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Investigation of finite element retrofit of T-shaped reinforced concrete beam–column joints by external bolts

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ABSTRACT: Understanding the performance of reinforced concrete (RC) structures against earthquake load to design them is imperative. One of the fundamental issues determining the performance of concrete structures against earthquake load is investigating the joint behavior and its appropriate ductility. To attain adequate ductility in beams and columns, the joint must have sufficient strength and ductility to withstand the ultimate loads of beams and columns. In many RC structures that have been exposed to severe earthquakes, joint shear failure has been observed. Shear failure of the joint can be due to the weakness of oblique reinforcements in the beam-column joint area of RC structures. The use of high-strength external bolts under axial and cyclic loadings in ABAQUS finite element software has been investigated in this paper. The arrangement and the amount of post-tension of the bolts are the parameters investigated in this study. The use of external bolts to retrofit the RC beam-column joints indicates an increase in confinement and consequently improves performance in the joint area. In addition to preventing shear failure in the joint fountain, the proposed method causes a capacity increase of about 44% in post-tension specimens. Also, it increases energy absorption by about 50% in retrofitting specimens.

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1- Introduction

Proper performance of joints in reinforced concrete flexural frames is crucial to maintaining the stability of these structures against severe earthquakes. In recent years, several researches have been conducted to evaluate the seismic performance of beam-column joints in RC structures designed according to standards of different countries [1, 2]. The research results on RC joints under seismic loading and severe damages caused by recent earthquakes confirm that the shear weakness of the joint zone is the leading cause of failure [3, 4]. Hence, the joint panel zone retrofitting is necessary for structures designed according to previous standards and structures whose joints are performed without transverse reinforcement. To retrofit the RC joints, various methods such as using a concrete and steel jacket, different types of haunch, Fiber Reinforce Polymer (FRP) materials, and various other methods are common [5, 6]. This study aims to propose an effective and practical method to improve the performance of RC beam-column joints against seismic loading. In this research, post-tensioned external bolts to retrofit the RC joints are introduced.

2- Methodology

In order to investigate the proposed patterns to retrofit the RC joints, 6 specimens of T-shaped joints were modeled in ABAQUS software. The Concrete Damage Plasticity Model (CDP Model), which is the most suitable model to simulate the behavior of concrete under cyclic loading, has been used to model concrete in ABAQUS software [7]. An experimental specimen that had previously been tested by Shafaei et al. was modeled in the software to verify the results obtained from ABAQUS software. The support and loading conditions were also applied based on the laboratory conditions [8]. Comparing the envelope curve of the experimental specimen and the modeled sample can be seen in **Figure 1**.

Next, to provide a suitable retrofitting pattern for the specimens with shear weakness at the joint panel zone, two patterns, diagonal and horizontal-vertical external bolts, were proposed. In each pattern, to investigate the post-tensioning effect of the retrofitting bolts, they were modeled in two modes with and without post-tensioning. The details of the retrofitting system based on the two proposed patterns are shown in **Figure 2**. The specimens were named according to **Table 1**.

3- Results and Discussion

In order to investigate the proposed retrofitting systems and their effect on the seismic performance of the joints, the envelope curve of the specimens was compared with each other (see Figure 3). Comparing the envelope curves

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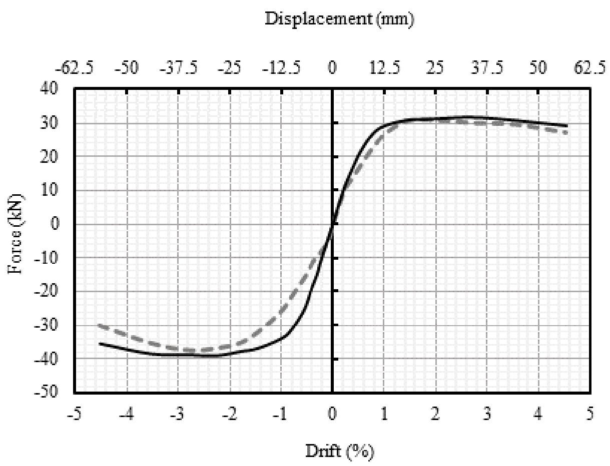

Fig. 1. Comparison of experimental [8] and analytical envelope curve

Table 1. Properties of specimens

Specimen	Type of retrofit	post-tensioning (%)
Control	———	———
Reference	———	———
DR-P0	diagonal	———
DR-P70	diagonal	70
HVR-P0	Horizontal-vertical	———
HVR-P70	Horizontal-vertical	70

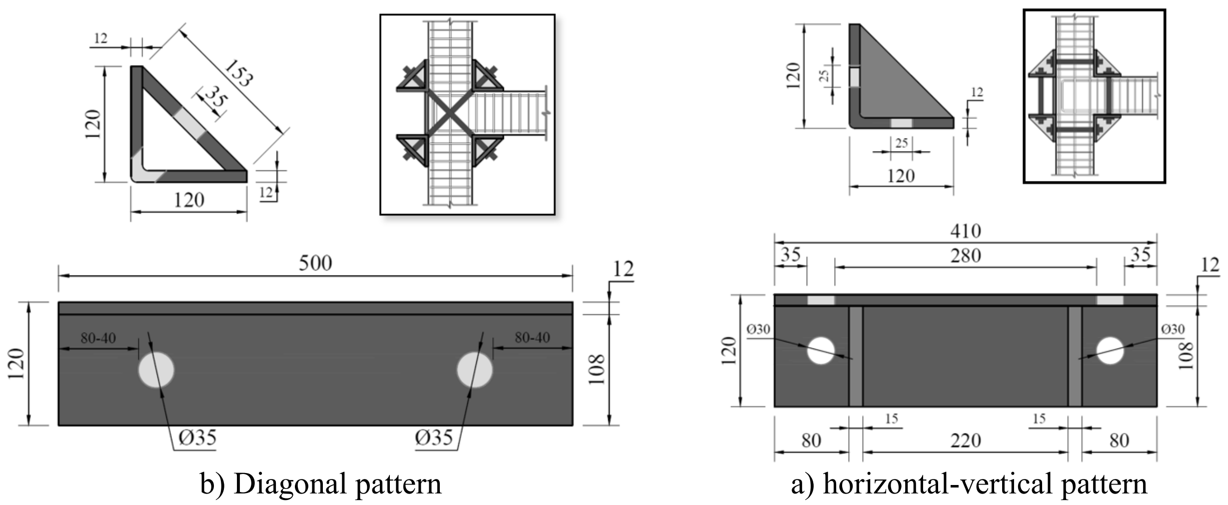

Fig. 2. Detail of retrofitting patterns (all dimensions are in mm)

of specimens indicates the significant effect of the proposed method on increasing the shear capacity and ductility of retrofitted specimens compared to the control specimen. One of the most important parameters indicating the seismic behavior of members is energy absorption. The amount of energy absorbed for each specimen is calculated by analyzing the sample diagram and is shown in **Figure 4**.

The length of the plastic hinge of retrofitted specimens increased significantly. Control specimen failure occurred suddenly in shear, while in the retrofitted specimens, it is clear that the plastic hinge has been transferred from the joint panel zone to the beam. The initial stiffness of the retrofitted specimens increased compared to the control specimen due to increased confinement.

4- Conclusions

Utilizing external bolts can have got a significant impact on the seismic behavior of reinforced concrete beam-column joints; As:

1- Using the high-strength external bolts causes significantly increases the shear capacity of the specimens. The final shear capacity was increased by 37%, 44.7%, 38.3% and 43.6% for DR-P0, DR-P70, HVR- P0, and HVR-P70 specimens, respectively, compared to the control specimen.

2- The amount of energy absorption was increased by 51%, 49%, 51% and 49% for DR-P0, DR-P70, HVR- P0, and HVR-P70 specimens, respectively, compared to the control specimen. The exciting result indicates the proper performance of the proposed retrofit under seismic loading.

3- Using high-strength external bolts almost doubles the

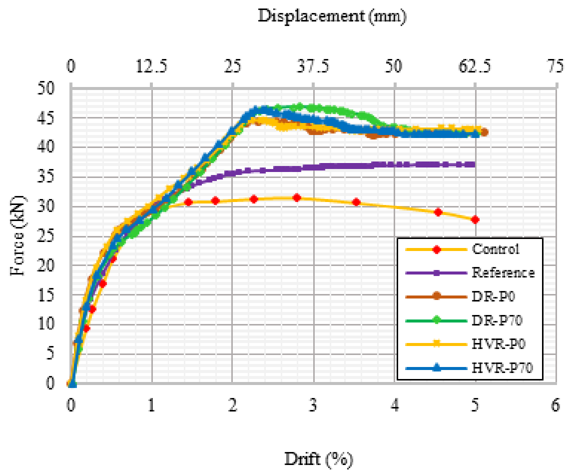

Fig. 3. Comparison of force-displacement envelope curves

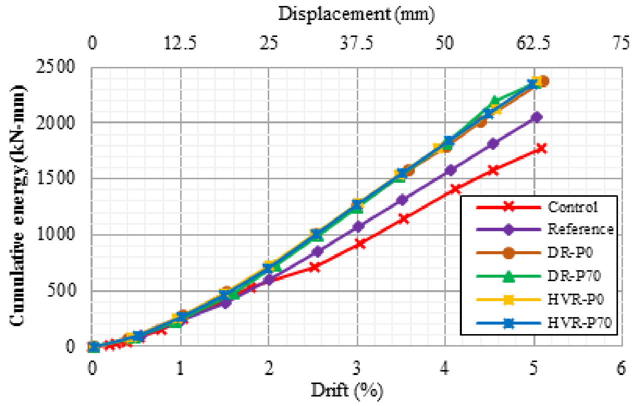

Fig. 4. Comparison of cumulative energy dissipation up to 5% drift

length of the plastic hinge. The plastic hinge length in Control and Reference samples is 215 mm and 230 mm, respectively, while in DR-P0 and HVR-P0 specimens, it is 420 mm, and in DR-P70 and HVR-P70 specimens, it is 430 mm.

References

[1] S. Hakuto, R. Park, H. Tanaka, Seismic load tests on interior and exterior beam-column joints with substandard reinforcing details, Structural Journal, 97(1) (2000) 11-25.

[2] R.P. Dhakal, T.-C. Pan, P. Irawan, K.-C. Tsai, K.-C. Lin, C.-H. Chen, Experimental study on the dynamic response of gravity-designed reinforced concrete connections, Engineering Structures, 27(1) (2005) 75-87.

[3] T. Gur, A. Pay, J.A. Ramirez, M.A. Sozen, A.M. Johnson, A. Irfanoglu, A. Bobet, Performance of school buildings in Turkey during the 1999 Düzce and the 2003 Bingöl earthquakes, Earthquake Spectra, 25(2) (2009) 239-256.

[4] W.Y. Kam, S. Pampanin, K. Elwood, Seismic performance of reinforced concrete buildings in the 22 February Christchurch (Lyttelton) earthquake, Bulletin of the New Zealand Society for Earthquake Engineering, 44(4) (2011) 239-278.

[5] C. Beschi, P. Riva, G. Metelli, A. Meda, HPFRC jacketing of non seismically detailed RC corner joints, Journal of Earthquake Engineering, 19(1) (2015) 25-47.

[6] S. Sasmal, S. Voggu, Strut-relieved single steel haunch bracing system for mitigating seismic damage of gravity load designed structures, Journal of Structural Engineering, 144(10) (2018) 04018167.

[7] J. Lee, G.L. Fenves, Plastic-damage model for cyclic loading of concrete structures, Journal of engineering mechanics, 124(8) (1998) 892-900.

[8] J. Shafaei, A. Hosseini, M.S. Marefat, Seismic retrofit of external RC beam–column joints by joint enlargement using prestressed steel angles, Engineering Structures, 81 (2014) 265-288.

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