



REVIEW ON SEISMIC ANALYSIS OF BUILDING WITH MULTILEVEL PARKING AND ELEVATED SWIMMING POOL WITH GARDEN AREA

Sanket dholu¹, Prof. J G Kulkarni²

¹PG Student, Department of civil Engineering, Arham Veerayatan Institute Of Engineering, Technology & Research, Mandvi-Kutchh

²Department of Civil Engineering, Arham Veerayatan Institute Of Engineering, Technology & Research, Mandvi-Kutchh

Abstract

Infrastructures are essential in all populated cities. To increase value in certain buildings there are associated risks that we take like providing swimming pool at terrace level. Water carrying structures are more important that must remain working following disasters such as earthquake. Most of the failures of structures after earthquakes are suspected to have resulted from the buckling caused by overturning moments of seismically induced liquid inertia and surface slosh waves. This paper investigates the seismic behaviour of water in the elevated swimming pool when subjected to earthquake forces. The main object of this paper is analysing building with extreme loads by different structural component to find and locate maximum design force, displacement, stresses etc. Hence get to know which a most effective design is.

Keywords-Elevated swimming pool, Sloshing effect, Lateral displacement control, TLCD;

I. INTRODUCTION

Urbanization is increase now days in India. In the addition, because of this, there is also a shortage of land in city area which is indirectly effect to increasing in land cost and due to this overall Price Hike in all Commodities.

The growing population has created many problems - one of the challenging ones being car parking which we come front almost every day. The problem of space for cars moving on the road, greater is the problem of space for a parked vehicle considering that private vehicles remain parked for most of time.

The trend of RCC high rise structure increasing in India. Many Leading construction and Real estate company is willing to do new in there project to attract people. Currently Terrace Garden and Swimming pool is one of them.

II. RESEARCH NECESSITY

Roads are being built for vehicle to play but are we also giving the car enough space to park? While residential projects doesn't have much problem with designated parking, the real problem comes with commercial spaces - many a time which is overcome by taking extra open spaces to park.

Families today, more than ever before, are placing greater demands on local communities for recreational facilities. Demand for quality facilities and services are at an all-time high. These changes have a direct impact on those on going future project belong to this group to give satisfaction towards their customer.

Multi-level Parking systems for some time have provided relief since they come with a number of advantages - utilisation of space, less maintenance and cost, lower construction cost, comfortable for the drivers, cost saving for builders by saving height or depth.

Here is the some example of this type of structure

- In India, New Delhi gets its first automated Multilevel Parking. It is 8th floor building with GF and First floor reserved for shopping complex and rest dedicates to Parking. Project is based on PPP model with NDMC & DLF, Which is leading construction company in India.
- The marina bay sands Singapore has a highest elevated 55 story swimming pool, length of 150 meter which is 3 times larger than Olympic size swimming pool.
- Bandra Ohm Residential Tower offers swimming pools enclosed in glass instead of balconies.

III. DESCRIPTION OF THE STRUCTURE

This is a commercial public building located at Maharashtra. Building is G+3 floors with basement. Which has 2 basement floors for parking purpose, GF for open occupancy, and above GF there are 3 floors, 2 of them is for shopping mall and restaurants while above two is swimming pool at top and second top is for machinery and swimming pool utility and service.

3.1. Building Dimension

Building is 70 meter in length and 35 metre in width. Height of each floor is 3.5 meter so height of the building from basement slab to top is 17.5 meter. Per floor slab area is 2450 m². Public lift and stair case is attaching separate and connect to main building with expansion join so it behave as a two separate structure.

3.2 Swimming pool Dimension

Swimming pool is located on terrace level, it has 50 meter in length and 25 meter in width and depth of the pool is 2 meter. So volume of the pool is 2500 m³ which contain 2,500,000 litre of massive water, weight of 2500 tone. So this is an extremely vulnerable during earthquake.

3.3 Parking Lot

Two basement floors are reserved for parking. This is generating heavy point load and moving load. Parking access by car lift which is attached separately with a main building it contains 300 cars & 1500 two wheelers that will generate 5880 KN of load (Two Floor).

3.4 Shopping mall & Restaurants

Commercial area is in 1st and 2nd floor which is accessible by lift as well as stair case. So there are 4900 m² area is reserved for commercial sell which contain dead load as well as live load.

IV. STRUCTURE COMPONENT USE TO REDUCE LATERAL DISPLACEMENT

4.1 Tuned liquid column damper

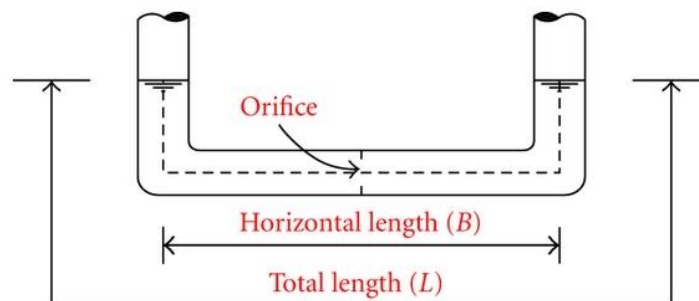


Figure 1TLCD

Tuned Liquid Column Dampers are a special type of Tuned liquid dampers relying on the motion of a column of liquid in a U-tube like container to oppose the forces acting on the structure. Damping is introduced in the oscillating water column through an obstacle called orifice in the liquid passage. The damping, however unlike TMDs, is amplitude dependent. The advantages of Tuned Liquid Column Damper systems include lower cost and maintenance and most importantly, such containers can be utilized for utility water supply, where in a TMD, the dead weight of the mass has no other functional use.

Tuned Liquid Column Dampers dissipates lateral vibration by combined action involving the motion of the water mass in the tube, where the restoring force is due to the gravity acting upon the liquid and the damping effect as a result of loss of hydraulic pressure due to the orifice inside the container.

4.2 Bracing System

The braces are usually install in vertically aligned spans. This system allows obtaining a great increase of stiffness with a minimal weight, and so it is favorable for existing structure for which the poor lateral stiffness is the problem. The bracings increase the lateral stiffness of the frame, thus increasing the natural frequency and also usually decreasing the lateral drift

However, increase in the stiffness effect a larger inertia force due to lateral vibration. While the bracings reduction the bending moments and shear forces in columns, they increase the axial compression in the columns. Since reinforced concrete columns are sturdy in compression, it may not create a problem in RC frame using bracings.

4.3 Shear Wall

Shear wall are one of the outstanding means of providing earthquake resistance to multi-storeyed reinforced concrete building. The structure is still injured due to some or the other reason during earthquakes. Behaviour of structure during earthquake motion depends on scattering of weight,

stiffness and strength in both horizontal and planes of building. To decrease the effect of earthquake reinforced concrete shear walls are used in the building.

V. Analysis Method

5.1 Model Formation

- Conventional Bare Frame of G+3 and two basements located at zone III.
- Structure with Shear wall of G+3 and two basement located at zone III.
- Structure with Bracing system of G+3 and two basement located at same zone.
- Structure with implementation of TLCD with similar geometric and condition.

As per the Indian Standard code for Earthquake IS:1893-2002, seismic static analysis can be performed by Equivalent Static Coefficient Method. Modeling of the structure is done in Staad pro. V8i Software. Here Shear wall provided only at corner in both direction to the 10 m and bracing is provided at alternate span as shown in fig.

Description	Dimension
Column section	0.300m x 0.600m
Beam section	0.300m x 0.450m
Slab thickness	0.175m
Shear wall thickness	0.150m
Bracing section 1	0.230m x 0.350m
Bracing section 2	0.200m x 0.200m
Pool bottom & side wall	0.400m

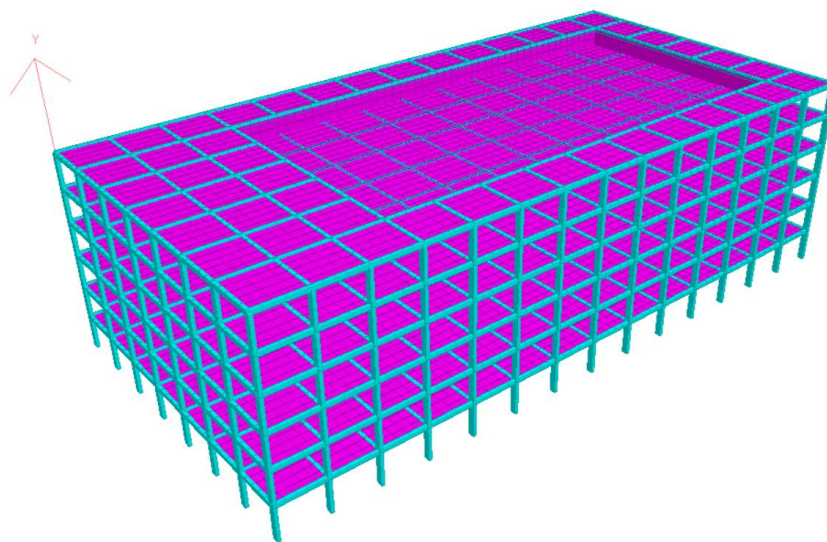


Figure 2 Conventional structure

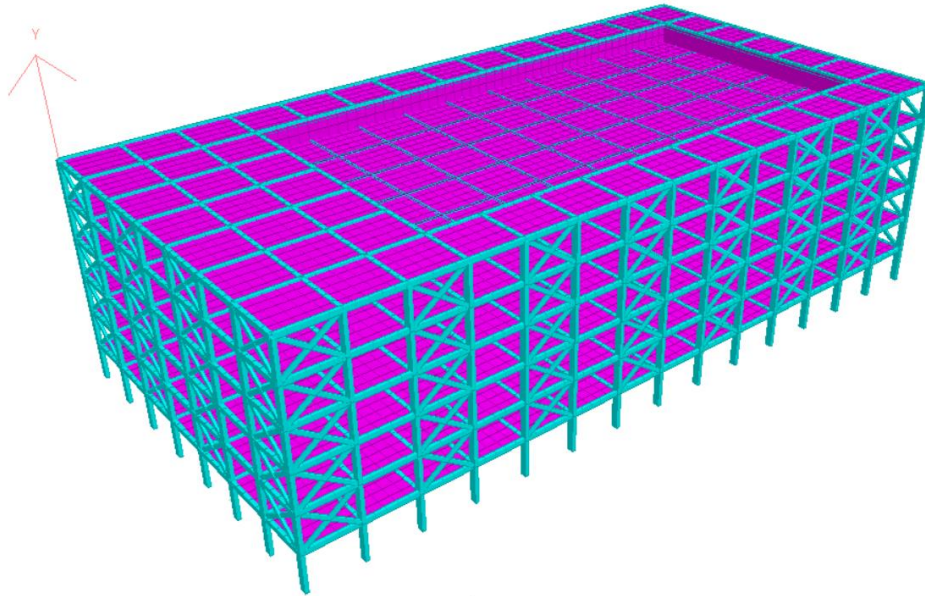


Figure 3 structure with braced

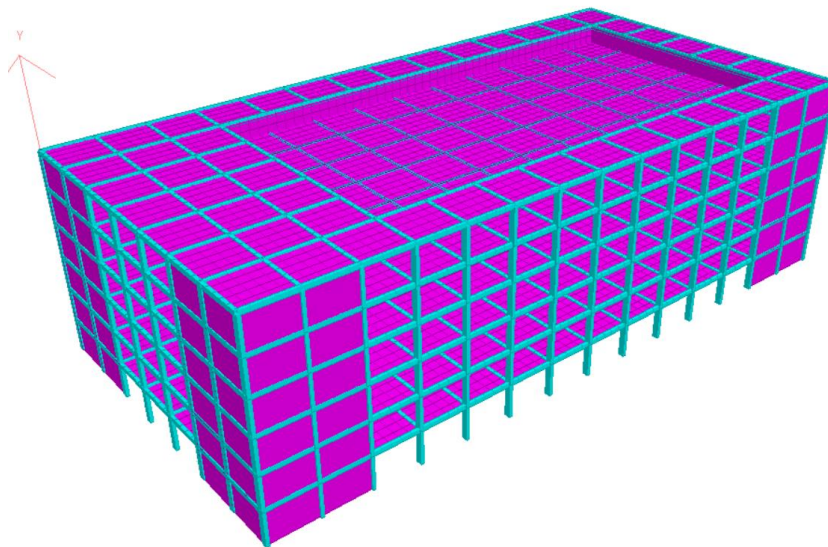


Figure 4 structure with shear wall

5.2 Applied Load

- Dead Load + Live Load:
 - Self-Weight is apply to all structure components.
 - As per **IS 1893(Part 1): 2002** impose load to be consider while seismic weight calculation is 50% for above 3 KN/m^2 . So here we can take 4 KN/m^2 so our live load is taken as 2 KN/m^2
 - Dead load is applied 2 KN/m^2
- Hydrostatic pressure in Pool Surface
 - Pressure due to water is 20 KN/m^2 which is applied on its side wall (Hydro static pressure) to its local direction also at pool bottom slab (pressure on full Plate)
- Parking area vehicle load
 - As per calculation there are 300 cars and 1500 two wheelers is occupy at the same time which is generate 5880 KN load. Divided by the floor area then it will be 2 KN/m^2 for car and 1.35 KN/m^2 for two wheeler. That is act as Pressure on full plate.
 - Moving load of vehicle is also consider , for that most worst condition is consider which is one plate is loaded and second adjacent plate is unloaded that will create hogging effect.

- We divided in a patten like chess board which is at a same time white colour box is loaded and black box is unloaded, while on the second case black box is loaded and white box is unloaded. Both of this case is consider in load combination.
- Earthquake load in X & Z direction
- Location: Maharashtra
 - Zone factor: III
 - Soil Type: Hard Dense
 - Important factor: 1
 - Response reduction factor: 5%

5.3 Load Combination detail

- When building is on full serviceable capacity then parking load, pool load, live load & dead load is generate at the same time.
DL + LL + Hydrostatic pressure + Parking Load + EQ (x & z)
- When the building is under maintenance pool is empty, parking area is almost nil, less amount of LL. Hence in this case stability issue may arise.
DL + LL + EQ (x & z)
- During the commercial close hour pool is full of water but parking lot contain less or no load.
DL + LL + Hydrostatic pressure + EQ (x & z)
- Pool is empty but other facility like shopping mall and restaurants open in this case
DL + LL + Parking Load + EQ (x & z)
- Auto Load Generation as per Indian Standard

5.4 Modeling of TLCD in small scale

5.4.1 Present structure concept with TLCD

In this structure TLCD introduce at the bottom slab of swimming pool as shown in figure. Now during the normal time TLCD is empty of water, when the earthquake happen water from the pool is transfer to the TLCD frame by means of any mechanical system sensor gate or anything, this result in two major advantage one is to reduce sloshing effect of water during earthquake time and second is to utilization of existing water to dissipate lateral displacement in the foam of TLCD.

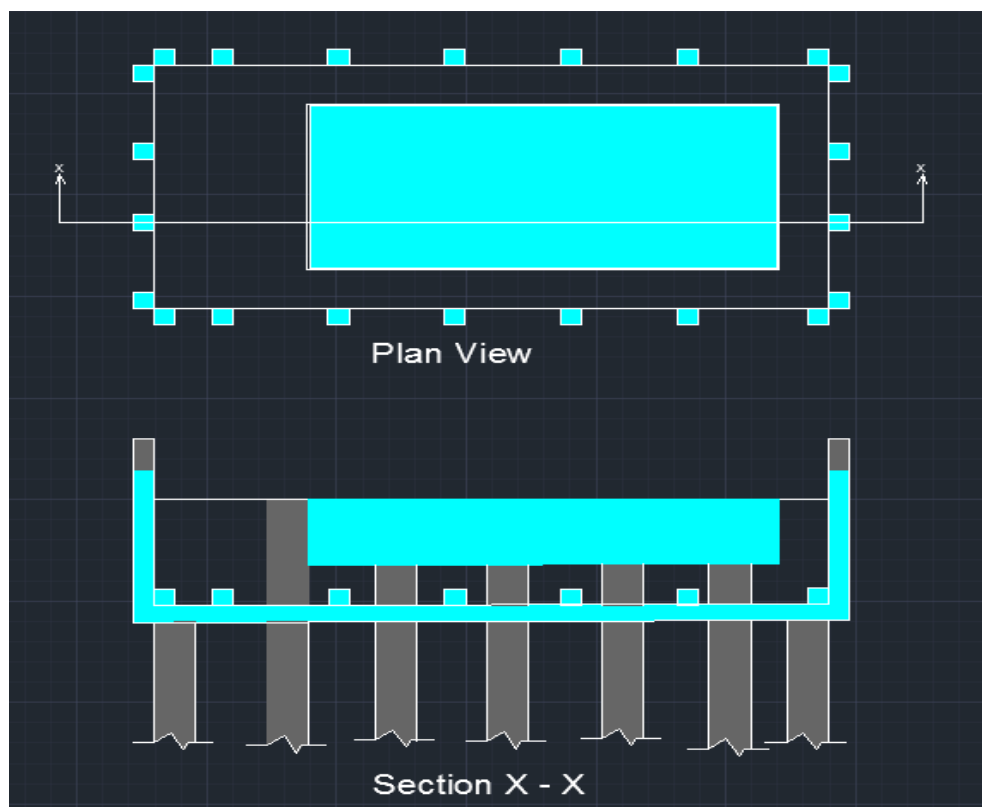


Figure 5 Arrangement of TLCD in structure

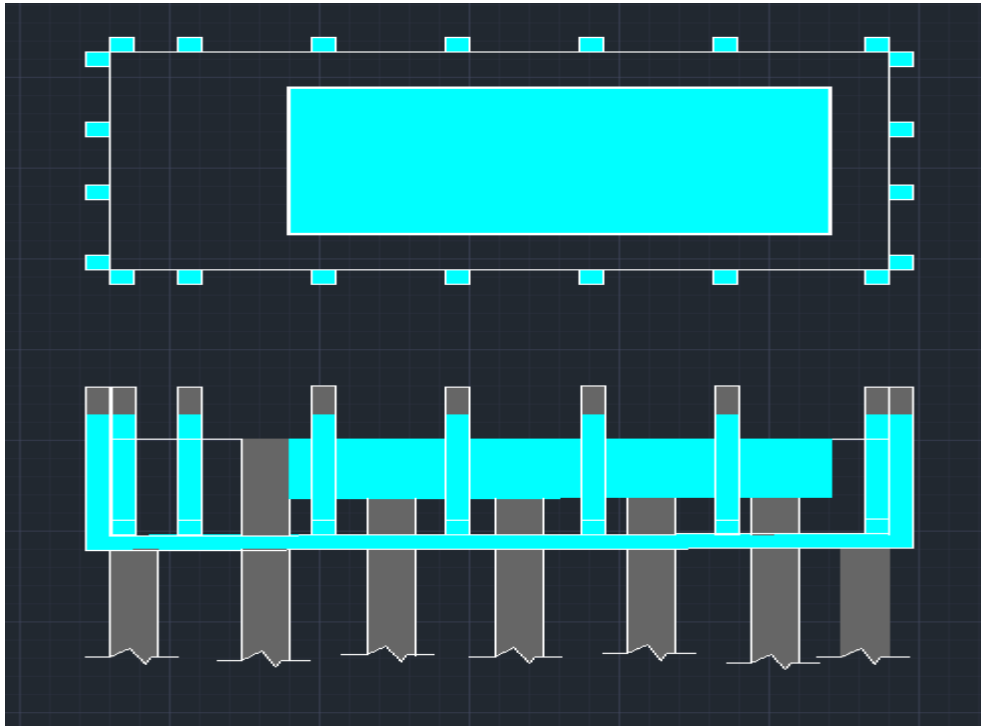


Figure 6 Arrangement of TLCD in Structure

TLCD is based on fluid movement therefore we can't analyze it in Staad Pro. Hence Ansys APDL is use to analyze TLCD but formation of the full structure is very difficult task in ansys and hence we only consider a small bare frame with TLCD and without TLCD to compare results. By doing this we can find the performance of TLCD during earthquake time.

Tuned liquid column damper is analyses in APDL, The fluid was modeled using FLUID 79, which defined by four nodes having two degrees of freedom at each node and with transformation in the nodal x and y directions. Degrees-of-freedom of the element in the interaction surface are joined with the adjacent node-degree-of-freedom of the tank wall in the normal direction of the tank. Two elements (Beam4, Link3) and (Shell63, Fluid79) were used to model the structure and TLCD respectively.

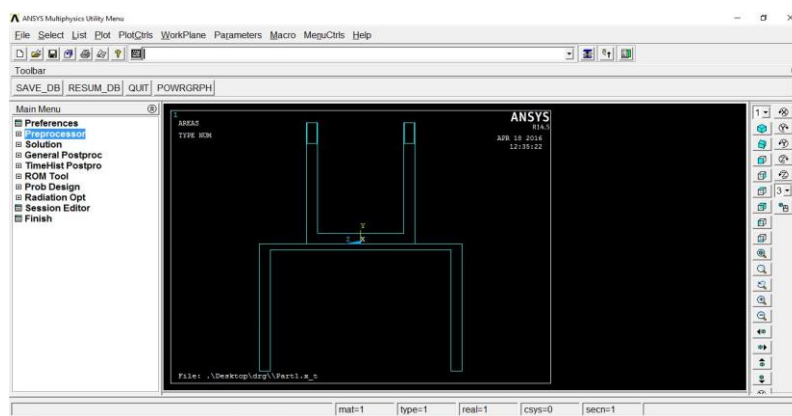


Figure 7 Ansys Model Formation

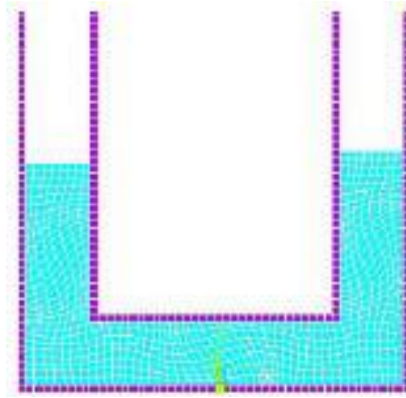


Figure 8 Ansys TLCD

VI. RESULTS & DISCUSSION

In this chapter, analysis of G+3 with two basement conventional RCC structural System, braced RCC structural system, Shear wall RCC structure system and TLCD with RCC structure is presented. Analysis of structures is carried out using Staad Pro & Ansys software.

The analysis is carried out considering earthquake loads on structures. Comparative analysis of conventional RCC structural system braced RCC structural system, shear wall RCC structure and TLCD structure is compared in terms of different parameters. Here we can't directly compare TLCD with the Shear wall and bracing hence individual comparisons is given for TLCD.

6.1 Axial Force

Axial Force (kN)			
Height	Conventional	Shear wall	Bracing
0	603.43	603.43	951.525
3.5	520.224	257.493	759.994
7	422.935	178.84	552.892
10.5	302.121	105.973	394.999
14	180.282	41.559	226.968
17.5	90.035	2.365	95.266

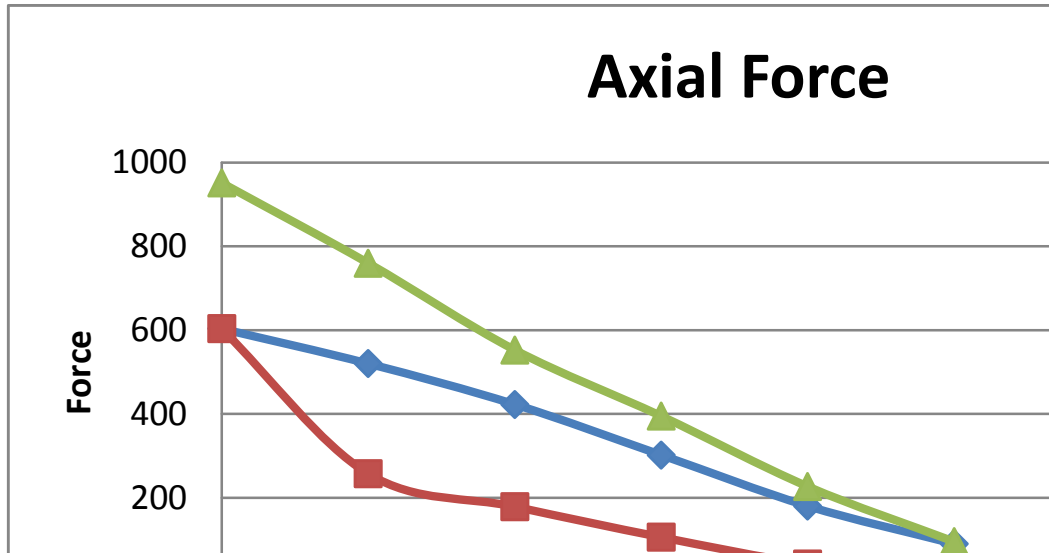


Figure 9 Axial Force

6.2 Shear Along Y-dir.

Shear Along Y-dir.			
Height	Conventional	Shear wall	Bracing
0	18.889	18.889	19.107
3.5	24.589	1.174	10.018
7	27.594	2.155	17.917
10.5	27.81	2.649	21.667
14	24.464	3.188	16.461
17.5	25.483	1.678	22.951

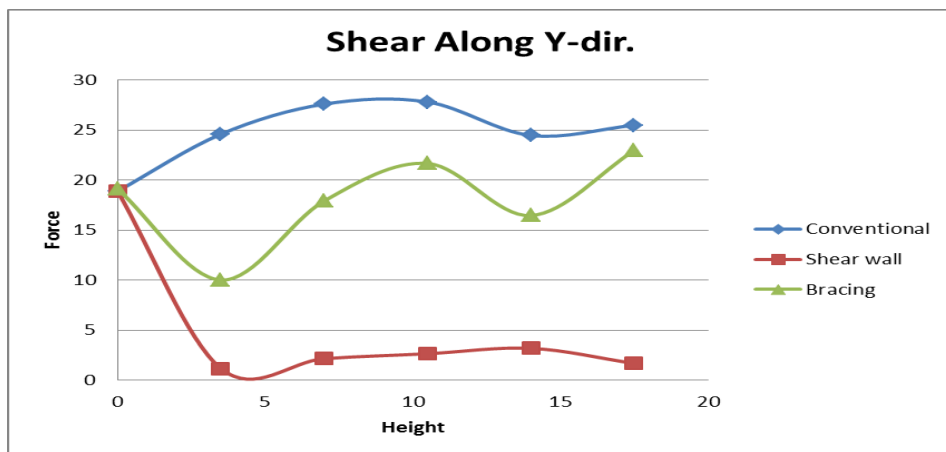


Figure 10 Shear along y-dir

6.3 Shear along Z-dir.

Shear Along Z dir.			
Height	Conventional	Shear wall	Bracing
0	21.095	21.095	29.025
3.5	28.135	1.615	18.178
7	27.594	2.155	17.917
10.5	27.81	2.649	21.667
14	24.464	3.188	16.461
17.5	25.483	1.678	22.951

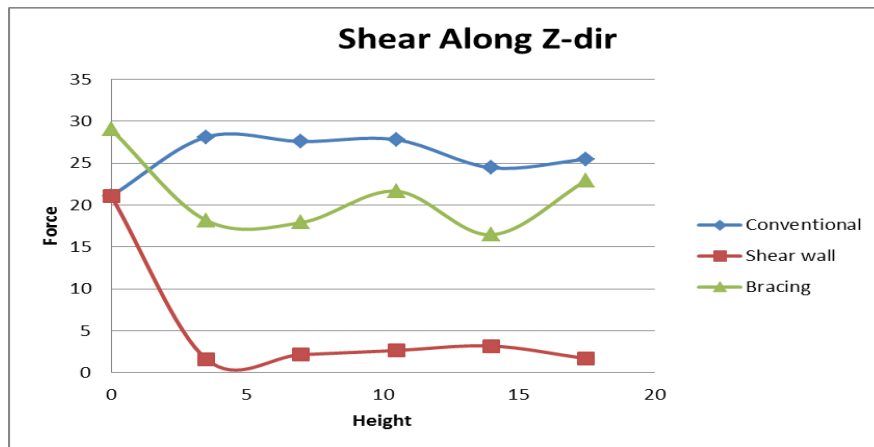
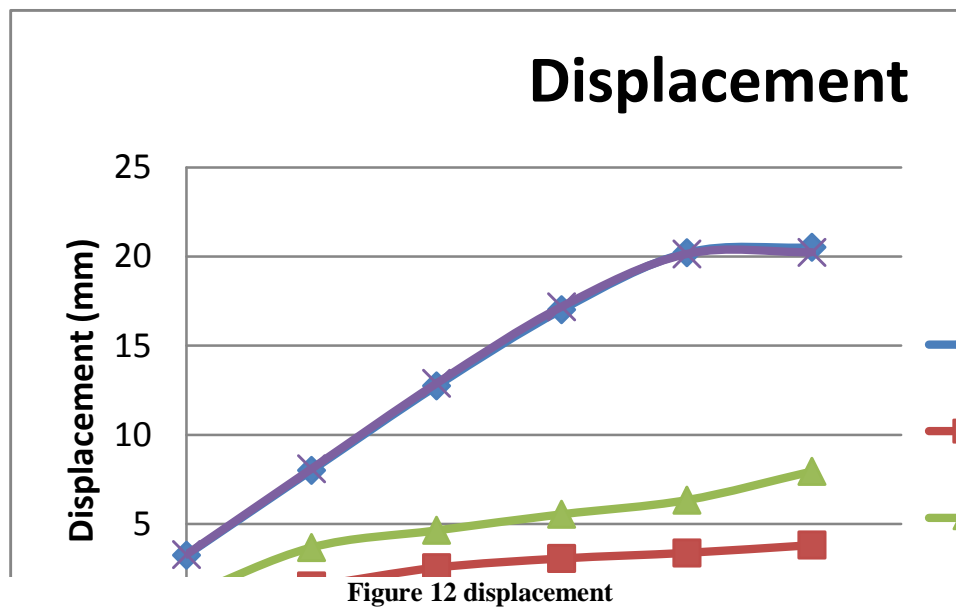


Figure 11 shear along z-dir

6.4 Displacement

Displacement				
Height	Conventional	Shear Wall	Bracing	Bracing at Pool Bottom
0	3.247	0.802	0.923	3.283
3.5	8.006	1.522	3.68	8.095
7	12.746	2.552	4.639	12.889
10.5	17.023	3.065	5.544	17.191
14	20.215	3.38	6.34	20.149
17.5	20.516	3.814	7.947	20.244



6.5 Tuned Liquid Column Damper

Model	Frequency of TLCD	Vibration Frequency	Vertical Height of water	Length of Horizontal Tube	Mass of Damper	Mass ratio	Displacement	Reduction%
Without TLCD		Random					1.68	
with TLCD Model 1	1.86	Random	3.5	0.15	2.1	1.8	1.43	14.88
With TLCD Model 2	1.5	Random	3	0.15	1.9	1.6	1.57	6.54
With TLCD Model 3	1.43	Random	2.5	0.15	1.7	1.5	1.29	23.21
With TLCD Model 4	1.48	Random	2	0.15	1.2	1	1.4	16.66

6.6 Based on above result for TLCD

From the numerous model with different parameters analyses some point which is mainly affect the property of TLCD performance is stated below by implementing that we can get most optimize TLCD design.

➤ Optimal mass ration

From the some case it is found that larger mass ratio results in better control performance but the geometry of the TLCD is affected by the mass ratio and become a larger. Since the mass of the structure is constant and increasing the mass ratio results in increasing the mass of the TLCD. Hence practically it is impossible to use mass ration greater then 3% and in this case it is better to use more the one damper which is call multiple tuned liquid column damper.

➤ Optimum length ration

It is observed that the larger mass ratio and L_h/L ratio result in better control performance in general. It is advantageous to increase L_h/L as much as possible. However L_h/L more than a certain there should value destroy the basic characteristic of TLCDs, because the liquid surface displacement will also become larger, so larger displacement greater then a vertical column should be avoided in the design of a TLCD.

➤ Effect of frequency

The frequency of an single TLCD and a MTLCD with a low frequencies range are similar. If the range is smaller than the optimum, the frequency response of the MTLCD resembles that of an STLCD, and so in a way, the MTLCD loses its effectiveness. So as range is very small compare to structure frequency, MTLCD act almost like an STLCD

6.7 Design as per optimize parameter

A Bhuj earthquake record load was imposed on the structure. The maximum acceleration response of a properly tuned structure-TLCD under earthquake excitation is shown in next Table and compared with the structure alone. As can be seen, Load was reduced up to 25% by adding a TLCD.

Type of Model	Max Acceleration	Acceleration Reduction	Displacement	Reduction %
Without TLCD	1.65		0.016	
with TLCD Model 3 Optimized design	1.3	21%	0.012	25%

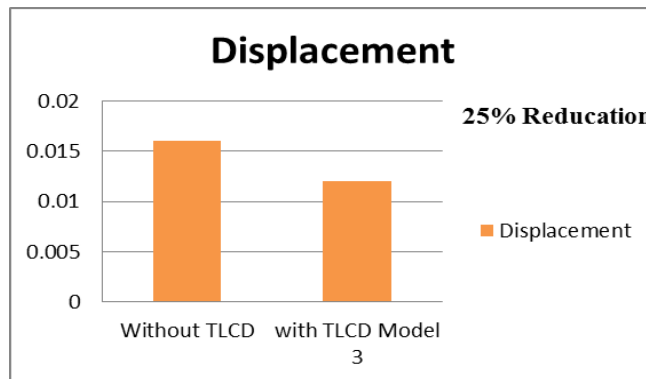


Figure 13 Structure with and without TLCD comparison

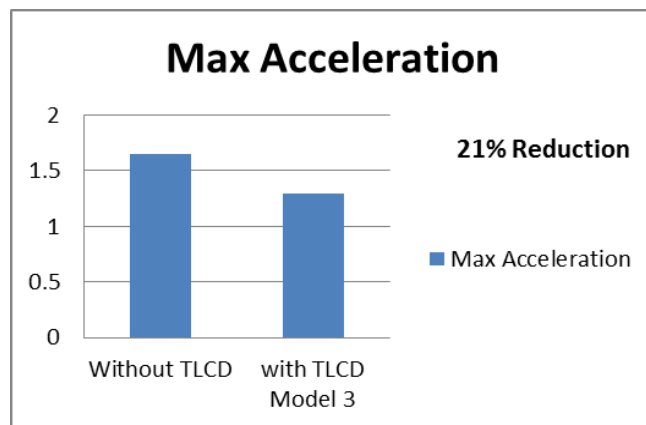


Figure 14 Structure with and without TLCD acceleration

VII. CONCLUSION

7.1 Displacement

- Shear wall are most effective in minimizing lateral displacement Peripheral braces do not execute larger lateral displacement then shear wall however this are smaller than that in conventional building.

7.2 Forces

- Axial force in corner column is found to maximum in the lowest segment and reduces upwards, this reduction is from gradual at a moderates pace.
- In the structure with shear wall it reduces statically from the base and the second basement level and then almost uniform thereafter. The rate of reduction is slow as compare to conventional structure.
- In case of braced structure maximum axial force attracted by worst column is form to reduce almost uniformly up to the top. The rate of reduction is the maximum in this case.

7.3 Tuned Liquid Column Damper

- As discuss above TLCD is depends on some parameter as well as earthquake frequency which is not predictable and hence we can't give perfect amount of displacement reduction. However it is also favourable in all case as it reduces lateral displacement upto good amount.
- If we design TLCD at optimized parameter and also give optimized frequency of vibration then it reduces 25% of lateral reduction which is large reduction in structure vibration.
- If the frequency of TLCD is smaller than the structure frequency, Multi tuned liquid column damper is act similar as a Single tuned liquid column damper. Hence it is advisable to design a different amount of frequency which improve a reduction of displacement.

REFERENCES

- [1] H.Kosaka, T.Noji, H. Yoshida, E.Tatsumi, H. Yamanaka & A.K.Agrawal, “**Damping Effects Of A Vibration Control Damper Using Sloshing Of Water**” Mitsui Construction Co Ltd, Japan, ISBN 90 5410 0605.
- [2] Roshni. V. Kartha, Ritzly. R, “**Tuned Liquid Damper To Control Earthquake Response In A Multi-Storied Building Frame**”, Issn: 2248-9622, Vol. 5, Issue 8, (Part - 4) August 2015, Pp.49-56
- [3] Bharadwaj Nanda, Kishore Chandra Biswal, “**Application Of Tuned Liquid Damper For Controlling Structural Vibration Due To Earthquake Excitations**”, Isec-6, Zürich, June 21–26, 2011
- [4] Jans Vejičko, Līga Gaile, “**Overview of tuned liquid dampers and possible ways of oscillation damping properties improvement**”, *10th International Scientific and Practical Conference, Volume I*, pp. 233-238.
- [5] A. Samanta and P. Banerji, “**Structural Control Using Modified Tuned Liquid Dampers**”, 14th World Conference on Earthquake Engineering, October 12-17, 2008, Beijing, China.
- [6] Pradipta BANERJI, “**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.
- [7] Dr. Suchita Hirde, Ms. Asmita Bajare, Dr. Manoj Hedao, “**Seismic Performance Of Elevated Water Tanks**”, International Journal of Advanced Engineering Research and Studies ,E-ISSN2249 – 8974.
- [8] Mangulkar Madhuri. N., Gaikwad Madhukar V., “**Review On Seismic Analysis Of Elevated Water Tank**”, IJCIET, Volume 4, Issue 2, March - April (2013), pp. 288-294.
- [9] Mohd Atif, Prof. Laxmikant Vairagade, Vikrant Nair, “**Comparative Study On Seismic Analysis Of Multistorey Building Stiffened With Bracing And Shear Wall**”, IRJET, Volume: 02 Issue: 05 ,Aug-2015.
- [10] A. Di Matteo , F. Lo Iacono , G. Navarra , A. Pirrotta, “Experimental validation of a direct pre-design formula for TLCD” , Elsevier, 27 May 2014.
- [11] Sakai F., Takaeda S., and Tamaki T., “**Tuned Liquid Column Damper – New type device for suppression of building vibrations**,” Proc. Of International conference on High-rise Buildings, Vol. 2, Nanjing, China, (1989).
- [12] Koh C.G., Mahatma S., and Wang C.M., “**Reduction of structural vibrations by multiple-mode liquid dampers**”, Engineering Structures, Vol. 17, No. 2, (1995),pp. 122-128
- [13] Gao H., Kwok K.C.S, Samali B., “**Optimization of Tuned Liquid Column Dampers**”, Engineering Structures, Vol. 19, No. 6, (1997), pp. 476-486.
- [14] Yamamoto K. & Kawahara M., “**Structural Oscillation Control using Tuned Liquid Damper**”, Computers and Structures, 71, (1999), pp. 435-446.
- [15] Pal N. C., Bhattacharyya S. K. and Sinha R. K., “**Experimental investigation of slosh dynamics of liquid-filled containers**”, Experimental Mechanics, Vol. 41, No. 1, March 2001: p. 63-69.