to validate his model.

The modeling of coupling beam of RC wall is shown in Fig. 4 which used an appropriate mesh seeds and interaction. In addition, embedded region is assigned as a type of interaction between concrete and bars. Furthermore, Tie is used to define the interaction between CFRP sheets and concrete surface.

It should be noted that the FRP method is partial using 75×150×500 mm and the thickness is 0.176 mm. The module of elasticity and tensile strength of CFRP are 151 GPa, 2280 MPa and for GFRP 80 GPa and 3600 MPa, respectively.

Figure 5 shows the different result of maximum load for ABAQUS versus experimental tests which indicates that numerical modeling has very good outcome. It should be noted that, the verification model is without retrofitting.

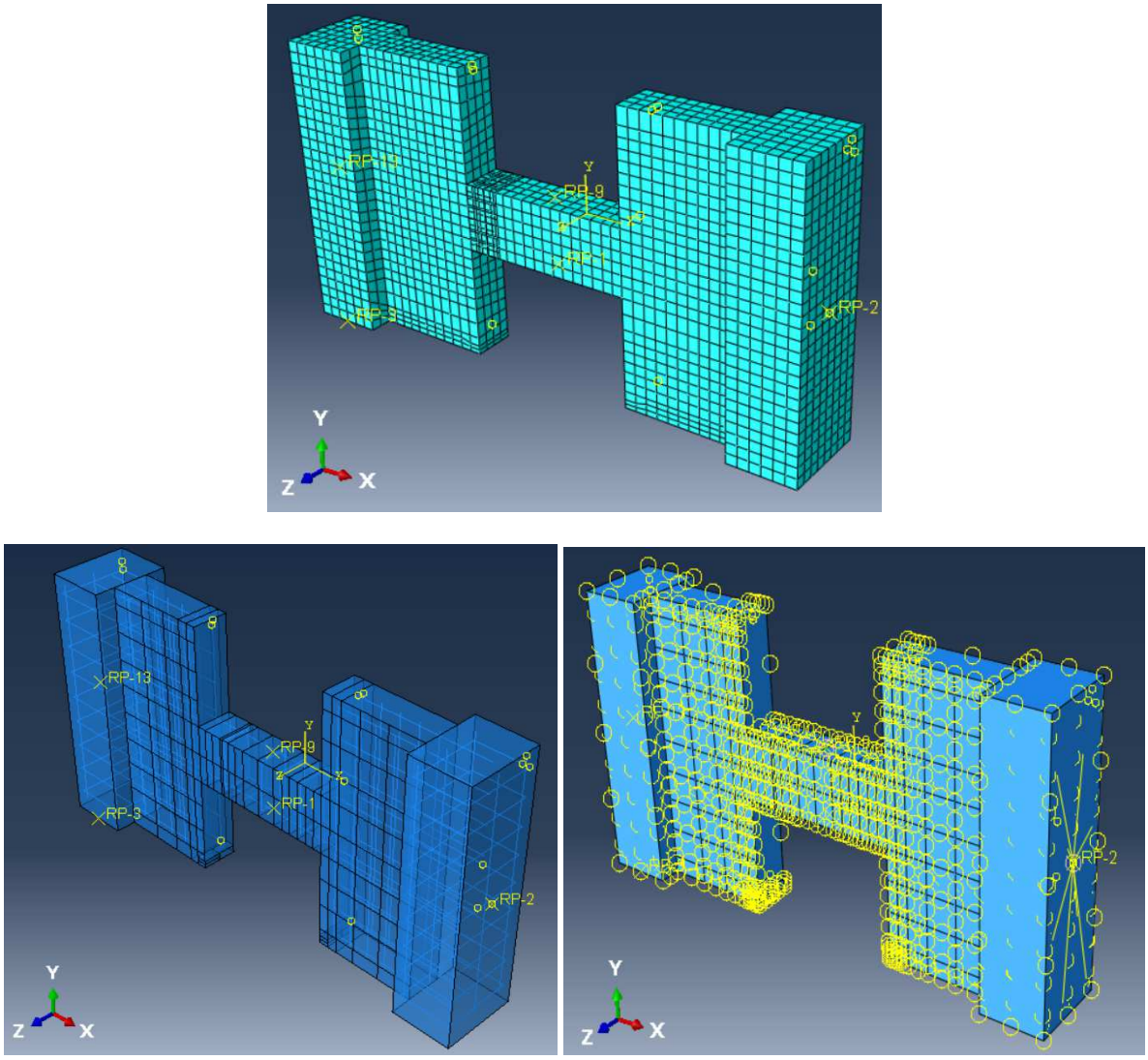

Fig. 4: Numerical modeling in ABAQUS

DOI: 10.3844/ajeassp.2018.1125.1129

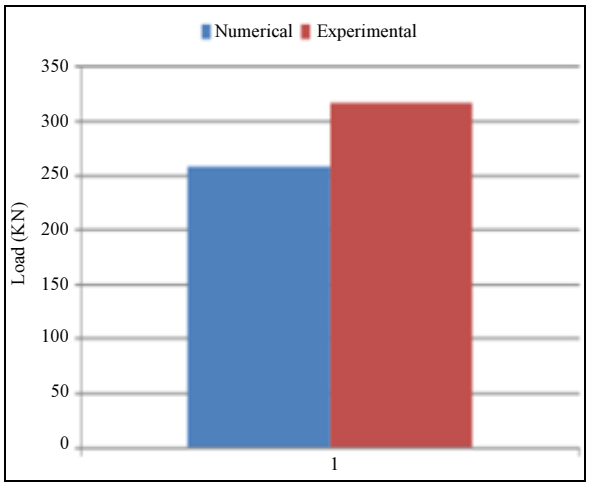

Fig. 5: The difference of maximum load capacity; ABAQUS versus experimental

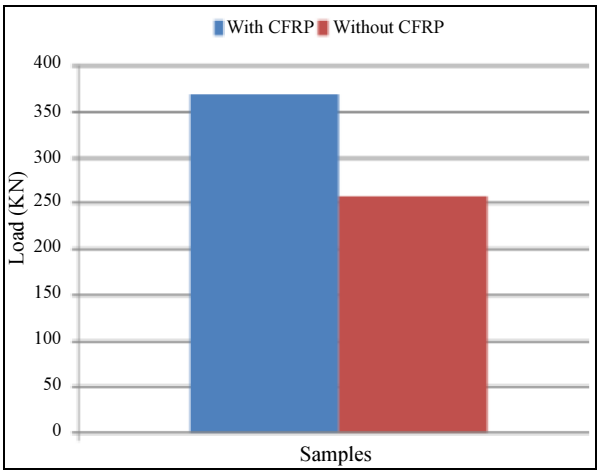

Fig. 6: The difference of maximum load capacity; without CFRP versus with 4 layers CFRP

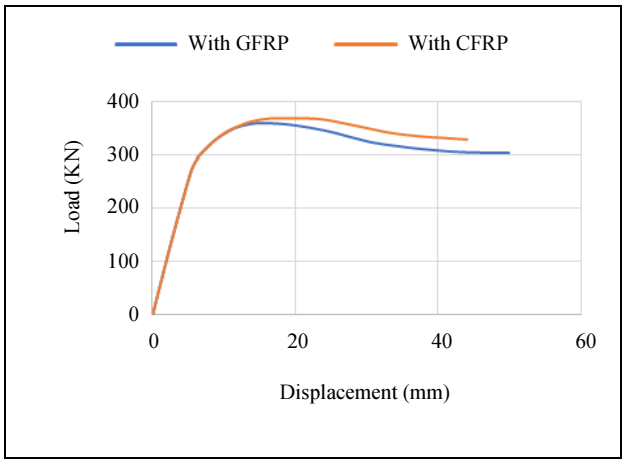

Fig. 7: The difference between 2 layers CFRP versus 2 layers GFRP

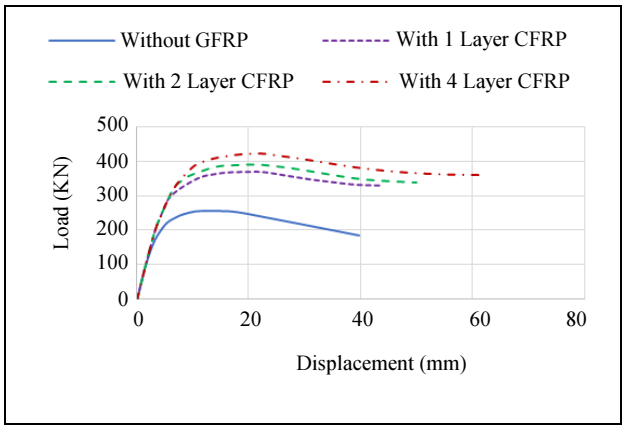

Fig. 8: Load-displacement diagram for different layers of CFRP

After validating the experimental result with FEM ones, the four layers of CFRP is used to retrofit the whole length of coupling beam as a wrapping method. Figure 6 shows the comparison of maximum load capacity for model with CFRP and without retrofitting.

In this section, the same layer of Glass Fiber Reinforced Polymer (GFRP) is modeled to find out the difference of CFRP and GFRP in load-displacement diagram. As it is cleared in Fig. 7 the GFRP has more ductility but less load capacity compared with CFRP. This retrofitting is done by 2 layers of FRP.

In the last part of modeling, different layers of CFRP has been used to evaluate the effect of CFRP on load capacity and ductility. The Fig. 8 indicates 1, 2 and 4 layers of CFRP sheet compared to RC coupling beam without retrofitting. As it is clear, four layers CFRP has more load capacity and ductility than two and one layers.

Conclusion

In this research, the following important results are:

- Using CFRP sheet can increase load capacity of RC coupling beam
- Ductility of GFRP sheet is more than CFRP in the same situation
- The more layer can have more load capacity and ductility
- Two layers of GFRP and CFRP sheets significantly increased the load capacity

Acknowledgment

The Authors all contributors to this study is university of Guilan, Iran.

Authors Contributions

Saeideh Hakimi: Performed numerical studies and conducted data analysis of the research. Also, participated in writing the manuscript.

Rahmat Madandoust: Provided the research topic and guided the research development, experimental plan and data analysis. Also, participated in writing the manuscript

Ethics

This article is an original research paper. There are no ethical issues that may arise after the publication of this manuscript.

References

Barnes, B.A., P.S. Baglin, G.C. Mays and N.K. Subedi, 2001. External steel plate systems for the shear strengthening of reinforced concrete beams. Eng. Structures, 23: 1162-1176. DOI: 10.1016/S0141-0296(00)00124-3

Chen, J.F. and J.G. Teng, 2003. Shear capacity of fiber-reinforced polymer-strengthened reinforced concrete beams: fiber reinforced polymer rupture. J. Structural Eng., 129: 615-625. DOI: 10.1061/(ASCE)0733-9445(2003)129:5(615)

El-Sokkary, H., 2012. Seismic retrofit of reinforced concrete shear walls using fibre reinforced polymer Composites. Doctoral dissertation, Concordia University.

El-Tawil, S. and C. Kuenzli, 2002. Pushover of hybrid coupled walls. II: Analysis and behavior. J. Structural Divis., 128: 1282-9. DOI: 10.1061/(ASCE)0733-9445(2002)128:10(1282)

Fallahi, M., M. Haghighfar, R. Madandoust and S.S. Roudsari, 2018. Modeling of reinforced concrete frames with Infill walls under cyclic loading Strengthening with CFRP. J. Eng. Applied Science.

Layssi, H., and D. Mitchell, 2012. Experiments on seismic retrofit and repair of reinforced concrete shear walls. Proceedings of the 6th International Conference on FRP Composites in Civil Engineering, (CCE' 12), pp: 13-15.

Riyazi, M., M.R. Esfahani and H. Mohammadi, 2007. Behavior of coupling beams strengthened with carbon fiber reinforced polymer sheets. Int. J. Eng., 20: 49-58.

Roudsari, S., H. Sameer, M. Soleimani, A.L. Taher and M. Haghighi Far, 2018. Analytical study of reinforced concrete beams strengthened by FRP bars subjected to impact loading conditions. Am. J. Eng. Applied Sci. DOI: 10.3844/ofsp.11916

Roudsari, S., S. Hamoush, A. Sameer and M. Soleimani, 2017. Evaluation of large-size reinforced concrete columns strengthened for axial load using fiber reinforced polymers. Construct. Build. Mater.

Soleimani, M. and S. Roudsari, 2015. Analytical Study of reinforced concrete beams tested under impact loadig. Proceedings of the 4th International Workshop Performance, Protection Strengthening of Structures Under Extreme Loading, (UEL' 15), pp: 620-627.

Woods, J.E., 2014. Seismic retrofit of deficient reinforced concrete shear walls using fibrereinforced polymer sheets: Experimental study and anchor design. Master dissertation, Carleton University Ottawa.