Innovative Brace Damper System for Mitigating Seismic Response in High-Rise Steel Structures

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Abstract

This study investigates the seismic response of a G+14 steel frame building with composite columns using fluid viscous dampers. The effectiveness of these dampers is assessed through analysis employing the Equivalent Static Method, Response Spectrum Method, and Time History Analysis in ETABS. Results indicate a significant 40–60% reduction in displacement and storey drift, underscoring the efficacy of fluid viscous dampers in enhancing structural resilience. This research underscores the importance of innovative damping systems in mitigating seismic risks in tall steel buildings.

Keywords: Fluid Viscous Dampers, Response Spectrum, Time History, Storey Shear, Storey Drift, Displacement

1. Introduction

Seismic events result from sudden energy releases within the Earth's crust, causing seismic waves that propagate and induce ground shaking. Earthquakes, driven primarily by tectonic plate movements, are categorized into tectonic and volcanic types. Magnitude quantifies the energy release, while intensity reflects local effects.

Earthquakes pose significant risks, including structural damage and loss of life, but advancements in earthquake engineering and early warning systems aid mitigation efforts. Techniques such as base isolation, bracing systems, and dampers enhance seismic resilience.

Dampers, including fluid viscous dampers (FVDs), absorb seismic energy effectively. FVDs dissipate energy through fluid viscosity, offer adjustable damping, exhibit reliability, and require minimal maintenance. They are suitable for retrofitting existing buildings and can be cost-effective compared to other damping technologies.

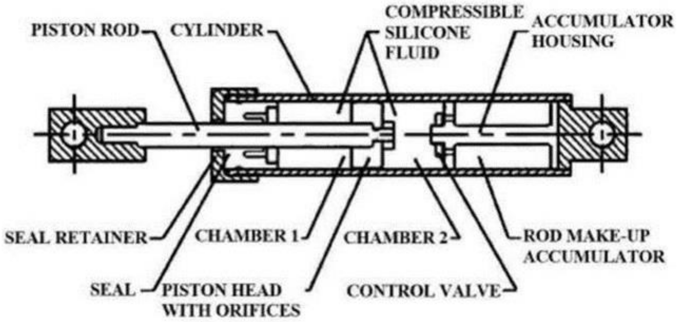

Figure 1: Fluid Viscous Damper

2. Objectives

- To contrast the seismic response of a G+15 building with and without fluid viscous dampers, considering various locations and patterns.
- To ascertain multiple parameters such as displacement fluctuations, storey drift, and base shear through the application of fluid viscous dampers.
- To check the effectiveness of various pattern and location of viscous dampers on the structure.

3. Methodology

The model considered in this project is steel structure with fluid viscous dampers. The dampers are arranged in different position which are X arrangement of FVD at corners, X arrangement of FVD at center, diagonal arrangement of FVD at corners,X arrangement of FVD at corners.

Table 1: Building Information

Building Information	
Plan Dimension	30mX40m
Structure Type	SMRF
Response Reduction Factor	5
Importance Factor	1
Soil Type	II
Damping Ratio	0.05
Height	45m
Floor Height	3m
Column	Composite column with ISMB 600 encased with 750mm X 750mm
Beam	ISMB 600
Secondary Beam	ISLB 350
Floor Loads	1KN(Dead) and 3KN(Live)
Wall Loads	9.94KN/m(External), 6.48KN/m(Internal), 4.14KN/m(Parapet)
Damper Type	FVD 250

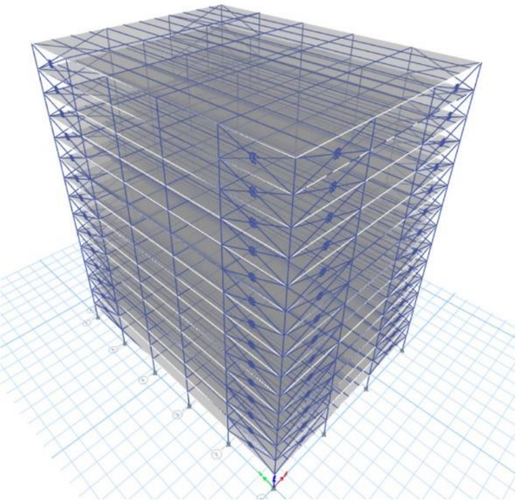

Figure 2: Model 1

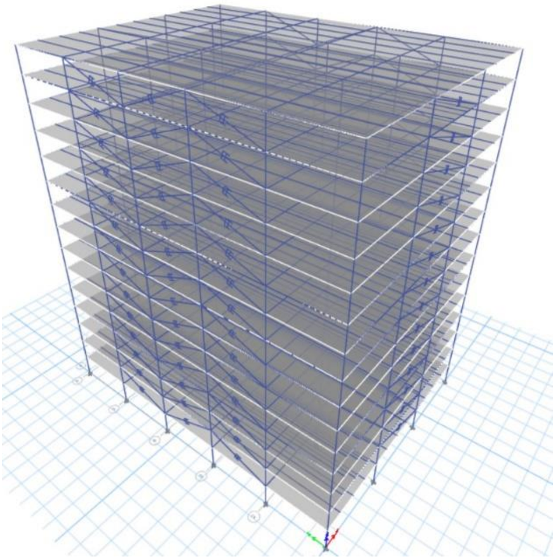

Figure 3: Model 2

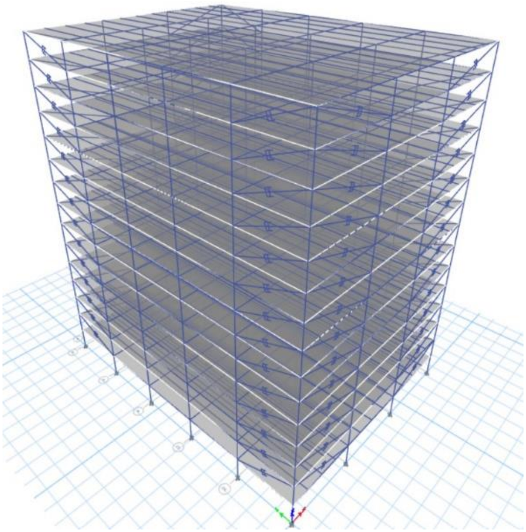

Figure 4:Model 3

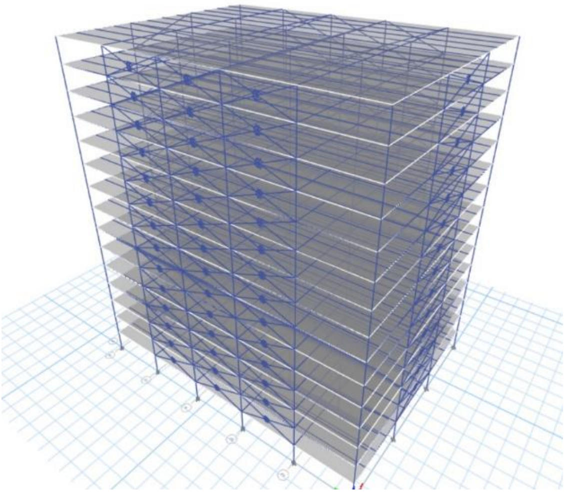

Figure 5: Model 4

4. Results and Discussion

Displacement

- By observing all models for EQ-X there is 65.63\%, 48.3\%, 56.7\%, 47.66 \% reduction in displacement for Model 1,2,3 and 4 repectively.
- For EQ-Y there is 48.26\%, 67.26\%, 41.88\% and 60.74\% reduction in displacement for Model 1,2,3,4.
- For RS-X there is 65.22\%, 57.72\%, 57.28\% and 51.17\% reduction in displacement for Model 1,2,3 and 4.
- For RS-Y there is 54.78\%, 66.17\%, 45.13\% and 59.95\% reduction in displacement for Model 1,2,3 and 4.
- For TH-X there is 72.2\%, 74.24\%, 69.6\% and 71.62\% reduction in displacement for Model 1,2,3 and 4.
- Finally for TH-Y there is 63.81\%, 71.37\%, 61.45\% and 56.98\% reduction in displacement for Model 1,2,3 and 4.
- According to the results obtained we can reduce the storey displacement by providing the fluid viscous dampers as X-bracing in the middle shows better reduction in displacement by taking the average for all cases.

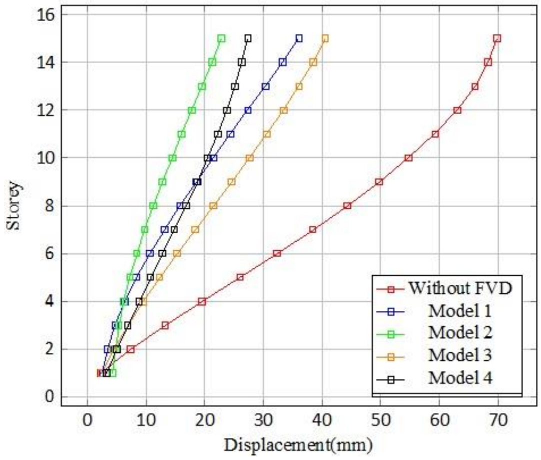

Figure 6: Displacement in EQ-X

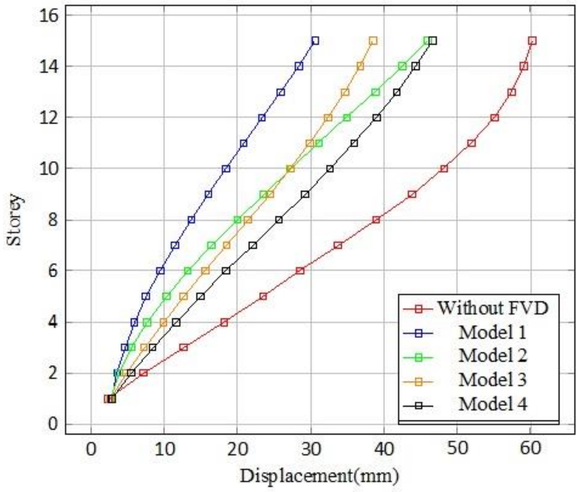

Figure 7: Displacement in EQ-Y

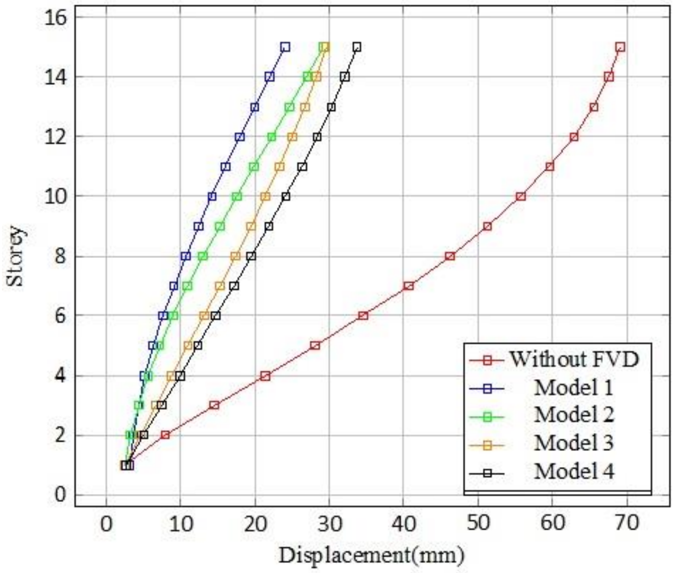

Figure 8: Displacement in RS-X

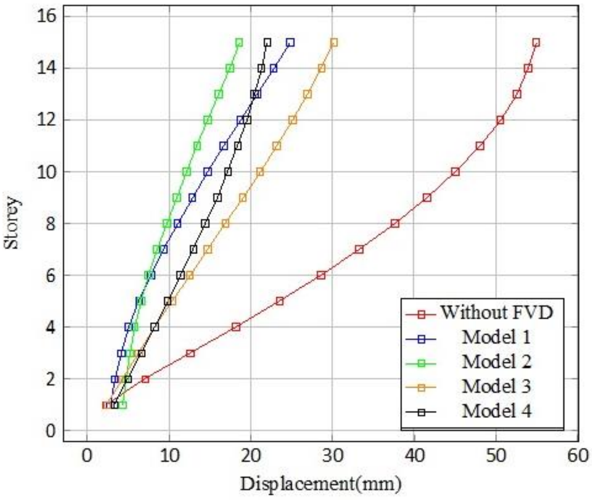

Figure 9: Displacement in RS-Y

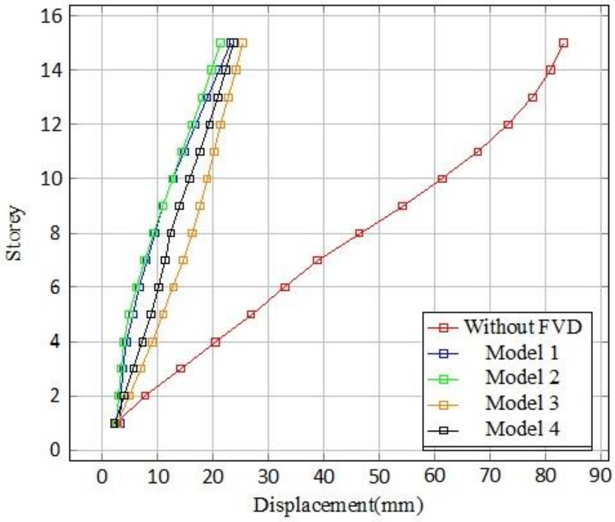

Figure 10: Displacement in TH-X

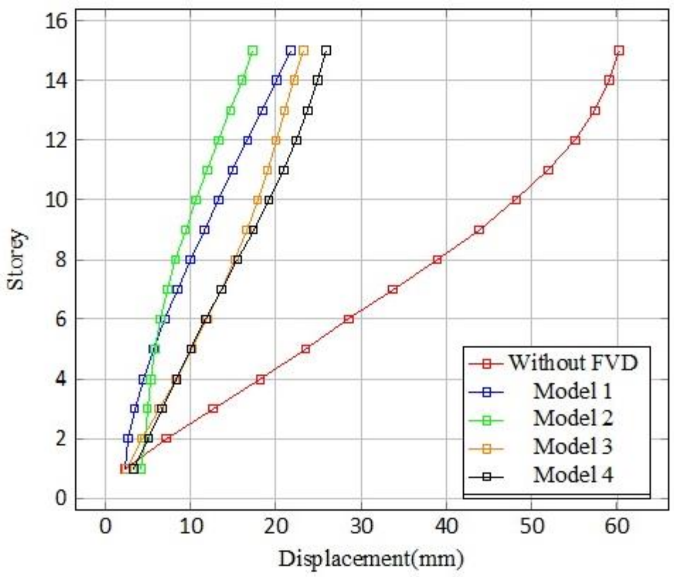

Figure 11: Displacement in TH-Y

Storey Drift

By observing all models we can observe that maximum storey drift occurs at storey 5 and 6.

In the X-direction across all cases it is observed that Model 1 gives the best result and, in the Y-direction Model 2 gives the best result.

In the X-direction there is 79.75\%, 68.72\%, 82.02\%, 75.23\%, 81.37\% and 76.4\% in load cases EQ-X, EQ-Y, RS-X, RS-Y, TH-X and TH-Y respectively for Model 1 compared to that without fluid viscous dampers.

In the Y-direction there is 68.17\%, 83.33\%, 75.9\%, 84.45\%, 80.75\% and 84.79\% reduction in storey drift in load cases EQ-X, EQ-Y, RS-X, RS-Y, TH-X and TH-Y respectively for Model 2 compared to that without fluid viscous dampers.

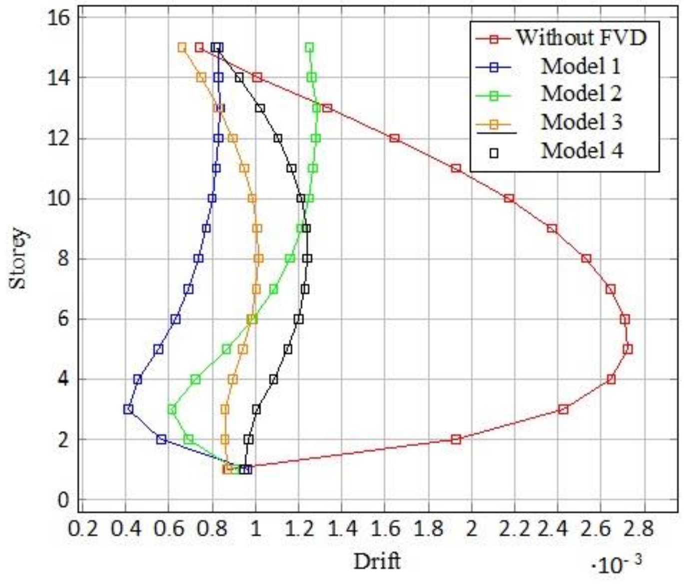

Figure 12: Storey Drift in EQ-X

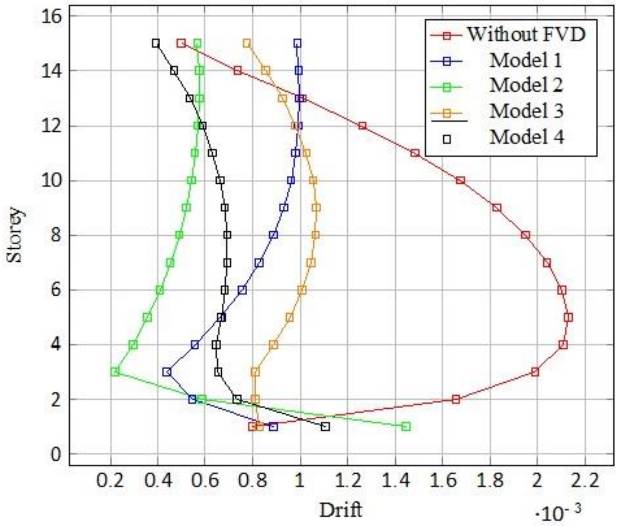

Figure 13: Storey Drift in EQ-Y

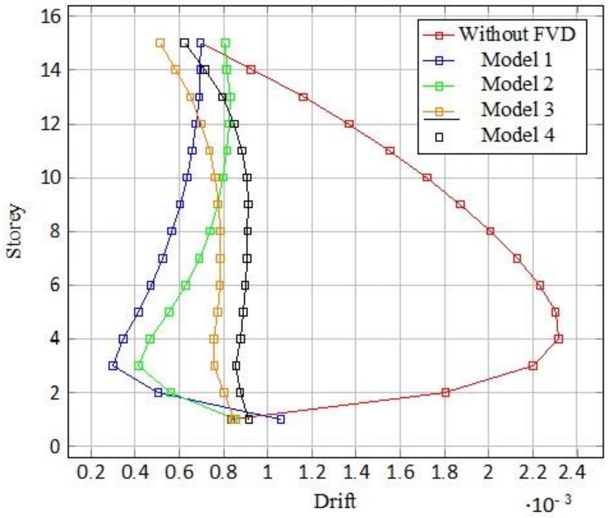

Figure 14: Storey Drift in RS-X

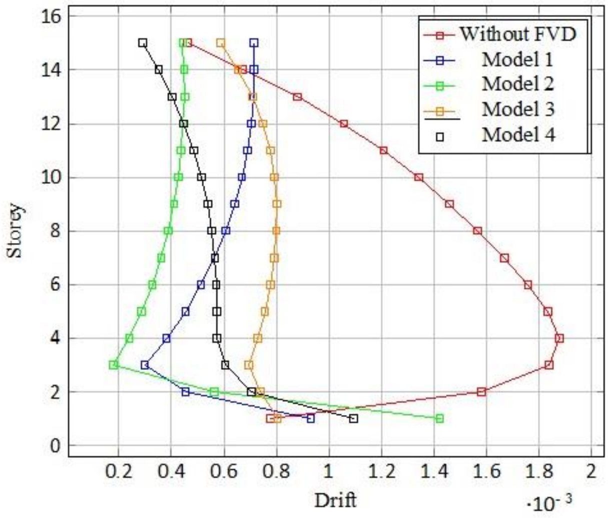

Figure 15: Storey Drift in RS-Y

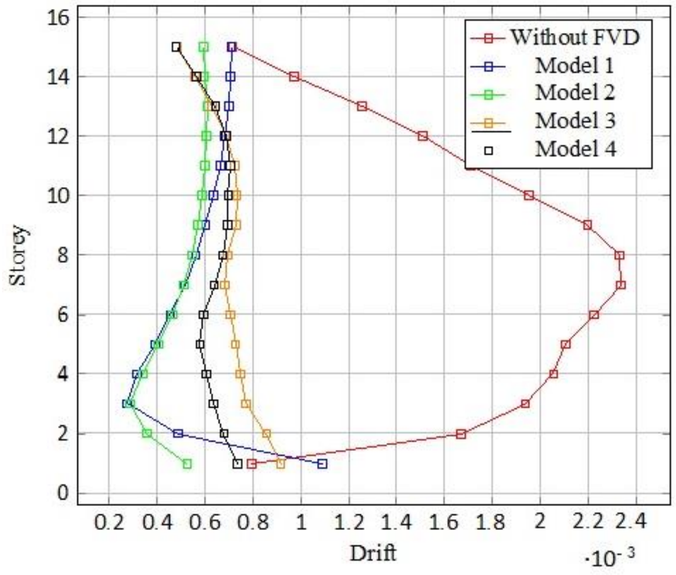

Figure 16: Storey Drift in TH-X

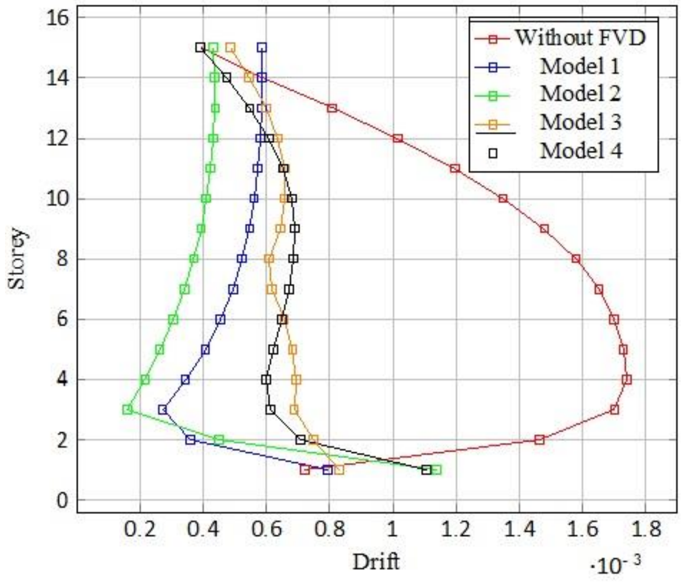

Figure 17: Storey Drift in TH-Y

Storey Shear

The storey shear value is derived from the cumulative lateral forces exerted on levels above the considered storey within the structure. Maximum shear occurs at the bottom stories, decreasing progressively towards the top. Below are the shear values for all models.

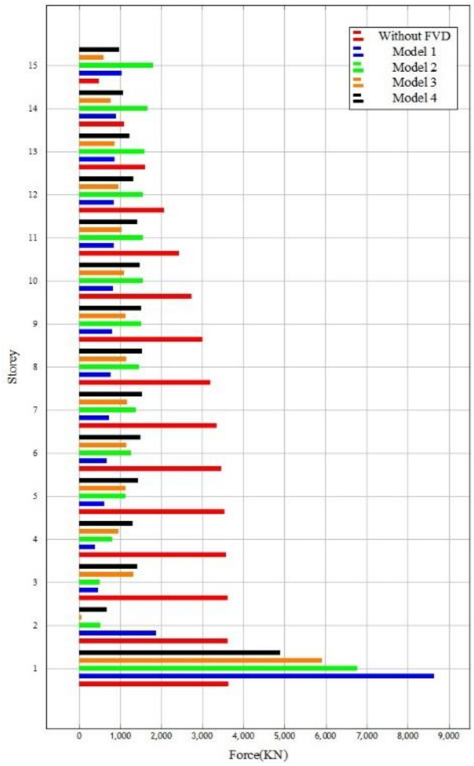

Figure 18: Storey Shear in EQ-X

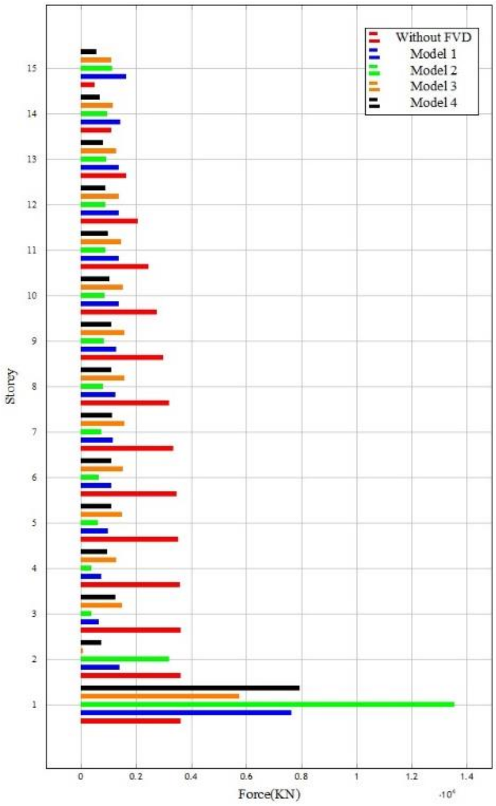

Figure 19: Storey Shear in EQ-Y

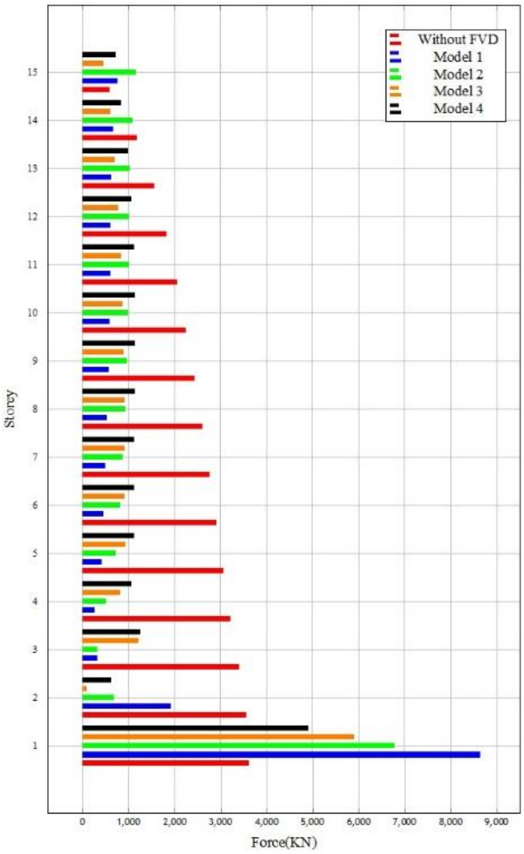

Figure 20: Storey Shear in RS-X

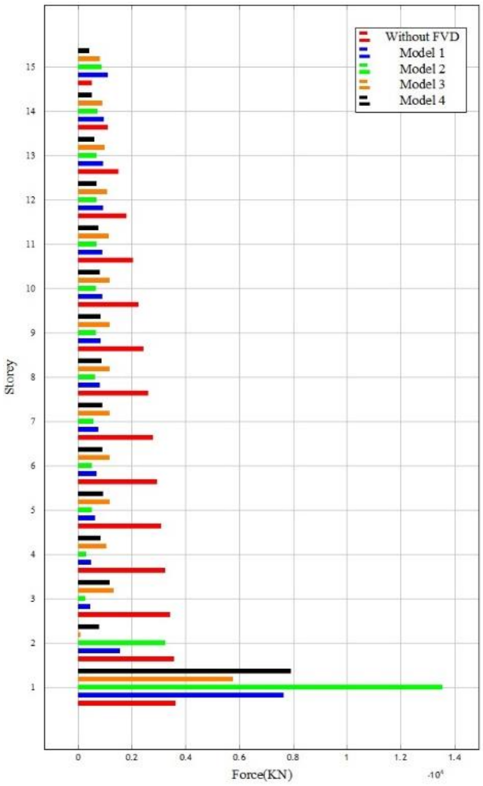

Figure 21: Storey Shear in RS-Y

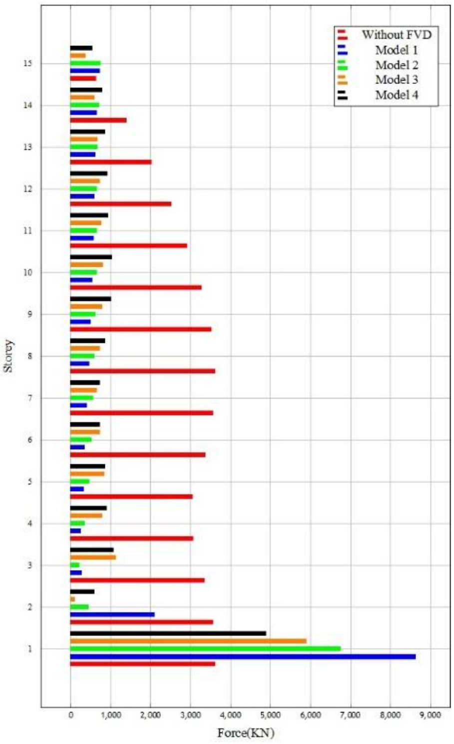

Figure 22: Storey Shear in TH-X

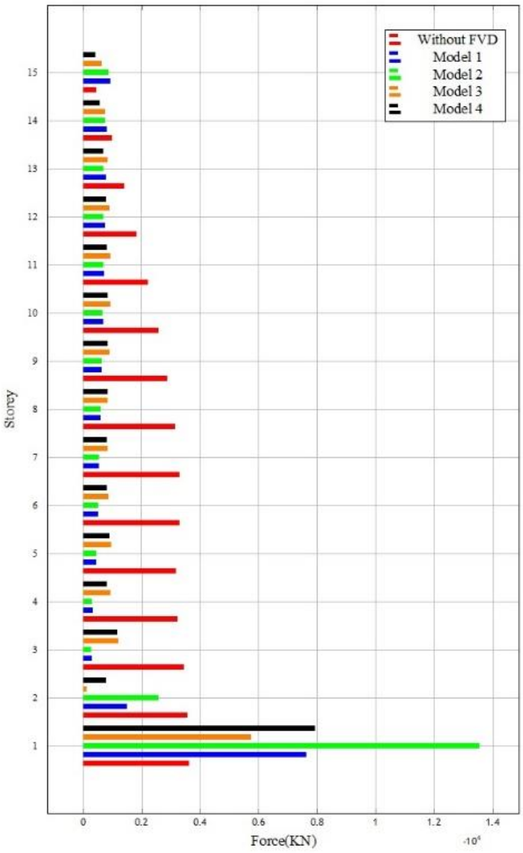

Figure 23: Storey Shear in TH-Y

5. Conclusion

Four patterns are used in this study to place fluid viscous dampers. Static earthquake load, response spectrum, and time history approach are used in the analysis, and characteristics such displacements, base shear, and storey drifts are compared for various models using ETABS software.

For Model 1, the static earthquake load results in a 65.63% reduction in displacement in the x-direction, a 48.26% reduction in the y-direction, and a 65.22% reduction in the x-direction response spectrum and a 54.78% reduction in the y-direction response spectrum.

For all seismic load instances (both dynamic and static), there is a reduction of 79.75% in storey drift in the x-direction and 68.17% in storey drift in the y-direction.

We compared several locations and patterns and discovered that Model 1 is the most efficient at dampening the seismic activity.

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