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Paper Authors **K. SANDEEP KUMAR1, P.Neeharika2**

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Design of High Raised Building for Vertical and HorizontalLoading With and Without Dampers

K. SANDEEP KUMAR[1], P.Neeharika[2]

1. Assistant Professor, Dept of Civil Engineering, University College of Engineering & Technology, A.N.U, Guntur, AP
2. Assistant Professor, Dept of Civil Engineering, University College of Engineering & Technology, A.N.U, Guntur, AP

Abstract: *The current trend toward buildings of ever increasing heights and the use of lightweight, high strength materials, and advanced construction techniques have led to increasingly flexible and lightly damped structures. Understandably, these structures are very sensitive to environmental excitations such as wind, ocean waves and earthquakes. In this study a Tuned mass damper proposed as energy dissipation devices for buildings subjected to earthquake loads. The springs of the Tuned mass damper are placed between the structure and the mass of the damper to eliminate or minimize the damage due to earthquake loads. To reduce the response of displacement, The Tuned mass damper are introduced as energy dissipation devices. The Tuned mass damper (with spring and dashpot) is sufficiently flexible to reduce the response of acceleration. The response of displacement due to provided flexibility is effectively controlled by the addition of energy dissipation devices, In this study the Response Spectrum Analysis are used. SAP 2000 is an extremely versatile and powerful program with many features and functions. This manual does not attempt to fully document all of those features and functions. Rather, we briefly show how to work with the program, providing some commentary along the way. A TMD system using spring units and visco-elastic dampers can reduce vibration in a building, and it is become more safety during the earthquakes. For applying this system in India, it is necessary to confirm the seismic safety. At first static loading tests of the spring units and dynamic loading tests of a visco-elastic damper were carried out. The analytical models created by SAP 2000 program with and without Tuned mass damper (TMD) to study the behavior of the building and the responses of it after subjected to earthquake load. The dampers in these models are installed on the top storey of the buildings, and the models created as regular and symmetrical models with 15 storey (45m) ,25 storey (75m) and 35 storey (105m).*

Keywords: Tuned Mass Damper, Time History, Response Spectrum Method.

I. INTRODUCTION

Earthquakes are the most unpredictable and devastating of all natural disasters, which are very difficult to save over engineering properties and life, against it. Hence in order to overcome these issues we need to identify the seismic performance of the built environment through the development of various analytical procedures, which ensure the structures to withstand during frequent minor earthquakes and produce enough caution whenever subjected to major earthquake events. So that can save as many lives as possible. There are several guidelines all over the world which has been repeatedly updating on this topic. The analysis procedure quantifying the earthquake forces and its demand depending on the importance and cost, the method of analyzing the structure varies from linear to nonlinear. The behavior of a building during an earthquake depends on several factors, stiffness, and adequate lateral strength, and ductility, simple and regular configurations. The buildings with regular geometry and uniformly distributed mass and stiffness in plan as well as in elevation suffer much less damage compared to irregular configurations. But nowadays need and demand of the latest generation and growing population has made the architects or engineers inevitable towards planning of irregular configurations. Hence earthquake engineering has become an important branch of civil engineering. 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 increase the 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. 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 absorbers and tuned mass dampers are the realizations of tuned absorbers and tuned dampers forstructural 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.

A. Seismic Control

All vibrating structures dissipate energy due to internal stressing, rubbing, cracking, plastic deformations, and so on; the larger the energy dissipation capacity the smaller the amplitudes of vibration. Some structures have very low damping of the order of 1% of critical damping and consequently experience large amplitudes of vibration even for moderately strong earthquakes. Methods of increasing the energy dissipation capacity are very effective in reducing the amplitudes of vibration. Many different methods of increasing damping have been utilized and many others have been proposed.

B. Need

In the Current Scenario of the world the Science and the Art of design is emerging rapidly for the development of high rise building. In developing countries like India, demand of high rise buildings is increasing day by day due to growing population and lack of land in urban areas. So, now the interesting part is for the Structural engineer’s that the design of high rise building includes a lot of parameters involve in it. From structural engineer’s point of view, high rise multi-storied building is the one that by virtue of its height is affected by lateral forces to an extent that they play an important role in the structural design. In this type of buildings, wind and seismic loads play a predominant role. Hence the lateral stability is most important for high rise building.

C. Objectives of the Study

The present work aims at the following objectives:

- Study of Seismic demands of regular R.C buildings using the static analysis.
- To illustrate the effects of Tuned mass damper, on the response of the High-rise Symmetric Buildings.
- To study various responses such as Base shear, Shear force, Bending moment, inter storey drift, storey shear, etc. of buildings.

D. Scope of the Study

The present work aims at an objective demonstrating the effect of Tuned mass damper techniques for symmetric high rise structures. The building studied in this section is 15, 25&35-storey Reinforced concrete Special Moment Resisting Space Frames Designed for Gravity and Seismic Loads Using Linear Analysis. The structure is evaluated in accordance with seismic code IS-1893:2002 under seismic zone v analysis with the help of the SAP2000 version 18 software (CSI Ltd) analysis engine.

II. DEVELOPMENT OF THE TUNED MASS DAMPER

A tuned mass damper (TMD) is adevice consisting of a mass, a spring, and a damper that 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. Energy is dissipated by the damper inertia force acting on the structure. Frahm (1909) first invented the basic form of tuned mass dampers which itself did not have any damping property. So the system was effective only when its natural frequency matched with that of the excitation force. Ormondroyd and Den Hartog (1928) introduced internal damping in TMD. Optimum choices of damper parameters were not considereduntil DenHartog (1947) proposed closed form expressions of frequency ratio and damping ratio of the TMD for an undamped single degree of freedom (SDOF) system. Later damping in the main system was included through several researches performed by Bishop and Welboum (1952), Snowdon (1959), Falcon et al. (1967), Ioi and Ikeda (1978). With time a number of studies were made by Warburton and Ayorinde (1980), Thompson (1981), Warburton (1982), Villaverde et al. (1985, 1993 and 1995), Sadek et al. (1997) to obtain optimum TMD parameters in different conditions. Rana and Soong (1998) simplified the design of TMD to control a single mode of a MDOF system. In addition they also inspected the prospect of controlling multiple structural modes with multi-tuned mass dampers (MTMD).

Afterward some more studies were made on determining optimal parameters of MTMDs to reduce dynamic response of structural system, by Yau and Yang (2004), Lee et al. (2006), Li and Qu (2006) and Carotti and Turci (1999). Chang (1999) studied and compared the performance of TMD, tuned liquid column damper (TLCD) and liquid column vibration absorber (LCVA). He also established generalized building mass damper equations by considering the building as SDOF system and derived some optimum design formulas in closed forms for both wind and earthquake. Lin et al. (2001) applied an extended random decrement method to reduce dynamic responses of a MDOF system subjected to seismic load. Lee et al. (2006) proposed an optimal design theory for buildings associated with TMDs at different story level and power spectral density (PSD) function of environmental disturbances. Optimal design parameters were expressed in terms of damping coefficients and spring constants through minimization of structural responses. Anumerical algorithm was also developed to search optimal design parameters of MTMDs. Bakre and Jangid (2007) developed explicit mathematical expressions for optimum TMD parameters using numerical searching technique. Rudinger (2007) included nonlinear viscous dampingelements to TMD and analyzed the effect. Unlike previous studies related to TMD optimization where TMD mass ratio was a preselected parameter, Marano et al. (2010) optimized TMD mass ratio along with other parameters.

Metaheuristic methods like genetic algorithm (GA), particle swarm, ant algorithm, simulated annealing, big bang big crunch and harmony search (HS) were applied to solve different optimization problems. A wide application of genetic algorithm for tuning of TMDs was made in studies of Hadi and Arfiadi (1998), Singh et al.(2002), Desu et al. (2006), Pourzeynali et al. (2007). Leung et al. used particle swarm optimization technique of tuned mass dampers. Gebrail and Sinan (2011) used harmony search to obtain optimum TMD parameters. They considered maximum acceleration transfer function and first story displacement as optimization criterion under harmonic loading. A global optimization algorithm named EVOP (Evolutionary Operation) was used by Ahsan et al. (2011) to optimize the design of simply supported, post-tensioned, prestressed concrete I-girder bridge. This optimization tool was found to be capable of locating global minimum directly with high probability and without any requirement of information related to gradient or sub-gradient of objective function. Also computational time needed for optimization was less which is really advantageous. Wu et al. (1999) investigated the effectiveness of Tuned Mass Damper under seismic excitation considering Soil-Structure Interaction for structure with flexible base and concluded on the fact that strong soil-structure interaction extensively reduces effectiveness of TMD in minimizing maximum structural response of structures.

It is very important to search for the optimum parameters to control the dynamic response due to first mode of structural system effectively using Tuned Mass Damper (TMD). In case of controlling multi modal dynamic response of a system under seismic excitation Multiple Tuned Mass Damper (MTMD) can be a solution. Considering this fact the prospect of applying Multiple Tuned Mass Damper (MTMD) technique for controlling structures associated with soft-story which have vertical stiffness irregularity can be studied. Again soil-structure interaction plays an influential role in defining structural response. Hence it is desirable to include this effect into structural system while searching for the most effective optimum parameters of Tuned Mass Damper to control vibration. In present study soil-structure interaction will be taken into account to obtain behavior of structural system associated with tuned mass dampers and a global optimization algorithm Evolutionary Operation (EVOP) (Ghani, 1989) will be used for optimization to explore the tool in the study of dynamic control.

III. BUILDING WITH TUNED MASS DAMPER

A. Citicrop Centre, New York

The first full-scale structural tuned mass damper was installed in the Citicorp Centre building in New York City. The height of the building is 279 m with fundamental period of around 6.5 s and damping ratio of 1% along both axes. It was finished in 1977 with a TMD placed on the sixty third floor in its crown having weight of 400 ton structure. That time the mass of the TMD was 250 times larger than any existing TMD. The damping of the overall building was increased from 1% to 4% of critical with a mass ratio of the TMD 2% of the first modal mass. Results in reduction of sway amplitude by a factor of 2. The TMD system consists of a large block of concrete bearing on a thin film of oil, with pneumatic spring which provides the structural stiffness.

Fig.1.

B. Act Tower, India

The ATC is one of the tallest structures in Delhi at 101.9 meters and is reported to have cost more than ` 350 crore. The tower have a 50-tonne tuned mass damper to prevent extra sway during critical winds and ensure structural stability. Such equipment has not been installed at any airport in the country before. The damper will move in the opposite direction to which the building is moving, thereby producing a counter-balancing and stabilizing force," said an airport official. The tower has also been designed to survive zone-5 seismic forces.

Fig.2.

IV. PRINCIPLE OF (TUNED MASS DAMPER)

With recent development in computer-based structural design and high-strength materials, structures are becoming more flexible and lightly damped. When subjected to dynamic loads such as traffic load, wind, earthquake, wave, vibration lasting for long duration may be easily induced in this type of structures. To increase comfort of working people, function of installed machineries and equipments, and reliability of structures, damping capacity of structures in the elastic region should be increased. If we have a fixed reaction wall adjacent to the top of a structure as shown in Fig.3 viscous or frictional damper can be installed effectively to increase damping capacity of the structure. However, this is usually impossible because flexible structures are very tall and no fixed point is available. TMD is a vibration system with mass m_T, spring $K_T$and viscous $C_T$usually installed on the top of structures as shown in Fig.4. When the structure starts to vibrate, TMD is excited by the movement of the structure. Hence, kinetic energy of the structure goes into TMD system to be absorbed by the viscous damper of TMD. To achieve the most efficient energy absorbing capacity of TMD, natural period of TMD by itself is tuned with the natural period of the structure by itself, from which the system is called "Tuned Mass Damper". The viscous damper of TMD shall also be adjusted to the optimum value to maximize the absorbed energy. TMD is a mechanically simple system which does not need any external energy supply for operation. Because of easy maintenance and high reliability, TMD is used in many flexible and lightly-damped towers, buildings and so on in Japan.

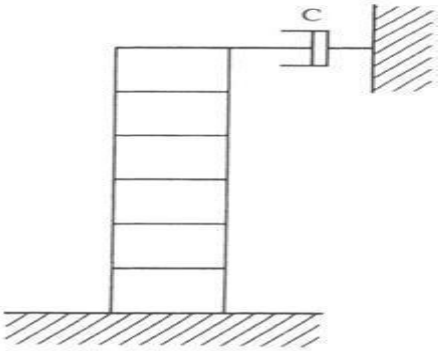

Fig. 3.Viscous damper with fixed reaction wall.

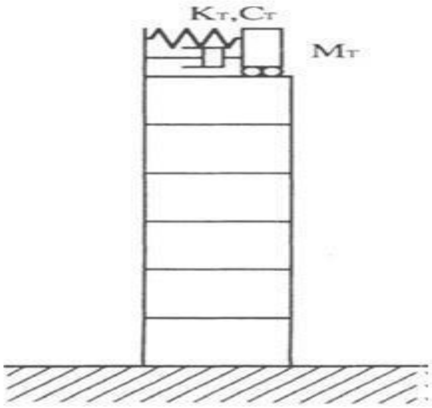

Fig. 4. Tuned mass damper on a structure.

V. DETERMINATION OF THE OPTIMUM TMD

One TMD is effective in reducing dynamic response of only a single vibration mode of the structure. Although a structure has many vibration modes in reality, basic properties of TMD can be clearly discussed using a simplified 2-DOF model consisting of the main structure and the TMD system (Fig. 5).

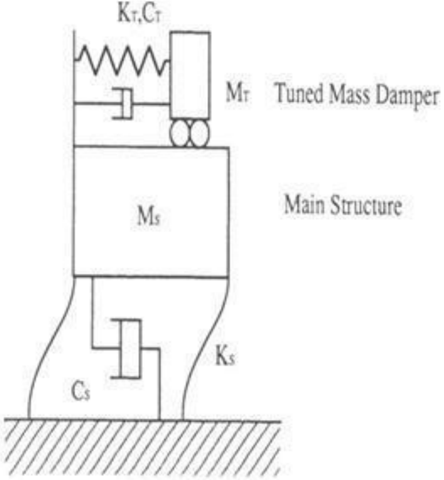

Fig. 5. 2-DOF modeling of main structure and tuned mass damper system.

Let us define the following parameters to be used in the following discussion.

Natural Frequency of TMD $\omega_T = \sqrt{\frac{K_T}{m_T}}$

Damping Ratio of TMD $\xi_T = \frac{C_T}{2m_T\omega_T}$

Natural Frequency of Main Structure $\omega_S = \sqrt{\frac{K_S}{m_S}}$

Damping Ratio of Main Structure

$\xi_S = \frac{C_S}{2m_S\omega_S}$

Mass Ratio $\mu = \frac{m_T}{m_S}$

Frequency (Tuning) Ratio$\gamma = \frac{\omega_T}{\omega_S}$

When $\xi_T = 0$, a 2-DOF system shows 2 uncoupled vibration modes and, when $\xi_T = \infty$ the 2-DOF system becomes a 1-DOF vibration system. Steady-state dynamic response subjected to harmonic excitation can be obtained analytically. It is usually called the resonant curve or dynamic magnification factor (DMF) curve plotted against angular frequency of the harmonic excitation. It is interesting to notice that DMF curves cross two fixed points independent of the damping ratioξ_T. Den Hartog defined the optimum TMD by letting the two fixed points the same value and as high as possible in the DMF curve. The physical meaning of this is to obtain flat DMF curve at the resonant frequency, and consequently to suppress the dynamic response of the main structure most effectively. From this definition, the optimum frequency ratio$\gamma_{opt}$and the optimum damping ratioξ_{Topt} of TMD are obtained by Den Hartog as function of mass ratio μ, i.e.

$$\gamma_{opt} = \frac{1}{1+\mu} \tag{1}$$

$$\xi_{Topt} = \frac{1}{2}\sqrt{\frac{3\mu/2}{1+3\mu}} \tag{2}$$

$$\Delta\xi_{eq} = \frac{1}{2}\sqrt{\frac{\mu/2}{1+\mu/2}} \tag{3}$$

VI. RESPONSE SPECTRUM METHODOF ANALYSIS

Development of the response spectrum method of analysis is first presented for singlepointexcitation, and then its extension to multi-point excitations is briefly described. The equivalent lateral load analysis as specified in earthquake codes is presented and codalprovisions regarding the base shear coefficient and response spectrums of a few codes are given for acomparative time study.

A. Concept of Equivalent Lateral Force and Response Spectrum Method of Analysis

The equivalent lateral force for an earthquake is a unique concept used in earthquake engineering. The concept is attractive because it converts a dynamic analysis into partly dynamic and partly static analyses for finding the maximum displacement (or stresses) induced in the structure due to earthquake excitation. For seismic resistant design of structures, these maximum stresses are of interest only, not the time history of stresses. The equivalent lateral force for an earthquake is defined as a set of lateral static forces which will produce the same peak response of the structure as that obtained by the dynamic analysis of the structure under the same earthquake. This equivalence is restricted only to a single mode of vibration of the structure, that is, there a set of lateral force exist for each mode of vibration. The equivalent (static) lateral force for an earthquake is obtained by carrying out a modal analysis of structures, and then a static analysis of the structure with equivalent (static) lateral force in each mode of vibration is performed to obtain the desired responses. The entire procedure is known as the response spectrum method of analysis and is developed using the following steps.

- A modal analysis of the structure is carried out to obtain the mode shapes, frequencies, and mode participation factors for the structure.
- An equivalent static load is derived to get the same response as the maximum response obtained in each mode vibration, using the acceleration response spectrum of the earthquake.
- The maximum modal responses are combined to find the total maximum response of the structure.

There are no approximations involved in the first two steps. Only the third one involves approximations. As a result, the response spectrum method of analysis is called an approximate method of analysis. The approximation introduces some errors into the computed response. The magnitude of the error depends upon the problem (both the type of structure and the nature of earthquake excitation). However, seismic response analysis of a number of structures have shown that for most practical problems, the response spectrum method of analysis estimates reasonably good responses for use in design. The method is primarily developed for single-point excitation with a single-component earthquake. However, the method could be extended to multi-point – multi-component earthquake excitations with certain additional assumptions. Furthermore, response spectrum method of analysis is derived for classically damped structures. Therefore, its application to non-classically damped structural systems is not strictly valid. However, with some other simplifying assumptions, the method has been used for no classically damped systems.

B. Modal Combination Rules

The maximum responses obtained in each mode of vibration are generally combined using three different types of modal combination rules, namely: (i) ABSSUM, (ii) SRSS, and (iii) CQC.

ABSSUM: ABSSUM stands for absolute sum of maximum values of response. Thus, if x is the response quantity of interest then

$$x = \sum_{i=1}^{m} |x_i|\, max \tag{4}$$

in which $|x_i|$ max is the absolute maximum value of response in the ith mode of vibration. The combination rule gives an upper bound to the computed value of the total response for two reasons: (i) it assumes that the modal peak responses occur at the same time; and (ii) it ignores the algebraic sign of the response. The actual time history analysis shows that the peak responses (considering both negative and positive peaks) occur at different times in different modes. Also, the total peak response occurs at a time different to those of the modal peaks, Thus, the combination rule provides a conservative estimate of the total peak response, and therefore it is not very commonly used in the seismic design of structures.

SRSS: In SRSS, square root of sum of squares, the response x is given by:

$$x = \sqrt{\sum_{i=1}^{m} x_{imax}^2} \tag{5}$$

The modal peak responses are squared, summed up, and then the square root of the sum is taken to obtain the total peak response. This combination rule generally provides a good estimate of the total peak response for structures with well separated natural frequencies. When the natural frequencies are not very well separated, the error in estimation of the total peak response becomes considerable. The underlying meaning of Equation 3.53 is that the modal peak responses are assumed to be independent random variables. However, there is always some degree of correlation between the modal responses, which maybe very small, and hence can be ignored when the natural frequencies are well separated.

CQC: The CQC, complete quadratic combination rule, is a generalization of the SRSS rule and is applicable for a wider class of structures. It is specifically used for structures having closely spaced frequencies. The response x is given by:

$$x = \sqrt{\sum_{i=1}^{m} x_i^2 + \sum_{i=1}^{m}\sum_{j=1}^{m}\rho_{ij}x_i x_j} \qquad \textbf{(6)}$$

The second term in the above expression is valid for $i \neq j$. Thus, the second term includes the effect of correlation between modal peak responses through the correlation coefficient terms ρ_{ij}. It is obvious that $0 \leq \rho_{ij} \leq 1$. If x_i and x_j are of opposite sign, then $\rho_{ij}x_i x_j$ becomes negative. Therefore, CQC may provide less response than that provided by SRSS. Different expressions for the correlation coefficient ρ_{ij} have been proposed in the literature. Here, two widely used expressions are given for the case when all modal dampings are assumed to be the same (that is $\xi_i = \xi_j = \xi$). The first one was proposed by Rosenblueth and Elordy and is given as:

$$\rho_{ij} = \frac{\xi^2(1+\beta_{ij})^2}{(1-\beta_{ij})^2+4\xi^2\beta_{ij}} \qquad \textbf{(7)}$$

VII. MODELING

In this study we take 3 models 15 storey, 25 storey and 35 storey RC buildings with 5 bays in X and Y direction and each bay with 5m in the horizontal directions, also these models with uniform height of story 3 m in vertical direction .The beams, columns, slabs and other specification of the frame building same for the three models as the following Figs.6 to 8:

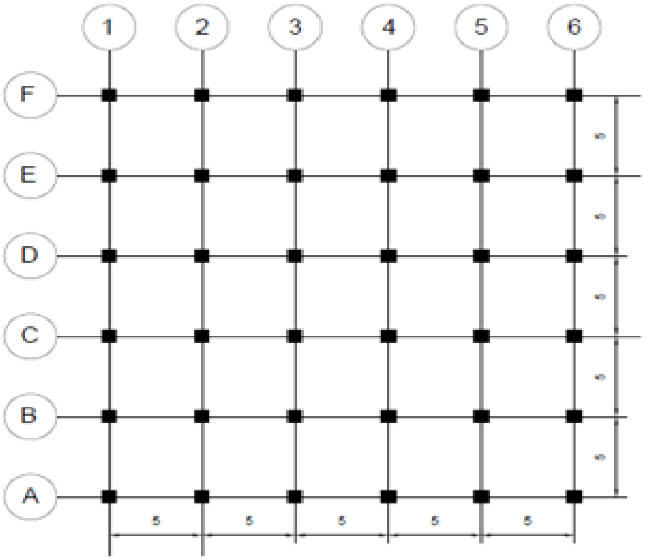

Fig.6. Plane of the models.

Variable	DATA
Types of building	Moment resistant frame
Number of storey	15, 25 and 35
Floor height	3m
Live load	3 KN/m^2
Dead load	Finishing load 1 KN/m^2 and wall load 12 KN/m^2
Materials	Concrete (M30) and Reinforced with HYSD bars (Fe415)
Size of column	600×600mm,800x800mm,850x850mm and 950x950mm
Size of beams	450×450 mm
Depth of slab	150 mm
Density of concrete	2500 Kg/m^3
Density of brick wall	2000 Kg/m^3
Seismic zone	V
Importance factor	1.5
Reduction factor	5
Soil type	1 or A

Fig.7. 25 storey 3D Model.

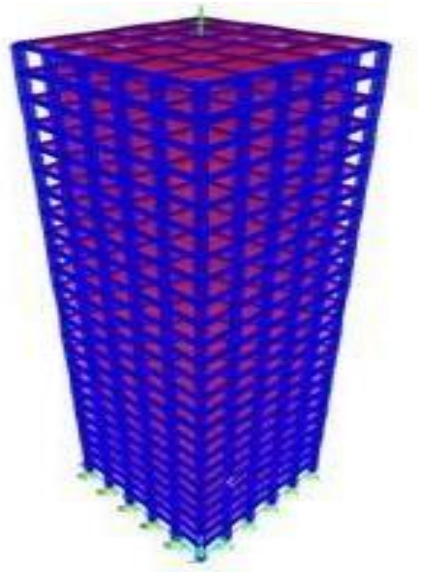

Fig.8. 25 storey 3D MODEL with TMD.

VIII. RESULTS

Results of this paper is as shown in bellow Figs.9 to 21.

A. Time Periods

TABLE II:

MODAL Periods without TMD			
MODE	15 STOREY	25 STOREY	35 STOREY
1	1.68413	2.855722	3.859249
2	1.68413	2.855722	3.859249
3	1.498129	2.476266	3.260167
4	0.547344	0.918478	1.343495
5	0.547344	0.918478	1.343495
6	0.488895	0.803322	1.163928
7	0.311837	0.514076	0.760524
8	0.311837	0.514076	0.760524
9	0.281666	0.458148	0.674428
10	0.211046	0.342075	0.528714
11	0.211046	0.342075	0.528714
12	0.191178	0.307012	0.472812

TABLE III:

MODAL Periods with TMD			
MODE	15 STOREY	25 STOREY	35 STOREY
1	1.689738	2.86562	3.874196
2	1.689724	2.8656	3.874167
3	1.498606	2.477053	3.261345
4	0.55047	0.923905	1.351092
5	0.550457	0.923887	1.351073
6	0.489232	0.803894	1.164673
7	0.402351	0.664722	0.911748
8	0.40226	0.66455	0.911511
9	0.389879	0.659555	0.895242
10	0.311218	0.513119	0.758402
11	0.311217	0.513117	0.758399
12	0.281646	0.458131	0.674388

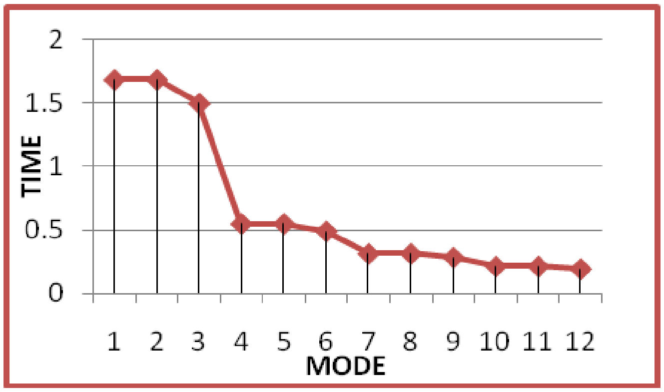

Fig.9. Modal Periods for 15 storey without TMD.

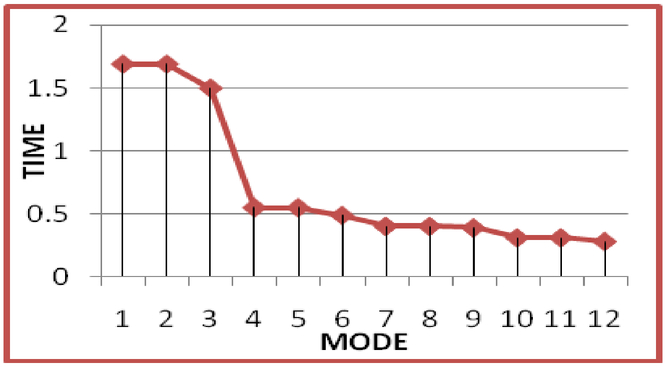

Fig.10. Modal Periods for 15 storey with TMD.

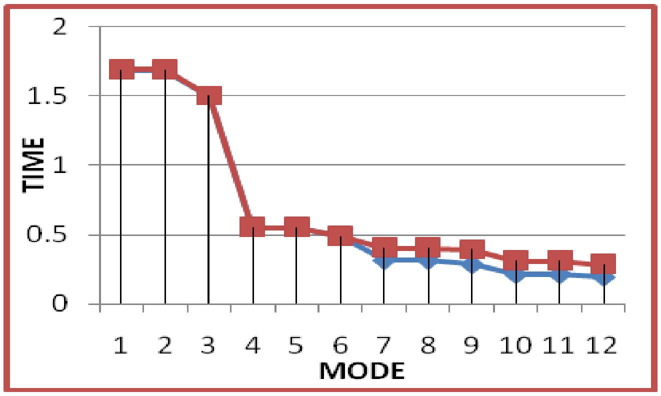

Fig.11. comparison between two building Modal Periods for 15 storey.

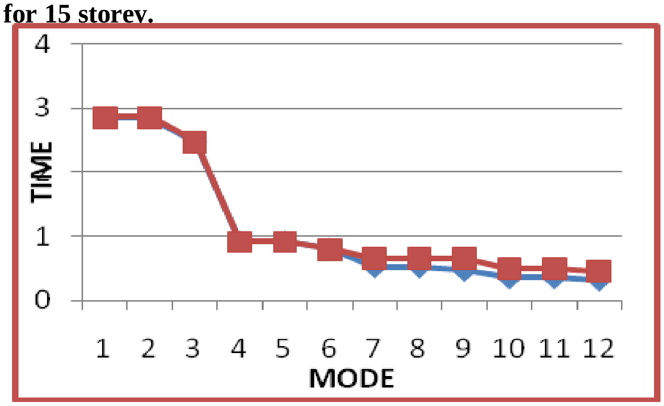

Fig.12. comparison between two building Modal Periods for 25 storey.

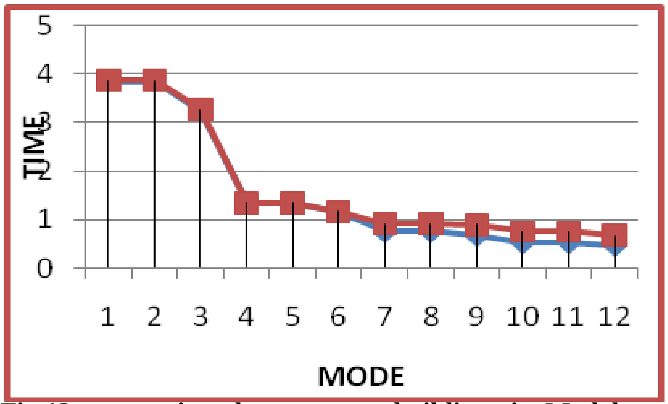

Fig.13. comparison between two buildings in Modal Periods for 35 storey.

B. Base Shear, Base Moment

TABLE IV:

Base Shear And Base Moment			
Building	B.shear X	MX	MY
15 Story Without TMD	1274.157	14649.97	35312.45
15 Story With TMD	961.45	27092.23	27092.23
25 Story Without TMD	1593.348	3651.557	73097.99
25 Story With TMD	1132.739	51839.83	51839.83
35 Story Without TMD	1536.817	34.4515	92385.74
35 Story With TMD	1059.256	65430.58	65432.03

TABLE V:

Reduction in base shear and base moment %		
BUILDING	base shear X	MY
15 story	24.54227	23.27854
25 story	28.908	29.081
35 story	31.07468	29.17519

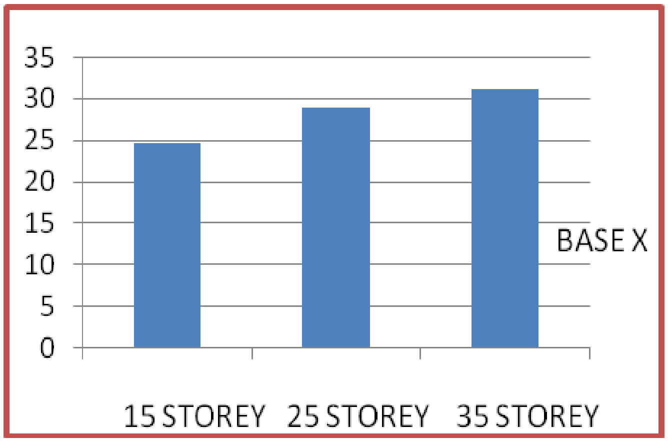

Fig.14. Reduction in base shear.

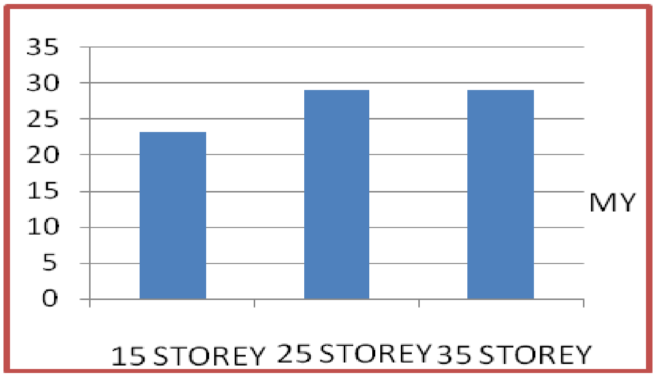

Fig.15. comparison Reduction in base moment.

C. Building Displacement (Ux)

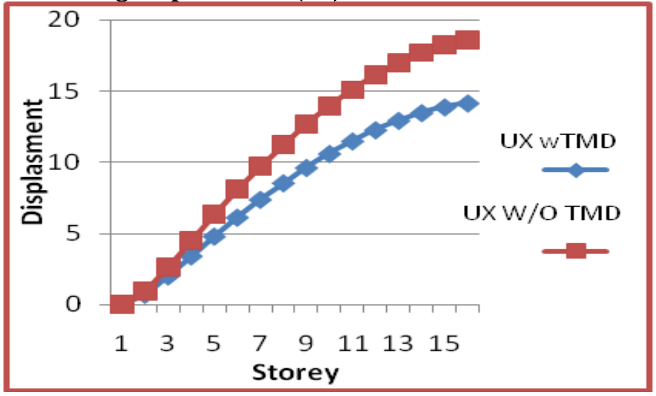

Fig.16. Displacement of 15 storey building.

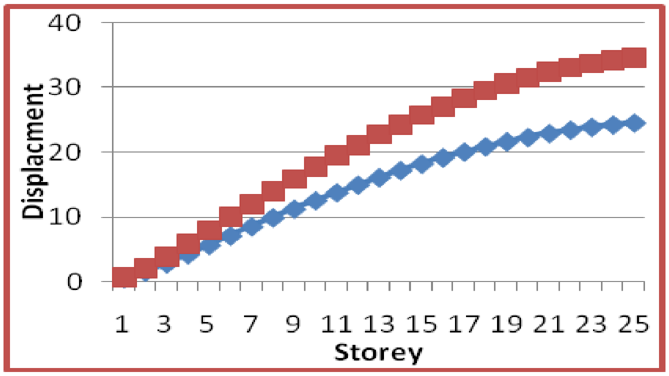

Fig.17. Displacement of 25 storey building.

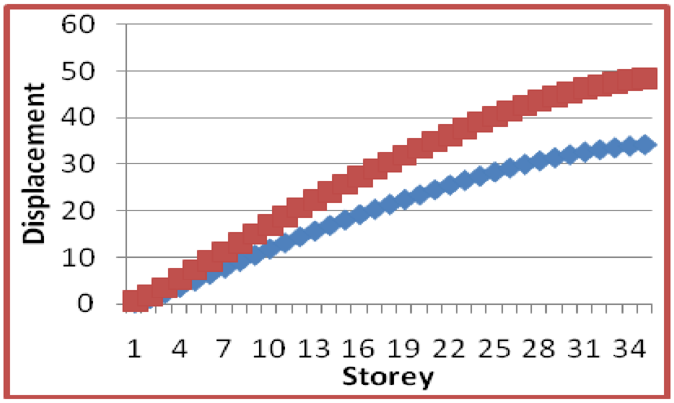

Fig.18. Displacement of 35 storey building.

D. Inter Storey Drift

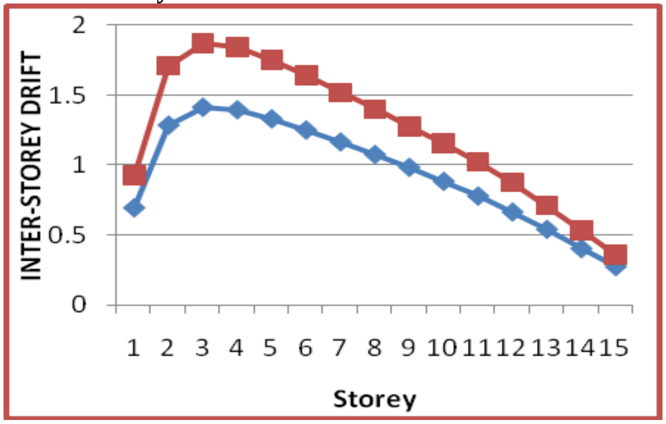

Fig.19. Inter storey drift for 15 storey building.

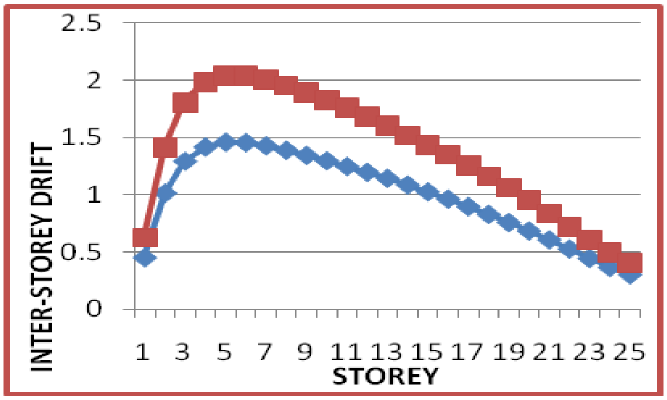

Fig.20. Inter storey drift for 25 storey building.

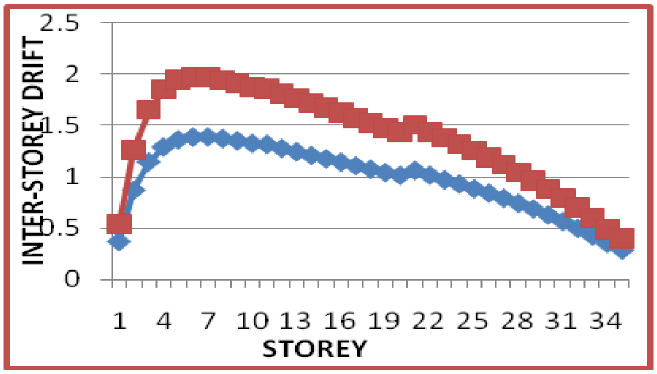

Fig.21. Inter storey drift for 35 storey building.

IX. CONCLUSIONS

Recently, use of seismic control systems has increased but choosing best damper and installing it into a building is very important for reducing vibration in structures when subjected to seismic loading. The controlling devices reduces damage significantly by increasing the structural safety, serviceability and prevent the building from collapse during the earthquake. Present study focused on the ability of TMD to reduced earthquake induced structural vibration. The models in this study created by using SAP 2000 program and using Response Spectrum Analysis when analyze these models. three models 15,25 and 35 storey created with and without TMD and comparison between the responses of these models when subjected to seismic ground motion load.

The results in this study suggest that the application of TMD is an appropriate to mitigate the dynamic response of the structures subjected to seismic ground motion. From reviewing the results that obtained in this study the following conclusions can be drawn: -Base shear reduction after used TMD as following:

- In 15 storey building the reduction 24%.
- In 25 storey building the reduction 28%.
- In 35 storey building the reduction 31%.

We conclude that when we use the TMD in the structure the base shear decreases and this decrease increases with rise building.

Lateral deflection (displacement) reduction after used TMD as following:

- In 15 storey building lateral deflection decrease between (23.8-24.9)%.
- In 25 storey building lateral deflection decrease between (28.5-28.9)%.
- In 35 storey building lateral deflection decrease between (29.4-30.9)%.

We conclude that the TMD is appropriate for tall building to reduce the lateral deflection.

Inter storey drift reduction after used TMD as following:

- In 15 storey building Inter storey drift decrease between (22.8 – 24.9)%.
- In 25 storey building Inter storey drift decrease between (25.9 – 29.2)%.
- In 35 storey building Inter storey drift decrease between (28.3 -30.9)%.

We conclude that the Inter storey drift decrease by using TMD.

Bending moment for exterior column reduction after used TMD as following :

- In 15 storey building Bending moment for exterior column decrease between (23.3 – 27.6)%.
- In 25 storey building Bending moment for exterior column decrease between (26 – 32.6)%.
- In 35 storey building Bending moment for exterior column decrease between (29.8 -63.2)%.

We conclude that the Bending moment for exterior column decrease by using TMD in tall building.

Shear force for exterior column reduction after used TMD as following :

- In 15 storey building Shear force for exterior column decrease between (23.5 – 34.6)%.

- In 25 storey building Shear force for exterior column decrease between (25.4 – 36)%.
- In 35 storey building Shear force for exterior column decrease between (29.9 -50)%.

We conclude that the Shear force for exterior column decrease by using TMD in tall building.

The results show that, generally, the response of structure can be dramatically reduced by using TMD. But it should be mentioned that, although this study produced results which corroborate the findings of a great deal of the previous work in this field, according to response spectrum analysis, the results of this study show significant decrease in shear forces. One of the most significant findings to emerge from this study is that, with increasing the number of storey, the reduction percentage of response of structure due to applying TMD has been raised too. In other words, it can be understood that, whatever is the number of stories increase, the performance of TMD is much better. Using of TMD on the top floor of the models will affect more the reduction of displacement and shear, which will be one of the solutions of resisting earthquake completely for both undesirable effect of it (large displacement and shear force in columns). The earthquake ground motions change from time to time when a new class of ground motions (e.g. long-period ground motions due to surface waves) is observed or a new type of damage appears during severe earthquakes, So it is useful to use TMD in sustainable buildings and cities.

Recommendations:

- In current study both the frame and damper has been modeled as linear one. Thus a further study of this problem can be carried out using a nonlinear model for frame or TMD or both.
- In this study the models taken as regular shapes. Thus a further study of this problem can be carried out using irregular shape for the models.
- A further study can be done with a group of TMD.

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