Comparative Study of Seismic Behaviour of G+15 Storey Building Without Damper and With Tuned Mass Damper and Fluid Viscous Damper

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Abstract— Dampers are used to dissipate energy and also resist the movement of reinforcement cement concrete during the earthquake era. With the support of dampers, we can decrease the buckling and failure of columns and beams by increasing the structure's stiffness. High-rise buildings are damaged during earthquakes and great deformation occurs in high-rise buildings. Through using dampers, during the earthquake, we can reduce vibration of reinforcement cement concrete construction. In this study we have used different types of dampers to check the suitability of type of various dampers during earthquake. For the comparative analysis of different types of dampers used for multi-story cement concrete building reinforcement, empirical work is completed. We have used the Time History Method to evaluate G+15 storey building seismic behaviour with and without dampers. In both x and y directions, earthquake load is applied for analysis. ETABS 2018 version 18.1.1 software is used for the purpose of analysis by considering seismic zone V as per the IS1893:2002(part 1) code. In terms of different parameters such as maximum absolute displacement, absolute acceleration, absolute velocity, storey shear, storey drift, storey stiffness, Modal participation mass ratio the results of these tests are addressed. It is done to compare these different parameters. For the seismic energy dissipation different types of dampers are used. In this paper comparison between two different building of different bay size (5mx5m & 6mx6m) is used and comparative study with respect to various parameter i.e. (maximum absolute displacement, absolute acceleration, absolute velocity, storey shear, storey drift, storey stiffness, and Modal participation mass ratio) by using 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 oscillation of an object at an equilibrium point is referred to as vibration. Controlling vibration in various forms of machinery is important. New engineering technologies have been created with the aid of new technologies. The vibration reduction technique has found its way into civil engineering and a variety of other areas of engineering. Countless multi-story buildings are being built around the world. This is not only in response to concerns about high population density in cities, commercial areas, and space conservation, but also to create country land marks and ensure that their countries meet the requirements of other developed countries

We stick to the concept of energy conservation in all of our endeavours. The system can vibrate less if we can ensure that the energy exerted on it by wind and earthquake loads is completely minimized or dissipated. Any structure naturally releases some energy through a variety of mechanisms. Natural damping is present in nearly any building to the tune of 5%. As a result, newer high-rise buildings have artificial damping devices for vibration control through energy dissipation. Vibration can be regulated in a number of ways: passive, active, semi-active, and mixed.

A. *Objectives of 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:-

- To study the comparison of performance of Tuned Mass Damper and Fluid Viscous Damper using public work as a reference and understand the behavior aspect.
- To do a literature review that covers different forms of tuned mass dampers as well as the behavior of systems that use tuned mass dampers.
- To do a literature review that covers different forms of Fluid Viscous Damper as well as the behavior of systems that use Fluid Viscous Damper tuned.
- To study the comparison of performance of building with and without damper using different bay size of structure.

B. *Damper:*

This system absorbs and dampens shock and vibration energy in a variety of ways. Multi-storey buildings are now protected from seismic and wind forces using a variety of techniques, one of which is the use of dampers, which is both common and useful in countering the external force provided by seismic and wind loads. Damper devices dissipate seismic energy and monitor the deformation of the building to maintain structural integrity, mitigate losses, and protect occupants from injury.

1) *Tuned Mass Damper*

A tuned mass damper (TMD) is a mechanism that is connected to a structure and consists of a mass, a spring, and a damper to minimize the structure's dynamic response. The damper's frequency is tuned to the structural frequency, causing the damper to respond out of phase with the structural motion when that frequency is excited. The damper inertia force working on the system dissipates energy. Frahm used the TMD idea for the first time in 1909 to minimize ship rolling motion and hull vibration. A Tuned Mass damper is the most effective device to control the energy of motion and vibration. Some example of Tuned Mass Damper 1) Statue of Unity, INDIA, 31 October 2018 2) Taipei 101 3) Perk Tower, Chicago

Fig. 1: Tuned mass damper in Taipei 101

2) Fluid Viscous Damper

Vibration management of a different structure is achieved in structural construction by using liquid viscous dampers, which are close to the protective features used in cars. For a long time, they were used in military construction and the aeronautic trade. Fluid viscous dampers have been developed to minimize both distraction and anxiety inside a structure; a standard illustration of a liquid viscous damper can be seen in Fig 2. A fluid thick damper is typically made with a cylinder head with holes contained in a barrel filled with a thick liquid, usually silicone or a similar type of oil

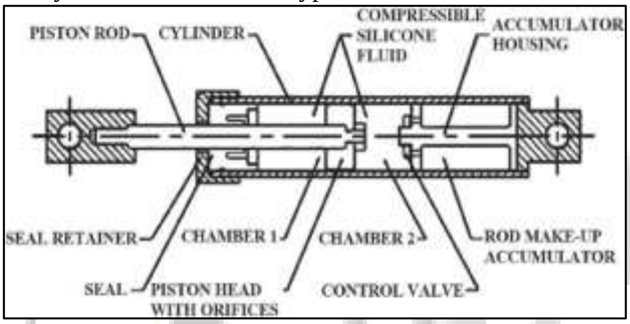
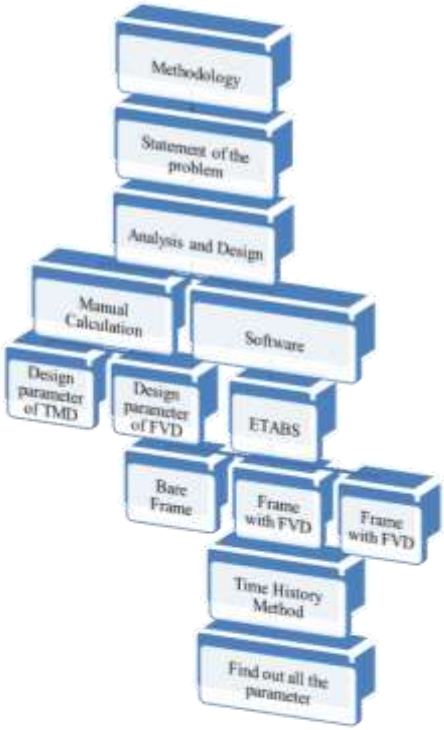


Fig. 2: Fluid Viscous Damper

II. METHODOLOGY



Following the selection of the structural model, analysis can be carried out to determine the seismically induced forces in the structures. Different method of analysis has been established with different degree of precision. The analysis processes are classified on the basis of three factors: the type of the externally applied loads, the behaviour of structure or structural materials, and type of structural model selected. The analysis can be further classified as follows, depending on the type of external action and structure behaviour:

1) Linear static analysis
   a) Equivalent static method
2) Linear dynamic analysis
   a) Response spectrum method
   b) Elastic time history method
3) Nonlinear static analysis
   a) Push over analysis
4) Nonlinear dynamic analysis
   a) Inelastic time history method

III. BUILDING PROPERTIES & SPECIFICATION

<table>
<tr><th>S.NO.</th><th colspan="2">Specification</th><th>Size</th></tr>
<tr><td>1</td><td colspan="2">Plan size (X x Y)</td><td>18m x 18, 15m x 15m</td></tr>
<tr><td>2</td><td colspan="2">Two bay size</td><td>6m x 6m, 5m x 5m</td></tr>
<tr><td>3</td><td colspan="2">Floor to floor height (m)</td><td>3.0m</td></tr>
<tr><td>4</td><td colspan="2">Total height of the building (G+15)</td><td>48.0m</td></tr>
<tr><td>5</td><td colspan="2">Types of structure</td><td>SMRF</td></tr>
<tr><td>6</td><td colspan="2">Size of beam</td><td>0.4m x 0.3m</td></tr>
<tr><td>7</td><td colspan="2">Size of column</td><td>0.5m x 0.5m</td></tr>
<tr><td>8</td><td colspan="2">Wall thickness</td><td>0.2m</td></tr>
<tr><td>9</td><td colspan="2">Thickness of slab</td><td>0.150m</td></tr>
<tr><td>10</td><td colspan="2">Grade of concrete and steel</td><td>M30, M20, Fe415, Fe250</td></tr>
<tr><td>11</td><td colspan="2">Types of soil(as per IS1893(part 1): 2002</td><td>Type II Medium rocky soil</td></tr>
<tr><td>12</td><td colspan="2">Response Reduction Factor (R)</td><td>5</td></tr>
<tr><td>13</td><td colspan="2">Importance Factor</td><td>1</td></tr>
<tr><td>14</td><td colspan="2">Seismic Zone Factor</td><td>0.36 (Zone V)</td></tr>
<tr><td>15</td><td colspan="2">Load Combination</td><td>According to IS:1893 (part 1) : 2002</td></tr>
<tr><td rowspan="4">116</td><td rowspan="4">Load Applied</td><td>Dead Load</td><td>Calculated as per Self Weight</td></tr>
<tr><td>Live Load</td><td>3 KN/m²</td></tr>
<tr><td>Seismic Load</td><td>As per IS 1893 (part 1) : 2002</td></tr>
<tr><td>Floor Finish</td><td>KN/m²</td></tr>
</table>

Table 1: Member properties & specification

IV. CALCULATION

A. Design Parameter of Tuned Mass Damper

Damping ratio for initial four modes along x direction

For Mode 1: $\xi_1 = \frac{\tilde{c}_1}{2\omega_1\,\tilde{m}_1} = 0.04,$

For Mode 2: $\xi_2 = \frac{\tilde{c}_2}{2\omega_2\ \tilde{m}_2} = 0.12$

For Mode 3: $\xi_3 = \frac{\tilde{c}_3}{2\omega_3\ \tilde{m}_3} = 0.202$

For Mode 4: $\xi_4 = \frac{\tilde{c}_4}{2\omega_4\tilde{m}_4} = 0.252$

Assume mass ratio 4 %

1) *Mode 1: optimum location node 9*

$f_{opt} = 0.9316$, $\xi_{dopt} = 0.127$

$m_d = \bar{m}\ \tilde{m}_{1e} = \frac{\bar{m}\ [\phi_1{}^T M\phi_1]}{\phi^2{}_{19}} = \frac{\bar{m}\ \tilde{m}1}{\phi^2{}_{19}} = \frac{.04 \times 430.4826}{(0.33)^2} =$ 158.024 tonne

$\omega_d = f_{opt}\ \omega_1 = 0.9316 \times 4.174 = 4.39 \mathrm{rad/sec}$

$k_d = \omega_d{}^2 m_d = 4.39^2 \times 158.024 = 3045.454\ \mathrm{kN/m}$

$c_d = 2\ \xi_{dopt}\ \omega_d\ m_d = 2 \times 0.127 \times 4.39 \times 158.024 = 176.206\ \mathrm{kN-s/m}$

2) *Mode 2: optimum location node 13*

$f_{opt} = 0.8823$, $\xi_{dopt} = 0.140$

$m_d = \bar{m}\ \tilde{m}_{2e} = \frac{\bar{m}\ [\phi_2{}^T M\phi_2]}{\phi^2{}_{213}} = \frac{\bar{m}\ \tilde{m}2}{\phi^2{}_{213}} = \frac{.04\ \times 426.349}{(0.335)^2} = 151.962$ tonne

$\omega_d = f_{opt}\ \omega_1 = 0.8823 \times 14.098 = 12.434 \mathrm{rad/sec}$

$k_d = \omega_d{}^2 m_d = 12.434^2 \times 151.962 = 23495.634\ \mathrm{kN/m}$

$c_d = 2\ \xi_{dopt}\ \omega_d\ m_d = 2 \times 0.140 \times 12.434 \times 151.962 = 529.058\ \mathrm{kN-s/m}$

3) *Mode 3: optimum location node 3*

$f_{opt} = 0.812$, $\xi_{dopt} = 0\ .154$

$m_d = \bar{m}\ \tilde{m}_{3e} = \frac{\bar{m}\ [\phi_3{}^T M\phi_3]}{\phi^2{}_{33}} = \frac{\bar{m}\ \tilde{m}3}{\phi^2{}_{33}} = \frac{.04\ \times 422.407}{(-0.338)^2} = 149.662$ tonne

$\omega_d = f_{opt}\ \omega_3 = 0.812 \times 23.347 = 18.957 \mathrm{rad/sec}$

$k_d = \omega_d{}^2 m_d == 18.957^2 \times 149.662 = 53778.96\ \mathrm{kN/m}$

$c_d = 2\ \xi_{dopt}\ \omega_d\ m_d = 2 \times 0.154 \times 18.957 \times 149.662 = 873.839\ \mathrm{kN-s/m}$

4) *Mode 4: optimum location node 15*

$f_{opt} = 0.801$, $\xi_{dopt} = 0.168$

$m_d = \bar{m}\ \tilde{m}_{4e} = \frac{\bar{m}\ [\phi_4{}^T M\phi_4]}{\phi^2{}_{415}} = \frac{\bar{m}\ \tilde{m}3}{\phi^2{}_{415}} = \frac{.04\ \times 419.510}{(0.337)^2} = 147.755$ tonne

$\omega_d = f_{opt}\ \omega_4 = 0.801 \times 32.3711 = 25.929 \mathrm{rad/sec}$

$k_d = \omega_d{}^2 m_d == 25.929^2 \times 147.755 = 99337.61\ \mathrm{kN/m}$

$c_d = 2\ \xi_{dopt}\ \omega_d\ m_d = 2 \times 0.168 \times 25.929 \times 147.755 = 1287.262\ \mathrm{kN-s/m}$

B. *Design Parameter of Fluid Viscous Damper*

Step 1: Design coefficient of design basic Earthquake

Let us assume Target damping ratio $\xi = 0.30$

$$C_{sa} = 2.5$$

Modification factor $C_D = \frac{1.5}{40 \times \xi + 1} + 0.5 = \frac{1.5}{40 \times 0.30 + 1} + 0.5 = 0.615$

Design Acceleration of the system

$$S_a = ZIC_{sa}C_D = 0.36 \times 1.2 \times 2.5 \times 0.615 = 0.6642(g)$$

Step 2: Calculate linear damping coefficient

$$C_L = \xi \times \omega \times \frac{W_{total}}{g} \times \frac{N+1}{n} \times \frac{1}{(\cos\theta)^2}$$

$$C_L = 0.30 \times \frac{2\pi}{1.018} \times 6757.4 \times \frac{16+1}{8} \times \frac{1}{0.615^2} = 70297.7905\ kN-s/m$$

Step 3: Calculate peak damper velocity

$$V_{max} = \frac{S_a}{\omega} \times \frac{2}{N+1} \times \cos\theta = \frac{0.6642}{6.172} \times \frac{2}{16+1} \times 0.615 = 0.076\ m/s$$

Step 4: Calculate peak damper force

$$F_{dmax} = 2 \times \xi \times M_{total} \times \frac{S_a}{n\cos\theta} = 2 \times 0.30 \times 6757.4 \times \frac{0.6642 \times 9.81}{8 \times 0.615} = 5369.497\ kN$$

Step 5: Calculate stiffness

$$K_L = \frac{\omega \times C_L}{2 \times \xi} = \frac{6.172 \times 70297.7905}{2 \times 0.30} = 723129.938\ kN/m$$

V. MODELING AND ANALYSIS

A. *Plan View of Building*

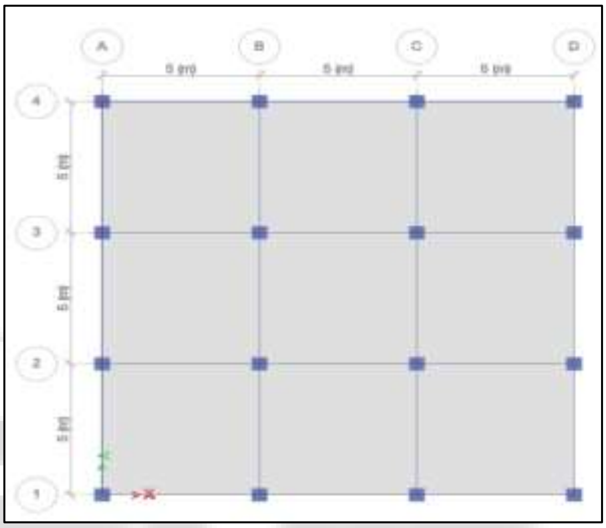


Fig. 3: Plan view of 6x6 bay size Building

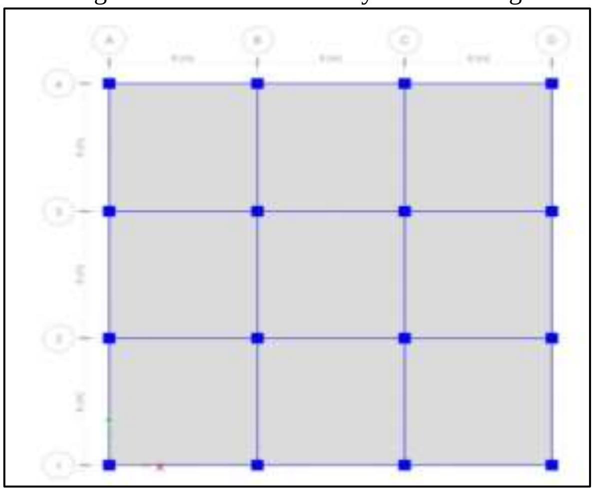


Fig. 4: Plan view of 6x6 bay size Building

B. *Elevation of Building*

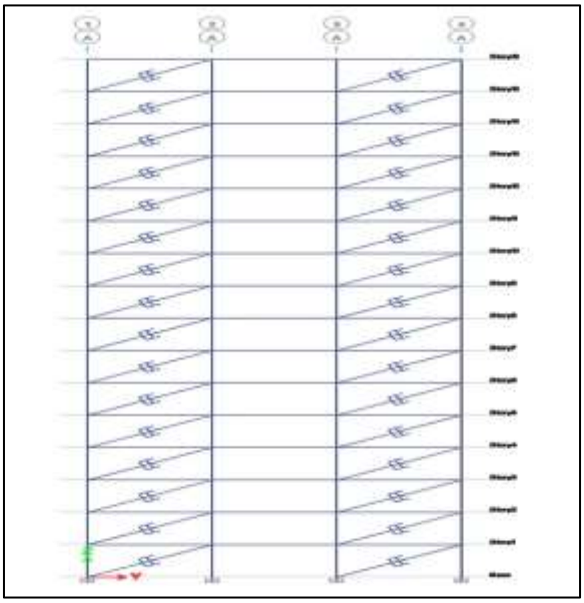


Fig. 5: Elevation of Building with FVD

C. *Isometric View of Building*

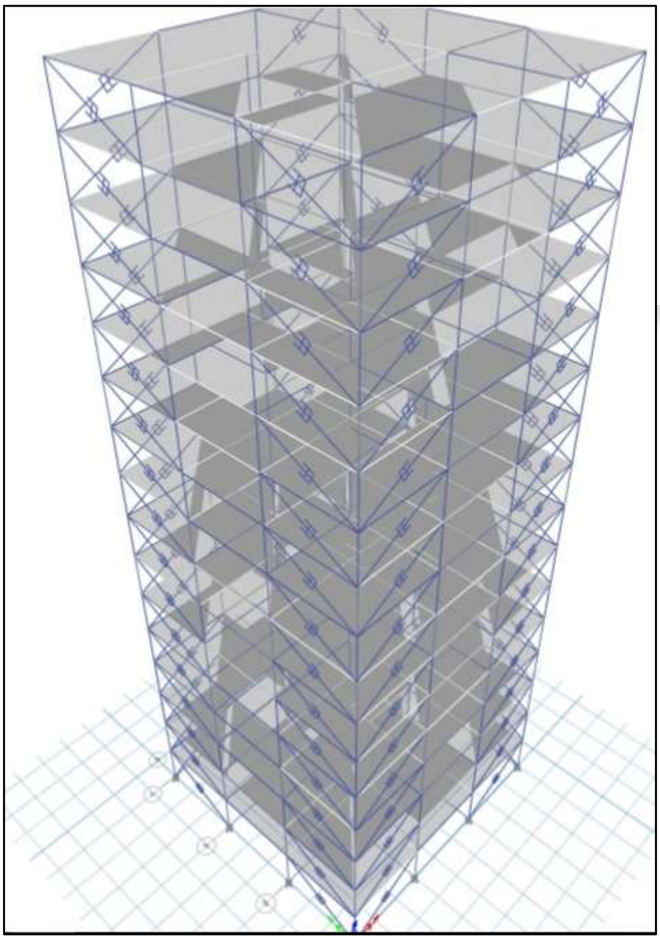


Fig. 6: Isometric View of 6x6 bay size Building with FVD

VI. RESULT

A. *Modal Participation Ratio:*

For the modal analysis carried out for 12 modes following time periods have been noted down in each case for frame with and without supplemental damping. The value of the modal participating mass ratio (MPMR) for each vibration mode reflects the mode's contribution to structural responses in general. For a building without a damper, a building with tuned mass damper, and a building with Fluid Viscous damper, modal participating mass ratio of different stories was calculated using Time History Analysis in the x and y directions. Tables and graphs are used to calculate the damper's efficiency and response reduction.

Mode	TMD					
	Sum RX 5X5	Sum RX 6X6	Sum RY 5X5	Sum RY 6X6	Sum RZ 5X5	Sum RZ 6X6
1	0	0	0	0	0.803	0.800
2	0.003	0.006	0	0	0.803	0.800
3	0.003	0.006	0.003	0.006	0.803	0.800
4	0.003	0.006	0.003	0.006	0.896	0.894
5	0.574	0.550	0.003	0.006	0.896	0.894
6	0.574	0.550	0.573	0.549	0.896	0.894
7	0.57	0.55	0.57	0.54	0.93	0.929
8	0.57	0.55	0.573	0.549	0.93	0.929
9	0.575	0.552	0.574	0.550	0.93	0.9299
10	0.575	0.552	0.574	0.550	0.95	0.949
11	0.734	0.706	0.574	0.550	0.951	0.949
12	0.734	0.706	0.732	0.704	0.951	0.949

Table 2: Tuned Mass Damper Modal Participating Mass Ratios

Mode	FVD					
	Sum RX 5X5	Sum RX 6X6	Sum RY 5X5	Sum RY 6X6	Sum RZ 5X5	Sum RZ 6X6
1	0.1519	0.1551	0.1519	0.1551	0.0023	0.0018
2	0.3069	0.3137	0.3069	0.3137	0.0023	0.0018
3	0.3073	0.314	0.3073	0.314	0.7423	0.7264
4	0.5103	0.5097	0.5103	0.5097	0.7425	0.7265
5	0.7054	0.6973	0.7054	0.6973	0.7425	0.7265
6	0.7055	0.6974	0.7055	0.6974	0.8996	0.8962
7	0.76	0.7534	0.76	0.7534	0.8998	0.8967
8	0.8162	0.8118	0.8162	0.8118	0.8998	0.8967
9	0.8174	0.8178	0.8174	0.8178	0.9443	0.9353
10	0.85	0.8451	0.85	0.8451	0.9456	0.943
11	0.885	0.8796	0.885	0.8796	0.9456	0.943
12	0.8982	0.8964	0.8982	0.8964	0.9505	0.9437

Table 3: Fluid Viscous Damper Modal Participating Mass Ratios

Mode	WITHOUT DAMPER					
	Sum RX 5X5	Sum RX 6X6	Sum RY 5X5	Sum RY 6X6	Sum RZ 5X5	Sum RZ 6X6
1	0.026	0.053	0.179	0.149	0	0
2	0.205	0.202	0.205	0.202	0	0
3	0.205	0.202	0.205	0.202	0.803	0.800
4	0.647	0.279	0.281	0.642	0.803	0.800
5	0.723	0.719	0.723	0.719	0.803	0.800
6	0.723	0.719	0.723	0.719	0.896	0.894
7	0.734	0.719	0.775	0.781	0.896	0.894
8	0.786	0.719	0.786	0.856	0.896	0.894
9	0.786	0.719	0.786	0.886	0.932	0.894
10	0.786	0.719	0.859	0.917	0.932	0.894
11	0.860	0.719	0.860	0.936	0.932	0.894
12	0.860	0.719	0.860	0.953	0.951	0.894

Table 4: Without Damper Modal Participating Mass Ratios

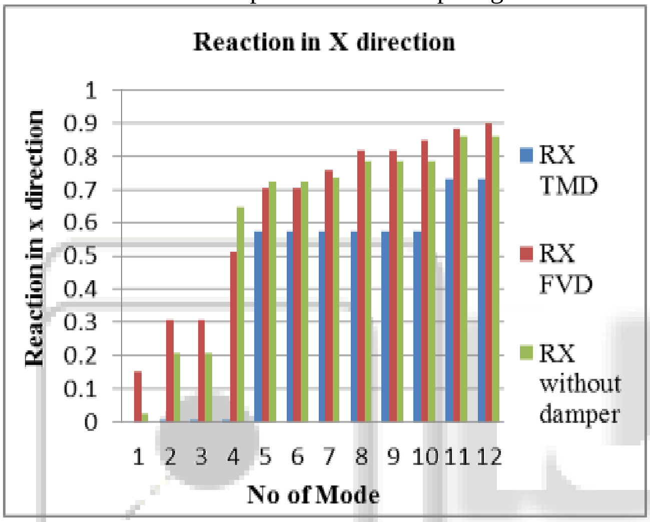


Fig. 7: Reaction in X direction without Damper and with TMD and FVD (bay size 5x5)

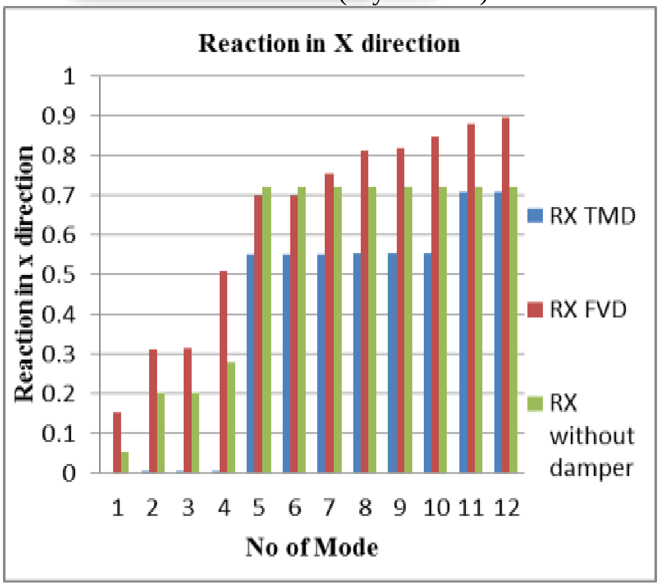


Fig. 8: Reaction in X direction without Damper and with TMD and FVD (bay size 6x6)

From table 2, 3, 4 show the modal participation ratio in the x, y, and z-direction. For analysis of that parameter, I have found that Tuned Mass Damper more vibration control as compare to Fluid Viscous Damper. It is clearly shown in figure 7 and figures 8 modal participation ratios in the x-direction much lower than for using TMD as compare to FVD and Without Damper.

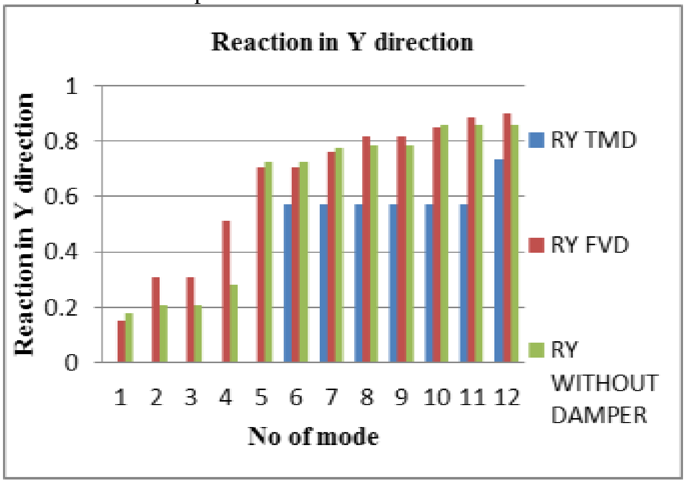


Fig. 9: Reaction in Y direction without Damper and with TMD and FVD (bay size 5x5)

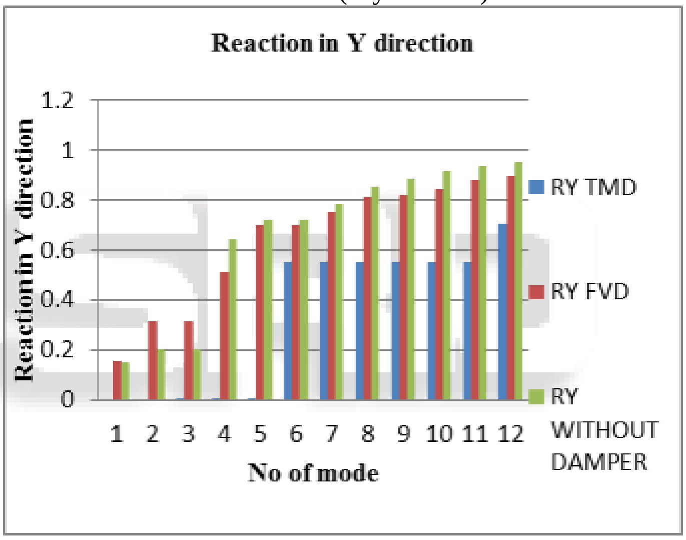


Fig. 10: Reaction in Y direction without Damper and with TMD and FVD (bay size 6X6)

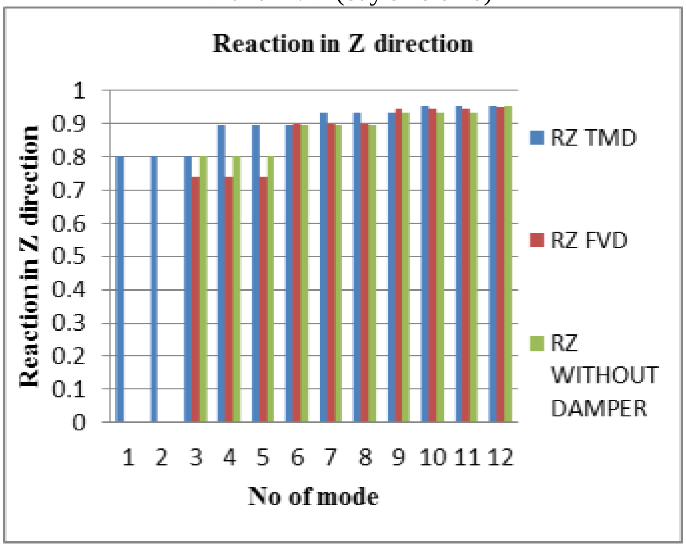


Fig. 11: Reaction in Z direction without Damper and with TMD and FVD (bay size 5X5)

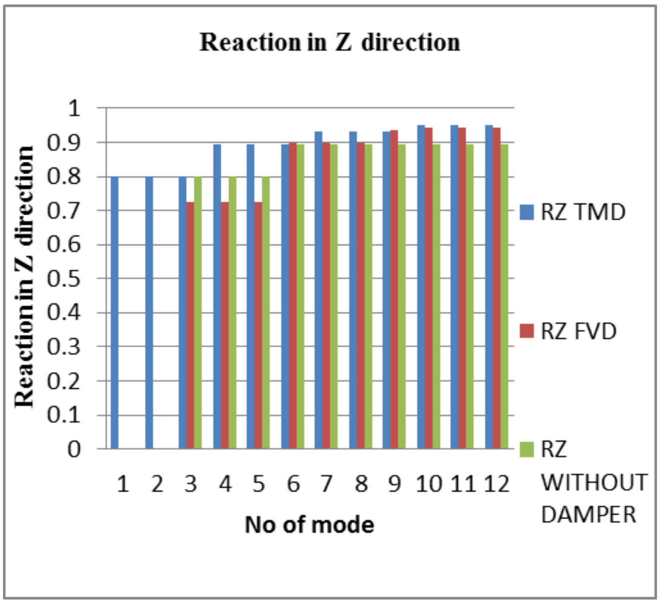


Fig. 12: Reaction in Z direction without Damper and with TMD and FVD (bay size 6x6)

The modal analysis carried out for 12 modes following periods has been noted down in each case for frames with and without supplemental damping. The value of the modal participating mass ratio (MPMR) for each vibration mode reflects the mode's contribution to structural responses in general. Figures 9, 10, 11, & 12 show the modal participation ratio in the y and z direction of building for different bay sizes (5x5 & 6x6). It is found that the tuned mass damper reduces more vibration than that of fluid viscous damper and without damper.

B. Storey Displacement:

If not thoroughly tested, lateral displacements caused by wind and earthquake on the building's rooftop could pose a problem for your architecture. The former is more popular when checking lateral displacement, while the latter does not seem to have a cap, although you can quantify and look at the value and see how high it is during a ground shaking case. However, under earthquake load, more attention should be paid to testing inter-story displacement. For a building without a damper, a building with tuned mass damper, and a building with Fluid Viscous damper, Storey Displacement of different stories was calculated using Time History Analysis in the x and y directions. Tables and graphs are used to calculate the damper's efficiency and response reduction. Table 5 & Table 6 are show the displacement value in x direction due earthquake load (Ex) acting in x direction.

Storey	Elevation	Without Damper	With FVD	With TMD
	m	mm	mm	mm
		X-Dir	X-Dir	X-Dir
Storey16	48	108.542	79.785	0.505
Storey15	45	106.279	74.201	8.524
Storey14	42	102.945	68.569	16.282
Storey13	39	98.494	62.773	22.23
Storey12	36	93.039	56.829	26.229
Storey11	33	86.722	50.773	28.46
Storey10	30	79.687	44.66	29.171
Storey9	27	72.068	38.555	28.609
Storey8	24	63.991	32.54	27.007
Storey7	21	55.568	26.702	24.573
Storey6	18	46.902	21.139	21.495
Storey5	15	38.084	15.957	17.937
Storey4	12	29.205	11.271	14.043
Storey3	9	20.37	7.2	9.95
Storey2	6	11.797	3.876	5.831
Storey1	3	4.164	1.428	2.077

Table 5: Displacement from time history analysis in x and y direction due to E_X (5x5)

Storey	Elevation	Without Damper	With FVD	With TMD
	m	mm	mm	mm
		X-Dir	X-Dir	X-Dir
Storey16	48	156.603	91.386	1.176
Storey15	45	153.294	84.886	10.548
Storey14	42	148.429	78.317	19.639
Storey13	39	141.981	71.571	26.65
Storey12	36	134.111	64.681	31.363
Storey11	33	125.018	57.694	33.975
Storey10	30	114.899	50.675	34.778
Storey9	27	103.941	43.702	34.065
Storey8	24	92.315	36.862	32.113
Storey7	21	80.177	30.252	29.173
Storey6	18	67.666	23.978	25.47
Storey5	15	54.911	18.15	21.199
Storey4	12	42.038	12.888	16.536
Storey3	9	29.213	8.316	11.648
Storey2	6	16.789	4.566	6.759
Storey1	3	5.834	1.758	2.363

Table 6: Displacement from time history analysis in x and y direction due to E_X (6x6)

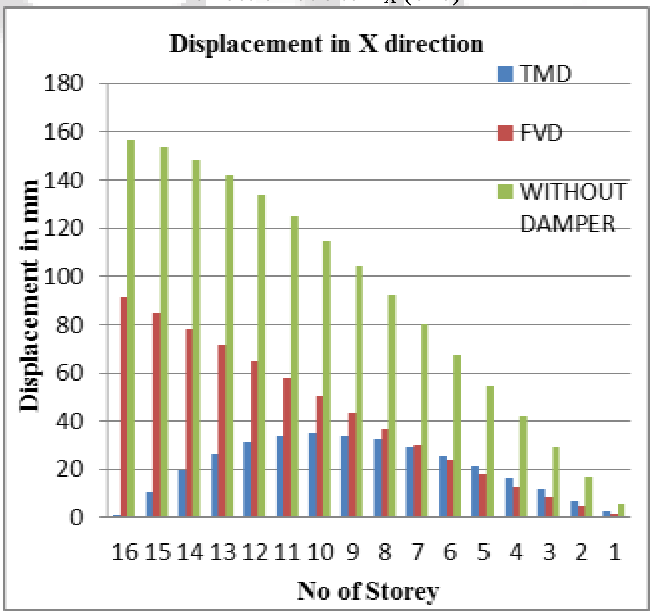


Fig. 13: Displacement from time history analysis in x and y direction due to EX (6x6)

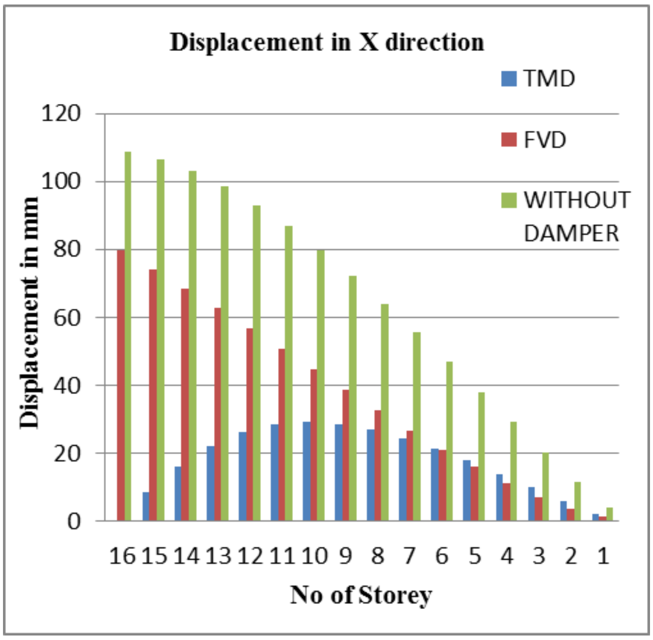


Fig. 14: Displacement from time history analysis in x and y direction due to E_X (5x5)

Figure 13 & Figure 14 show the storey displacement bar chart for different bay sizes (5x5 & 6x6) with Tuned Mass Damper & Fluid Viscous Damper and without Damper. Now we are taken symmetrical building if the response of the building both x and y direction are the same. So I have discussed the response of x-direction in the building.

VII. CONCLUSION

The following conclusions can be drawn from all of the findings result and discussions:-

1) We found that a tuned mass damper eliminates vibrations more effectively than a fluid viscous damper or no damper.
2) Analytical study is done for multi-storey building by using Fluid Viscous Damper and Tuned Mass Damper separately, it is found that Tuned Mass Damper more effectively control the displacement as compare to Fluid Viscous Damper and without Damper.
3) In this analysis, we used G+15 storey building to implement two types of bays: 5x5 and 6x6. We found that the 6x6 bays structure decreases drift more than the 5x5 bays structure.
4) We also looked at buildings with different dampers and bays, and found that tuned mass dampers are more effective at absorbing shocks than fluid viscous dampers.
5) We use the earthquake zone v to evaluate the dampers as the most effective instrument for seismic energy management, thus reducing structural damage during the earthquake.

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