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Influence of Vibration in High-Rise Building with Tuned Mass Damper Account into Diverse Loads

Prateek Papriwal[1], *Nivedita*[2], *PV Ramana*[3]

[1]*PG Scholar, Department of Civil Engineering, Malaviya National Institute of Technology, Jaipur - 302017, India*

[2]*Department of Civil Engineering, Malaviya National Institute of Technology, Jaipur - 302017, India*

[3]*Department of Civil Engineering, Malaviya National Institute of Technology, Jaipur - 302017, India*

Email: 2019PEQ5515@mnit.ac.in

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Abstract

Current research focuses on the ability of TMD and MTMD to reduce structural vibration caused by earthquakes. Use the finite element method to scan the frame. The soft computation technique to linearly analyze the time course of the frame at each time step. The result compares the frame's response with uniform and uneven mass ratios and the effects of changes in MTMD and TMD damping coefficients. The response of the frame design decreases as the proportion of a single TMD increases. Effectively reduce the vibration of the structure when exposed to earth acceleration. Non-uniform mass is more effective than MTMD than a single TMD with the same mass ratio. In this study, MTMD with uniform mass ratio distribution is the most effective for vibration control. Multiple TMDs with uniform or uneven mass ratio distribution correspond to the same structural frequency, and there are multiple TMDs. The reaction of the frame structure does not affect the change of the damping coefficient of the damper.

1. Introduction

Vibration refers to the mechanical vibration near the equilibrium point. Vibration can be periodic or non-periodic. Vibration control is essential for cars, spacecraft, airplanes, and ships floating on water. With the modernization of technology, damping technology came into being. Today, countless skyscrapers are being built all over the world. Due to concerns about the high population density of cities, business parks, and cities, the number of skyscrapers is increasing day by day. Due to the structure's weight, these structures are relatively light and flexible and have relatively low natural damping. The structure is more susceptible to wind vibration and seismic loads. In many cases, such a large displacement will not affect the integrity of the structure. However, stable vibration conditions may cause severe discomfort or even illness for people in the building. Energy-saving measures have been found in all regions of the world. When the energy transferred to the structure by wind and earthquakes is completely dissipated, the structure will decrease. Due to various internal stresses, friction, and plastic deformation, each structure naturally generates some energy. In modern large buildings, the total attenuation is almost 5% of the critical attenuation. Therefore, the new generation of high-rise buildings is equipped with artificial damping devices, which can control vibration through energy dissipation. Different vibration control methods include passive, active, semi-active, and hybrid. Passive damping systems that use auxiliary masses are usually connected to the main structure through springs and dampers. Reduce the dynamic performance of the redesigned structure. It is widely used for vibration control of mechanical motors. Today, TMD theory has been applied to reduce vibration in high-rise buildings and other building structures. The calculated natural frequency of the secondary mass system depends on its mass and stiffness. Select the frequency of the main structure. When this specific frequency of the structure is excited, the TMD resonates out of phase and reduces the movement of the structure (Palacios-Quiñonero et al.). Then, the excess energy stored in the structure can be transferred to the auxiliary mass and then removed by the dampers due to the relative movement between the dampers. When multiple TMDs are adjusted to different unfavourable design frequencies, they can monitor the movement of high-rise buildings caused by earthquakes. Or demolish buildings. Severe vibration can cause damage to a ground motion, depending on the situation. B. The condition of the ground and the slippage of the structural foundation are shown. Earthquake is the main factor that causes damage to buildings. Earthquake poses a threat to buildings (O. A. Al-Fahdawi, Barroso, and Soares). Therefore, it is vital to formulate seismic risk design plans in earthquake areas. The best design for any building is safety, maintainability, and economy. Achieving the best earthquake site design plan is critical and challenging. The vulnerability and instability of when, where, and how earthquakes occur increase the likelihood of structural damage. This work aims to study the seismic performance of advanced structural protection systems that can reduce the destructive effects of these environmental forces. These systems absorb or reflect some of the incoming energy; otherwise, this energy will be transferred to the structure itself. The result obtained may be the most realistic solution for protecting new and existing buildings from natural disasters. The TMD works inverse way and the damper was invented by Fram MS (Coble) in way back in 1909 tried to control the ship's roll with a mass spring damper, thereby reducing the amplitude of the main frequency system to zero. Then, Khatibinia, Mohsen, et al (Khatibinia, Gholami, and Kamgar) proposed a closed-loop TMD equation for frequency ratio (fopt) and optimal damping ratio (ζopt). This equation is obtained by minimizing the uniform response of the structure that has been subjected to harmonic stimuli acting on the structural block. Warburton proposed a better formula to calculate the TMD of a structure exposed to random acceleration from the ground in the form of white noise. In deriving the above-mentioned TMD formula for optimal design, the inherent damping of the structure was not considered. Kamgar, Reza, et al. (Kamgar, Samea, and Khatibinia) Considering the damping of the structure, the optimal equation for calculating the TMD of a structure that can withstand seismic loads is proposed. Usually called a tuned mass damper, it is connected to the mass of the structure through springs and permanent damping elements.

1.1. The Basic Principle

The resulting differential equations for the displacements u1 and u2 are:

$$m_1 \cdot \ddot{u}_1 + k_1 \cdot u_1 + k_2 \cdot (u_1 - u_2) + c_2 \cdot (\dot{u}_1 - \dot{u}_2) = p_0 \cdot cos(\omega \cdot t) \; \ldots\ldots \qquad (1)$$

$$m_2 \cdot \ddot{u}_2 + k_2 \cdot (u_2 - u_1) + c_2 \cdot (\dot{u}_2 - \dot{u}_1) = 0. \; (2)$$

After solving the equations, we get the amplification function:

$$\frac{u_{1,\max}}{u_{1,stat}} = \sqrt{\frac{4 \cdot \xi^2 \cdot \beta^2 + \left(\beta^2 - \alpha^2\right)^2}{4 \cdot \xi^2 \cdot \beta^2 \left(\beta^2 - 1 + \mu \cdot \beta^2\right)^2 \left[\mu \cdot \alpha^2 \cdot \beta^2 - \left(\beta^2 - 1\right) \cdot \left(\beta^2 - \alpha^2\right)\right]^2}} \quad ..(3)$$

Tanwar, Vinod, et al (Tanwar et al.) in the field of seismic design of adjacent high-rise buildings, various passive and semi-active control devices have been employed to link adjacent buildings with structural control purposes. The efficacy of using the simple adaptive control method for alleviating the seismic responses of two nonlinear adjacent buildings connected at multiple levels with magneto-rheological dampers is investigated by Ramana, P.V., et al. (Bagheri and Rahmani-Dabbagh)

The damping element has an important role in controlling the stroke of the TMD. Due to its relatively stable performance, the oil damper has often been adopted the damping element in the TMDs for buildings Vahid Rahmani-Dabbagh (Domenico, Impollonia, and Ricciardi). One method to generate force with fluids is by driving a mechanical flywheel with a hydraulic motor and another is by forcing the fluid to move rotationally in a helical pipe De Domenico, D., et al. (Bekdaş et al.).

Nigdeli, Sinan Melih (Ren et al.). paper proposes the optimal design of TMD subjected to continuous stationary critical excitation as the most severe earthquake. Additional research is available in Ren, Kui, et al. (Chang, Shia, and Lai). where the effect of the soil-structure interaction on the optimum design of TMDs were studied by using some of these algorithms

Anamika, et al. (Bisht, Kabeer, and Ramana). have studied the mechanical and durability properties were best at 45% GGBS and 5% Waste Glass with 0.4 water/cement ratio. The recycled materials implemented for mix proportion were waste glass provided considerably to enhance its properties when added with GGBS. Surendranath, Arigela (Bekdaş, Nigdeli, and Yang). The design variables of the optimization problem such as the period and damping ratio of TMD are tuned according to a metaheuristic algorithm called flower pollination algorithm.

Chang, Chia-Ming, et al. (Al-Kodmany). studied originated from Darwin's theory of biological evolution. Among the available genetic algorithms, the fast and elitist Non-dominated Sorting Genetic Algorithm NSGA-II has been widely used in practical optimization problems. Kunal, et al. (Kusiak, Zhang, and Verma). research on utilization of waste glass for production of sulphuric acid resistance concrete.

The efficacy of using the simple adaptive control method for alleviating the seismic responses of two nonlinear adjacent buildings connected at multiple levels with magneto-rheological dampers is Gebrail, et al (Wang et al.) conducted digital image processing on Recycled materials execution. Al-Kodmany, Kheir (Astolfi et al.) developed a new design procedure for optimal parameters of TMDs based on an active control algorithm, namely, the H2/LQG control by minimizing the response objective function of the primary structure.

Kusiak, Andrew (Domenico and Ricciardi). In the proposed method, the design variables such as the mass, period and damping ratio of tuned mass damper are optimized. Wang, Shiang-Jung, et al. (**O. A. S. Al-Fahdawi, Barroso, and W Soares**). investigate building mass damper (BMD) design features the use of partial structural mass, instead of additional tuned mass, as an energy absorber. Ayush, et al. (Goel et al.). studied Impact of Blast Loading over Reinforced Concrete Structure

The investigate bond strength between controlled concrete and fiber test specimen interaction and their bonding properties at various levels described. Experimented the investigation of properties and resistance to acid and sulphate attack of GGBS based concrete mixes with beverage glass waste as fine aggregate. An elastic-plastic spring is utilized in a tuned mass damper (TMD) with eliminating its viscous damper to establish a new seismic response control system & analyzing extensive data, the research presented here contrasts building activities of skyscrapers before and after the of the 21st century. The use of fluid viscous dampers (FVDs) together with isolators, frequent in near-fault buildings, is effective in reducing displacements of the isolation layer.

2. Work on Soft Computation

Different types of structures were analyzed using SAP2000 software. Table 1. shows Geometrical Parameters of various details of structural dimension that has been used in the analysis. We have also performed. Pushover Analysis on these structures and also compare these structures with and without TMD using sinusoidal acceleration.

SAP2000 can perform a static or dynamic, direct or nonlinear investigation of structure. Pushover analysis is a nonlinear static method that determines the lateral load versus deformation behavior of building corresponding to the incremental load. SAP2000 gives better visualizations of collapse/damage state for every step.

3. Computational Results and Discussion

3.1. Pushover Analysis

Traction analysis is a nonlinear static process that gradually increases the magnitude of the shear force while maintaining sample distribution and building height. As the load increases, Figure 1. shows dif-

TABLE 1. Geometrical Parameters

Sizes	G+1	G+3	G+9		G+14	
			Bottom 6 Storeys	Top 4 Storeys	Bottom 11 Storeys	Top 4 Storeys
Beam (m)	0.23x0.3	0.23x0.3	0.5x0.6	0.23x0.3	0.5x0.6	0.23x0.3
Column (m)	0.23x0.4	0.23x0.4	0.5x0.8	0.23x0.4	0.5x0.8	0.23x0.4
Slab Thick. (m)	0.1	0.1	0.125	0.125	0.125	0.125
Concrete	M20	M20	M35	M30	M35	M30
Live Load (kN/m^2)	3	3	3	3	3	3
Earthquake Zone	V	V	V		V	

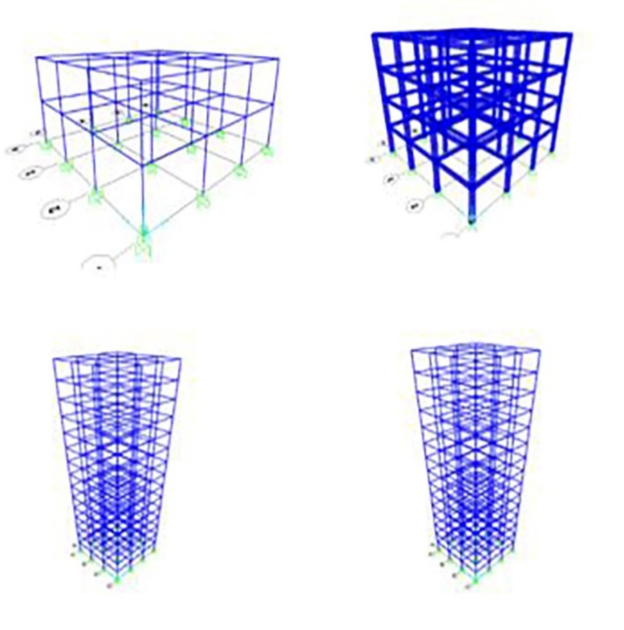

FIGURE 1. Different building types (a) G+1, (b) G+3, (c) G+9, (d) G+14

ferent building types (a) G+1, (b) G+3, (c) G+9, (d) G+14 and the weakness and damage type of the model increases by 1 degree. Free tensile analysis can determine the behavior of the building, including ultimate load and maximum inelasticity. Simulate nonlinear local effects and transfer the structure until the collapse mechanism develops. Intersecting curves for each step. Specify the maximum foundation displacement that the structure can withstand during an earthquake. Ordinary buildings can also approximate the overall stiffness of the building. On soft ground, the displacement is most significant. In nature, they lack the strength to withstand the pressure of the last stick. The bottom of the soft soil foundation moves up and down in the structure, the affected structural resistance eventually increases, and the corresponding results may be the opposite. The interim analysis confirmed by the software's finite element analysis meets the purpose of this research. Adapt to the reasons for changing trends. Software controlled by UBC determines the impact of the earthquake. 94 According to the Bangladesh National Building Code (BNBC), the load is calculated by developing an Excel spreadsheet to obtain the point load. Professional designers and engineers can accept static and dynamic loads. Accept standard load combinations according to BNBC. Throughout the research process, a comprehensive analysis of the axial load analysis will be carried out. The design is based on experimental data and experience. Calculated and determined the allowable deformation of beam and column hinges at different execution levels. According to the required type, three types of hinges are assigned to each element. Then load the structure. The analysis shows that during the transverse shearing process of the structure, the hinge components are gradually damaged due to the plastic deformation of the hinge, and the hinge is plastically deformed. After the simulation, the behavior of the structure was used to illuminate the changing characteristics. The calculation is a static analysis, with a constant vertical load, and the load gradually increases. The equivalent static shear force is approximately equal to the generated seismic force. Perform analysis before structural failure. The analysis identified weaknesses in the structure so that appropriate controls can be carried out. Attribute-based analysis and design, where the requirement is the seismic motion of the ground, and the storage tank is a structure that can withstand seismic loads. Performance depends on how the storage tank handles seismic loads. Capacity curve and demand of research use nonlinear static shear analysis to evaluate the structure's seismic performance. ATC-40 software and guidelines were used for numerical analysis. FEMA 356 used foundation shear, deflection, floor drift, floor drift rate, and multi-stage hinges.

The results of the axial load analysis ensure the consistency of the plastic hinge structure and hinge conditions under different building performance levels. The result provides information about the weakest member of the structure as we can see in Figure (O. A. Al-Fahdawi, Barroso, and Soares Coble Khatibinia, Gholami, and Kamgar) that defines G+1, G+3 and G+14 where ADRS Plot and Hinge Formation are explained in detail. The refinement of the element can be carried out appropriately to obtain the required element fracture pattern in the case of a strong earthquake. Different colors indicate acceptance of standard IO (use immediately), LS (life safety) and CP (prevent damage) to indicate the status of the cycle at different stages.

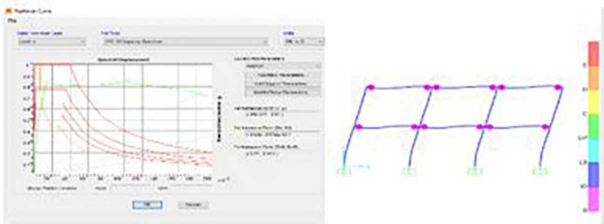

FIGURE 2. (a) G+1: ADRS Plot, (b) Hinge Formation

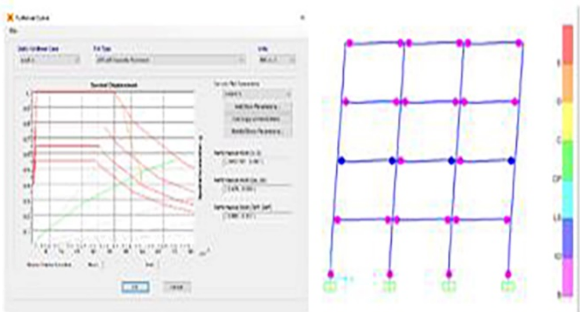

FIGURE 3. (a) G+3: ADRS Plot, (b) Hinge Formation

3.2. TMD Analysis

Using the nonlinear time history analysis of the shear room under sinusoidal acceleration load, the vibration control effect of the tuned shock absorber was compared and studied as it can be seen in Figure [5-8] that defines G+1, G+3, G+9 and G+14

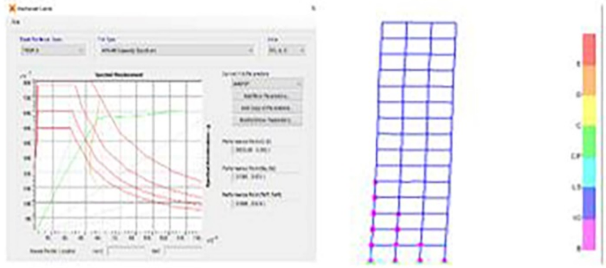

FIGURE 4. (a) G+14: ADRS Plot, (b) Hinge Formation

that is with TMD as well as without TMD where the displacement values are reducing after installing TMD. TMD is an inertial mass connected to the construction site with a maximum displacement (usually at the top) through properly adjusted springs and damping elements. Generally, viscous and viscoelastic dampers are used. A structure attached to it reduces its movement. The resistance depends on its dynamic characteristics, stroke and the amount of additional mass used. Under specific vibration modes, the additional damping introduced by TMD also depends on the ratio between the masses of the dampers. And the adequate quality of the structure. The basic model of the TMD weight is approximately considered the total mass of the structure 0.25% to 1.0% of the weight of the building, including all the material self-weight and instrumental weight. The TMD frequency has been adjusted to a specific design frequency. The frame will move and narrow to the answer. The position of the damper is parallel to the natural frequency distributed around the controller. In the same total mass, several mass dampers can significantly increase the equivalent damping of the introduced system. In the analysis, a mass ratio of 0.1 was used. The frame structure is subjected to sinusoidal acceleration λ= Amax sin (ω.t) at the bottom. Among them, Amax and ω are the maximum acceleration amplitude and sinusoidal acceleration frequency, respectively. Taking into account the resonance conditions, the parameters Amax and ω are equal to 1/10 m/s^2. In Table 2. The Story Displacement with and without TMD in mm is shown.

4. Conclusion

A small-scale analysis of 14-story buildings G + 1, G + 3, G + 9, G + was carried out in SAP2000. The results show that the hinge structures of vari-

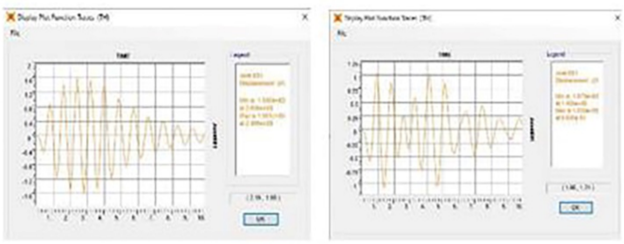

FIGURE 5. **G+1: (a) Without TMD, (b) with TMD**

TABLE 2. **Story Displacement**

Building Type	w/o TMD (mm)	w/TMD (mm)
G+1	142.5	124.3
G+3	218.1	181
G+9	305.4	258.6
G+14	497	286

FIGURE 6. **G+3: (a) Without TMD,(b) with TMD**

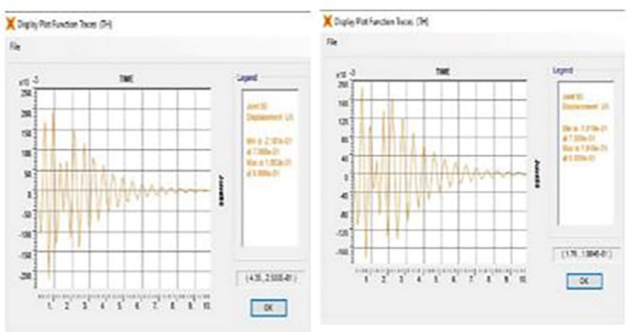

FIGURE 7. **G+9: (a) Without TMD,(b) with TMD**

ous buildings are located in the SAFE LIFE area (as shown by the hinge-deformation section). Below), we can say that these structures can handle certain types of seismic loads well. The loop formation sequence shows a partial collapse in the rays in front of the pillars. G+1, G+3, G+9, G+ analyzed 14-story buildings with matched mass attenuators

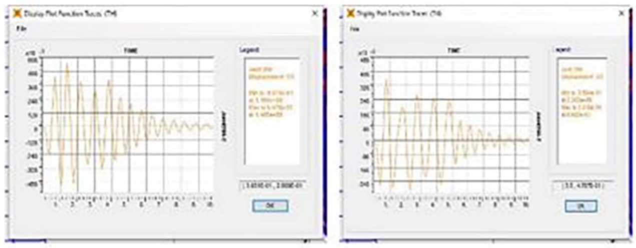

FIGURE 8. **G+14: (a) Without TMD, (b) with TMD**

but no matched mass attenuators. TMD effectively reduces displacement and acceleration so that it can be used for seismic structures. They were moving the seismic excitation structure. It has been found that TMD can be successfully used for structural vibration control. It can be seen that TMD works well on the upper deck, and the natural frequency of the first mode gives the best results.

ORCID iDs

PV Ramana https://orcid.org/0000-0003-1429-5519

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