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A Review Paper on Tuned Mass Damper

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***Abstract*: A tuned mass damper is a passive energy dissipating device which is compressed of amass, spring and a damper. The idea behind these type of dampers is that if a smaller mass is attached to the multiple degree of freedom system and its parameters are tuned precisely, then the oscillation of the whole system can be reduced by this smaller mass. Some investigations are carried out to identify the importance and performance of tuned mass damper in different structures. The study went on different paths such as alignment, placement, type, it's kind of applications etc. In every study, each aims on the optimization of parameters of the dampers to bet maximum results and thereby reducing the displacement of the structure under seismic forces.**
***Keywords*: Tuned mass damper, MTMD**

I. INTRODUCTION

During earthquake structural performance of Reinforced Concrete (RC) buildings always play crucial roles in losing of life, injuries, economic losses etc. But to a certain extend structures already built are vulnerable to future earthquakes. Earthquake risk is associated with seismic hazard and vulnerability of building. Therefore, to protect such civil structures from significant damage one of the way is to increase flexibility of structures. But will affect the comfortability of people inside the building. so the response reduction of civil structures during dynamic loads such as severe earthquakes and strong winds has become an important topic in structural engineering.

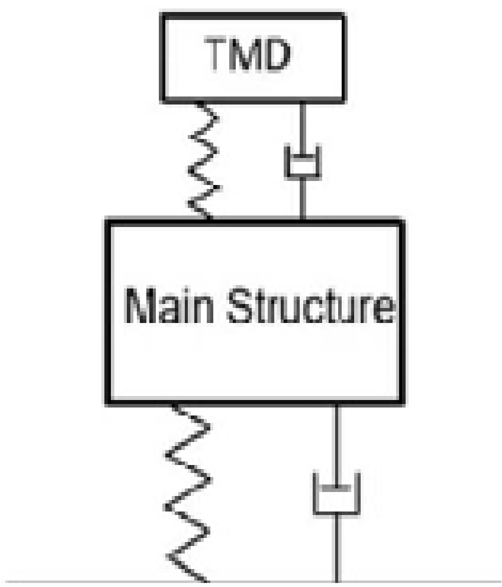

Fig 1: Schematic diagram of a tune mass damper

A number of methods have been developed to reduce the structural response due to lateral excitations. Tuned Mass Damper (TMD) is one of the device that is the most popular one due to its simple principle that have been utilized to control the behavior of tall structure subjected to excitations. It is a passive control system which consist of a mass, and spring that is attached to a structure in order to reduce the dynamic response of the structure. The idea behind a tuned mass damper is that if a multiple-degree-of-freedom system has a smaller mass attached to it, and the parameters of the smaller mass are tuned precisely, then the oscillation of the system can be reduced by the smaller mass.

II. TYPE OF DAMPERS

TMDs can have many different forms depending upon the application.

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III. LITERATURE REVIEW

Various literatures reviewed on friction pendulum isolations are carried out below.

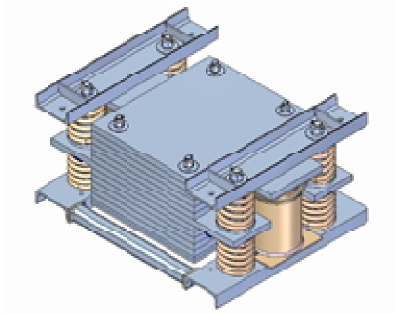

Fig.2 Regulatory mass damper

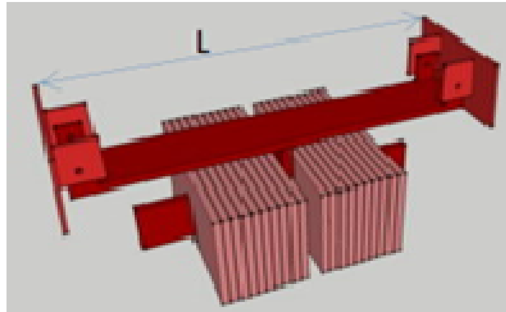

Fig.3 mass and Flexure type TMD

A. Regulatory Mass Damper

$$fTMD = \frac{1}{2\pi}\sqrt{\frac{\sum k(spring)}{m}}$$

It is a very compact form of TMD which is ideal for space-limited applications or when concealment is critical.

B. Mass and Flexure

$$fTMD = \frac{1}{2\pi}\sqrt{\frac{48EI}{L^3 m}}$$

Probably the least expensive form of TMD; can be tailored for almost any application.

C. Pendulum

Fig.3 pendulum

$$fTMD = \frac{1}{2\pi}\sqrt{\frac{g}{L}}$$

Ideal for low-frequency applications like tall buildings or flexible walkways.

IV. LITERATURE REVIEW

Various literature reviewed on fragility assessment is presented in this section. A number of works have been performed on seismic vulnerability assessment A review of literatures is presented in brief summarizing the work done by different scholars and researchers on development of fragility curves for building structures.

Kenny C. S. et al. (1984) Spectral density functions of wind-induced acceleration responses of Sydney Tower identify natural frequencies of vibration of 0.10 Hz and 0.50 Hz for the first mode and second mode respectively was analysed. For natural frequencies and damping measurements, two accelerometers were installed in the Tower, one at Turret Level 8 to monitor the first mode vibrations and one near the Intermediate Anchorage Ring to monitor the second mode vibrations. Each accelerometer has a pair of sensors a lined perpendicular to each other and at north-south and east west directions. Wind-induced accelerations were recorded on magnetic tape using an FM tape recorder. The recorded signals were analyzed by a digital computer to determine the natural frequencies of vibrations and damping level. Spectral density functions of wind-induced acceleration responses of Sydney Tower identify natural frequencies of vibration of 0.10 Hz and 0.50 Hz for the first mode and second mode, respectively. Decay of autocorrelation functions of the response showed that the water tank TMD produces moderate increases in the damping levels of the first mode and second mode, and the secondary damper causes a substantial increase in the damping level of the second mode.

Genda Chen et. al. (2001) discusses the effects of modal responses reduction of a six-story building structure by implementing tuned mass damper. Multistage and multimode tuned mass dampers are then introduced. Based on intuitive reasoning and a sequential procedure is proposed for practical design Several optimal location indices are defined and placement of the dampers in seismically excited building structures. The proposed procedure is applied to place the dampers on the floors of the six-story building for maximum reduction of the accelerations under a stochastic seismic load and 13 earthquake records. Numerical results show that the multiple dampers can effectively reduce the acceleration of the uncontrolled structure by 10–25% more than a single damper. It is found that time-history analyses indicate that the multiple dampers weighing 3% of total structural weight can reduce the floor acceleration up to 40%. The multiple dampers can even suppress the peak of acceleration responses due to impulsive exciytations, which a single damper of equal mass cannot achieve. A sequential procedure has been proposed for optimal placement of multiple dampers on building structures and optimal design of dampers' damping and frequency and found that placement of multiple dampers that considerably outperform the conventional TMD in peak response reduction. The another finding is that the multiple dampers are necessary in reducing the peak acceleration of building structures only when the soil characteristic frequency is close to or higher than the second natural frequency of the structures. Multiple dampers are more effective in suppressing the accelerations at lower floors than at upper floors. They do not appear advantageous over a conventional TMD for displacement control. Multiple dampers can moderately reduce the first peak of acceleration responses due to impulsive earthquakes while a single TMD cannot. They are more robust and each occupies a much smaller space for installation. Overall, multiple dampers can mitigate the seismic acceleration 10–25% more than a conventional TMD.

Roberto Villaverde et. al. (2002) An investigation is carried out of a 13-story building to assess the viability and effectiveness of a recently proposed roof isolation system that aims at reducing the response of buildings to earthquakes. The roof isolation system entails the insertion of flexible laminated rubber bearings between a building's roof and the columns that support it, and the addition of viscous dampers connected between the roof and the rest of the building. It is based on the concept of a vibration absorber and the idea of constructing the mass, spring, and dashpot of such an absorber with the building's roof, flexible bearings, and viscous dampers, respectively. The investigation includes a comparison of the building's response under severe ground motion when it is considered with and without the isolation system, as well as determination of the properties and size of the isolation system components required. It is found that the proposed isolation system is effective, is able to be constructed, and has the potential to become an attractive way by which to reduce structural and nonstructural earthquake damage in low- and medium-rise buildings.

Jerod G. Johnson et. al. (2003) gives the feasibility of placing a tuned mass damper at top in the form of a limber rooftop moment frame to reduce seismic acceleration response. Six existing structures were analytically studied using a suite of time history and response spectra records. The analyses indicate that there is an increase in the fundamental period of each structure by adding mass in conjunction with a limber frame. The fundamental period increase generally results in a decrease in seismic acceleration response for the same time history and response spectra records. Non-linear analysis methods were required to evaluate the stability of the rooftop tuned mass damper frame due to its limber nature of the rooftop frames. The results indicate the addition of a rooftop tuned mass damper frame reduces the seismic acceleration response for most cases although acceleration response can increase if the rooftop frame is not tuned to accommodate the specific structure's dynamic behavior and localized soil conditions. Appropriate design of the rooftop tuned mass damper frame can result in decreased seismic acceleration response. This translates to safer structures if used as a retort measure or a more economical design if used for new construction.

O. R. Jaiswal et al. (2004) Proposed a simple tuned mass damper to control seismic response of RCC elevated tanks. The simplicity of proposed TMD lies in the fact that it has been derived from the existing components of tank. It is the assemblage of roof slab of tank and container columns, which support the roof slab. By considering sloshing and impulsive modes of vibration, tank becomes a 3-DOF system, in which sloshing mass and TMD are not attached to each other. To retain the simplicity of proposed TMD, here the damping of TMD is kept as structural damping of its material. That means the proposed TMD is a non-optimum TMD. Effectiveness of proposed TMD is demonstrated in the form of a tank. From response spectrum analysis using design acceleration spectra of IS 1893 it has been found that such a non-optimum TMD reduces the tank response by 20%. Further investigation shows that if 5% mass of tank is provided as TMD, the required sizes of container column and roof slab thickness are practically feasible and stresses in TMD columns are within permissible limits. Using time history analysis, performance of such a TMD is also shown to be effective under past earthquakes.

Thakur V.M. et al. (2012) carried out a Seismic Analysis of Multistoried Building with tuned mass damper (TMD) to reduce the dynamic vibrations induced by wind or earthquake loads. In these studies Tuned Mass Damper is designed in the form of a soft storey made up of concrete and its columns, beams, and slab sizes is smaller than columns, beams, and slab sizes other stories of the building. The height, member, sizes of soft storey will be devised based on the principle of TMD i.e. the natural frequency of TMD (soft storey) should have same natural frequency as that of main building. A rectangular shaped six storied building is considered for analysis. Analysis is done by FE software SAP 2000 by using direct integration approach. 2% and 3% mass of building are taken as TMDs. Three different recorded time histories of past EQ. are used for the analysis. TMD being made up of concrete has same damping ratio as that of the main building. TMD with optimum frequency ratio given is considering here. To tune the natural frequency of TMD with that of building, the natural frequencies and natural mode shapes of building and TMD is found with the help of SAP. From the results of free vibration analysis of TMD, it is seen that frequency of Modal with TMD (2 & 3% of mass of building) in almost all cases is less than frequency of corresponding Modal without TMD. It is found that a soft storey at the top of building reduces top building deflection by about 10 to 50%. And 3% TMD is found better than 2%.

Yogesh Ravindra Suryawanshi et al. (2012) Carried out a study of inner working of Tuned Mass Damper and technology of TMD in Taipei 101 tower. The theory behind this TMD is that, if a smaller mass is attached to a multi degree of freedom system and tuned it precisely, it will help to reduce the oscillation of the system in any direction. For the efficient working its frequency should be tuned to the fundamental frequency of the structure. Here in Taipei 101 tower in Taiwan a massive steel sphere is provided as TMD. This massive steel sphere will counteract the building's oscillations. For this optimization is essential to the efficient working of the tuned mass damper system, as well as the safety of the structure and inhabitants around it. As the number of storeys are increasing day by day and buildings reach greater and greater heights, tuned mass damper technology is an essential part of maintaining the structural integrity of the places. No power source is required for its operation.

Ashish A. Mohite et. al. (2015) A Tuned mass damper (TMD) is a device which compresses of a mass, and spring that is attached to a structure to reduce the dynamic response of the structure. The frequency of the damper is tuned to a particular structural frequency so that when that frequency is excited, the damper will resonate out of phase with the structural motion. Taller become more susceptible to dynamic excitations such as wind and seismic excitation. For the structure safety and occupants comfort, the vibrations of the tall buildings are serious concerns for both engineers and architects. In order to mitigate the vibration, here adopted Tuned Mass Damper. Tall buildings and observation towers are occasionally vibrated under strong winds and become uncomfortable for occupants. Therefore, to reduce the vibration in those structures, various types of dampers are being developed recently. However, there is no sure way to predict the wind-induced response of a structure with a damper system and to estimate the suppressing effects of dampers under earthquake loadings. Here a symmetrical moment resistance frame (MRF) three – dimensional model with and without tuned mass damper analysed by using software ETABS which is constructed from concrete, steel or composite material. Moment resistance frames can be sufficient for a building up to 20 storey. A tuned mass damper (TMD) is placed on its top and through it to study its effects on structural response due to time history analysis with and without the tuned mass damper (TMD) in a ETABS. The result obtained from software analysis of 10th, 12th, 14th, 16th, 18th, and 21th storey building with and without tuned mass damper and compare result with each other and found that it is more efficient in reducing acceleration and displacement of structure.5% TMD is more efficient for regular building. Provision of TMD is more efficient by providing it on the top storey.

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Haruna Ibrahim et. al. (2015) Preliminary results on the passive control of the structural response of single degree of freedom (SDOF) and two dimensional multi-storeyed frames using Tuned Mass Damper (TMD) are presented here. At first a numerical analysis was developed to investigate the response of a shear building fitted with a tune mass damper. Then another numerical was developed to investigate the response of a 2D frame model fitted and without Tuned Mass Damper (TDM). From the study it was found that, tuned mass damper can be effectively used for vibration control of structures. Tuned mass damper (TMD) was more effective when damping ratio of the structure is less. It is also observed that due to increase in tuned mass damper damping ratio, the movement of tuned mass damper is also decreases. The most important feature of the TMDs is the tuning of frequencies, that is, the frequency of the TMD is made equal to the fundamental frequency of the structure. Because of various uncertainties inherent in the properties of both the TMD and the structure, perfect tuning is very difficult to achieve. As a consequence, there comes multi-tuned mass dampers (MTMDs) for better tuning. Tuned mass damper are designed to reduce wind responses on tall buildings, this study is made to study the effectiveness of using tuned mass damper for controlling vibration of structure due to excitation force (wind). Based on the simulation results, it shows that the response of the structure subjected to excitation force system is relatively higher without tuned mass damper which shows the effectiveness of TDM in controlling the vibration on the structure. It also observed that the displacement response is decreased by increasing damping ratio of TMD.

V. CONCLUSIONS

A brief review of several literatures presented shows the application of a passive energy dissipating device Tuned Mass Damper. It is found that a single TMD is not much effective than series of multiple tuned mass dampened arrangement. Because heaver mass dampers reaches its full potential slowly than lighter. A mitigation of 10-25% in seismic acceleration can be done by MTMD than single TMD. But from best of knowledge it seems that no work has been reported on a systematic approach to place the multiple dampers of various frequencies in a multistory building structure for optimal performance. If TMDs are providing on a building as a retrofitting element, it the seismic acceleration response for most cases although it is not tuned to accommodate the specific structure's dynamic behavior and localized soil condition. And this arrangement will be effective not only in high rise buildings but also in low and medium rise buildings. This will helps to reduce displacement, storage drift, and base shear. And also it have best control in first mode. From all the researches, it is found that the proper implementation of TMD in any high-rise buildings in earthquake prone area is necessary.

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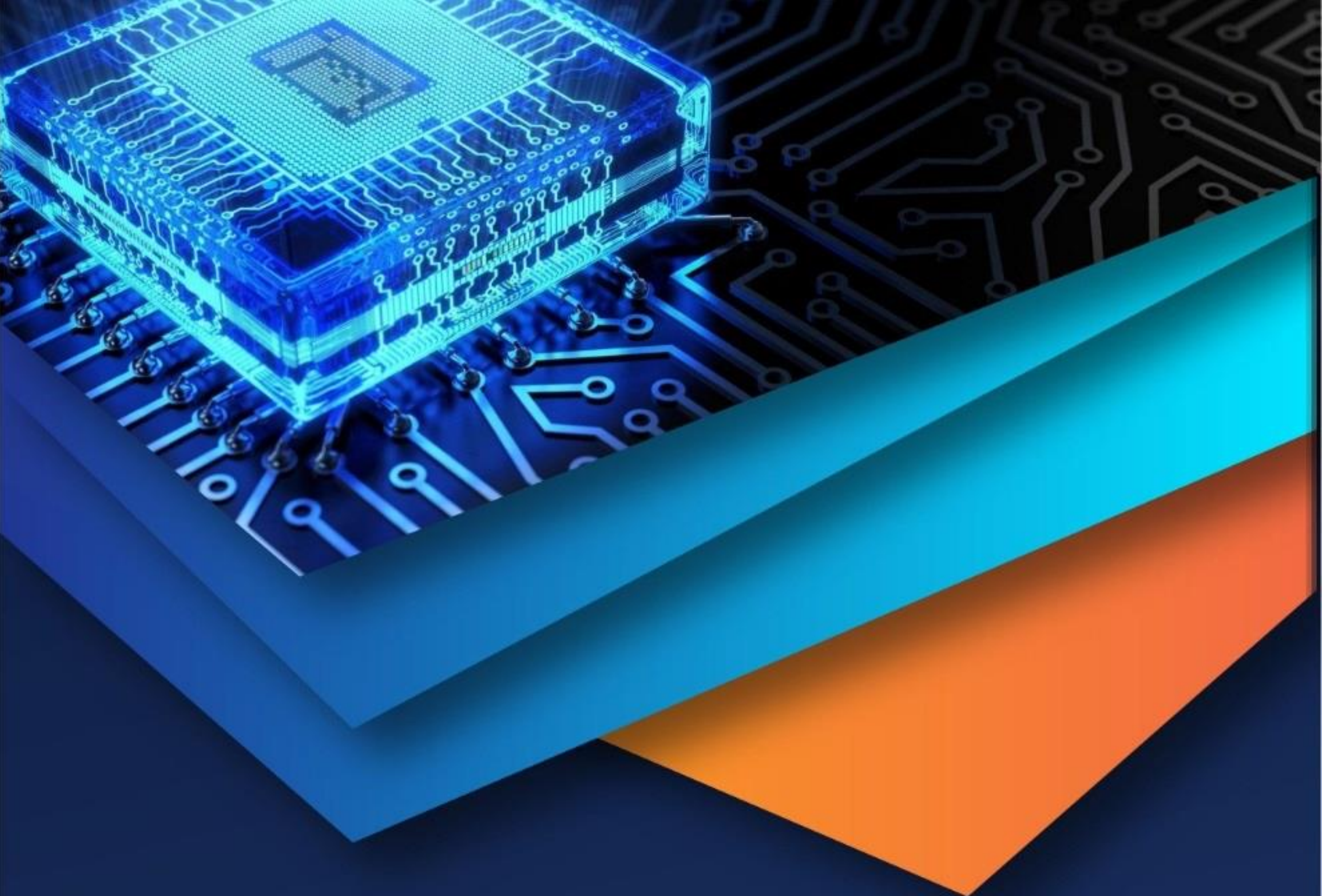

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