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ENHANCING SEISMIC PERFORMANCE OF HIGH-VALUE BUILDINGS USING VISCOUS WALL DAMPERS: A CASE STUDY OF A MULTI-TOWER COMMERCIAL FACILITY

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Abstract

High-value and mission-critical facilities—including premium commercial buildings, luxury residences, hospitality developments, hospitals, and data centres—require much higher levels of seismic performance. These building types must not only protect life safety but also ensure operational continuity, minimize functional downtime, and safeguard sensitive interior systems and equipment. Traditional code-based seismic design relying primarily on strength and ductility may not be adequate to meet these stringent performance requirements. This paper evaluates the effectiveness of Viscous Wall Dampers (VWDs) in improving seismic resilience for such high-performance buildings. A detailed nonlinear time history analysis was conducted for a real multi-storey, multi-tower reinforced concrete building consisting of 3B+G+11 and 3B+G+8 storey towers. Nine ground motions were used, and 160 VWDs (64 in X and 96 in Y) were optimized and incorporated. The results demonstrate a reduction in interstorey drift (from ∼1% to <0.4%), and major reductions in base shear and floor accelerations. These findings confirm that VWDs offer a highly reliable, architecturally compatible, and performance-driven seismic solution for a broad class of buildings — particularly commercial towers, hotels, high-value residences, hospitals, and data centres, that must remain operational after an earthquake.

Keywords: Viscous wall damper; High-value buildings; Seismic performance; Drift reduction; Damping

1. Introduction

High-value and mission-critical buildings represent a rapidly growing segment of the built environment. This category includes:

- Premium commercial buildings – Class-A office towers housing corporate headquarters, financial institutions, and premium tenants.
- Luxury residential high-rises – Towers with premium finishes, floor-to-ceiling façades, and tight serviceability requirements.
- Hotels and hospitality developments – High-occupancy structures with complex architectural layouts, high-value interiors, and strict business continuity expectations.
- Hospitals and healthcare facilities – Facilities where operational continuity is critical, as disruption directly impacts human life.

Data Centres and IT Facilities - Structures containing acceleration-sensitive server racks, cooling systems, cable trays, UPS units, and high-value electronic hardware. Across all these building types, seismic performance demands exceed conventional design objectives. For these occupancies:

- Downtime must be near-zero
- Damage to non-structural components is unacceptable
- Acceleration limits are far stricter than code requirements
- Operations are expected to continue during and after earthquakes
- Occupants expect minimal perceptible motion

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Conventional methods such as RC jacketing, shear walls, and steel bracing:

- Reduce usable or leasable space
- Interfere with architectural elements
- Are difficult to implement in operating hospitals or data centres
- Disrupt ongoing operations
- Add stiffness, forcing the structure to attract even higher seismic loads

Thus, the design philosophy must shift from strengthening the building to resist forces to damping the building to reduce these forces.

1.1. Need for Supplemental Damping in Premium and Critical Facilities

Supplemental damping provides the following critical benefits:

- Significant drift reduction - Protects sensitive medical equipment, luxury finishes, façade systems.
- Acceleration control - The most important parameter for data centres and hospitals.
- Force reduction - Allows lighter structural components and less reinforcement congestion.
- Improved functional continuity - Essential for business-critical operations.
- No visible architectural intrusion - Critical in premium design-driven projects.
- Installation flexibility - Ideal for retrofitting operating hospitals, hotels, and data centres with minimal disruption.

Among all supplemental damping solutions, Viscous Wall Dampers (VWDs) strike the best balance between performance, architectural integration, and long-term durability.

2. Building Description and Analytical Framework

2.1. Case Study Building

The building analyzed is a real multi-tower high-value facility with dual-tower RC construction:

- Tower 1: 3B + G + 11 floors (63 m)
- Tower 2: 3B + G + 8 floors (50 m)
- Plan: 79 m × 37 m
- Use-case Compatibility: Originally commercial, but structurally representative of hospitals, luxury residences, and data centres due to its large floor plates and complex layout.

This building typology—large plan area, multiple basements, mixed-height towers—is increasingly common in urban hospitals, IT campuses, high-value residential complexes, and hospitality developments.

A detailed ETABS 3D model was developed, refer Figure 1.

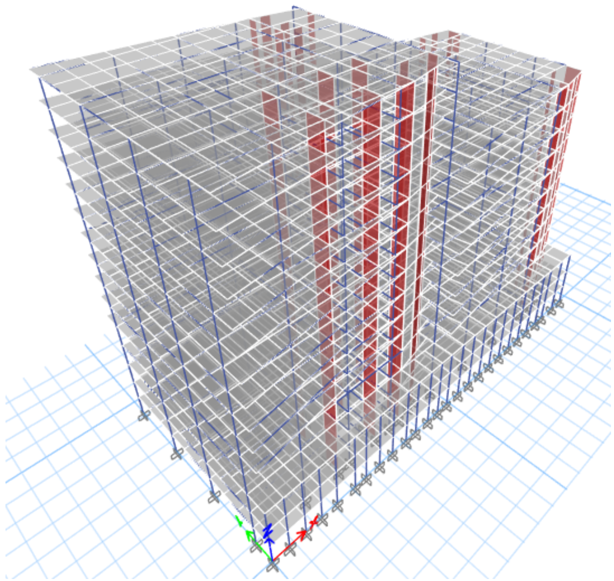

Figure 1. ETABS-3D Model of the Building

2.2. Ground Motions

Nine time histories were selected from NGA West 2, representing magnitude, site class, and distance compatible with the project's seismicity (THS-1 to THS-9). Each motion was scaled to match the design spectrum.

Table 1. Ground Motions used for analysis

THS No.	RSN No.	Acceleration Filename*
THS-1	122	FRIULI.A_A-COD000
THS-2	136	SBARB_SBA132
THS-3	232	MAMMOTH.I_I-MLS254
THS-4	308	SMART1.05_05I12EW
THS-5	512	PALMSPR_ATL270
THS-6	1122	KOZANI_EDE–L
THS-7	1140	DINAR_DEN000
THS-8	1743	SKULLMTN_LSM4000
THS-9	1984	ANZA1_12102360

The "Acceleration Filename" refers to the name of the recorded ground-motion acceleration corresponding to the unique ID – RSN.

3. Viscous Wall Damper System

3.1. Device Characteristics

Viscous Wall Dampers dissipate seismic energy through the shearing action of a highly viscous silicone-based fluid, which is confined within a rigid steel vessel. When relative displacement occurs between adjacent floors during an earthquake, the internal vane or piston forces the viscous fluid to deform and flow. This shearing deformation requires significant energy, and that energy is absorbed and converted into heat within the fluid, thereby reducing the amount of dynamic energy transmitted into the structural system. Unlike yielding metallic systems, this mechanism is stable, repeatable, velocity-dependent, and does not degrade under cyclic loading, making it particularly effective for long-duration seismic events. Their properties make them ideally suited for:

- Hospitals: where vibration-sensitive medical equipment (MRI, CT) require low accelerations
- Data Centres: where server racks cannot withstand high floor accelerations
- Hotels and residences: where perceptible sway must be minimized

3.2. Why VWDs Are Ideal for Critical Buildings

- No yielding → stable performance for long-duration earthquakes
- No leakage → safe near medical and electrical rooms
- No loss of stiffness → does not increase seismic demand
- Fully concealed → compatible with luxury architectural finishes
- Non-interfering installation → minimal operational disruption

3.3. Placement Strategy for the Case Study Building

160 VWDs were placed strategically:

- 64 in X-direction and 96 in Y-direction
- Positioned to maximize energy dissipation
- Integrated into non-structural walls for concealment

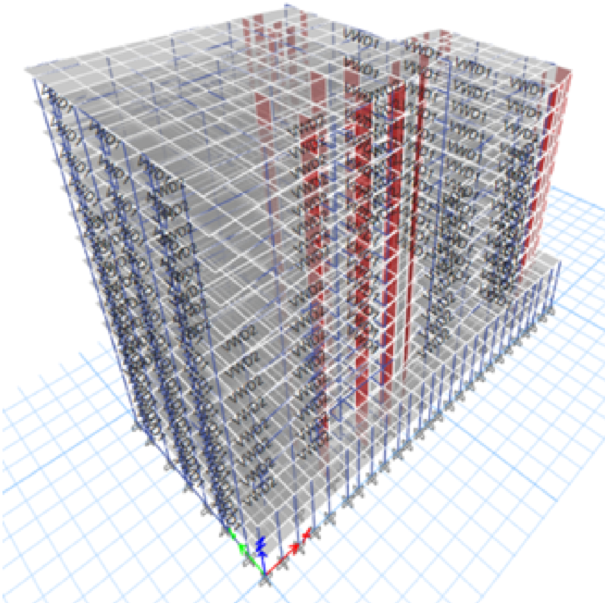

Figure 2. ETABS, 3D model-building with dampers

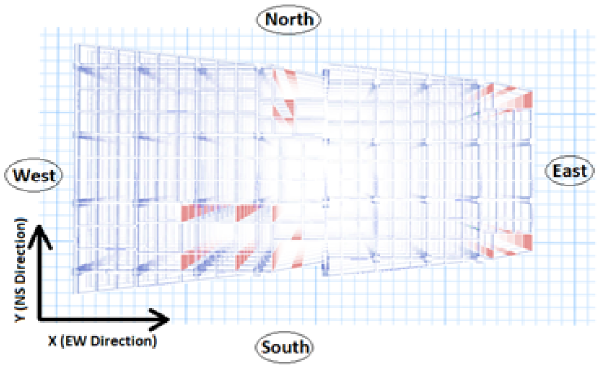

Figure 3. Orientation of the building

4. Results and Discussion

4.1. Base Shear Reduction

Base shear reduction of 45–55% has broad advantages:

Hospitals

- Reduces demand on building components
- Increases safety margins for emergency departments

Data centres

- Avoids excessive demand on isolated power rooms and battery banks

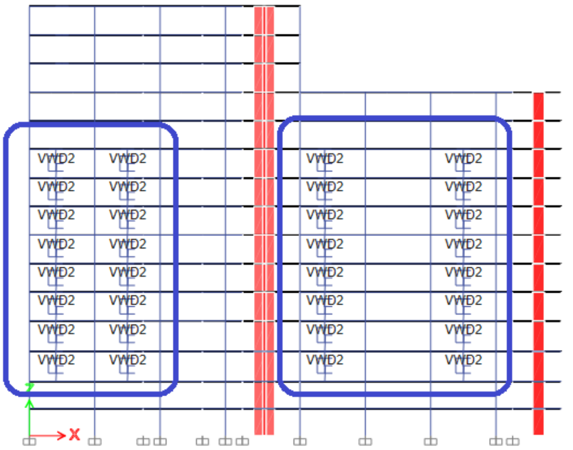

Figure 4. ETABS, typical elevation in X with dampers – VWD2

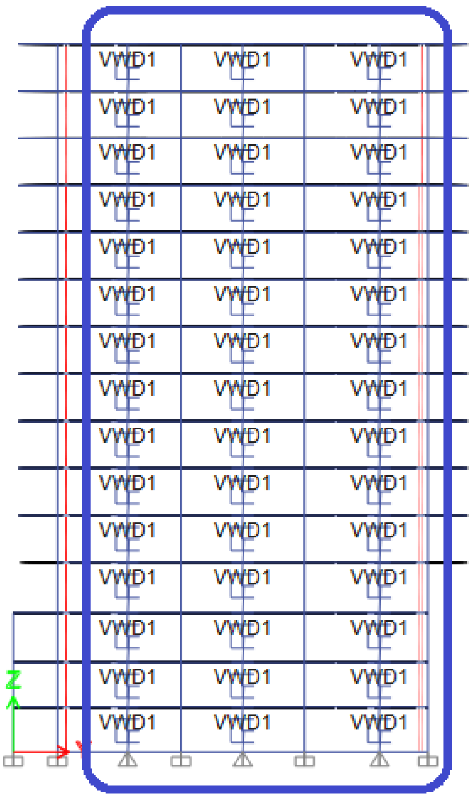

Figure 5. ETABS, typical elevation in Y with dampers – VWD1

Commercial/Hotel/Residential

- Makes structural design more economical
- Reduces reinforcement congestion in core walls

4.2. Interstorey Drift Reduction

Reducing drift from 1% to <0.4% ensures:

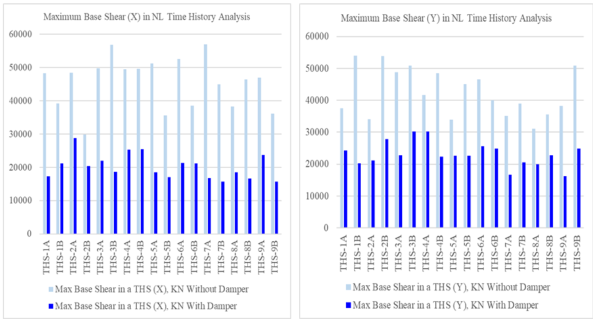

Figure 6. Base Shear reduced: 55% (X) & 45% (Y)

Hospitals

- No cracking of medical gas lines
- No failure of partition walls
- Safe operation of vertical transportation

Data centres

- No disruption to raised floors
- Protection of cable trays and cooling lines

Hotels and residences

- No damage to stone finishes, glass closets, or premium fixtures

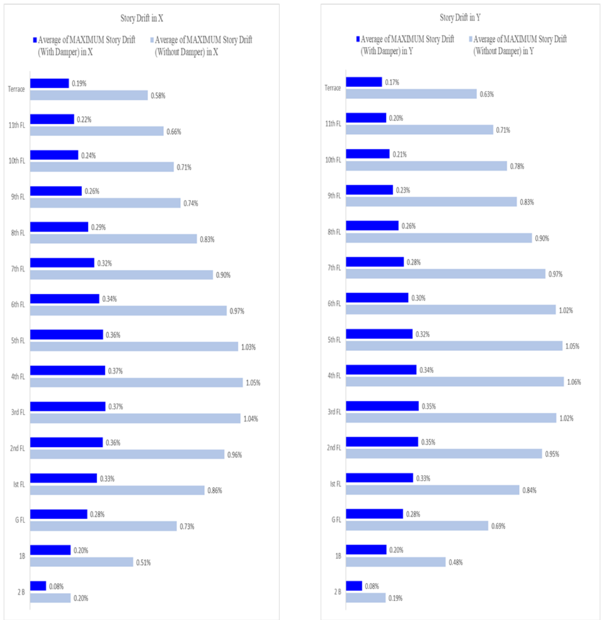

Figure 7. Interstorey drift reduced from more than 1% to less than 0.4% in both X and Y

4.3. Acceleration Reduction

Acceleration reduction of ~40% is the most critical result:

For Hospitals

- Protects MRI, CT, X-Ray units
- Prevents oxygen manifold line rupture
- Protects surgical lighting and HVAC systems

For Data centres

- Protects server racks
- Prevents hard-drive failures
- Ensures continuity of operation

For Hotels and residences

- Protects fragile interior fit-outs
- Improves occupant comfort dramatically

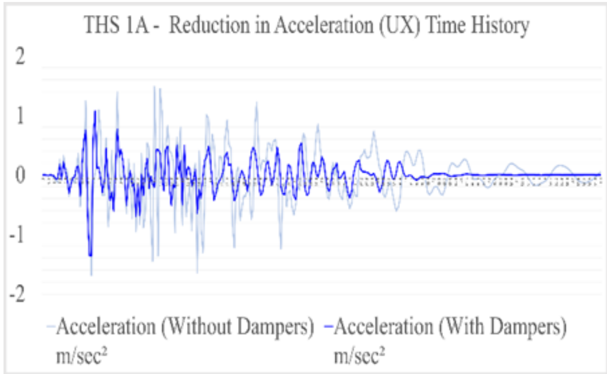

Figure 8. Reduction of maximum acceleration in X

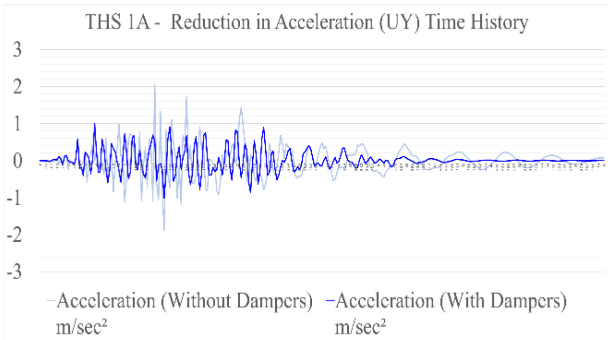

Figure 9. Reduction of maximum acceleration in Y

5. Advantages of VWDs for Multi-Category High-Value Buildings

Viscous Wall Dampers provide a superior solution compared to conventional retrofits:

- Hospital-safe (no heat, no fire risk)
- Data-centre safe (non-conductive, no mechanical sparks)
- Architecturally invisible
- No loss of rentable or medical floor space
- Fast installation

6. Conclusion

This study confirms that Viscous Wall Dampers offer a powerful, versatile, and highly effective seismic protection strategy for high-value and mission-critical buildings, including:

- Hospitals
- Data Centres

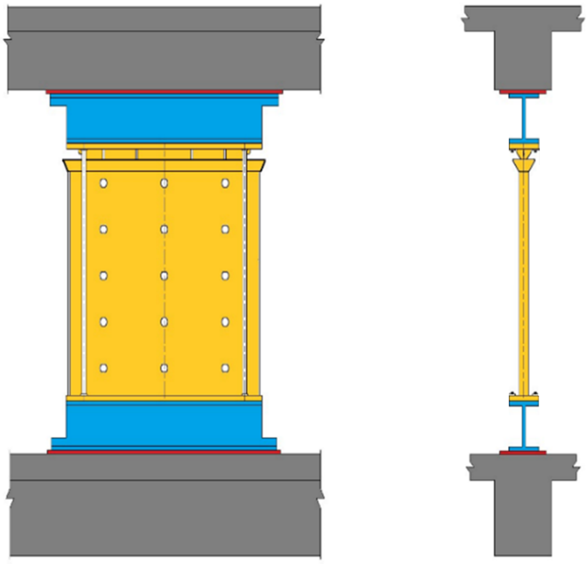

Figure 10. Proposed connection of the VWD

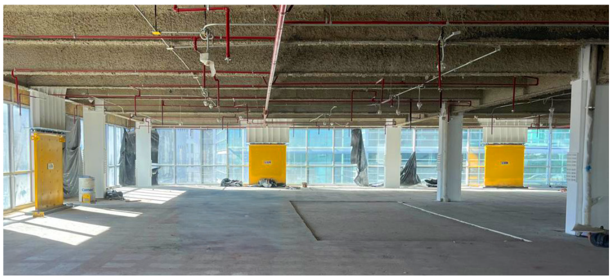

Figure 11. Illustration of the VWD installation

- Luxury Residential Towers
- High-value Offices
- Hotels and Hospitality Buildings

Using the real building case study, the incorporation of VWDs provided:

- Drift reduction >60%
- Acceleration reduction ~40%
- Base shear reduction up to 55%

These improvements directly support immediate occupancy and operational continuity—essential for hospitals and data centres—and protect high-value architectural and mechanical systems in premium hotels and residences.

Thus, VWDs represent an optimal seismic resilience solution across a wide spectrum of high-performance building categories.

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