Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 54(6) (2022) 449-452
DOI: 10.22060/ceej.2021.19238.7129

Analytical Investigation of the Effect of Steel X-Bracing Connection Type on the Reinforced Concrete Frames

Y. Hodaipour, A. Ferdousi*

Department of Civil Engineering, Tabriz Branch, Islamic Azad University, Tabriz, Iran

ABSTRACT: Using steel braces is regarded as one of the significant methods for retrofitting and seismic rehabilitation of reinforced concrete frames. Thanks to its easy implementation, economic considerations and appropriate seismic retrofitting performance against lateral forces, this system has received more attention from researchers in comparison with other seismic resistant systems. In this type of structural system, the connection properties are of high significance which can play a significant role in the obtained results including ductility, resistance, stiffness, etc. The detailed behavior and performance of this type of connection have received less attention from researchers; hence, it is regarded as an under-researched issue that we have addressed in the present study; we made an effort to explore and investigate this issue comprehensively. ABAQUS finite element software was applied for modeling and numerical analysis; a total of 8 models were analyzed and investigated which were categorized into 3 different groups with respect to the steel brace connection type of the reinforced concrete frame. These connections include steel bolts and plates, steel jacket and steel box which were modeled and discussed under different conditions within each group. Nonlinear analysis of samples indicated that the connection of steel bracing to the concrete frame by penetrating bolts in concrete and steel plates led to significant enhancement of stiffness, resistance and ductility. Furthermore, these reinforcements have maximum energy dissipation, minimum concrete frame cracking and steel consumption reduction in joints.

Review History:

Received: Nov. 24, 2020
Revised: Oct. 11, 2021
Accepted: Oct. 24, 2021
Available Online: Nov. 22, 2021

Keywords:

Building Retrofitting
Connections
Reinforced Concrete Frames
Steel Jacket
Finite Element Method

1- Introduction

What is important in designing structures in areas with high seismicity is to provide appropriate ductility and rigidity of structures. As a case in point, the system of reinforced concrete frame braced with steel bracing is one system type which is resistant to lateral loads such as earthquakes. It has sufficient stiffness to control lateral displacement so as to prevent any structural and non-structural damage during moderate but frequent earthquakes. Furthermore, it has such remarkable ductility that it prevents the collapse of the structure under severe earthquakes [1]. Research into the reinforcement of concrete structures has gained momentum since the early 1980s. In most cases, bracing has been applied indirectly by means of a steel frame enclosed in a concrete frame. This system, in addition to imposing high costs, may cause a dynamic interaction between steel and concrete frame with a different dynamic response; hence, how the load is transferred among members and the issue of stiffness distribution should be investigated meticulously [2]. Although some research studies have been conducted on reinforcing concrete buildings by means of steel braces, there is no comprehensive and reliable data on how to attach steel braces to the frame for reinforcing them in severe earthquakes [3]. The results indicate that, using CBF and EBF braces for reinforcing concrete frames can enhance the yield capacity of concrete frames by 3.2 and 2 times, respectively [4]. Retrofitting of low-height RC frames via steel X braces is considered to be advantageous for the performance of concrete frame columns with regard to almost every aspect. However, reinforcement side-effects regarding medium to long frames, particularly for columns connected to the bracing system, are of high significance; if necessary, local reinforcement of the columns should be carried out simultaneously [5]. The experimental results revealed that concrete frames reinforced with X braces perform better than other concrete frame types in terms of strength and stiffness [6]. When an appropriate design criterion is taken into consideration, concrete frames reinforced with ductile X braces demonstrate desirable structural behavior. Also, it has been observed that the balance of shear strength distribution at height has a significant impact on reducing floor displacement [7]. When steel braces are added to an already reinforced concrete frame, the load paths through which the lateral forces are transmitted change significantly; as a result, it modifies the demand for frame and its elements [8].

*Corresponding author's email: a_ferdousi@iaut.ac.ir

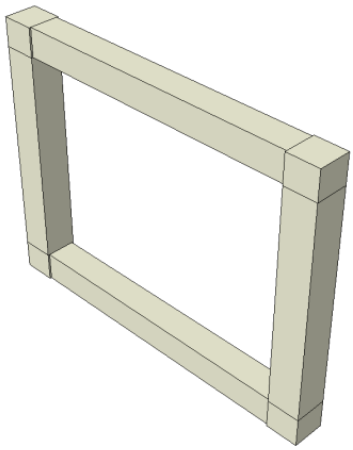

Fig. 1. Overview of the studied concrete frame

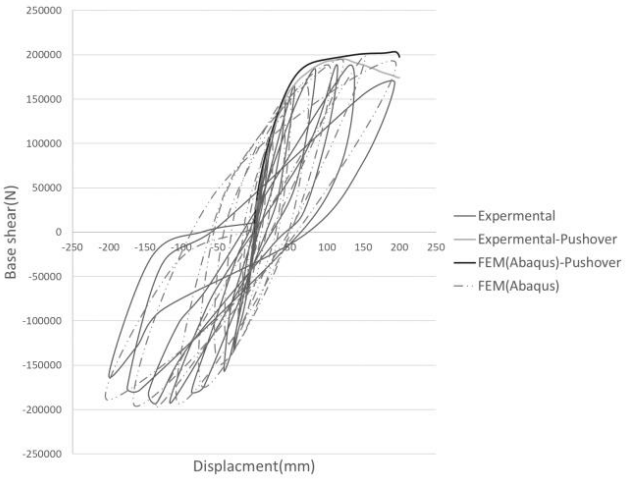

Fig. 2. Comparison of inelastic response curves and hysteresis of experimental concrete frame and analytical sample

2- Methodology

8 samples were modeled in ABAQUS software for testing and investigating the proposed pattern of connecting steel braces to the concrete frame. The plastic Damage Plasticity Model (CDP Model), considered to be the most appropriate model for simulating concrete behavior, was applied for modeling concrete in ABAQUS software. The intended type of connecting steel braces to concrete frame include bolts and steel plates which are applied both externally and in the buried manner in the form of steel jacket and steel box. Both of the proposed connection types (either steel plates connecting braces to the concrete frame or bolts used in the steel plates) in the models are the results of manual calculations. Before reporting the numerical results for the analyzed models, it was necessary to ensure the accuracy and precision of the applied models. Hence, to check the validity of the results, the model tested by Hong-Gun Park & Rak Choi [9] in the laboratory in 2011 was applied via the finite element method. Then, the obtained results of the two methods were compared with one another. As shown in Figure 2, it was observed that there is a meaningful consistency and compatibility between the results of finite element modeling and laboratory results.

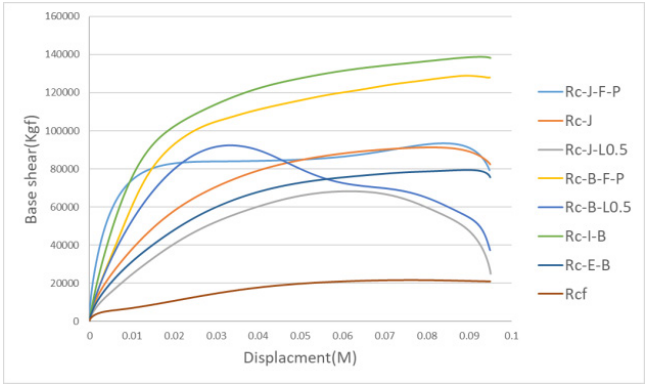

Fig. 3. Comparison of inelastic response curves of all studied models

3- Results and Discussion

As shown in Figure 3, we compared the envelope curves of the samples with each other to investigate reinforcement systems of the proposed connection types and their impact on the performance of the concrete frame. The results of comparisons regarding the envelope curves indicate the remarkable impact of the proposed method on enhancing the ductility, strength and stiffness of all samples in comparison to the reference sample. One critical parameter of models is energy dissipation. The amount of depreciated energy for each sample was computed based on the area under their curves. Figure 4 illustrates the comparison of the results in a bar chart.

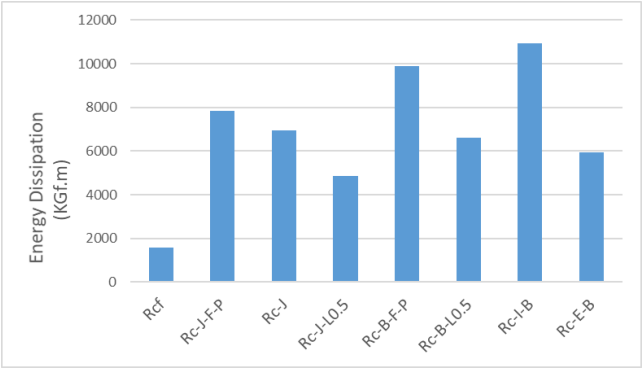

Fig. 4. Comparison of energy dissipation in all the investigated models

4- Conclusion

Based on the discussion of the issues given in the previous sections on the respective models examined in this study, the following results are obtained:

1. The application of convergent steel X braces in reinforced concrete frames has enhanced strength, energy dissipation and also stiffness. Furthermore, the issue of how steel brace is connected to the concrete frame has a significant impact on the seismic performance of the brace frame.

2. The findings of the study reveal that Rc-I-B model, in general, has the highest performance with respect to both overall structural behavior and parameters such as strength, stiffness, ductility coefficient, energy dissipation, amount consumption of steel joints and minimum increase in the cracking of braced concrete frame in comparison to other models. The issues raised are the most appropriate way to connect steel brace to concrete frame among the existing models.

References

[1] Y. Hodaipor, Evaluation of seismic performance improvement of reinforced concrete buildings strengthened with several types of steel brace, M.Sc. Thesis, Islamic Azad University Tabriz Branch (2017).

[2] A. Chegoi, MA. Rahgozar, Investigating the coefficient of behavior and seismic behavior of concrete steel composite frames by comparative pushover analysis method, Seismology and Earthquake Engineering Journal(2012),15(3).

[3] H. Pahlavan , A. Naseri, A. Einollahi, Probabilistic Seismic Vulnerability assessment of RC Frame Structures Retrofitted with Steel Jacketing, Amirkabir J. Civil Eng., 51(3)(2019)585-598.

[4] A. Kheyroddin, M. Gholhaki, Gh. Pachideh, Seismic evaluation of reinforced concrete moment frames retrofitted with steel braces using IDA and Pushover methods in the nearfault field, Amirkabir J. Civil Eng., 52(5) (2020) 1-16.

[5] A Rahimi, Mahmoud R. Maheri, The effects of retrofitting RC frames by X-bracing on the seismicperformance of columns, Engineering Structures, 173 (2018) 813–830.

[6] Kai Qian, M.ASCE, Yun-Hao Weng and Bing Li, Improving Behavior of Reinforced Concrete Frames to Resist Progressive Collapse through Steel Bracings, Journal of Structural Engineering, 145(2) (2019) 04018248.

[7] Eber Alberto Godínez-Domínguez, Arturo Tena-Colunga, Behavior of ductile steel X-braced RC frames in seismic zones, Earthq Eng & Eng Vib 18 (2019) 845-869.

[8] A. Rahimi, Mahmoud R. Maheri, The effects of steel X-brace retrofitting of RC frames on the Seismic performance of frames and their elements, Engineering Structures Vol: 206 (2019), Page: 110-149.

[9] IR. Choi, HG. Park, Cyclic loading test for reinforced concrete frame with thin steel infill plate, Journal of Structural Engineering, 137(6) (2011) 654–664.

HOW TO CITE THIS ARTICLE

Y. Hodaipour, A. Ferdousi, Analytical Investigation of the Effect of Steel X-Bracing Connection Type on the Reinforced Concrete Frames, Amirkabir J. Civil Eng., 54(6) (2022) 449-452.

DOI: 10.22060/ceej.2021.19238.7129