International Journal of Engineering and Techniques - Volume 8 Issue 2, march 2022

RESEARCH ARTICLE OPEN ACCESS

Non Linear Analysis of Multistorey Buildings Having Water Tank as Tuned Mass Damper

Rohit Singh[1], Sumit Singh Shekhawat[2], Kavita Golghate[3]
1 (II year Student, Department of Civil Engineering, SDBCE, Indore,
Email: rohit8818.singh@gmail.com)
2 (Ass. Professor Department of Civil Engineering, SDBCE, Indore)
3 (Ass. Professor Department of Civil Engineering, SDBCE, Indore)

Abstract:

Globally, urban cities have witnessed rapid industrialization due to which requirement of new commercial and residential space have arises and to keep a pace with that, buildings are growing in to the skyscraper structures. In addition, the architectural innovation has led to the use of many materials and technology to enhance the aesthetical appearance of the building. Use of Lightweight, high-strength materials, welded connections has significantly affected the sensitivity of structures to the response of seismic and wind forces. Structural vibrations caused by wind or earthquakes are providing additional damping in the structural system which has caused severe damage to the non-structural element as well as the structural elements leading to the loss of human life as a result of collapse of buildings and severe structural damages. Therefore, to prevent the multistorey buildings from collapse and crucial damages, structural engineers are practicing seismic response control methods based on vibration suppressing elements. A tuned mass damper (TMD) is a device 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 object of the present work is to study the behaviour of multistorey buildings having tuned mass damper (TMD) as Tuned liquid damper (TLD), where the mass is replaced by liquid (generally water). For this purpose, two cases of multi-storey buildings are considered having 12 storey and 15 storey. These two cases are considered having Tuned Mass Damper (TMD) provided with different shapes of water tank and Water-depth ratio, excitation frequency for zone IV by using software Staad-Pro with dynamic analysis methods. Observation shows that the provision of Tuned Mass Damper (TMD) is advantageous in increasing FSI of the building. From the results, it is observed that by the use of Tuned Mass Damper, Storey Drift and Lateral Displacement, Time Period and Frequency values reduces in all the models.

***Keywords* — Tuned Mass Damper (TMD), Water tank, Seismic analysis Lateral displacement, Storey drift, Time-period and frequency, Dynamic Analysis.**

I. INTRODUCTION

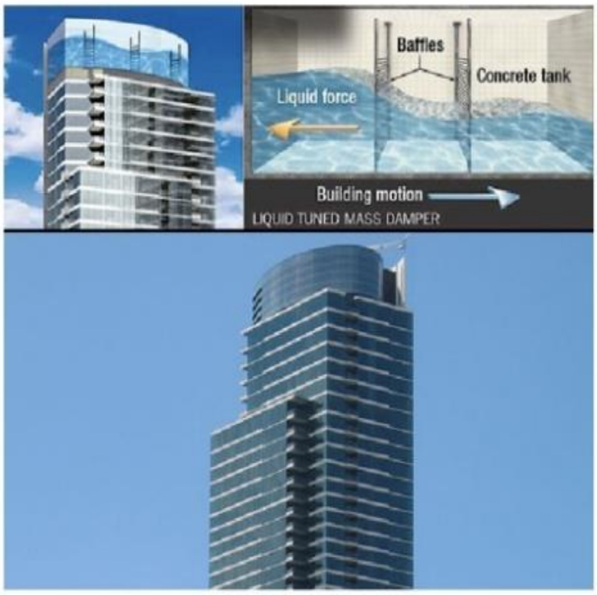
A Tuned Mass Damper (TMD), also called a "harmonic absorber", is a device mounted to a specific location in a structure, so as to reduce the amplitude of vibration to an acceptable level whenever a strong lateral force such as an earthquake or high winds hit. There are two basic types of TMD; the Horizontal TMD, which is normally found in slender buildings, communication towers, spires and the like. The other type is the Vertical TMD, which is usually applied in long span horizontal structures such as bridges, floors and walkways. Both types have similar functions, though there might be slight differences in terms of mechanism.

An earthquake is a natural phenomenon depending upon the intensity, it may cause damage to life and property. A tuned mass damper (TMD) is a device 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. This additional mass can be utilized as TMD to absorb the extra energy imparted on the structure during earthquakes. Earthquakes create vibrations on the ground that are translated into dynamic loads which cause the ground and anything attached to it to vibrate in a complex manner and cause damage to buildings and other structures.

Today there are 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. 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.

Now a day's TMD theory has been adopted to reduce vibrations of tall buildings and other civil engineering structures.

The passive device, tuned liquid damper (TLD), is a type of tuned mass damper (TMD) where the mass is replaced by liquid (generally water). A conventional TMD needs frictionless rubber bearings, special floor for installation, springs, dashpots and other mechanical components, which increase the cost of this device. However, the dead weight of the mass has no other functional use.



Palestra in London, United Kingdom

TMD is a damper that is used to reduce the dynamic response of structure with the provision of mass, spring and dampers. Use of TMD was started in early 90's with SDOF system but with the continuous development in the research of vibration control systems now it is rigorously used in MDOF system. When a structure is subjected to a particular excitation, the mass dampers absorbs the vibration to limit the motion of structure. Tuned mass damper stabilize structure against violent motion caused by earthquake's harmonic vibration. Tuned Mass Damper work as passive control device that means it does not require any external source of power. TMD device can be modelled with already installed mass component or built in component like water tank. Study shows that with consideration of sloshing effect, the earthquake load is significantly reduces and thus economic and safe design is possible. Many codes made the damping for high rise buildings a mandatory. Vibration controller devices are provided when the resisting of vibration induce force are not possible completely. To bring the center of gravity and center of rigidity in range, tuned liquid column dampers are provided i.e. lateral forces may not increase much. These TMD or TLCD may be of varying shape such as rectangular, square and circular which can be located at the top of building or the mid-height of the building. TMD are oriented in vertical direction like inverted pendulum, which dissipates earthquake vibrations, and they are usually provided along the center of both width and length of the buildings. TMD of structures located in high seismic regions requires special detailing. Tuned Liquid Damper are effective both in construction cost and effectiveness in minimizing earthquake damage to the structural and nonstructural elements also, without adding any additional load of the building.

II. OBJECTIVE

In the present dissertation work different cases of multistorey buildings having water tank as TMD have been taken to study the behaviour under seismic loading. The objectives of the present work are:

1. To study the seismic behaviour of different multi-storey buildings with varying number of storeys along with having water tank as TMD.
2. To perform the dynamic analysis of the multistorey buildings for lateral forces considering seismic zone IV.
3. To study the effect of aspect ratio (S=H/R) of the tank in the same buildings under the seismic forces for zone IV.
4. To compare the behaviour of multi-storey buildings having water tank as TMD with varying height and weight of water under earthquake loads.

III. METHODOLOGY

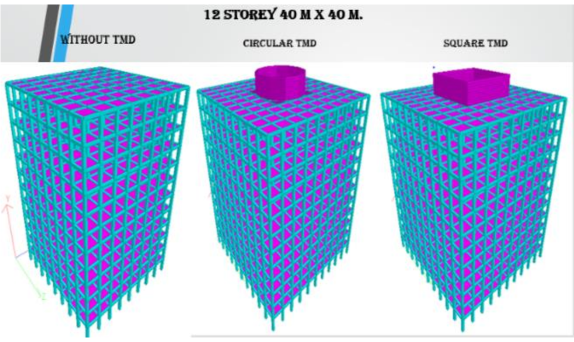
The objective of the present research work is to analyze the behaviour of multi-storey buildings having Tuned Mass Damper of Liquid as mass system with Circular and Square shape and without TMD under

Seismic forces by using non-linear dynamic analysis. To analyze this two system of high-rise building are considered with two different water tank as TMD system and one without TMD are provided to resist lateral displacement and storey drift.

In case-I, Building area provided is **40m x 40 m**. Total **12 storeys** are provided.

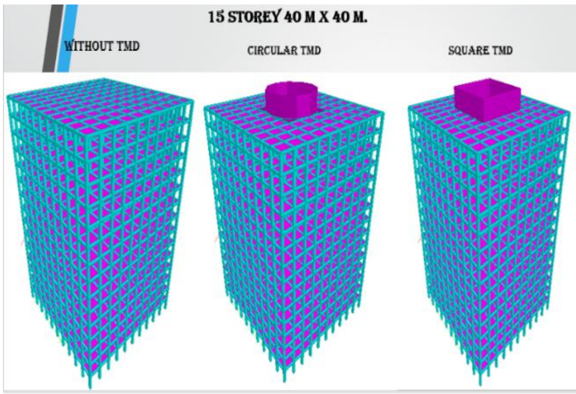
1. Square TMD water tank of 16 m x 16 m on top floor.
2. Circular TMD water tank of 16 m x 16 m on top floor.

3. Without TMD water tank.



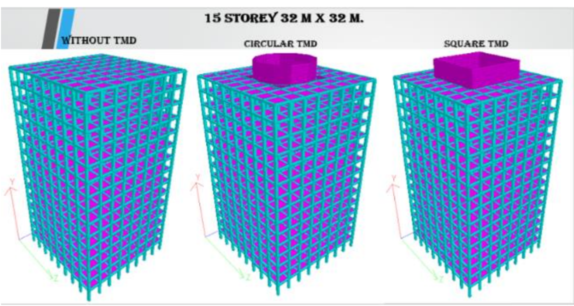
In case-II, Building area provided is 40 m x 40 m. Total 15 storeys are provided.

1. Square TMD water tank of 16 m x 16 m on top floor.
2. Circular TMD water tank of 16 m x 16 m on top floor.
3. Without TMD water tank.



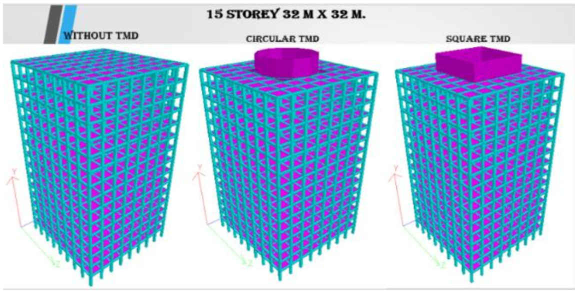
In case-III, Building area provided is 32 m x 32 m. Total 12 storeys are provided.

1. Square TMD water tank of 16 m x 16 m on top floor.
2. Circular TMD water tank of 16 m x 16 m on top floor.
3. Without TMD water tank.



In case-IV, Building area provided is 32 m x 32 m. Total 15 storeys are provided.

1. Square TMD water tank of 16 m x 16 m on top floor.
2. Circular TMD water tank of 16 m x 16 m on top floor.
3. Without TMD, water tank.



To study the behavior the response parameters selected are lateral displacement and storey drift. All the cases are assumed to be located in zone IV and analyzed by nonlinear dynamic methods using STAAD.Pro software. All the four cases are analyzed with 3-meter water depth, which is dead storage reserved for function of TMD.

Table I Summary of Variables

Parameters	Variables
Zone	IV
Types of TMD	Square, Circular and Without TMD
Plot size	40m x 40m & 32m x 32m.
Case-I	40 m x 40 m. Total 12 storeys
Case-II	40 m x 40 m. Total 15 storeys
Case-III	32 m x 32 m. Total 12 storeys
Case IV	32 m x 32 m. Total 15 storeys

IV. RESULTS AND DISCUSSIONS

The performance of multistorey buildings is assessed for building area 40m x 40m followed by 32m x 32m having different number of storeys i.e. 12 storey and 15 storey for zone IV. The results obtained from analysis.

Storey Drift

1. According to IS:1893:2002 (part I), maximum limit for storey drift with partial load factor 1.0 is 0.004 times of storey height. Here, for 4.0m height and load factor of 1.5, though maximum drift will be 24mm.
2. It is observed from results that for all the cases considered drift values follow around similar path along storey height with maximum value lying somewhere near about 1st storey.,
3. In all the models it is observed that by providing Water Tank TMD drift values reduces in 12 storey models compared to 15 storey models of both 40m x40m and 32m x 32m building area in dynamic methods of analysis.
4. From the results, it is observed that drift values of 12 storey models are less in comparison to 15 storey

models in dynamic analysis with 3 meter water depth in Water Tank. Hence it may be preferable to adopt a relative water depth in practice.

5. It is observed that with the increase of number of storeys values of storey drift also increases.
6. In the 12 storey building models of 40m x 40m values of storey drift varies from 5.97 mm to 1.38 mm in without TMD model from dynamic analysis. Also from dynamic analysis in Circular TMD model these values varies from 5.73mm to 1.54mm, in Circular TMD model values reduces to 0.01 mm.
7. In the 12 storey building models of 32m x 32m values of storey drift varies from 5.87 mm to 1.62 mm in without TMD model from dynamic analysis. Also from dynamic analysis in Circular TMD model these values varies from 5.73mm to 1.97mm, in Circular TMD model values reduces to 0.98 mm to 0.076 mm.
8. As limiting value of storey drift is 24 mm, according to this all the models of 12 storey building and 15 storey building are safe within permissible limits with dynamic analysis methods.

Lateral Displacement

1. According to IS: 456:2000, maximum limit for lateral displacement is H/500, where H is building height. For 12 storey building model it is 96mm and for 15 storey building model it is 120 mm.
2. It is observed from results that for all the models considered displacement values follow around similar gradually increasing straight path along storey height.
3. By providing Water Tank as TMD displacement values reduces as compared to without TMD models in dynamic analysis.
4. The lateral displacement is maximum at the top storey and least at the base of the structure.
5. In 12 storey building, values compared of with and without TMD building models, values of displacement are more in case of without TMD type. 12 storey building of 40m X 40m area without TMD shows displacement of 87 mm, which reduces to 58.15 mm in circular type TMD and in square TMD it reduces to 5.00 mm. Therefore, with Circular TMD displacement values are reduces to 66 % and in Square TMD it reduces to 5 %.
6. 12 storey Building with 32m x 32m have shown the similar pattern of values.
7. It is observed that displacement values of Square TMD are less in comparison to Circular TMD. Hence it may be preferable to adopt Square TMD method in practice. Study should be done with varying height of water depth also.
8. It is observed that with the increase of number of storeys values of displacement also increases.
9. In 15 storey building, values compared of with and without TMD building models, values of displacement are more in case of without TMD type. 15 storey building of 40m X 40m area without TMD shows displacement of 115.6 mm, which reduces to 73.61 mm in circular type TMD and in square TMD it reduces to 73.00 mm. Therefore, with Circular TMD displacement values are reduces to 64 % and in Square TMD it is same as 64 %.
10. As limiting value of displacement in 12 storey it is 96mm and for 15 storey it is 120mm. In all the cases of dynamic analysis methods due to the IV zones, no models fails at higher storeys but there is significant reduction in displacement values from Without TMD to Circular TMD to Square TMD in 12 storey models. Whereas in 15 storey models displacement reduces from without TMD to TMD models but it does not changes over the type of TMD.

V. CONCLUSIONS

Within the scope of present work following conclusions are drawn:

1. In building models considered displacement values follow around similar gradually increasing straight path along storey height.
2. .In all the cases considered drift values follow around similar path along storey height with maximum value lying somewhere near about 1st storey.
3. Water Tank as TMD storey drift and displacement values reduces as compared to without TMD models for all the zones.
4. It is observed that drift values of dynamic analysis are less in all the models analyzed.
5. Displacement values of dynamic analysis are less in comparison of Without TMD, Circular TMD and Square TMD. Hence it may be preferable to adopt Square TMD with dynamic analysis method in practice.
6. It is also observed that circular tank in 12 storey has shown more displacement values compare to square tank that is due to circular wall resist load evenly, thus a counteracting reaction to resist oscillation and displacement is less in circular TMD compare to Square TMD.
7. In 15 storey models displacement reduces in less

extent compared to 12 storey models. The factor corresponding to it i.e. water depth ratio (3.0m) shall be studied with variation.

REFERENCES

1. 2021, Vibhavari Shankar Bangi, "WATER TANK AS A TUNED MASS DAMPER", International Journal of Engineering Sciences & Research Technology, Bangi et al., 10(1): January, 2021] Impact Factor: 5.164 IC™ Value: 3.00.
2. 2020, Lakshmi S1, M Gayathri Devi, "A Review on Tuned Liquid Column Dampers (TLCDs) and Tuned Liquid Column Dampers with Embossments (ETLCDs)", International Research Journal of Engineering and Technology (IRJET) Volume: 07 Issue: 03 Mar 2020.
3. 2019, Mr. RIMAL, Prashant, ZAFAR, Usama, AZAM, Sakia, REFAIE, Abdelrahman, IBANEZ, Stalin, MIRBOLAND, Mahsa, "Structural control using tuned liquid column dampers: An experimental study", Faculty of Civil Engineering, Bauhaus University Weimar, Germany STARC, Jure Faculty of Civil Engineering, University in Ljubljana, Slovenia.
4. 2017, Mr. Chuan Fu, "Transforming Method of TLCD-structure to TMD-structure for Vibration Control", KSCE Journal of Civil Engineering (2018) Accepted May 11, 2017/Published Online July 21, 2017.
5. 2017, Manjusha M1, Dr.Vra Saathappan2, "Analytical Investigation of Water Tank as Tuned Mass Damper Using Etabs 2015", International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056 Volume: 04 Issue: 05 | May -2017.
6. 2016, Saha1 • Rama Debbarma Mr. Supradip, "An experimental study on response control of structures using multiple tuned liquid dampers under dynamic loading", Int J Adv Struct Eng (2017) 9:27–35 Accepted: 2 December 2016 / Published online: 24 December 2016.
7. 2016, Muhammad Jamil Ahmad, Qasier uz zaman Khan, Syed Muhammad Ali (2016). "Use of water tank as tuned Liquid Damper for (RC)reinforced Concrete Structures."Arab J Sci Eng 10.1007/s13369-2188-1.
8. 2013, Bhattacharjee, Lipika Halder* and Richi Prasad Sharma, "An experimental study on tuned liquid damper for mitigation of structural response", An experimental study on tuned liquid damper for mitigation of structural response.
9. 2013, Bhattacharjee, Lipika Halder* and Richi Prasad Sharma, "An experimental study on tuned liquid damper for mitigation of structural response", An experimental study on tuned liquid damper for mitigation of structural response.
10. 2011, Pradipta Banergi, Avik samanta. "Earthquake Vibration Controle Of Structures using hybrid mass liquid damper". Engineering structures 33(2011)1291-1301.
11. 2008, Mr. G. Hemalatha* and K.P. Jaya, "WATER TANK AS PASSIVE TMD FOR SEISMICALLY EXCITED STRUCTURES", ASIAN JOURNAL OF CIVIL ENGINEERING (BUILDING AND HOUSING) VOL. 9, NO. 4 (2008) PAGES 349-366.
12. 2007, Sung-Kyung Leea , Eun Chum Parka, Kyung-Won Mina ,*, Sang-Hyun Leea , Ji-Hun Park, "Experimental Implementation of a Building Structure with a Tuned Liquid Column Damper Based on the Real-Time Hybrid Testing Method", Journal of Mechanical Science and Technology 21 (2007) 885-890 November 16, 2006; Revised January 8, 2007).
13. 2004 Pradipta Banerji (2004). "Tuned Liquid Dampers for Control Of Earthquake Response" 13th World Conference on Earthquake Engineering, Vancouver, B.C., Canada. August 1-6, 2004. Paper No.1666.
14. 2004, M. J. Hochrainer. "Tuned liquid column damper for structural control" Acta Mechanical 175, 57– 76 (2005) DOI 10.1007/s00707-004-0193-z.
15. 2003, Takashi Ikeda,. "Nonlinear Parametric Vibrations of an Elastic Structure with a Rectangular Liquid Tank". Nonlinear Dynamics 33: 43–70, 2003.