ISSN 2229-5518

Effectiveness of Tuned Liquid Dampers in Reducing Vibrations of Tall Structure – A Parametric Study.

Aditee S. Patil, N.G. Gore, P.J. Salunke,
adi.patil8511@yahoo.com

ABSTRACT : Current trends in construction industry demands taller and lighter structures, which are also more flexible and having quite low damping value. This increases failure possibilities and also, problems from serviceability point of view. Several techniques are available today to minimise the vibration of structure, out of which concept of using of TLD is a newer one. This study was made to study the effectiveness of using TLD for controlling vibration of structure. For actual analysis process simple plan of building was decided according to requirements building structure water tank was designed and effective water depth designed from impulsive and convective concepts of water during vibration.

A ten story building was considered for the study. The effectiveness of the TLD was calculated in terms of amplitude of displacements at top story of the structure. From the study it was found that, TLD can effectively used to control the vibration of the structure. Only TLD which were properly tuned to natural frequency of structure was more effective in controlling the vibration. The damping effect of TLD is sharply decreases with mistuning of TLD.

1. Introduction

An increase in the frequency of occurrence of natural disaster event (Earthquakes and hurricanes) has been evident over the past few years. Strong vibration and possible collapse of structures during these events can lead to catastrophic human and economical losses. Damping is one of the most important parameters that limit the response of the structures during these dynamic events. Recently, a technique to increase the damping of a building has been developed by attaching one or multiple liquid-fluid tanks to the structures. The sloshing motion of the fluid that results from the vibration of the structure dissipates a portion of the energy release by the dynamic loading and therefore increases the equivalent damping of the structure. These tank devices are referred to as Tuned Liquid Dampers (TLD). In the past few years, a number of TLD was attached to various buildings to reduce the level of vibrations of the structures during their normal operation.

The spread of the applicability of this technique is hindered by the lack understanding of the behaviour of the TLD under high level of excitations. A research program is currently progressing at the University of Western Ontario to understand the behaviour of this device. The final objection is to develop means that can be used in designing tuned liquid dampers to be attached to structural buildings for up-grading their seismic resistance.

As a result of this development, the integrity of a building strengthened using TLD, can be maintained during a strong earthquake motion occurring in the vicinity of this building. This could reduce the huge human and economical losses that might occur during this disaster event.

ISSN 2229-5518

Now-a-days there is an increasing trends to construct tall structures, to minimize the increasing space problems in urban areas. These structures are often made relatively light & comparatively flexible, possessing quite low damping, thus making the structure more vibration prone. Besides increasing various failure possibilities, it may damage cladding and partitions and can cause problems from service point of view. Therefore, to ensure functional performance of tall buildings, it is important to keep the frequency of objectionable motion level bellow threshold.

1.1 History

Since 1950s dampers utilizing liquid is being used in anti-rolling tanks for stabilizing marine vessels against rocking and rolling motions. In 1960s, the same concept is used in Nutation Dampers used to control wobbling motion of a satellite in space. However, the idea of applying TLDs to reduce structural vibration in civil engineering structures began in mid 1980s, by Bauer, who proposed the use of a rectangular container completely filled with two immiscible liquids to reduce structural response to a dynamic loading.

The principles of operation of all of these dampers were based on liquid sloshing, for which these are sometimes referred as Tuned Sloshing Damper (TSDs). Several other types of liquid dampers are also proposed during last two decades, out of which Tuned Liquid Column Damper (TLCDs) which suppresses the wind induced motion by dissipating the energy through the motion of liquid mass in a tube like container fitted with orifice, is well known.

2. Mathematical Formulation

2.1 Assumptions

- The liquid is considered homogeneous, irrotational and incompressible.
- The walls of the damper are treated rigid
- The liquid surface is remains smooth during sloshing (No breaking wave produced)
- It should be emphasized that the structural response acts as an excitation for the damper thus affecting the sloshing motion of the liquid and its dissipation. On the other hand, the nutation damping affects the structural response. The analysis accounts for this conjugate character.

2.2 Governing equation for the liquid

The governing differential equation in terms of pressure variable is

$$\nabla 2P = 0 \qquad \text{On V} \qquad (2.1)$$

Where, V is the volume of liquid domain

P = P(x, y, z, t) is the liquid dynamic pressure, And, $\nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}$ in Cartesian coordinate system

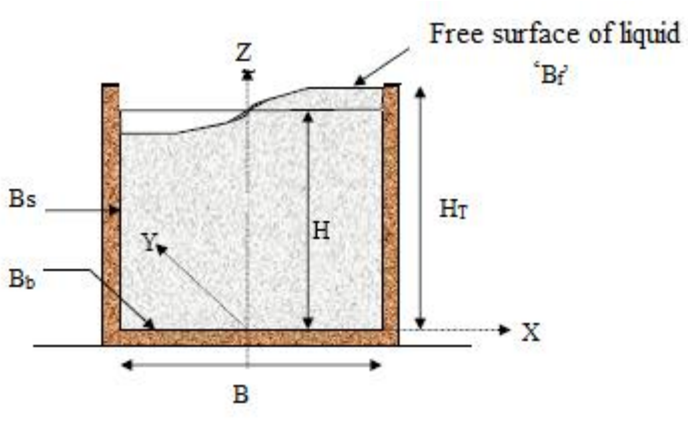

Fig. 1 Dimensions of a Rectangular Tank

2.3 The fundamental sloshing frequency of a TLD

The fundamental sloshing frequency of a TLD, f_{TLD} can be estimated using linear water sloshing frequency, f_w Ca, given by

$$fw = \frac{1}{2\pi}\sqrt{\frac{\pi g}{h}}\tanh(\frac{\pi h}{L})$$

Where, g = acceleration due to gravity,

h = still water depth,

L = length of tank in the direction of sloshing motion.

The sloshing frequency, f_{TLD} is amplitude dependant; However, for small sloshing amplitude we can assume $f_{TLD} = f_W$.

3. Results And Discussion

Then going before actual analysis process, simple plan of building was decided first. According to requirements building structure water tank was designed and effective water depth was designed from impulsive and convective concepts of water during vibrations. Analysis work was done for mass variable density of sloped bottom water tank.

This work comparative analysis was done with software's. It reduces time and give minimum errors in analysis work. For software analysis accurate model will be prepared, designed tanks also mounted on

ISSN 2229-5518
structure. Then required properties, loading and parameters required for vibration analysis was given to the structures as per the IS 1983. Then structure will be analyzed for rectangular, sloped bottom water tank for mass variable density and also for material variable density inside the tank. Now a day's software's will give plots for vibration of structures. From the plots of displacement and results for different cases of analysis comparison will be done. Studying the plots and interpreting the results of analysis work conclusion was made.

4. Conclusions

From this study, it has been found that the TLD can be successfully used to control vibration of the structure.

1. The TLD is found to be more effective, when it is placed at the top storey of the structure. In the study to access the effect of TLD in structural damping placed at various floors, it has been found that the amplitude of displacement at 10^{th} storey with 30 degree which gives 30% damping.
2. A study has been done to found the effect of mistuning of the damper in damping effect of TLD. It has been found that, TLD is most effective when it is tuned to the fundamental natural frequency of structure. Under tuning or over tuning of TLD to fundamental natural frequency of structure puts adverse effect on the damping of the TLD.
3. A study has been conducted to find out the effect of TLD size in structural damping while keeping the mass of TLD constant.

6. ACKNOWLEDGEMENT

I take this opportunity to thank staff members of Civil Engineering Department, Mahatma Gandhi Mission's College of Engineering and Technology, Kamothe, library staff for their assistance useful views and tips. A word of thanks is also reserved for all my batch mates for their selfless help, support and entertaining company.

7. References

1) M.J.Tait, N Isymov, A.A. EI Damatty, "Performance of tuned liquid Dampers", *Journal Engineering Mechanics*, ASCE, May 2008, pp.266-271.

2) Ming- Yi Liu, Wei- Ling Chiang, Jin-Hung Hwang, Chia-Ren Chu,"Wind-induced vibration of high rise building with tuned mass damper Including soil-structure interaction",

Journal of wind engineering and industrial academics 96,(2008),pp.1092-1102.

3) S.L.T. de Souza, T.L. Caldas, R.L. Viand, J.M. Bolthazor, R. M. Brasil, "Controlling oscillators with limited power supply", *7th Brazilian conference on Dynamics control and applications,* May 2008.

4) G.D. Chen, L.Y.Lu, "Current development of functionally upgrade Passive devices for seismic response reduction", *14th World conference on Earthquake Engineering,* Beijing, Oct 2008.

5) K.M.Shum, Y.L. Vu, W.H. Guo, "Wind induced vibration control of Long span cable stayed bridges using multiple pressurized tuned liquid column damper", *Journal of Wind Engineering and Industrial Aerodynamics-96*, (2008), pp.166-192.

6) Rogerio Bairrao, Luis guerreiro and Rui C. Barros, "Shaking table tests on semi-active tuned mass and tuned liquid dampers", *The 14th World Conference on Earthquake Engineering, Beijing, Chaina,* Oct 2008.

7) M.J. Falcao, A. Campos Costa, "Experimental studies on the Characteristics of tuned liquid dampers for reducing vibration in structure", *The 14th World Conference on Earthquake Engineering, Beijing, Chaina* Oct 2008, pp.12-17.

8) Adam Marsh, Mahesh Prakash, S.E. Semercigil and O.F. Turan, "Predicting the dynamic structural response controlled by a sloshing Absorber using SPH", *7th International conference on CFD in the minerals And process industries CSIRO, Melbourne, Australia,* Dec 2009.

9) P. Chaiviriyawong, W. Prachaserce, "Applications of passive mass Dampers for civil engineering structural control : A review", *RSID6-STR-23,* July 2009.

10) Tuomo Karna, "Damping methods to mitigate wind-induced vibration", *Journal of Structural Mechanics, vol.42,* (2009), pp.38-47.

ISSN 2229-5518
11) J.S. Love, M.J. Tait, H. Toopchi, "A hybrid structural control system using a tuned liquid damper to reduce the wind induced motion of a base isolated structure", Engineering Structure-33, (2010), pp.738-746.

12) Adam Marsh, Mahesh Prakash, S.E. Semercigil and O.F. Turan "Energy dissipation through sloshing in an egg shaped shell", *17th Australasian Fluid Mechanics conference, Auckland, New Zealand*, Dec 2011.

13) O.M. Faltinsen, R. Firoozkoohi, A.N. Timokha, "Steady-state liquid Sloshing in a rectangular tank with a slat-type screen in the middle: Quasilinear modal analysis and experiments", *Physics of Fluids-23*, (2011).