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BY USING TUNED MASS DYNAMIC RESISTANCE OF TALL BUILDINGS

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Abstract: Tuned Mass Damper (TMD) is to be most effective for controlling the structural responses for harmonic and wind excitations. This paper reviews on the comparison of using shear wall and TMD for reducing vibration of tall buildings due to wind and earthquake loading by using SAP2000 software. Current trends in construction industry demands taller and lighter structures. These structures are flexible and constructed as light as possible (as seismic load acts on a structure is a function of self-weight), which have low value of damping makes them vulnerable to unwanted vibration. This vibration creates problem to serviceability requirement of the structure and also reduce structural integrity with possibilities of failure. Now-a-days several techniques are available to reduce wind and earthquake induced structural vibration. Shear wall is an already existing technique and commonly used. Passive tuned mass damper (TMD) is widely used to control structural vibration under wind load but its effectiveness to reduce earthquake induced vibration is an emerging technique.

Keywords- SAP2000, Dynamic load, Tuned Mass Damper, Passive control,

INTRODUCTION

In many cases this type of large displacements may not be a threat to integrity of the structure but steady state of vibration can cause considerable discomfort and even illness to the building occupant.Vibration means mechanical oscillation about an equilibrium point. Now-a-days innumerable high rise building has been constructed all over the world and the number is increasing day by day. This is not only due to concerned over high density of population in the cities, commercial zones and space saving but also to establish country land marks and to prove that their countries are up to the standards. The structural system designed to carry vertical load may not have the capacity to resist lateral load or even if it has, the design of lateral load will increase the structural cost substantially with increase in number of storey. As the seismic load acting on a structure is a function of the self-weight of the structure these structures are made comparatively light and flexible which have relatively low natural damping. Results make the structures more vibration prone under wind, earthquake loading. The oscillation may be periodic or non-periodic. Vibration control is essential for machinery, space shuttle, aeroplane, ship floating in water. With the modernisation of engineering the vibration mitigation technique has find a way to civil engineering and infrastructure field. In every field in the world conservation of energy is followed. If the energy imposed on the structure by wind and earthquake load is fully dissipated in some way the structure will vibrate less. Every structure naturally releases some energy through various mechanisms such as internal stressing, rubbing, and plastic deformation. In large modern structures, the total damping is almost 5% of the critical. So new generation high rise building is equipped with artificial damping device for vibration control through energy dissipation. The various vibration control methods include passive, active, semi-active, hybrid. Various factors that affect the selection of a particular type of vibration control device are efficiency, compactness and weight, capital cost, operating cost, maintenance requirements and safety A Tuned mass damper (TMD) is a passive damping system which utilizes a secondary mass attached to a main structure normally through spring and dashpot to reduce the dynamic response of the structure. It is widely used for vibration control in mechanical engineering systems. Now a days TMD theory has been adopted to reduce vibrations of tall buildings and other civil engineering structures. The secondary mass system is designed to have the natural frequency, which is depended on its mass and stiffness, tuned to that of the primary structure. When that particular frequency of the structure gets excited the TMD will resonate out of phase with the structural motion and reduces its response. Then, the excess energy that is built up in the structure can be transferred to a secondary mass and is dissipated by the dashpot due to relative motion between them at a later time. Mass of the secondary system varies from 1-10% of the structural mass. As a particular earthquake contains a large number of frequency content now a day's multiple tuned mass dampers (MTMD) has been used to control earthquake induced motion of high rise structure
where the more than one TMD is tuned to different unfavourable structural frequency.

The SAP name has been synonymous with state of the art analytical methods since its introduction over 30 years. SAP2000 is a stand-alone finite-element-based structural program for the analysis and design of civil structures. It offers an intuitive, yet powerful user interface with many tools to aid in the quick and accurate construction of models, along with the sophisticated analytical techniques needed to do the most complex projects. SAP2000 is object based, meaning that the models are created using members that represent the physical reality. SAP2000 has proven to be the most integrated, productive and practical general purpose structural program on the market today. Complex models can be generated and meshed with powerful built in templates. Integrated design code features can automatically generate wind, wave, bridge, and seismic loads with comprehensive automatic steel and concrete design code checks per US, Canadian and international design standards. Results for analysis and design are reported for the overall object, and not for each sub-element that makes up the object, providing information that is both easier to interpret and more consistent with the physical structure. SAP2000 is an easiest and most productive solution for our structural analysis and design needs.

Research Significance

Many scientists have conducted numerous works in related with Tuned Mass Dampers in the history. Earlier it was having mechanical applications. Later its effectiveness in the consruction field was found out and numerous experiments were conducted on it. First, experiments with single Tuned Mass Damper were done and slowly scientists identified the dominancy of Multiple Tuned Mass Dampers over single TMD. Then various and varieties of experiments were done with MTMDs to find out various characteristics and behavior of these MTMDs by constructing the building models. It was little bit difficult to construct the models of various structures. Later a Finite Element based software SAP 2000 was introduced in to the field. In the various structural models can be created very easily and various alterations also can be made easily. So the problem of constructing the model was solved and analysis of various structural models can be done by using the software SAP 2000.This paper focuses on the effective method of construction of high rise structures for resisting lateral forces and to reduce the response of these structures by using response spectrum analysis.

-To find out the vibrational charecteristics of 30 storey building with shear wall.

-To find out the vibrational characteristics of 30 storey buildings with TMDs arranged at various symmetrical locations on each floor.

-To compare the vibrational charecteristics of building with shear wall and the buildings with Tuned Mass Dampers.

-To apply the most suitable method in a 50 storey building and to analyse these structure by using Response spectrum method and also Time History Analysis of El-Centro earthquake.

REVIEW OF LITERATURE

Based on experimental studies

Many researches have been done on single as well as multiple tuned mass damper. The concept of TMD was first used by Frahm (1909) to reduce the rolling motion of ships as well as ship hull vibrations.

Den Hartog (1940) developed analytical model for vibration control capabilities of TMDs. Later he optimized TMDs parameter for harmonic excitations as well as wide band input. The main drawback of a single TMD is its sensitivity of the effectiveness to the error in the natural frequency of the structure and the damping ratio of the tuned mass damper. The effectiveness of a tuned mass damper is reduced significantly by mistuning. As a result of more than one TMD with different dynamic characteristics has been proposed to improve the effectiveness.

Clark (1988) studied the methodology for designing multiple tuned mass dampers for reducing building response. The method used was based on extending Den Hartog work from a single degree of freedom to multiple degrees of freedom system. A significant motion reduction was achieved for a structure by using simplified linear mathematical models and design technique under 1940 El Centro earthquake excitation.

Igusa and Xu (1994) examined the vibration control capability of multiple tuned mass dampers with natural frequency distributed over a certain frequency range for the structures subjected to wide band input. TMDS design was optimize by using calculus of variations with a constraint on the total mass. Results showed that the optimal designed multiple TMDs are more robust than a single TMD with equal total mass in vibration mitigation of main structure.

Kareem and Kline (1995) studied the dynamic characteristics and effectiveness of multiple mass dampers (MMDs) (a collection of several mass dampers with distributed natural frequencies) under random loading. The random loads considered were narrow- and wide-banded excitations represented by wind and seismic load. In this regard two different buildings were taken. A 31m□31m square building in plan with 93m height, having natural frequency and damping ratio equal to 0.01 Hz and 0.4, respectively, was used for seismic analysis. For wind loading a rectangular building 31m□155m in plan with height 186m was considered. Response under wind and earthquake loading was found by changing different parameters like effect of number of damper, damping, and non-uniform distribution of mass. Result showed that the MMDs configuration is more effective in controlling the motion of the primary structure. Due to smaller size of individual than a single TMD it is very easily portable and installable in old as well as retrofitted structure.

Abe and Igusa (1995) studied the effectiveness of one or more TMDs to minimize the maximum structural response with closely spaced natural frequencies by analytical method. The input load considered was a harmonic load with a possible range of frequencies.12 Perturbation theory was used with three sets of small parameters the ratio of TMD and structure modal masses, the damping of the system, and the differences between the structural and loading frequencies. Studies were carried for both lumped-mass and continuous structures (simply supported beam). It was concluded that the vibration mitigation of a structure depends upon correct placement of TMD along with the number of TMD, regardless of the spacing of the structures natural frequency.

It was concluded that the optimally designed MTMD system is more effective for vibration control than the single tuned mass damper for same mass ratio, damping of the main system does not have any influence on the optimum damping ratio of both the single TMD and the MTMD system, number of TMDs also does not have much influence on the optimum tuning frequency and the corresponding effectiveness of the MTMD system.Joshi and Jangid (1997) investigated the effectiveness of optimally designed multiple tuned mass dampers (MTMD) for reducing the dynamic response of a base excited structure in a particular mode of vibration. The base excitation was modelled as a stationary white noise random process. The parameters like damping ratio, the tuning frequency ratio and the frequency bandwidth of the MTMD system were optimised based on the minimization of the root mean square (r.m.s.) displacement of the main structure. The stationary response of the structure with MTMD was analysed for the optimum parameters of the MTMD system.

Jangid and Datta (1997) conducted a parametric study to investigate the effectiveness of MTMDs for reducing the dynamic response of a simply torsionally coupled system subjected to lateral excitation, modeled as a broad-band stationary random process. MTMDs considered for this purpose having uniformly distributed frequencies and are arranged in a row covering the width of the system. The parameters considered were the eccentricity of the main system, its uncoupled torsional to lateral frequency ratio and the damping of MTMDs. It was concluded that the effectiveness of MTMDs in controlling the lateral response of the torsionally coupled system decreases with the increase in the degree of asymmetry.

Jangid (1999) investigated the optimum parameters of Multiple Tuned Mass Dampers (MTMD) for an undamped system under harmonic base excitation using a numerical searching technique. The criteria used for the optimality was the minimization of steady-state displacement response of the main system. Curve fitting technique was used to find the formulae for the optimum parameters of MTMD (i.e. damping ratio, bandwidth and tuning frequency) which can further be used for engineering applications. The optimum parameters of the MTMD system were calculated for different mass ratios and number of dampers. From numerical study it was concluded that the optimum damping ratio of MTMD system decreases with the increase of the number of MTMD and increases with the increase of mass ratio, optimum band-width of the MTMD system increases with the increase of both the mass and number of MTMD and optimum tuning frequency increases with the increase of the number of MTMD and decreases with the increases of the mass

Li (2000) studied the robustness of multiple tuned mass dampers (MTMDs) having a uniform distribution of natural frequencies for decreasing unwanted vibration of a structure underground acceleration. The MTMD was fabricated by keeping the stiffness and damping constant and changing the mass. The structure was represented by its mode-generalized system to control a particular mode of vibration using the mode reduced-order method. The optimum parameters of the MTMD like: the frequency spacing, average damping ratio, mass ratio and total number of dampers were investigated for steel structure (whose damping ratio is 0.02) by conducting a numerical searching technique in two directions. Optimization was done by the minimization of the maximum value of the dynamic magnification factor (DMF) of the structure with MTMD. It was concluded from the study that the optimum average damping ratio of the MTMD decreases with the increase of the total number of the MTMD and increases with the increase of the mass ratio, the optimum frequency spacing of the MTMD increases with the increase of both the total number and mass ratio. It was also found that the optimum MTMD is more effective than the optimum MTMD (II) (mass constant and varying the stiffness and damping coefficient) and the optimum single TMD with equal mass.

Wu and Chen (2000) investigated the optimal placement and the seismic performance of MTMD whose frequency is tuned to different structural frequency. Optimization objective of the MTMD was to decrease the acceleration of the main structure. Numerical simulation was performed on a six-story shear building having identical floor mass of $4x10^4$ kg and the identical stiffness of $4x10^7$ N/m for each floor for four optimal location of MTMD. The 1st to 3rd mode frequencies were respectively 7.624, 22.43 and 35.93 rad/s. A damping ratio of 3% was assumed for all modes. It was concluded that the optimal MTMD showed great advantage over conventional single TMD in acceleration control as well as in efficient usage of building spare space.

Chen and Wu (2001) studied the seismic ineffectiveness of a tuned mass damper on the modal response of a six storey shear building. Later he proposed multistage and multimode tuned mass dampers and its several optimal locations for practical design and placement of the dampers in seismically excited building structures to reduce its response. The effectiveness of the proposed procedure was checked under a stochastic seismic load and 13 earthquake records for different MTMD location. Numerical results showed that the multiple dampers can effectively reduce the acceleration of the uncontrolled structure by 10–25% more than a single damper. From time-history analysis it was found that the multiple dampers weighing 3% of total structural weight can reduce the floor acceleration up to 40%.

Park and Reed (2001) numerically evaluated the performance of multiple dampers with uniformly and linearly distributed masses, under harmonic excitation. A linearly elastic single degree of freedom system with damping ratio 0.01; and the total mass ratio of the MMD system 0.01 was taken. An algorithm was developed to identify the optimum tuning of the individual dampers, which evaluate the performance by effectiveness, robustness and redundancy. It was concluded that the uniformly distributed system is effective in reducing the peak dynamic magnification factor also slightly more reliable when an individual damper fails. The linearly distributed system is also more robust under mistuning. It was also found that the 11 and 21 mass system is optimum for both configurations (uniformly and linearly distributed masses) for harmonic excitationand the El Centro earthquake simulation respectively.

Li (2002) studied and compared the performance of five number of TMD (MTMD-1 – MTMD-5) model, which comprise of various combinations of the stiffness, mass, damping coefficient and damping ratio with a uniform distribution of natural frequencies to reduce unenviable vibration of a single degree of freedom structure (having damping ratio 0.02) under the ground acceleration using a numerical searching technique. The structure was represented by its mode-generalized system in the specific vibration mode being controlled by adopting the mode reduced-order approach. The optimization was done by minimizing the maximum value of the displacement dynamic magnification factor and that of the acceleration dynamic magnification factor of the structure with the MTMD-1 – MTMD - 5. It was concluded that the optimum MTMD-1 and MTMD-4 yield approximately the same control performance, and offer higher effectiveness and robustness than the optimum MTMD-2, MTMD-3, and MTMD-5 in reducing the displacement and acceleration responses of structures. It was further found that for both the best effectiveness and robustness and the simplest manufacturing, it is preferable to select the optimum MTMD.

Li (2003) studied the performance of multiple active–passive tuned mass dampers (MAPTMD) with a uniform distribution of natural frequencies to prevent oscillations of a single degree of freedom structures under the ground

It was concluded that the optimum tuning frequency ratio of MAPTMD decreases with the increase of the mass ratio and it has better robustness and effectiveness than single APTMD which increases with the increase in mass ratio. Acceleration through numerical studies. The controlling forces in the MAPTMD are generated by keeping the identical displacement and velocity feedback gain and varying the acceleration feedback gain. To control a particular oscillation mode the structure was represented by the mode-generalized system.

Chen and Wu (2003) studied the performance of MTMD systems and compared the result with the TMD systems numerically as well as through shake table tests on a 1/4-scale three-storey building structure under the white noise excitation (the scaled 1940 El-Centro earthquake and the scaled 1952 Taft earthquake). Experimental results showed that the multiple damper systems are better than a single tuned mass damper in reducing the floor accelerations. It was also found that the numerical and experimental results are in good agreement to validate the dynamic properties of the structure.

Li and Qu (2006) studied the effectiveness of multiple tuned mass dampers (MTMD) with identical stiffness and damping coefficient but different mass to reduce translational and torsional responses for two-degree-of-freedom (2DOF) structure (which represents the dynamic characteristic of a general asymmetric structure) using numerical simulation. The 2DOF structure was a modelled as a 2DOF system of an asymmetric structure with prevalent translational and torsional responses under earthquake excitations using the mode reduced-order method. From the study it was concluded that MTMD is capable of reducing the torsional response of the torsionally flexible structures and the translational and torsional responses of the torsionally stiff structures.

Han and Li (2006) investigated the vibration control capacity of active multiple tuned mass damper (AMTMD) with identical stiffness and damping coefficient but varying mass and control force. A three storey steel structure model with three ATMDs which was subjected to several historical earthquakes implemented in SIMULINK. During numerical simulation, a stiffness uncertainty of 15% of its initial stiffness of the structure was considered. The optimization ATMD parameters were done in frequency domain by minimization of the minimum value of the maximum dynamic magnification factor for general structure. From numerical result it was concluded that AMTMD has better effectiveness than a single ATMD for structure subjected to historical earthquake and also in structure where there is a stiffness uncertainties of 15%.

Li and Ni (2007) studied a gradient-based method for optimizing non-uniformly distributed multiple tuned mass dampers (MTMD) and their effectiveness on a single degree of freedom of system. The main objective of optimization was to reduce the maximum displacement or frequency response of the main rather than the root-mean-square response. It was concluded that the effectiveness of optimal non-uniformly distributed MTMD is better than the optimal uniformly distributed MTMDs whose frequency spacing, stiffness or mass and damping sometimes has restrictions for simplicity. Due to the flexibility of the proposed method, other errors of estimate can be taken into account easily.

Han and Li (2008) estimated the performance of general linearly distributed parameter-based multiple-tuned mass dampers (LDP-MTMD) with respect to the MTMD with identical damping coefficient and damping ratio but unequal stiffness and uniform distribution of masses (UM-MTMD3) on single degree freedom system. The optimization criterion was considered to minimize the minimum values of the maximum dynamic magnification factors of structures with four LDP-MTMD models. It was concluded that it is preferable to select the optimum UM-MTMD3 or the optimum MTMD with identical stiffness and damping coefficient but unequal mass and uniform distribution of natural frequencies. It was also found that optimum tuning frequency ratios of both general LDP-MTMD and UM-MTMD3 are close to each other.

An appropriate PTMD initial velocity is applied to effectively reduce the first few local peak responses of a structure under near-fault earthquake excitation. Due to the limitation of PTMD's stroke as well as the applied force, the initial velocity cannot be too large in practical applications. It is primarily focuses on the PTMD control effectiveness for structures subjected to a transient loading, like a near-fault earthquake. It gave the PTMD's as an initial velocity is intuitive.Zuo (2009) studied the characteristics and optimization of a new type of TMD system, in which multiple TMDs are connected in series to the main structure. The parameters of spring stiffness and damping coefficients were optimized for mitigation of random and harmonic vibration. It was concluded that series multiple TMDs are more effective, robust and less sensitive to the parametric variation of the main structure than all the other types of parallel MTMDs and single TMD of the same mass ratio. It was also found that a series of two TMDs 21 of total mass ratio of 5% can appear to have 31–66% more mass than the classical TMD, and it performs better than the ten TMDs in optimal parallel of the same total mass ratio.Chi-Chang Lin *et al.*(2010) studied the applicability of passive tuned mass damper (PTMD) for reducing the dynamic responses of structures under near-fault earthquake excitations. Three types of pulse-like time functions are employed to simulate the near-fault ground motion. The vibration control effectiveness of PTMDs is extensively investigated through the comparisons of response spectrum and response time histories of a structure with and without PTMDs. PTMDs are more effective in vibration control of structures under impulse-like ground motion with more forward-and-backward cycles

The results presented that the application of Tuned Mass Dampers (TMDs) with mass ratios between 2% and 8% is an appropriate measure to mitigate the dynamic response of structures subjected to ordinary seismic ground motions. It applies both for stiff and soft structures. The seismic effectiveness of an optimally tuned TMD decreases with increasing initial structural damping of the vibrating structure. The optimal tuning of the TMD parameters under the assumption of white noise base acceleration is sufficiently accurate. The seismic performance of the TMD is robust against mistuning of the viscous element in the TMD. The accurate tuning of the TMD natural frequency is essential for its effectiveness.
Christoph Adam *et al.* (2010) Earthquake excited vibration prone structures are modeled as elastic single-degree-of-freedom oscillators and they are equipped with a single TMD. The TMD performance is assessed by means of response reduction coefficients, which are generated from the ratio of the structural response with and without TMD attached. It is found that TMDs are effective in reducing the dynamic response of seismic excited structures with light structural damping. The studies are based on a set of 40 recorded ordinary ground motions.

2.2 Based on studies using SAP

Thakur and Pachpur (2012) used TMDs as soft story which is considered to be made up of RCC, constructed at the top of the building. A six storied building with rectangular shape is considered for analysis. Analysis is done by FE software SAP 2000 by using direct integration approach. TMDs with percentage masses 2% & 3% are considered. Three different recorded time histories of past EQ. are used for the analysis. Comparison is done between the buildings with TMD and without TMD. Simple TMD with optimum frequency ratio, provided in the form of soft storey at building top is found to be effective in reducing seismic response of building.

Bandivadekar and Jangid (2012) studied different mass distributions like parabolic mass distribution and bell-shaped mass distribution and its effect on controlling the dynamic response of the system is reported. To increase the effectiveness of the MTMD system, modified parabolic mass distribution and modified bell shaped mass distribution by skewing the mass distribution is proposed. Optimum parameters for MTMD with optimum mass distribution and main system damping varied as 2% and 5% are presented. Among the various mass distributions proposed in the present study Modified bell shaped mass distribution for MTMD is superior. It was found to be more promising in terms of reducing dynamic response of structure making it more flat and increasing bandwidth of flat region. Also, lower values of damper damping associated with this mass distribution makes system more workable.

Hossein Shad and Azlan Adnan (2013) studied the simplification of using TMD for controlling vibration of structure in finite element software under a harmonic analysis. A 5 story building with TMD simulated in software in order to vibration control of structure. A Spring-mass system instead mass damper located in different level of story. Then displacement response of structure obtained from variety model compared together. From this it can be seen that increasing the mass ratio of the TMD results increment in the displacement response of the structure.

Prashant Pandey *et al.* (2015) Studied to control the vibration and drift of the seven storey concrete structure. The Behavior of the TMD subjected to five earthquake data, namely, Imperial, Loma Prieta, Northridge, Oakland, San-Fernando was studied under five conditions, numerical simulations are performed to study the structure with and without TMD installed. The building was installed in multiple TMD, single, double and triple TMD as a tuned properly it can reduce the peak response of structures subjected to seismic forces. The optimum parameters of tuned mass dampers considerable reduction in the displacement are mass ratio, damping ratio of structure, and time period of structures. The behavior of the TMD subjected to time history data in an average of reduction the displacement of single TMD is 10.91%, double TMD is 16.55%, and triple TMD is 17.28%. It control maximum displacement of building were triple TMD located. these MTMDs by constructing the building models. It was little bit difficult to construct the models of various structures. Later a Finite Element based software SAP 2000 was introduced in to the field. In the various structural models can be created very easily and various alterations also can be made easily. So the problem of constructing the model was solved and analysis of various structural models can be done by using the software SAP 2000.

METHODOLOGY

3.1 Method of study by using various models

Considering a gap in the literature, model has been created with TMD and shear wall for comparing lateral resistance capability. A 30 storey building model has been created and shear wall is provided in it to make it safe under lateral loading conditions. The various characteristics of the structure has analyzed and studied. Then the shear wall has been removed from the model and TMD has been designed and assigned based on the mass and frequency of the building. TMD is arranged symmetrically in various positions to find the behavior of the structures when these TMDs are located at various positions. A total of 7 models have been created with TMDs at various positions. Figure 1 shows the TMD arrangements for various models. The models created are as follows :

Model 1: 30 storey building with shear wall.

Model 2: 30 storey building with 4 TMDs located at four exterior corner joints of all the floors.

Model 3: 30 storey building with 4 TMDs located at interior corner joints of all the floors.

Model 4: 30 storey building with 8 TMDs located at exterior and interior corner joints of all the floors.

Model 5: 30 storey building with 8 TMDs located at joints in a plus shape of all the floors.

Model 6: 30 storey building with 12 TMDs located at all exterior joints of all the floors.

Model 7: 30 storey building with 12 TMDs located at joints in a plus shape of all the floors.

Model 8: 30 storey building with 16 TMDs located at all joints of all the floors.

The methodologies adopted in this study are as follows:

1. Modelling a 30 storeyed three dimensional moment resisting frame structure with shear wall and TMD by using SAP 2000.
2. Analysing and designing the structure by considering lateral loads.
3. Removing the shear wall from the model and designing the optimum parameters of the Tuned Mass Dampers.
4. Assign the designed TMDs on various joints symmetrically according to the number of TMDs and arrangement selected for various numbers of TMDs.
5. Analysing and designing the structures.
6. Comparing the vibrational characteristics such as Base shear, storey displacement, joint acceleration and frequency of these structures with that of structure with shear wall.
7. Assigning the most suitable method or arrangement in a fifty storey building.
8. Analysing and designing of this structure by using response spectrum analysis and time history analysis (El-centro earthquake) and to study its effectiveness in controlling the vibrations

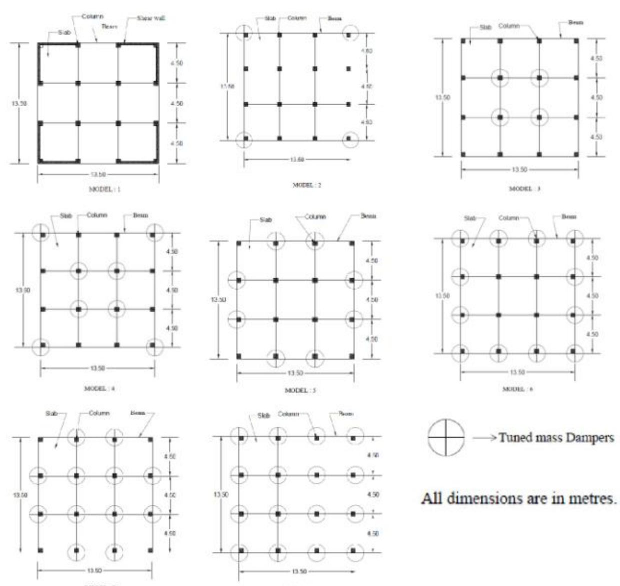

Fig 1: TMD arrangements for various models

IV. CONCLUSIONS

. Software analysis is better than experimental analysis. Software analysis is time saving , reduce human effort and it contains varieties of analysis techniques Model with shear wall and models with TMD at various locations has been created for analyzing lateral resisting force. SAP2000 could be effective in doing the analysis since it contains varieties of options and swift analysis techniques.It has been observed in all the reffered literatures that TMD's are effective in reducing vibrations. It can also be effective in reducing building vibrations Multiple Tuned Mass Dampers are more effective than single Tuned Mass Dampers

V. FUTURE STUDY

Various models have been created with TMD at various locations. These models has to be analysed in SAP2000 to get lateral resistance resistance force, model with shear wall alone has also been created and it has to be analysed both model with TMD and shear wall separately at various location has to be compared for better lateral resisting capability.

REFERENCES

[1] Jangid R. S. ,-Optimum multiple tuned mass dampers for base-excited undamped system, *Earthquake Eng. Struct. Dyn.*, Vol. 28, 1999,pp.1041–1049.

[2] Jangid R. S and Datta T. K., -Performance of multiple tuned mass dampers for torsionally coupled system, *Earthquake Eng. and Struct. Dyn.*, Vol. 26,1997,pp. 307–317.

[3] Joshi A. S and Jangid, R. S., -Optimum parameters of multiple tunedmass dampers for base-excited damped systems,*Journal of Sound and Vibration*, Vol. 202(5),1997,pp. 657–667.

[4] Kareem A and Kline S., -Performance of multiple mass dampers under random loading,*Journal of Structural Engineering*, Vol. 121(2), 1995,pp.348–361.

[5] Li C., -Performance of multiple tuned mass dampers for attenuating undesirable oscillations of structures under the ground acceleration, *Earthquake Eng. Struct. Dyn.*, Vol. 29,2000,pp. 1405–1421. Li C.,-Multiple active–passive tuned mass dampers for structures under the ground acceleration, *Earthquake Eng. Struct. Dyn.*, Vol. 32,2003,pp. 949–964.

[6] Li C and Qu W., -Optimum properties of multiple tuned mass dampers for reduction of translational and torsional response of structures subject to ground acceleration,*Engineering Structures*, Vol. 28,2006,pp. 472–494.

[7] Li H and Ni X., -Optimization of non-uniformly distributed multiple tuned mass damper,*Journal of Sound and Vibration*, Vol. 308,2007,pp. 80–97.

[8] Park J and Reed D., -Analysis of uniformly and linearly distributed mass dampers under harmonic and earthquake excitation, *Engineering Structures*, Vol. 23,2001,pp. 802–814.

[9] Thakur V.M and Pachpur P.D., -Seismic Analysis of Multistoried Building with TMD (Tuned Mass Damper) ,*International Journal of Engineering Research and Applications (IJERA),2012, ISSN: 2248-9622, pp. 319-326*

[10] Wu J. and Chen G., -Optimization of multiple tuned mass dampers for seismic response reduction, *Proceedings of the American Control Conference*,2000,pp. 0-7803-5519-523/00.

[11] Zuo L., -Effective and robust vibration control using series multiple tuned-mass dampers, *Journal of Vibration and Acoustics*, Vol. 131, 2009,pp.031003–11.

[12] Prashant Pandey, Shrinivas Raydu and Laxmikant Tibude ., - Tuned mass dampers as an energy dissipater , IJIERE , volume 2, issue 5, 2015, pp.48-57.

[13] Christoph adam and Thomas Furtmueller ., -Seismic performance of tuned mass dampers , springer, 2010, pp.11-18.

[14] N.Handayani, D.Kusumastuti and Rildova ., -An experimental study on MTMD to improve structural performance under dynamic loading, The 14th world conference on Earthquake Engineering October 12-17, 2008, Beijing, China.

[15] Chi-Chang Lin, Chi-Lun Chen and Jer-Fu Wang ., - vibration control of structures with initially accelerated passive tuned mass dampers under near-fault earthquake excitation,computer-aided civil and infrastructure engineering 25,2010,pp.69-75

[16] Abe M and Igusa T., -Tuned mass dampers for structures with closely spaced natural frequencies ,*Earthquake Eng. and Struct. Dyn.*, 1995, Vol. 24,pp. 247–261.

[17] Bandivadekar T.P and Jangid R.S. ,- Mass distribution of multiple tuned mass dampers for vibration control of structures . *International Journal of Civil and Structural Engineering* , 2012, Volume 3 ISSN :0976-4399.

[18] Chen G. and Wu J. ,-Experimental study on multiple tuned mass dampers to reduce seismic responses of a three-storey building structure ,*Earthquake Eng. Struct. Dyn.*,2003, Vol. 32,pp. 793–810.

[19] Chen G and Wu J , -Optimal placement of multiple tune mass dampers for seismic structures , *Journal of Structural Engineering*,2001, *ASCE,* Vol. 127(9), pp.1054–1062.

[20] Clark A. J. ,- Multiple passive TMDs for reducing earthquake induced building motion ,*Proceedings of ninth world conference on Earthquake Engineering Tokyo Kyoto Japan*, 1988,Vol. 5.

[21] Han B and Li C. , -Characteristics of linearly distributed parameter-based multiple-tuned mass dampers , *Struct. Control Health Monit.*,2008, Vol. 15,pp. 839–856.

[22] Han B., and Li C. , -Seismic response of controlled structures with active multiple tuned mass damper , *Earthquake Engineering and Engineering vibration*,2006, Vol. 5(2), pp.205–213.

[23] Hossein Shad and Azlan Adnan. , - An investigation on the effectiveness of Tuned Mass Damper (TMD) in suppressing the displacement response of a 5 - storey building under harmonic load .*4th International Graduate Conference on Engineering , Science and Humanities – UTM- 16-17 ,2013, Paper 121.*

[24] Igusa T and Xu K , -Vibration control using multiple tuned mass dampers, ‘ *Journal of Sound and* Vibration, 175(4),1994,pp. 491–503.