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EFFECT OF TUNE MASS DAMPER (TMD) ON HIGHRISE BUILDING SUBJECTEDTO LATERAL LOADS

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ABSTRACT

Strong earthquakes have occurred in many countries and have caused many problems including casualties, economic loss, destruction of infrastructures, and even leaking of radioactive materials. Therefore, earthquake resistant design and reinforcement of existing structures have become increasingly more important due to increasing probability of strong earthquakes. Especially, a higher level of earthquake resistance is required for infrastructures and industrial facilities as it has been shown in historical earthquake studies.

In the field of the structural; engineering the major aspect of analysis and designing the building is to ensure the structural stability against effect of various forces especially lateral forces, earthquake and wind are the two important external forces that must be taken in to considerations while designing a building as they play a major role in effecting the stability of structure. The main principle of designing the structure under seismic is to reduce the seismic force or seismic risk. Due to rapid urbanization and growth in industrial sector which led to the increase in the multistory structures construction. Efforts are being taken to reduce or control the seismic response due to wind and earthquake loading (lateral loading) which resulted in developing of seismic control devices such as active control devices and passive control devices. Several seismic resistance techniques are available, depending on the various types and conditions of structures.

In this project a symmetrical building of 20 stories with and without dampers (TMD) in zone II and zone V with medium soil is modelled and analyzed in ETABS 2015 under seismic zone II and V and the change in structural response in this is studied.

Keywords: *high-rise building, nonlinear dynamic analysis, tune Mass damper (tmd), seismic response, vibration control*.

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 analysing the structure varies from linear to nonlinear. The behaviour 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 a ero space 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.

II. LITERATURE REVIEW

i) 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.

ii) John Hancock Tower, Boston

Two dampers each having weight of 2700kN was added to the 60-storey John Hancock Tower in Boston to reduce the response to wind loading. The dampers were placed at opposite ends of the fifty-eighth story of the building with a spacing of 67 m. Due to typical shape of the building the damper was designed to counteract the sway and twisting of the building.

iii) CN Tower, Toronto

Due to uniqueness in the design perspective of the Canadian National Tower in Toronto adding TMD was compulsory to suppress the wind induced motion of the building in second and fourth modes. It was required to suppress dynamic wind loading effects of the 102 meter steel antenna at the top of the tower. The first and third modes of the antenna had the same vibrational characteristic as the more heavily damped concrete structure.

To reduce the vibrations, two doughnut-shaped steel rings with having mass of 9 tons were added at elevations corresponding to the peak vibration of the problematic modes. Each ring was mounted on a universal joint in such a way that could rotate in all directions and act as a tuned mass regardless of the direction of wind excitation. Four hydraulically activated dampers per ring were provided to dissipate the energy.

iv) Chiba Port Tower, Japan

Chiba Port Tower, a steel structure of 125 m in height 1950 tons weight and having a rhombus-shaped plan with a side length of 15 m (completed in 1986) was the first tower in Japan to be equipped with a TMD. The time period in the first and second mode of vibrations are 2.25 s and 0.51 s, respectively for the x direction and 2.7 sand 0.57 s for the y direction. Damping for the fundamental mode was computed at 0.5%. For higher mode of vibration damping ratios proportional to frequencies were assumed in the analysis. The use of the TMD was to increase damping of the first mode for both the x and y directions. The mass ratio of the damper with respect to the modal mass of the first mode was about 1/120 in the x direction and 1/80 in the y direction; periods in the x and y directions of 2.24 s and 2.72 s, respectively; and a damper damping ratio of 15%.

III. OBJECTIVES

Asian Journal of Civil Engineering (Building and Housing) Vol. 9, No. 3 (2009) Pages 347-359.This Study by**A. Mortezaei, S.M. Zahrai.**

Near-field earthquakes are characterized by short duration pulses of long periods with large peak ground velocities and accelerations. Recent studies have shown that the performance of passive energy dissipation systems depends significantly on the characteristics of near-field ground motion pulses. This paper is focused on the viscoelastic (VE) dampers to be used as energy-absorbing devices in buildings. Detailed and systematic investigation on the performance of passive energy dissipation systems during near-field ground motions has been carried. The analytical studies of the model structures exhibiting the structural response reduction due to these VE devices are presented. In order to exhibit the benefits of VE dampers, a nonlinear time history analysis is carried out under strong ground motion records from near-field and far-field earthquakes for all case studies: (a) a 5-story, (b) a 10-story and (c) a 15-story reinforced concrete building. The top story relative displacements as well as the top story absolute accelerations and also the base shear values obtained indicate that these VE dampers when incorporated into the super-structure reduce the earthquake response significantly in proportion to the amount of damping supplied in these devices. Reduction response of structure in 5 and 15 story building is harmonic but in 10 story building, there is no harmony in response of structure. Overall, the highest reduction has been achieved in 5 story building with an average reduction of 100%. Additional viscous damping is suggested as a way to control very large displacements. In order to be effective for mitigating the effects of large near fault motions, large damping values would be required

IV. METHODOLOGY

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 equipment's, and reliability of structures, damping capacity of structures in the elastic region should be increased.

A passive TMD system is a damping system in its most primitive form. It consists of a spring, damper and mass with fixed properties and does not require an external power supply to function as damping system. The damping system is only tuned for one frequency of the primary system and can only perform optimally when a reliable estimate of the design loading and an accurate numerical model of the physical system are available. A passive control scheme often results in an over conservative design, which makes the damping system not as effective as desired when it is used in practice. The advantage of a passive TMD system is that it is simple, robust and relatively inexpensive compared to their more advanced variants. The disadvantage is that, when the tuning is not done properly, the performance of the TMD system decreases significantly

If we have a fixed reaction wall adjacent to the top of a structure as shown in Fig. (3.1), 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 massm_T, spring $K_T$and viscous $C_T$usually installed on the top of structures as shown in Fig. (3.2). 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.

Principle of TMD (Tuned Mass Damper)

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Newmark Family of Methods

In 1959 Newmark represented a family of single-step integration methods for solving structural dynamic problems for both blast and seismic loading. During the past Forty years, Newmark's Method has been applied to the dynamic analysis of many practical engineering structures. In addition, it has been modified and improved by many other researchers. To illustrate the use of this family of numerical integration methods, Newmarkdeveloped family of time stepping methods based on the following equations

The Hilber, Hughes and Taylor α Method

The method uses the Newmark method to solve the following modified equations of motion:

$$\mathrm{M}\ddot{U}_t + (1+\alpha)\dot{C}_t + (1+\alpha)\,\mathrm{K}U_t = (1+\alpha)F_t$$
$$-\ \alpha F_t + \alpha\ \mathrm{C}\dot{u}_{t-\Delta t} + \square\ \alpha\ \mathrm{k}u_{t-\Delta t}$$

When α equals zero, the method reduces to the constant acceleration method. Itproduces numerical energy dissipation in the higher modes.However, it cannot be predicted as a damping ratio as in the use of stiffness proportional damping.

Nonlinear Dynamic Analysis

Nonlinear Dynamic Analysis It is known as Time history analysis. It is an important technique for structural seismic analysis especially when the evaluated structural response is nonlinear.

Tuned Mass Damper (TMD)

TMD systems are a practical well accepted strategy in the area of structural control for flexible structures, and particularly for tall buildings. It consists of added mass with properly tuned spring and damping elements, providing a frequency-dependent hysteresis that increases damping in the primary structure. The mechanism of suppressing structural vibrations by attaching a TMD to the structure is to transfer the vibration energy of the structure to the TMD and to dissipate the energy in the damper of the TMD. In other words, the frequency of the damper is tuned to a particular structural frequency so that when that frequency is excited, the TMD will resonate out of phase with the structural motion.It is not always necessary to dissipate a large amount of energy. Instead, the TMD can reduce the amount of energy that goes into the system by changing the phase of the vibration. The addition of a TMD, in fact, transforms the lightly damped first mode of the uncontrolled structure into two coupled and highly damped modes of the2-DOF modal system.Compared to control devices that are connected to structural elements or joints, the TMD involves a relatively large mass and displacements. The method used to support the mass and provide precise frequency control is an important issue in the design of a TMD. Thus, the ultimate performance of the TMD system is limited by the size of the additional mass, where is typically 0.25~1.0% of the building's weight in the fundamental mode or 2.0% of the whole building demand. Hence "A mathematical model directly incorporating the nonlinear characteristic of individual component and element of the building shall be subjected to earthquake shaking represented by ground motion time history to obtain forces and the displacement". Since numerical model directly accounts for the effect of material nonlinearity, inelastic responses and calculated internal forces will be reasonably approximate to those expected during the design earthquake. There are two methods by which the time history analysis is carried out a) Nonlinear Modal Time History Analysis b)Nonlinear Direct Integration Time History Analysis.

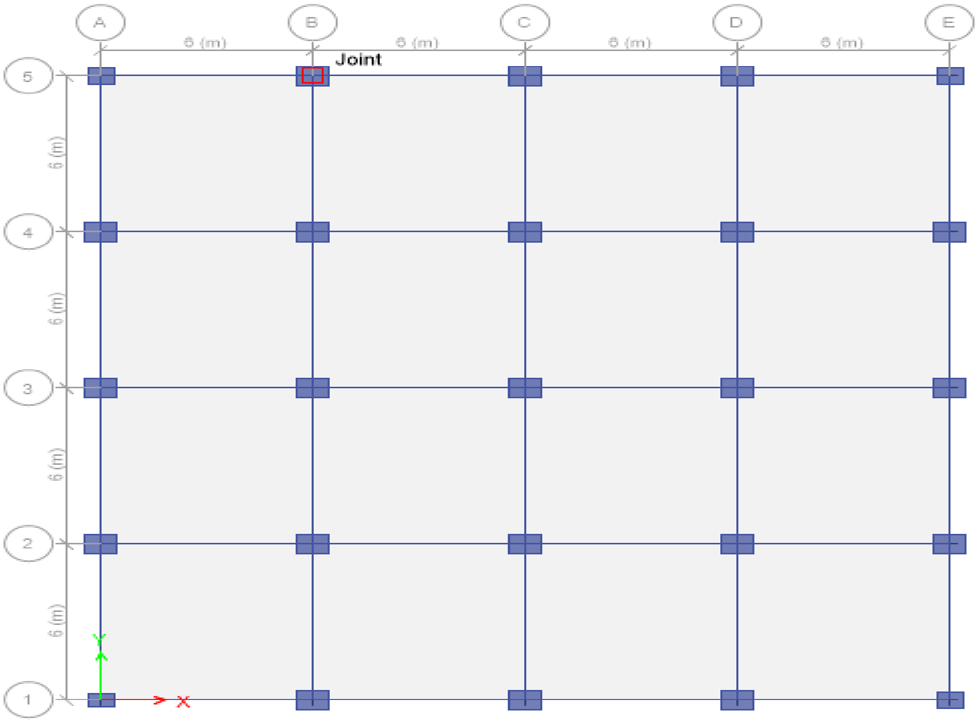
Time Steps

Time-history analysis is per formed at discrete time steps. Number of output time steps are specified with parameter n step and the size of the time steps with parameter dt. For periodic analysis, the period of the cyclic loading function is assumed to be equal to this time span. Responses are calculated at the end of each dt time increment, resulting in (nstep+1) values for each output response quantity.

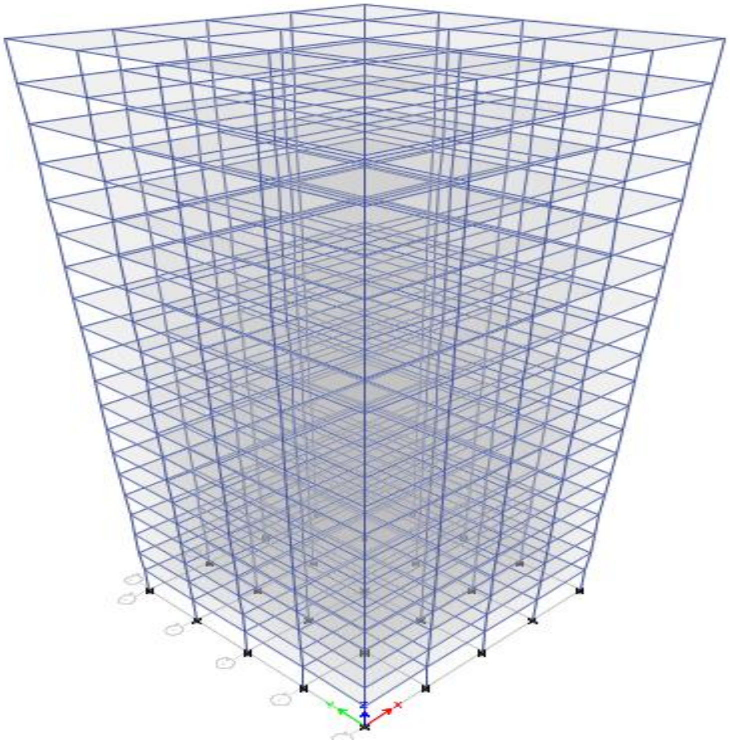
Response is also calculated, but not saved, at every time step of the input time functions in order to accurately capture the full effect of the loading. These time steps are called load steps. For modal time-history analysis, this has little effect on efficiency.For direct-integration time-history analysis; this may cause the stiffness matrix to be resolved if the load step size keeps changing. For example, if the output time step is 0.01 and the input time step is 0.005, the

The fundamental equation governing the response of MDOF system subjected to ground acceleration is given bẏ(t)
m¨+ c˙ + fs(u.sin ̇) = -mt¨g(t) 32

The only unknown quantity in the above expression is the displacement vector u. In this method the above equation is formulated for the entire structure at every time step at which the ground acceleration is determined. This equation is then solved by any of the well-known methods to get directly the displacement at each time step. The other response quantity time history is then calculated from known displacement time history. The peak from the particular response time history is then selected as the design demand.



4.1:Plan Views of Buildings



4.2: Isometric views of Model

V. CONCLUSION

1. The storey displacement were decreased by 30 % for twenty storey symmetric building under Zone II & medium soil suggesting the effectiveness of Tuned mass damper for Buildingssymmetric.
2. The storey displacement were decreased by 35 % for twenty storey symmetric building under Zone V & medium soil suggesting the effectiveness of Tuned mass damper for Buildings symmetric.
3. TheTuned mass damper were found to be excellent seismic control devices for twenty storey buildings in controlling forced Responses such as base shear as well as base torsion moment for symmetric buildings because of the reduction in Base shear by 30% for symmetric Buildings and by reducing base torsion moment by 25% Respectively for Zone II & Medium soil.
4. The Tuned mass damper were found to be excellent seismic control devices for twenty storey buildings in controlling forced Responses such as base shear as well as base torsion moment for symmetric buildings because of the reduction in Base shear by 35% for symmetric Buildings and by reducing base torsion moment by 30% Respectively for Zone V & Medium soil.
5. The overall results suggested thatTuned mass damper were excellent seismic control devices only for high - rise symmetric.
6. In conclusion by performing Non Linear Time-History Analysis, it can be demonstrated that Tuned mass damper are effective for high-rise symmetric Buildings.
7. Single TMD distributed through the elevation of the model is better than using only in the top of the model. This will reduce both overall displacements and base shear Forces especially.
8. TMD is effective for controlling structural response to harmonic base excitation.
9. TMD is most effective when the structural frequency is close to the central frequency of ground motion.
10. TMD is most effective for lightly damped structure, and its effectiveness decreases as with increase in structural damping format of the capacity spectrum method. Furthermore, by reversing the procedure, a direct deformation-based design can be performed..

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