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Analysis of Lateral Loads for a Framed Model with Tuned Liquid Damper

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Abstract: *Earthquake resistant study is an area of concern since ancient period. Researchers are studying structures which are tall yet flexible, light weight and also problems from service abilities of structures. These structures are called as Smart structures. Scientist has invented types of smart structures for mitigation of winds and earthquake induced vibrations in tall buildings and many other structures. Seismic resistant tall buildings are a growing need in the civil engineering sector. One of the types of smart structure is a tuned liquid damper based on a passive system mechanism which is an inertial secondary effect.Tuned Liquid Dampers (TLD) is properly designed liquid tanks. The liquid in the tank is generally water. These tanks are either rigid rectangular or cylindrical liquid tank which is rigidly connected to the top of the structure and is used as a vibration absorber. The main function of the tuned liquid dampers is to absorb portion of the input energy associated with external dynamic excitation acting on the structure. Their application can prevent discomfort, damage or outright structural failure.*

Keywords: *Tuned Liquid Dampers, Dynamic, Excitation, Inertia.*

I. Introduction

Since ancient era, practices to strengthen the structures during earthquake is been carried out. This was done by constructing the structures at a height above the ground level. Later, techniques were invented to provide desired strength to the structure so as to prevent the damages of the structure during earthquake. These techniques were used not only to stabilize the structure but also to control the stress developed in the structure. The method was named as Seismic Protection Systems and was first documented in early 1800s. In 1970's a professor named John Milne successfully implemented this technique by isolating the entire structure from ground and thus provided minimal damping to the structure. Seismic Protection Systems are classified as below:-

1. Conventional methods are based on traditional concepts to dissipate energy. These include Flexural Plastic Hinges, Shear Plastic Hinges, etc.
2. Isolation Systems are provided below the superstructure and the substructure in case of bridges it is provided between the deck and the piers. These devices are called as base isolators and the method as Base Isolation. Structures with base isolations have been constructed in many countries such as japan, Germany, etc. In India, Burj Building in Assam is constructed with this technique.
3. Supplementary Dampers are activated by the movement of the structure and decrease the structural displacements by dissipating energy. These are further classified as active systems, semi-active systems and passive systems.

Passive System: - In this system, characteristics of the devices are designed once and installed. These devices are installation requires no sensors, actuators or controllers to be effective. These devices are relatively easy to maintain and are cost effective. Passive Dampers includes frictional damper, viscoelastic damper, fluid viscous damper, tuned mass damper and tuned liquid damper. Among these, frictional dampers use the natural force of friction to absorb the seismic shaking. The dynamic friction force generated provides the required damping to absorb the energy of the earthquake. Viscoelastic dampers consist of layers of viscoelastic material alternatively bonded to steel plates. Whereas, a fluid viscous damper works similar to an automobile shock absorber. A piston transmits the seismic energy to the fluid in the damper, causing the fluid to move inside the damper. The movement absorbs the kinetic energy by converting it into heat. Such systems have proven to be an affordable and effective solution for both steel and reinforced concrete structures during seismic activity.Tuned Mass Dampers consist of a mass, a spring and a dashpot. A properly designed tuned mass damper resonates at a frequency near the natural modal frequency of the primary structure to be suppressed. It is also called as harmonic absorbers.

Tuned Liquid Damper consist of a rigid tank, partially filled with a liquid usually water. When a structure, fitted with a properly tuned liquid damper begins to sway during a dynamic loading event, it causes fluid sloshing motion inside the tank. The fluid sloshing motion imparts inertia forces approximately anti-phase to the dynamic forces exciting the structure, thereby reducing structural motion. The inherent damping mechanism of the TLD dissipates the energy of the fluid sloshing motion. These dampers are cost effective and low-maintenance dynamic vibration absorbers that are being used in flexible and lightly damped structures.

II. Experimental Setup

This consists of four aluminum columns and four aluminum slabs each attached to the four columns at an interval of 400 mm. the entire structure assembly is placed on a shake table driven by an electric motor. The RPM of the motor can be varied to achieve harmonic base motions at different frequencies.

The model is an idealized demonstration of this phenomenon since the building can be subjected to harmonic base motions. The frequency of the base motion can be varied by changing the RPM of the electric motor; it is also possible to vary the amplitude of the base motion by adjusting the stroke. By changing the motor RPM it would be possible to set the frame into resonant motions, which would enable to visualize the first three normal modes of the frame.

Table: Geometric data of structure

Sr No.	Parts	Dimensions In Mm		
		DEPTH (D)	WIDTH (B)	LENGTH (L)
1.	COLUMN	$D_A = 3.00$	$B_A = 25.11$	$L_A = 400.00$
2.	SLAB	$D_B = 12.70$	$B_B = 150.00$	$L_B = 300.00$

III. Designing of Tuned Liquid Damper

Assumptions:-
The liquid is considered homogeneous, irrotational and incompressible
The walls of the dampers are treated rigid.
The liquid surface remains smooth during sloshing (No breaking wave produced). It should be emphasized that the structural response acts as an excitation for the damper thus affecting the sloshing motion of the liquid and its dissipation.

IV. Fundamental Frequency of A Rectangular Shape TLD

The fundamental frequency of a TLD, f_{TLD} can be estimated using linear water sloshing frequency f_W given by,

$$\boxed{f_W = 1/ 2\pi \sqrt{(\pi g/h \tanh (\pi h/L))}}$$

Where, g = acceleration due to gravity.
h = still water depth
L= length of tank in the direction of sloshing motion.

V. Damper Structure Arrangement

The water tank is placed at the top of the structure .Here, from the derivation and trial and error method the width and depth of the damper is calculated. The width is considered as 100 mm and the length is 96 mm. For height of water equal to 100 mm, first natural frequency is 2.84 rad/sec. Therefore the height of the water is considered as 100 mm. the density of the water (ρ_f) is 1000 kg/m^3**.** Then the experiment is conducted with the frame placed on the ED vibration shaker and accelerometers have connected to the top floor. The displacement on the floor due to the vibration table is record by the accelerometer. The frequency range starts from 2 Hz up to 20 Hz.

TABLE: OBSERVATIONS

Frequency	without TLD	with TLD @ second floor	with TLD @ top floor
2	3.89	7.96	4.03
2.1	3.41	6.27	3.72
2.2	2.88	5.21	3.54
2.3	5.93	6.01	3.17
2.4	9.01	15.76	2.95
2.5	9.12	21.54	2.91
2.6	16.83	21.63	3.7
2.7	41.86	19.81	4.23
2.8	218.53	12.85	5.36
2.9	239.55	9.83	5.57
3	68.08	6.81	5.14
3.1	61.69	5.61	3.97
3.2	39.22	4.91	3.92
3.3	21.44	4.93	4.17
3.4	18.51	4.78	4.18
3.5	17.67	6.15	3.94
3.6	17.01	6.97	3.89
3.7	16.9	6.9	4.34
3.8	12.9	5.8	5.23
3.9	12.08	5.09	6.47
4	10.12	4.79	6.77
4.1	9.05	4.23	5.77
4.2	8.08	4.28	3.62
4.3	8.2	4.09	2.78
4.4	6.72	4.06	2.46
4.5	6.59	4.18	2.41
4.6	6.05	4.33	2.36
4.7	5.54	4.13	2.43
4.8	5.2	3.95	2.81
4.9	4.86	3.46	3.17
5	4.86	3.26	3.09
5.1	4.27	2.95	3.38
5.2	3.99	2.83	3.69
5.3	3.92	2.84	3.93
5.4	3.34	2.76	4
5.5	3.29	2.63	3.16
5.6	3.42	2.64	2.91
5.7	3.48	2.65	2.41
5.8	3.44	2.53	1.93
5.9	3.54	2.58	1.55
6	3.43	2.57	1.15
6.1	3.58	2.58	1.06
6.2	3.59	0.21	0.1
6.3	3.61	0.22	0.11
6.4	0.28	0.24	0.12
6.5	0.28	0.25	0.16
6.6	0.29	0.26	0.19

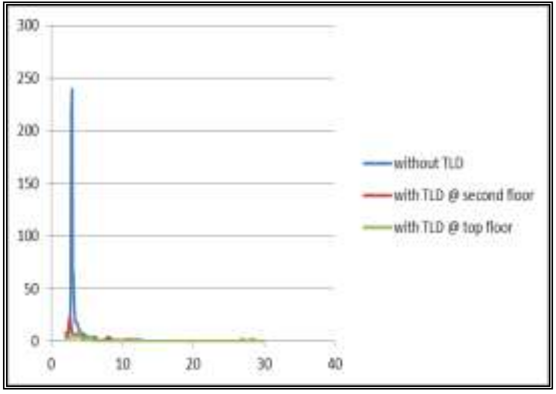
6.7	0.34	0.28	0.23
6.8	0.35	0.32	0.3
6.9	0.37	0.34	0.4
7	0.39	0.36	0.41
7.1	0.39	0.39	0.21
7.2	0.42	0.46	0.16
7.3	0.47	0.5	0.14
7.4	0.52	0.58	0.13
7.5	0.57	0.74	0.13
7.6	0.76	0.9	0.13
7.7	1.54	1.11	0.13
7.8	3.18	1.46	0.12
7.9	3.99	2.09	0.12
8	4.09	2.85	0.11
8.1	3.53	3.27	0.11
8.2	1.15	3.33	0.11
8.3	0.94	2.77	0.1
8.4	0.88	2.01	0.09
8.5	0.61	1.23	0.09
8.6	0.56	1.12	0.09
8.7	0.53	0.74	0.08
8.8	0.48	0.72	0.08
8.9	0.44	0.58	0.08
9	0.42	0.49	0.08
9.1	0.4	0.46	0.09
9.2	0.38	0.45	0.09
9.3	0.36	0.44	0.09
9.4	0.36	0.42	0.1
9.5	0.34	0.41	0.11
9.6	0.34	0.41	0.14
9.7	0.33	0.43	0.21
9.8	0.32	0.43	0.33
9.9	0.31	0.43	0.38
10	0.3	0.45	0.32
10.1	0.3	0.47	0.23
10.2	0.29	0.49	0.18
10.3	0.28	0.53	0.15
10.4	0.28	0.57	0.14
10.5	0.28	0.64	0.13
10.6	0.28	0.74	0.12
10.7	0.28	0.92	0.11
10.8	0.28	1.2	0.1
10.9	0.29	1.53	0.1
11	0.31	1.8	0.09
11.1	0.33	1.63	0.09
11.2	0.36	1.01	0.1
11.3	0.38	0.58	0.1
11.4	0.42	0.53	0.1
11.5	0.51	0.35	0.1
11.6	0.68	0.25	0.1
11.7	0.91	0.2	0.09
11.8	1.26	0.16	0.09
11.9	1.49	0.14	0.09
12	1.31	0.12	0.09

VI. Experimental Results

It has been analyzed from the readings that when the frame were compared with TLD at top floor with respect to the readings for the frame without TLD it was seen that 97.67 % reduction occurred for first mode at 2.9 Hz frequency whereas 96.88% reduction occurred in the second mode at a frequency of 8.1 Hz.

Similar to the top floor, the same procedure was conducted for the second floor. Here it was found 95.89 % reduction occurred in the first mode but only 7.38 % reduction could take in the second mode, further which there was increment in the displacements.

Fig.3. Comparison of frame with TLD @ Second floor, TLD @ third Floor and without TLD



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