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Investigation of Seismic Performance of Asymmetric Structures Using Rotational Friction Moments

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Abstract

Design based on performance enables engineers the selection of a wide range of performance targets for design of buildings according to a suitable method that fulfills the selected objectives.

Due to the fact that frictional dampers play an important role in the energy depreciation and the decrease of the story drifts while buildings is affected by lateral forces, the use of dampers in the structures have been evaluated both technically and feasibility through initial studies and from references such as the information of researches, papers and relevant articles, and similar designs implemented with the damper.

In this research, the seismic performance of rotational frictional dampers in asymmetric frames is investigated, which is an irregularity caused by the cutoff of the lateral resistance system. Non-linear time history dynamic analyses were performed on 6, 9 and 12-story moment resistance frames with various spans of 4, 5 and 6 meter and irregular in height due to discontinuity in lateral resistance system. The frames have also been braced with inverted chevron type bracing equipped with frictional dampers. The frames were designed and loaded to comply with the requirements of Seismic Resistant of Building-Code of Practice (std 2800), fourth edition and Building National Regulations NO. 10, 1392 edition. The Sap2000 and Opensees software were used for this analysis.

The results showed that the use of this type of dampers in irregular steel structures increases energy absorption and improves the vibration behavior of the structure such as reduction of base shear, story drifts and internal forces.

Keywords: *Rotational friction dampers, story drifts, Sap2000, Opensees*

1. Introduction

Considering the experience of severe damage during past earthquakes, a new approach based on the use of modern technology is clearly felt to reduce the financial and psychological damage to the earthquake. In the building and bridge construction industry, the new approach reduces the demand for power in the structure rather than increasing the stiffness and resistance. This idea is based on absorbing the least energy from the earthquake effects to the structure, rather than adding resistance to the members of the lateral resistance system. The prevailing approach in classical and conventional methods for increasing the efficiency and safety against seismic loads is based on adding more members to the lateral resistance system, as well as adding to their resistance. In this way, the addition of rigid members and the use of stronger members will be accompanied by increased stiffness and more energy absorption of the earthquake. This means the deployment of larger concentrated forces to the connections and the imposition of these forces on the supporting members in the structure.

In recent years, methods of controlling vibration of the seismic resistance structures have been under special attention of engineers and researchers. One of the most common methods of passive control of structures is the use of dampers.

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The frictional rotational dampers are an example of passive dampers that are used in inactive control systems of the structure. In this study, the effect of stiffness irregularity due to discontinuity of lateral resistance system is investigated. Steel moment frames with inverted chevron bracing and equipped with frictional damper are analyzed for 6, 9 and 12-story buildings. To increase the knowledge of use of dampers in the construction industry, it is necessary to have a comprehensive perspective of dampers' performance in the seismic loads.

2. Background

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In 2008, Vaseghi, Nagipour and Jalili studied the performance of moment steel frames fitted with dampers under a record of accelerated mapping with different PGAs based on dynamic nonlinear time history analysis to determine the optimal slip load. The results indicated that damper performance improved with the elevation of the structure, and it was also found that the damage index with suitable slip load significantly decreased.

Mirza Bagheri investigated the use of multiple friction dampers in frames both experimentally and numerically in 2015. The results from multiple dampers were compared with single damper application and it showed the increase in energy dissipation. The behavior of dampers at 3, 7 and 12-story frames were also studied using non-linear dynamic analysis. It was found that with increasing number of floors in the building, multiple dampers should be used for proper earthquake performance. The equivalent damping method was also used to consider the effects of this damper without direct damper modeling. The effective damping of the frames equipped with this type of damper was estimated and used in the dynamic nonlinear time history analysis. It was observed that the responses of these structures with the damper can be achieved by non-damper moment resistant frames but with a damping equal to an effective damping due

to a frictional damper.

3. The implementation of the research

In this research, first, the modeling of the structures is designed for the percentage of the shear base per the seismic resistant building code so that, in the absence of a control system or any defect of such systems, the necessary resistance is provided to the earthquake forces and also delivers the suitable seismic performance.

In the next step, the dampers were added to the model and the structure was analyzed while rules, guidelines and the results from validated papers were applied for verification and comparison. The tools used in this research are refinement and rehabilitation topics related documents, writings, journals, articles and internal and external journals.

The modeling of 6, 9 and 12-story frames with rotational friction dampers were studied in the Sap2000 software and the results of the analysis of the asymmetric steel structure performance (from the cutoff system in height) were compared with outcomes from Opensees software.

4. Research Objectives

In this research, the effective seismic parameters which are considered in the most of the seismic code of practices to control the seismic effects are investigated as follows:

Maximum roof displacement
Maximum story drifts
Story shear load at base

5. Modeling

To evaluate the seismic performance of asymmetric steel structures with friction dampers, three types of frames with a number of stories of 6, 9 and 12-story (short, average, high order buildings) are considered in this research.

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Following assumptions are applicable for this analysis:

- The proposed structures are in Tehran, which is categorized in high risk zone per the earthquake zoning map of the Seismic Resistant Design of Buildings- Code of Practice, (Standard 2800) (fourth edition). The design acceleration is 0.35g.(12)
- The soil type is II is according to the classification of the Code Of Practice (std. 2800), fourth edition (12)
- The structure has 4 spans in X direction and 3 spans in Y direction.
- The height of the stories is 3.2 meters.
- The columns are of ordinary double-I (IPE) and beams are selected from the I-pillar beam (IPE). Bracing are double channels sections. All sections are made from ST-37 steel with specification as illustrated in Table 1.
- The bracing is inverted chevron shape from double channels (back to back) and equipped with friction dampers.
- The building is residential in all models with medium importance per code of practice-2800.

Table 1. Material Properties (Steel)

Yield Stress (MPa)	240
Ultimate Stress (MPa)	370
Modulus of Elasticity (GPa)	205
Poisson Ratio	0.3
Density (kN/m^3)	77

The dead weight and live loads of the floors are considered in accordance with theBuilding National Regulations (No. 6) as shown in Table 2.

Table 2. Story Applied Load (Dead and live)

Load	Roof	Floors
Partitions (dN/m^2)	-------	100
Dead Load (dN/m^2)	500	600
Live Load (dN/m^2)	150	200

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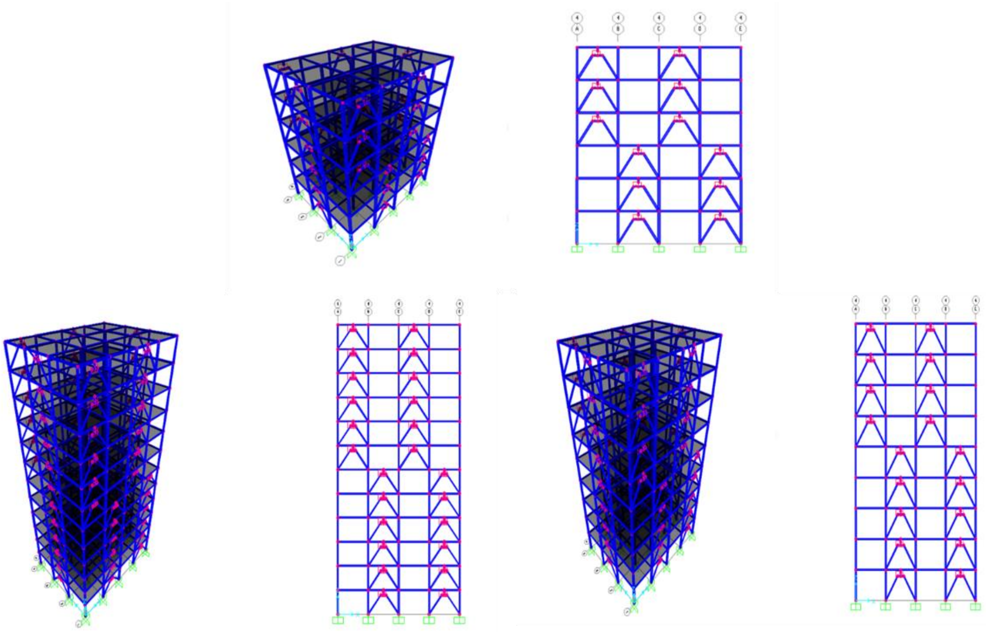

Figure 1. Sap2000 Simulation of 6, 9 & 12-Story Building

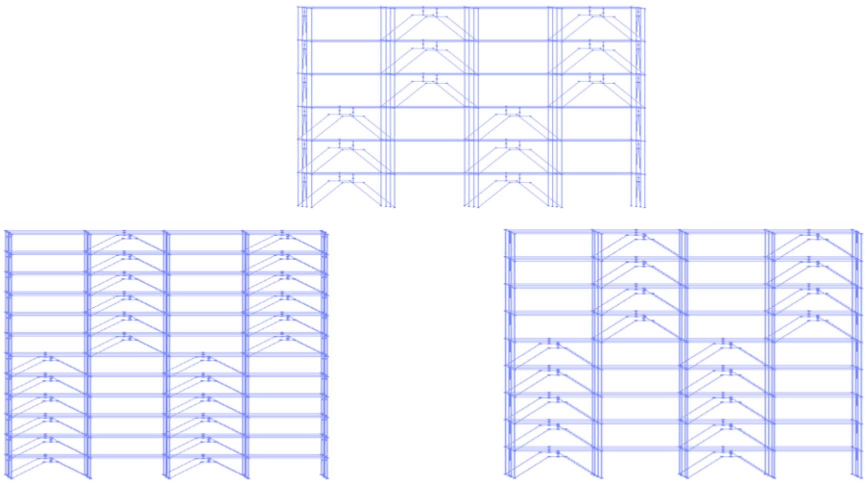

Figure 2. Opensees Simulation of 6, 9 & 12-Story Building

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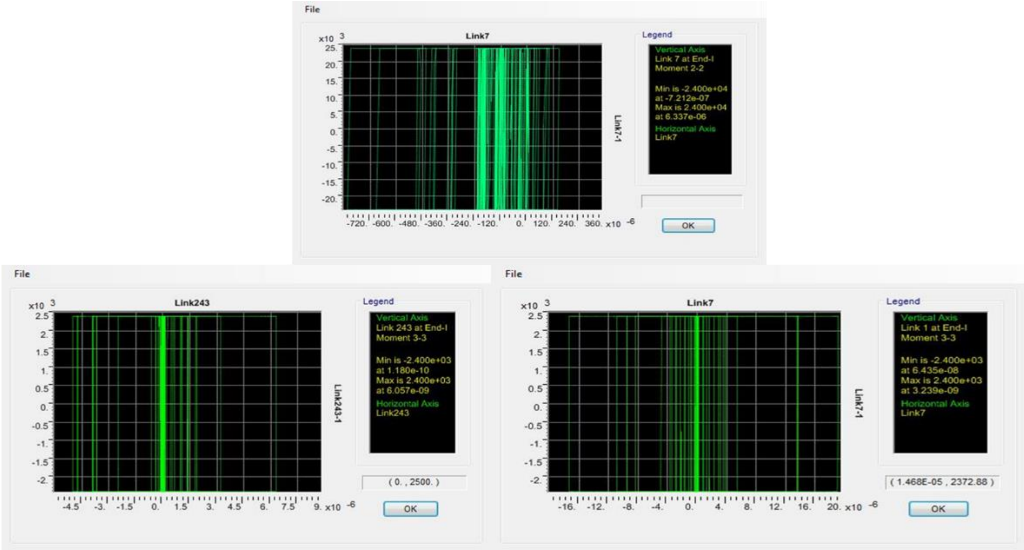

Figure 3. Hysterias Form of Damper in 6, 9 & 12-Story Buildings

6. Study of Story Drifts

The story drifts (relative displacement of floors) for all 6, 9 and 12 –story buildings have been calculated and the maximum drift in altitude for various earthquakes has been shown in the following figures. The main period of the studied buildings in this research for 6, 9 and 12-story buildings is equal to 9.1, 1.8 and 3.2 seconds, respectively. According to the Code of Practice - 2800 (paragraph 2-5- 4) (12), the actual relative drift of the structure at the mass center location for buildings with period greater than or equal to 0.2 seconds, should not be greater than 0.02 height. After applying acceleration, the story drifts of the surveyed building were graphed. From these diagrams, it is observed, the design of the structures and application of the seismic load per Code of Practice – 2800 (4th edition) and after the addition of rotational friction dampers, there was a significant reduction in the values of the story drifts. In the following, graphs, story drifts for all buildings are shown in non-damped and damped states and the results are considered for different situations.

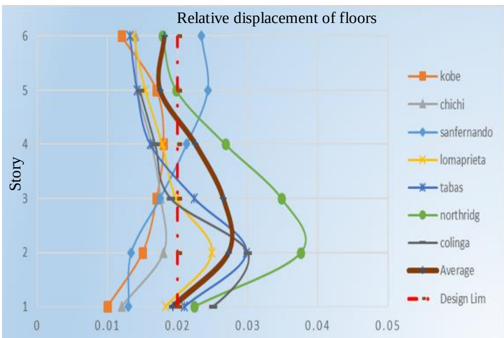

Figure 4. Story Drifts in 6-Story Building without damper

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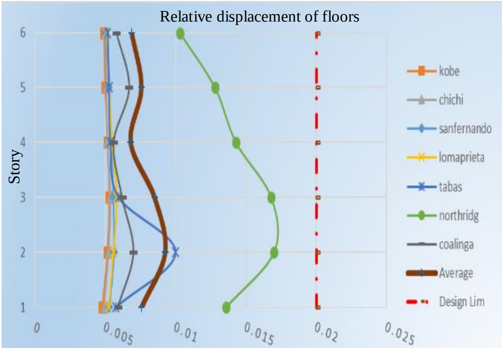

Figure 5. Story Drifts in 6-Story Building with damper

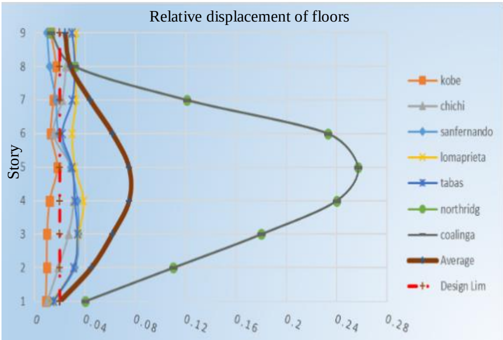

Figure 6. Story Drifts in 9-Story Building without damper

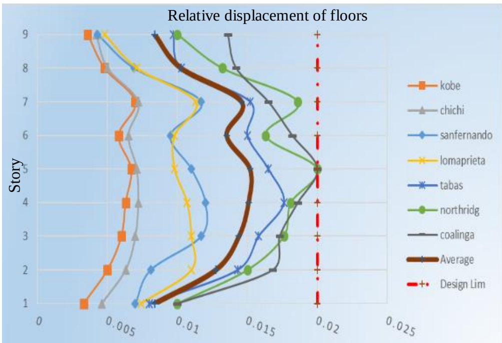

Figure 7. Story Drifts in 9-Story Building with damper

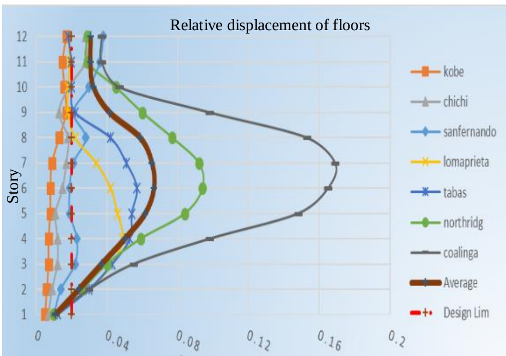

Figure 8. Story Drifts in 12-Story Building without damper

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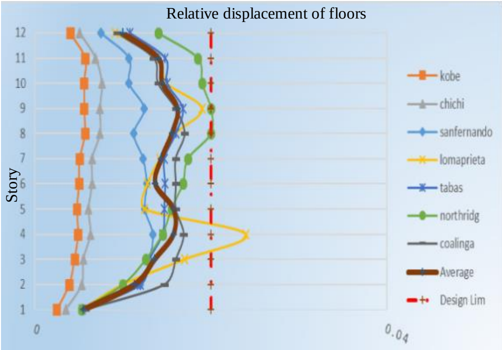

Figure 9. Story Drifts in 12-Story Building with damper

7. Investigate the Results of the Rooftop Displacement

The average amount of roof swing for the surveyed buildings is shown under seven records of the near-field in the non-damped and damped scenarios. The decrease in displacement of the roof top after adding dampers to the frames have been compared.

As illustrated by the diagrams, for all 6, 9 and 12-story studies buildings, a considerable amount of displacement reduction occurs in the roof top with the addition of a damper to the frames, which shows the effect of the dampers on the floor.

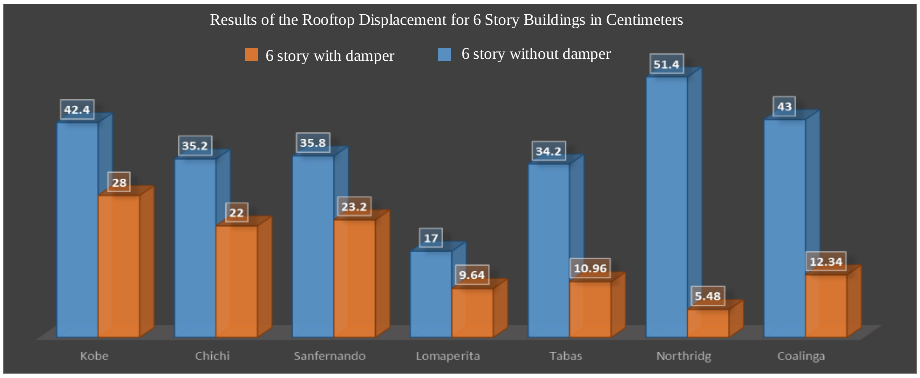

Figure 10. Roof displacement in 6-Story Building (cm)

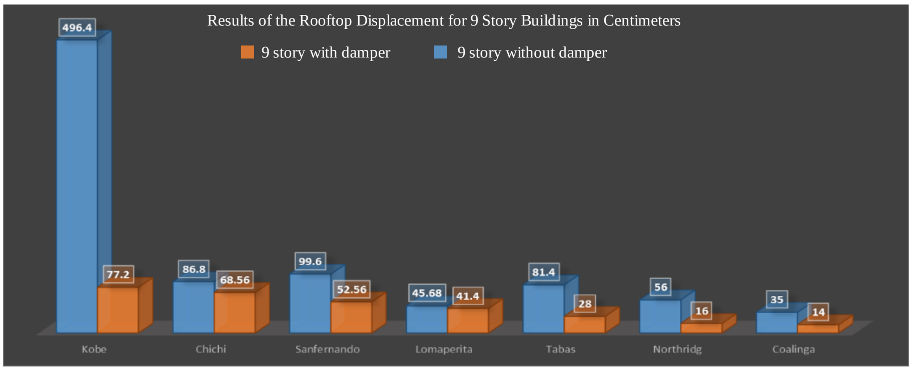

Figure 11. Roof displacement in 9-Story Building (cm)

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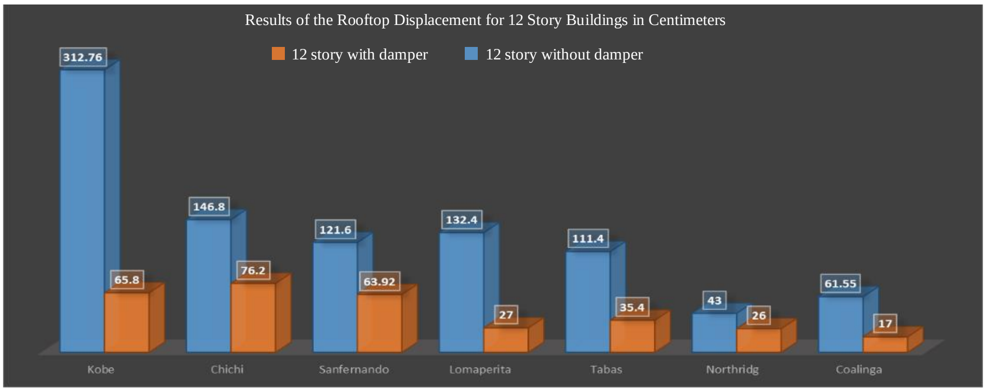

Figure 12. Roof displacement in 12-Story Building (cm)

8. Conclusion

The use of friction damper in the buildings under study has greatly reduced the relative displacement of the stories and reduced all values to the extent permitted by the regulations.

Adding a rotational friction damper to buildings causes a large part of the intake energy to be absorbed by the dampers and greatly reduces hysteresis energy. Due to the fact that the hysteresis energy is directly related to the damage, the damage to the structure also greatly decreases. By calculating the damage of the stories and the damage to the entire building, it is observed that the damage in structures with higher number of floors is higher, so that for buildings 9 and 12 stories, the structure is severely damaged and by adding the damper, it significantly reduces the amount of damage.

By comparison of the base shear in the studied buildings, the results show that with the increase in the number of floors, the amount of base shear also increases. By adding a rotary friction damper to the buildings, the amount of shear is significantly reduced.

By comparing the displacement values of the roof before and after the damper is added to the structure, it is observed that the dampers greatly reduce the amount of roofing displacement.

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