SEISMIC PROTECTION THROUGH SUPPLEMENTARY DAMPING USING VISCOUS WALL DAMPERS IN NEW AND EXISTING BUILDINGS

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1. INTRODUCTION

Regions prone to seismic activity necessitate robust structural designs to ensure the safety and operational continuity of buildings. While conventional building design traditionally relies on strength, ductility, and inherent material damping, achieving elevated performance levels, such as "Immediate Occupancy" or "Continuous Operation," often demands more advanced solutions. Extensive research in supplementary damping [1] mechanisms has paved the way for innovative approaches to seismic protection. Among these, Viscous Wall Dampers (VWD) [2] have emerged as highly efficient devices for improving key performance parameters of buildings subjected to seismic events.

This paper highlights the versatile application of VWD for enhancing seismic resilience, not only in new constructions but also as a vital retrofitting solution for existing buildings. It will be presented how integrating supplementary damping through VWD can address structural deficiencies arising from factors such as increased live loads [2, 4, 5] or changes in use of the building, thereby ensuring buildings meet current seismic safety standards and desired performance objectives.

2. VISCOUS WALL DAMPERS: AN OVERVIEW

Viscous Wall Dampers are simple yet highly effective energy dissipation devices. They consist of a sleek steel vessel filled with a viscous mass, connected to the lower floor beam of a building, and a vane or piston attached to the upper floor beam. This design allows the damper to dissipate seismic energy by shearing and displacing the highly viscous fluid, which generates damping forces. VWDs are characterized by their robust design, minimal maintenance requirements, and cost-effectiveness. They provide supplementary damping that significantly enhances the dynamic performance of a building during seismic events.

3. BUILDING MODEL AND ANALYSIS: A RETROFITTING CASE STUDY

To illustrate the effectiveness of VWDs, an existing Reinforced Concrete (RC) building originally designed for office use was considered. A change in the building occupancy necessitated a significant increase in live load, rendering the existing structure seismically deficient, even after conventional retrofitting techniques like jacketing of columns, beams, slabs, and foundations were considered.

The building comprises two connected towers, with a total length of 79m, a width of 37m, and heights of 63m (taller tower) and 50m (shorter tower). It features three basements, a ground floor, and 11 and 8 floors for the taller and shorter towers, respectively (3B+G+11 and 3B+G+8). Refer Figure 1 for a view of the ETABS – 3D model of the building.

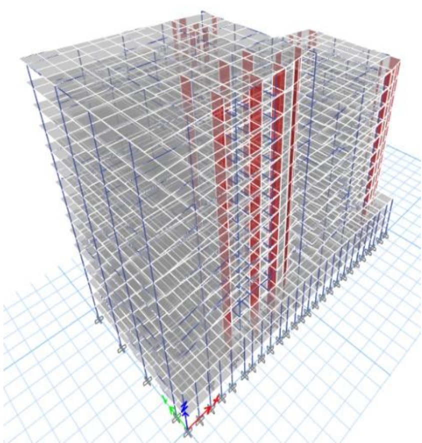

Figure 1. ETABS-3D Model of the Building

For the seismic analyses, Non-linear time history analysis was conducted using ETABS software [6]. Nine suitable ground motions, refer Table 1, were selected from the PEER ground motion database NGA West 2, chosen based on the project's location, proximity to fault lines, and anticipated earthquake magnitude. Initially, the analysis was performed on the building without dampers to establish baseline performance parameters such as base shear and drift.

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.

After several iterations to determine the optimal quantity and placement of dampers, a total of 160 VWDs—of a specific geometrical size and with defined damping resistance and stiffness properties were strategically installed: 64 in the X-direction and 96 in the Y-direction. Refer Figure 2 for a view of the ETABS – 3D model of the building with the dampers modelled. Refer Figure 3 for the orientation of the building. Refer Figure 4 and 5 for typical elevations in X and Y with the dampers.

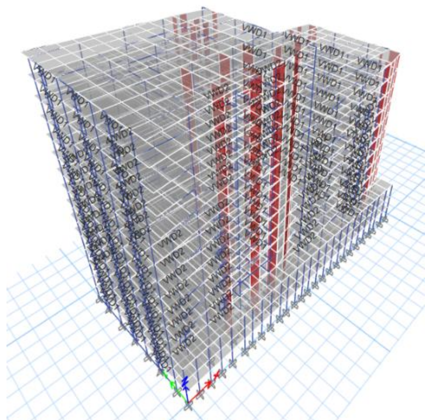

Figure 2. ETABS, 3D Model-Building with Dampers

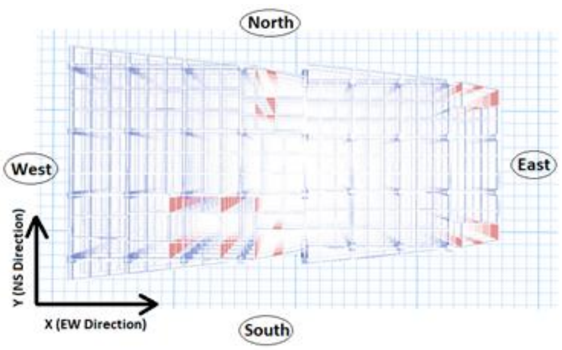

Figure 3 Orientation of the building

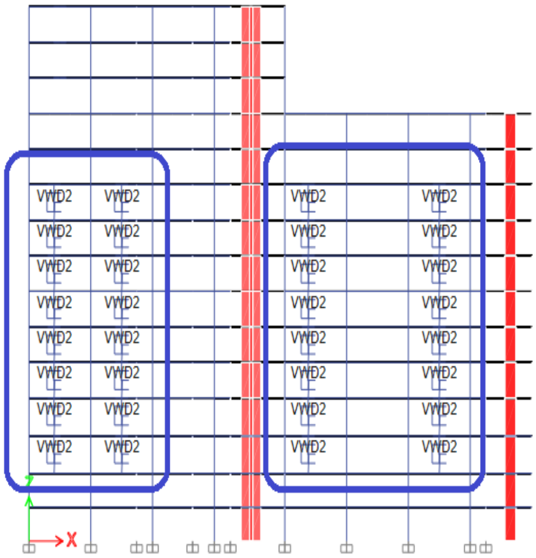

Figure 4. ETABS, Typical Elevation in X with Dampers – VWD2

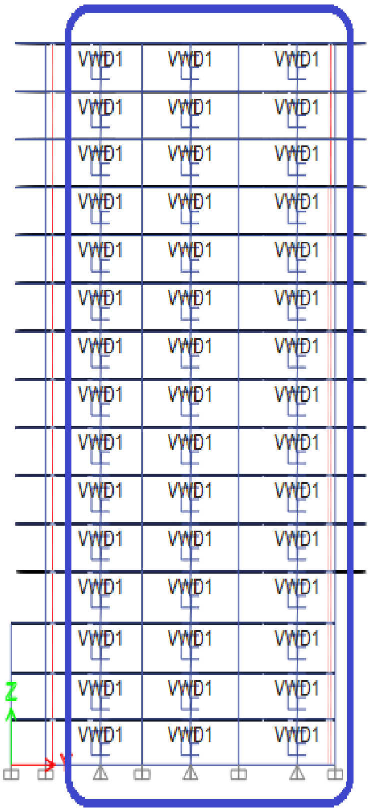

Figure 5. ETABS, Typical Elevation- Y with Dampers – VWD1

4. RESULTS AND DISCUSSIONS

The integration of 160 VWDs significantly improved the building's seismic performance, as demonstrated by the following key parameters:

4.1 TOTAL DAMPING

The incorporation of VWDs substantially increased the overall damping of the building. With an inherent damping of 5%, the supplementary damping provided by the VWDs resulted in a total damping to the level required corresponding to the reduction factor for the base shear as per the Code. This marked increase in damping capacity is crucial for dissipating seismic energy more effectively.

4.2 REDUCTION IN BASE SHEAR

The maximum base shear, a critical indicator of seismic forces experienced by a structure, showed a substantial reduction after the installation of VWDs. This significant reduction directly translates to lower seismic demands on the structural elements.

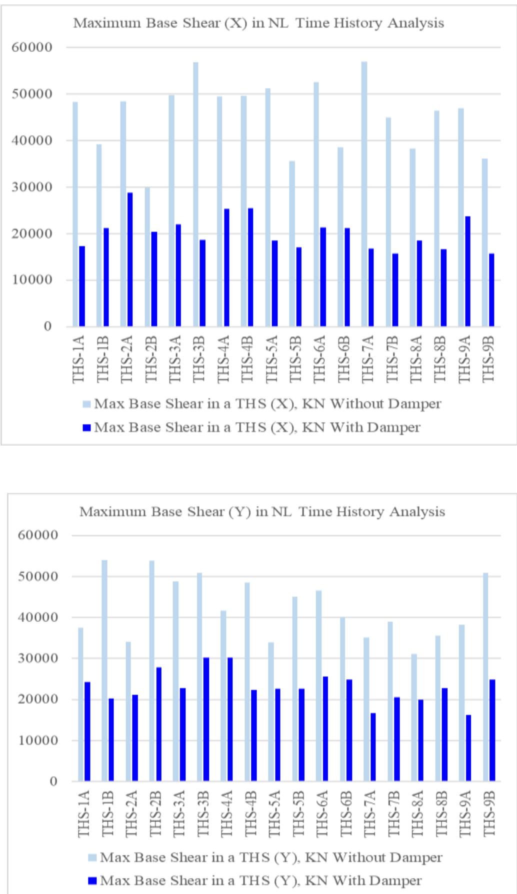

Figure 6. Reduction in Base Shear in X & Y Dir

4.3 REDUCTION IN INTERSTORY DRIFT

Inter-story drift, which measures the lateral displacement between adjacent floors, is a key parameter for assessing structural damage and occupant comfort during an earthquake. The analysis revealed a remarkable reduction in Inter-story drift both in the X and Y directions. This reduction ensures that the building remains within acceptable deformation limits, minimizing structural damage and maintaining functionality.

4.4 REDUCTION IN FLOOR ACCELERATION

Floor acceleration is a critical factor influencing the safety of non-structural components and building contents, as well as the comfort of occupants. Significant reduction in acceleration was observed, with the acceleration tending to minimum value within a much shorter timeframe in the building equipped with VWDs compared to the building without them.

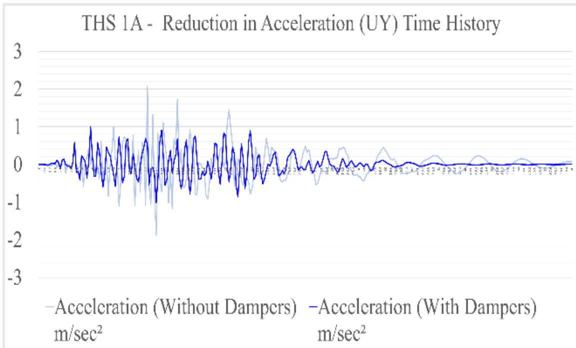

Figure 7. Reduction of Max Acceleration in Y

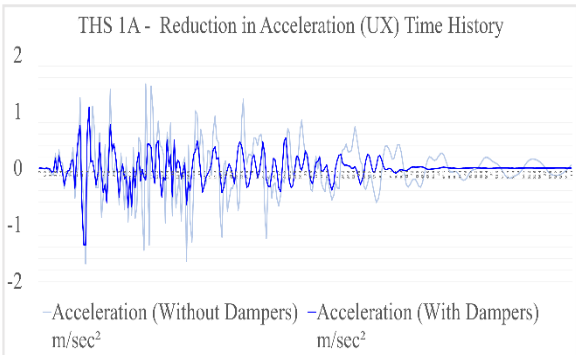

Figure 8. Reduction of Max Acceleration in Y

5. VWD INSTALLATION

The installation of Viscous Wall Dampers is designed for simplicity and adaptability. VWDs can be connected to beams using various methods, including anchor bolts, post-installed anchors, or welding on embedded plates. This flexibility allows for easy integration into both existing buildings during retrofitting and new constructions. Refer Figure 9.

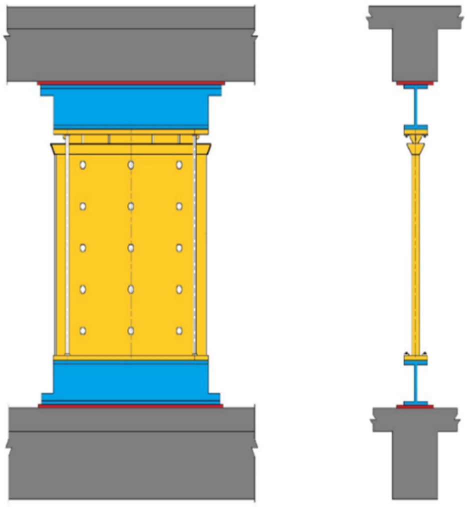

Figure 9. Proposed Connection of the VWD

6. CONCLUSION

Viscous Wall Dampers (VWD) is a very effective passive damping device in enhancing seismic resilience, making them an indispensable for seismic retrofit and protection in both new and existing buildings.

The significant reductions observed in base shear, inter-story drift, and floor acceleration highlight the capabilities of VWDs as a seismic dissipating device and in delivering significant enhancement in seismic resilience.

The case study presents the adaptability and reliability of Viscous Wall Dampers as a comprehensive seismic strategy, offering building owners and engineers a viable means of safeguarding structures and their occupants in the face of seismic hazards. By harnessing the proven seismic resilience that VWDs provide, the performance of both new building constructions can be optimized, and existing buildings can be retrofitted to the required performance level.

7. REFERENCES

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- [2] P. Nawrotzki, D. Siepe, Control Devices For Mitigation Of Seismic Damage
- [3] American Society of Civil Engineers ASCE 7 Minimum Design Loads for Buildings and Other Structures
- [4] American Society of Civil Engineers ASCE 7-16 Minimum Design Loads and Associated Criteria for Buildings and Other Structures
- [5] Indian Standards IS 1893 Part 1 & Part 4 - Criteria for Earthquake Resistant Design of Structures
- [6] ETABS Building Analysis and Design, Computers & Structures, Inc, Structural and Earthquake Engineering Software

Note: Results of the analysis are not presented explicitly due to Non-Disclosure Agreement is still in-place.