Sujata D. Ingale, 2025, 13:5
ISSN (Online): 2348-4098
ISSN (Print): 2395-4752

International Journal of Science, Engineering and Technology

An Open Access Journal

Seismic Behaviour of Structure by Using TMD Technique: A review

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Abstract- The application of tuned-mass dampers (TMD) is effective in improving the dynamic performance of structures. A TMD consists of a relatively small mass which is attached elastically to the main structure. The elastic connection is tuned in regard to the disturbing natural frequency of the system. The main structure usually possesses little damping and hence, it is easily excited by wind, traffic or earthquakes. A TMD is equipped with dampers as they control the relative motion between main structure and the TMD. Moreover, they can also be used to improve comfort conditions, for example in bridges and buildings. A TMD should be taken into consideration during the design stage of a project, but it is also possible to design such a system later. Then, frequency measurements can be taken as a reliable basis for the layout. Nowadays, the theory of TMDs is well known and there are many examples of application worldwide. The present paper shows application of tuned-mass dampers (TMD) for high rise building and TMD in India context.

Keywords - Tune Mass Damper, Displacement, Vibration, Seismic.

I. INTRODUCTION

In order to increase the durability of new and existing structures against wind, earthquakes, and human activity, the TMD has been recognized as an effective vibration control device via extensive research and development in recent years. With less interference than other passive energy dissipation devices, TMDs can be integrated into an existing structure. The TMD is a straightforward, efficient, affordable, and dependable method of reducing unwanted vibrations in structures brought on by wind or harmonic excitations. In order to achieve this decrease, some of the structural vibration energy is transferred to the TMD, which is a mass, spring, and damper linked to the main structure in its most basic form. The idea of controlling vibration with a mass damper was first introduced by Frahm in 1909 when he created a dynamic vibration absorber, a device for controlling vibration.

Among the earliest and most used vibration control devices are TMDs. They don't require any renovations to be connected to the main system. A mass, an elastic spring, and a viscous (or hysteretic) damper make up a TMD system. The reaction of the primary structural system is directly impacted by the TMD parameters. Consequently, adjusting TMD settings is one among the crucial concerns for designers [Hartog et al. 1947; Warburton 1981; Warburton 1982]. When designing structures for seismic activity, two primary issues are human comfort and safety. Two popular tools for lowering the dynamic response of structures are tuned mass dampers and floor isolation systems, both of which fall under the category of passive systems (Salvi and Rizzi 2016). Accordingly, TMD offers the most widely used method for reducing the vibrations of tall buildings that are subjected to wind loads (Zhou et al. 2015). Other civil constructions like offshore wind turbines also make extensive use of adjustable mass dampers (Lackner and Rotea 2011; Jiang 2018; Si et al. 2014). These passive control systems are made up of a mass, a spring, and a damper. In order to avoid damage, complete structural failure, and discomfort, these devices absorb the kinetic energy of the structure (Domizio et al. 2015).

Fundamentals and Specifications

Tall structures exhibit free vibrations corresponding to their first horizontal natural vibration mode under an excitation caused by wind loads. This system can be reduced to a lumped mass model shown in Fig. 1, where the structural mass (mS) and structural stiffness (kS) correspond to the system's horizontal natural frequency. A TMD is a vibrating mass that exhibits movements that are in opposition to those of the main structure.

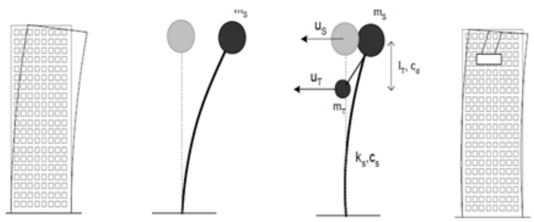


Fig: 1 TMD effect simplified as a two- lumped mass model

All pertinent structural information, including stiffness and structural damping, which determine the natural frequency fS, is included in the two-lumped mass model. The tuning frequency fT, the damping ratio cd of the damping element, and the effective mass mT of the TMD are defined by the pendulum length. The Tuned Mass Damper effect can be demonstrated with an amplification function for a 2-mass model using these terms for the analytical solution of a 2-mass.

It is evident that the second mass's application reduces the horizontal motions shown in Fig. 2. Furthermore, a subdivision of the natural frequencies results from the interplay between TMD and structure. The amplification happens in a wider frequency range as a result of the structural damping increasing.

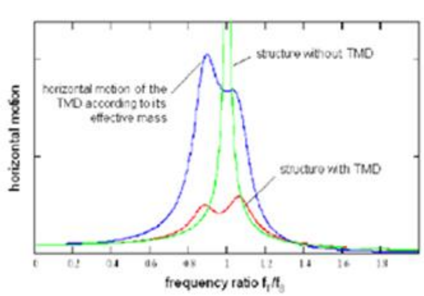


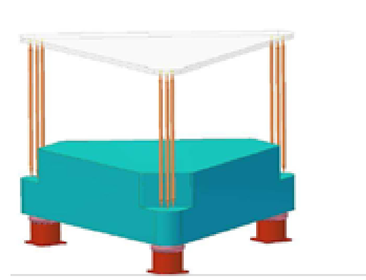
Fig: 2. Horizontal motion vs frequency

Design Aspects of TMD Systems

Generally speaking, TMD systems fall into one of two categories: devices that operate vertically or horizontally. To lessen this vibration, the program relies on the disturbing mode's shape as well as the TMD's location and orientation. Helical steel springs are typically used to support TMDs that operate vertically. The mass and spring stiffness are the only factors that affect the frequency. The frequency range of operation is dispersed by the viscous dampers. Fig. 3 depicts a typical example of such a system. In order to load the springs under tension, the spring system can alternatively be constructed as a hanger system.

Applications combining compression and tension springs are also feasible. In general, horizontally operating systems can also be set up as Fig. The target frequencies are then determined by the mass's form and the springs' horizontal stiffness. Sometimes the mass is set up like a pendulum. The mass at the bottom of the hanger system moves horizontally to provide flexibility. In addition to working in a single direction, the mass may also act horizontally. The mass's material (such as steel or concrete) is one of the primary determinants of the TMD's design.

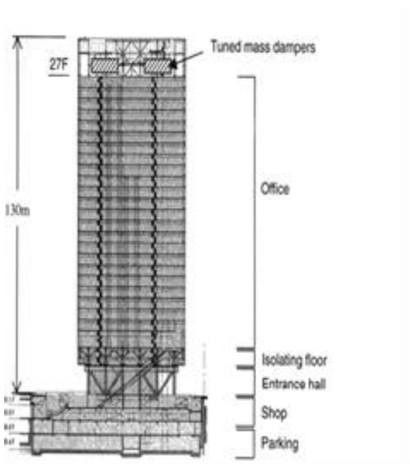
Fig. 3 a) Typical Vertical TMD



b) Pendulum type TMD

Design of Multiple Tune Mas Dampers

Tuning damper parameters to the modal properties of certain vibration modes is the goal of MTMD design. It indicates that the natural frequency of a chosen vibration mode of structure ωs (ωd=ωs) must be near the natural frequency of the damper (or set of dampers) ωd. Additionally, the damper's damping factor needs to be properly selected. The calculations provided in a publication (Warburton 1982) can be used to obtain the ideal parameters of such a damper (or group of dampers). The optimal frequency ratio is determined from:



$$\frac{\omega_d^2}{\omega_s^2} = \frac{2+\mu}{2(1+\mu)^2},$$

where

$$\mu = \frac{m_d}{M_s}, \quad \omega_s^2 = \frac{K_s}{M_s}, \quad \omega_d^2 = \frac{k_d}{m_d}.$$

In this case, Ms and Ks stand for the structure's modal mass and the s-th mode of vibration's modal stiffness, respectively. The mass of the damper is denoted by md, and the stiffness coefficient by Kd, assuming just one damper is tuned to the s-th mode of vibration with frequency ωs. On the other hand, Md and Kd stand for the mass and stiffness coefficients of the chosen damper of a set of dampers that are intended to tune to the frequency ωs, respectively. The preceding formulae can be used to determine the damper frequency ωd and the damper stiffness coefficient Kd, assuming that the mass ratio μ is known. The value of the damping coefficient Cd can be calculated from the relation

$$\gamma_{opt} = \sqrt{\frac{\mu(4+3\mu)}{8(1+\mu)(2+\mu)}}.$$

Cd = 2ropt ωd Md

How TMD work

Harmonic vibration causes violent motion, which is stabilized by tuned mass dampers. When a tuned damper is present, the inertia of a large mass can be counterbalanced by a relatively light structural element, like a heavy concrete block positioned so that the block moves in one direction while the structure moves in the other, thereby reducing oscillation in the structure. Hydraulic dampers and large spring coils can be used to mount the counterbalance. Leaf springs and weights on a pendulum are used if the vibration's axis is essentially horizontal or torsion-based. Tuned mass dampers are designed, or "tuned," to particularly block dangerous vibration or oscillation frequencies.

A spring and damper k1/c1 are positioned between the principal mass M1 (such as a wheel and suspension arm) and the body. We are attempting to reduce the force that enters the body, which is F0. The excitation force, denoted as F1, is applied to m1. Another spring/damper/mass system, k2/c2 and m2, is added to the system.

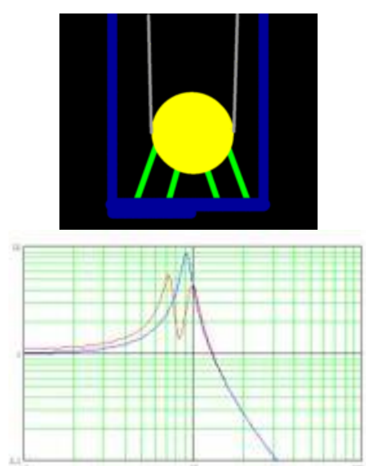


Fig.4 Effect of TMD on simple system

The system's reaction to a 1 N force, both with and without the 10% adjusted mass, is shown in red and blue. The peak reaction drops to 5.5 N from 9 N.

Figure 4 illustrates how a tuned mass damper affects a basic spring/mass/damper system that is activated by a force of 1 N applied to the primary mass. The ratio of the force delivered to the body, F0, as a result of F1, is the crucial metric for this system. With a maximum response of 9 N into the base at 9 Hz, the baseline system is represented by the blue line. The impact of adding a tuned mass equal to 10% of the baseline mass is depicted by the red line. At 7 Hz, its highest response is 5.5 N. The stiffness of the spring in the tuned mass damper can be changed to alter the relative heights of the two peaks. In a complicated way, altering the damping also alters the peak heights. By adjusting the percentage of the baseline mass utilized in the damper, the split between the two peaks can be altered. Displacements in the system with (red) and without (blue) the 10% tuned mass are shown in a Bode plot. In comparison to F1, the Bode plot is more intricate and displays the phase and magnitude of each mass's motion in the two scenarios. The baseline is represented by the black line, which only displays m1's motion.

In the case of the tuned mass absorber, the blue line represents the motion of m2. With a greater amplitude, it enters resonance early and in phase with m1. As a result, the damping element at c2 absorbs some of the energy that would have been used to vibrate the body (via F0). Maximum energy is pumped into the damper at c2 as the frequency rises because m2 begins to move out of phase with m1 until it is in ant phase with m1 at about 9.5 Hz.

TMD in Indian Context

Need to Develop TMD in Indian Context

These days, despite the fact that many multistory structures are being built, individuals are unwilling to spend money to make them earthquake-resistant. The cost of installing the complex TMD, which was just discussed above, and the engineering expertise needed to do so could be the source of this. India's researchers are therefore searching for a TMD-functioning device that is affordable and simple to set up.

Currently, advanced TMDs that are employed in other nations cannot be used in practice in India. It is not even practical to spend so much money on the installation. Additionally, the dampers that have been put in other nations, as previously mentioned, have significant drawbacks, such as

- They need skillful labours for the installation.
- They incur high construction cost.
- They require costly and constant maintenance.

TMD in the Form of Soft Storey

The entire plan space at the top of the structure is covered by a soft storey, which is a basic tuned mass damper (tmd). because of its mass, stiffness, and damping, this soft tale has the potential to develop into a very basic kind of tmd. It is necessary to adjust this soft narrative to meet tmd's specifications. the mass of tmd should be between 2 and 5% of the building's mass, and its natural frequency should be extremely close to the building's natural frequency (Miyama, 1992). Thirdly, its damping value must be greater than the building's damping value. At the summit of the building, this TMD takes the shape of a soft story. The entire building's plan area is covered by this soft story, which has no infill brick walls and only beams and columns. Its beam and column diameters are smaller than those of the structure. This soft story is adjusted so that its inherent frequency bears an ideal frequency ratio with the building's inherent frequency. This soft storey's mass typically falls between two and five percent of the building's total mass.

Advantages of TMD:

They are easy to install.
They are not very costly.
No great engineering skill is required to install it.
They have very less maintenance

Disadvantages

There is no control over it as regards to restriction over its movement.
They are not as effective and sophisticated as the above discussed dampers.

Case Study

Fig 5 and 6 shows the maximum displacement time histories of structures with and without TMD under the El Centro earthquake. It demonstrates that the maximum displacement of 10-story structure, the maximum displacement of the top story of the uncontrolled case is 39.57 cm and that of the controlled case is 24.84 cm.

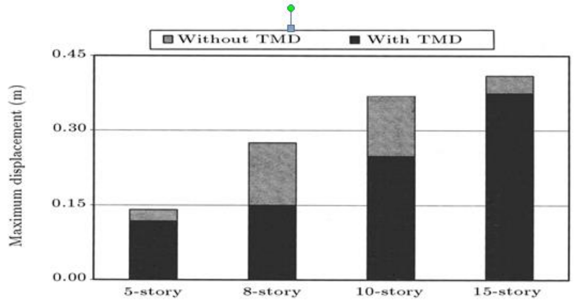


Fig.5 Maximum Displacement of Structures under the El Centro Earthquake (Miyama, 1992)

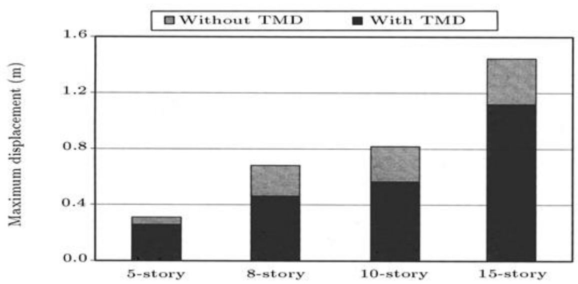


Fig.6 Maximum Displacement of Structures under the Tabas Earthquake (Miyama, 1992)

II. CONCLUSION

To date, a number of earthquake-resistant strategies have been developed to regulate a building's seismic reaction.

A tuned mass damper has shown itself to be a useful tool for managing multistory buildings' vibration response. Since 1973, a variety of TMD kinds have been effectively employed worldwide. In the Indian setting, TMD can be put as a soft story, which has been shown to be effective in lowering the structure's seismic reaction. To increase the dynamic performance of structures, the current research begins with a brief taxonomy of tuned-mass systems. TMDs can be utilized to reduce resonant excitation from wind or traffic because their effects are comparable to the increase in damping for the equivalent structural mode. Although TMD can also be used to lessen the effects of fatigue, are mostly used to enhance the comfort of structures. They could be viewed as key players in terms of the structural integrity in this way.

REFERENCES

1. J. Den Hartog, Mechanical Vibrations, McGraw-Hill, New York, 1947.
2. G. Warburton, Optimum absorber parameters for minimizing vibration response, Earthq. Eng. Struct. D 9 (3) (1981) 251–262.
3. G. Warburton, Optimum absorber parameters for various combinations of response and excitation parameters, Earthq. Eng. Struct. D 10 (3) (1982) 381–401.
4. Salvi J, Rizzi E (2016) Closed-form optimum tuning formulas for passive tuned mass dampers under benchmark excitations. Smart Struct Syst 17(2):231–256.
5. Zhou X, Lin Y, Gu M (2015) Optimization of multiple tuned mass dampers for large-span roof structures subjected to wind loads. Wind Struct 20(3):363–388.
6. Lackner MA, Rotea MA (2011) Passive structural control of offshore wind turbines. Wind Energy 14(3):373–388.
7. Jiang Z (2018) The impact of a passive tuned mass damper on offshore single-blade installation. J Wind Eng Ind Aerodyn 176:65–77.
8. Si Y, Karimi HR, Gao H (2014) Modelling and optimization of a passive structural control design for a spar-type floating wind turbine. Eng Struct 69:168–182
9. Domizio M, Ambrosini D, Curadelli O (2015) Performance of TMDs on nonlinear structures subjected to near-fault earthquakes. Smart Struct Syst 16(4):725–742.
10. Miyama, T. (1992) Seismic response of multi-story frames equipped with energy absorbing story on its top. 10th World Conference on Earthquake Engineering, 7, 4201-4206.