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Seismic Analysis Of High-Rise Building Using Tuned Liquid Damper

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Abstract

Current patterns in development industry requests taller and lighter structures, which are likewise progressively adaptable and having very low damping worth. This builds disappointment potential outcomes and furthermore issues from usefulness perspective. Presently a-days a few procedures are accessible to limit the vibration of the structure, out of the few methods accessible for vibration control, idea of utilizing TLD is a more up to date one. This study means to consider the feasibility of Tuned Liquid Dampers (TLD) in decreasing the seismic vibration of a structure when it is exposed to horizontal excitation. TLD is a water bound compartment, or essentially a water tank, which utilizes the sloshing vitality of water to diminish the dynamic reaction of a structure when it is exposed to excitation. In this investigation, a technique for design TLD for a structure has been recommended and a strategy has been proposed to demonstrate the TLD in ETABS 2018 software. At that point, numerous investigations have been done to break down the impact of various parameters of TLD which may influence its presentation. Examinations are directed with shifting mass ratio, depth ratio, Different types of soil, Seismic zones of India. It is analyzed by response spectrum dependent on maximum base shear, maximum displacement of top story and maximum story drift. With reference to the outcomes from these examinations, ends are inferred and suggestions are given for an ideal design of TLD.

Keywords: *TLD, Etabs 2018, seismic zones of India.*

Introduction Due to dynamic loads, such as those caused by wind, earthquakes, etc., various passive control devices have been developed to control the vibrations of civil engineering structures. Passive energy dissipation systems provide a variety of materials and tools for enhancing damping, stability and strength, which can be used in new structures for both natural hazard mitigation which restoration of ageing or defective structures. Significant attempts have been undertaken in recent years to improve the idea of energy dissipation or supplementary damping into a feasible technology and many of these devices are used worldwide. There has been a rise in the level of occurrence of natural disaster incidents (earthquakes and hurricanes) in the past couple of years. During these activities strong shaking and potential collapse of structures will result in major human and economic losses. Damping is one of the

most significant parameters that limit structure response through these dynamic events. Recently, a method has been developed for increasing the damping of a building by adding one or more liquid-fluid tanks to the structures. The sloshing movement of the fluid resulting from the vibration of the structure dissipates a portion of the release of energy by the dynamic load and thus improves the structure's equal damping. Those tank devices are called Tuned Liquid Dampers (TLD). A variety of TLDs have been added to different buildings in recent years to reduce the vibration rates of the structures during their daily service. Vibration management is rooted mainly in space-related issues such as monitoring and pointing, and in versatile space structures, the concept has increasingly shifted to civil engineering and infrastructure-related issues such as building and bridge safety from severe earthquake and wind loads. Tuned mass dampers (TMD) were commonly used in the mechanical engineering systems for vibration control. TMD theory has been implemented in recent years to reduce the vibrations of tall buildings and other structures in civil engineering. Dynamic absorbers and tuned mass dampers are
the realizations of tuned absorbers and tuned dampers for the application of structural vibration management. In these devices, the inertial, robust, and dissipative elements are: mass, spring, and dashpot (or material damping) for linear applications and their rotary equivalents for rotational use. Such devices are sized from a few ounces (grams) to several tones, depending on the specification. For vibration reduction applications, other configurations such as pendulum absorbers / dampers, and sloshing liquid absorbers / dampers were also found.
TMD is installed to a structure to get the structure's dynamic response. The frequency of the damper is tuned to a different structural frequency such that the damper resonates out of phase with structural motion when that frequency is excited. Typically, the mass is connected to the building through a spring-dashpot device, and the dashpot dissipates energy as relative motion occurs between the mass and the structure.

DAMPERS

Damping is a process in which a system's energy is slowly decreased or the vibration intensity begins to decrease and eventually the system's vibration is removed entirely. The rate at which the amplitude decreases depends on the amount of damping.
Damping is described by a quality factor Q where Q is the frictional loss of energy per cycle

$2\pi/Q = -\Delta E/E$

Where, ΔE = energy lost per cycle

E = total energy stored in the wave

$A = A_{\circ} \exp(-\pi r/Q\lambda) = A_{\circ}\exp(-\alpha r)$

$A = \omega/2QV$

To free these structures from the structural displacement caused by earthquake and wind, various techniques were introduced that can be loosely divided into 4 categories.
i) Active, (ii) Passive, (iii) Semi-active and (iv) Hybrid control.

➢ **Active control system**:

The active control system uses external forces to control the vibrations because, in comparison to the dynamic loading, they may provide additional energy to the controlled structure Active control systems require considerable external power to operate actuators which provide the structure with a control force. An active control system should calculate and estimate the response across the entire structure to define suitable control forces. Active control techniques are often more difficult than passive ones. Example- Active tuned mass damper, active stiffness variable damper etc.

Passive control system:

By using the motion of the system, a passive control device produces forces at the device's position. A passive control system, through the forces created, reduces the demand for energy dissipation on the structure by absorbing some of the energy input. Thus, the structural system cannot be energized by a passive control device. In addition, a passive control device requires no external power supply. Example- Base insulation, mass damper tuning (TMD), friction dampers, etc.

➢ **Semi active control system**:

Semi-active control systems incorporate the beneficial characteristics of passive and active control devices. Like passive control devices, semi-active control devices produce forces as a result of the motion of the structure and cannot introduce energy to the structural system. However, like an active control system, a controller uses feedback measurements of the excitation to produce a suitable signal for the semi-active system. Furthermore, the operation of a semi-active control system requires only a small external power source. Example- orifice damper, controllable dampers of fluids etc.

➢ **Hybrid control system:**

Usually, a hybrid control system contains a mixture of passive and active or semi-active devices. Since multiple control systems are working, some of the constraints and limitations that occur when each system operates alone can be alleviated by hybrid controls. But higher output levels can be reached. Since the passive system accomplishes a portion of the control goal, less active control effort, which means less power resource, is needed. A side advantage of hybrid systems is that, unlike a fully active control system, the passive components of the control also provide some degree of safety in the event of a power failure. Example- hybrid mass damper and hybrid base isolation.

Tuned Liquid Damper (TLD)

If earthquake forces strike a structure, it imparts vibration-causing energy to it, if we can absorb the energy imparted by some means, then we can reduce the building's vibration amplitude. Typically, this is called damping. One way to do this is by making the structure simpler with a "Tuned Liquid Damper (TLD)" It was first implemented by Bauer in the 1980s and later built in many other structures, the San Francisco tower recently being One Rincon Hill. TLDs are essentially a tank that is partially filled with water or often with a sugar solution that is normally placed at the rim. Buildings under earthquake forces tend to vibrate at a particular frequency called natural frequency, TLDs are built to have the same natural frequency such that liquid sloshing in the tank under external excitation creates antiphase to the building movement.

Tuned liquid mass damper is made of liquid sloshing tanks and depth of liquid mass. It is a passive control system installed on top of the structure, which disperses energy from the input excitation through the friction of the liquid boundary layer. The establishment of TLD takes place at Nagasaki air terminal pinnacle, Japan's Shin Yokohama Prince Hotel.

Advantages of Tuned Liquid Damper:

➢ Low cost installation and maintenance

➢ Easy installation in new and existing buildings

➢ Non-restriction of unidirectional vibration

➢ Easy natural frequency adjustment of the tank simply by changing the water depth.

➢ Water can be used in tanks during emergencies such as fire hazards.

Parameters can affect TLD behavior

There are various parameters influencing TLD's actions in building. Those include natural building frequency, excitation frequency ratio, mass ratio, depth ratio, tuning frequency ratio, tank form and tank position at the house. All of these are set out below.

➢ Tuning ratio: Tuning ratio is the frequency ratio of the TLD to the building frequency. T LD's damping effect is strongest when the tuning ratio is 1, and is known to decrease sharply when it is heading away from unity.

➢ Mass ratio: Mass ratio is the ratio of the liquid mass in the TLD to the building mass. With the change in the mass ratio the impact of damping also increases. This is because weight gain would mean that the TLD will have more damping force or sloshing force to counter the force of the earthquake.

➢ Depth ratio: Depth ratio is the ratio of tank depth to tank length in sloshing direction. Water mass may be divided into convective mass and impulsive mass from which convective mass has the involvement in the process of sloshing. The ratio of convective mass to impulsive water mass is in opposite relation to the ratio of volume. Higher depth ratio would therefore mean less convective mass, and thus less involvement in the sloshing. Therefore, a lower ratio of depth is always preferred.

Shape of tank: The tank type can be circular, rectangular, conical or geometric in shape. Similar tank form portrays specific slurry behavior. Also, because of their simplicity, it is the rectangular tank or circular tank that is used. Also, in concept codes such as part 2 of IS1893:2002 the charts are only valid for circular and rectangular tanks; So, they're more favored for the purpose of research.

➢ Position of tank: The tank place also influences TLD behavior. TLD's location may be at any mid story or at the top of the building somewhere. The location can also be at the center, edge or corner of the storey where it is situated. Most literature reveals that when put on the terrace, the best effect of TLD is obtained.

Main Classification Of tuned liquid damper

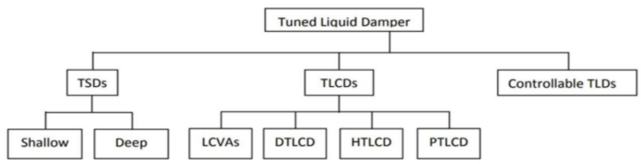

Fig. 1

Classification of tuned liquid damper

➢ TSD- Tuned Sloshing Damper

➢ TLCD- Tuned Liquid Column Damper

➢ LCVA- Liquid Column Vibration Absorbers

➢ DTLCD- Double Tuned Liquid Column Damper

➢ HTLCD- Hybrid Tuned Liquid Column Damper

➢ PTLCD- Pressurized Tuned Liquid Column Damper

Tuned Sloshing Damper (TSD)

Tuned Sloshing Damper is usually used according to construct form and objectives. These are in either rectangular or circular, and are mounted at the building's top floor to produce better performance. Additionally, TSD is graded as shallow level of water and level of deep water. The classification is based on the principle of the wave, depending on the tank's water height.

When tank height is 'h' and length 'L' ('D' diameter for circular tank) ratio is less than 0.15 is called as shallow type and more than 0.15 is called the deep-water type.

Damping mechanism of TLD

Within this section the modified liquid damper's damping mechanism is discussed. Since the tuned mass damper is one of the most widely used passive mechanical damping system, used for structural vibration control based on service efficiency. The tuned liquid damper is explained by comparison of tuned mass damper.

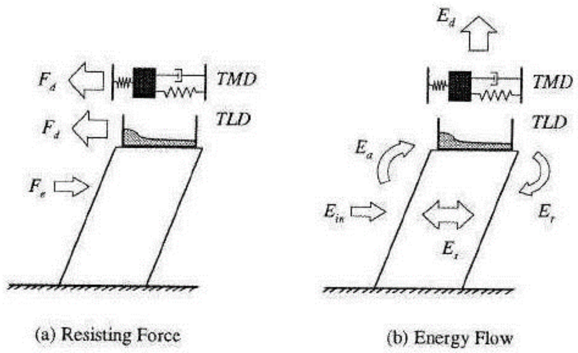

Fig. 2

Schematic description of associated TLD and TMD inactive mechanical dampers. Section (a) the friction force of the solid mass in the TMD and the water mass in the TLD movement in contrast to the structure as the system is subjected to external force. Figure (b) refers to the flux of vitality between the structure's excitation force and the damper. The damper absorbs a portion of the energy from the structural vibration. The vitality consumed is distributed through the damping limits characteristic of the dampers. "Heat absorption process" is the heat transfer from the structure to the damper. The damper adjusts the structure's dynamic properties by using the retention function to adjust the duration of the basic movement. The structural vibration energy is dissipated through the damper's capacity for energy dissipation. The motion of the solid mass and the TMD's firmness and damping properties have been extensively investigated. However, the movement of the water mass and the characteristics of the TLD's stiffness and damping were not subject to the same degree of the specific inspection as the wave break occurs, the water sloshing motion cannot be predicted using analytical procedure.

Liquid Mass Damper Assumptions:

➢ The liquid is called regular, irrotational and incompressible.

➢ The damper walls are treated rigidly.

➢ The liquid surface stays smooth during sloshing (the wave is not breaking)

➢ It should be pointed out that the structural reaction serves as an excitation to the damper influencing the liquid's movement and dissipation. On the other hand, the damping of nutation’s affects the structural response.

Properly Designed Tuned-Mass Control Systems Can Be Characterized as Follows:

They that seismically induced reactions in terms of displacement, acceleration, internal stresses and stresses as well as the demands of subsoils.

➢ They improve systemic protection. A building's collapse is less likely and, therefore, human life is secured.

➢ They improve structural serviceability. Harm and related repair costs are greatly reduced in case of seismic events.

➢ Compared to traditional methods of reinforcement, the building can normally be in service during TMCS installation (if no additional steps are required).

With respect to the overall process and the material needed to build a tuned mass device, this technique can be rated as 'cost-effective.'

METHODOLOGY

The methodology used in the analysis is explained in this chapter. This explains the software package used in modelling, and briefly explains some of the essential modeling and analysis field using ETABS.

Methods of seismic analysis of structure

Diverse complexity methods are developed for structure seismic analysis. Could define them as follows:

Static analysis

The anti-quake load structure should think about the load dynamics. Be that as it may, equivalent linear static analysis is sufficient for standard simple structure, as code practice prescribes for normal low to medium ascension structure. The means begins with estimating the base shear load and discovering its appropriation on each story using formulae given in code. This inquiry works admirably for the framework of low to medium ascents. Because of the torsional effect, large structures over 75 m are less appropriate for this strategy, these require ever more complex strategies.

Dynamic analysis

Total example. Response of the idealized SDOF device during the earthquake has some time and damping. The max response plotted against undamped natural time and can be expressed as max for different damping values. True acceleration, max. Related, or total displacement. Relative Pace.

Response spectrum analysis

A response spectrum is a frequency or duration feature, showing the peak response of a simple harmonic oscillator that undergoes a temporary event. The response spectrum is a function of the oscillator's natural frequency and damping thereof. Consequently, it is not a direct reflection of the frequency content of the excitation (as in a Fourier transformation), but rather one of the effects that the signal has on a single degree of freedom (SDOF) postulated method.

Response spectrum method (Dynamic Analysis)

General Codal provision (IS 1983-2016)

For the following buildings, dynamic analysis should be performed in order to obtain the design seismic force and its distribution to different rates along the building height and to different lateral resistant components.

➢ Regular buildings-they are larger than 40 m in zone IV, V and larger than 90 m in zones II, III

➢ Irregular buildings-All framed buildings in areas IV and V above 12 m and those in areas II and III over 40 m in height

Dynamic analysis can be carried out either by method of time history or by method of response spectrum. Nevertheless, the design base shear Vb shall be compared in either approach with the base shear Vb' calculated using a fundamental period Ta. When Vb is below Vb 'all the response quantities are multiplied by Vb'/Vb'. For all the purpose of comparative study of steel and reinforced concrete buildings, the damping values for a building can be taken as 2 and 5 per cent of the critical.

Modelling using a finite element package e-tab

In the present work, G+20 of without tank building models are considered. The performance with water tank with different seismic zones and different soil types and it is analyzed by Response Spectrum Method without water tank conditions in the building.

ETABS (Extended Three-dimensional Analysis of Building System)

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Modelling and analysis were performed using ETAB software. ETABS is a powerful system for program and structure developed by Inc. Berkeley, USA California, which confirms the engineer's structural research and design skills.

ETAB is modern, easy to handle, and designed specifically for the design and study of building systems. Using common database, it has integrated graphical interface, with ultimate modelling and design procedures. The device is very easy to use software. The user one will set the gridlines, define the content property, position the objects on the grid.

Features and benefits of ETABS

➢ ETAB's numerical arrangement scheme of input yields was properly intended to overcome the one kind of physical and numerical qualities associated with structure type structure. As a consequence, this method of analysis and design advances data planning, interpretation of the output.

➢ The need for specific purpose programs was never slowly apparent as simple specialists placed nonlinear dynamic analysis practices and higher PC variants are now needed for broad diagnostic models on a daily basis.

➢ ETABS programming is clearly viewed as the most ground-based and efficient tool for the static and dynamic investigation of multi-story housing and shear wall construction.

➢ In recent years, ETABS has accepted numerous user behaviors and has developed a common programming plan for businesses.

Analytical model overview

The G+20 buildings are analyzed in ETABS. This is the regular building which is considered in the plan.

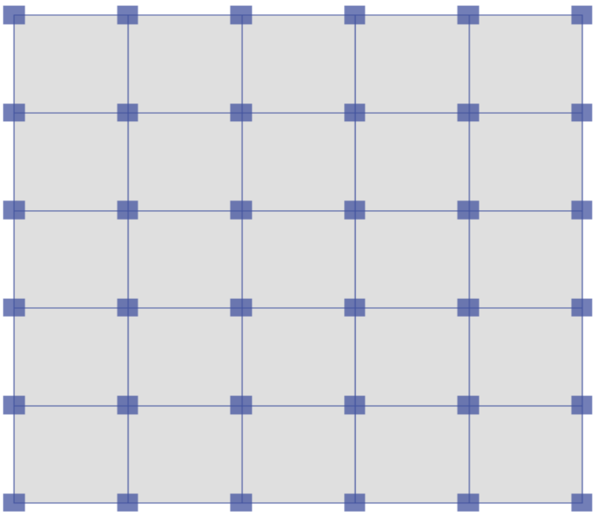

Fig. 3

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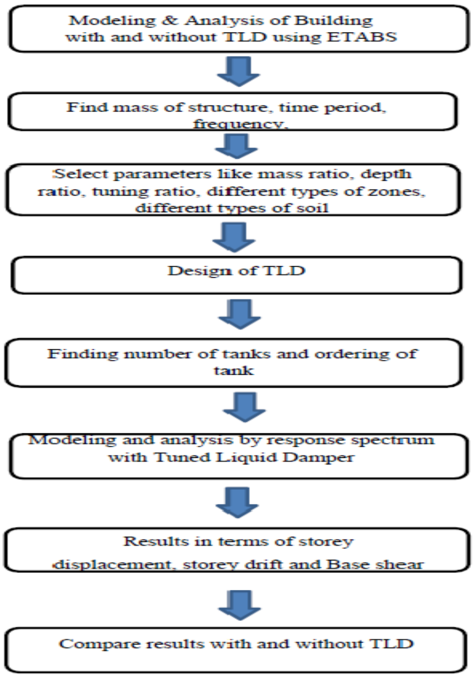

Sl. No.	Storey	Ht. of storey (m)
1	Base	0
2	Plinth	1.5
3	First	3
4	Second	3
5	Third	3
6	Fourth	3
7	Fifth	3
8	Six	3
9	Seven	3
10	Eight	3
11	Nine	3
12	Ten	3
13	Eleven	3
14	Twelve	3
15	Thirteen	3
16	Fourteen	3
17	Fifteen	3
18	Sixteen	3
19	Seventeen	3
20	Eighteen	3
21	Nineteen	3
22	Twenty	3
Total Height of building		**61.5**

Table. 1

Defining material Properties

M30 cement of Indian standard is considered. HYSD rebar of Fe500 is considered.

Defining the Structural elements

Column size of 750X750mm of M30 grade concrete utilizing Fe500 rebars. Beam size of 500X500mm of M30 grade concrete utilizing Fe500 rebars. The slab of 200 mm thickness of M30 grade concrete utilizing Fe500 rebars for modeling of a structure.

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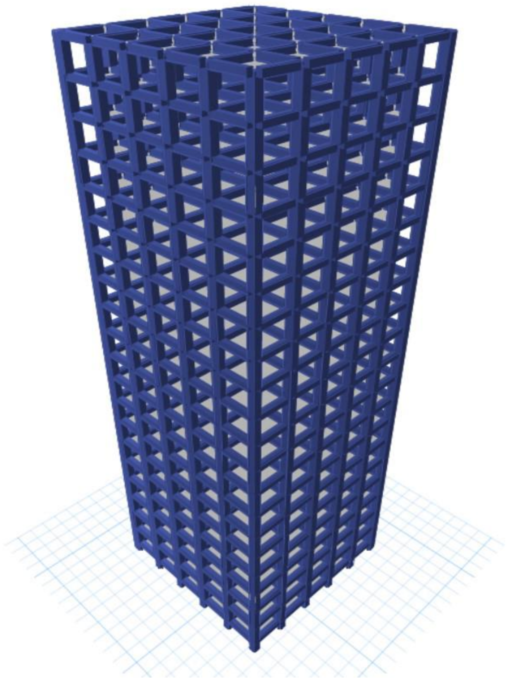

Fig. 4

Load, Defining Load Pattern and Load cases

Table: Loads on building assigned

Live Load As Per Is-875 Part 2	3 kN/m²
Wall Thk.	150 mm
Wall Load	10.2 kN/m²
Floor Finish	1.5 kN/m²

Table. 2

Sl. No.	Particulars		Codes	Zone no.			
				V	IV	III	II
1	Zone Factor	Z	IS 1893:2016 part 1	0.36	0.24	0.16	0.1
2	Importance Factor	I	IS 1893:2014 part 2	1.5	1.5	1.5	1.5
3	Soil Type II	Sa/g	IS 1893:2016 part 1	0.8	0.8	0.8	0.8
4	Reduction Factor	R	IS 1893:2014 part 2	2.5	2.5	2.5	2.5

Table. 3

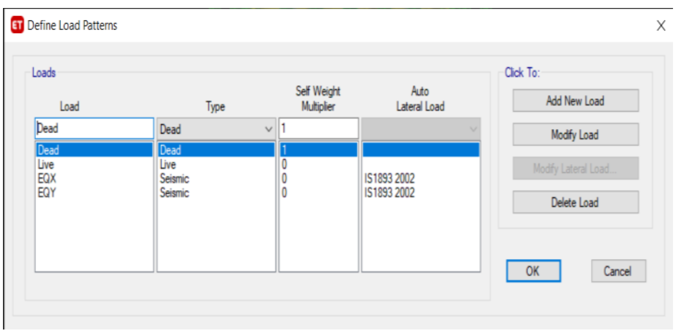

Fig. 5

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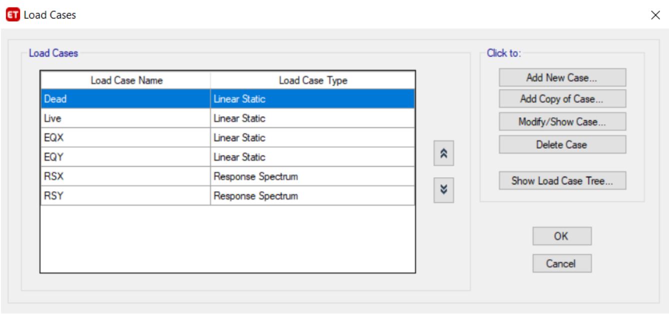

Fig. 6

Assigning the support condition:
The base of the structure in the arrangement the XY plane view is chosen and fixed condition was allocated.

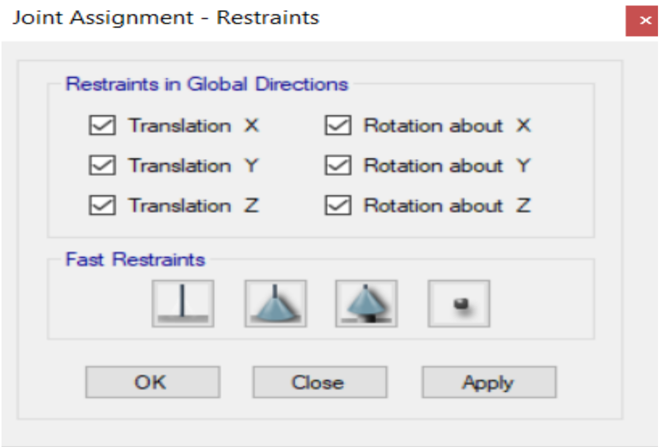

Fig. 8

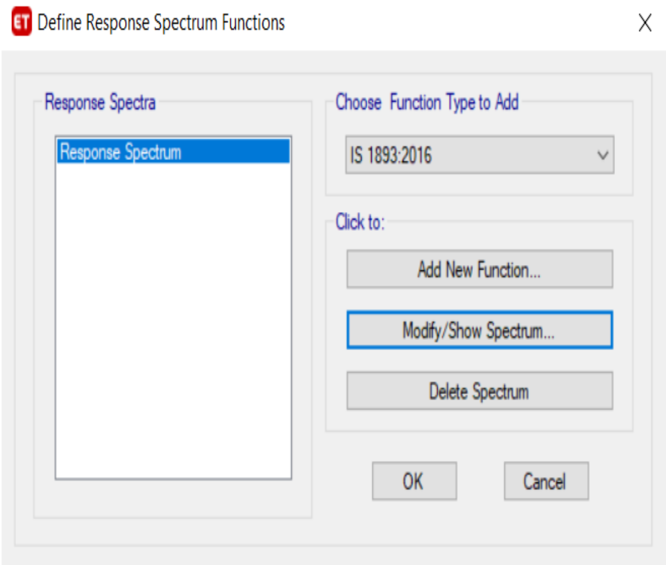

Fig. 9

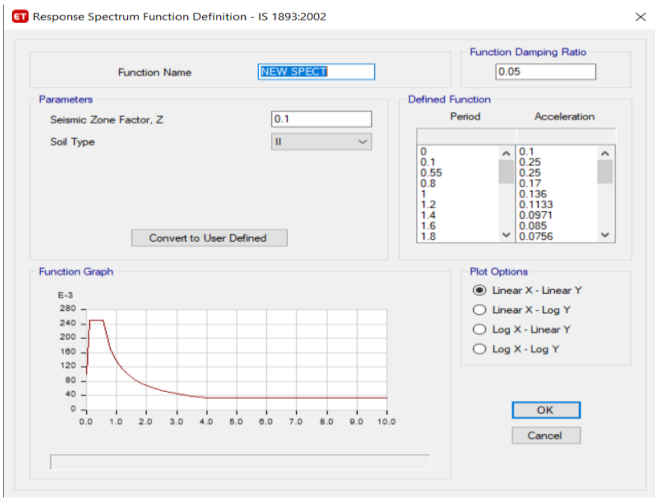

Fig. 7

Modelling of the TLD using ETABS

The structure of the tank is designed using columns of the same size as the building, which are then filled with concrete wall panels.

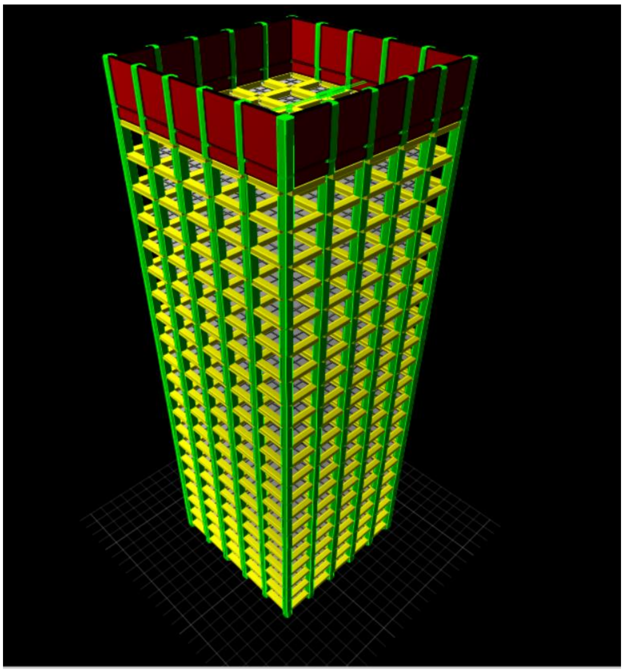
Fig. 10

Spring for convective mass is modelled using the "linear connection" variable, the steadiness of which is given as K/2 in X and Y direction and its DOF in Z direction is set as fixed.

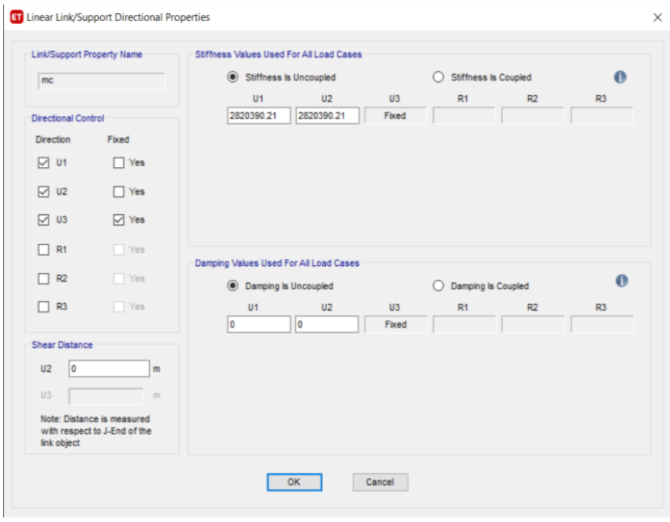

Fig. 11

Using linear link element, Spring for impulsive mass is also modelled, but its DOF is set in all directions. The Mc and Mi values in X and Y direction assigned as "Joint mass" at the joint of the spring. The Mc and Mi values in Z direction assigned as "Joint force" at the joint of the spring.

Analysis

The investigation was carried out by considering different conditions for understanding TLD's behavior. A typical G+20 storey was shown operating with TLD and was tested with various seismic zones, different types of soil. When examining one particular parameter, different parameters and different parts of the structure were held stable. All the seismic zones are contemplated. Impact of TLD is looked at.

- Depth proportion is the depth of water in TLD to the length of fluid in sloshing course. The depth proportion was taken 0.2 and examination was done.

- Impact of TLD when set at various seismic zone was examined. The various types of soil is considered in the examination.

- The mass ratio is the proportion of mass of TLD to the mass of the structure. The mass ratio was taken 2% were considered.

- The results were analyzed based on rate of decreasing in storey displacement, decreasing in storey drift and decreasing in base shear rate after TLD was performed.
- The investigation was done in dynamic analysis technique according to IS codes.

Proposed TLD configuration

TLD system consists of a large number of water tanks which needs to be placed at the top of a building with required level of water. This multi-tank system can be realized in many ways as we can see in existing buildings. For example: In Nagasaki Airport Tower, sets of circular steel tanks of required dimensions are placed. And in One Rincon Hill Tower, a single large tank with baffle screens is used. Similar to that, one another simple method has been developed in this project. Let's consider a TLD system with 125 tanks where 5x5 tanks are mounted in 5 layers. Every tank here constitutes one unit. The multi-tank network is designed to represent one layer by putting certain units in a 5x5 grid. Our TLD set is complete with an arrangement of 5 layers placed one top of another. The units are interconnected via water pipes. Each unit is connected to other adjacent units, except for the first and last units in the network that either collect water from another layer or convey water to a separate layer. Water enters at the top of the first corner unit and then flows into the next adjacent unit after the required water height is filled. The water enters at one end into the top layer and goes to the adjacent tank in the x-direction. After filling all the systems in one row, the water goes down to the next row along the y-direction. The whole layer is filled in in this way. After a layer is filled the water goes fall to the next lower layer in the direction of Z and the process proceeds until all the tanks are complete. The tanks can consist of concrete, or any other suitable material. It should be noted that this proposed tank set model in this section is merely a conceptual idea for the development of a TLD package. No scientific studies on this method have yet been performed. Future aim for this project is to create a simple and full TLD package.

Parameters considered for TLD

There are various parameters influencing TLD's actions in a system. These are naturally occurring structure frequency, mass ratio, depth ratio, tuning frequency ratio, tank configuration and tank location on the structure. Both of those are discussed below.

Natural Frequency of structure: A structure's normal frequency is the recurrence of a system, in which it vibrates violently. A system can have different normal frequencies. However, only the first mode is considered in the design of TLD, i.e. main mode. TLD provides maximum execution when it is finely tuned to the frequent recurrence of the structure. Nevertheless, due to anomalies and unexpected reasons, natural building frequency will differ from what is expected. This must also be kept in mind when designing TLD.

Tuning ratio: Tuning proportion is the degree to which the form is replicated with TLD. TLD's damping effect is strongest when the level of tuning is 1, and is referred to as decreasing sharply as it shifts from solidarity.

Mass ratio: Mass proportion is the sum of the liquid's weight in TLD to the structural mass. The effect of damping increases with the growth of mass proportion every now and again. This is because mass expansion would mean that the TLD will have the greater damping force or sloshing ability to combat seismic power.

Depth ratio: Depth ratio is the proportion of the tank's depth to the tank's length against sloshing. Water mass can be divided into convective mass and impulsive mass out of which convective mass is engaged in sloshing. Contrary to the depth proportion the proportion of convective mass to impulsive mass of water is defined. Higher proportion of depth would therefore mean less convective mass, and therefore less excitement for sloshing. Therefore, a lower depth ratio is often used.

Geometry of tank: Tank state can be roundabout, rectangular, pipe-formed, or geometric shape. Specific tank condition delineates distinctive sloshing behavior. As much as possible, because of their convenience, it is the rectangular tank or round tank that is used. To be sure, also in design codes, for example, section 2 of IS1893:2002 the diagrams are available only for roundabout and rectangular tanks, and they are slowly assisted for the purpose of the test.

Position of tank: The tank's location further impacts the TLD's actions. TLD's situation might be at some mid-storey or some spot at the structure's most prominent function. Moreover, the location may be at the center, side or side of the storey where it is mounted. Most composers demonstrate the TLD's best effect is the point at which it is put on top.

RESULTS AND DISCUSION

This chapter presents data from 3-Dimensional analysis to be tabulated. The parameter discussed in this study involves dynamic analysis of the displacement, storey drift and base shear.

The results obtained are given below under various topics.

- Standard TLD designed for a G+20 building.
- TLDs with different seismic zones.
- TLDs with different soil type
- TLDs with depth ratio 0.2 and mass ratio 2%.
- TLDs Results obtained by response spectrum method.

STOREY DISPLACEMENT

Different seismic zones with different soil type

Storey displacement in X direction results for different seismic zones with (soil type I) with and without TLD

STOREY DISPLACEMENT IN X DIRECTION (mm) (SOIL TYPE I)								
Ht. of storey (m)	ZONE NO.							
	V		IV		III		II	
	Without TLD	With TLD	Without TLD	With TLD	Without TLD	With TLD	Without TLD	With TLD
61.5	139.636	44.237	127.758	42.054	116.838	41.741	107.399	39.338
58.5	32.233	26.187	33.022	17.458	33.689	11.639	34.27	7.274
55.5	35.782	25.615	36.528	17.077	37.164	11.384	37.719	7.115
52.5	39.114	24.907	39.806	16.604	40.403	11.07	40.927	6.918
49.5	41.961	24.071	42.593	16.047	43.146	10.698	43.634	6.686
46.5	44.205	23.12	44.77	15.413	45.276	10.276	45.726	6.422
43.5	45.773	22.065	46.27	14.71	46.727	9.807	47.137	6.129
40.5	46.619	20.916	47.047	13.944	47.454	9.296	47.823	5.81
37.5	46.716	19.678	47.078	13.118	47.436	8.746	47.765	5.466
34.5	46.063	18.358	46.366	12.238	46.676	8.159	46.964	5.099
31.5	44.645	16.961	44.895	11.307	45.159	7.538	45.406	4.711
28.5	42.471	15.49	42.673	10.327	42.894	6.884	43.104	4.303
25.5	39.573	13.95	39.732	9.3	39.914	6.2	40.088	3.875
22.5	35.998	12.342	36.12	8.228	36.266	5.485	36.409	3.428
19.5	31.807	10.669	31.896	7.112	32.012	4.742	32.126	2.964
16.5	27.069	8.931	27.132	5.954	27.22	3.969	27.309	2.481
13.5	21.87	7.132	21.912	4.755	21.976	3.17	22.042	1.981
10.5	16.319	5.283	16.346	3.522	16.389	2.348	16.434	1.467
7.5	10.592	3.415	10.607	2.277	10.633	1.518	10.66	0.949
4.5	5.059	1.629	5.065	1.086	5.077	0.724	5.089	0.453
1.5	0.759	0.246	0.76	0.164	0.761	0.109	0.763	0.068
0	0	0	0	0	0	0	0	0

Table. 4

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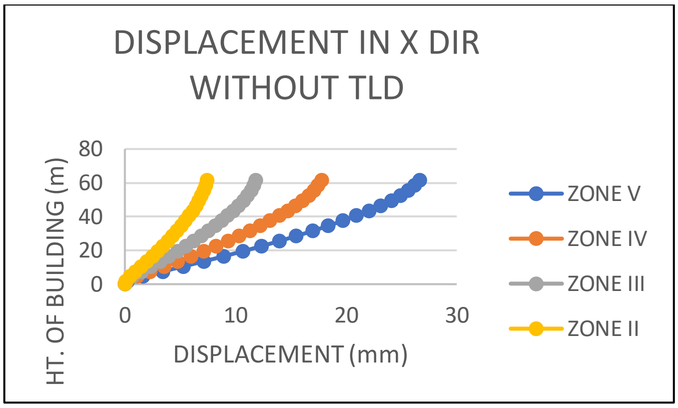

Fig. 12

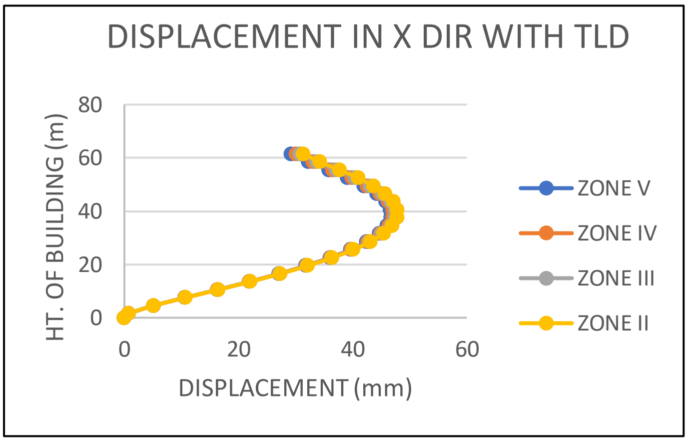

Fig. 13

Storey displacement in Y direction results for different seismic zones with (soil type I) with and without TLD

STOREY DISPLACEMENT IN Y DIRECTION (mm) (Soil type I)									
	ZONE NO.								
Ht. of storey (m)	V		IV		III		II		
	Without TLD	With TLD	Without TLD	With TLD	Without TLD	With TLD	Without TLD	With TLD
61.5	136.481	43.64	140.88	41.76	142.14	41.84	144.34	40.39
58.5	140.337	26.187	141.722	17.458	141.975	11.639	142.169	7.274
55.5	137.523	25.615	138.89	17.077	139.132	11.384	139.316	7.115
52.5	133.986	24.907	135.334	16.604	135.562	11.07	135.736	6.918
49.5	128.731	24.071	131.057	16.047	131.272	10.698	131.436	6.686
46.5	123.779	23.12	126.085	15.413	126.285	10.276	126.438	6.422
43.5	117.161	22.065	120.445	14.71	120.632	9.807	120.773	6.129
40.5	111.912	20.916	114.175	13.944	114.347	9.296	114.477	5.81
37.5	105.071	19.678	107.311	13.118	107.469	8.746	107.589	5.466
34.5	97.679	18.358	99.897	12.238	100.041	8.159	100.149	5.099
31.5	88.781	16.961	91.978	11.307	92.107	7.538	92.204	4.711
28.5	81.425	15.49	83.6	10.327	83.715	6.884	83.802	4.303
25.5	72.663	13.95	74.816	9.3	74.917	6.2	74.993	3.875
22.5	62.548	12.342	65.68	8.228	65.767	5.485	65.833	3.428
19.5	54.138	10.669	56.25	7.112	56.323	4.742	56.379	2.964
16.5	44.499	8.931	46.59	5.954	46.65	3.969	46.695	2.481
13.5	33.703	7.132	36.775	4.755	36.821	3.17	36.856	1.981
10.5	24.857	5.283	26.908	3.522	26.942	2.348	26.967	1.467
7.5	14.152	3.415	17.185	2.277	17.206	1.518	17.222	0.949
4.5	6.088	1.629	8.104	1.086	8.113	0.724	8.121	0.453
1.5	1.202	0.246	1.204	0.164	1.205	0.109	1.206	0.068
0	0	0	0	0	0	0	0	0

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Table. 5

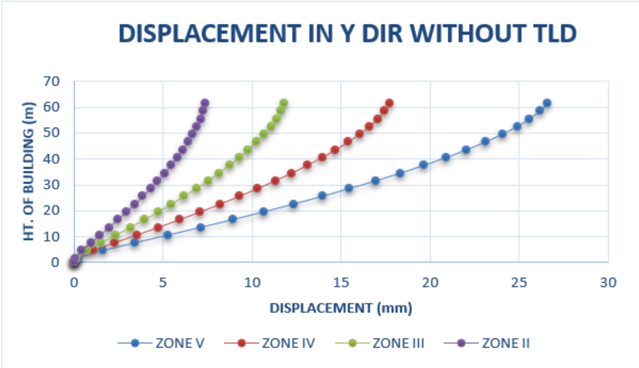

Fig. 14

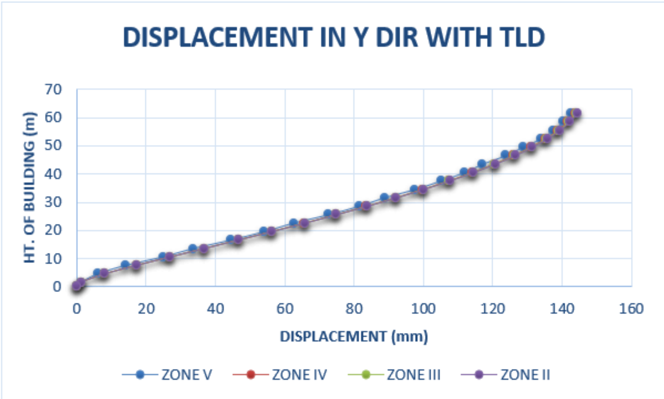

Fig. 15

Table 5. 7: Percentage reduction in Max. Storey displacement for top storey in X direction results for different seismic zones with (soil type I) with and without TLD

MAX. STOREY DISPLACEMENT IN X DIRECTION FOR TOP STOREY (mm)				
	ZONE NO.			
	V	IV	III	II
Without TLD	139.64	127.76	116.84	107.39
With TLD	44.24	42.05	41.74	39.34
% reduction	68.31	66.93	64.28	63.36

Table. 6

Percentage reduction in Max. Storey displacement for top storey in Y direction results for different seismic zones with (Soil type I) with and without TLD

MAX. STOREY DISPLACEMENT IN Y DIRECTION FOR TOP STOREY (mm)				
	ZONE NO.			
	V	IV	III	II
Without TLD	136.48	140.88	142.14	144.34
With TLD	43.64	41.76	41.84	40.39
% reduction	68.02	70.35	70.56	72.02

Table. 7

From the above results it is noticed that TUNED LIQUID DAMPER (TLD) is practical in reducing the displacements of top storey in the building. TLD is helpful in all seismic zones. For seismic ZONE V displacement is reduced up to 68%, for ZONE IV reduced to 66%, 64% for ZONE III and 63% in ZONE II. For soil type I. TLD is useful in reducing displacement in both X & Y direction.

Discussion on results

The model is subjected to dynamic loads and the results are comparing in terms of storey displacement, storey drift and base shear. The selected model where subjected to linear dynamic analysis using response spectrum analysis with and without TLD. The design of TLD was calculated manually and the displacement, storey drift and base shear were observed in two different directions namely X and Y direction according to ETABS 2018.

From the above figures and tables for storey displacement, storey drift, and base shear it is observed that the values goes on decreased due to providing TLD in the structure for using different seismic zones with different soil types.

- The displacement reduced up to 63-68% for soil type I, 61-65% for soil type II and 60-62% for soil type III.
- The storey drift reduced up to 50-59% for soil type I, 50-57% for soil type II and 56-62% for soil type III.
- The base shear reduced up to 33-53% for soil type I, 52-57% for soil type II, 40-56% for soil type III.

Conclusion

From this study, the following conclusions can be made,

- It was discovered that TLD could be demonstrated effectively in ETABS 2018 given the fact that there are various quantities of tanks utilizing a comparable spring mass structure.
- TLD research shows that TLDs can be used in a viable manner to minimize the structural response during seismic activity.
- It can be inferred from this analysis that a properly constructed TLD with efficient design parameters such as damping ratio, depth ratio, and mass ratio is considered to be a very effective tool for reducing structural response.
- Displacement is more for non-TLD structure than TLD structure. Displacement falls by 63-68 percent for soil type I, 61-65 percent for soil type II and 60-62 percent for soil type III for 2 percent mass ratio and 0.2 percent depth ratio.
- The layout without TLD and with TLD, the storey drift is more TLD-like than TLD-like. It needs to be seen from questioning.
- Without this study, the structure evaluation found that the TLD can be effectively used to track structural vibrations
- The base shear of the structure is more for non TLD Structure than TLD Structure. The base shear reduced to 33-53 percent for soil type I, 52-57 percent for soil type II and 40-56 percent for soil type III. For 2 percent mass ratio and 0.2 percent depth ratio.
- The structural dynamic response of the building with and without water tank at the top is entirely different.
- The TLD effect is found to be only important in highly resonance seismic zone. In other words, TLD is found to be the most effective in increasing the resonant violent shaking of buildings. But TLD doesn't have much effect during low resonance seismic zone.
- In addition, TLD has also been found to be more functional and cost-effective for larger buildings. This is because the scale of each TLD tank would be much greater for larger

buildings and buildings these large tanks would be more practical than the construction of many small tanks.

Future Scope of the work

- Analysis shall be carried out irregular buildings with different irregularities.
- Study may further be extended for different geometry of tanks.
- Analysis shall be carried out for different infill's and Different storeys.
- Analysis shall be carried out using different analysis methods.
- Different methods can be used to design TLD.
- Experimental work can be done utilizing shaking table test.

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