Investigating and comparing the seismic behavior of the ConXL Connection with the WUF-W Connection by using fragility curves

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ABSTRACT

Steel moment frames are among the structure systems for bearing gravity and lateral loads, which are more common in high-rise structures due to their lower weight than reinforced concrete moment frames. The ductility capacity of steel moment frames depends on the types of their connections, hence the moment connections are particularly important. Nowadays, in the American Steel Codes and the Iranian National Building Regulations, models have been introduced as Prequalified Connections. The ConXL modern moment connection is one of these connections and in this research that is under study. This connection is designed to create a cost-effective and resistant moment frame that allows quick installation of the frame by eliminating workshop welding. Also, WUF-W, which is known as a rigid connection in domestic codes, is a conventional connection in construction and can be a suitable reference for comparison with ConXL, which is less known in terms of seismic behavior. To do this comparison, fragility curves, which are suitable tools for determining the probability of vulnerability, are used. For this purpose, fragility curves are determined for both ConXL and WUF-W connections. The criterion of this comparison is the performance levels of IO and CP in the fragility curves of joints in a special two-dimensional bending frame. Finally, after comparing the seismic behavior of the two mentioned connections and expressing the more favorable performance and ease of implementation, it can be concluded that the modern ConXL Connection is a more suitable option for special moment frames.

KEYWORDS

Fragility curve, ConXL connection, WUF-W connection, Prequalified connection, Probability of vulnerability

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1. Introduction

It is very difficult and even impossible to completely prevent damage caused by severe earthquakes to structures, however, increasing knowledge and using tools to assess the risk of building vulnerability will largely lead to the selection of safer and more reliable systems to reduce losses and casualties. One of these tools is the use of fragility curves[1]. In the last two decades, the application of the fragility curves has been widely developed in order to evaluate seismic behavior and the risk caused by earthquakes. The fragility curve approach has the significant advantage of simplifying the method of estimating the vulnerability of the structures. Steel frames are one of the most common structures in Iran and the world. These structures are designed and implemented with various kinds of connections. Studying the effect of connections' role on behavior and overall failure of the structure can be of prominent help in making main decisions in the design procedure of earthquake-resistant structures[2].

Modern ConXL connection is considered as the prequalified connection in the AISC358 standard and has high operational advantages. Hence, in this article, an attempt is made to analyze and compare the seismic behavior of the modern ConXL connection with the rampant and renowned WUF-W connection by modeling and analyzing the two-dimensional ten-story special steel moment frame and then preparing fragility curves. The connection's components and beams installation are indicated in Figure 1.

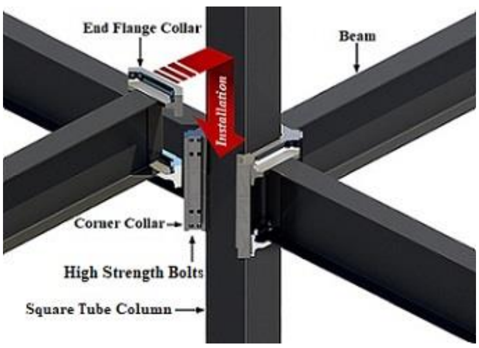

Figure 1. Connection's Components and Beams Installation Procedure. Courtesy of the *ConXtech Inc.*

Due to the benefits of this connection, several researches have been conducted on. In a research in 2013, Shahidi et al. modeled the ConXL Connection in 9 samples with 32 and 16 bolts. The findings showed that the most optimal position of the bolts will be a point near the middle of the beam flang[3]. In 2016, a research was presented by Yang et al. to investigate the seismic performance of ConXL connection without column filling concrete. In this research, a sample of ConXL connection with infill concrete in the square box column which was tested by ConXTech, and FEM modele were analysed and compared. After verifying the Abaqus results, four different finite element states of the connection without column-filling concrete were developed and loaded under unidirectional and bidirectional cyclic loads. The results showed that in different forms of ConXL connections without the column infill concrete when the axial load level in the column is not very high, plastic hinges occurs in the beam. Regarding the results that were mentioned in previous research, the rigid moment ConXL connection has high performance in seismic areas. Thus, in this paper, an attempt was made to study the seismic behavior and determine the seismic level of performance of the ConXL and the WUF-W connections with the fragility curves and compare them.

2. Methodology

Initially, to validate the accuracy of the FEM results, the seismic behavior obtained from Abaqus and Yang et al.[4] was compared. A comparison of two FEM hysteresis curves is depicted in Figure 2, illustrating their close resemblance.

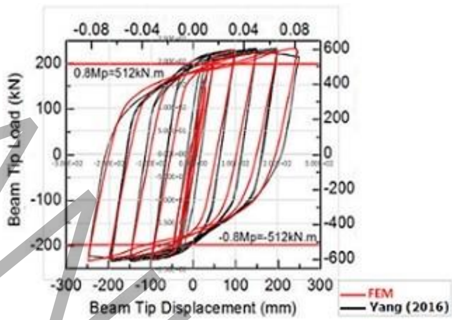

Figure 2. Comparing the results of the load-displacement curves of the two models

Subsequently, to assess the seismic response of the connections, a nonlinear time history analysis was conducted. A ten-story steel special moment frame was simulated in ETABS software, subjected to seven earthquakes of varying intensity, all scaled to Sa(T1). The time-history of shear forces for two connections, representing different states for middle and corner connections that were located on the second and eighth floors was obtained from the software, as detailed in Table 1.

Table 1. Selected accelerogram for the analysis

Number	Record's Name	PGA(g)	Duration (sec)
1	Tabas	0.104	39.98
2	Northridge	0.25	34.98
3	Kobe	0.225	40.95
4	Manjil	0.183	60.42
5	Kokaeli	0.364	17.185
6	Elcentro	0.1385	39.995
7	Loma	0.511	39.99

After finite element modeling of two types of connections and applying the shear force time-history to each one, the Dynamic Implicit analysis was conducted in Abaqus software. The time-history of the shear force is the input of the FEM analysis and the displacement history of the top of the column is derived as the output of the software then the maximum displacement of the column tip is calculated. For each connection the IDA curve is calculated by using the maximum displacement at the column tip and the acceptance criteria values of two performance levels of IO and CP which are shown in Table 2.

Table 2. Acceptance Criteria of Connections

	ConXL connection		WUF-W connection	
	IO level	CP level	IO level	CP level
2nd story	0.0103	0.0435	0.0103	0.041
8th story	0.0107	0.0446	0.0103	0.041

To prepare fragility curves, a log-normal distribution is assumed for the seismic response of each earthquake intensity. To estimate the probability of exceedance from certain limits, the mean and standard deviation for the effects of each response of earthquake records are evaluated. In this article, the probability function with the log-normal standard distribution based on the values of the probability function obtained from the output data of the nonlinear dynamic analysis of inter-story drift ratio as damage index against the earthquake intensity index Sa(T1) is considered. For more clarification of the connection performance, the fragility curve of the WUF-W Connection is determined and compared with the fragility curve of the ConXL Connection. Figure 3. Shows this comparison.

3. Discussion and Results

Comparing both connections on the second floor across both IO and CP levels, the ConXL connection proves more reliable than WUF-W, with WUF-W exhibiting an earlier tendency to exceed the limit state. Similarly, on the eighth floor, the same trend observed on the second floor persists, albeit with a smaller margin. This reduction in the disparity between fragility curves is due to decreased shear forces in the upper floors of the structure.

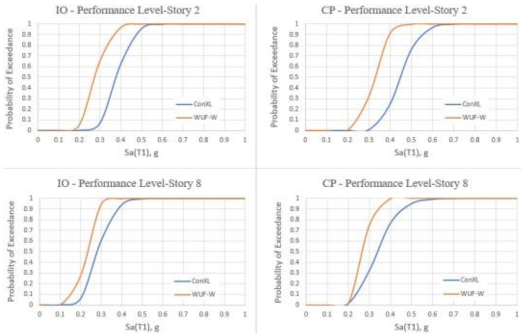

Figure 3. Comparison of fragility curves

4. Conclusions

The study compares the seismic performance of ConXL and WUF-W connections in a ten-story steel moment frame through fragility curves. Both ConXL and WUF-W connections were subjected to Incremental Dynamic Analysis (IDA) to assess their performance levels, including Immediate Occupancy (IO) and Collapse Prevention (CP). ConXL exhibited superior reliability over WUF-W, with delayed limit state exceedance. Despite reduced shear forces in upper floors, the disparity between fragility curves lessened. ConXL's higher stiffness and ductility allow it to endure higher spectral accelerations, making it recommended for use in high-risk scenarios requiring greater performance levels.

5. References

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