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Seismic Behavior of Multi-Storey Structure Using Different Energy Dissipation Devices A-review

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Abstract: Earthquake is a most disaster event, responsible a lot of structural damage and casualties worldwide on the earth's surface without any early warning. The trends in using dampers in buildings and tall buildings, increasing yearly based on their outstanding feature during an earthquake event. Typically, there are four types of energy dissipation device system such as friction damper, viscous damper, viscoelastic damper and metallic damper. The theoretical and experimental study results indicate that all fourth types of dampers can be able to minimize the structural damages and cracking during an earthquake occurrence event. But only viscous damper device has an acceptable feature against of earthquake forces as compare to other kinds of damper devices in symmetric and asymmetric building plan configurations as well. Based on the reviews, a viscous damper device system plays major role in reducing the lateral displacement of buildings about 30% to 85%, inter-storey drift of building about 60% to 80% and 1487.82KN drop in base shear of structural components in symmetric and asymmetric building plan configurations upward as compared to friction dampers, viscoelastic dampers and metallic dampers. Contradictory, dampers can decrease the construction cost limitation of multi-storey structures economically rather than conventional buildings.

Keywords: Friction Damper, Viscous Damper, Viscoelastic Damper and Metallic Damper

1. Introduction

From the past decades, the world has experienced a number of disaster earthquake with causing loss of human's life and properties due to collapse and severe damages of structures [1]. The structural damages during an earthquake hazard clearly clarify that the buildings such as residential buildings, infrastructures and industrial buildings should be designed and constructed to overcome safely lateral and horizontally under earthquake forces without any structural damage and cracking [2]. Based on the structural design, nowadays the using seismic response control devices are offered widely in the engineering field. Commonly, the structural devices are classified namely active energy dissipations, semi-active and passive energy dissipations [3]. The main purpose using of passive devises to minimize the effect of earthquake energy on structural members and reducing amount of structural cracking during an earthquake event [3]. Basically, there is no required any external power supply for passive device as compared to semi-active and active devices [5]. The processing of active control devices is controllable and need some amount of external energy supply which attached to the structure [4]. The semi-active devices are the combination of both active and passive device [4]. Hence, in this review different types of passive device system are evaluated and recognized according to their functions against of earthquake forces.

2. Principles of Damper

Dampers are the passive devices system which is designed and manufactured to protect and control, structural cracking, improve the stiffness, strength and performance of the structural members and prevent injuries in the residence by dissipating energy and minimizing displacement in structure during an earthquake in earthquake hazard zones as well [6]. Dampers are the passive devices system which is designed and manufactured to protect and control, structural cracking, improve the stiffness, strength and performance of the structural members and prevent injuries in the residence by dissipating energy and minimizing displacement in structure during an earthquake hazard zone as well [7].

2.1. Friction Damper

Friction damper device is a composite of solid metal material and friction surfaces which absorb energy with friction surfaces between them, rubbing against each other to reduce energy comes from the ground acceleration close to zero. The Friction damper is one of the most effective and economical system to dissipate kinetic energy from moving body and stop vibration of the building by dissipating energy in friction as shown in figure 1 and figure 2 [7].

Figure 1. *Installed friction damper to building [7].*

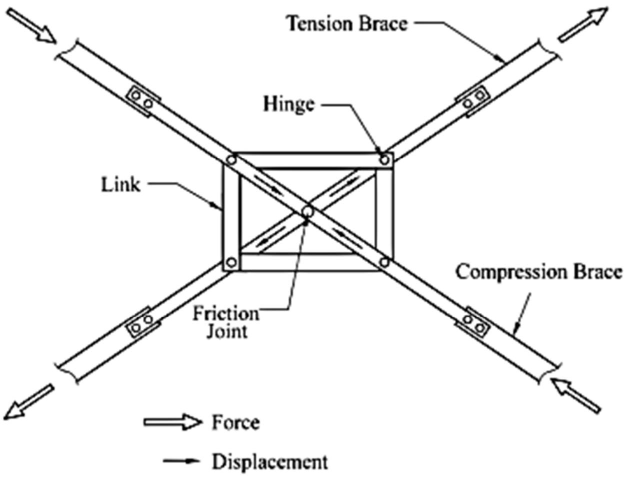

Figure 2. *Detailing of friction damper [19].*

2.2. Viscous Damper

Viscous damper composites of stainless steel piston, steel cylinder separated into two chambers by the piston head. In this type of damper, the energy dissipates by the flow of fluid existent inside the cylinder. Viscous dampers basically use for high rise building to reduce energy produced by earthquake and wind load excitations as shown in figure 3 and figure 4 [8].

Figure 3. *Installation of viscous damper to building [9, 11].*

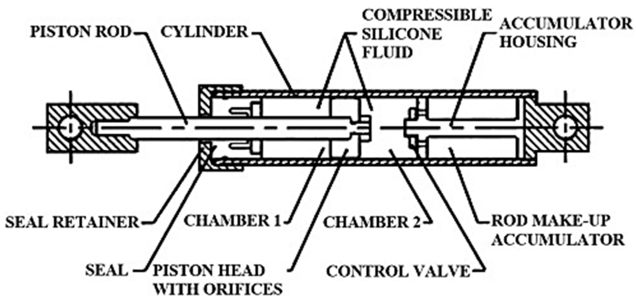

Figure 4. *Detail of viscos damper [4, 8, 20].*

2.3. Viscoelastic Damper

Viscoelastic dampers are consistent of viscoelastic layer materials which are often used for the reduction of earthquake force and wind load vibrations produced in buildings. Viscoelastic damper commonly absorbs the energy by using solid control sharing material as shown in figure 5 [9].

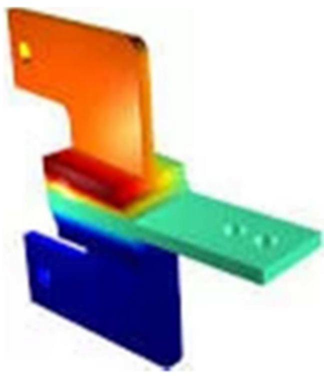

Figure 5. *Viscoelastic Damper [9].*

2.4. Metallic Damper

Typically, metallic dampers are made from the steel frame and lead for energy dissipations. This kind of damper is usually used to prevent the transferred energy to the structure before submission and behave non-linearly element during an earthquake occurrence. The materials are used in metallic damper deforms so many while the structure vibrates during an earthquake event and will not return to its original positions. By installation of metallic damper into the building The structural response can reduce and its effectiveness and low cast are now well recognized and tested in the past as shown in figure 6 and figure 7 [9].

Figure 6. *Metallic damper installed to the building [21].*

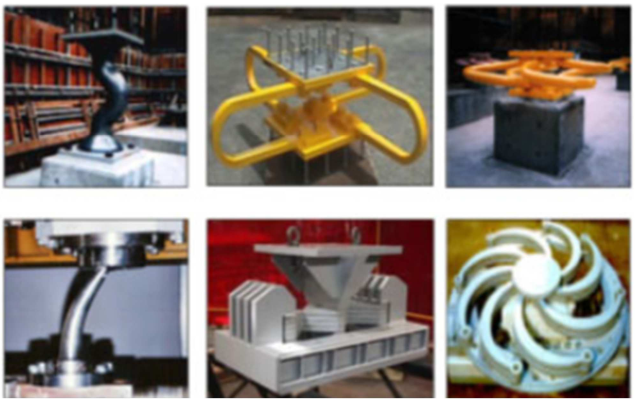

Figure 7. *Different types of Metallic Damper [9].*

3. Literature Review

This review presents an overview of previous studies which was done by researchers worldwide. The main aim of this research is to identify and interpret various methodologies to superlative approach for our future research.

Xiaoli Wu, et. al (2020) Presented and modeled a nine storey steel building based on the chines seismic design, code near-fault earthquakes, using different dampers such as brace dampers, friction dampers, self-centering dampers, viscous dampers and viscoelastic dampers. The results indicate that the building damper high seismic response and possible damper of failure under near fault earthquake excitations. Then, the influence of the damper was investigated damper failure at the building plan with self- centering damper [10].

Anshul Malhotra et al. (2020) Explored influence of friction damper of symmetric and asymmetric connected steel buildings under different earthquake and wind load. A steel building with different friction damper from five to twenty storey modeled as a plane structure with mass lumped at each joint node. The seismic response of connected and unconnected buildings assessed in terms of top storey displacement and acceleration under seismic and wind load excitations. It was shown that friction damper helps to reduce the gap and seismic response of the adjacent asymmetric building as compare to symmetric building with 30% reduction gap as well as minimizing its pounding [12].

Usha and Prabahkara, (2017) Focused on the effect of friction dampers in multi-storey RC buildings using IS-2002 Indian code of practice. The structure was modelled and analyzed using static analysis, response spectrum method and time history analysis using SAB-2000 software. The results of parameters as time history, base shear, lateral displacement and the inter-storey drift was compared with and without friction damper in the structural system [13].

Puneeth and Praven (2018) Concentrated on the analysis and modeling of an eight storey building with symmetric plane configuration using ETABS 2015 software. The response spectrum function method was used for dynamic analysis. To control the seismic analysis and increase the stiffness of the structure, viscous dampers are provided to install on the structure. After analysis, the results show 30% to 85% reduction in lateral displacement, 60% to 80% decrease in inter story drift and 1487.82kN drop in base shear of structural members [4].

Abhisinah et al. (2014) Considered the seismic response control of asymmetric three storey building with regular shape, C shape, L shaped and T shape plane configurations under various earthquake records using viscous damper and designed in ETABS software. It was concluded that viscous damper is effective for controlling the seismic response of asymmetric buildings under various earthquake records. The results shown between 22.27%-73.80%, reduction in displacement, 2.648% -73.80% decrease in inter-storey drift and acceleration 3.05%-63.07% reduction was found for asymmetric building under several earthquake records [14].

Yousef Zandi, et al (2012) Preformed seismic response of a number of 2D model frame structure in “opensees” software installation of viscoelastic damper for several damping ratios. The non-linear dynamic analysis was done under horizontal earthquake acceleration to consider the reduction amount of lateral displacement and base shear of structural members. The results indicate 25% damping in viscoelastic damper and 25% up to 56% reduction value of base shear and lateral displacement in structural member [15].

U. Vijay et al. (2015) Investigated the seismic influence of viscoelastic damper due to overall increases in the damping ratio of the RC structure significantly and improvement in dynamic performance of sensitive structures. A finite element analysis was done in ETABS software. In order to clarify the influence of viscoelastic damping, a comparative and analytical study was done between bare without damper and damped structure. The results are shown a specific rise up in damping ratio about 2% as compared to the RC structure without damper. The influence of adding viscoelastic damper reduced the seismic parameters as drift, displacement, shear force and overturning moment of structure about 4%-20% respectively [16].

Amadeo Benavent et al. (2021) Conducted an extreme experimental work using static cyclic tests and dynamic shake table test for RC buildings with additional of metallic damper. After testing the results, four phases were noticed in the response of buildings. A hysteretic model relation force-displacement curve predicted under cyclic loading for damper system. The model reached accurately higher stiffness and strength under large deformation and ultimate energy dissipation. The capacity of metallic damper was found depending on the different phases in which fail. Contradictory, it was concluded that the metallic damper has stable hysteric, ultimate energy dissipation and cyclic behavior [17].

Roman and Dipti (2018) Presented a strengthening technique for two storey large scale RC frame spacemen test with a combination of metallic damper under pseudo earthquake records to investigate its seismic performance of the damper under different amplitudes of selected ground motions. A numerical model using opensees software was developed to predict the seismic behavior of RC strengthening and both pushover and dynamic analysis was conducted to predict the seismic response of RC frame structures. The results illustrated good correlation between numerical and experimental results as shown in figure 8 [18].

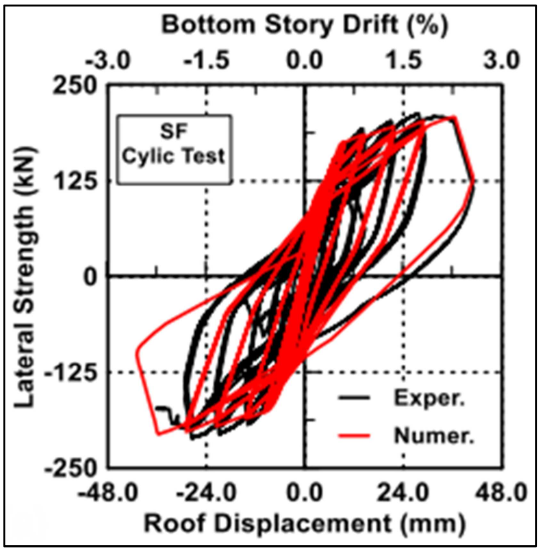

Figure 8. *Comparison of experimental and numerical results [18].*

4. Conclusion

Earthquake is a major threat of structural collapse and damages in high seismic regions worldwide, especially for the countries which are located near an earthquake fault and pacific "Ring of fire" This study mainly focuses on using of various types of dampers which are friction dampers, Viscous damper, Visco-elastic damper and metallic damper in symmetric and asymmetric building plane configurations. Numerous research had been done regarding damper device system around the world using different mythologies to identify their influence technical and economical for construction of buildings in high seismic regions. All the passive devices have the best performance against of the earthquake load, but only viscous damper can be able to produce outstanding performance symmetric and asymmetric plane configuration buildings about 30% to 85% decrease percentage in lateral displacement, 60% to 80% reduction in inter-storey drift and 1487.82KN drop in base shear of structural member when compared to friction damper, viscoelastic damper and metallic damper. Therefore, the usage of this system will reduce the construction cost of building up to 20% when compared to conventional building.

5. Discussion

Basically, the important factors as regular plane configurations, height, straight elevations view, stiffness, mass and ground motion of the buildings play major roles on seismic behavior of buildings in high earthquake hazard zones. The rigidity and strength materials used for developing of damper devices also important and need to accurately consider. The trends in using of damper devices have been changing from past decades until present. By installation of different energy dissipation at the buildings plane configurations can be able to minimize the structural collapse and cracking under different earthquake motions. From past reviews, only viscous damper plays major role in reducing of percentage drifts at building within 60% to 80% as compared to other kinds of energy dissipation devices and can protect the construction cost of buildings in high seismic pone zones worldwide.

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