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Analytical Comparison of A G+15 Storey Building with Tuned Mass Damper & Fluid Viscous Damper

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ABSTRACT: Dampers were utilized to disperse energy and inhibit the structure from deforming during the earthquake period. By using dampers to increase the frame's stability, we can prevent buckling and failure of columns and beams. High-rise buildings are demolished and substantial deformation occurs during earthquakes. Using dampers, we can lessen the shaking of reinforced cement concrete structures during an earthquake. To test the applicability of various damper types during an earthquake, we used numerous types of dampers in this investigation. A comparative review of several types of dampers utilized for multi-story cement concrete building reinforcement was conducted in an empirical study. The seismic behaviour of a G+15 storey structure with and without dampers was studied using the Time History Method. For study, the earthquake load is applied in both the x and y directions. For analysis, the IS1893:2002(part 1) code is used in conjunction with the ETABS 2018 version 18.1.1 package. These experiments' results are addressed in terms of several parameters such as maximal absolute displacement, absolute acceleration, absolute velocity, storey shear, storey drift, storey stiffness, and modal participation mass ratio. It is done in order to compare these different parameters. To diffuse seismic energy, many types of dampers are utilized. A comparison of two separate buildings with varying bay sizes (5mx5m & 6mx6m) is used in this article, as well as a comparison of various parameters utilizing Tuned Mass Damper and Fluid Viscous Damper.

KEYWORDS: Fluid Viscous Damper, Tuned Mass Damper, Max. Absolute Displacement, Storey Drift, Time History Analysis, Storey Stiffness

I. INTRODUCTION

The building industry's current trends demand taller, lighter buildings that are also more flexible and have a low damping value. This increases the chances of failure and creates challenges in terms of serviceability. The vibration reduction approach has found its way into a variety of fields, including civil engineering. Thousands of multi-story skyscrapers are being built around the world. This is in response to concerns about high population density in cities, commercial districts, and space conservation, as well as to build national landmarks and match the standards of other industrialized countries.(Vargas & Bruneau, 2007) As a result, buildings that are subjected to wind and earthquake stresses are more prone to shaking. Large displacements may not always put the structure's integrity in jeopardy, but a persistent condition of vibration can cause significant discomfort and even illness to building occupants. We follow the notion of energy conservation in all of our endeavors. The system will vibrate less if we can assure that the energy exerted on it by wind and seismic loads is fully reduced or dispersed.(Sotnikov et al., 2002) To the tune of 5%, natural damping may be found in practically any building. Vibration can be controlled in a number of methods, including passive, active, semi-active, and hybrid.(Gutierrez Soto & Adeli, 2013)

1.1 Objectives of the Study

The main objective of this work is to find out the effect of tuned mass damper and fluid viscous damper of a multi-story building with different bay sizes. Some other objectives of study are as follows:-

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- To compare the performance of a Tuned Mass Damper with a Fluid Viscous Damper utilizing public work as a benchmark and to comprehend the behavior aspect.
- To conduct a review of the literature on various types of tuned mass dampers as well as the behavior of systems that employ tuned mass dampers.
- To conduct a review of the literature on various types of Fluid Viscous Damper as well as the behavior of systems that employ Fluid Viscous Damper tweaked.
- To compare the performance of a building with and without a damper using various bay sizes of construction.

II. DAMPER

This device absorbs and dampens shock and vibration energy in a variety of ways. Several ways are now employed to protect multi-story structures against seismic and wind forces, one of which is the use of dampers, which is both common and effective in lowering the external force induced by seismic and wind loads. Damper devices disperse seismic energy and track building deformation to maintain structural stability, reduce losses, and keep inhabitants safe.(Naziya Ghanchi & Shilpa Kewate, 2015)

2.1 Fluid Viscous Damper

The military and aerospace industries were the first to adopt fluid viscous dampers. They were created in the late 1980s and early 1990s for application in structural engineering.(Damping, 2001) A piston head with orifices is often enclosed in a cylinder filled with a highly viscous fluid, commonly silicone or a similar type of oil. When the piston head passes through the fluid, energy is lost by the fluid opening in the damper. Because the fluid in the cylinder is nearly incompressible, when the damper is compressed, the fluid volume inside the cylinder is reduced due to the piston rod area movement. A restoring force is produced by a reduction in volume. The use of an accumulator prevents this undesired force. The volume of fluid displaced by the piston rod is collected by an accumulator and stored in the makeup area. The fluid will be drawn out when the rod retreats due to the vacuum formed.(Palermo et al., 2017; Silvestri et al., 2010) Figure1(a) depicts a damper with an accumulator.

2.2 Tuned Mass Damper

The tuned mass damper (TMD) is a concept that dates back to the 1940s.(*Dynamic_Absorber.Pdf*, n.d.) It comprises of a secondary mass with suitably tuned spring and damping elements that provide frequency-dependent hysteresis in the primary structure, increasing damping. It is now well proven that such a device can reduce wind-excited structural vibrations. TMDs' efficiency in lowering seismic response of structures has recently been studied numerically and experimentally. Figure1 (b) shown An active Tuned Mass Damper Configuration (Connor, n.d.)

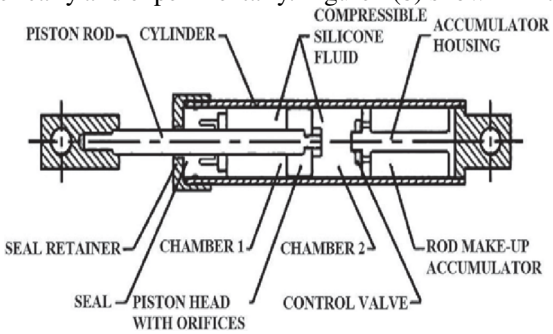

Fig.1 (a)

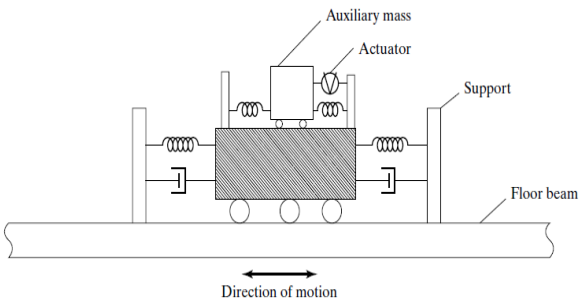

Fig.1 (b)

Figure 1:The Typical representation of Fluid Viscous Damper Fig.1(a) (Ras & Boumechra, 2016) & An active Tuned Mass Damper Configuration Fig.1(b) (Connor, n.d.)

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III. METHODOLOGY

The study focuses on the seismic activity of a G+15 multi-story building frame. There has been a large number of researches published on damper-enhanced structures, including linear and nonlinear static as well as linear and nonlinear dynamic assessments of damper-enhanced building frames. We'll utilize two types of dampers in this experiment: a fluid viscous damper and a tuned mass damper. The Fluid Viscous Damper in this study is positioned on the structure's periphery, while the Tuned Mass Damper is situated on the top level of the building, near the centre of mass action, to improve the building's seismic behaviour. In a time history research with and without damper, essential metrics such as Story Displacements, Modal Participation Mass Ratio, Base Shear, and Modal Frequency are compared.

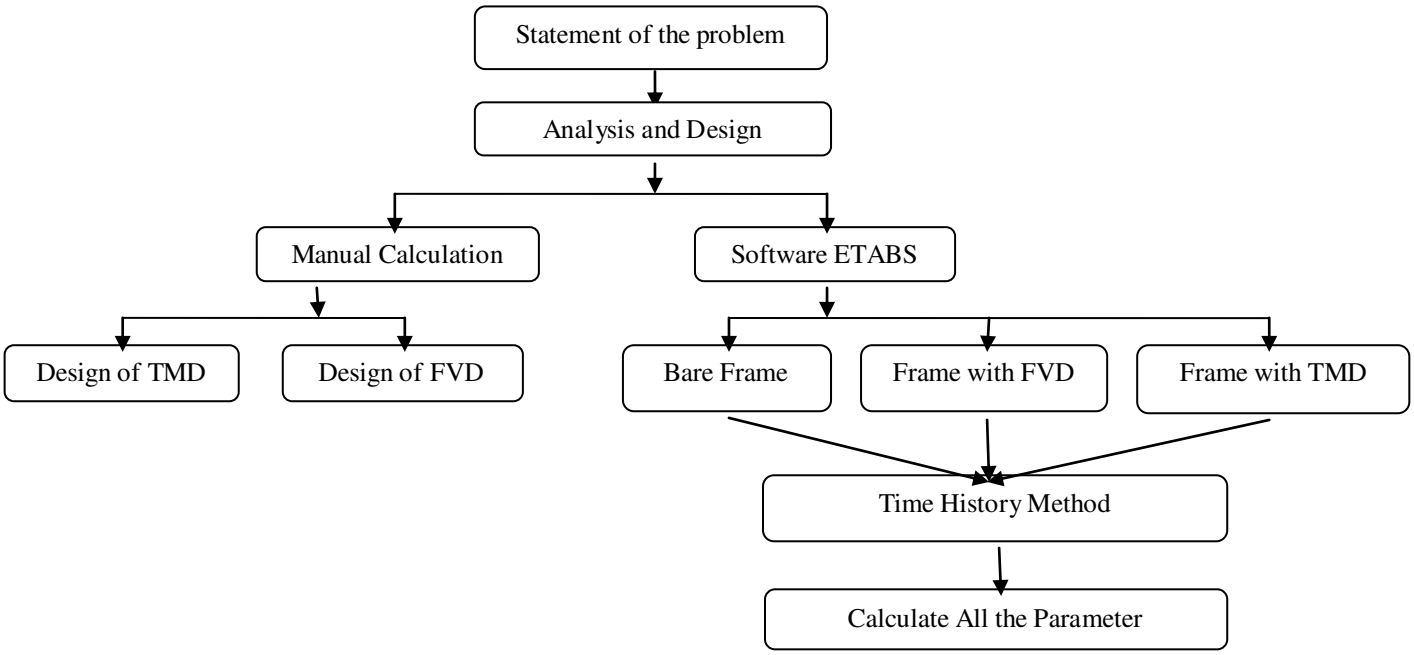

Chart 1: Methodology

3.1 Modelling and assumption

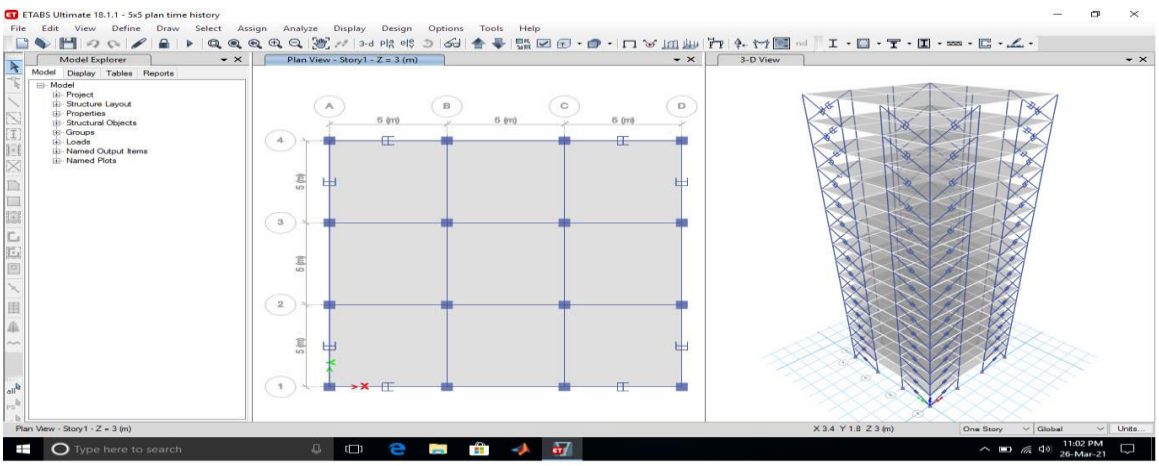

Figure 2: 2D and 3D View of G+15 Building with FVD along the Periphery of Building

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The G+15 Frame structure is the structural framework studied in this article. The building has 3 bays in the X direction and 3 bays in the Y direction [Figure 2 & 3], and it is 48 meters tall. The FVD damper is located on the structure's perimeter, while the TMD is located on the top storey. The current research uses an SMRF to investigate the structure's seismic activity, assuming that seismic responses in two perpendicular directions are independent of one another. The building materials, loads, and properties of the frame, as well as area of section, are shown in Table1.

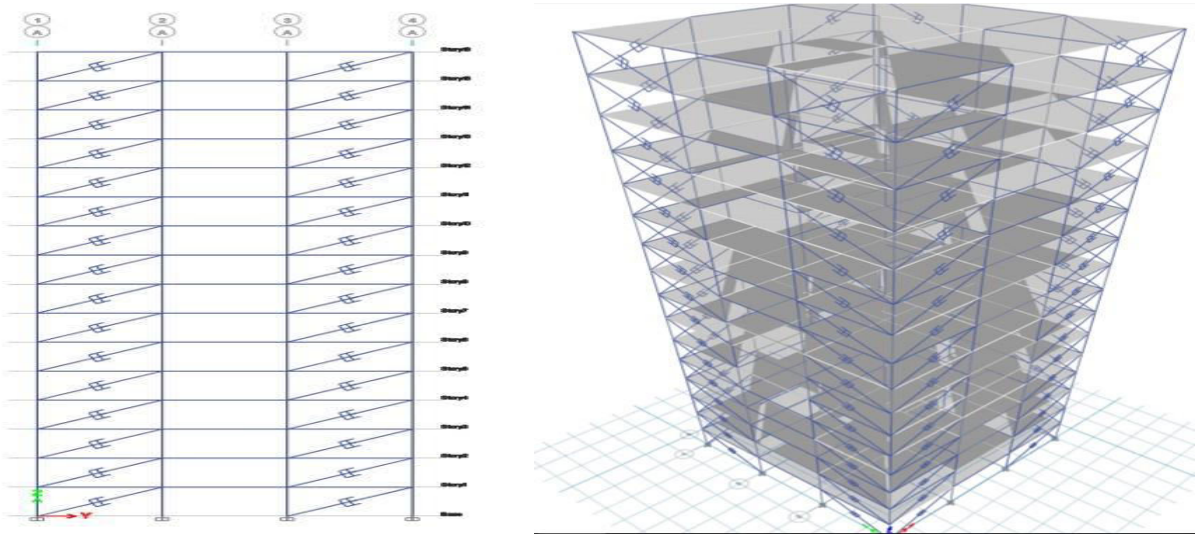

Figure 3: Elevation & Isometric view of G+15 Building with FVD

Table 1: The member properties and specification of model are as follows:

S. NO.	Specification		Size
1	Plan size (X x Y)		18m x 18m, 15m x 15m
2	Two bay size		6m x 6m, 5m x 5m
3	Floor to floor height (m)		3.0m
4	Total height of the building (G+15)		48.0m
5	Types of structure		SMRF
6	Size of beam		0.4m x 0.3m
7	Size of column		0.5m x 0.5m
8	Wall thickness		0.2m
9	Thickness of slab		0.150m
10	Grade of concrete and steel		M30, M20, Fe415, Fe250
11	Types of soil(as per IS1893(part 1): 2002		Type II Medium rocky soil
12	Response Reduction Factor (R)		5
13	Importance Factor		1
14	Seismic Zone Factor		0.36 (Zone V)
15	Load Combination		According to IS:1893 (part 1) : 2002
16	Load Applied	Dead Load	Calculated as per Self Weight
		Live Load	3 KN/m^2
		Seismic Load	As per IS 1893 (part 1) : 2002
		Floor Finish	1 KN/m^2

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IV. EXPERIMENTAL RESULTS

4.1 Storey Displacement

Storey compares a building without a damper, one with a tuned mass damper, and one with a Fluid Viscous damper. Time History Analysis was used to calculate the displacement of distinct stories in the x and y directions. The damper's efficiency and response reduction are analyzed using tables and graphs. The displacement values of the various storeys are shown in Table4. Now investigate the G+15 structure if maximal displacement happens at the top of the structure without the use of a damper. TMD and FVD are two dissipation devices that are employed separately to manage the building's displacement. If the bay size is modified while the building's displacement is also modified, we consider the two modes with different bay sizes (5x5 & 6x6). The displacement value of the 6x6 building is higher than the 5x5 structure without damper and with damper, as shown in Table2. Figures 4 and 5 show a comparison graph of x-direction and y-direction displacement values owing to earthquake forces in the x-direction at storey 16, storey 12, storey 8, storey 4, and storey 1 in the x-direction. To carefully examine the graph, we discovered that displacement is at its greatest in a 6x6 structure, and the effectiveness of the Tuned Mass Damper in dissipating storey displacement is greater than that of the Fluid Viscous Damper.

Table 2: Displacement from time history analysis in x and y direction due to EX

Storey	Elevation	Displacement 15m x 15m Building (bay 5m x 5m)						Displacement 18m x 18m Building (bay 6m x 6m)					
		Without Damper		With FVD		With TMD		Without Damper		With FVD		With TMD	
	m	mm		mm		mm		Mm		mm		mm	
		X-dir	Y-dir	X-dir	Y-dir	X-dir	Y-dir	X-dir	Y-dir	X-dir	Y-dir	X-dir	Y-dir
Storey16	48	108.54	0.0003	79.78	2.855	0.505	0.086	156.60	0.001	91.38	3.427	1.176	0.625
Storey15	45	106.27	0.003	74.20	2.813	8.524	0.001	153.29	0.005	84.88	3.389	10.54	0.488
Storey14	42	102.94	0.002	68.56	2.773	16.28	0.006	148.42	0.003	78.31	3.355	19.63	0.462
Storey13	39	98.49	0.001	62.77	2.744	22.23	0.003	141.98	0.002	71.57	3.326	26.65	0.424
Storey12	36	93.03	0.001	56.82	2.702	26.22	0.002	134.11	0.002	64.68	3.269	31.36	0.389
Storey11	33	86.72	0.001	50.77	2.635	28.46	0.002	125.01	0.002	57.69	3.18	33.97	0.354
Storey10	30	79.68	0.001	44.66	2.541	29.17	0.002	114.89	0.001	50.67	3.058	34.77	0.319
Storey9	27	72.06	0.001	38.55	2.42	28.60	0.001	103.94	0.001	43.70	2.903	34.06	0.284
Storey8	24	63.99	0.001	32.54	2.271	27.00	0.001	92.31	0.001	36.86	2.715	32.11	0.25
Storey7	21	55.56	0.0004	26.70	2.095	24.57	0.001	80.17	0.001	30.25	2.496	29.17	0.215
Storey6	18	46.90	0.0003	21.13	1.892	21.49	0.001	67.66	0.001	23.97	2.245	25.47	0.18
Storey5	15	38.08	0.0002	15.95	1.661	17.93	0.0003	54.911	0.0004	18.15	1.964	21.19	0.146
Storey4	12	29.20	0.0002	11.27	1.402	14.04	0.0003	42.03	0.0004	12.88	1.652	16.53	0.111
Storey3	9	20.37	0.0004	7.2	1.113	9.95	0.001	29.21	0.001	8.31	1.307	11.64	0.077
Storey2	6	11.77	0.001	3.876	0.794	5.831	0.002	16.78	0.002	4.56	0.926	6.759	0.045
Storey1	3	4.164	0.005	1.428	0.479	2.077	0.002	5.834	0.007	1.75	0.504	2.363	0.018

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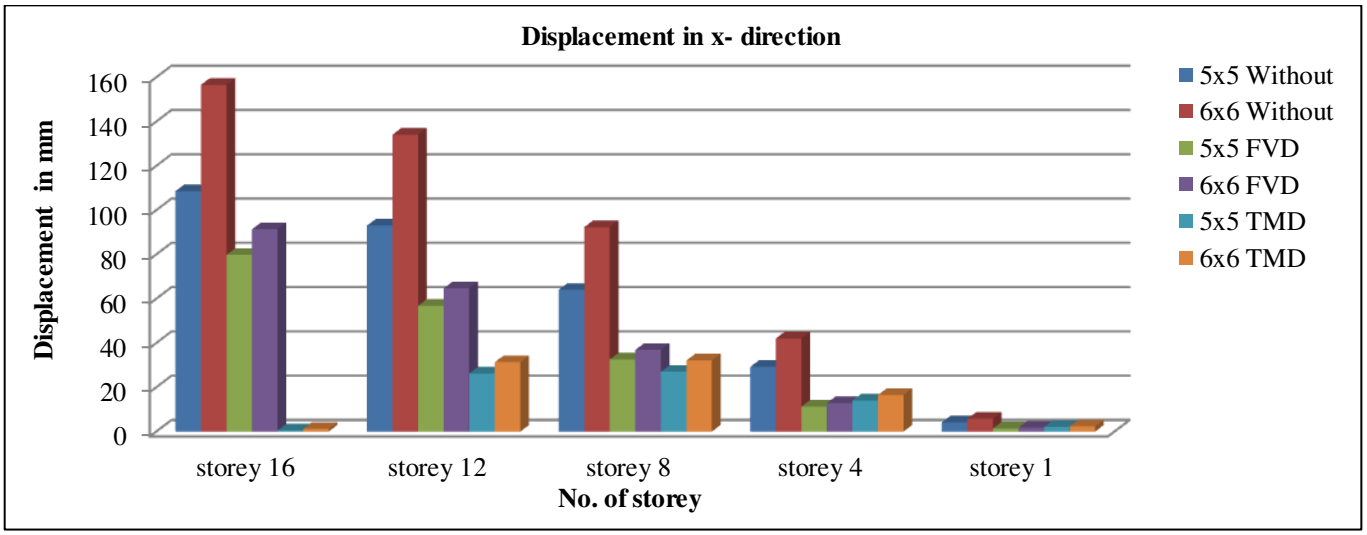

Figure 4: Combined graph of Story displacement of both building bay sizes (5x5 & 6x6) in x-direction due to E_X

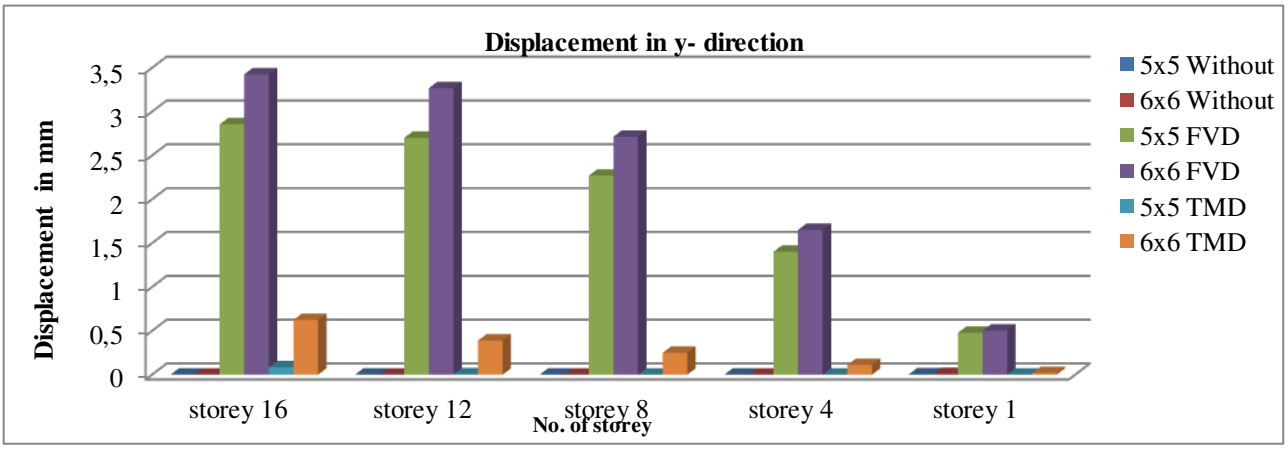

Figure 5: Combined graph of Story displacement of both building bay sizes (5x5 & 6x6) in y-direction due to E_X

4.2 Base Shear

Base shear is the largest expected lateral stress on the structure's base owing to seismic activity. The seismic zone, soil content, and lateral force formulae from the building code are used to calculate it. We'll talk about base shear in this part. When opposed to a damper, base shear without a damper is less. In comparison to a 6x6 bay building, a 5x5 bay building has less base shear. The base shear of both modes in the X- and y-direction is represented in table3 and figure6. The base shear is determined by the type of structure and the load that is applied to it.

Table 3: Base Shear from time history analysis in x and y direction

Modal	Direction	Without Damper	With FVD	With TMD
		kN	kN	kN
First Modal (bay size 5x5)	X-Dir	1327.1095	2774.6494	2875.2258
	Y-Dir	1327.1095	2774.6494	2873.6327
Second Modal (bay size 6x6)	X-Dir	1718.4083	3234.6256	3158.1628
	Y-Dir	1718.4083	3234.6256	3156.1327

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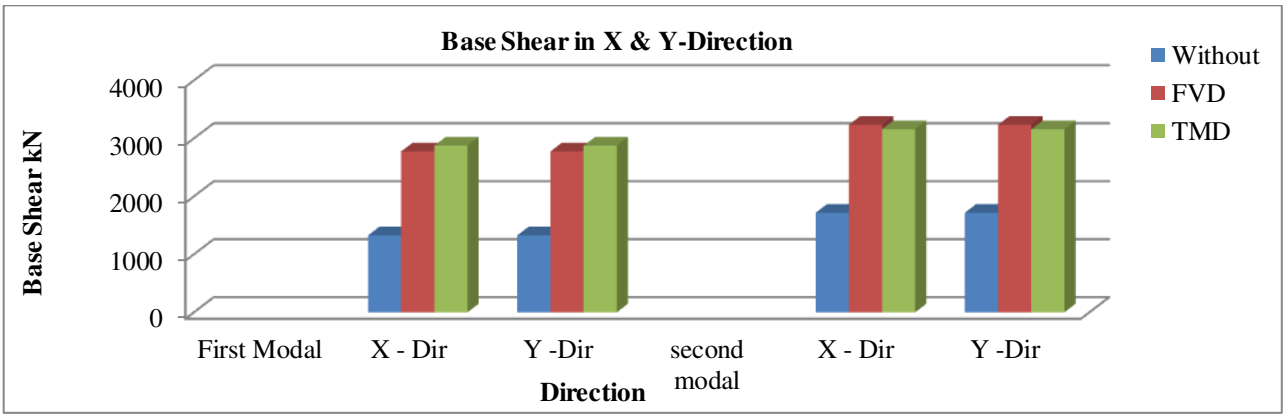

Figure 6: Base Shear of both the modal in X and Y direction

4.3 Model Participation Mass Ratio

In each case, the modal analysis for 12 modes following periods has been documented for frames with and without additional damping. Table4 depicts the median participation ratios of two buildings for various bay sizes (5x5 & 6x6). The comparison graph between 15x15 building response and 16x16 building response of modal participation ratio of x-direction, y-direction, and z-direction is shown in Figures 7, 8, and 9.

Table 4: Modal Participating Mass Ratio without Damper and with FVD & TMD

Mode	Modal Participating Mass Ratio Building 15m x 15m bay size 5mx5m									Modal Participating Mass Ratio Building 18m x 18m bay size 6mx6m								
	Without Damper			FVD			TMD			Without Damper			FVD			TMD		
	Sum RX 5x5	Sum RY 5x5	Sum RZ 5x5	Sum RX 5x5	Sum RY 5x5	Sum RZ 5x5	Sum RX 5x5	Sum RY 5x5	Sum RZ 5x5	Sum RX 6x6	Sum RY 6x6	Sum RZ 6x6	Sum RX 6x6	Sum RY 6x6	Sum RZ 6x6	Sum RX 6x6	Sum RY 6x6	Sum RZ 6x6
1	0.0261	0.1792	0	0.1519	0.1519	0.0023	0	0	0.8031	0.0532	0.149	0	0.1551	0.1551	0.0018	0	0	0.8007
2	0.2053	0.2053	0	0.3069	0.3069	0.0023	0.0036	0	0.8031	0.2023	0.2023	0	0.3137	0.3137	0.0018	0.0061	0	0.8007
3	0.2053	0.2053	0.8031	0.3073	0.3073	0.7423	0.0036	0.0037	0.8031	0.2023	0.2023	0.8007	0.314	0.314	0.7264	0.0061	0.0063	0.8007
4	0.6472	0.2816	0.8031	0.5103	0.5103	0.7425	0.0036	0.0037	0.8964	0.2794	0.6427	0.8007	0.5097	0.5097	0.7265	0.0061	0.0063	0.8941
5	0.7236	0.7236	0.8031	0.7054	0.7054	0.7425	0.5744	0.0037	0.8964	0.7198	0.7198	0.8007	0.6973	0.6973	0.7265	0.5506	0.0063	0.8941
6	0.7236	0.7236	0.8964	0.7055	0.7055	0.8996	0.5744	0.5732	0.8964	0.7198	0.7198	0.8941	0.6974	0.6974	0.8962	0.5506	0.5491	0.8941
7	0.7346	0.7754	0.8964	0.76	0.76	0.8998	0.5744	0.5732	0.932	0.7198	0.7819	0.8941	0.7534	0.7534	0.8967	0.5506	0.5491	0.9299
8	0.7865	0.7865	0.8964	0.8162	0.8162	0.8998	0.5755	0.5732	0.932	0.7198	0.8561	0.8941	0.8118	0.8118	0.8967	0.5522	0.5491	0.9299
9	0.7865	0.7865	0.932	0.8174	0.8174	0.9443	0.5755	0.5743	0.932	0.7198	0.8864	0.8941	0.8178	0.8178	0.9353	0.5522	0.5508	0.9299
10	0.7869	0.8599	0.932	0.85	0.85	0.9456	0.5755	0.5743	0.9514	0.7198	0.9175	0.8941	0.8451	0.8451	0.943	0.5522	0.5508	0.9497
11	0.8603	0.8603	0.932	0.885	0.885	0.9456	0.7343	0.5743	0.9514	0.7198	0.936	0.8941	0.8796	0.8796	0.943	0.7069	0.5508	0.9497
12	0.8603	0.8603	0.9514	0.8982	0.8982	0.9505	0.7343	0.7324	0.9514	0.7198	0.9535	0.8941	0.8964	0.8964	0.9437	0.7069	0.7043	0.9497

TMD has better X- and y-direction vibration control than FVD, while z-direction modal participation control is slightly lower than FVD. The graph clearly illustrates that the Tuned Mass Damper has a strong grip on the modal participation ratio of 6x6 bay buildings versus 5x5 bay buildings. As a result, we may conclude that the tuned mass damper decreases vibration more effectively than the fluid viscous damper.

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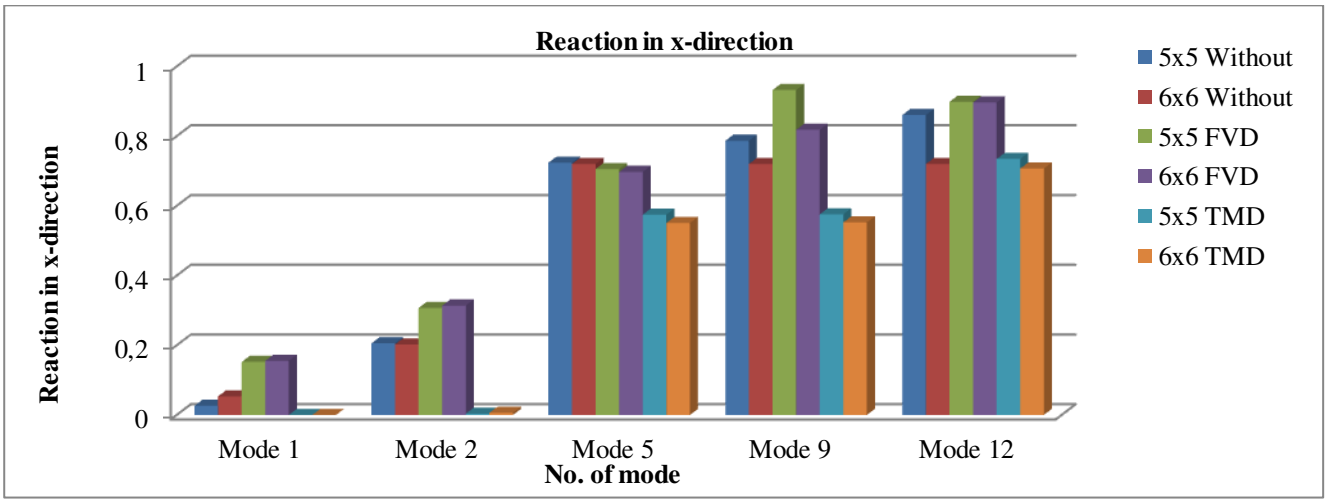

Figure 7: Reaction in X- direction for both modal (bay size 5x5 and 6x6)

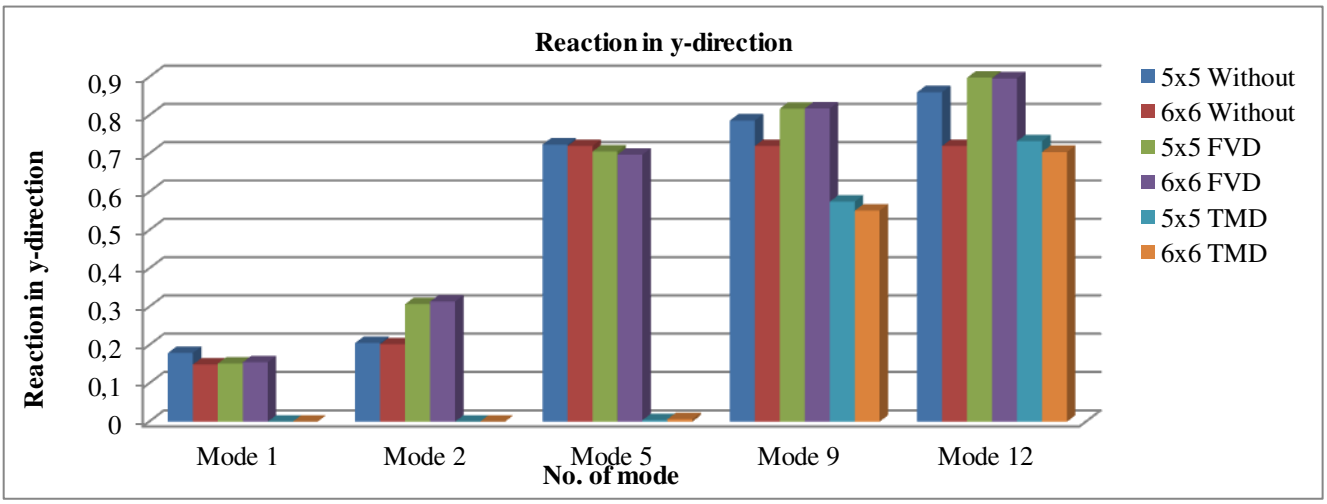

Figure 8: Reaction in Y- direction for both modal (bay size 5x5 and 6x6)

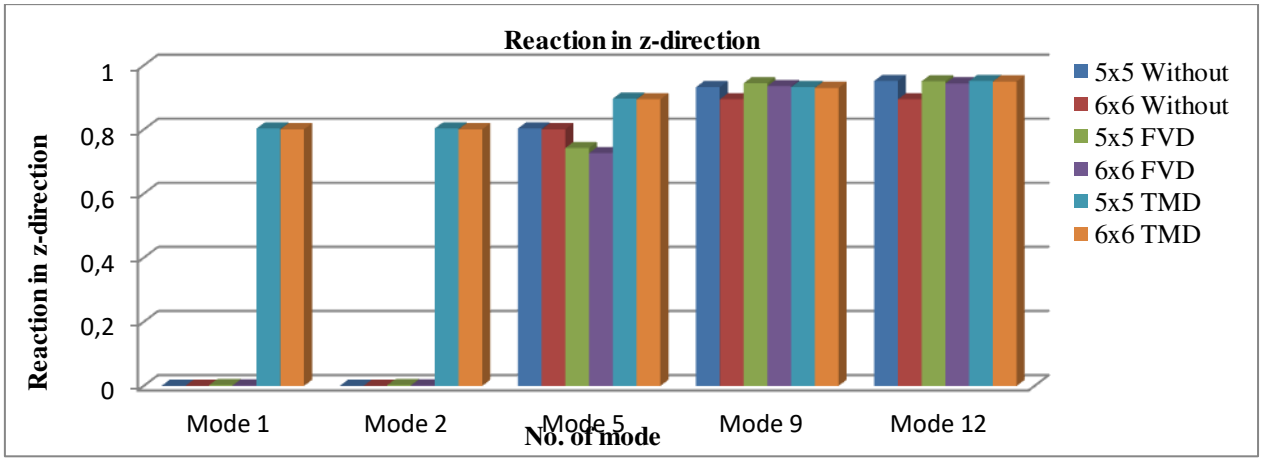

Figure 9: Reaction in Z- direction for both modal (bay size 5x5 and 6x6)

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V. CONCLUSION

This study looked at the difference in SMRF structure behaviour with and without a damper when subjected to a seismic load. ETABS2018 Version 18.1.1 software and numerical computations were used to analyse a G+15-story structure. The findings suggest that controlling seismic energy in buildings with FVD and TMD reduces structural reaction significantly when compared to buildings without Damper. The following are the important conclusions in the instance of a G+15 story building:

- The ability to avoid maximum displacement using a fluid viscous damper is 26.5 percent, while the usage of a tuned mass damper is 73 percent in the initial building bay size of 5m x 5m. When using the fluid viscous damper and the tuned mass damper, the efficiency in other buildings bay size (6mx6m) is 41 percent and 77 percent, respectively.
- We also checked the frequencies in a static and dynamic way, and discovered that there is no difference in the three parameters in static. However, there are certain alterations in dynamic acceleration. One thing has been discovered: the acceleration of the fluid viscous damper is continuously increasing.
- We evaluate the dampers as the most effective instrument for seismic energy management, limiting structural damage during the earthquake, using earthquake zone v.
- We also investigated structures with various dampers and bays and discovered that tuned mass dampers are more effective than fluid viscous dampers at absorbing shocks.
- When a multi-story structure is analysed using Fluid Viscous Damper and Tuned Mass Damper individually, it is discovered that Tuned Mass Damper controls displacement more effectively than Fluid Viscous Damper and without Damper.

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