International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

A REVIEW ON RECENT DEVELOPMENT IN VIBRATION CONTROL IN BUILDING & BRIDGES

Preetha S [1] ***, Anusuya M*** [1] ***, Shanmathy S*** [1]***, Kartika M*** [1] ***, Dr. Vennila A*** [2]

[1]First year M.E. Structural Engineering, Department of civil engineering, kumaraguru college of technology, Coimbatore- 641049, Tamilnadu, India.

[2]Associate professor, Department of civil engineering, kumaraguru college of technology, Coimbatore- 641049, Tamilnadu, India

ABSTRACT:

A current overview of structural response control, mostly employing passive tuned mass damper(s) (TMD/s), is provided. The review focuses primarily on the response control of wind- and earthquake-excited structures, as well as the theoretical underpinning of TMD and research achievements in this area. Investigations are conducted to assess the effectiveness and performance of tuned mass dampers in various constructions. This thesis presents one- and two-story building frame models for shaking table experiments with sinusoidal stimulation. To compare the reaction of the structure with and without TMD. The TMD is adjusted to the structure's frequency while maintaining consistent stiffness and damping. TMD efficacy and resilience are measured using factors such as frequency ratio, mass ratio, and tuning ratio, resulting in a percentage reduction in amplitude of the structure. The answers are confirmed quantitatively using the finite element approach. The study found that TMD can be utilized to regulate the vibration of structures.

Keywords: Earthquake structures, FEA, TMD

Introduction

Passive systems examined include the tuned mass damper (TMD), tuned liquid column damper (TLCD), tuned liquid column ball damper (TLCBD), circular TLCD (CTLCD), and pendulum TLCD (PTLCD). Piezoelectric actuators and active tuned mass dampers (ATMD) are two examples of active control systems. Semi-active systems consist of magnetorheological (MR) dampers, negative stiffness devices (NSD), magneto-rheological damper TMD (MR-TMD), variable stiffness semi-active TMD (VS-STMD), variable damper STMD (VD-STMD), and re-entering variable friction device (RVFD). Hybrid systems consist of an active base isolation system and semi-active MR dampers with nonlinear base isolators. Semi-active structural control and hybridization of several control systems are currently at the forefront of study. The challenge is complicated, necessitating the integration of several hardware and software technologies with structural design, such as smart materials, adaptive dampers, actuators, and sensors.

Vibration control options for transit designers include precision straightened rail, ballast mats, floating slabs, and extremely soft direct fixation fasteners, as well as rail grinding, wheel truing, and continuous welded rail. Recently, the Los Angeles Metro created standards for a soft resilient direct fixation fastener that has the same base dimensions as the regular direct fixation fastener. To alleviate the projected ground vibration impacts on adjoining residential structures in San Francisco, low resonance frequency (8 Hz) floating slabs were built. In Atlanta, low resonance frequency loading slabs have been developed to preserve a low vibration environment in a medical facility that will be built above the subway construction.

The proposed approach involves placing dampers on the floors of a six-story structure to achieve maximum reduction. Accelerations under stochastic seismic stress, including 13 earthquake records. Numerical data indicate that numerous dampers can minimize uncontrolled structural acceleration by 10-25% compared to a single damper. Time-history analyses show that numerous dampers weighting 3% of the total structural weight can minimize floor acceleration by up to 40%. Multiple dampers can inhibit acceleration reactions caused by impulsive excitations, beyond the capabilities of a single damper with equivalent mass. In 2012, Ikago presented a method for integrating an inertial mass with a viscous mass damper to generate a tuned viscous mass damper (TVMD), which has demonstrated superior control efficiency over typical viscous mass dampers (VMDs) and viscous dampers (VDs). Garrido created a rotating inertia dual tuned mass damper (RIDTMD) by replacing the standard viscous damper (VD) with a tuned mass damper (TMD) in 2013. Marian et al. created a tuned mass damper inertial (TMDI) device in 2014 by parallel connecting an inertial mass to the damper and spring components of a TMD.

LITERATURE REVIEW

Zhang et al. investigated the structural control of high-rise buildings under wind and earthquake loads and found that under a multi-modal control mechanism involving TMDI, it is primarily determined by the contribution of two aspects of TMDI: the damping effect associated with inertia, auxiliary mass, and damping coefficient, and the negative stiffness effect associated with auxiliary mass. In the vibration reduction of tall structures with wind excitations, the performance of the TMDI is greatly impacted by the floor to which the inerter is attached. As a result, the building's vibration reduction performance is computed based on this value. Designers must carefully examine the inerter's installation position, since this might have a considerable impact on the overall performance of the TMDI system. The inerter end attached to the ground level experiences zero absolute acceleration, which results in optimal TMDI performance. However, by connecting the inerter to a floor under the pendulum mass, TMDI can only outperform TMD if the inerter is attached to a floor that is roughly one-third the height of the structure.

The use of TMD systems has the potential to dampen aero elastic reactions caused by aerodynamic turbulence from gust loads. In wind turbine constructions, Zhang and Hoe improved the attenuation capabilities of a basic translational TMD by incorporating a rotating inertia double TMD (RIDTMD) into the model to damp in-plane vibrations of floating offshore wind turbines. This feature allows for the introduction of extra-resonance into the model. Del Campo et al. demonstrated in a very interesting statistical study that including passive damping systems in land-based wind turbines, such as optimally tuned TMD devices, results in an 80% fragility reduction under severe atmospheric turbulence excitations, such as cyclone-induced winds, and a much lower fragility reduction for seismic excitations. Regarding the reduction of flutter oscillations in bridges, Boonyapinyo et al. explored a model of an STMD and MTMD using the modal method, indicating that the buffeting response may be significantly decreased with the right tuning of the constitutive parameters.

Tuned Mass Dampers (TMDs) have grown in popularity as a technique for shielding buildings against unexpected vibrations due to its comparatively basic principles and ease of performance adjustment, as seen by multiple recent successful applications. This study includes a comprehensive overview of active, passive, semi-active, and hybrid TMD control methods used to protect structures from earthquake or wind forces, as well as a comparison of their efficiency, benefits, and limitations. Despite the relevance and recent advances in this sector, past reviews have primarily looked at passive or active TMDs. Since Frahm offered a patent that incorporates a mass-spring system into a structure as a damping mechanism, the passive TMD has piqued the interest of civil and mechanical engineers worldwide. The passive TMD has been successfully used in many tall buildings, including two sets of 360-ton TMDs installed diagonally on the 58th floor of the John Hancock building in Boston (height 244 m) and one set of 660-ton suspension TMD installed on the 92nd floor of the Taipei 101 building in Taipei (height 508 m). Wind-induced acceleration was decreased by approximately 40% in structures equipped with TMD.

Engineers are particularly interested in the proper design of TMD. Den Hartog included the TMD into an undamped SDOF structure subjected to external harmonic disturbance, then used the "fix-point" in the frequency response function to derive a set of optimal design equations. Tsai and Lin provided an optimal design formula for the undamped SDOF structure in harmonic base excitation using fix-point theory, and then got the design formula for the damped structure by regression. Warburton suggested an optimization method to reduce the mean square response of structural displacement or velocity in undammed structures subjected to random wind or seismic loads.

Tuned liquid column dampers (TLCDs) use the motion of a liquid column in a U-shaped tube to counteract external stresses on a structure. The inherent damping is introduced in the oscillation. A liquid column passes through an aperture. Sun (1991) studied the performance of a single-degree-of-freedom structure with a TLD under sinusoidal excitations. Wakahara et al. (1989) applied this knowledge to control wind-induced vibration. Welt and Modi (1989) were among the first to advocate using a TLD in structures to lessen responsiveness during heavy winds or earthquakes. The tuned mass damper (TMD) concept first appeared in the 1940s (Den Hartog 1947). The design includes a secondary mass with tuned springs and damping devices, resulting in frequency-dependent hysteresis and increased damping in the primary structure. The success the effectiveness of such a technology in decreasing wind-induced structural vibrations is well known. Villaverde (1994) conducted a study on the usefulness of TMDs in lowering seismic response in buildings.

To structure the review, the large family of tuned liquid dampers is divided into five groups based on their energy dissipation mechanism: tuned sloshing damper, tuned liquid column damper, combined tuned sloshing damper-tuned liquid column damper system, compliant liquid damper, and liquid damper with submerged tuned oscillator. The modelling, analysis, design, and performance features of the many types of tuned liquid dampers are discussed. The benefits and application of several types of tuned liquid dampers are discussed, as well as their actual installations. Current gaps in the development of various tuned liquid damper designs are recognized, as is the scope of future advances. Saidi, A D Mohammed, et al. (2007). Optimal design for passive tuned mass dampers utilizing viscoelastic materials. This conference paper is part of a research effort. The project intends to create a cost-effective Tune Mass Damper (TMD) utilizing viscoelastic materials. A TMD comprises of a mass, spring, and dashpot connected to a floor, creating a two-degree of freedom mechanism. This study outlines a methodology for determining the optimal TMD parameters for a particular floor system. This article shows how to estimate the equivalent viscous damping of a viscoelastic damper. We demonstrate a novel prototype viscoelastic damper and preliminary finding.

The potential efficacy of TMDs is also dependent on the structure under consideration. TMDs, for example, may be more successful in tall and flexible buildings that are prone to pulse-like ground vibrations than in highly rigid structures. The research does not address the effectiveness of TMDs in moderating the reaction of tall structures such as chimneys to pulse-like ground vibrations. This study looks at this critical problem by numerically simulating the behaviour of a tall reinforced concrete chimney to several near-fault pulse-like ground movements observed during previous earthquakes. A tuned mass damper (TMD) was created to be mounted on the roof of a medium-rise structure to modify its seismic behaviour from dissipative to non-dissipative. The TMD was used to reduce stresses in structural members and floor movement, hence avoiding damage to structural and non-structural materials during significant earthquakes. As a result, the building with TMD would not require repair interventions following such earthquakes. In the suggested approach, the mass of the TMD is formed by an RC slab laid on flat surface sliders (FSSs) put on the building's rooftop. The DTMD system's core design concept is to modify the natural frequencies of a network of miniature TMDs placed around the principal structure's specified vibration mode. A TMD is defined as a passive vibration device that can attenuate vibration at a given tuned frequency. Thus, a single TMD may reduce vibration in a short bandwidth around the tune frequency. DTMD systems boost efficacy and bandwidth by tuning the natural frequencies of a collection of TMDs at frequencies close to the desired vibration mode of the main structure.

Recent developments in engineered timber materials, together with their availability, durability, and renewability, have permitted the construction of higher and more flexible structures. However, when wind or earthquake loads are applied to these buildings, severe vibrations may occur, raising safety and serviceability problems. In this research, we offer a dynamic analysis of a 42-story hybrid-timber structure and compare the performance of three damping devices: pendulum pounding tuned mass damper (PTMD), tuned mass damper inerter (TMDI), and tuned mass damper (TMD). We assess the TMD and TMDI's vibration reduction capabilities using filtered white noise and variable frequency sinusoidal excitations. We establish a fair comparison by keeping the TMD, TMDI, and pendulum PTMD at equal masses. Our findings show that the pendulum PTMD outperforms TMD and TMDI in terms of peak acceleration reduction during earthquakes. This device significantly decreases damage to structural and non-structural components during earthquake activity. Furthermore, we find that linking the inerter and TMD to produce a TMDI shifts the optimal frequency and damping ratios, resulting in poor performance. In comparison to TMD and TMDI, the suggested pendulum PTMD is more resilient and performs better, with lower base shear, base moment, and inter-story drift ratio.

To increase robustness, it has been proposed to employ more than one TMD, also known as multiple TMD (MTMD), with differing dynamic properties. MTMDs, like single TMDs, are not resilient to modifications in both the main structure's inherent frequencies and the damping ratio. The adoption of an active TMD offers one solution to these disadvantages. ATMD and AMD are frequently used for response control in buildings and bridges. Active TMD can reduce responsiveness and be more resilient to tuning errors with proper feedback. However, it requires active forces and high power to work. Magnetorheological elastomers (MREs) have also been explored and utilized to reduce structural vibrations. MREs can be viewed as a solid form of magnetorheological fluid (MRF). As a result, they may vary their stiffness or elastic modulus when the magnetic field changes and then instantaneously return to their previous state once the magnetic field is eliminated.

Roberto Villaverde et al. (2002).The analysis comprises a comparison of the building's reaction to severe ground motion with and without the isolation system, as well as determining the qualities and sizes of the isolation system components needed. The suggested isolation system is proven to be effective, constructible, and has the potential to become a popular method of reducing structural and nonstructural earthquake damage in low- and medium-rise structures. Haruna Ibrahim, et al. (2015)4 This paper presents preliminary results on passively controlling the structural response of single degree of freedom (SDOF) and two-dimensional multi-storeyed frames with Tuned Mass Damper (TMD). It is a device that transmits forces generated in response to the motion of the structures. Absorbing portion of the incoming energy minimizes energy dissipation demand on the structure. As a result, the structural system does not require an external power source to add energy. Examples of passive control devices include base isolation, TMD, TLD, metallic yield dampers, and viscous fluid dampers. Applications include municipal halls in Oakland, the US Court of Appeals in San Francisco (Friction Pendulum), the New Zealand Parliament Building and Assembly Library, the new Museum of New Zealand, USC Teaching Hospital in Los Angeles, and the Matumura Research Institute in Kobe.

T. Pinkaew et al. (2002) explained about After yielding, the efficiency of TMD utilizing displacement reduction of the structure is insufficient. Therefore, damage reduction of the structure is offered as an alternative. Numerical simulations of a 20-story reinforced concrete structure. We describe an analogous inelastic single-degree-of-freedom (SDOF) system with harmonic and 1985 Mexico City (SCT) ground movements. TMD can greatly minimize structural damage after yielding, but does not lower peak displacement. Additionally, TMD can provide damage protection and avoid collapse. Baki Ozturk et al. thought that This study examines the optimal design of a tuned mass damper (TMD) to reduce dynamic response in cantilever beams across all frequency ranges. Random vibrations are utilized to determine the objective. Reduce the RMS acceleration at the cantilever beam's endpoint. Marian Sikora studied about The author develops and simulates a damper using the TMD idea with oscillatory inputs and analyzes the results. Anand S et al. learned about this research evaluates the usefulness of Tuned Mass Dampers in passenger automobiles and finds that adding a tuned mass to the suspension system greatly lowers transmissibility.

The Python code demonstrates how a building responds with and without a Tuned Mass Damper (TMD). The simulation demonstrates how a TMD may dampen external vibrations in buildings. The advantages of using a TMD to increase structural stability are highlighted by comparing the two scenarios. Reducing building vibrations benefits occupant comfort, structural integrity, and durability. Uncomfortable vibrations can cause structural damage and, in extreme cases, endanger the building's safety. Tuned mass dampers employ a secondary mass-spring system to offset external vibrations, making them an effective solution. When the structure exhibits elastoplastic behavior, the PTMD performance deteriorates. When a structure reaches the nonlinear region, effective stiffness decreases, resulting in a loss of tuning between the PTMD and primary frequencies. Yielding structural parts offer a significant amount of energy dissipation, implying that TMD energy dissipation contributes only little to building responsiveness. Under increased dynamic loads caused by earthquakes, bigger changes in the structure's effective stiffness can occur as a result of inelastic processes that may be connected to damage. These adjustments increase the structural period, resulting in a considerably more substantial detuning impact.

Shear walls and Tuned Mass Dampers are allocated in the structure alternately. Tuned mass dampers are arranged in several ways in this 30. The research examines the optimal design for managing vibration in a 50-story skyscraper. The 50-story building's characteristics were evaluated using Time History Analysis of the El Centro earthquake. The use of TMDs in a 50-story skyscraper was likewise safe. The structure exhibits little base shear, storey displacement, joint accelerations, and frequency. TMD's impact on seismic response of structures and its relationship with ground motion parameters. The efficacy of TMD has been explored. This study focuses on an idealized single-degree-of-freedom (SDOF) structure with a natural vibration period and damping ratio. The study examines structures under various earthquake ground movements, both documented and intentionally manufactured. TMD can effectively limit seismic response in weakly damped buildings, for both recorded and intentionally created ground movements. Geotechnical centrifuge experiments were done to study how TMDs affect a multiple-storey sway frame structure during dynamic soil-structure interaction (SSI).

Shimazu and Araki et al. (1996) analyzed the effectiveness of mass damper systems in real-world structures against wind and earthquakes. The impacts of mass damper systems on structures are explored, including their natural period, mass weight ratios, wind force levels, and seismic ground motion. Fahim Sadek et al. (1997) identified optimal TMD settings for reducing structural reaction to seismic loads. The optimal parameters were determined by selecting frequencies and damping ratios based on a specific mass ratio. Abe (1995) provided analytical findings for vibration control of structure with one or more tuned mass dampers (TMDs). The input is a harmonic load with various frequencies. The control aim is to decrease the maximum amplitude of the structural reaction. Perturbation theory is applied to three sets of tiny parameters. The ratio of TMD between structural modal masses and dampening of the system. Analytical analysis demonstrates that structures with widely spread natural frequencies may be well modeled by the response of the well-known single mode structure/TMD system, despite changes in mass and damping. Oshi (1996) investigates the settings of multiple tuned mass dampers (MTMD) to suppress the dynamic response of a base stimulated structure in a specie mode.

Dr. Mohan M. Murudi's research paper Tuned Mass Damper (TMD) has this method is effective for managing fundamental reactions in symphonies and wind excitations. This article examines the effectiveness of TMD in regulating earthquake reactions and how different ground movement factors affect its seismic adequacy. The admired single-level of opportunity (SDOF) structure is characterized by its normal sensory time and damping proportion. The study examines structures that have been subjected to both genuine seismic ground movements and simulated ones. TMD can effectively manage tremor reactions in delicately damped buildings, for both actual and simulated seismic ground motions. Tests by Christopher Adam and Thomas Furtmuller show that tailored mass dampers may effectively limit seismic excitation for masses ranging from 2% to 8%. The study uses genuine earthquake ground vibrations to analyse the construction. This collection contains 40 ground movements reported in California with moment magnitudes ranging from 6.5 to 7. An appropriately designed mass damper's efficiency diminishes as structural dampening increases. The study found that optimum tuning of TMD parameters under white noise base acceleration provides acceptable accuracy. However, proper tuning of TMD's inherent frequency is required for efficacy.

Semi-active dampers are an advancement of passive energy-dissipating technology, incorporating adaptive technologies for increased efficacy and intelligence. They are commonly referred to as controlled passive devices or clever dampers. The adaptive system collects information on excitation and structural reaction and alters damper behavior in real-time to optimize performance. Enhance its performance. Semi-active damper systems include sensors, a control computer, a control actuator, and a passive damping mechanism. The sensors monitor the excitation and/or structural reaction. The control computer processes measurements and sends control signals to the actuator. The actuator adjusts the behavior of the passive device. Hybrid control systems, which combine passive and active control approaches, are becoming increasingly popular. A hybrid system obtains the benefits of both hybridized procedures while mainly removing the constraints of each methodology alone. Researchers and engineers prefer passive systems due of their simplicity and reliability.

CONCLUSION

Tall structure construction has rapidly increased in India, introducing new problems that must be addressed by engineering judgment. Choosing the right structural system for a tall structure under earthquake stresses is a challenging challenge. The tuned mass damper system effectively reduces horizontal displacement and storey drift. As the structure's height climbs, it loses its rigidity, causing storey drift to exceed safe levels. TMD (tuned mass damper) is a structural system designed for tall constructions. This technology eliminates structural movement, including storey drift and lateral displacement. Energy dissipation devices play a crucial role in regulating a structure's response to earthquakes. The TMD reduces displacement, drift, base shear, and first mode frequency in the structure. However, TMD requires a customized design for each building based on its mass and stiffness. To create a weak story over a stiff structure, it's important to use the right approach. VFDs, available in various masses and damping, can assist reduce displacement and reaction on the structure. Semi-active friction multiple tuned mass dampers are used to regulate vibrations in seismic constructions. When static friction force deactivates a friction-type tuned mass damper, there is no difference between it and a dead mass in the primary structure. This research presents a semi-active friction-type multiple-tuned mass damper (SAF-MTMD) to regulate vibrations in seismic constructions. The proposed SAF-MTMD system uses variable friction mechanisms to maintain all mass units operational during earthquakes of varying intensities. Compared to PF-MTMDs, the SAF-MTMD effectively suppresses seismic motion and reduces mass unit strokes, particularly during high-intensity earthquakes.

A series of numerical analyses are performed to assess the efficacy of unconventional TMDs connected to a damped main structure via harmonic stimulation. The Hybrid Pattern Search (HPS) approach is used to achieve optimal values. The optimal values for NT-TMD are higher than those achieved for TMD. Increased mass ratio leads to higher NT-TMD tuning ratio and lower TMD tuning ratio. As the mass ratio increases, so do the damping ratios of both control devices. When the mass ratio is more than 0.03, NT-TMD performs better than TMD. For optimal control efficiency, NT-TMD should have a mass ratio higher than 0.03. The Python code demonstrates how the building responds with and without a Tuned Mass Damper (TMD). The simulation demonstrates how a TMD may dampen external vibrations in buildings. The advantages of using a TMD to increase structural stability are highlighted by comparing the two scenarios. Reducing building vibrations benefits occupant comfort, structural integrity, and durability. Uncomfortable vibrations can cause structural damage and, in extreme cases, endanger the building's safety. Tuned mass dampers employ a secondary mass-spring system to offset external vibrations, making them an effective solution.

Simulation findings show that the TMD system reduces vehicle acceleration, with effectiveness rising with TMD mass. The conclusion states that a TMD system may significantly increase a vehicle's ride comfort during random vibrations. The paper provides a paradigm for assessing and optimizing TMDs with additional mass, using readily available data inputs. The authors suggest that using an Active Tuned Mass Damper (ATMD) over a passive Tuned-Mass Damper (TMD) system improves vehicle vibration characteristics. The ATMD technology can alter settings in real-time to fit changing road conditions, resulting in more effective vibration control. The building industry is moving towards higher, lighter, more flexible structures with reduced damping values. This raises the possibility of failure and causes challenges in terms of serviceability. TMD is one of the approaches available for reducing structural vibration. This research is designed to examine the effectiveness of employing TMD to control structural vibrations. A numerical approach was created to simulate the multistorey, multi-degree of freedom building frame structure as a shear building with a TMD. A numerical approach is also created to analyze 2D-MDOF frame structures with a TMD. At the structure's base, three different loading conditions are applied.

REFERENCE

1. Van der Geer, J., Hanraads, J. A. J., & Lupton, R. A. (2000). The art of writing a scientific article.*Journal of Science Communication, 163*, 51–59.
2. Strunk, W., Jr., & White, E. B. (1979).*The elements of style* (3rd ed.). New York: MacMillan.
3. Mettam, G. R., & Adams, L. B. (1999).How to prepare an electronic version of your article. In B. S. Jones & R. Z. Smith (Eds.), *Introduction to the electronic age* (pp. 281–304). New York: E-Publishing Inc.
4. Fachinger, J., den Exter, M., Grambow, B., Holgerson, S., Landesmann, C., Titov, M., et al. (2004).Behavior of spent HTR fuel elements in aquatic phases of repository host rock formations, 2nd International Topical Meeting on High Temperature Reactor Technology. Beijing, China, paper #B08.
5. Fachinger, J. (2006). Behavior of HTR fuel elements in aquatic phases of repository host rock formations.*Nuclear Engineering & Design,236*, 54.