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Application of Tuned Mass Damper For Vibration Control of Frame Structures Under Seismic Excitations

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Abstract: Current trends in construction industry demands taller and lighter structures, which are also more flexible and having quite low damping value. This increases failure possibilities and also problems from serviceability point of view. Now-a-days several techniques are available to minimize the vibration of the structure, out of the several techniques available for vibration control, concept of using TMD is a newer one. This study was made to study the effectiveness of using TMD for controlling vibration of structure. At first a numerical algorithm was developed to investigate the response of a shear building fitted with a TMD. Then another numerical algorithm was developed to investigate the response of a 2D frame model fitted with a TMD. A total of three loading conditions were applied at the base of the structure. First one was a sinusoidal loading, the second one was corresponding to compatible time history as per spectra of IS-1894 (Part -1):2002 for 5% damping at rocky soil with (PGA = 1g) and the third one was 1940 El Centro Earthquake record with (PGA = 0.313g). From the study it was found that, TMD can be effectively used for vibration control of structures. TMD was more effective when damping ratio of the structure is less. Gradually increasing the mass ratio of the TMD results in gradual decrement in the displacement response of the structure.

***Index Terms* – damping value, serviceability, vibration, tuned mass damper, spectra of IS-1894.**

I. INTRODUCTION

Vibration control is having its roots primarily in aerospace related problems such as tracking and pointing, and in flexible space structures, the technology quickly moved into civil engineering and infrastructure-related issues, such as the protection of buildings and bridges from extreme loads of earthquakes and winds. The number of tall buildings being built is increasing day by day. Today we cannot have a count of number of low-rise or medium rise and high rise buildings existing in the world. Mostly these structures are having low natural damping. So increasing damping capacity of a structural system, or considering the need for other mechanical means to increasethe damping capacity of a building, has become increasingly common in the new generation of tall and super tall buildings. But, it should be made a routine design practice to design the damping capacity into a structural system while designing the structural system. The control of structural vibrations produced by earthquake or wind can be done by various means such as modifying rigidities, masses, damping, or shape, and by providing passive or active counter forces. To date, some methods of structural control have been used successfully and newly proposed methods offer the possibility of extending applications and improving efficiency. The selection of a particular type of vibration control device is governed by a number of factors which include efficiency, compactness and weight, capital cost, operating cost, maintenance requirements and safety.

Aim and Scope of this work

The aim of the present work is to study the effect of TMD on the dynamic response of multi- storey frame structures under earthquake excitations. The scope of the work includes the modelling the multi-storey building as 1D and 2D models. The finite elements have been used to discretize the building frame structures and TMD. The Newmark Beta method is used to solve the dynamic equations for the structure-TMD system.

II. LITERATURE REVIEW

Byung-Wan Jo et al (2001).To reduce the structural vibration of a three span steel box bridge a three axis two degree of freedom system is adopted to model the mass effect of the vehicle; and the kinetic equation considering the surface roughness of the bridge is derived based on Bernoulli-Euler beam ignoring the torsional DOF. The effects of TMD on steel box bridge shows that it is not effective in reducing the maximum deflection, but it efficiently reduces the free vibration of the bridge. It proves that the TMD is effective in controlling the dynamic amplitude rather than the maximum static deflection. Optimal placement of multiple tuned mass dampers for seismic structures. Genda Chen et al(2001). In this paper effects of a tuned mass damper on the modal responses of a six-story building structure are studied. Multistage and multimode tuned mass dampers are then introduced. Several optimal location indices are defined based on intuitive reasoning, and a sequential procedure is proposed for practical design 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. Time-history analyses indicate that the multiple dampers weighing 3% of total structural weight can reduce the floor acceleration up to 40%. Seismic effectiveness of tuned mass dampers for damage reduction of structures. T. Pinkaew et al(2002).The effectiveness of TMD using displacement reduction of the structure is found to be insufficient after yielding of the structure, damage reduction of the structure is proposed instead. Numerical simulations of a 20-storey reinforced concrete building modelled as an equivalent inelastic single-degree-of-freedom (SDOF) system subjected to both harmonic and the 1985 Mexico City (SCT) ground motions are considered. It is demonstrated that although TMD cannot reduce the peak displacement of the controlled structure after yielding, it can significantly reduce damage to the structure. In addition, certain degrees of damage protection and collapse prevention can also be gained from the application of TMD. Tuned Mass Damper Design for Optimally Minimizing Fatigue Damage. Hua-Jun Li et al[47](2002). This paper considers the environmental loading to be a long-term non- stationary stochastic process characterized by a probabilistic power spectral density function. One engineering technique to design a TMD under a long-term random loading condition is for prolonging the fatigue life of the primary structure. Seismic structural control using semi-active tuned mass dampers. Yang Runlin et al(2002).This paper focuses on how to determine the instantaneous damping of the semi- active tuned mass damper with continuously variable damping. An off-and- towards- equilibrium (OTE) algorithm is employed to examine the control performance of the structure/SATMD system by considering damping as an assumptive control action. Two numerical simulations of a five-storey and a ten-storey shear structures with a SATMD on the roof are conducted. The effectiveness on vibration reduction of MDOF systems subjected to seismic excitations is discussed Structural vibration suppression via active/passive techniques. Devendra P. Garg et al[(2003). The advances made in the area of vibration suppression via recently developed innovative techniques (for example, constrained layer damping (CLD) treatments) applied to civilian and military structures are investigated. Developing theoretical equations that govern the vibration of smart structural systems treated with piezo-magnetic constrained layer damping (PMCLD) treatments; and developing innovative surface damping treatments using micro-cellular foams and active standoff constrained layer (ASCL) treatments. The results obtained from the above and several other vibration suppression oriented research projects being carried out under the ARO sponsorship are also included in this study. Performance of a five-storey benchmark model using an active tuned mass damper and a fuzzy controller. Bijan Samali, Mohammed Al-Dawod(2003). This paper describes the performance of a five-storey benchmark model using an active tuned mass damper (ATMD), where the control action is achieved by a Fuzzy logic controller (FLC) under earthquake excitations. The advantage of the Fuzzy controller is its inherent robustness and ability to handle any non-linear behaviour of the structure. The simulation analysis of the five-storey benchmark building for the uncontrolled building, the building with tuned mass damper (TMD), and the building with ATMD with Fuzzy and linear quadratic regulator (LQR) controllers has been reported, and comparison between Fuzzy and LQR controllers is made. In addition, the simulation analysis of the benchmark building with different values of frequency ratio, using a Fuzzy controller is conducted and the effect of mass ratio, on the five-storey benchmark model using the Fuzzy controller has been studied. Behaviour of soil-structure system with tuned mass dampers during near-source earthquakes. Nawawi Chouw(2004). In this paper the influence of a tuned mass damper on the behaviour of a frame structure during near-source ground excitations has been presented. In the investigation the effect of soil-structure interaction is considered, and the natural frequency of the tuned mass damper is varied. The ground excitations used are the ground motion at the station SCG and NRG of the 1994 Northridge earthquake. The investigation shows that the soil-structure interaction and the characteristic of the ground motions may have a strong influence on the effectiveness of the tuned mass damper. But in order to obtain a general conclusion further investigations are necessary. Wind Response Control of Building with Variable Stiffness Tuned Mass Damper Using Empirical Mode Decomposition Hilbert Transform Nadathur Varadarajan et al(2004).The effectiveness of a novel semi-active variable stiffness-tuned mass damper ~SAIVS-TMD! for the response control of a wind-excited tall benchmark building is investigated in this study. The benchmark building considered is a proposed 76-story concrete office tower in Melbourne, Australia. Across wind load data from wind tunnel tests are used in the present study. The objective of this study is to evaluate the new SAIVS-TMD system, that has the distinct advantage of continuously retuning its frequency due to real time control and is robust to changes in building stiffness and damping. The frequency tuning of the SAIVS- TMD is achieved based on empirical mode decomposition and Hilbert transform instantaneous frequency algorithm developed by the writers. It is shown that the SAIVS- TMD can reduce the structural response substantially, when compared to the uncontrolled case, and it can reduce the response further when compared to the case with TMD. Additionally, it is shown the SAIVS-TMD reduces response even when the building stiffness changes by ±15%. Effect of soil interaction on the performance of tuned mass dampers for seismic applications. A. Ghosha, B. Basu(2004).The properties of the structure used in the design of the TMD are those evaluated considering the structure to be of a fixed-base type. These properties of the structure may be significantly altered when the structure has a flexible base, i.e. when the foundation of the structure is supported on compliant soil and undergoes motion relative to the surrounding soil. In such cases, it is necessary to study the effects of soil-structure interaction (SSI) while designing the TMD for the desired vibration control of the structure. In this paper, the behaviour of flexible-base structures with attached TMD, subjected to earthquake excitations has been investigated. Modified structural properties due to SSI has been covered in this paper. Optimal design theories and applications of tuned mass dampers. Chien-Liang Lee et al(2006).An optimal design theory for structures implemented with tuned mass dampers (TMDs) is proposed in this paper. Full states of the dynamic system of multiple-degree-of- freedom (MDOF) structures, multiple TMDs (MTMDs) installed at different stories of the building, and the power spectral density (PSD) function of environmental disturbances are taken into account. The optimal design parameters of TMDs in terms of the damping coefficients and spring constants corresponding to each TMD are determined through minimizing a performance index of structural responses defined in the frequency domain. Moreover, a numerical method is also proposed for searching for the optimal design parameters of MTMDs in a systematic fashion such that the numerical solutions converge monotonically and effectively toward the exact solutions as the number of iterations increases. The feasibility of the proposed optimal design theory is verified by using a SDOF structure with a single TMD (STMD), a five-DOF structure with two TMDs, and a ten-DOF structure with a STMD. Optimum design for passive tuned mass dampers using viscoelastic materials. I Saidi, A D Mohammed et al(2007). This paper forms part of a research project which aims to develop an innovative cost effective Tune Mass Damper (TMD) using viscoelastic materials. Generally, a TMD consists of a mass, spring, and dashpot which is attached to a floor to form a two-degree of freedom system. TMDs are typically effective over a narrow frequency band and must be tuned to a particular natural frequency. The paper provides a detailed methodology for estimating the required parameters for an optimum TMD for a given floor system. The paper also describes the process for estimating the equivalent viscous damping of a damper made of viscoelastic material. Finally, a new innovative prototype viscoelastic damper is presented along with associated preliminary results. Semi-active Tuned Mass Damper for Floor Vibration Control .Mehdi Setareh et al(2007). A semi-active magneto-rheological device is used in a pendulum tuned mass damper PTMD system to control the excessive vibrations of building floors. This device is called semi-active pendulum tuned mass damper SAPTMD. Analytical and experimental studies are conducted to compare the performance of the SAPTMD with its equivalent passive counterpart. An equivalent single degree of freedom model for the SAPTMD is developed to derive the equations of motion of the coupled SAPTMD-floor system. A numerical integration technique is used to compute the floor dynamic response, and the optimal design parameters of the SAPTMD are found using an optimization algorithm. Effects of off-tuning due to the variations of the floor mass on the performance of the PTMD and SAPTMD are studied both analytically and experimentally. From this study it can be concluded that for the control laws considered here an optimum SAPTMD performs similarly to its equivalent PTMD, however, it is superior to the PTMD when the floor is subjected to off-tuning due to floor mass variations from sources other than human presence. Seismic Energy Dissipation of Inelastic Structures with Tuned Mass Dampers. K. K. F. Wong(2008).The energy transfer process of using a tuned mass damper TMD in improving the ability of inelastic structures to dissipate earthquake input energy is investigated. Inelastic structural behaviour is modelled by using the force analogy method, which is the backbone of analytically characterizing the plastic energy dissipation in the structure. The effectiveness of TMD in reducing energy responses is also studied by using plastic energy spectra for various structural yielding levels. Results show that the use of TMD enhances the ability of the structures to store larger amounts of energy inside the TMD that will be released at a later time in the form of damping energy when the response is not at a critical state, thereby increasing the damping energy dissipation while reducing the plastic energy dissipation. This reduction of plastic energy dissipation relates directly to the reduction of damage in the structure. Dynamic analysis of space structures with multiple tuned mass dampers. Y.Q. Guo, W.Q.Chen(2008). Formulations of the reverberation matrix method (RMM) are presented for the dynamic analysis of space structures with multiple tuned mass dampers (MTMD). The theory of generalized inverse matrices is then employed to obtain the frequency response of structures with and without damping, enabling a uniform treatment at any frequency, including the resonant frequency. For transient responses, the Neumann series expansion technique as suggested in RMM is found to be confined to the prediction of accurate response at an early time. The artificial damping technique is employed here to evaluate the medium and long time response of structures. The free vibration, frequency response, and transient response of structures with MTMD are investigated by the proposed method through several examples. Numerical results indicate that the use of MTMD can effectively alter the distribution of natural frequencies as well as reduce the frequency/transient responses of the structure. The high accuracy, lower computational cost, and uniformity of formulation of RMM are also highlighted in this paper. Exploring the performance of a nonlinear tuned mass damper. Nicholas A. Alexander, Frank Schilder (2009).In this the performance of a nonlinear tuned mass damper (NTMD), which is modelled as a two degree of freedom system with a cubic nonlinearity has been covered. This nonlinearity is physically derived from a geometric configuration of two pairs of springs. The springs in one pair rotate as they extend, which results in a hardening spring stiffness. The other pair provides a linear stiffness term. In this paper an extensive numerical study of periodic responses of the NTMD using the numerical continuation software AUTO has been done. Two techniques have been employed for searching the optimal design parameters; optimization of periodic solutions and parameter sweeps. In this paper the writers have discovered a family of resonance curves for vanishing linear spring stiffness Application of semi-active control strategies for seismic protection of buildings with MR dampers. Maryam Bitaraf et al(2010).Magneto-rheological (MR) dampers are semi-active devices that can be used to control the response of civil structures during seismic loads. They are capable of offering the adaptability of active devices and stability and reliability of passive devices. One of the challenges in the application of the MR dampers is to develop an effective control strategy that can fully exploit the capabilities of the MR dampers. This study proposes two semi-active control methods for seismic protection of structures using MR dampers. The first method is the Simple Adaptive Control method which is classified as a direct adaptive control method. The controller developed using this method can deal with the changes that occur in the characteristics of the structure because it can modify its parameters during the control procedure. The second controller is developed using a genetic-based fuzzy control method. In particular, a fuzzy logic controller whose rule base determined by a multi- objective genetic algorithm is designed to determine the command voltage of MR dampers. Vibration control of seismic structures using semi-active friction multiple tuned mass dampers. Chi-Chang Lin et al.(2010) There is no difference between a friction-type tuned mass damper and a dead mass added to the primary structure if static friction force inactivates the mass damper. To overcome this disadvantage, this paper proposes a novel semi-active friction-type multiple tuned mass damper (SAF-MTMD) for vibration control of seismic structures. Using variable friction mechanisms, the proposed SAF-MTMD system is able to keep all of its mass units activated in an earthquake with arbitrary intensity. A comparison with a system using passive friction-type multiple tuned mass dampers (PF-MTMDs) demonstrates that the SAF-MTMD effectively suppresses the seismic motion of a structural system, while substantially reducing the strokes of each mass unit, especially for a larger intensity earthquake. Tuned mass dampers (TMD) have been widely used for vibration control in mechanical engineering systems. In recent years, TMD theory has been adopted to reduce vibrations of tall buildings and other civil engineering structures. Dynamic absorbersand tuned mass dampers are the realizations of tuned absorbers and tuned dampers for structural vibration control applications. The inertial, resilient, and dissipative elements in such devices are: mass, spring and dashpot (or material damping) for linear applications and their rotary counterparts in rotational applications. Depending on the application, these devices are sized from a few ounces (grams) to many tons. Other configurations such as pendulum absorbers/dampers, and sloshing liquid absorbers/dampers have also been realized for vibration mitigation applications. TMD is attached to a structure in order 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. The mass is usually attached to the building via a spring-dashpot system and energy is dissipated by the dashpot as relative motion develops between the mass and the structure.

III. DESIGN AND ANALYSIS

Figure 1:Concept of tuned mass damper using two mass system

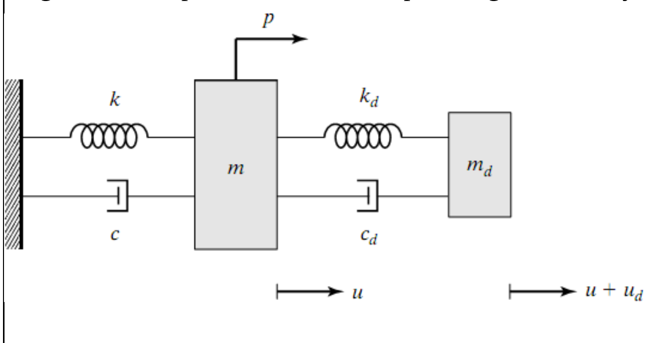


Figure 2:Tuned Mass Damper theory for SDOF systems

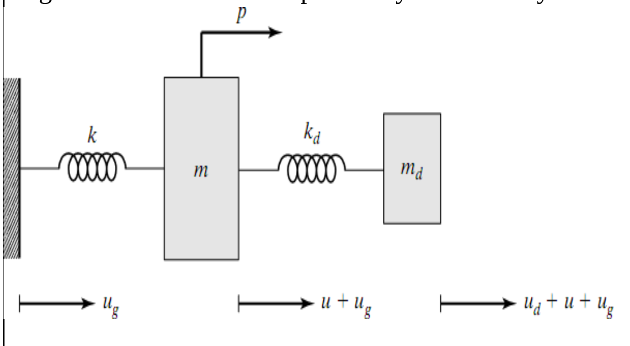
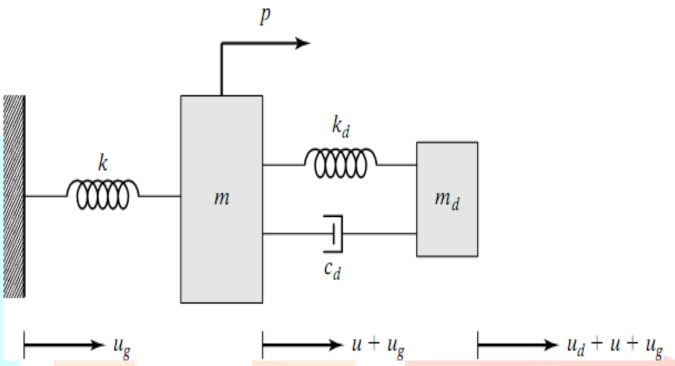


Figure 3:Undamped Structure: Damped TMD



Equation for forced vibration analysis of multistory plane frame

The equation of motion for the frame structure subjected to external dynamic force p(t):

The dynamic response of the structure to this excitation is defined by the displacement x(t), velocity $\dot{x}(t)$, and acceleration $\ddot{x}(t)$. The external force may be visualized as distributed among the three components of the structure, first is fs(t) to the stiffness components, second is fD(t) to the damping component and the third one is fI(t) to the mass component.

Thus fs+ fD+ fI= p(t)

The force fs is associated with displacement x such that

fs= kx

where k is the stiffness matrix of the structure; it is a symmetric matrix(i.e, kij = kji).

The force fD is associated with velocity $\dot{x}$ such that

fD= c$\dot{x}$

where c is the damping matrix of the structure fI is associated with acceleration $\ddot{x}$ such that

fI= m$\ddot{x}$

Substituting eqns (11), (12) and (13) in eqn(10) gives $[M]\{\ddot{X}\}+ [C]\{\dot{X}\} + [K]\{X\} = p(t)$

Where,

[M] = The global mass matrix of the 2D frame structure

[C] = The global damping matrix of the frame structure (Assumed to be a zero matrix, as damping is neglected in the structure)

[K] = The global stiffness matrix of the 2D frame structure

{X} = The global nodal displacement vector p(t) = External force

RESULTS ANALYSIS:

Time Histories of Random Ground Acceleration:

A total of two random ground acceleration cases are considered for the analysis. The first is the compatible time history as per spectra of IS-1894 (Part -1):2002 for 5% damping at rocky soil. (PGA = 1.0g). The second is the 1940 El Centro Earthquake record (PGA = 0.313g).

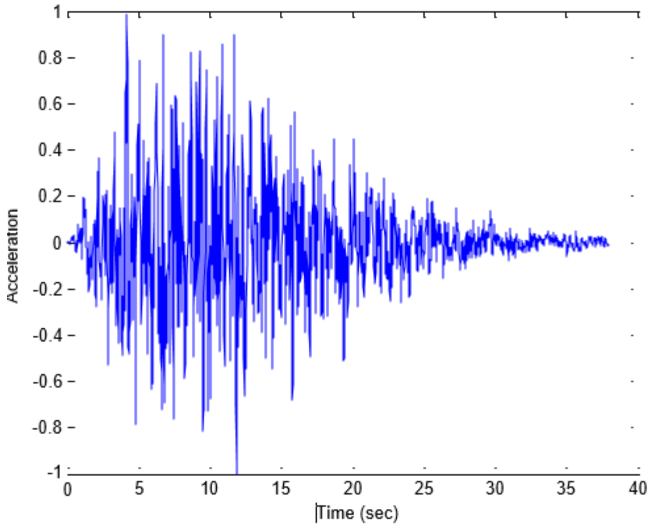


Figure 4:Compatible time history as per spectra of IS-1894 (Part -1):2002 for 5% damping atrocky soil

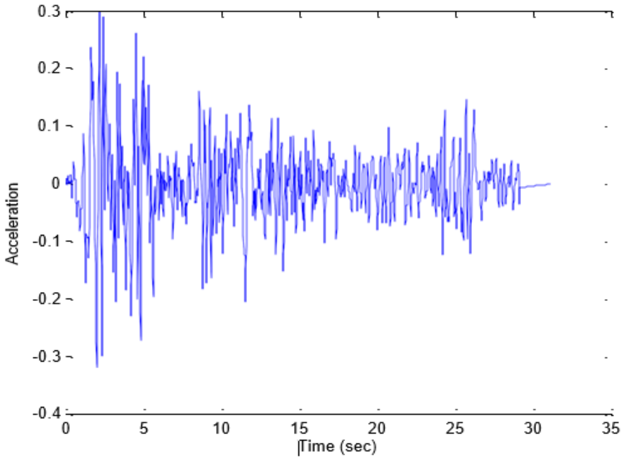


Figure 5:1940 El Centro EQ Time History

Response of shear building to Random Ground Acceleration

The above mentioned time histories are applied on the structure. The response of the structure is measured in terms of amplitude of displacement of the 100th storey.

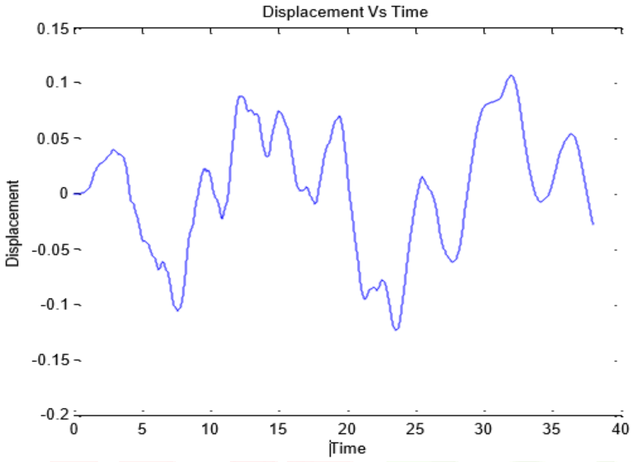


Figure 6: Response of shear building to Compatible time history as per spectra of IS-1894 (Part -1):2002 for 5% damping at rocky soil.

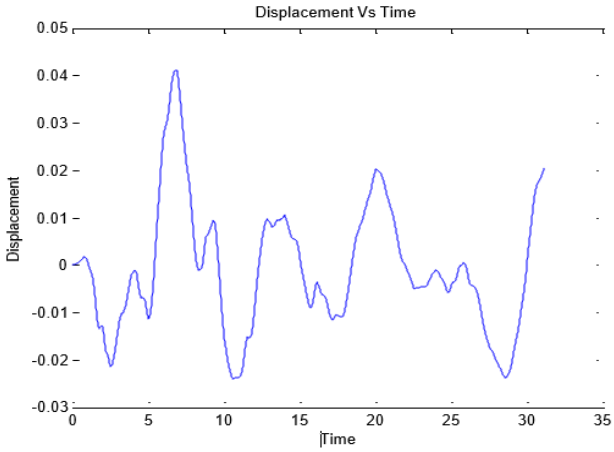


Figure 7:Response of shear building to the 1940 El Centro earthquake

Effect of TMD in structural damping when damping ratio of the structure is varied for shear building

To study the effect of TMD on reducing the response of the structure to seismic loading compatible time history as per spectra of IS 1894-2002(Part-1) and 1940 El Centro earth quakes are applied to the structure. The damping of the TMD is kept at 2% while the damping of the structure is varied from 2% to 5%.

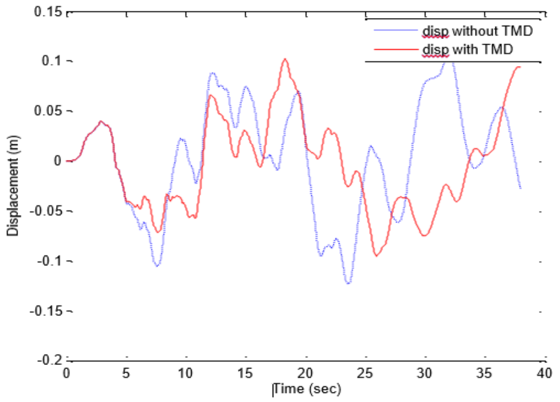


Figure 8:Response of the structure when damping ratio of the structure is 2%

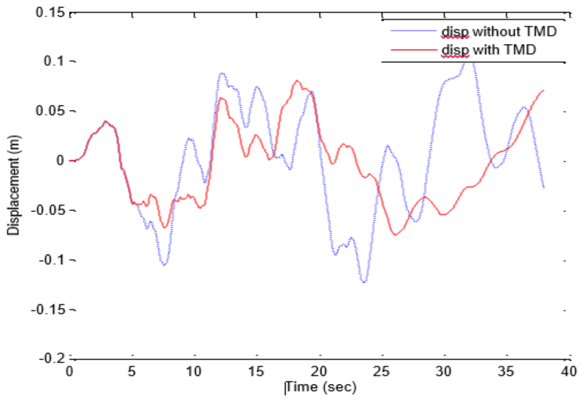


Figure 9:Response of the structure when damping ratio of the structure is 5%

Amplitude of vibration at top storey by placing TMD at top storey with variation of damping ratio of the structure when corresponding to compatible time history as per spectra of IS-1894(Part-1):2002 for 5% damping at rocky soil acting on the structure.

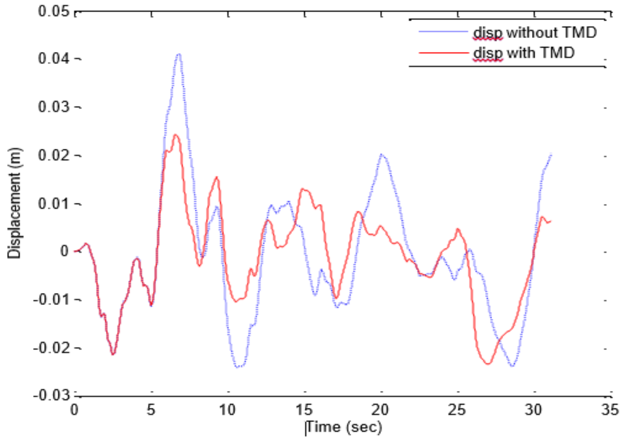


Figure 10:Response of the structure when damping ratio of the structure is 2%

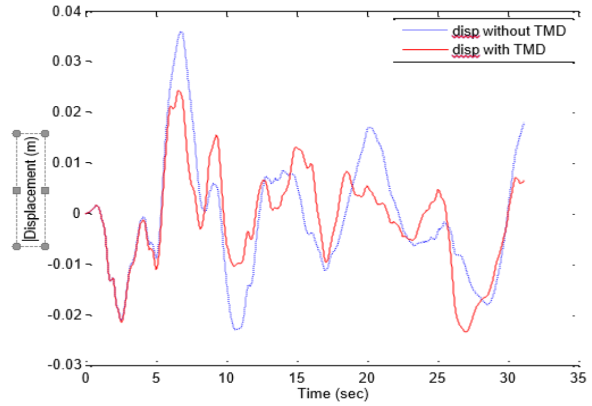


Figure 11:Response of the structure when damping ratio of the structure is 5%

Above figure shows Amplitude of vibration at top storey by placing TMD at top storey with variation of damping ratio of the structure when, El Centro (1940) earthquake loading acting on the structure. From the above figures it can be concluded that TMD is more effective in reducing the displacement responses of structures with low damping ratios (2%). But, it is less effective for structures with high damping ratios (5%).

Effect of TMD on structural damping with variation of mass ratio:

A study has been carried out to see the effect of variation of mass ratio by keeping the damping of TMD and structure constant at 2% and considering four mass ratios and two earthquake loads.

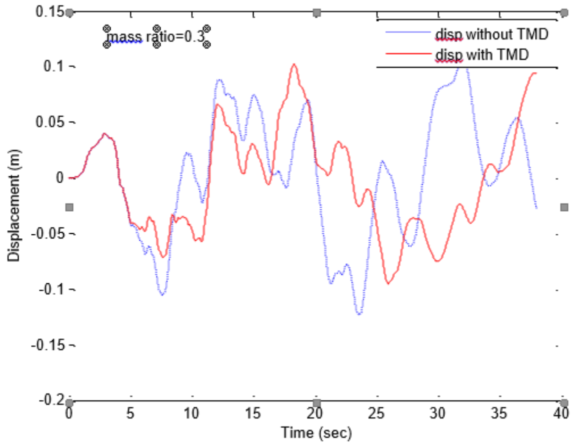


Figure 12:Response of the structure with TMD with 0.3 mass ratio

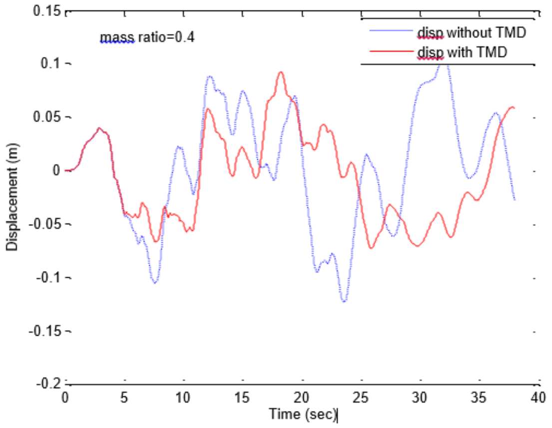


Figure 13:Response of the structure with TMD with 0.4 mass ratio

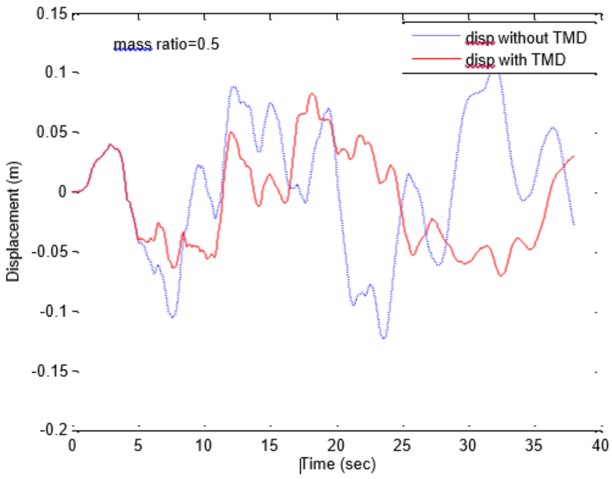


Figure 14:Response of the structure with TMD with 0.5 mass ratio

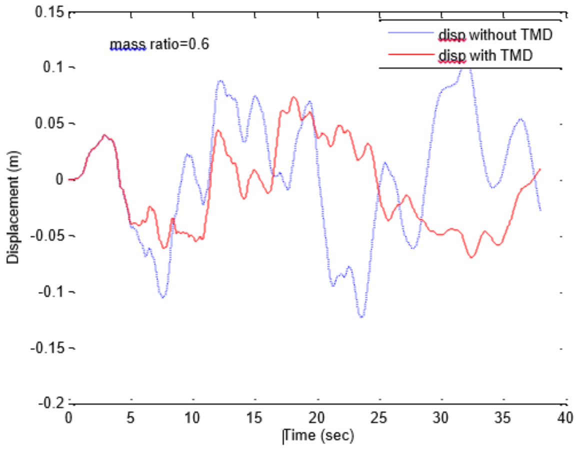


Figure 15:Response of the structure with TMD with 0.6 mass ratio

Figure shows, Amplitude of vibration at top storey by placing TMD at top storey with variation of mass ratio of the TMD when corresponding to compatible time history as per spectra of IS- 1894(Part-1):2002 for 5% damping at rocky soil acting on the structure.

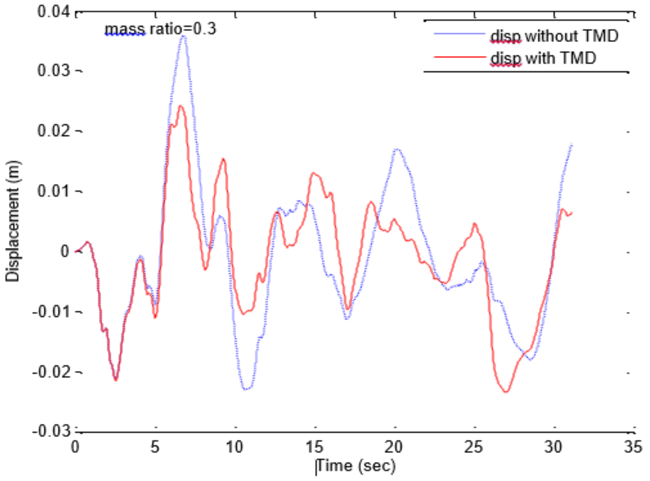


Figure 16:Response of the structure with TMD with 0.3 mass ratio

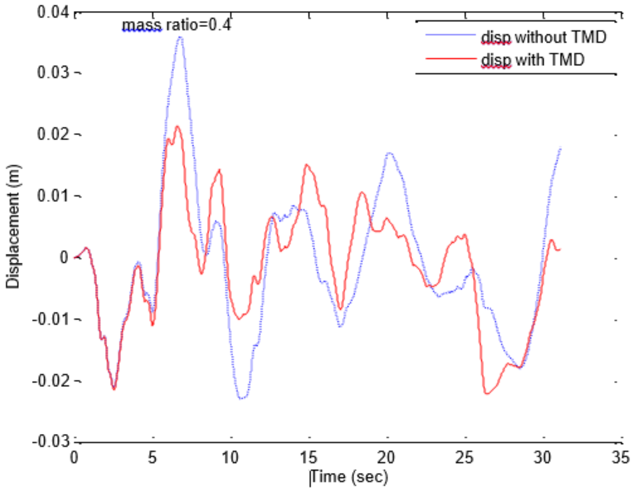


Figure 17:Response of the structure with TMD with 0.4 mass ratio

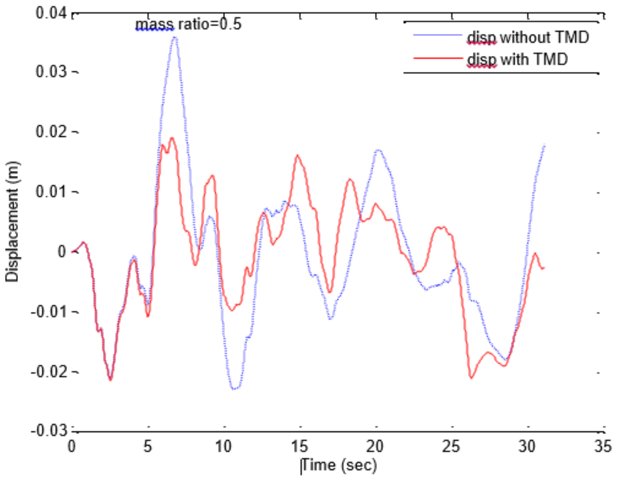


Figure 18:Response of the structure with TMD with 0.5 mass ratio

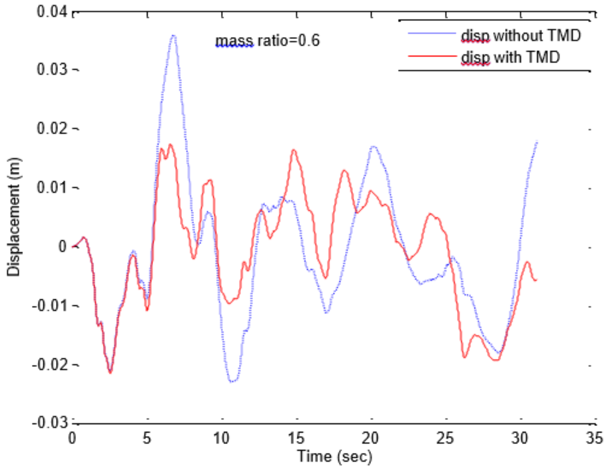


Figure 19:Response of the structure with TMD with 0.6 mass ratio

Figure Shows, Amplitude of vibration at top storey by placing TMD at top storey with the variation of the mass ratio of the TMD when, El Centro (1940) earthquake loading acting on the structure. It can be concluded from the above graphs that increasing the mass ratio of the TMD decreases the displacement response of the structure.

Two Dimensional MDOF frame model

A multistorey plane frame having storeys of height _H'and bays of length _L'is analyzed. The 2D frame model is discretized into a number of elements, we can consider infinite numbers of nodes in each element such that inc = number of intermediate nodes per each column, inb = number of intermediate nodes per beam. Three degrees of freedom i.e, two translations and one rotation are associated with each node.

The following data are taken for analysis of the above frame:

1) Type of the structure Multi-storey rigid jointed plane frame.
2) Size of columns 0.250 m × 0. 450m
3) Size of beams 0.250m× 0.400m in longitudinal direction
4) Depth of slab 0.100 mm
5) Modulus of elasticity 22360.6×106N/m^2

Preliminary Calculations:

1) MOI of Column= 0.25×0.453/12 = 1.9× 10−3 $m4$

2) MOI of Beam = 0.25×0.43/12 = 1.33× 10−3 $m4$

3) Loading on column per unit length

a)Self weight of column=0.25×0.45×25×1000 N = 2812.5 N 4)Loading on column per unit length

a)Self weight of beam=0.25×0.4×25×1000 N = 2500 N

b)Weight of slab =0.1×5×25×1000 N = 12500 N

c) Live load on slab=5×3.5×1000 N= 17500 N Total weight per metre length of beam=2500+12500+17500 N=32500 N

Free Vibration Analysis of the Multi-storey frame

Convergent study for Natural frequencies of the structure

Table 1 shows, Convergent study for Natural frequencies of the structure (No of storey = 5, No of bay = 1, Ht. of each storey = 3.5 m)

Modes	Natural frequencies in(rad/sec)				
	No of elements				
First	13.424	13.424	13.424	13.424	13.424
Second	43.513	43.511	43.510	43.510	43.510
Third	81.725	81.709	81.706	81.704	81.704
Fourth	126.600	126.545	126.532	126.527	126.525
Fifth	167.534	167.015	166.924	166.899	166.889

Variation of Natural frequencies with increase in number of storey

Table 2shows, Variation of Natural frequencies with increase in number of storey (No of Bay = 1, Height of each storey=3.5 m and Width of each Bay = 5 m) when inc=inb = 5.

Modes	Natural frequencies(rad/sec)				
	No of stores				
	1	2	3	4	5
First	86.433	39.970	25.113	18.125	14.102
Second	230.385	135.935	85.117	59.917	45.708
Third	552.9759	213.111	159.087	113.867	85.832
Fourth	592.899	257.433	207.109	171.342	132.918
Fifth	788.338	470.714	237.3117	196.733	175.321

Forced vibration analysis of the Multi-storey frame

Response of structure to Harmonic Ground Acceleration:

Forced Vibration analysis is carried out for the structure. The structure is subjected to a sinusoidal forced horizontal base acceleration given by: (t) = X0 sin(ωt)

Where, X0 and ω are the amplitude and frequency of the sinusoidal excitation respectively. The structure is discretized into 60 elements. The response of the structure at 10th storey are measured in terms of displacement, velocity, acceleration as shown in figure below;

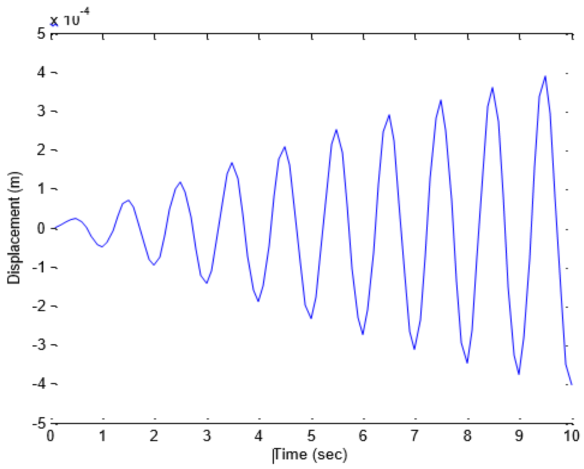


Figure 20:Displacement Vs Time

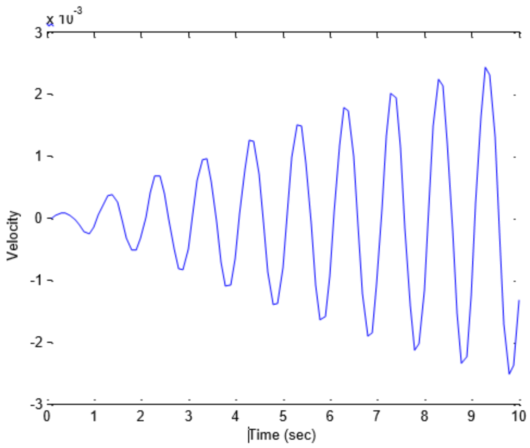


Figure 21:Velocity Vs Time

Response of the 2D frame structure to Random Ground Acceleration:

The above mentioned time histories are applied on the multi-storey frame. The response of the structure is measured in terms of amplitude of displacement of extreme right node of the 10th storey.

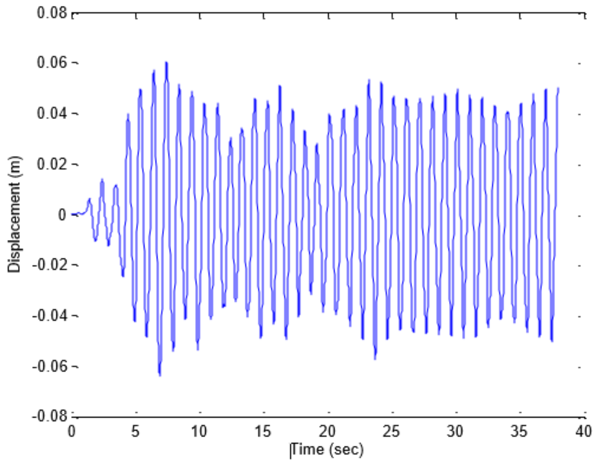


Figure 22:Response of the frame structure to Compatible time

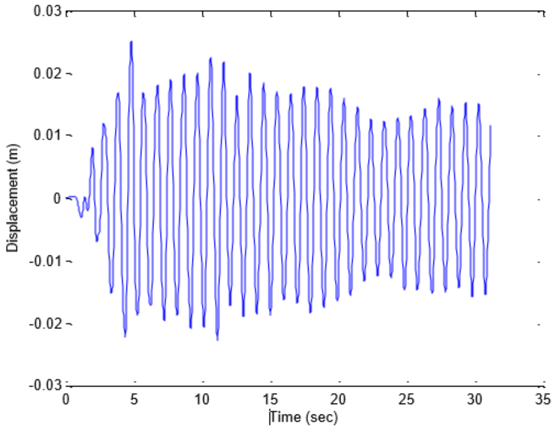


Figure 23:Response of the frame structure to 1940 El Centro earthquake

Two Dimensional MDOF frame model with TMD

The TMD is placed at the 10th storey and the 2D frame structure is subjected to both corresponding to compatible time history as per spectra of IS-1894(Part-1):2002 for 5% damping at rocky soil and 1940 El Centro earthquake load and the amplitudes of displacement is noted at the extreme right node of the 10th storey with TMD and without TMD. The TMD is having mass ratio=0.1 and tuning ratio=1

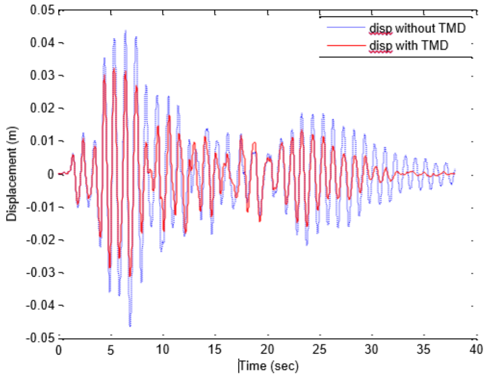


Figure 24: Amplitude of vibration at top storey of 2D frame by placing TMD at top storey when, corresponding to compatible time history as per spectra of IS-1894(Part- 1):2002 for 5% damping at rocky soil earthquake loading acting on the structure.

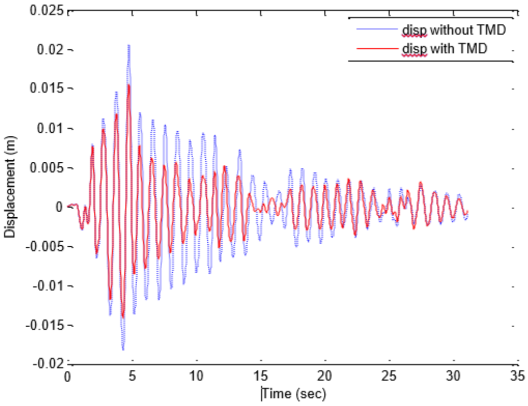
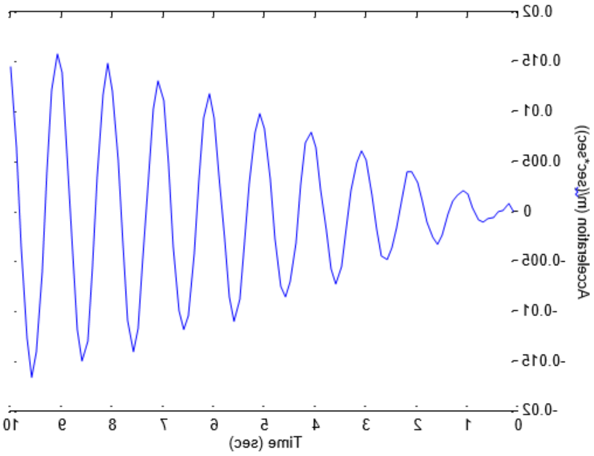


Figure 25: Amplitude of vibration at top storey of 2D frame by placing TMD at top storey when, El Centro (1940) earthquake loading acting on the structure.



Acceleration Vs Time

Figure 26:Response of 10^{th} storey of the structure to sinusoidal ground acceleration

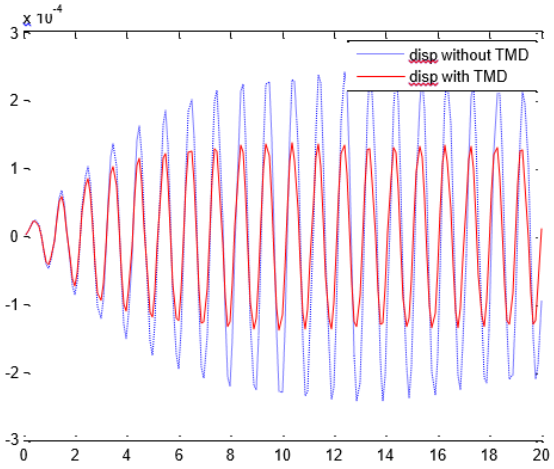


Figure 27:Amplitude of vibration at top storey of 2D frame by placing TMD at top storeywhen subjected to sinusoidal acceleration

IV. CONCLUSION AND FUTURE SCOPE

Conclusion:

Current trends in construction industry demands taller and lighter structures, which are also more flexible and having quite low damping value. This increases failure possibilities and also, problems from serviceability point of view. Several techniques are available today to minimize the vibration of the structure, out of which concept of using of TMD is one. This study is made to study the effectiveness of using TMD for controlling vibration of structure. A numerical algorithm was developed to model the multi-storey multi-degree of freedom building frame structure as shear building with a TMD. Another numerical algorithm is also developed to analyse 2D-MDOF frame structure fitted with a TMD. A total of three loading conditions are applied at the base of the structure. First one is a sinusoidal loading and the second one corresponding to compatible time history as per spectra of IS-1894(Part -1):2002 for 5% damping at rocky soil and the third one is 1940 El Centro Earthquake record (PGA = 0.313g).

Following conclusions can be made from this study:

1) It has been found that the TMD can be successfully used to control vibration of the structure.
2) TMD is more effective in reducing the displacement responses of structures with low damping ratios (2%). But, it is less effective for structures with high damping ratios (5%).
3) Applying the two earthquake loadings, first is the one corresponding to compatible time history as per spectra of IS-1894(Part -1):2002 for 5% damping at rocky soil and second being the 1940 El Centro Earthquake it has been found that increasing the mass ratio of the TMD decreases the displacement response of the structure.

Future Scope:

1) Both the structure and Damper model considered in this study are linear one; this provides a further scope to study this problem using a nonlinear model for TMD as well as for structure.
2) The frame model considered here is two-dimensional, which can be further studied to include 3-dimensional structure model.
3) Further scope, also includes studying the possibility of constructing Active TMD.
4)

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