



Tuned mass damper for high rise building under excessive structural excitation

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Abstract

Tuned mass are used to regulate the vibration of high rise structure subjected to heavy wind and other seismic forces. Under the influence these forces (wind, earthquake etc.) structure performance of buildings will be realized using both active and passive systems. But active system required very high enough engineering and implementation costs, high maintenance costs, unnecessary system complexities and it requires continuous and non interrupted power supply when compared to passive systems. A design for passive tuned mass damper system is presented with analytical simulations and component test results. These demonstrate the effectiveness of using tuned mass in conjunction with a maintenance free, hydraulic damper, having frictionless flexural seals to successfully reduce the response of a high rise building subject to severe wind inputs.

Keywords: tuned mass, high rise structure, hydraulic damper

1. Introduction

In recent years, many strong earthquakes have occurred one after another in many countries. These earthquakes have caused severe damages to large-scale infrastructures. To protect structures from significant damage and response reduction of structures under such severe earthquakes has become an important topic in structural engineering.

Conventionally, structures are designed to resist dynamic forces through a combination of strength, deformability and energy absorption. These structures may deform well beyond the elastic limit, for example, in a severe earthquake. It indicates that structures designed with these methods are sometimes vulnerable to strong earthquake motions. In order to avoid such critical damages, structural engineers are working to figure out different types of structural systems that are robust and can withstand strong motions. Alternatively, some types of structural protective systems may be implemented to mitigate the damaging effects of these dynamic forces. These systems work by absorbing or reflecting a portion of the input energy that would otherwise be transmitted to the structure itself.

In such a scenario, structural control techniques are believed to be one of the promising technologies for earthquake resistance design. The concept of structural control is to absorb vibration energy of the structure by introducing supplemental devices. Various types of structural control theories and devices have been recently developed and introduced to large-scale civil engineering structures.

Tuned mass damper (TMD) systems have been incorporated into many structures and dynamic systems throughout the world to effectively increase the level of damping within the structure itself and thereby reduce undesirable oscillations. Typical applications include tall and narrow structures that generally produce high resulting amplitudes due to the ease at

which the structure can be excited in its primary mode. The first mode natural frequencies of tall buildings that may require additional damping are typically in the range of 1 Hz or below. However, TMD's have also been incorporated into other mechanical components that are being driven at or near their natural frequency either by an internal or external source. TMD's for these types of applications have been used to effectively attenuate first mode responses in the range of up to 25 Hz or more.

A. Control systems

During the last decade more and more attention has been put to vibration mitigation of structures subjected to environmental (i.e. seismic and wind loads) and manmade (i.e. traffic or heavy machinery) loads. Such a structures needs to be protected against vibrations in order to improve the safety and durability.

Different types of structural control devices have been developed and a possible classification is done by their dissipative nature. Structural control systems can be classified as passive, active, semi-active and hybrid.

B. Passive control devices

A passive control device is a device that develops forces at the location of the device by utilizing the motion of the structure. Through the forces developed, a passive control device reduces the energy dissipation demand on the structure by absorbing some of the input energy [As Shown in Figure 1(b)]. Thus, a passive control device cannot add energy to the structural system. Furthermore, a passive control device does not require an external power supply. Examples of passive devices include base isolation, tuned mass dampers (TMD), tuned liquid dampers (TLD), metallic yield dampers, viscous fluid dampers and friction dampers.

C. Active control devices

The active control systems are the opposite side of passive systems, because they can provide additional energy to the controlled structure and opposite to that delivered by the dynamic loading [As shown in Figure 1(c)]. Active control devices require considerable amount of external power to operate actuators that supply a control force to the structure. An active control strategy can measure and estimate the response over the entire structure to determine appropriate control forces. As a result, active control strategies are more complex than passive strategies, requiring sensors and evaluator / controller equipments. Cost and maintenance of such systems are also significantly higher than that of passive devices. Examples among active control devices include active tuned mass damper, active tuned liquid column damper and active variable stiffness damper.

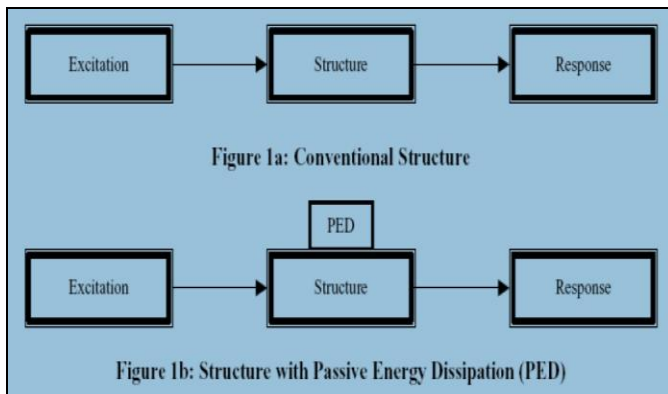


Fig 1a, 1b

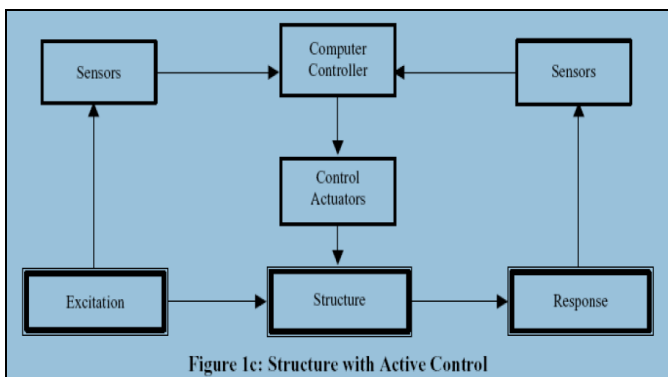


Fig 1c

D. Semi- active control devices

Semi-active control devices combine the positive aspects of passive and active control devices. Like passive control devices, semi-active control devices generate forces as a result of the motion of the structure and cannot add energy to the structural system. However, like an active control device, feedback measurements of the excitation and/or structural system are used by a controller to generate an appropriate signal for the semi-active device. In addition, only a small external power source is required for operation of a semi-active control device. Examples of semi-active devices include variable orifice dampers, variable friction dampers, variable stiffness damper, and controllable fluid dampers.

E. Hybrid control devices

A hybrid control system typically consists of a combination of passive and active or semi-active devices [As shown in Figure 1 (d)]. Because multiple control devices are operating, hybrid control systems can alleviate some of the restrictions and limitations that exist when each system is acting alone. Thus, higher levels of performance may be achieved. Since a portion of the control objective is accomplished by the passive system, less active control effort, implying less power resource, is required. A side benefit of hybrid systems is that, in the case of a power failure, the passive components of the control still offer some degree of protection, unlike a fully active control system. Examples of hybrid control devices include hybrid mass damper and hybrid base isolation.

Dampers in buildings and related structures

Typically, the dampers are huge concrete blocks or steel bodies mounted in skyscrapers or other structures, and moved in opposition to the resonance frequency oscillations of the structure by means of springs, fluid or pendulums

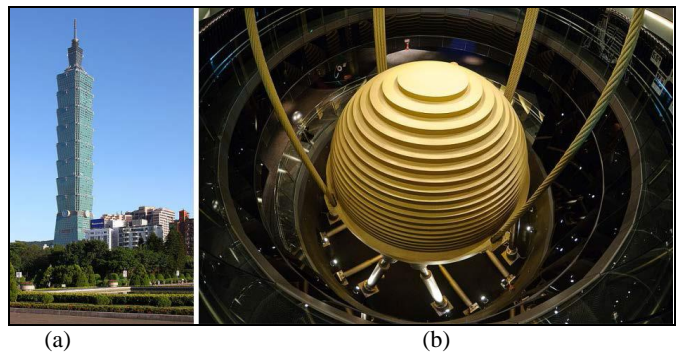


Fig 2: (a) Taipei 101 (Powell 2007) (b) Taipei 101 PTMD (2010)

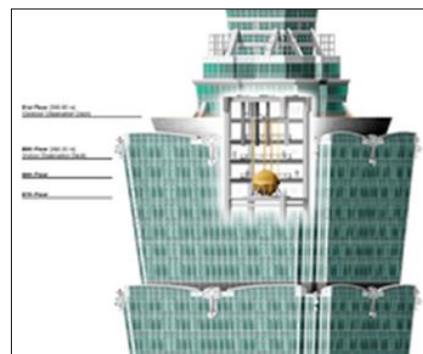


Fig 2: (c) Taipei 101's largest tuned mass damper



Fig 2(d): Tuned mass damper atop Taipei 101

Sources of vibration and resonance

Unwanted vibration may be caused by environmental forces acting on a structure, such as wind or earthquake, or by a seemingly innocuous vibration source causing resonance that may be destructive, unpleasant or simply inconvenient.

A. Earthquakes

The seismic waves caused by an earthquake will make buildings sway and oscillate in various ways depending on the frequency and direction of ground motion, and the height and construction of the building. Seismic activity can cause excessive oscillations of the building which may lead to structural failure. To enhance the building's seismic performance, a proper building design is performed engaging various seismic vibration control technologies. As mentioned above, damping devices had been used in the aeronautics and automobile industries long before they were standard in mitigating seismic damage to buildings. In fact, the first specialized damping devices for earthquakes were not developed until late in 1950.

B. Mechanical human sources

Masses of people walking up and down stairs at once, or great numbers of people stomping in unison, can cause serious problems in large structures like stadiums if those structures lack damping measures. Vibration caused by heavy industrial machinery, generators and diesel engines can also pose problems to structural integrity, especially if mounted on a steel structure or floor. Large Ocean going vessels may employ tuned mass dampers to isolate the vessel from its engine vibration.



Fig 3: Dampers on the Bridge in London.

C. Wind

The force of wind against tall buildings can cause the top of skyscrapers to move more than a meter. This motion can be in the form of swaying or twisting, and can cause the upper floors of such buildings to move. Certain angles of wind and aerodynamic properties of a building can accentuate the movement and cause motion sickness in people. A TMD is usually tuned to a certain building's frequency to work efficiently. However, during their lifetimes, high-rise and slender buildings may experience natural frequency changes under wind speed, ambient temperatures and relative humidity variations, among other factors, which require a robust TMD design.

Examples of buildings and structure with tuned mass dampers

Canada

- One Wall Centre in Vancouver — it employs tuned liquid column dampers, at the time of its installation, a unique form of tuned mass damper.

China

- Shanghai World Financial Center in Shanghai, China

Germany

- Berlin Television Tower (Fernsehturm) - tuned mass damper located in the spire.

Ireland

- Dublin Spire in Dublin, Ireland - this narrow slender structure was designed with a tuned mass damper to ensure aerodynamic stability during a wind storm.

Japan

- Akashi-Kaikyō Bridge, between Honshu and Shikoku in Japan, currently the world's longest suspension bridge, uses pendulums within its suspension towers as tuned mass dampers.
- Tokyo Skytree, vertically placed two units (total 100 tons) in the housing as atop.
- Yokohama Landmark Tower

Russia

- Sakhalin-I - An offshore drilling platform

Taiwan

- Taipei 101 skyscraper - contains the world's largest and heaviest tuned mass dampers, at 660 metric tons.

United Arab Emirates

- Burj al-Arab in Dubai - 11 tuned mass dampers.

United States of America

- Bally's to Bellagio, Bally's to Caesars Palace, and Treasure Island to The Venetian Pedestrian Bridges in Las Vegas, NV
- Bloomberg Tower/731 Lexington in New York City, NY
- Citigroup Center in New York City, NY - Designed by William LeMessurier and completed in 1977, it was one of the first skyscrapers to use a tuned mass damper to reduce sway. Uses a concrete version.
- Comcast Center in Philadelphia, PA - contains the largest Tuned Liquid Column Damper (TLCD) in the world at 1,300 tons.
- Grand Canyon Skywalk, AZ
- John Hancock Tower in Boston, MA - a tuned mass damper was added to it after it was built making it the 1st building to use a tuned mass damper.
- One Rincon Hill South Tower, San Francisco, CA - First building in California to have a liquid tuned mass damper
- Park Tower in Chicago, IL - the first building in the United States to be designed with a tuned mass damper from the outset.

- Random House Tower - Uses two liquid filled dampers in New York City, NY
- Theme Building at Los Angeles International Airport Los Angeles, CA
- Trump World Tower in New York City, NY

United Kingdom

London Millennium Bridge - 'The Wobbly Bridge'

Objectives and methodology

A. Objectives

The main aim of the thesis is to compare the behavior of high rise building using with TMD and without TMD.

- To compare the natural frequency of a single degree of freedom system with and without tuned mass damper
- To compare the natural frequency of a multi degree of freedom system with and without tuned mass damper
- To compare the natural frequency, velocity and displacement of a multi degree of freedom system under the influence of external acceleration with and without tuned mass damper

B. Methodology

- Literature survey
- Selection of structures with the desired specifications
- The respective buildings has been analyzed using software
- Tuned mass dampers has been induced on the buildings
- These buildings has been analyzed under the influence of tuned mass damper
- Comparison of the results in both cases
- Results and discussion

Investigation of structures

Introduction

This chapter deals with the study of various methods and parameters used in the present investigation.

Definitions

1. **Mass:** Dynamically it is the property that describes how an unrestricted body resist the application of external force.
2. **Stiffness:** It is defined as the force required to produce unit deformation. It is an elastic property that describes the level of resisting force.
3. **Natural period:** It is defined as the time required completing one cycle of free vibration. It is expressed in seconds.
4. **Natural frequency:** There is no external force act on a system after giving it an initial displacement the body vibrates. These vibrations are called free vibrations and their frequency is called natural frequency. It is expressed in rad/sec or hertz.
5. **Fundamental mode of vibration:** Fundamental mode of vibration of a structure is the mode having the lowest natural frequency.
6. **Damping:** It is the resistance to the motion of vibrating body. It is a phenomenon in which the vibrational energy of the system is gradually reduced. Unit of damping is N/m/s.

7. Single degrees of freedom (SDOF) system: If a single coordinate is sufficient to define the position or geometry of the mass of the system at any instant of time, it is known as single degrees of freedom system.

8. Multi degrees of freedom (MDOF) system: If more than one independent co ordinate is required to completely specify the position or geometry of different masses of the system at any instant of time, it is called multiple degrees of freedom system.

Various Methods

- Frequency and mode shape using modal calculation method for SDOF system
- Frequency and mode shape using modal calculation method for MDOF system
- Responds spectrum analysis
- Time history analysis.
- Time history analysis for 14 story building

Analysis methodology

A. Frequency and mode shape of SDOF system

Here we consider a frame of SDOF system with the following specifications

Beam dimension	:	.25m x .25m
Column dimension	:	.25m x.25m
Supports are fixed		
Load defined	:	Seismic load as per IS 1893 2002/2005
Zone value	:	0.075
Response reduction factor	:	1
Important factor	:	1
Damping ratio	:	0.05
Load case	:	Self weight of the structure modal calculations

Structure without damper

The above specified structure has been subjected to seismic charecteristics and the frequency and mode shape has been calculated.

Structure with damper

A damper has been imposed on the same sturcture. And the specifications of the damper is given below. And the frequency and mode shape has been calculated.

Damper stiffness property

Size of damper beam : 0.15m x0.15m

Size of damper column: 0.15m x0.15m

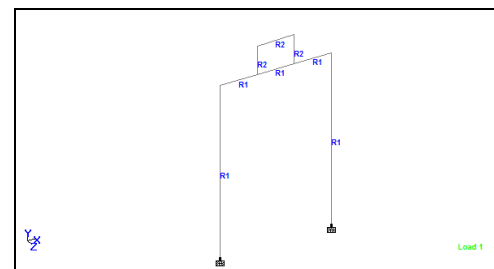


Fig 4: skeletal structure with damper

Mode shape for SDOF system
Without TMD With TMD

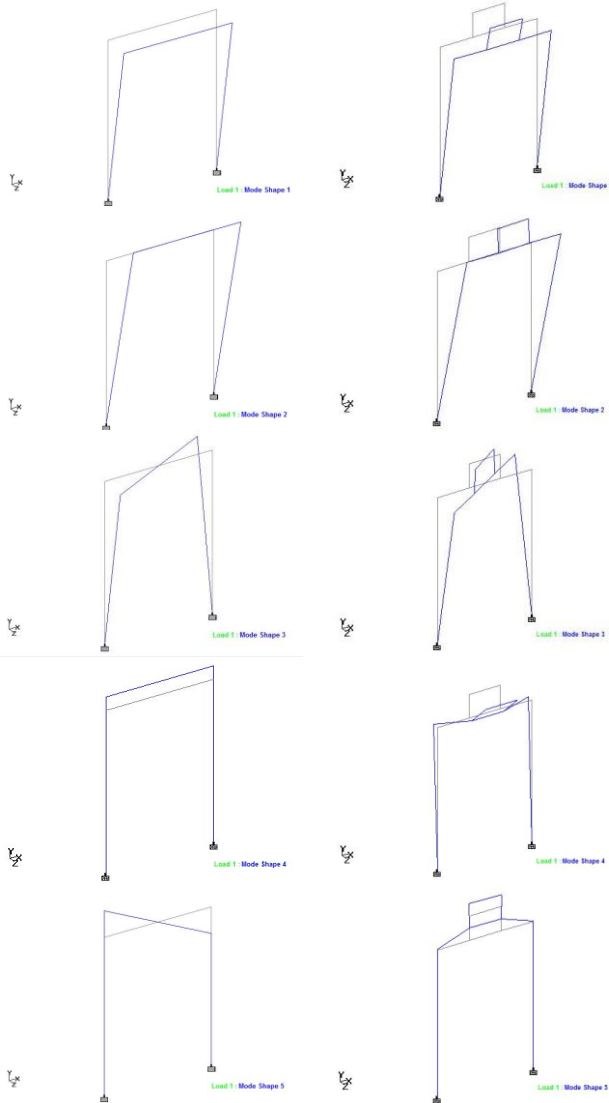


Fig 5: Mode Shape For SDOF System

Comparison of structures with and without damper

The value of frequency and mode shape in both cases has been compared and its figures and values are given in Table 5.1 and figure 5.2

Table Calculated modal Frequencies and Mass Participation SDOF system

Table a): Without TMD

Mode	Frequency (Hz)	Period (sec)	Participation (x)	Participation (y)	Participation (z)
1	1.819	0.550	0.00	0.00	100.00
2	3.179	0.315	100.00	0.00	0.00
3	3.664	0.273	0.00	0.00	0.00
4	87.364	0.011	0.00	100.00	0.00
5	87.521	0.011	0.00	0.00	0.00

Table b): With TMD

Mode	Frequency (Hz)	Period (sec)	Participation (x)	Participation (y)	Participation (z)
1	1.681	0.550	0.00	0.00	99.542
2	3.010	0.315	99.98	0.00	0.00
3	4.161	0.273	0.00	0.00	0.00
4	20.415	0.011	0.00	38.817	0.357
5	24.538	0.011	0.00	0.00	0.00

From the above analysis we can find out that the values of frequency and mode shape are affected by the influence of tuned mass damper.

B. Frequency and mode shape of MDOF

Here we consider a frame of MDOF system with 4 stories of building with 12m total height

Beam dimension : 0.4m x 0.4m

Column dimension : 0.4m x 0.4m

Supports are fixed

Load defined : Seismic load as per IS 1893 2002/2005

Zone value 0.075

Response reduction factor 1

Important factor 1

Damping ratio 0.05

Load case : Self weight of the structure X direction

Self weight of the structure Y direction

Self weight of the structure Z direction

Floor loads 3 KN in X direction

Floor loads 3 KN in Y direction

Floor loads 3 KN in Z direction

Modal calculations

Structure without damper

The above specified structure has been subjected to seismic characteristics and the frequency and mode shape has been calculated.



Fig 6: skeletal structure without damper MDOF

Structure with damper

A damper has been imposed on the same structure. And the specifications of the damper is given below. And the

frequency and mode shape has been calculated.

Damper stiffness property

- Size of damper beam : 0.4m x0.3m
- Size of damper column : 0.4m x0.3m
- Hight of damper : 3.13 m

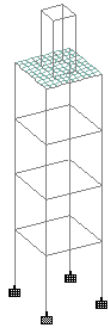


Fig 5.4: skeletal structure with damper MDOF

Comparison of sturctures with and without damper

The value of frequency and mode shape in both cases has been compared and its figures and values are given below.

MODE SHAPE FOR MDOF SYSTEM
Without TMD With TMD

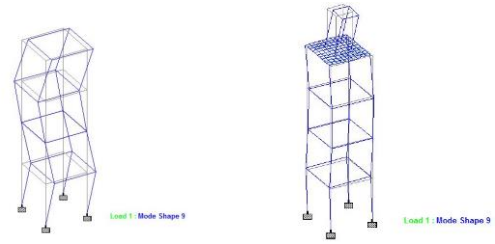
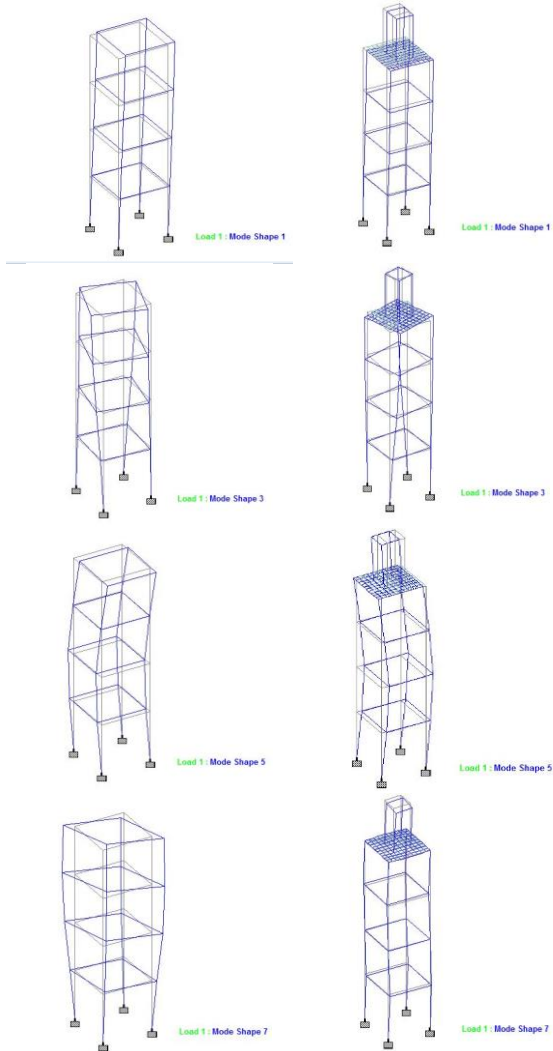


Fig 6: Mode Shape For MDOF System

Table Calculated modal Frequencies Mass Participation MDOF system

Table a): Without TMD

Mode	Frequency (Hz)	Period (sec)	Participation (x)	Participation (y)	Participation (z)
1	2.859	0.350	72.853	0.000	9.709
2	2.859	0.350	9.709	0.000	72.853
3	3.581	0.279	0.000	0.000	0.000
4	9.258	0.108	11.664	0.000	0.282
5	9.258	0.108	0.282	0.000	11.664
6	10.931	0.091	0.000	0.000	0.000
7	13.478	0.074	0.000	0.000	0.000
8	16.266	0.061	0.000	0.000	0.000
9	17.004	0.059	3.151	0.000	0.693
10	17.004	0.059	0.693	0.000	3.151

Table b): With TMD

Mode	Frequency (Hz)	Period (sec)	Participation (x)	Participation (y)	Participation (z)
1	1.922	0.520	0.001	0.000	85.284
2	2.178	0.459	83.842	0.000	0.002
3	3.143	0.318	0.002	0.000	0.000
4	6.631	0.151	0.004	0.000	10.747
5	7.792	0.128	11.427	0.003	0.005
6	9.558	0.105	0.001	0.000	0.009
7	11.529	0.087	0.050	0.032	1.804
8	12.528	0.080	0.573	0.082	0.278
9	13.385	0.075	0.024	0.101	1.186
10	14.842	0.067	0.002	0.013	0.003

From the above analysis we can find out that the values of frequency and mode shape are affected by the influene of tuned mass damper.

C. Responds spectra analysis

Here we consider a frame of MDOF system with 4 storey of building with 12m total height and 9m length in X and Z directions using response spectrum analysis.

- Beam dimension : 0.3m x 0.3m
- Column dimension : 0.3m x 0.3m
- Supports are fixed
- Load defined : Seismic load as per IS 1893 2002/2005
Zone value 0.075
Response reduction factor 1
Important factor 1
Damping ratio 0.05
- Load case (1) : Self weight of the structure
- Floor load, Dead load : 12KN up to 9m
10 KN above 9m

Live load: 4KN up to 9m
2KN above 9m

Load case (2) : Response spectrum:
Self weight of the structure X direction
Self weight of the structure Y direction
Self weight of the structure Z direction

Floor load,
Dead load : 12KN up to 9m
10 KN above 9m in X, Y, Z directions

Live load : 4KN up to 9m
2KN above 9m in X, Y, Z directions

Structure without damper

The above specified structure has been subjected to seismic characteristics and the frequency and mode shape has been calculated.

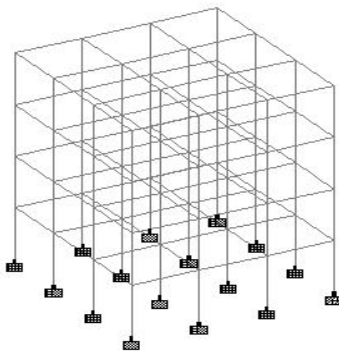


Fig 7: skeletal structure without damper MDOF

5.3.2 Structure with damper

A damper has been imposed on the same structure. And the specifications of the damper is given below. And the frequency and mode shape has been calculated.

Damper stiffness property
Size of damper beam : 0.5m x0.5m
Size of damper column: 0.5m x0.5m
Height of damper : 3.0m

Comparison of structures with and without damper

The value of frequency and mode shape in both cases has been compared and its values are given below figures.

Table: Calculated modal Frequencies Mass Participation MDOF system

Table: a) Without TMD

Mo de	Freque ncy (Hz)	Period(sec)	Particip ation (x)	Particip ation (y)	Particip ation (z)
1	0.982	1.019	45.850	0.000	43.535
2	0.982	1.019	43.535	0.000	45.850
3	1.177	0.849	0.000	0.000	0.000
4	3.325	0.301	0.000	0.000	0.000
5	3.390	0.295	3.277	0.000	4.789
6	3.390	0.295	4.789	0.000	3.277

Table: b) With TMD

Mode	Frequency (Hz)	Period (sec)	Participation (x)	Participation (y)	Participation (z)
1	0.940	1.064	15.068	0.000	72.039
2	0.940	1.064	72.039	0.000	15.068
3	1.164	0.859	0.000	0.000	0.000
4	3.021	0.331	1.609	0.000	4.759
5	3.021	0.331	4.759	0.000	1.609
6	3.380	0.296	0.000	0.000	0.000

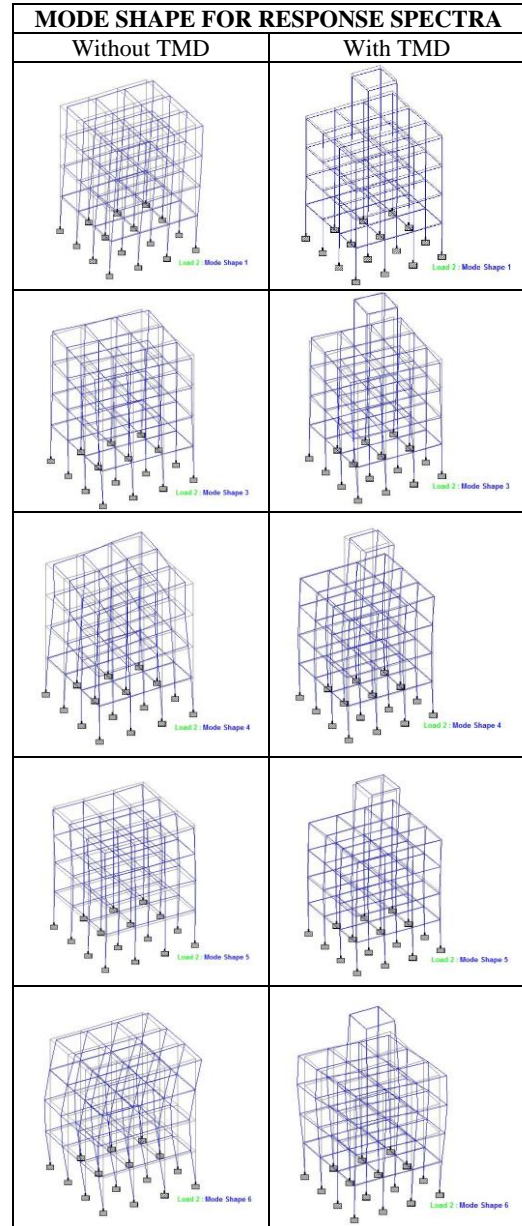


Fig 5.7: Mode Shape For MDOF System

From the above analysis we can find out that the values of frequency and mode shape are affected by the influence of tuned mass damper. In this case high stiffened Tuned mass dampers are used so the influence also very small.

D. Time history analysis

Here we consider a frame of MDOF system with 5 storey of

building with 15m total height using time history analysis.

- Beam dimension : 0.5m x 0.4m
- Column dimension : 0.5m x 0.4m
- Supports are fixed
- Load defined : Time history
 - Arrival time 1, 2, 3
 - Time steps: 0.25
 - Damping Ratio: .05
 - Zone value 0.075

Consider the external excitation of Imperial Valley1940 EI Centre Values given in table below

Table: 5.4 Time-Acceleration graph

Time (sec)	Acceleration(m/s)
0.25	1.2
0.5	0.768
0.75	0.748
1.0	0.836
1.25	0.767
1.5	0.732

- Load case (1): Self weight of the structure
- Load case (2): Floor load: 5 KN
- Load case (2): Time history dynamic loading
 - Self weight of the structure X direction
 - Self weight of the structure Y direction
 - Self weight of the structure Z direction
 - Floor load, 5KN in X, Y, Z directions
 - Time history ground motion as defined

Structure without damper

The above specified structure has been subjected to accelerated ground motion and the frequency, mode shape, time-acceleration, time-velocity, time-displacement etc. has been calculated.

Structure with damper

A damper has been imposed on the same sturcture. And the specifications of the damper is given below. And the frequency and mode shape has been calculated.

- Damper stiffness property
- Size of damper beam : 0.3m x0.3m
- Size of damper column: 0.3m x0.3m
- Same floor load
- Hight of damper 3.0m

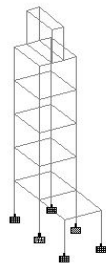


Fig 5.8: skeletal structure with damper MDOF

Comparison of sturctures with and without damper

The value of frequency and mode shape in both cases has been compared and its figures and values are given below.

MODE SHAPE FOR RESPONSE SPECTRA

Without TMD

With TMD

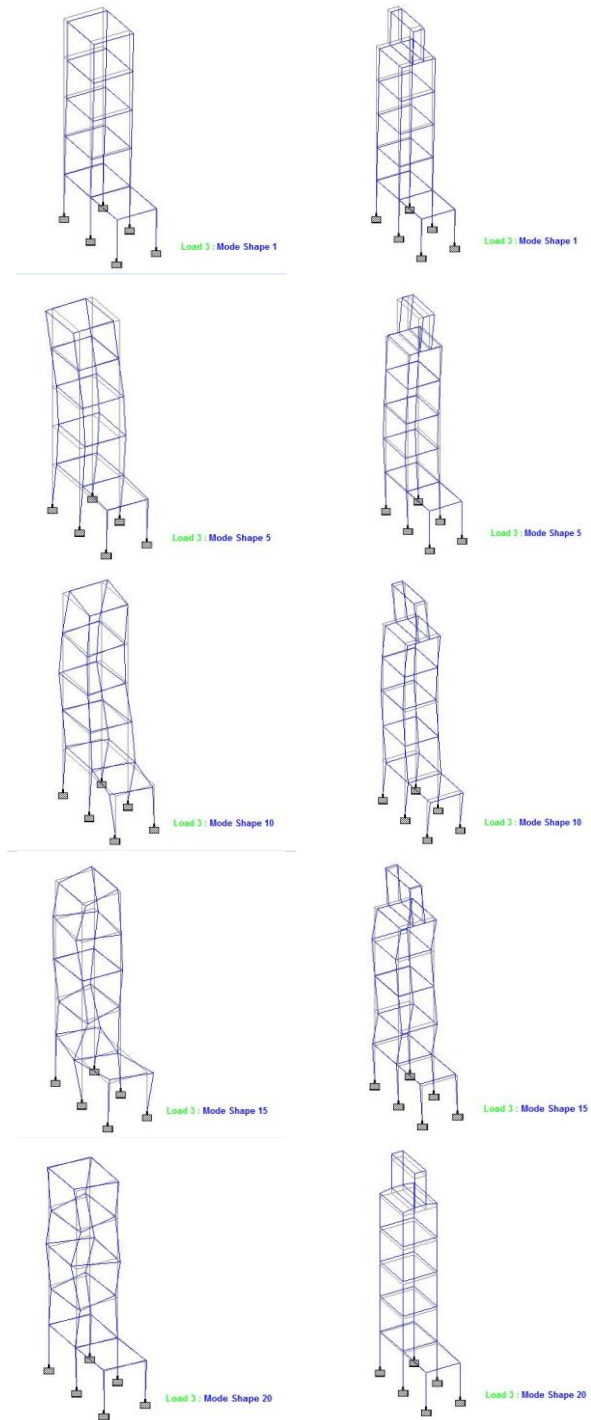


Fig 6: Mode Shape For MDOF System

Calculated modal Frequencies Mass Participation MDOF system

Table: a) Without TMD

Mode	Frequency (Hz)	Period (sec)	Participation (x)	Participation (y)	Participation (z)
1	2.294	0.436	0.000	0.000	77.947
2	2.342	0.42694	76.505	0.000	77.947
3	3.103	0.32231	77.272	0.000	77.947
4	7.408	0.13499	77.272	0.002	91.876
5	8.059	0.12409	89.276	0.002	91.876
6	9.96	0.1004	90.017	0.002	91.876
7	12.6	0.07936	90.017	0.004	99.004
8	13.987	0.0715	90.36	0.004	99.004
9	14.283	0.07001	97.305	0.004	99.004
10	15.286	0.06542	98.33	0.004	99.004
11	16.305	0.06133	98.496	0.004	99.004
12	18.014	0.05551	98.916	0.004	99.004
13	18.049	0.05541	98.916	0.005	99.946
14	19.579	0.05108	98.917	0.005	99.946
15	22.013	0.04543	98.919	0.005	99.946
16	22.543	0.04436	99.83	0.005	99.946
17	25.18	0.03971	99.83	0.063	99.998
18	25.529	0.03917	99.897	0.063	99.998
19	26.114	0.03829	99.897	86.648	99.999
20	28.146	0.03553	99.897	86.648	99.999
21	29.334	0.03409	99.897	86.66	99.999
22	30.071	0.03325	99.95	86.66	99.999
23	32.097	0.03116	99.991	86.66	99.999
24	32.387	0.03088	99.997	86.66	99.999
25	34.528	0.02896	99.998	86.66	99.999

Table: b) With TMD

Mode	Frequency (Hz)	Period(sec)	Participation (x)	Participation (y)	Participation (z)
1	2.149	0.46537	0.000	0.000	77.419
2	2.199	0.4548	76.623	0.000	77.419
3	3.042	0.32873	77.098	0.000	77.419
4	6.116	0.16349	77.098	0.001	88.833
5	7.007	0.14271	88.333	0.001	88.833
6	8.25	0.12121	88.692	0.001	88.833
7	8.258	0.1211	88.692	0.002	93.528
8	9.057	0.11042	90.662	0.002	93.528
9	10.491	0.09532	91.087	0.002	93.528
10	12.703	0.07872	91.087	0.005	99.132
11	14.186	0.07049	95.599	0.005	99.132
12	14.448	0.06921	97.715	0.005	99.132
13	15.291	0.0654	98.586	0.005	99.132
14	17.16	0.05828	98.653	0.005	99.132
15	18.058	0.05538	98.653	0.006	99.949
16	18.395	0.05436	98.938	0.006	99.949
17	19.918	0.05021	99.014	0.006	99.949
18	22.369	0.04471	99.707	0.006	99.949
19	23.211	0.04308	99.872	0.006	99.949
20	24.276	0.04119	99.872	82.359	99.951
21	25.073	0.03988	99.872	82.371	99.997
22	25.666	0.03896	99.901	82.371	99.997
23	27.292	0.03664	99.901	82.371	99.999
24	28.613	0.03495	99.901	82.371	99.999
25	30.507	0.03278	99.976	82.371	99.999

5.4.3.2 Time-Acceleration Relationship comparison with and without TMD

The value of acceleration in both cases has been compared and its figures and values are given below

a) Without TMD

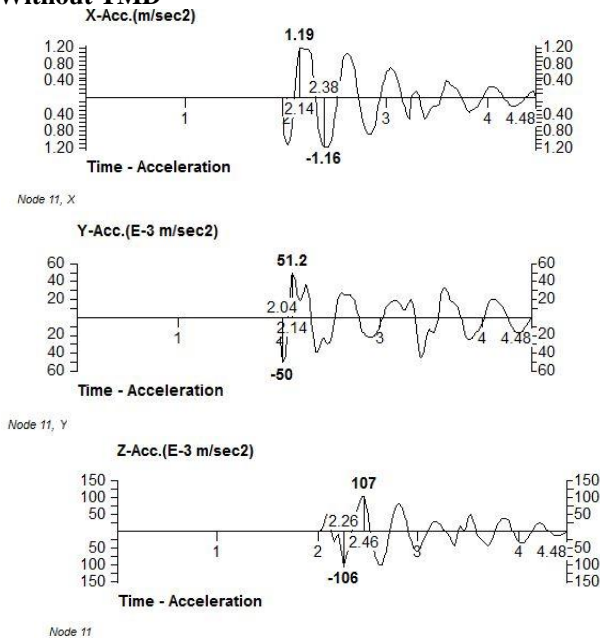


Figure 5.10: Time acceleration graph

b) With TMD

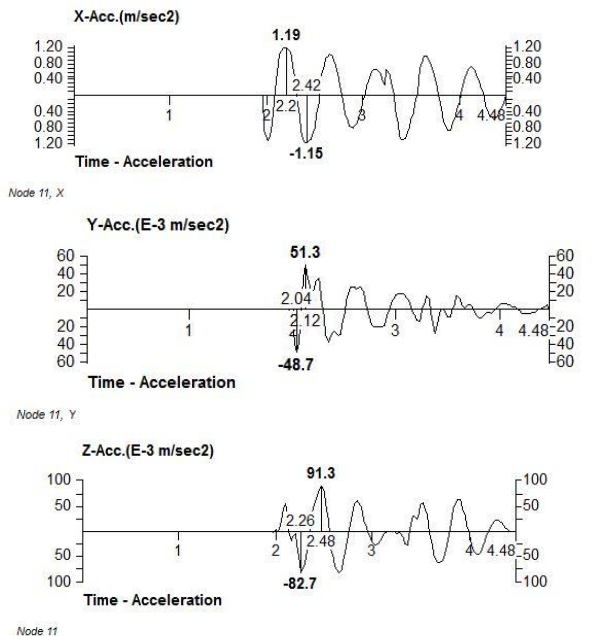


Figure 5.11: Time acceleration graph

A. Time-Velocity Relationship comparison with and without TMD

The value of velocity in both cases has been compared and its figures and values are given below

a) Without TMD

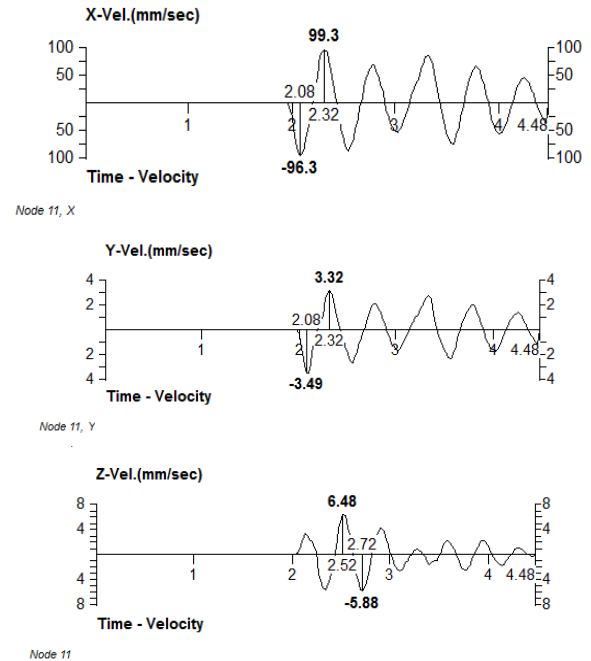


Fig 5.12: time velocity graph

b) With TMD

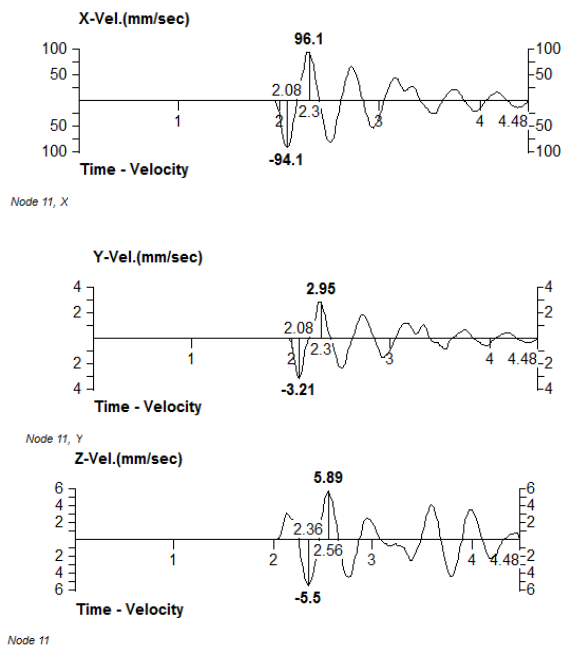


Figure 5.13: Time velocity graph

B. Time-Displacement Relationship comparison with and without TMD

The value of displacement in both cases has been compared and its figures and values are given below

a) Without TMD

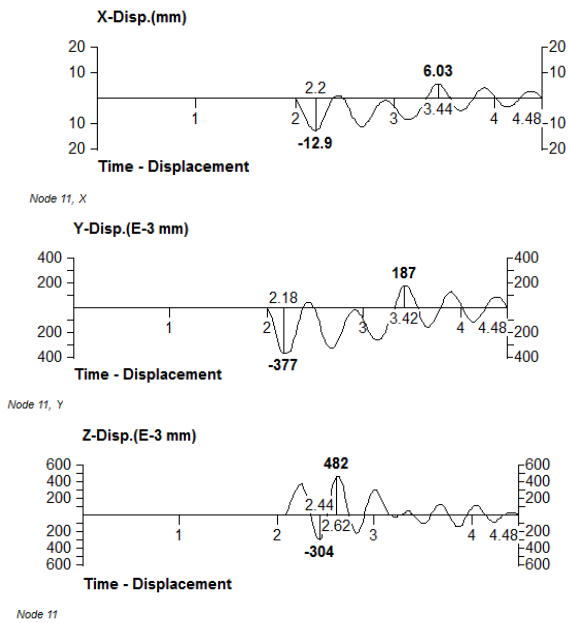


Fig 5.14: time displacement graph

b) With TMD

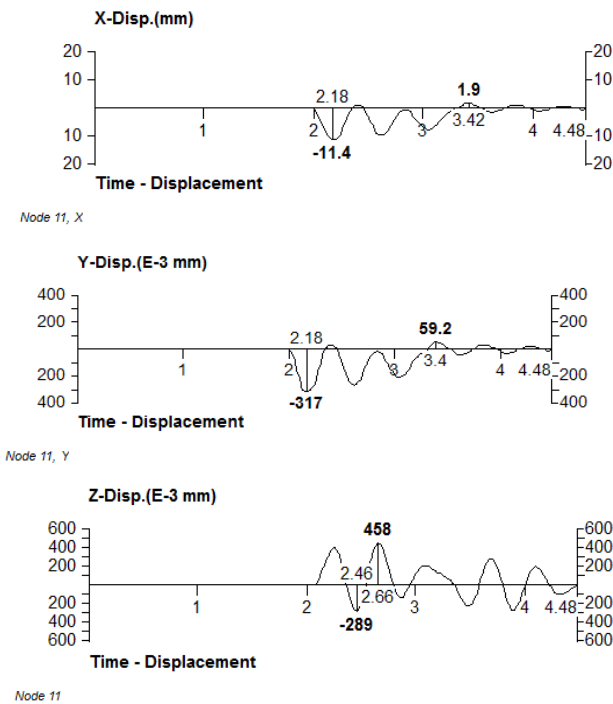


Fig 5.15: Time displacement graph

From the above analysis we can find out that the values of frequency, mode shape, acceleration, velocity, displacement are affected by the influence of tuned mass damper.

Conclusion

From the above analysis of the SDOF frame structure under seismic loads, it has been found that the frame under tuned mass damping has recorded less frequency of vibration and

deflection when compared to the frame without tuned mass damping. Tuned mass damping system is one of the most effective methods of reducing the vibrations in tall structures which are subjected to seismic forces.

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