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Performance of Concrete Framed Structure with Different Dampers

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Abstract

This article is focused on evaluating the seismic performance of concrete framed structures, particularly in relation to lateral load resistance, story displacement, and drift. The study examines the effects of including or excluding various dampers within the structural systems to assess their contribution to seismic resilience. By adhering to Indian standards, the project aims to determine the most effective structural configuration that prioritizes safety. The analysis, conducted using ETABS, seeks to provide insights into the optimal use of materials and seismic mitigation techniques for high-rise buildings. The findings will offer valuable guidance for structural engineers and designers in creating resilient structures capable of withstanding seismic forces, with comparisons made across outcomes such as maximum story displacement and story drift.

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Keywords

Concrete Framed Structure, Friction Dampers, Fluid Viscous Dampers, Tuned Mass Dampers.

Introduction

Concrete framed structures are a widely used building type where reinforced concrete serves as the main material for key structural elements such as beams, columns, slabs, and foundations. Known for its exceptional compressive strength, concrete is a preferred choice for constructing strong and durable buildings. The addition of steel reinforcement (rebar) significantly improves its tensile strength, enabling it to resist various loads and stresses effectively (Anand Vijayan, et al., 2023).

These structures provide a dependable and sturdy option for diverse construction requirements. Their strength, durability, and adaptability make them a favoured option in the construction industry. However, when selecting concrete framed structures, it is important to consider factors like weight, construction time, cost, and environmental impact. By carefully evaluating these aspects, builders and engineers can make well-informed decisions to maximize the benefits of concrete framed structures while addressing any potential challenges (Rakesh, *et al*., 2022; Mohammadreza Oliaei, *et al*., 2023).

Types of Dampers used

Friction Dampers

Friction dampers are structural components engineered to absorb and dissipate energy during dynamic events, such as earthquakes, in order to reduce vibration intensity and lessen the impact on buildings. These dampers function by using frictional resistance to convert kinetic energy into heat, thereby absorbing and releasing energy. They typically consist of sliding surfaces made with high-friction materials, often paired with springs or other mechanisms to enhance damping (Vegda Vipul and Aakash Suthar, 2021).

Fluid Viscous Dampers

Fluid viscous dampers are devices used in buildings to reduce the effects of seismic forces and other dynamic loads, including wind and vibrations.

These dampers work by using fluid resistance to motion, which helps dissipate energy and lower the intensity of structural vibrations.

Tuned Mass Dampers

Tuned Mass Dampers (TMDs) are devices designed to reduce the amplitude of mechanical vibrations in structures, enhancing their stability and comfort. These dampers are particularly effective at mitigating the effects of seismic events and wind-induced vibrations, especially in tall buildings, bridges, and other large-scale structures.

Objectives

The goals of the learning can be listed following:

Assess the impact of earthquakes on a G+8 concrete-framed structure by evaluating critical factors like maximum story displacement and maximum story drifts.
Perform a comparative analysis of structural element performance under seismic and wind loads, considering scenarios without dampers, and with friction dampers, fluid viscous dampers, and tuned mass dampers.
Compare the seismic performance of concrete-framed structures with and without the incorporation of various types of dampers.

Materials and Methods

The static seismic analysis, also known as equivalent static or simplified seismic analysis, is a method employed to evaluate the seismic performance of structures under earthquake-induced forces (IS : 875, 1987, 2015).

This approach reduces the complex dynamic behavior of an earthquake into static forces that are easier to apply to the structure, simplifying the process of assessing and designing for earthquake resistance. In this particular project, a G+8 concrete-framed building is analyzed.

The structure is built with M40 grade concrete, known for its high compressive strength and durability, making it ideal for buildings that need to withstand significant loads and challenging environmental conditions. The analysis, carried out using ETABS 2021, adheres to the guidelines specified in IS 1893:2016, with input parameters derived from Table 1.

Results and Discussion

A Concrete Framed Structure, detailed in Table 1, was analysed under various conditions: without dampers, with Friction Dampers, with Fluid Viscous Dampers, and with Tuned Mass Dampers.

The analysis was conducted in accordance with Indian Standards. The outcomes for the structure, both with and without these dampers, were compared, and a comprehensive conclusion was drawn from this evaluation.

Maximum Story Displacement

Incorporating dampers in a building significantly enhances its performance under seismic forces by bringing the maximum story displacements within permissible limits.

Notably, Tuned Mass Dampers and Friction Dampers demonstrate exceptional effectiveness, resulting in the lowest maximum displacements. This indicates that these dampers can substantially boost the seismic resilience of the structure, ensuring it remains safely operational during seismic events and compliant with the displacement criteria set forth by Indian standards (IS1893:2016).

Maximum Story Drifts

According to IS 1893:2016, structures equipped with damping systems such as friction dampers, fluid viscous dampers, or tuned mass dampers demonstrate a notable improvement in controlling story drifts compared to those without dampers.

Among the different types of dampers, friction dampers offer the most substantial reduction in drift values, with fluid viscous and tuned mass dampers also providing significant improvements.

This analysis highlights the critical role of incorporating damping systems in structures located in seismic regions to ensure compliance with safety standards and to enhance overall structural resilience.

Table.1 Structural Details

Sl. No.	Item	Specifications
01	Material	M40 Grade Concrete
02	No. of Stories	G + 08
03	No. of Bay in X – Direction	06
04	No. of Bay in Y – Direction	04
05	Bay spacing in X – Direction	5000mm
06	Bay spacing in Y – Direction	6000mm
07	Floor Height	3500mm
08	Depth of Slab	150mm
09	Size of Column	400mm X 400mm
10	Size of Beam	450mm X 450mm
11	Seismic Zone Considered	Zone V
12	Support Condition	Fixed Support

Table.2 Maximum Story Displacement

Story No.	No Dampers (mm)	Friction Dampers (mm)	Fluid Viscous Damper (mm)	Tuned Mass Dampers (mm)
Base	0.000	0.000	0.000	0.000
1	25.645	23.721	23.880	24.970
2	58.962	28.793	29.989	29.895
3	89.960	38.973	39.982	36.985
4	116.94	46.800	49.568	43.985
5	139.98	55.984	62.462	53.976
6	160.10	67.699	73.706	60.985
7	175.54	77.002	82.925	68.940
8	184.41	87.370	92.963	78.385
9	190.97	95.974	101.966	85.980

Table.3 Maximum Story Drift

Story No.	No Dampers (mm)	Friction Dampers (mm)	Fluid Viscous Damper (mm)	Tuned Mass Dampers (mm)
Base	0.00000	0.00000	0.00000	0.00000
1	0.00675	0.00609	0.00679	0.00761
2	0.00974	0.00126	0.00189	0.00161
3	0.00869	0.00230	0.00289	0.00189
4	0.00769	0.00259	0.00299	0.00209
5	0.00659	0.00279	0.00309	0.00230
6	0.00550	0.00290	0.00329	0.00273
7	0.00429	0.00289	0.00308	0.00235
8	0.00300	0.00287	0.00278	0.00246
9	0.00169	0.00268	0.00267	0.00235

Figure.1 Floor Plan

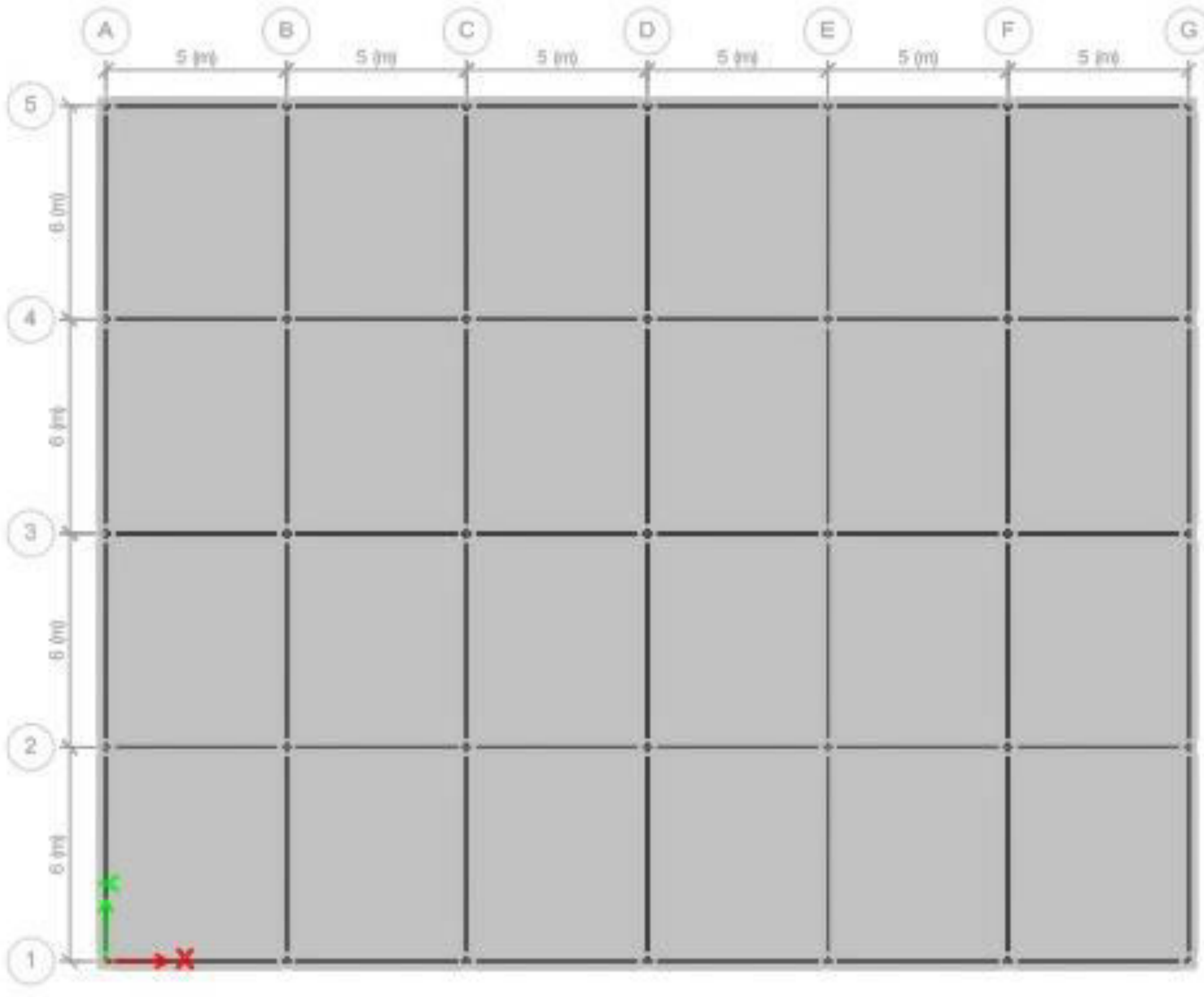


Figure.2 3D Elevation of the Structure

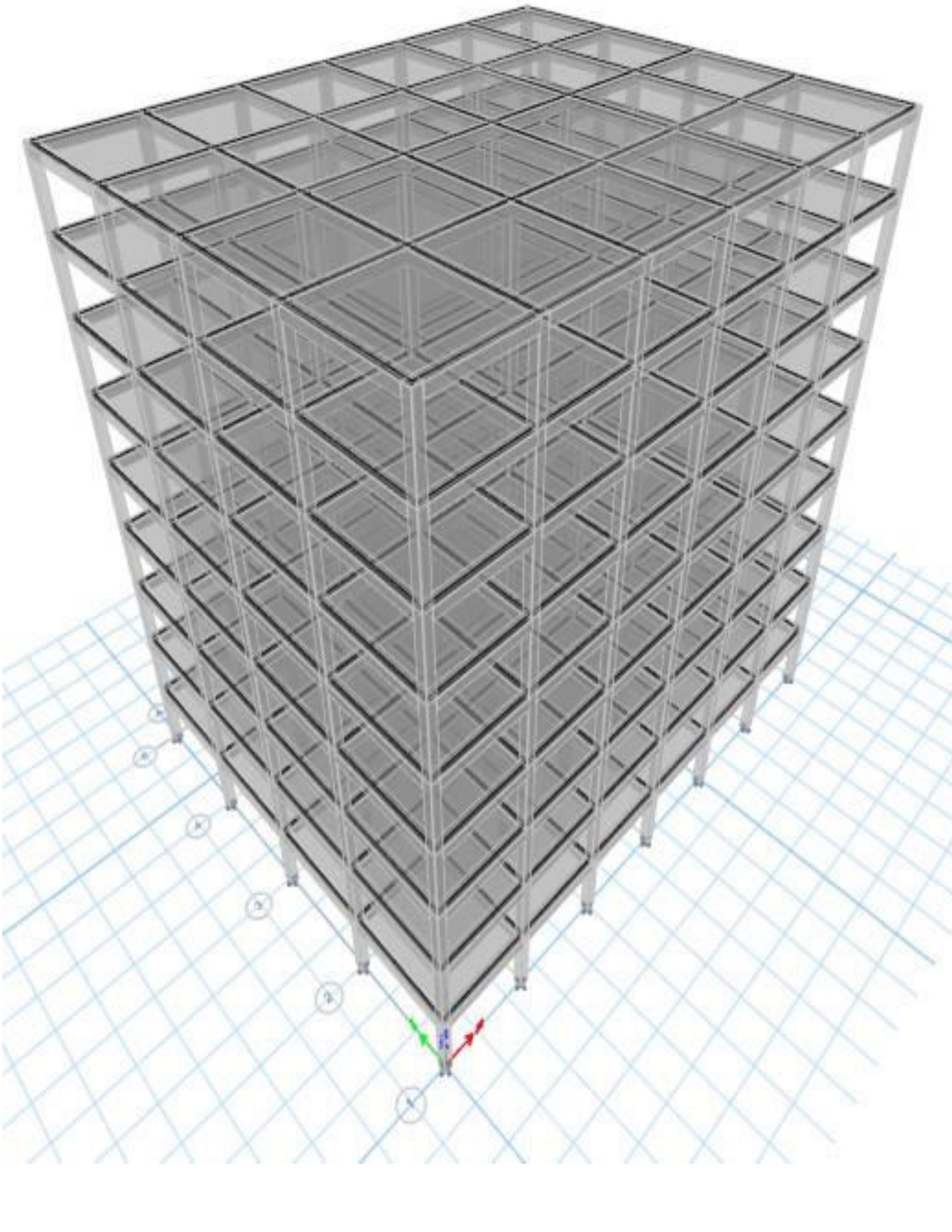


Figure.3 Front Elevation with Friction Dampers

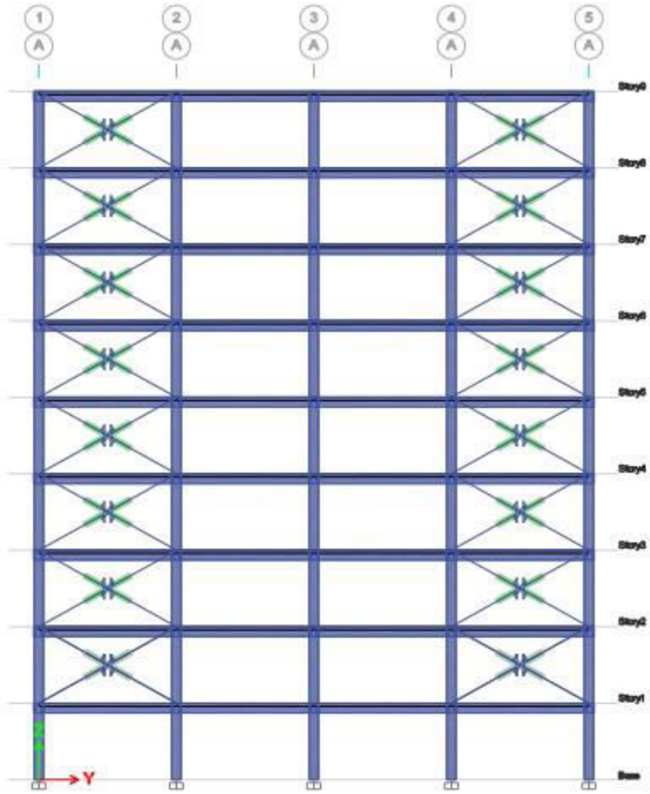


Figure.4 Front Elevation with Fluid Viscous Dampers

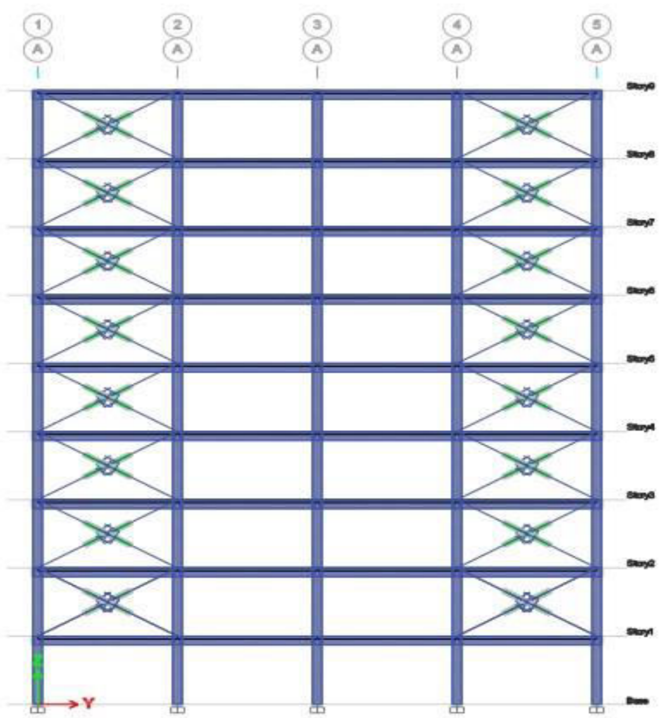


Figure.5 Front Elevation with Tuned Mass Dampers

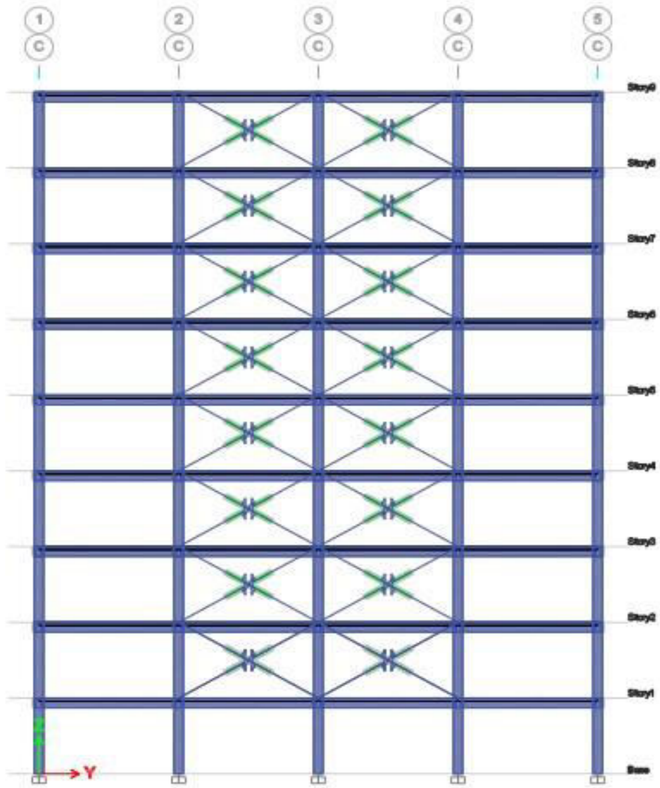


Figure.6 Maximum Story Displacement

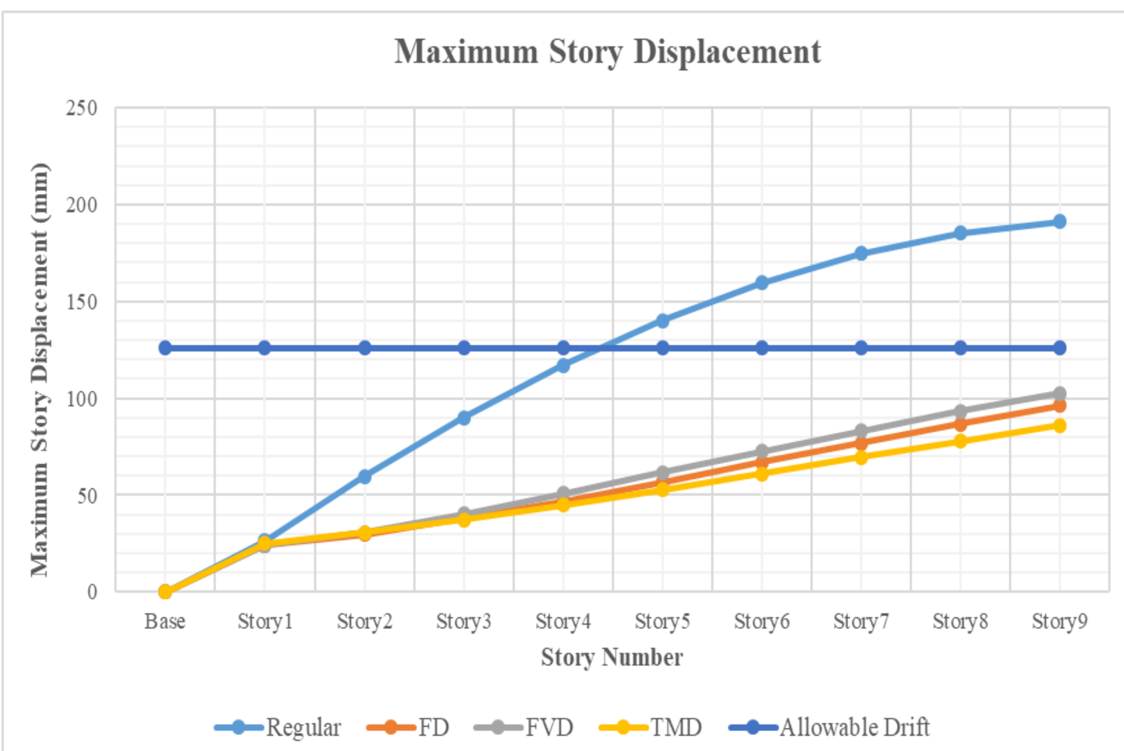
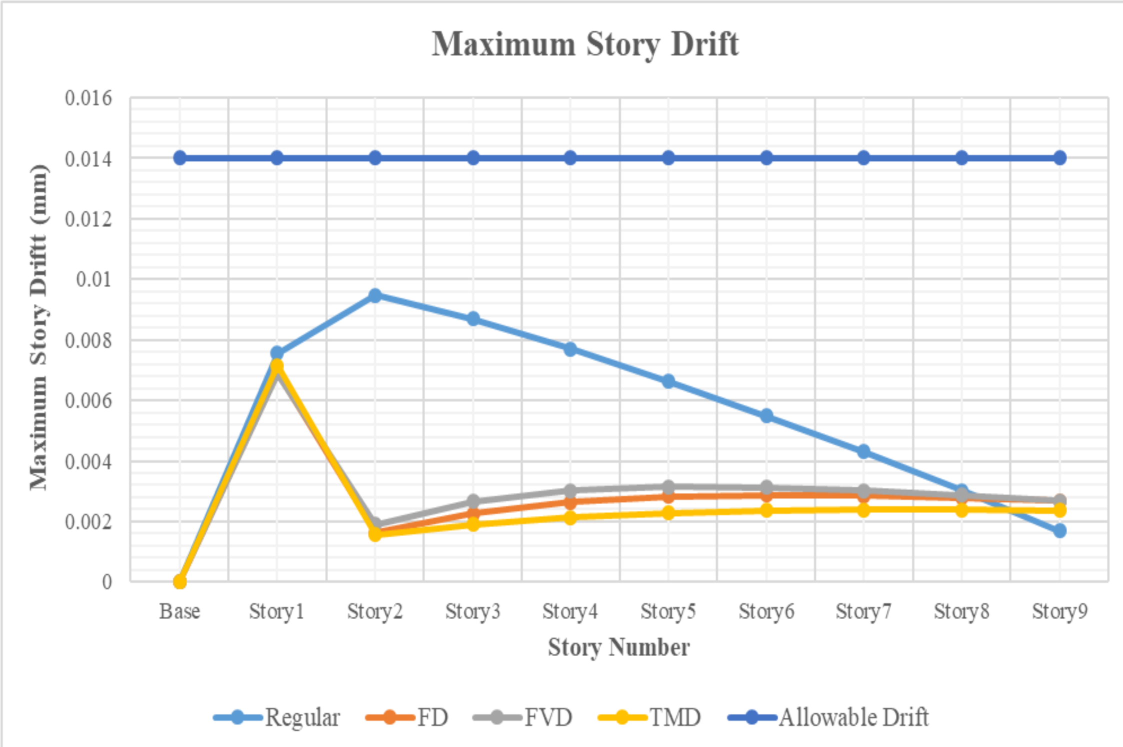


Figure.7 Maximum Story Drifts



Conclusions

The incorporation of dampers considerably lowers the maximum story displacement. Friction Dampers achieve a reduction of 59.83%, Fluid Viscous Dampers yield a 56.04% decrease, and Tuned Mass Dampers result in a 62.35% reduction. In each scenario, the displacement remains comfortably within the allowable limit of 126 mm.

Additionally, the implementation of dampers significantly reduces the maximum story drift. Friction Dampers lead to an 82.89% reduction, Fluid Viscous Dampers bring about a 69.31% decrease, and Tuned Mass Dampers provide an 83.42% reduction. All recorded drift values fall within the acceptable limit of 0.014.

Concrete framed structures require the installation of dampers because their maximum story displacement values without dampers surpass the allowable limit of 126 mm.

The reduced tensile strength and ductility associated with M40 grade concrete lead to increased localized stresses and the risk of cracking under seismic forces. Consequently, the inclusion of dampers is essential for managing story displacements and drifts, thereby ensuring the structure meets safety standards.

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