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Analysis of G+20 Horizontally Connected Buildings with and Without Fluid Viscous Dampers

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Abstract

As urban populations continue to grow globally, the demand for new cities and high-rise structures is increasing due to limited land resources and expanding social and commercial activities. To address these challenges, this study investigates the seismic performance of G+20 horizontally connected buildings, focusing on the effects of fluid viscous dampers (FVDs) on structural response. A 3D model of two G+20 buildings, one with and one without FVDs, was developed using ETABS software, and seismic analysis was conducted for a Zone V seismic region in India. The study evaluates key performance parameters, including storey displacement, storey drift, and storey shear, to assess the effectiveness of the dampers. Results showed that adding FVDs significantly reduced overall building displacement, particularly in the X-direction at the top storey, with a reduction of approximately 40%. The Y-direction saw a more modest 5% reduction, attributed to geometric and stiffness irregularities. Additionally, storey drifts in the X-direction were higher than in the Y-direction but were significantly reduced after installing dampers. The findings highlight the importance of FVDs in improving the seismic resilience of horizontally connected high-rise buildings and offer valuable insights for future structural design in earthquake prone areas.

Keywords: *Connected building, Fluid Viscous Dampers, Seismic analysis, Storey displacement, Story drifts, Storey shear.*

1. Introduction

In contemporary times, elevated connections such as multi-tower sky bridges, skywalks, or elevated walkways that link two commercial edifices are being developed, solely aimed at facilitating the seamless transition of individuals from one meeting to another, thereby eliminating the necessity of ascending or descending or traversing through open air. Presently, sky bridges are commonplace in various infrastructures such as airports, shopping centers, transit terminals, and healthcare facilities, serving as conduits adjacent to landscaped areas. Nonetheless, certain architects conceptualize sky bridges at significant altitudes. These structures extend across the uppermost levels of some of the tallest edifices globally.As the global population growth accelerates, there arises an imperative demand for the development of new urban areas, architectural structures, high-rise edifices, and extraordinarily tall constructions on a worldwide scale. The escalation of social and commercial endeavors, juxtaposed with the finite land resources in contemporary urban environments, has resulted in an increasing tendency for structures to be erected in close proximity to one another or to form intricate complexes. (Mayuri M. Baviskar, 2020) (Basanagouda I. Patil, 2022) Seismic events impose a significant and frequently catastrophic influence on architectural constructs, thereby illustrating the unwavering prowess of the natural world to confront human ingenuity in engineering. As seismic waves propagate through the lithosphere, edifices are subjected to dynamic forces that instigate rapid and vigorous displacements. Such forces can initiate a spectrum of adverse consequences on structural integrity. Primarily, these forces engender vibrations and oscillations that may compel structural components to flex and deform beyond their designed thresholds. This deformation has the potential to precipitate fissures, fractures, and in extreme cases, complete structural collapse, thereby jeopardizing both human safety and material assets. The development of buildings resilient to seismic activity necessitates an amalgamation of diverse methodologies and engineering doctrines, all directed towards the reduction of damage and the safeguarding of occupants during seismic occurrences. One significant methodology involves the utilization of adaptable materials and structural systems that are capable of absorbing and dissipating the energy produced by seismic waves. This encompasses the integration of base isolators, which facilitate the independent movement of a building relative to the ground motion, thereby diminishing the forces transmitted to the structural framework. Another strategy pertains to the adoption of reinforced concrete and steel frameworks that confer improved structural integrity. These materials are designed to endure the lateral forces imposed during seismic events. Furthermore, engineers implement damping mechanisms, such as tuned mass dampers or viscous dampers, which ameliorate the oscillations of the edifice and reduce the likelihood of structural compromise. [1-5]

1.1. Seismic Analysis

An Earthquake is a vibration of earth surface due to sudden release of energy from earth's crust. Vibrations due to seismic activity cause severe damage to buildings, bridges, etc., Hence it is necessary to prevent the structure from harmful effects of the earthquakes. Seismic analysis is a subset of structural analysis and is the calculation of the response of a building structure to earthquakes. It is part of the process of structural design, earthquake engineering or structural assessment and retrofit in regions where earthquakes are prevalent. [6-10]

1.2. Fluid Viscous Dampers

Fluid viscous dampers, frequently utilized in reinforced concrete (RCC) edifices, serve a crucial function in bolstering seismic resilience. These specialized mechanisms are engineered to absorb and dissipate the energy produced by ground motion during seismic events, thereby mitigating structural damage and safeguarding the well-being of occupants. Fluid viscous dampers are comprised of a piston that traverses a chamber filled with a viscous fluid, typically characterized by a high-viscosity oil. When the structure undergoes lateral displacement as a result of seismic forces, the piston exerts pressure against the fluid, thereby generating resistance and absorbing kinetic energy. This mechanism of controlled damping markedly diminishes the oscillations of the building and inhibits excessive lateral movement, which could result in structural failure. (Refer Figure 1)

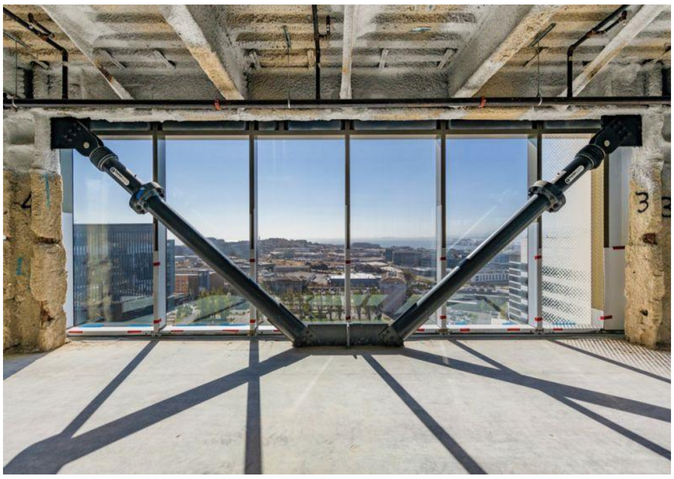

Figure 1 **Fluid Viscous Dampers**

2. Experimental Programs

2.1. Response Spectrum Analysis

A Response Spectrum constitutes a graphical representation delineating the maximum responses (displacement, velocity, or acceleration) exhibited by a structural entity in reaction to a particular ground motion, across a spectrum of natural frequencies or periods. This analytical tool streamlines seismic evaluation by depicting peak responses across diverse modes, thereby facilitating the proficient design of earthquake-resistant structures and the assessment of their performance efficacy. [11-13]

2.2. Description of Building

In current study, a G+20 storeythree-dimensional reinforced concrete moment resisting frame building is considered to investigate the storey response under lateral loads. (Refer Table 1)

Table 1 Description Table

Particulars	Values
Type of building	Horizontal connected multistorey building
Height of each storey	3m
Size of beam	650mm*450mm
Size of column	750mm*750mm and 650mm*650mm
Total height of buliding	63m
Thickness of slab	180mm
Support conditions	Fixed
Concrete grade	M40, fck = 50N/mm2
Live load	3.5KN/m2
Seismic zone	5
Type of soil	Type 2
FVD	250KN

2.3. Load Consideration

A dead load is defined as the constant, static mass of a construction, encompassing its immobile constituents such as beams, columns, walls, floors, roofs, and structural components. It signifies the invariant load that the structure is required to bear throughout its lifespan. It is assigned according to codal provision as per IS 875-Part 1(1987). A live load denotes transient, dynamic forces exerted upon a structure, encompassing elements such as inhabitants, furnishings, vehicular traffic, or environmental influences like precipitation and atmospheric pressure.It is assigned according to codal provision as per IS 875-Part 2(1987). An earthquake load denotes the dynamic forces imposed upon a structure amidst seismic events. These loads arise from ground movements, instigating oscillations and vibrations that edifices are required to endure. It is assigned according to codal provision as per IS 1893-2002(Part 1). (Refer Figure 2,3)

Details for the Response spectrum analysis is

- Zone factor = 0.36
- Importance factor = 1.5
- Response spectrum reduction factor = 5
- Condition of soil = Medium

Load combinations as per IS 875-Part 5(1987)

1.5(DL+LL)
1.5(DL±EQX)
1.5(DL±EQY)]
1.2(DL+LL±EQX)
1.2(DL+LL±EQY)
0.9DL±1.5EQX
0.9DL±1.5EQY

2.4. Modelling and Analysis

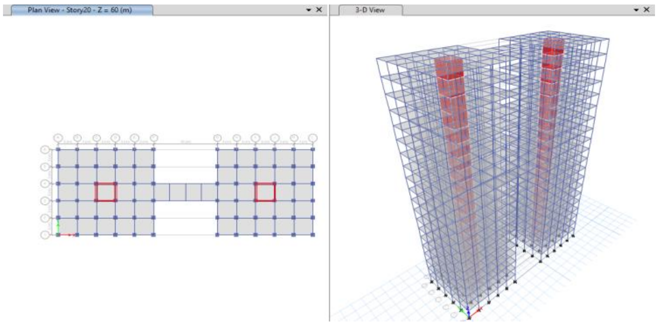

Figure 2 Plan and 3D View (Model 1 without Dampers)

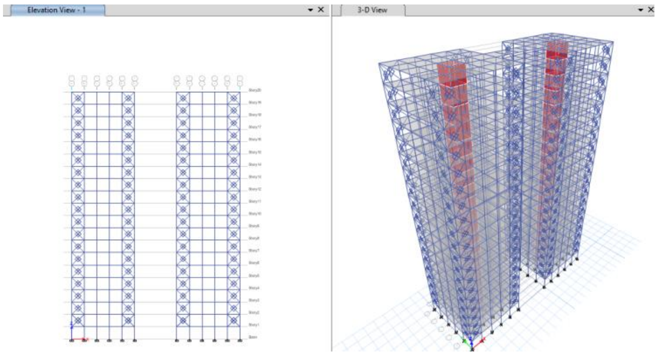

Figure 3 Elevation and 3d View (Model 2 with Dampers)

3. Results and Discussion

3.1. Storey Displacement

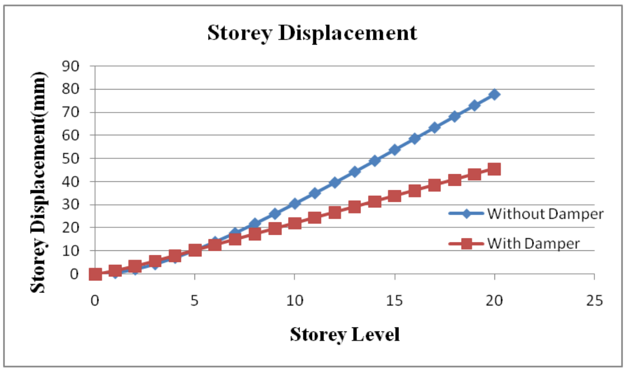

Figure 4 Storey Level Versus Storey Displacementat X-Direction for Zone V (X-Direction)

As shown in Figure 4, The topstorey displacement for EQ load in X direction for zoneV without dampers is 77.762mm and it is reduced to 45.574mm after installation of dampers.

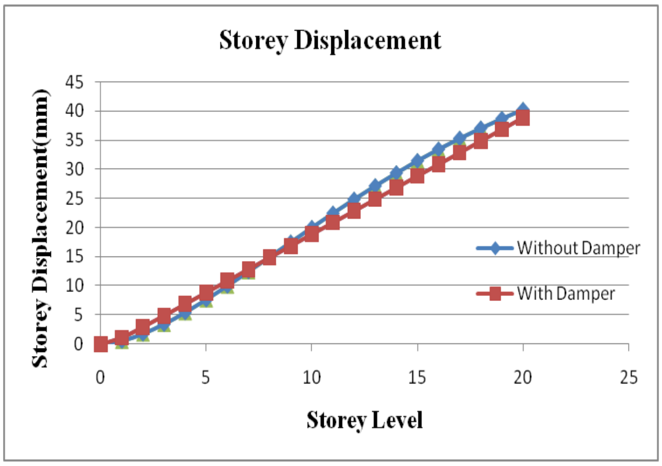

Figure 5 Storey Level Versus Storey Displacement at Y-Direction for Zone V (Y-Direction)

As shown in figure 5, The topstorey displacement for EQ load in Y direction for zoneV without dampers is 40.169mm and reduced to 38.831mm after installation of dampers.

3.2. Storey drift

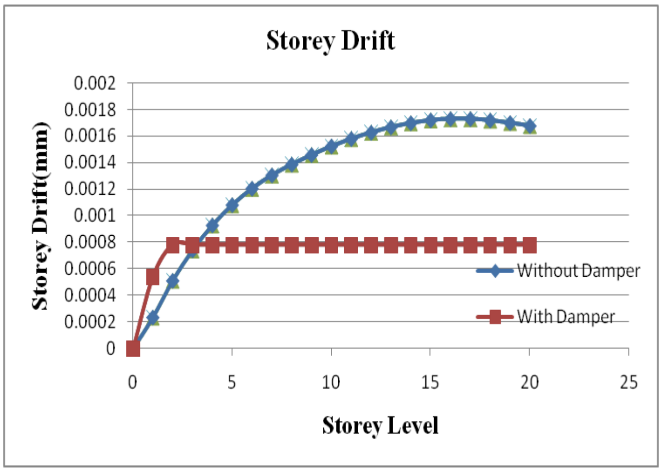

Figure 6 Storey Level Versus Storey Drift at X-Direction for Zone V (X-Direction)

As shown in figure 6, The maximum storey drift for EQ load in X direction for zoneV without dampers is 0.00173mm and with dampers is 0.000782mm.

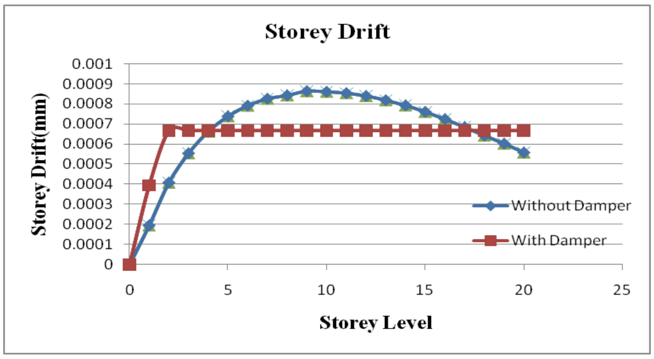

Figure 7 Storey Level Versus Storey Drift at Y-Direction for Zone V (Y-Direction)

As shown in figure 7, The maximum storey drift for EQ load in Y direction for zoneV without dampers is 0.000864mm and with dampers is 0.000666mm.

3.3. Storey Shear

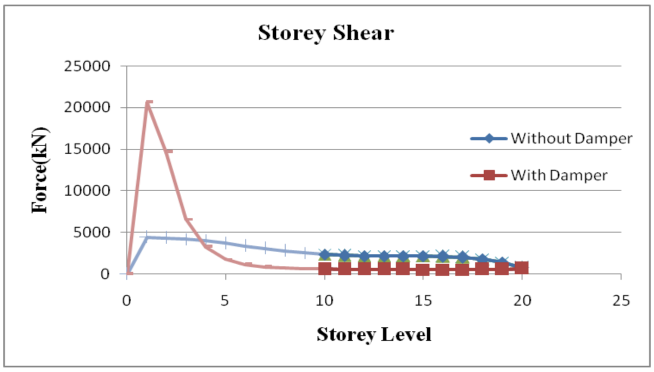

Figure 8 Storey Level Versus Storey Shear at X-Direction for Zone V (X-Direction)

As shown in Figure 8, The maximum storey shear for EQ load in X direction for zone V without dampers is 4428.9716KN and with dampers is 20613.96kN.

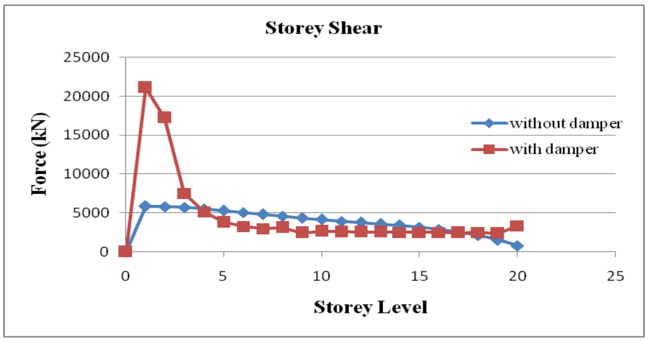

Figure 9 Storey Level Versus Storey Shear at X-Direction for Zone V (Y-Direction)

As shown in Figure 9, The maximum storey shear for EQ load in X direction for zone V without dampers is 5886.27KN and with dampers is 21087.3598KN.

Conclusion

By comparing connected multi storey buildings with and without fluid viscous dampers of capacity 250 KN, the displacement reduces by placing dampers.

The reduction was most pronounced in the X-direction at the top storey, where it reached approximately 40%. In contrast, the reduction in the Y-direction at the top storey was only about 5%. This difference is attributed to the geometric and stiffness irregularities of the building. The study suggests that increasing the stiffness and capacity of the dampers could further enhance the displacement reduction percentage. Additionally, the analysis revealed that dampers effectively reduced storey drifts, making them a valuable tool for improving seismic performance in earthquake-prone regions.

We can conclude that among the two models by placing the dampers gives the best results considering displacement get highly reduced and also storey drift reduces gives more stiffness to structure compared to buildings without dampers.

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