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Advance earthquake resistance technique to reduce the seismic intensity by using tuned liquid damper

Abhijeet A. Pawar[#1], Dayanand R. Mathwale[#2], Mahesh B. Patil[#3], Gopal S. Salunke[#4], Ashish R. Kondekar [#5]

[#1-4] *UG Student, Department of Civil Engineering, Savitribai Phule Pune University, Pune*

[#5] *Assistant professor, Department of Civil Engineering, Savitribai Phule Pune University, Pune*

[1] *abhijeetpawar8081@gmail.com*

[2] *dayanandmathwale@gmail.com*

[3] *mahesh199812345@gmail.com*

[4] *gopalsalunke100@gmail.com*

[5] *ashish.kondekar.sits@sinhgad.edu*

Abstract

TLD can be used in building structures to minimize the vibrations created by earthquake. The performance of the tuned liquid dampers is measured in terms of efficiency and robustness. 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 can cause seasick feeling for the residents living on top. Mass damper, Liquid dampers, base isolators and other supplemental damping systems (SDSs) are among the various alternatives used to reduce the vibrations on the structures. This paper will focus on one of these methods, Tuned liquid Damper (TLD). A TLD 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. TLD has also been found to be very effective in cancelling vibrations caused due to wind. Tuned Mass Dampers (TMDs) are the origin of TLDs. TMDs implemented in most tall buildings to achieve vibration control since the 1950s.

Keywords— Tuned liquid damper, Frequency, Sloshing energy, Vibrations, etc.

I. INTRODUCTION

The human population is increasing day by day and so is the need of more houses. This puts lots of pressure on construction Vibration control is an important aspect when designing buildings, especially if are tall. Buildings can get subjected to real vibration due to wind earthquakes. When an earthquake waves travel, through the building subjected to massive forces, acceleration and displacement that makes the building highly unstable and eventually it collapses. Since our structures are highly prone to earthquake disasters and one of the few problems wherein prevention is must. It is better to solidify our structures than facing the loss of human life and property. The need for earthquake resistance is must in the upcoming future. TLD is effective in controlling the response of a structure to broad-banded long duration earthquake ground motions. It shown that a TLD water particle motion formulation based on a shallow-wave theory proposed by earlier researchers is reasonable for predicting the response of a structure with a TLD attached to it and subjected to large amplitude earthquake type motions at its base. It is, however, interesting to note that experiments show that the above theory consistently under-predicts the reduction in structural response for a variety of structures and ground motions. This possibly due to energy being dissipated by breaking waves, which is seen to occur during the excitation phase in the software analysis.

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II. METHODOLOGY

A. Materials

If we consider experimental analysis, then horizontal shake table is used to induce vibrations on the modelled structure and calculate its resistivity against it. This is a device for shaking scaled slopes, structural models or building components with a wide range of simulated ground motions, including reproductions of recorded earthquakes time-histories. By considering scale ratio of 1: 100 a (G+9) model replicating the actual site model was prepared. The diameter of bars being 10 mm for beams and columns. The slabs are depicted by using aluminum or steel sheets along with walls of the tuned liquid damper. The liquid used in tuned liquid damper is water. If we consider software analysis, E-tabs model is used and in this software, method of response spectrum analysis is applied to understand maximum and minimum displacement comparison for buildings with and without tuned liquid damper. Response spectrum is an important tool in the seismic analysis and design of structures. It describes the maximum response of damped single degree freedom system to a particular input motion at different natural periods.

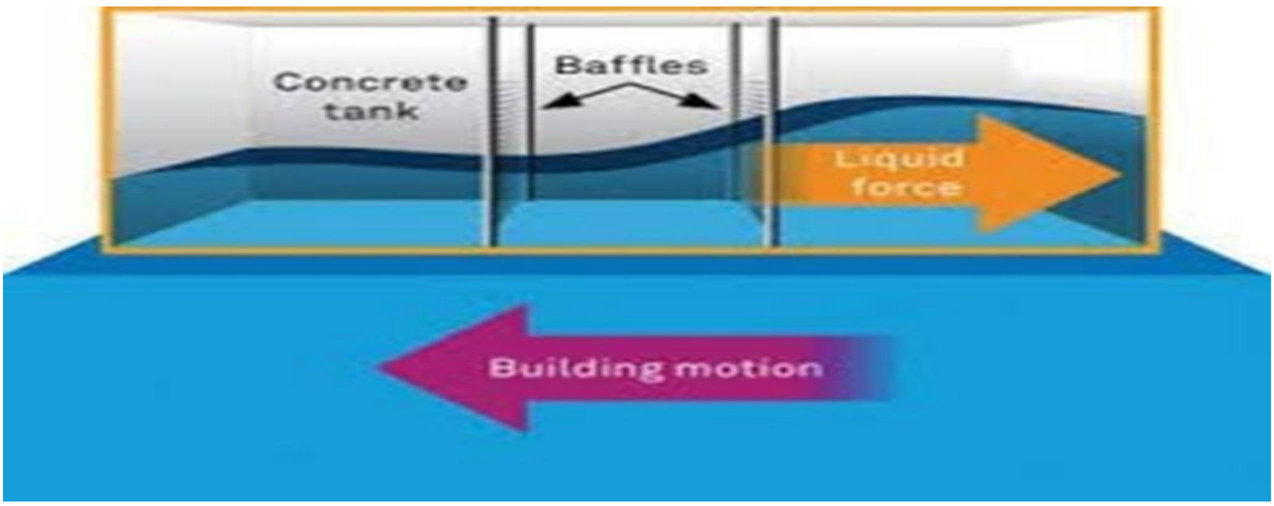

Fig. 1 Principle of tuned liquid damper

Fig. 1 The figure above represents the movement of water in the tuned liquid damper during an earthquake. As this principle obeys Newton's second law of motion, the sloshing energy of water opposes the swaying motion of the structure caused due to seismic energy of waves.

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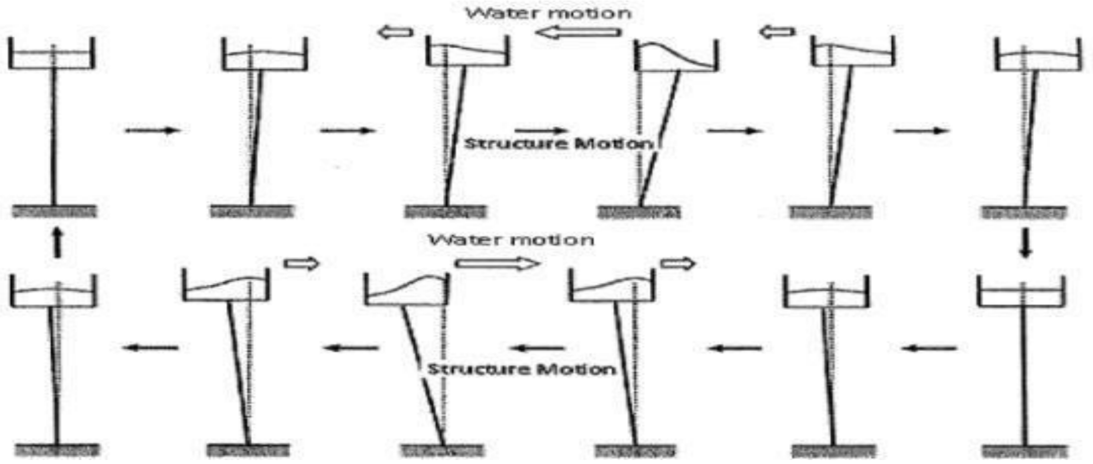

Fig. 2 Water motion vs Structure motion (8)

Fig. 2 The figure above gives us a brief idea about the movement of water in the tank during seismic excitation. Here as we can see the motion of water is exactly in the opposite direction as of the motion of the structure dominated by seismic waves. We consider in this paper software Analysis method for TLD and differentiate between (G+9) building as with TLD and without TLD.

B. *Model preparation on ETABs software*

Model without tuned liquid damper details

1) Dead load-3KN
2) Live load-2KN
3) Frame Load-1KN
4) Elevation of each floor-3.5m (G+9)

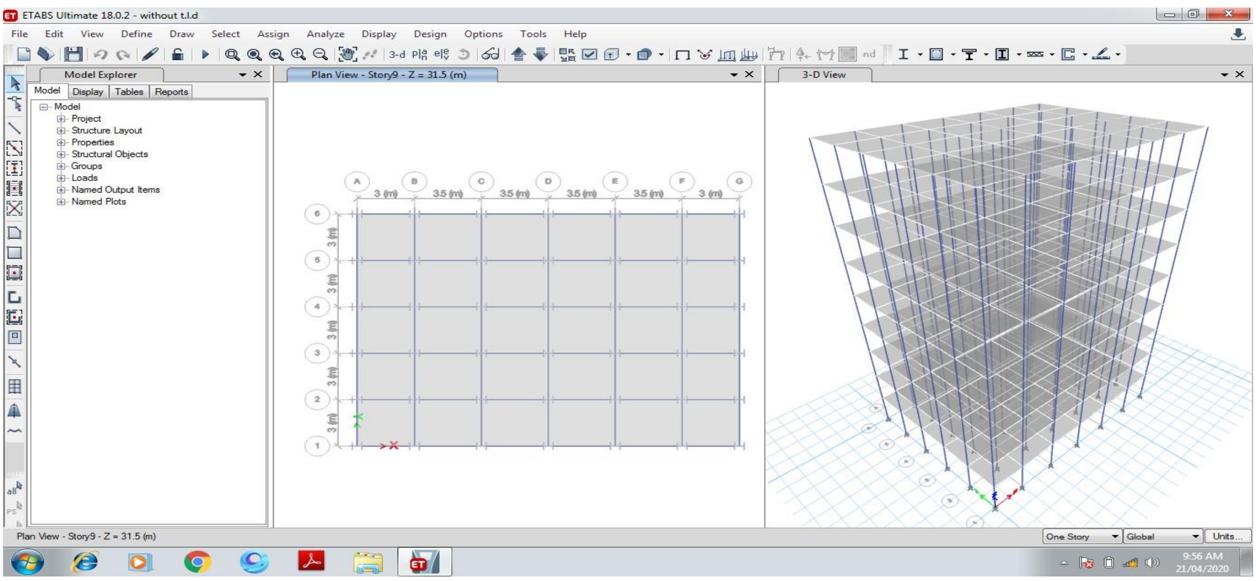

Fig.3 Plan of each floor and structure without TLD

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Model with tuned liquid damper

1) Dead load-3KN
2) Live load-2KN
3) Frame Load-1KN
4) Elevation of each floor-3.5m (G+9)
5) Height of the tank =2m
6) Volume of tank=4% of mass structure

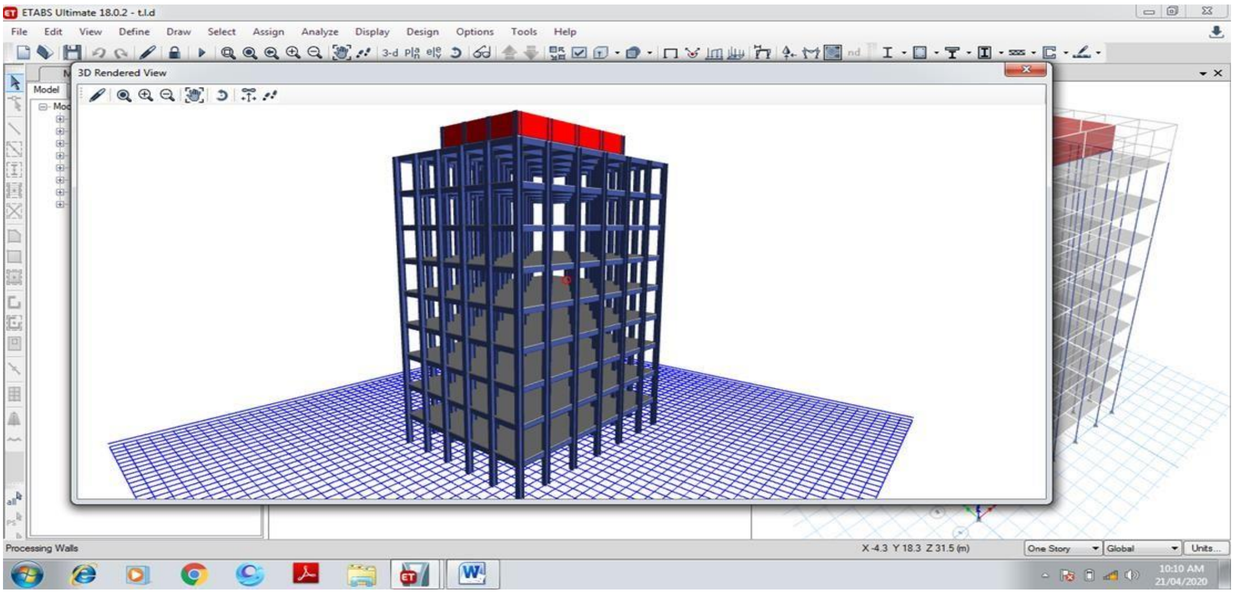

Fig.4 resembles the rendered view of TLD structure in e-tabs

III. RESULTS AND DISCUSSION

1. Analysis of base shear

Table no.1 Comparison of base shear in structure with and without TLD

Load Pattern	Without TLD	With TLD
	Base Shear	Base Shear
	kN	kN
EQ+X	293.461	411.4061
EQ-X	293.461	411.4061
EQ+Y	236.9121	325.8418
EQ-Y	236.9121	325.8418

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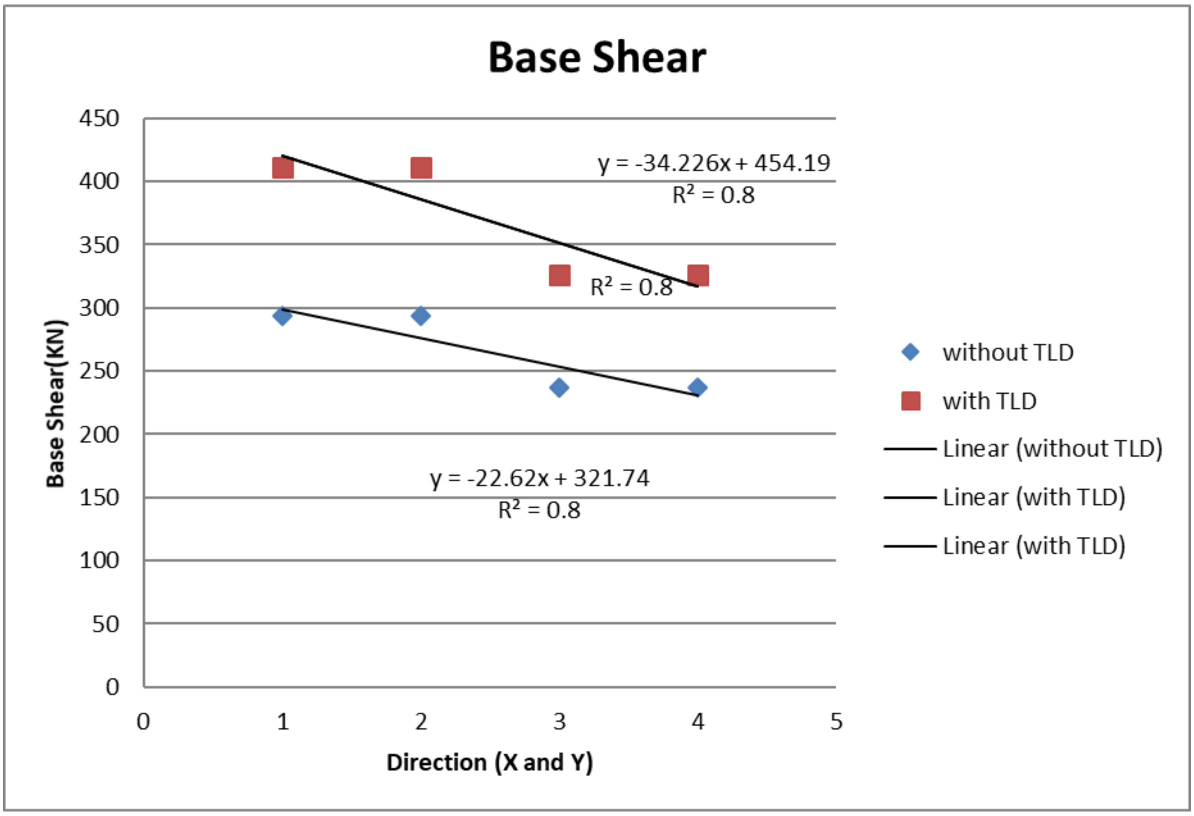

Graph no.1 Comparison of base shear in structure with and without TLD

2. Seismic displacement without water tank

Analysis of seismic displacement

Table no. 2 Comparison of seismic mass displacement in structure in x-direction

Story	**Without TLD**	**With TLD**
	UX	**UX**
	mm	**mm**
Story11	0	7.547
Story10	10.188	7.53
Story9	9.429	7.197
Story8	8.531	6.651
Story7	7.477	5.926
Story6	6.285	5.061
Story5	4.996	4.096
Story4	3.667	3.077
Story3	2.377	2.055
Story2	1.227	1.104
Story1	0.363	0.346
Base	0	0

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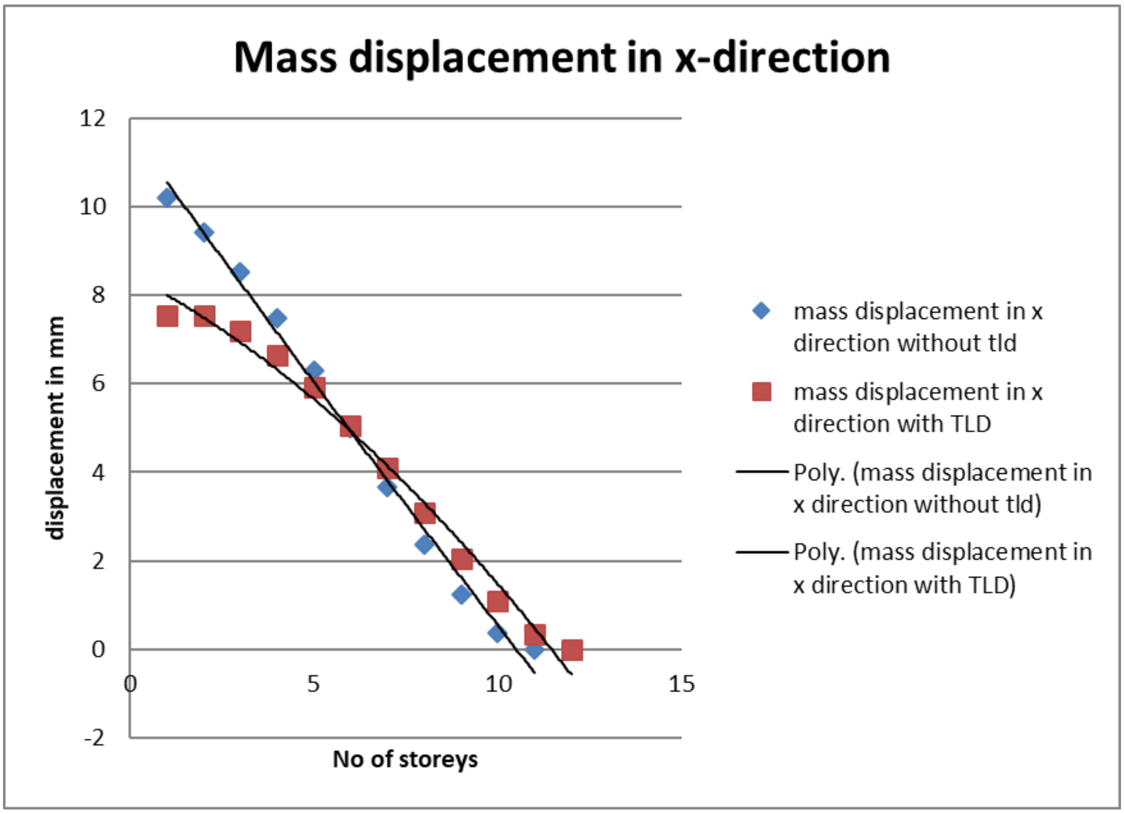

Graph no. 2 Comparison of seismic mass displacement in structure in x-direction

3. Wind displacement analysis

Table No. 3 Comparison of wind displacement with and without TLD in x-direction

Story	Without TLD	With TLD
	UX	UX
	mm	mm
Story11	0	6.778
Story10	12.026	6.765
Story9	11.27	6.525
Story8	10.364	6.125
Story7	9.267	5.573
Story6	7.973	4.881
Story5	6.503	4.063
Story4	4.907	3.145
Story3	3.272	2.166
Story2	1.738	1.2
Story1	0.528	0.386
Base	0	0

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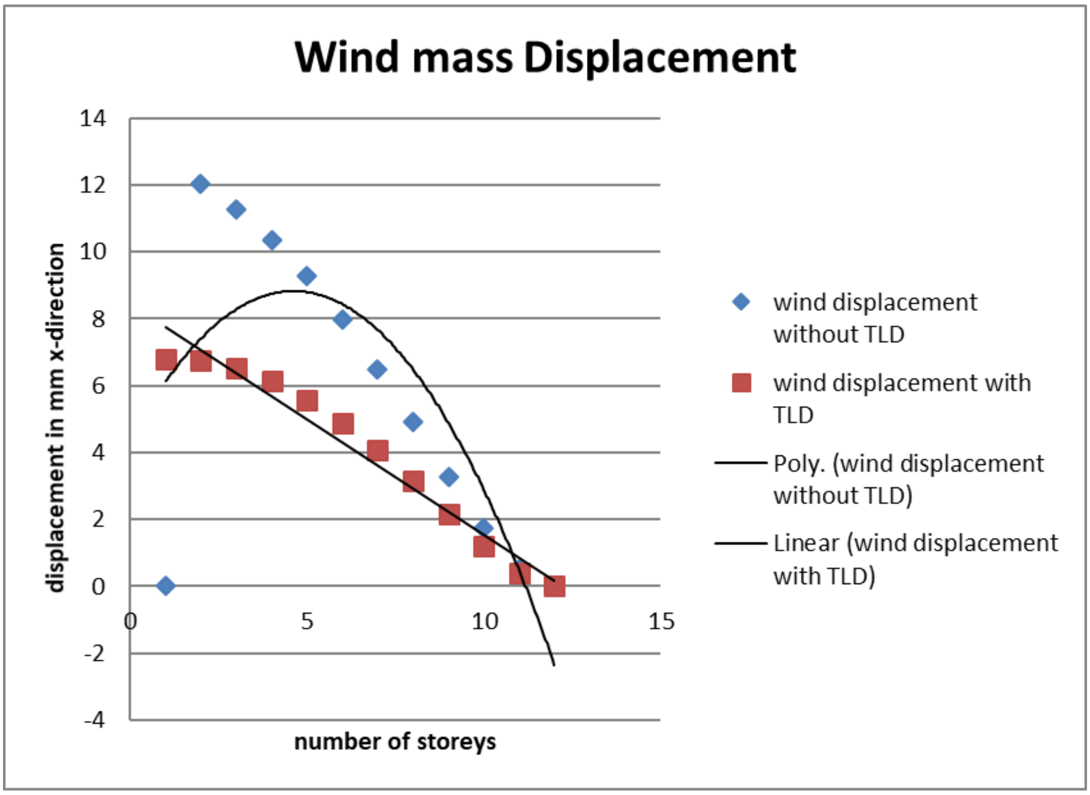

Graph no. 3 Comparison of wind displacement with and without TLD in x-direction

4. Calculation of hydrostatic force on exterior tank walls

1) Formula for calculation of pressure: - Density X Gravity acceleration X Length X (height height)/two. Thus, we got the pressure as 17.17KN

2) Force=Pressure/Area =5.72KN/m2., AX+BY+CZ+D= Hydrostatic Load, where x, y and z are directions for hydrostatic loading. Value of x and y is zero and 17.17KN/m2 at height 32.5 and 33m respectively. Thus by using equation C*Z+D=hydrostatic load at certain height. We have calculated the above force.

IV. CONCLUSION

1. The inclusion of Tuned liquid damper in the G+9 structure proves to be beneficial in reducing the impact of the seismic waves on the structure. Further improvisation is possible by using a denser liquid in the tank, which depends on need of the structure.
2. The inclusion of TLD showed improved resistance towards seismic waves and wind pressure. The model analyzed at seismic zone 3 with design wind speed of 39m/s.
3. This technique is much suitable for steel structures and preferred steel grade is Fe345.

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