

# Comparison Of Seismic Performance Of High Rise Rcc Building For Various Configurations Of Fluid Viscous Damper

<sup>1</sup>Abhinesh Khatri, <sup>1</sup>Roshan Kumar Sah, <sup>1</sup>Sachin Lama, <sup>1</sup>Suyog Shrestha, <sup>2\*</sup>Bimal Ojha

<sup>1</sup>Department of Civil Engineering, Kantipur Engineering College, Affiliated to Tribhuvan University, Nepal

<sup>2</sup>Department of Civil Engineering, Thapathali Campus, Institute of Engineering, Tribhuvan University, Nepal

Corresponding email: \*bimalojha@tcioe.edu.np

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## Abstract

The vulnerability of reinforced concrete (RC) buildings to earthquake forces specially in seismically active region like Nepal highlights the need for improved seismic performance through the use of energy dissipation devices. This study investigates the effectiveness of fluid viscous dampers in improving the seismic behavior of a multi-storey RC building by comparing different damper configurations. A G+12 reinforced concrete building located in Kathmandu (Seismic Zone V) was modeled and analyzed using ETABS v19 in accordance with the provisions of NBC 105:2025. Response spectrum analysis was performed to evaluate the seismic response of five different structural models: a building without dampers and four models with fluid viscous dampers arranged in different configurations, including alternate bay all-storey, corner bay all-storey, alternate bay alternate-storey, and corner bay alternate-storey arrangements. The seismic performance of the building models was evaluated in terms of time period, storey displacement, storey drift, and storey shear. The results indicate that the installation of fluid viscous dampers significantly reduces storey displacement by about 45% compared to the building without dampers. Among the studied configurations, the alternate bay alternate-storey damper configuration demonstrated the most effective reduction in displacement and drift, providing better control of structural response while using fewer dampers compared to the all-storey configurations. Although the inclusion of dampers slightly increases storey shear due to additional damping forces, the overall structural performance is significantly enhanced. The findings of this research may contribute to the adoption of supplemental damping systems for improving earthquake resilience of buildings in seismic regions like Kathmandu.

**Keywords**—*Fluid Viscous Damper, Response Spectrum Analysis, Damper Configuration*

## 1. INTRODUCTION

Nepal lies within the seismically active Himalayan belt, a tectonically unstable region formed due to the ongoing collision between the Indian and Eurasian plates. This continental convergence results in high seismicity, making Nepal particularly prone to destructive earthquakes[1]. Several destructive earthquakes have occurred in Nepal in the past, including the 1934 Nepal–Bihar Earthquake, the 1988 Udayapur Earthquake, the 2015 Gorkha Earthquake and the 2023 Jajarkot Earthquake causing widespread destruction of structures[2]. The earthquake sequence resulted in significant structural damage to both traditional masonry buildings and reinforced concrete (RC) buildings, highlighting the need for improved seismic design and performance of buildings in the country[3][4][5].

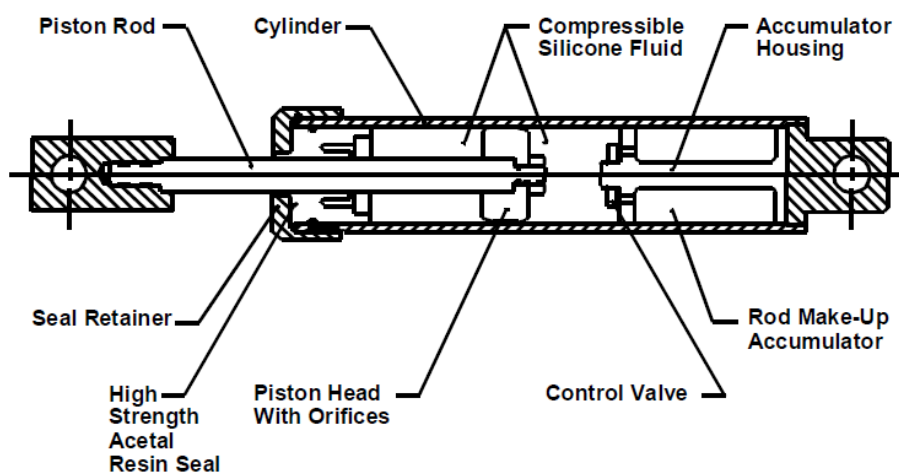
In order to address the seismic risk, Nepal has developed, implemented and continuously updated the seismic design building code NBC:105[6] for estimating seismic forces and ensuring adequate strength, stiffness and ductility. Reinforced concrete frame structures designed according to these provisions are expected to resist seismic forces while maintaining acceptable levels of damage[7]. However, conventional design approaches mainly focus on ensuring life safety and preventing collapse rather than minimizing structural damage during strong earthquakes[8].

During seismic events, buildings are subjected to dynamic lateral forces that cause vibration, displacement, and internal stresses. In conventional structures, the seismic input energy is primarily dissipated through inelastic deformation of structural members such as beams, columns, and joints[9][10][11]. While this mechanism prevents collapse, it may lead to significant structural and non-structural damage. Therefore, modern earthquake engineering has increasingly focused on structural control systems that enhance the seismic performance of buildings by dissipating seismic energy more efficiently[12]. The approach of handling lateral loads by structural control systems can be classified into three major categories based on amount of input energy needed: passive control, semi-active control and active control. Among these, passive control system being highly reliable, cost effective and require no external power to operate during seismic events, remains widely using in structural applications. The energy transferred from seismic forces to the structure will be absorbed by installing damping mechanisms like visco-elastic dampers, tuned mass dampers, steel dampers, friction dampers, fluid viscous dampers etc. Among these, fluid viscous dampers are widely used in modern structural control systems due to their high energy dissipation capacity, reliability, and effectiveness in reducing seismic response[13] [14] [15]. Therefore, this study focuses on fluid viscous dampers and investigates the comparative seismic performance of high-rise reinforced concrete buildings with and without dampers, considering various damper configurations.

### **Working of Fluid Viscous Damper:**

A fluid viscous damper (FVD) is a passive energy dissipation device that operates on the principle of viscous fluid resistance to reduce the dynamic response of structures

during earthquakes. The damper typically consists of a cylinder filled with viscous fluid (usually silicone oil) and a piston with small orifices attached to a piston rod as shown in Figure 1. Fluid viscous dampers transform the kinetic energy of building movement into heat before dissipating it into air in accordance with energy conservation principles[16].



**Figure 1:** Construction of Fluid Viscous Damper [17]

When a building experiences vibration due to seismic forces, relative movement occurs between structural members where the damper is installed. This movement causes the piston to move inside the cylinder, forcing the viscous fluid to flow through the small openings in the piston head. The resistance offered by the fluid to this flow generates a damping force, which is proportional to the velocity of motion. This process converts the kinetic energy of structural motion into heat energy, which is dissipated through the fluid. As a result, the damper reduces structural vibrations, storey displacement, and inter-storey drift, thereby improving the overall seismic performance and stability of the building.

In structural analysis, the damping force generated by a fluid viscous damper is commonly expressed as:

$$F = CV^{\alpha} \dots\dots\dots \text{Eq. 1}$$

Where,

F = damping force,

C= damping coefficient,

V= relative velocity across the damper,

$\alpha$  = velocity exponent (usually between 0.3 and 1.0).

## 2. METHODOLOGY

This study evaluates the seismic performance of a reinforced concrete (RC) multi-storey building with and without the use of fluid viscous dampers. The methodology involves numerical modeling and analysis of different structural configurations to compare their seismic response parameters such as storey displacement, inter-storey drift, and base shear. A G+12 storey reinforced concrete building with a square plan has been considered in this study, as it represents a typical mid- to high-rise structure commonly constructed in urban areas such as Kathmandu. Fluid viscous dampers are generally more effective for such building heights, and the square plan ensures a regular and symmetric geometry with uniform distribution of mass and stiffness, as recommended by NBC 105:2025. The structural modeling and analysis are carried out using finite element software ETABS. The building is assumed to be located in Kathmandu, which lies in Seismic Zone V, representing the highest seismic hazard zone in Nepal. For evaluating the dynamic behavior of the structure under earthquake loading, response spectrum analysis is performed in accordance with the response spectrum specified in NBC 105:2025.

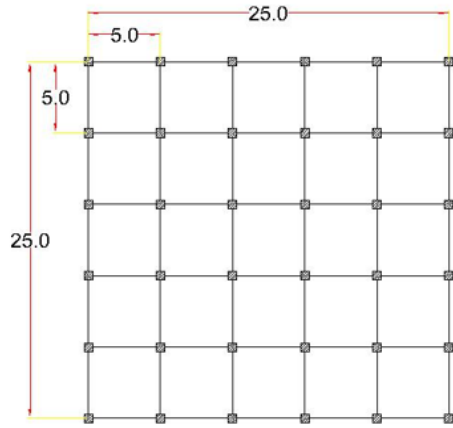
Five different building models were modeled in ETABS v19 with different configurations of fluid viscous dampers.

- a. G+12 RCC multi-storey building without damper
- b. G+12 RCC multi-storey building alternate bay fluid viscous dampers for all storeys
- c. G+12 RCC multi-storey building corner fluid viscous dampers for all storeys
- d. G+12 RCC multi-storey building alternate bay viscous dampers for alternate storeys
- e. G+12 RCC multi-storey building corner fluid viscous dampers for alternate storeys.

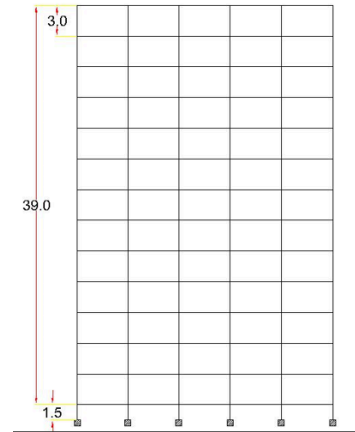
The configurations were chosen to represent different realistic damper distribution patterns that influence seismic performance, including:

- Alternate bay at all storeys: to ensure uniform distribution of damping along the height and across the plan, enhancing global energy dissipation.
- Corner bay at all storeys: to evaluate the effectiveness of dampers placed at the building perimeter, which also helps in controlling torsional response.
- Alternate bay at alternate storeys: to assess a cost-effective configuration with reduced number of dampers while maintaining acceptable performance.
- Corner bay at alternate storeys: to study the combined effect of reduced damper quantity and perimeter placement.

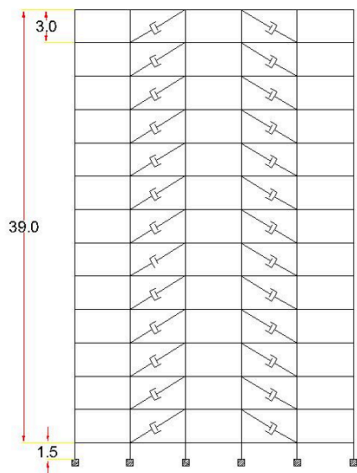
The structural responses obtained from the response spectrum analysis are compared in terms of time period, storey displacement, inter-storey drift, base shear, and overall structural behavior for different configurations of fluid viscous damper. Based on the comparative results, the effectiveness of different damper configurations in improving the seismic performance of RC buildings is evaluated.



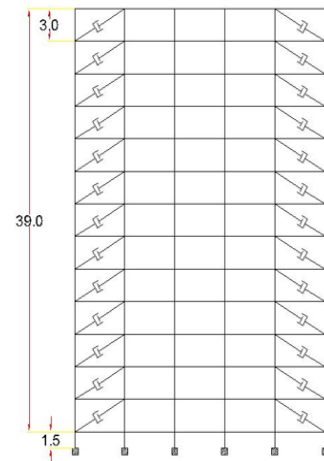
**Figure 2:** Typical Floor Plan of Building



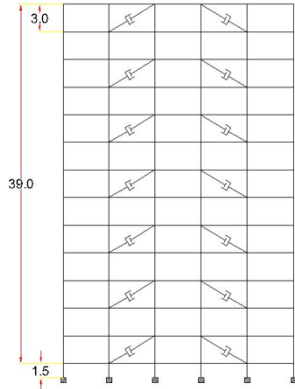
**Figure 3:** Building without damper



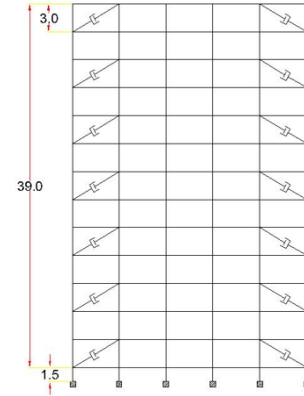
**Figure 4:** Alternate bay fluid viscous dampers for all storeys



**Figure 5:** Corner fluid viscous dampers for all storeys



**Figure 6:** Alternate bay viscous dampers for alternate storeys



**Figure 7:** Corner fluid viscous dampers for alternate storeys

#### A. Building Parameters:

- Type of building: Special Moment Resisting Frame
- Number of storeys: G+12
- Basement height: 1.5m
- Floor height: 3m
- Building height: 40.5m
- Number of bays in x & y direction: 5
- Length of each bay: 5m
- Size of beam: 400\*500mm
- Size of column: 600\*600mm
- Slab Thickness: 150mm
- Grade of concrete: M25
- Steel reinforcement Grade: Fe500
- Live load: 3kN/m<sup>2</sup>
- Soil Type: Soft Soil (Type D)

#### B. Damper Parameters (FVD250)

The damper properties are kept constant throughout the study, while the damper location and configuration are considered as the primary variables to evaluate their influence on the seismic performance of the structure. The damper properties for FVD250 adopted from various literatures [18] [19] [20] are mentioned below.

- Weight: 250KN

- Mass: 44 kg
- Effective Stiffness: 84723kN/m
- Effective damping: 12821kN-s/m
- Stiffness: 178804kN/m
- Damping: 0.05
- Damping Exponent: 0.3

The value of damping exponent reflects a nonlinear damper behavior, which is widely used in seismic applications as it provides an effective balance between energy dissipation and force demand.

### 3. RESULTS AND DISCUSSION

The seismic performance of the G+12 reinforced concrete building models was evaluated using response spectrum analysis in ETABS v19, following the provisions of NBC 105:2025. The comparison of structural responses mainly focused on parameters such as time period, storey displacement, inter-storey drift and base shear.

#### A. Time period:

The fundamental time periods obtained from modal analysis for different damper configurations are presented in Table 1. The results indicate that the building without dampers exhibits the highest time period values, with the fundamental time period equal to 1.98 seconds. A higher time period generally indicates a more flexible structure, which tends to experience larger lateral displacements during seismic excitation.

**Table 1:** Time Period Results for Different Damper Configurations

Building Configuration	Fundamental Time Period (sec)
Without Damper	1.981
Alternate Bay all Storey	1.34
Corner Bay All Storey	1.35
Corner Bay Alternate Storey	1.35
Alternate Bay Alternate Storey	1.36

When fluid viscous dampers are introduced into the structural system, time period has reduced to about 1.34 – 1.36 seconds for different configurations of damper as shown in Table 1 which is a significant reduction by about 31%.

This reduction indicates that the presence of dampers increases the effective stiffness and damping of the structural system, thereby reducing its dynamic response. This improvement in dynamic behavior contributes to better seismic performance by limiting excessive vibration and displacement during earthquake loading.

### B. Storey Drift:

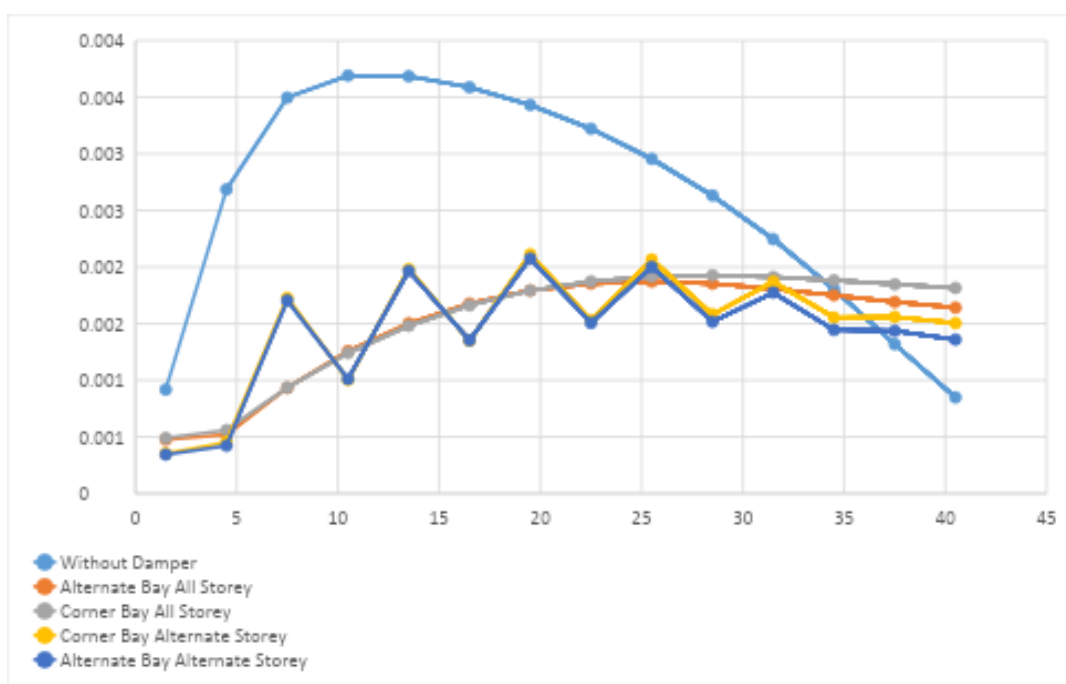
The storey drift results obtained from response spectrum analysis for different damper configurations are presented in Table 2 and Figure 8. The results show that the maximum storey drift in the building without dampers occurs around the mid-height of the structure, with a peak value of approximately 0.003691 at 10.5 m elevation. This indicates that the structure experiences significant lateral deformation under seismic excitation when no supplemental damping system is provided.

The introduction of fluid viscous dampers significantly reduces the storey drift throughout the height of the building. Among the studied configurations, the alternate bay alternate storey configuration shows the most effective reduction in storey drift, particularly in the middle and upper storeys. This indicates that the distribution of dampers in alternate bays at alternate storeys provides an efficient balance of stiffness and energy dissipation along the building height. The alternate bay all-storey and corner bay all-storey configurations also demonstrate considerable drift reduction compared to the building without dampers. Similarly, the corner bay alternate storey configuration shows improved performance compared to the reference model but with relatively higher drift values than the alternate bay alternate storey arrangement.

**Table 2:** Storey Drift Results for Different Damper Configurations

Storey Elevation (m)	Drift ( $\times 10^{-3}$ )				
	Without Damper	Alternate Bay All Storey	Corner Bay All Storey	Corner Bay Alternate Storey	Alternate Bay Alternate Storey
40.5	0.849	1.642	1.816	1.504	1.36
37.5	1.318	1.692	1.847	1.561	1.436
34.5	1.805	1.751	1.883	1.554	1.444
31.5	2.247	1.81	1.913	1.873	1.775
28.5	2.632	1.853	1.928	1.582	1.517
25.5	2.956	1.871	1.917	2.067	2.002

22.5	3.222	1.854	1.874	1.529	1.506
19.5	3.432	1.793	1.792	2.112	2.076
16.5	3.588	1.678	1.662	1.349	1.354
13.5	3.684	1.503	1.481	1.982	1.964
10.5	3.691	1.258	1.241	1.004	1.012
7.5	3.497	0.933	0.935	1.728	1.704
4.5	2.687	0.521	0.56	0.454	0.421
1.5	0.919	0.476	0.49	0.354	0.344



**Figure 8:** Comparison of Storey Drift for different configurations of damper

### C. Storey Displacement:

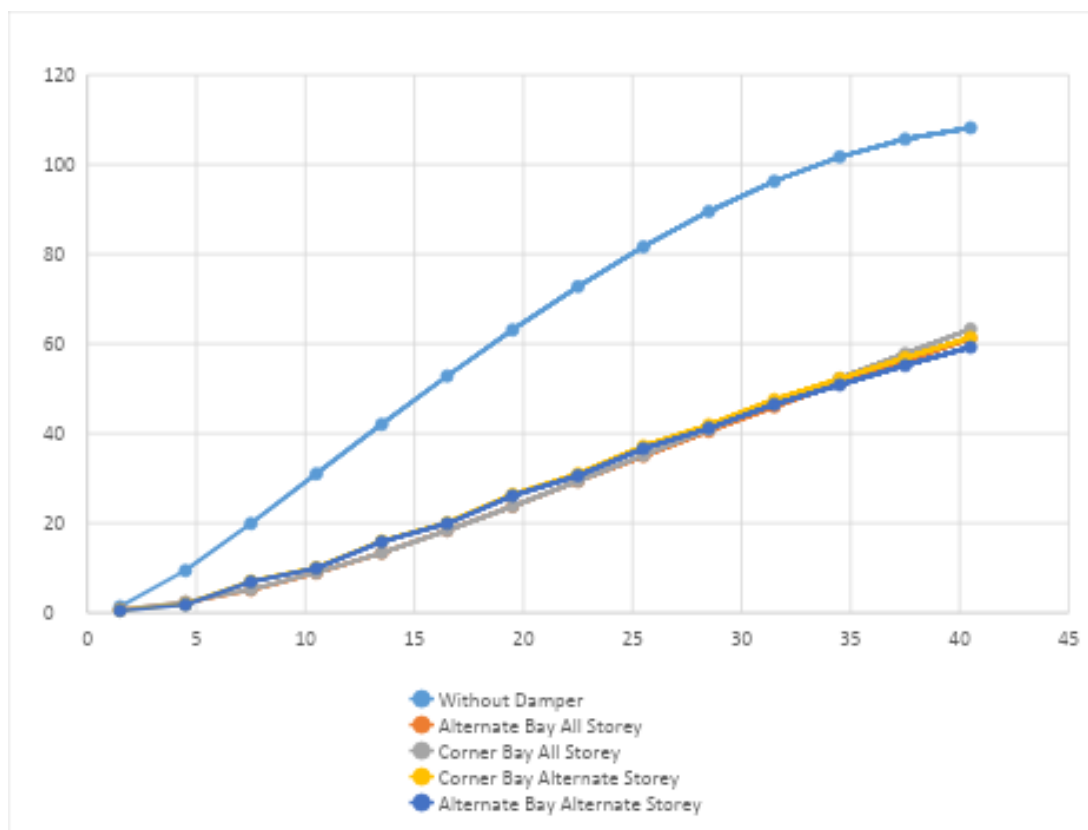
The storey displacement results obtained from the response spectrum analysis for different damper configurations are presented in Table 3 and Figure 9. The results show that the maximum displacement occurs at the top storey for all models. The building without dampers exhibits the highest displacement, reaching 108.21 mm at the roof level.

The installation of fluid viscous dampers significantly reduces storey displacement throughout the building height. Among the studied configurations, the models with

dampers installed at alternate bay alternate storey show greater reduction in displacement compared to those with other configurations. The alternate bay alternate storey configuration shows 59.23 mm top storey displacement which is about 45% reduction in top storey displacement compared to building without damper. The alternate bay all-storey configuration reduces the top displacement to 61.19 mm, while the corner bay all-storey configuration shows 63.28 mm. The configurations with dampers at corner bay alternate storeys also reduce displacement showing the lowest top displacement of 61.43 mm.

**Table 3:** Storey Displacement Results for Different Damper Configurations

Storey Elevation (m)	Displacement (mm)				
	Without Damper	Alternate Bay All Storey	Corner Bay All Storey	Corner Bay Alternate Storey	Alternate Bay Alternate Storey
40.5	108.21	61.19	63.28	61.43	59.23
37.5	105.66	56.268	57.834	56.919	55.146
34.5	101.704	51.193	52.292	52.235	50.839
31.5	96.29	45.939	46.644	47.572	46.505
28.5	89.548	40.509	40.905	41.953	41.181
25.5	81.653	34.949	35.122	37.206	36.631
22.5	72.785	29.335	29.37	31.004	30.626
19.5	63.118	23.773	23.747	26.416	26.11
16.5	52.821	18.395	18.372	20.08	19.881
13.5	42.056	13.36	13.385	16.032	15.818
10.5	31.004	8.85	8.943	10.088	9.927
7.5	19.93	5.075	5.221	7.077	6.891
4.5	9.438	2.276	2.416	1.892	1.778
1.5	1.378	0.714	0.735	0.531	0.516



**Figure 9:** Comparison of storey displacement results for different damper configurations

#### D. Storey Shear:

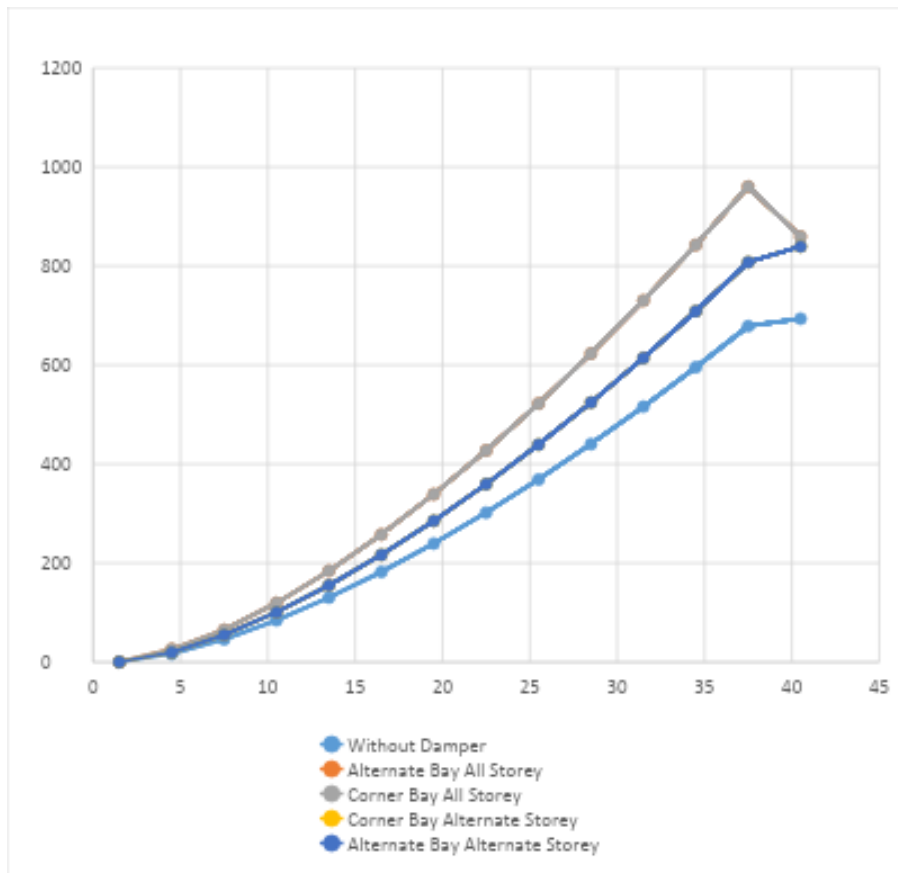
The storey shear results for different damper configurations are presented in Table 4 and Figure 10. From the results, it is observed that the storey shear is highest at the top storey and gradually decreases towards the base, which represents the distribution of seismic forces along the building height. The building without dampers shows lower storey shear values compared to the models with dampers.

The inclusion of fluid viscous dampers increases the storey shear values in the structure. This occurs because the dampers introduce additional damping forces that resist seismic motion, thereby increasing the internal force demand within the structural system. Among the studied configurations, the alternate bay all-storey and corner bay all-storey configurations show the highest storey shear values, indicating greater stiffness and resistance to lateral motion.

The configurations with dampers installed at alternate storeys show comparatively lower storey shear than the all-storey damper configurations but still higher than the building without dampers. This indicates that the distribution of dampers influences the force demand within the structure.

**Table 4:** Storey Shear Results for Different Damper Configurations

Storey Elevation (m)	Storey Shear (KN)				
	Without Damper	Alternate Bay All Storey	Corner Bay All Storey	Corner Bay Alternate Storey	Alternate Bay Alternate Storey
40.5	693.60	859.38	859.38	839.56	839.56
37.5	678.43	960.25	960.25	807.75	807.75
34.5	595.29	842.57	842.57	708.76	708.76
31.5	515.87	730.15	730.15	614.20	614.20
28.5	440.34	623.25	623.25	524.27	524.27
25.5	368.92	522.16	522.16	439.24	439.24
22.5	301.85	427.24	427.24	359.39	359.39
19.5	239.45	338.91	338.91	285.09	285.09
16.5	182.07	257.70	257.70	216.78	216.78
13.5	130.21	184.29	184.29	155.03	155.03
10.5	84.51	119.62	119.62	100.62	100.62
7.5	45.96	65.04	65.04	54.72	54.72
4.5	16.22	26.15	26.15	19.31	19.31
1.5	0	0	0	0	0



**Figure 10:** Comparison of storey shear results for different damper configurations

#### 4. CONCLUSION

Based on the results obtained from the response spectrum analysis carried out using ETABS v19 in accordance with NBC 105:2025 for a G+12 RCC building located in Kathmandu, the following conclusions can be drawn:

- The incorporation of fluid viscous dampers significantly alters the dynamic characteristics of the building, resulting in a reduction in the fundamental time period compared to the structure without dampers.
- The presence of dampers leads to a substantial reduction in storey displacement and drift throughout the height of the building, indicating improved lateral stiffness and enhanced seismic performance.
- The storey shear values are higher in models with dampers, which reflects the additional damping forces introduced in the structural system and contributes to improved energy dissipation during seismic events.
- Among the analyzed configurations, the alternate bay alternate storey damper configuration provides the most effective reduction in storey displacement and storey

drift providing better control of structural response while using fewer dampers compared to the all-storey configurations.

## 5. RECOMMENDATION FOR FURTHER STUDY

Based on the findings and limitations of the present study, the following recommendations are proposed for future research:

- Future studies should focus on optimization of damper properties such as damping coefficient and velocity exponent ( $\alpha$ ) to achieve better seismic performance.
- Advanced techniques can be applied for optimization of damper number and location to obtain the most efficient and economical configuration.
- Nonlinear time history analysis using real earthquake records should be conducted for more realistic assessment of structural behavior.
- Further research can consider different building configurations, including irregular plans and varying heights.

## CONFLICT OF INTEREST

The Authors Declare No Conflict of Interest.

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