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Seismic performance of asymmetric isolated steel structures with different bracing systems

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ABSTRACT: In this paper, the seismic performance of asymmetric isolated structures with different bracing systems under near-fault strong ground motions is investigated. Non-linear dynamic analyses are performed under the simultaneous application of horizontal and vertical components of seismic acceleration. For this purpose, three types of chevron, cross and zipper bracing systems in 5 and 10-story structures with 0%, 10% and 20% mass eccentricity have been studied. Non-linear time history analysis is performed by seven selected accelerograms. First, the symmetrical structure was analyzed in fixed and isolated base states. Then, the asymmetric effect on two eccentricity cases 10% and 20% in the target structures, was compared. The parameters studied in this paper are the average shear force, drift and rotation of floors, and input energy to the structure. With an increasing eccentricity of the structure, the energy absorption by the isolator is reduced and the base shear is increased. Among the different bracing systems, the energy absorbed by the isolation system in the structure with zipper bracing increased by 53% and the base shear rate decreased by 80%. Based on the analysis results, base-isolation in the structure with cross-bracing in symmetrical and asymmetric has caused a reduction of more than 70% of the floor rotation compared to other bracing systems..

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1- Introduction

Seismic isolators to improve the seismic performance of structures have received much attention in recent years. In the base-isolated structures, during an earthquake, most of the lateral deformation occurs at the level of the isolator and the deformation of the superstructure will be very low, so the non-linear behavior and consequently damage to the superstructure will be greatly reduced [1]. Ryan and Chopra (2004) studied one-story building by different eccentricities in two directions under time history analysis. They concluded that by increasing the eccentricity, the displacement of the isolators would be increased [2]. Kangda and Baker (2018) investigated the effect of isolated system parameters including yield strength, post-yield stiffness ratio and yield displacement on the seismic response of the building. In this study, it was observed that LRB effectively reduces structural acceleration and damage of the building due to the vibration of strong ground motion [3].

In this paper, the behavior of 5 and 10-story asymmetric isolated-structure with three types of cross-bracing systems (X), Chevron (V) and Zipper (Z) applying non-linear dynamic analysis under the effect of three horizontal and vertical components of earthquake has been studied. Two mass asymmetric ratio 10% (A10%), 20% (A20%) and symmetric case (A0%) are considered in the analysis.

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The study of the performance of asymmetric isolated steel structures with different bracing systems under the effect of horizontal and vertical components is the distinguishing feature of this study from other previous studies.

2- Structural modeling and specification of seismic isolation

The modeling and seismic assumptions in this paper are as follows. Soil type II, site seismicity (A=0.35), coefficient of behavior (R=6) and importance of the structure (I=1) are assumed. The dead and live load of the floor is 500 kg/m^2

Table 1. Specifications of Isolators

Story Level	5	10
Type of Base Isolation	LRB	LRB
D_d (mm)	258	355
K_{eff} (kN/m)	941	1206
K_1(kN/m)	1280	7433
F_y (kN)	417.72	
K_1/K_2	0.1	

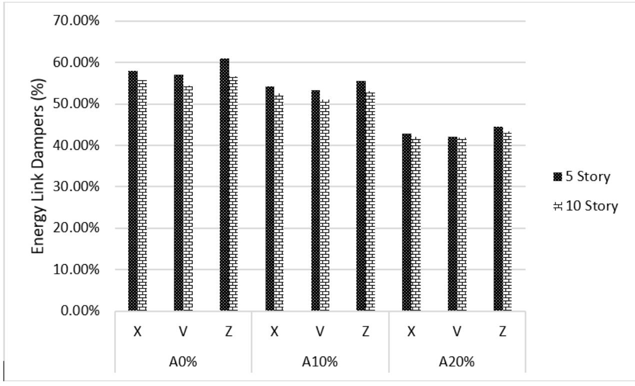

Fig. 1. Average energy absorption by the isolation system in structures of 5 and 10 story with different braces (X, V, Z) & asymmetric rate (A0%, A10%, A20 %)

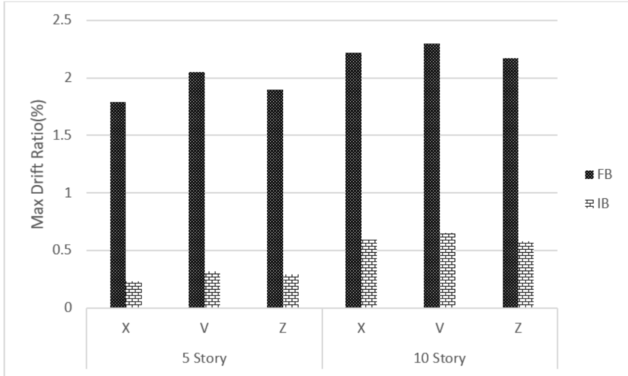

Fig. 3. Average maximum drift by the isolation system in structures of 5 and 10 story with different braces (X, V, Z) & asymmetric rate (A0%, A10%, A20%)

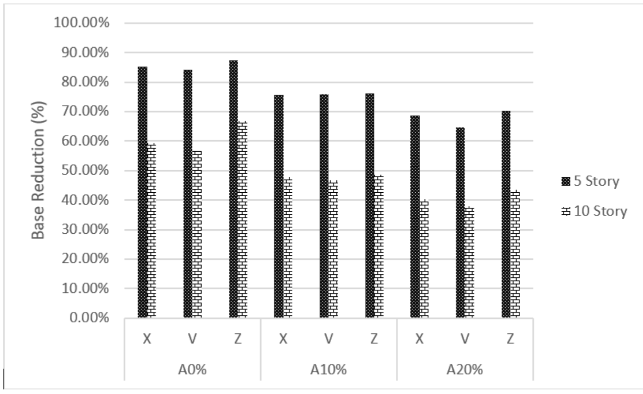

Fig. 2. Average base shear reduction by the isolation system in structures of 5 and 10 story with different braces (X, V, Z) & asymmetric rate (A0%, A10%, A20%)

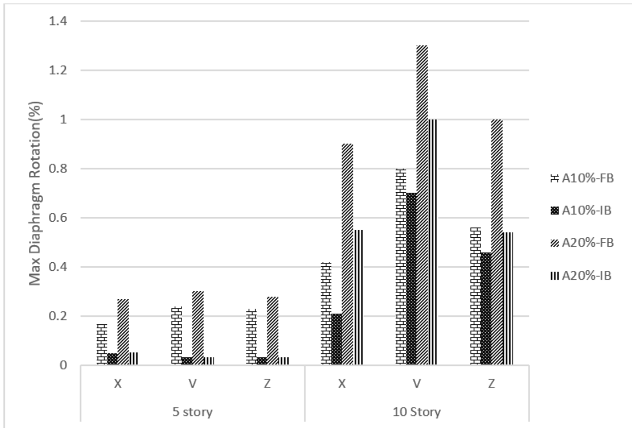

Fig. 4. Maximum of rotation of floors by the isolation system in structures of 5 and 10 story with different braces (X, V, Z) & asymmetric rate (A0%, A10%, A20 %)

and 1000 kg/m^2, respectively. The design of the structure is based on the Iranian seismic regulations (Code 2800) and the national building regulations for steel structures. Isolator design based on ASCE7-16 regulation is based on MCER. [4-6] The specifications of the isolators of 5 and 10 story structures are presented in Table 1. Dynamic analysis of the three-component time history is performed with seven different accelerometers recorded in the near field.

3- Results and Discussion

Studies on the input energy of the structure showed that by increasing the number of floors from 5 to 10, energy absorption by the isolation system has decreased. Figure 1 shows the average energy absorption changes of the isolation system in 5 and 10 story structures. With increasing the height of the structure, this value decreased by 7% on average. The highest energy absorption by this system was due to the increase in the number of floors occurs in the zipper bracing system (Z) and the lowed occurs in the chevron bracing system. Figure 2 shows the average changes in the reduction of the base shear in the isolated and the fixed base structures. By increasing the story number, the reduction of the base shear has decreased by an average of 27%, which indicates that the isolator has been more effective in the 5-story structure.

The maximum change in shear force reduction assuming an increase in the height of the structure is 28% in the chevron bracing system (V) and 25% in the zipper bracing system (Z), which is the lowest value compared to other bracing systems.

As can be seen in Figure 3, the maximum drift has also increased as the number of structural story increases. Among the different bracing systems, the zipper (Z) and chevron (V) bracing system has the best and weakest performance, respectively.

In general, by increasing the number of structure story from 5 to 10, the rotation of the structure increases by an average of 70%. Due to the isolation of the structure, the amount of changes in the rotation of floors in the 5-story structure decreased by 75% and in the 10-story structure decreased by 45% (Figure 4).

4- Conclusions

1. In 5 and 10 story isolated-structures, bracing system Z had the best performance of energy absorption (53%). With increasing the height of the structure, this value has decreased by 7%.
2. Among the structures with different braces, the structure with Z brace had the least value of base shear and the most reduction. V brace had the least reduction in base shear due to isolation.
3. In the 5-story structure, the z bracing system and in the 10-story structure, the X bracing system had the lowest drift rate. Also, asymmetric increase in the structure has no effect on the drift rate of fixed or base-isolated structures.
4. The structure with X brace has the lowest amount of torsion and the structure with V brace has the highest amount of torsion in the floors.
5. Among the structures with different braces, the structure with X bracing and the structure with V bracing have the lowest and highest torsion rates in the floors, respectively. With the increase in the number of structural floors from 5 to 10, the rotation of structural floors has also increased. Based on the results.

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