CASE STUDY ON SEISMIC ANALYSIS OF RC FRAME BUILDING WITH SURMOUNTED WATER TANK AS TUNED LIQUID DAMPER

Sagar Chaudhary[1], Aakash Suthar[2]

[1]*P.G. Student, Department of Civil Engineering, L.J. Institute*
[2]*Assistant Professor, Department of Civil Engineering, L.J. Institute*

Abstract - *Earthquakes are one of nature's greatest hazards, throughout historic time they have caused significant loss of life and severe damage to property, especially to man-made structures. Engineering community is striving hard to innovate different methods that can provide a solution to minimize this damage. The idea of seismic response control of the structures by using TMD's is considered for this study. Water tanks are used to store water to tide over the daily requirements in buildings. Water tanks contains huge water mass resting at top of buildings which are most critical consideration during earthquakes. The present study is aimed to analyze the RC frame buildings with irregularity in plan surmounted by water tank under seismic excitations. The plan irregularities of + shape, C shape and T shape are considered.*

***Key Words*: Tuned Liquid Damper, ETABS 17, Net displacement, Shapes of building, Storey Drift**

1. INTRODUCTION

High rise structures are also called "vertical cities", having the potential to decongest urban sprawl. Indian cities are witnessing immense demographic expansion due to migration from surrounding villages, leading to urban sprawl, housing demand, rise in cost of land. Housing has developed into an economy generating industry. Given this demand while high rise residential structures have become a solution in the metropolitan cities. Natural calamities fear the man kind since the day first. Earthquake is the most distressing hazard on the earth. An essential requirement of present-day in new trend structural design and assessment of existing structures is seismic hazard extenuation paper. A tuned liquid is a container that is partially filled with a mixture of water and glycol. It has no moving parts, the damping is provided by the sloshing of the internal liquid. A tuned liquid damper is a unique way to reduce the vibration of high rise structures. TLDs were gradually installed in the high rise structures as well as ships. Designing the structures to withstand these earthquake lateral forces is very expensive hence it is not always desirable. The tall buildings are in generally highly vulnerable to lateral forces arising out of earthquakes.

1.1 How Tuned Liquid Dampers Work?

Tuned liquid dampers are energy dissipating substructures, which can be used to improve the dynamics of structures. The basic operating principle is an energy transfer from the vibrating host structure to the TLD. For a TLD system, the liquid ratio (d_0 / L, d_0=liquid depth, L=tank width) must be suitable to have significant response reduction.

Besides, the maximum motion reduction can be obtained when the liquid depth ratio decreases to 0.2 and the motion reduction rate reach nearly 70%.

The maximum motion reduction always occurs when the exciting frequency is equal to the fundamental frequency of the TLD. However, the violent sloshing of liquid in the tuned liquid damper tank with small liquid depth ratio is found in the experiments.

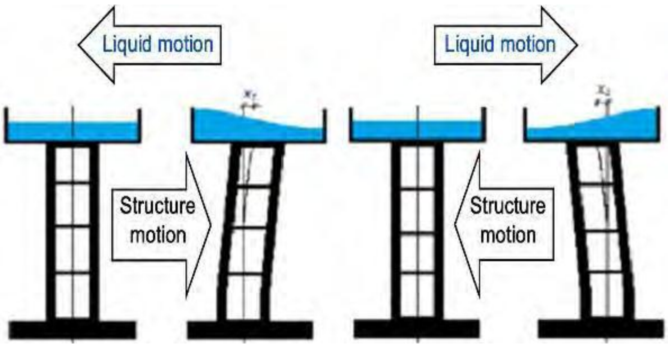

Fig.1 The motion of structure with TLD.

2. Objectives

(i) To design TLD as the effectively control the response of a structure subjected to large amplitude broad banded base excitations, such as those experienced during an earthquake.

(ii) To check the reduction in seismic response of the building considering both parameters simultaneously.

(iii) To find the most effective water level condition in water tank for maximum reduction in seismic responses.

(iv) To check the effectiveness of the tuned liquid dampers (water tanks) in reduction of the seismic responses such as joint displacements, storey shears and joint accelerations.

3. LITERATURE VIEW

Thomas Furtmüller, Alberto Di Matteo[(1)] (2017) investigated the effective of the use of a tuned liquid damper (TLD) as a cost-effective means to control the seismic response of a base-isolated structure. Comparison with the optimal parameters obtained considering a classical iterative statistical linearization technique proves the reliability of the proposed approach. The performance of the base-isolated TLCD-controlled structure is examined and compared with that of the simple base-isolated one (without TLCD).

Qaiser uz Zaman Khan, Syed Muhammad Ali(2) (2016) investigated the suitability of water tank as passive tuned liquid damper for RC structure against earthquake vibrations. Two four storey RC frame structural models with symmetrical in plan and vertical with water tank monolithically attached on top were constructed and tested on with different levels of water in water tank. 0%, 1% , 2%, 2.5% and 3% quantity of water is used.

M. J. Tait, M.ASCE(3) (2015) analysed a study of the application of the Time history analysis which has been carried out for models without water tank and with five condition of water level for both models. The behaviour of the tank subjected to four earthquake data, namely, EI-Centro, Hachinohe, Kobe and Northridge was studied under five conditions, namely tank empty, 1/4th water, half full, 3/4th water and full tank. The analytical investigation carried out to study the feasibility of implementing water tank as TLD using ANSYS.

Yongjian Chang, Oya Mercan(4) (2018) investigated the objective of dimensionless rotational stiffness parameter, frequency ratio, and damping ratio are studied in detail. It is shown both analytically and experimentally that when properly designed, the MTLD can exhibit more efficiency than a traditional TLD in mitigating vibrations.

S. Crowley, R. Porter(5) (2012) investigated the TLD is composed of a rectangular tank fitted with an arbitrary configuration of vertical slatted screens to provide damping when the fluid is in motion. They function by allowing fluid to slosh in a tank which is mounted rigidly to the structure and contain devices for dissipating energy. The influence of the fluid motion in the tank is analysed by adopting classical linearised water wave theory and a boundary value problem formulated with linearised conditions both on the free surface and across the screens. The rectangular tank TLD is coupled to a simple mechanical model for the displacement of an externally forced structure of large mass. Numerical predictions are shown to compare very well with experimental results for particular screen arrangements.

4. METHODOLOGY

4.1 MODELLING OF BUILDING

In the present study 5 storey, 10 storey, 15 storey buildings are modeled using ETABS. Seismic zones III, IV and V are considered. Medium soil type is considered.

4.2 BUILDING PLAN AND DIMENSION DETAILS

Tank frame is modeled using columns of same size as that of building which is then in filled with concrete wall panels. Springs for convective mass is modeled using “linear link” element whose stiffness in X and Y direction is given as K/2 and its DOF in Z-direction is set as fixed. Spring for impulsive mass is modeled using linear link element, but its DOF is set fixed in all direction. “Joint mass is assigned at the joint of the spring with values Mc and Mi in X and Y direction. Joint force is assigned at the joint of the spring with values Mc and Mi in gravity direction.”

$$Mi = \frac{\tanh\left(\frac{\sqrt{3}\times L}{2H}\right)}{\left(\frac{\sqrt{3}\times L}{2H}\right)} \times M$$

$$Mc = \frac{0.83\tanh\left(\frac{3.2H}{L}\right)}{\left(\frac{3.2H}{L}\right)} \times M$$

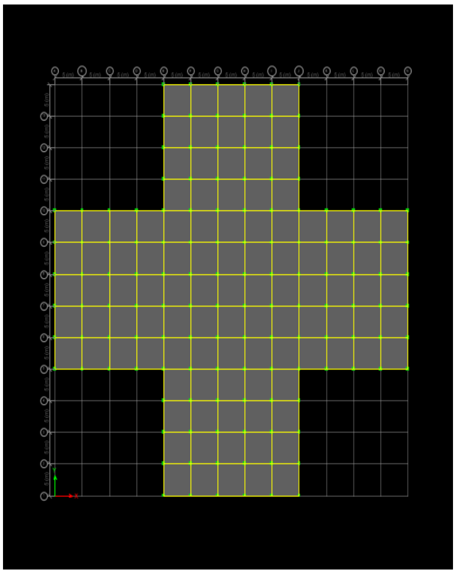

Fig.2 Plan of plus (+) shape building (65m X 65m)

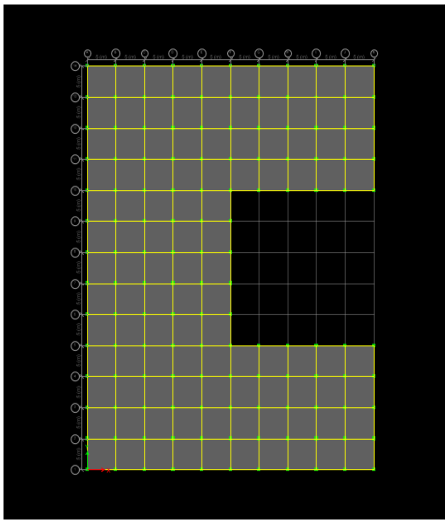

Fig.3 Plan of C-shape building (50m X 65m)

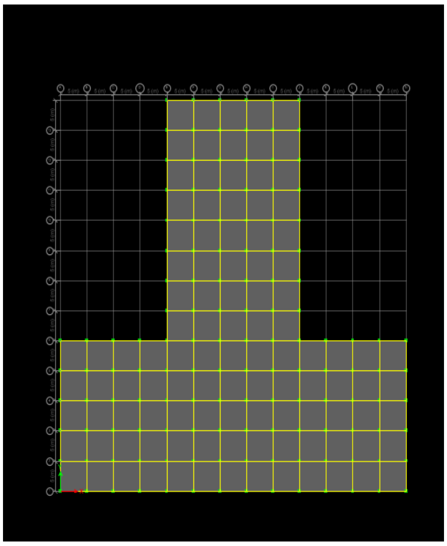

Fig.4 Plan of T-shape building (65m X 65m)

4.3 DIMENSIONS OF THE STRUCTURAL ELEMENTS

No. of story: 5 story, 10 story, 15 story

Story height: 3m

Bottom story height: 3.3m

Spacing in X-Direction & Y-direction: 5m

Size of column: 600mm x 600 mm

Size of beam: 300 mm x 600mm

Slab thickness: 150 mm

Thickness of exterior walls: 230 mm

Thickness of inner walls: 115 mm

4.4 MATERIAL PROPERTIES

Grade of concrete: columns M30, Beams and Slab M25

Grade of steel: Fe500

4.5 LOAD CONSIDERATION

Dead load: 1.5 kN/m^2

Live load: 3 kN/m^2

4.6 OTHER CONSIDERATIONS

Soil type: II

Seismic zones: III, IV, V

Importance factor: 1

SMRF building type considered.

Response reduction factor: 5

4.7 DIMENSIONS OF WATER TANK

Size of the water tank: 5 m x 5 m x 4 m

Height of water tank from Terrace: 2 m

Size of column: 600mm x 600 mm

Size of beam: 300 mm x 600mm

Bottom Slab thickness: 150 mm

Top slab thickness: 100 mm

Live load on top slab: 0.75 kN/m^2

6. RESULTS

After analyzing the models, the following results were obtained for different seismic zones III, IV & V. the charts were generated for easy comparison of the results for different parameters i.e. joint displacements, base shears.

SEISMIC ZONE 3							
Building type	No. of storey	Displacement (mm)		storey shear (kN)		Joint Acceleration (m²/sec)	
		Without TLD	With TLD	Without TLD	With TLD	Without TLD	With TLD
Plus(+) Shape	5 storey	6.14	5.89	3377.61	3133.82	0.374	0.314
	10 storey	12.54	11.4	3421.14	3017.9	0.268	0.225
	15 storey	19.18	17.19	3438.22	3015.42	0.211	0.206
C Shape	5 storey	6.28	5.55	3406.96	2891.69	0.373	0.297
	10 storey	12.61	10.93	3451.71	2883.35	0.267	0.208
	15 storey	19.3	15.77	3468.5	2780.81	0.21	0.157
T Shape	5 storey	6.8	5.58	3249.18	2883.51	0.369	0.295
	10 storey	13.6	10.85	3397.49	2830	0.263	0.206
	15 storey	20.77	15.92	3424.42	2702.59	0.207	0.155

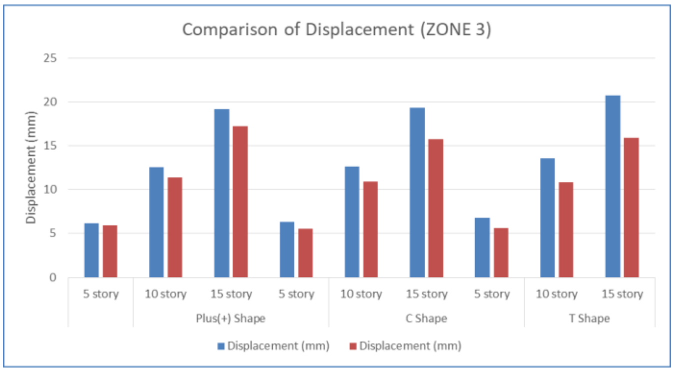

Fig. 5 Comparison of joint displacement (Zone III)

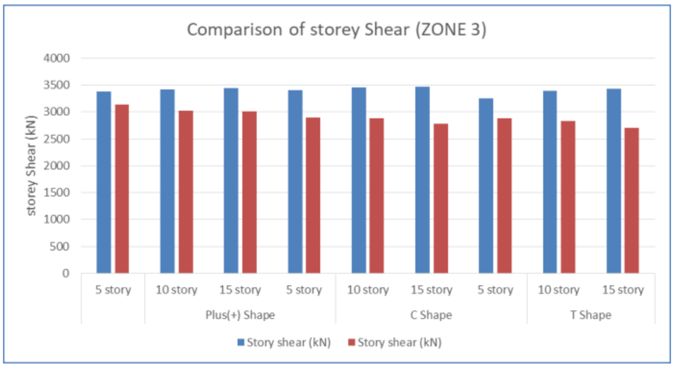

Fig.6 Comparison of storey shear (Zone III)

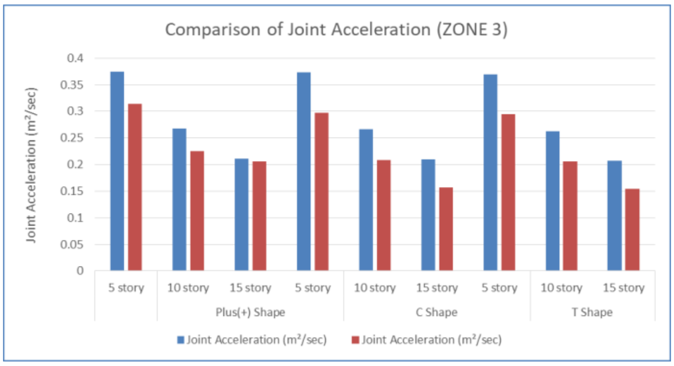

Fig.7 Comparison of joint acceleration (Zone III)

SEISMIC ZONE 4							
Building type	No. of storey	Displacement (mm)		storey shear (kN)		Joint Acceleration (m^2/sec)	
		Without TLD	With TLD	Without TLD	With TLD	Without TLD	With TLD
	5 storey	9.21	8.83	5066.41	4700.73	0.561	0.471
Plus(+) Shape	10 storey	18.8	17.1	5131.72	4526.85	0.402	0.338
	15 storey	28.77	25.79	5157.32	4523.13	0.316	0.309
	5 storey	9.28	8.32	5110.45	4207.72	0.56	0.446
C Shape	10 storey	18.91	16.35	5177.56	4332.88	0.401	0.313
	15 storey	28.95	23.66	5202.76	4171.21	0.315	0.236
	5 storey	10.2	8.38	4873.77	4325.27	0.553	0.442
T Shape	10 storey	20.4	16.28	5006.35	4245	0.395	0.309
	15 storey	31.15	23.89	5038.88	4075	0.31	0.233

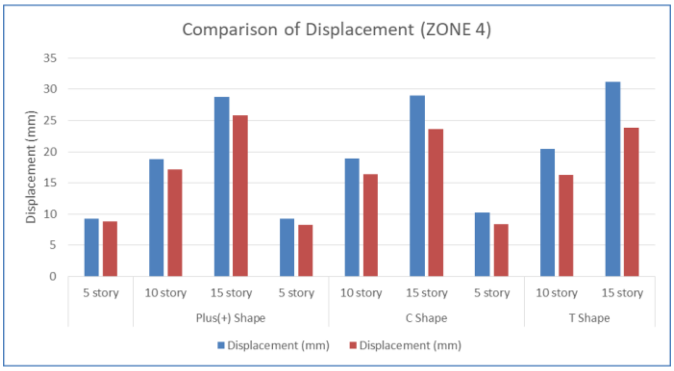

Fig.8 Comparison of joint displacement (Zone IV)

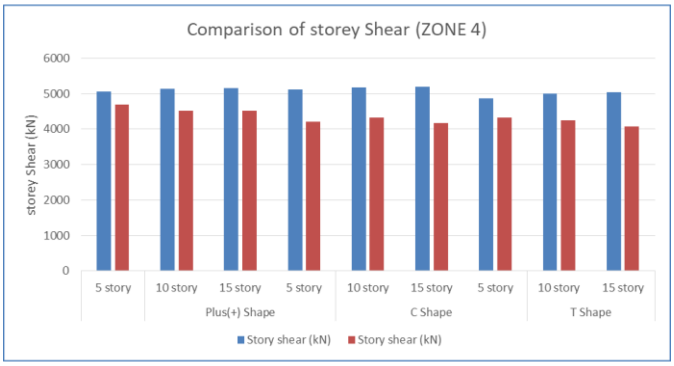

Fig.9 Comparison of storey shear (Zone IV)

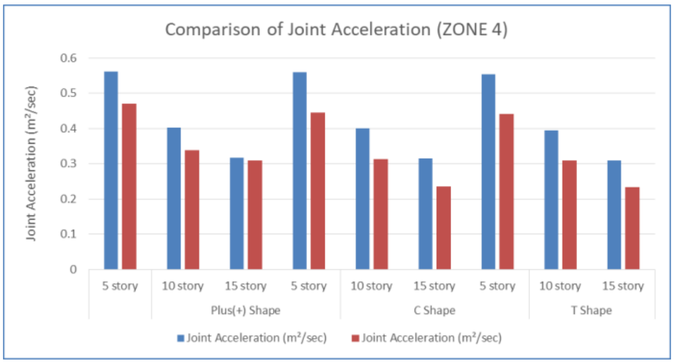

Fig.10 Comparison of joint acceleration (Zone IV)

SEISMIC ZONE 5							
Building type	No. of storey	Displacement (mm)		storey shear (kN)		Joint Acceleration (m^2/sec)	
		Without TLD	With TLD	Without TLD	With TLD	Without TLD	With TLD
	5 storey	13.82	13.24	7599.61	7051.1	0.842	0.707
Plus(+) Shape	10 storey	28.2	25.65	7697.58	6790.28	0.603	0.569
	15 storey	43.15	38.69	7735.99	6784.7	0.474	0.463
	5 storey	13.91	12.48	7665.68	6311.58	0.84	0.669
C Shape	10 storey	28.38	24.53	7766.34	6499.32	0.601	0.469
	15 storey	43.43	35.49	7804.13	6256.82	0.473	0.354
	5 storey	15.3	12.56	7310.65	6487.9	0.83	0.663
T Shape	10 storey	30.6	24.42	7509.52	6367.51	0.592	0.463

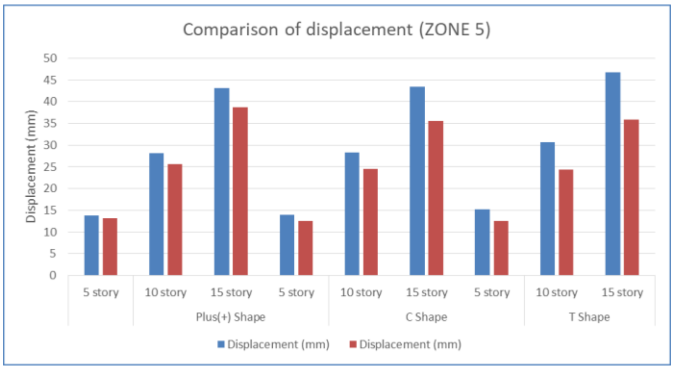

Fig.11 Comparison of displacement (Zone V)

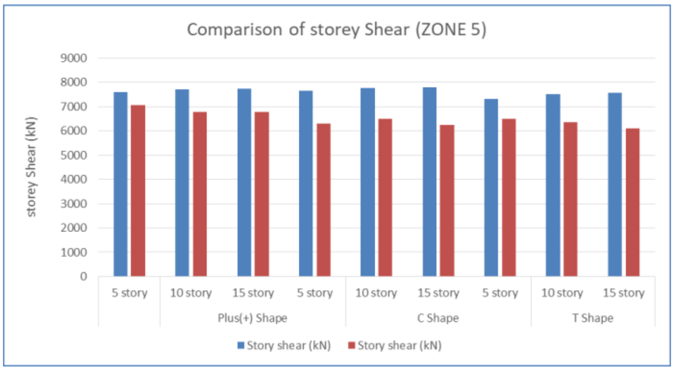

Fig.11 Comparison of storey shear (Zone V)

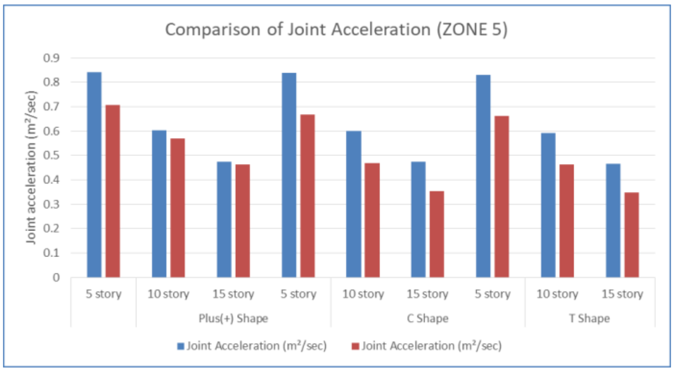

Fig.12 Comparison of joint acceleration (Zone V)

7. CONCLUSIONS

The important conclusions which can be derived from this research work are as follows:

(i) The reduction in joint displacement is higher for higher storey buildings as compared to low rise buildings. Hence TLD can be effectively used to reduce seismic excitations of high rise buildings.

(ii) The water tank placed on top of the buildings with plan irregularity is found to be an effective tuned mass damping mechanism.

(iii) The results also show the reduction in base shears by providing water tank. Hence the size of the structural members can be reduced up to some extent in high rise buildings. Which will results in the reduction of the overall construction cost.

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