International Journal of Scientific Research in Civil Engineering
© 2019 IJSRCE | Volume 3 | Issue 5 | ISSN : 2456-6667

Analysis of a Composite High-Rise Building Frame Under Lateral Forces Considering Tuned Liquid Dampers using ETAB

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ABSTRACT

Current trends in construction industry demands taller and lighter Steel structures, which are 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 minimize the vibration of the structure, out of which TLD is a new concept. The main motive of this study is to determine the effectiveness of structure considering TLD (Tuned liquid damper technique) for controlling vibrations generated over a structure due to lateral forces. In this study we will analyze a tall structure considering seismic zone III & V as per Indian provision, and compare a general conventional structure with TLD assigned structure to prepare a comparative study using Analysis tool ETABS. Designing of the tall structure is done as per IS-800 : 2007 (General code for Design of Steel Structure).

Keywords : Tuned Liquid Dampers, Time History, Analysis Tool, Tall Structure, Forces, Modes, Vibrations, Moment.

I. INTRODUCTION

Controlling Vibrational loading is an important aspect while designing the structure, especially if they are tall. Buildings can get subjected to substantial vibrations due to wind and earthquakes. When an earthquake waves travel through the building, it is subjected massive forces, acceleration and displacement that makes the building highly unstable and eventually it collapses. Additionally, as modern skyscrapers are made tall using flexible beams, wind can cause significant swaying of the building. This repeated load cycles can induce fatigue into the beams and also can cause failure of the structure.

Seismic analysis is a subset of structural analysis and is the calculation of the response of a building structure subjected to seismic hazards. It is part of the process of structural design, earthquake engineering or structural assessment and retrofit in regions where earthquakes are prevalent.

Liquid dampers is among the various alternatives used to reduce the vibrations on the structures. A liquid damper is water confined in a container that uses the sloshing energy of the water to reduce the dynamic response of the system when the system is subjected to excitation. It has also been found to be very effective in cancelling vibrations caused due to wind.

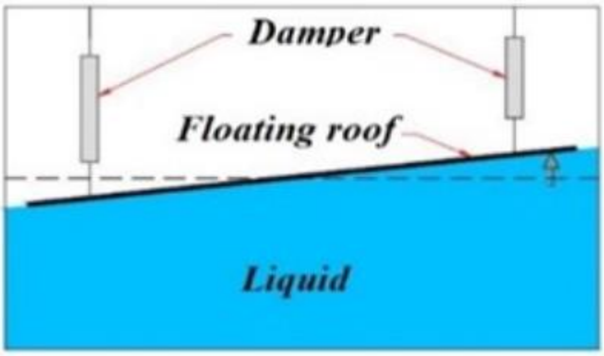

Fig 1: T.L.D.

II. LITERATURE REVIEW

Rana et. al. (2018) Authors illustrated that the effectiveness of Tuned Liquid Dampers (TLD) in reducing the seismic vibration of a building when it is subjected to horizontal sinusoidal excitation. TLD is a water confined container, or simply a water tank, which uses the sloshing energy of water to reduce the dynamic response of a structure when it is subjected to excitation.

Here researchers adopted a procedure for designing TLD for a building is suggested and a method is proposed to model the TLD in SAP2000 software. Then, multiple analyses have been carried out to analyse the effect of different parameters of TLD which may affect its performance. Analyses are conducted with varying mass ratio, tuning ratio, excitation ratio, number of storeys, position of TLD, etc.

The structural response is compared based on maximum base shear, maximum relative acceleration and maximum displacement of top storey. With reference to the results from these analyses, conclusions are derived and recommendations are given for an optimal design of TLD.

Roshni and Ritzy (2015) investigated the performance of a new type of cost-efficient damper for mitigating wind and earthquake induced vibrations in tall buildings. Tuned Liquid Damper (TLD) is a type of Tuned Mass Damper (TMD) where the mass is replaced by a liquid (usually water). A TLD relies upon the motion of shallow liquid in a rigid tank for changing the dynamic characteristics of a structure and dissipating its vibration energy under harmonic excitation. The effectiveness of TLD is evaluated based on the response reduction of the structure which is a two-storied steel building frame. Various parameters that influence the performance of TLD are also studied.

Pardeshi et. al. (2014) Assessed new kind of TLD installed with rigid baffle wall and varying water depth i.e. 50mm, 70mm, 90mm and 110mm. Experimental tests are conducted on scaled model (G+5 storey) subjected to sinusoidal excitations using shaking table experiment. The main objective behind installing such baffle wall is to reduce the structural vibrations subjected to earthquake excitation. From this study it is found that TLD with 90mm water depth and single baffle proved to be more effective leading to 80% reduction in acceleration. It is also found that only TLD which were properly tuned to natural frequency of structure is more effective in controlling the vibration. The damping effect of TLD sharply decreases with mistuning of TLD.

Objectives:

The primary objectives of this study is as follows:

- Analysis of a tall structure considering tuned liquid damper.
- To determine the effectiveness of liquid dampers comparing to general structure under vibrational load.
- To determine the Cost of operating and constructing liquid damper as per S.O.R

III. METHODOLOGY

Step-1 Literature Survey related to Seismic assessment and tuned dampers.

Step-2 Selection of building boundary conditions and its utility.

Step-3 Assigning Liquid Dampers.

Step-4 Assigning Sectional Properties and materials

Step-5 Analysis of liquid dampers and compare it with general structure.

Step-6 Problem formulation and loading calculation.

Step-7 Comparative study of results as Max bending moments, Maximum Axial force, Max displacements, story wise displacement, Maximum shear force , Maximum Axial force, Support reactions.

Table 1: Tuned liquid dampers

Geometrical Data	
Plan dimension	14 x 18 m
Length (m)	14 m
Width (m)	18 m
Height each floor(m)	3.2 m
Number of floors	G+10
Tuned damper	4x4 m
Column Size	400 x 350 mm
Beam Size	300 x 250 mm

Table 2 : Weight of Composite Structure

Seismic Weight Calculation								
S. No.	Category	no.	length	breadth	height	volume m3	density (T/m3)	weight (T)
1	columns	30	0.35	0.3	3.2	0.336	78.5	26.376
2	beams	96	0.3	0.2	0.3	0.018	78.5	1.413
3	slab		17.8	13.5	0.125	30.0375	2.5	75.0938
4	brick wall		120	0.2	3	72	1.8	129.6
Total building weight								232.4828

Seismic Definition

Earthquake zone – III & V (Z=0.16 & 0.36)
Response reduction factor – 5
Importance Factor – 1
Damping - 5%
Soil Type: As per site
Natural Time Period (T_a) - $0.075h^{0.75}$ (T_a = 2.145 sec)
h = Height of building, in m. This excludes the basement storeys, where basement walls are connected with the ground floor deck or fitted between the building columns. But it includes the basement storeys, when they are not so connected.

Analysis results

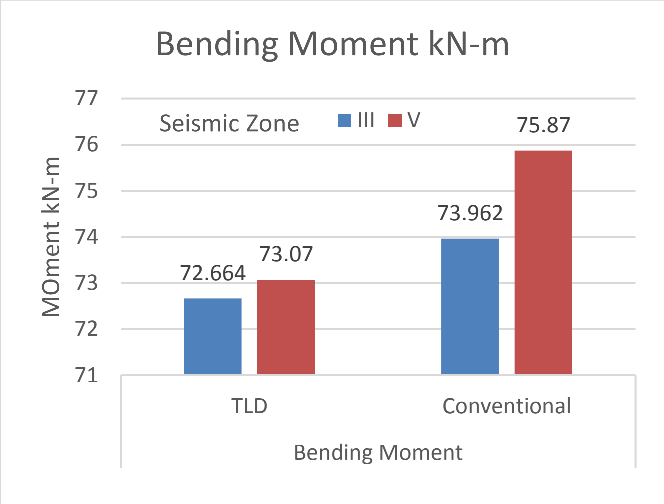

Fig 2: moment

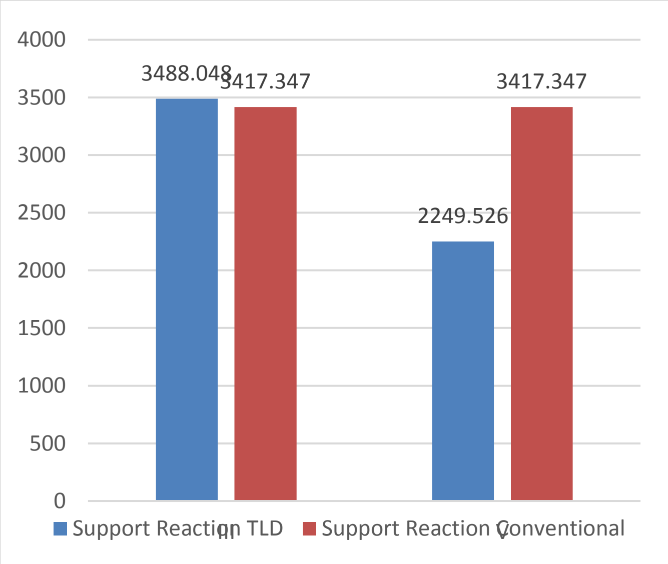

Fig 3: Support conditions

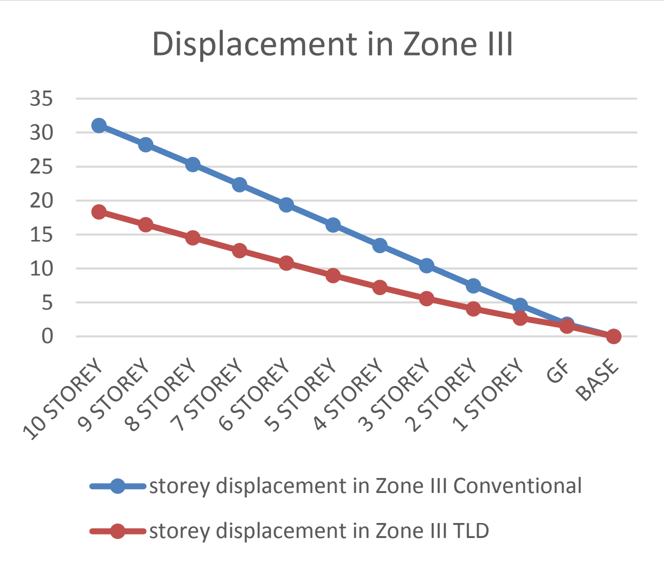

Fig 4: Displacement in Zone III

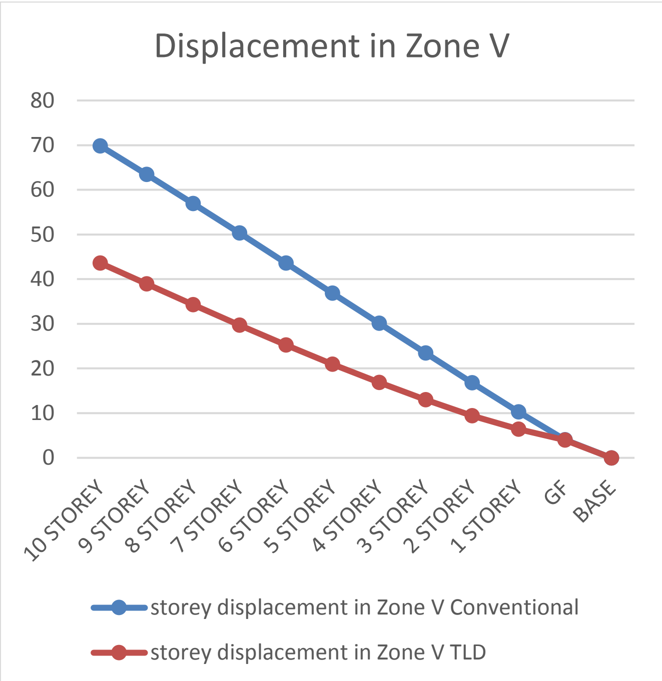

Fig 5: Displacement in Zone V

IV. CONCLUSION

From the study we can conclude that the optimal tuning ratio of the liquid damper may be sensitive or insensitive to the mass ratio and to the damping ratio of the main system. In addition, can conclude the head loss coefficient in less or more flexible structures.

- The base shear capacity of T.L.D. frame is increased as compared to bare frame (Conventional) building which indicates that the stiffness of building has increased.
- T.L.D. has found in the most efficient in terms of story displacement and story drift reduction when T.L.D. is provided at the C.G. of the building. Also moment is also decreased which results in economical structure.

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Cite this article as :