Reduction of Structural Vibration using Tuned Liquid Damper by Experimental Method

[1]N. A. Shinde and [2]Prof. M. M. Pawar

[1]Civil Engineering Department, SVERI's College of Engineering, Pandharpur, India
[2]Civil Engineering Department, SVERI's College of Engineering, Pandharpur, India

Abstract

Response controls of structures with various types of dampers have been a center territory of study which was embraced to alleviate different characteristic risks like quake and wind. Dynamic, aloof what's more, crossover dampers of various structures are commonly utilized in structures to make structures progressively adaptable. Tuned fluid damper or TLD has been normal type of damper as a reaction controller and has experienced various alterations in its usefulness and establishment to diminish the auxiliary vibration during a seismic tremor. Till now a few fruitful applications approve with the numerical, exploratory also, explanatory examination has been displayed on TLD. For the trial concentrate shake table is utilized to discover the reaction of the structure. This paper shows a point by point study did to explore the advances in tuned fluid dampers and its appropriateness in the structure. Likewise gives the report on different parts of the tuned fluid damper.

1. Introduction

The present pattern toward the structures of consistently expanding statures and the utilization of light-weight, high quality materials, and propelled development strategies have prompted progressively adaptable and daintily damped structures. Justifiably, these structures are very touchy to ecological excitations, for example, wind, sea waves and seismic tremors. This causes undesirable vibrations instigating conceivable auxiliary disappointment, inhabitant inconvenience, and glitch of hardware. Hence it has become important to search for practical and effective devices for suppression of these vibrations. In anti-rolling tanks, dampers using liquid have been used to stabilize marine ships against rocking and rolling movements since the 1950s. However, the concept of implementing TLDs to decrease structural vibration in civil engineering buildings started in the mid-1980s, which suggested the use of a fully filled rectangular container with two immiscible liquids to decrease the structural reaction to dynamic loading. There are two popular methods used to model the behavior of liquid tanks. In the first, the dynamic equations of motion are solved by using potential flow theory and shallow water theory, while in the second approach the properties of the liquid damper are presented by an equivalent mass, stiffness and damping ratio, essentially modeling the TLD as an equivalent TMD (Tuned mass damper). Response controls of structures with various types of the utilization of Tuned Liquid Dampers as a technique for vibration controlling method was examined in this work. TLD's are fundamentally fluid tanks (typically water) incompletely loaded up with the fluid, and is commonly situated at the highest floor of the structure or quickly underneath it. (Karth and Ritzy, 2015). At the point when the tank is left through vibration, the fluid in the tank starts to slosh against the divider, bestowing inertial powers into the structure, out of stage with the auxiliary movement, along these lines diminishing the development. (Karth and Ritzy, 2015). TLD‘s can be classified into Tuned Sloshing Dampers (TSD‘s), Tuned Liquid Column Dampers (TLCD‘s) and controllable TLD‘s. TSD‘s are generally rectangular and circular tanks. TLCD‘s reduces structural vibration due to the motion of liquid in the tube as a result of gravity action and by the loss of hydraulic pressure due to the orifice installed inside the container. Controllable TLD‘s are used to increase the effectiveness of the damper when the forces acts on the building are spread over a band of frequencies. This is done by active and semi active control devices by controlling the angle of baffle provided in the tanks or by using propellers powered by motor.

2. Prototype RC Building Frame Considered For the Analysis

In the present work, the model RC building outline G+3 is considered. The structure casings considered are square in plan with single sound in the two bearings. The geometry of building edges are chosen dependent on the possibility of test study on scale down steel model. The subtleties of dimensional attributes are represented in Table 1

Sr.No.	Content	Description
1	Structure	Multi-storey rigid joint frame
2	No of stories	G+3
3	Grade of concrete	3.5 m
4	Grade of steel	M25
5	Bay width(Both direction)	M415
6	Slab thickness	0.15 m
7	Size of column	0.45m X 0.3m
8	Size of beam	0.4m X 0.23

Table 1: Geometric and material properties of building frames

3. Preparation of Scaled-Down Structural Model

The major task in the scaling down process is to achieve “Dynamic Similarity” where model and prototype experience homologous forces. According to this approach two principal test conditions are established

1) Natural frequency of the prototype should be scaled by an appropriate scaling relation to that of model.

2) Density of the prototype and model should be similar.

4. Scale Factor

Receiving suitable geometric scale factor is one of the significant strides in scale demonstrating. The scaling relations for the factors embraced in this examination, are appeared in Table 2.

Sr.No.	Parameters	Scale Factors
1	Mass density	1
2	Stiffness	S2
3	Force	S3
4	Modulus	s
5	Acceleration	1
6	Frequency	S1/2
7	Time	S1/2
8	Shear Wave Velocity	S1/2
9	Length	S
10	Stress	S

11	Strain	1
12	EI	S5

Table 2: Scaling Relations in Terms of Geometric Scaling Factor (S)

Typical scaling down procedure for G+ 3 scale down steel model is described below:

According to the first principle, the relation between natural frequency of model (fm) and prototype (fp) is

fm/fp = S1/2

= 3.6

Frequency of the G+3 prototype structure is calculated by using software (STAAD Pro) and it is,

fp = 2.13 Hz.

Therefore required frequency of the model (fm) is

fm = 2.13×3.6

= 7.67 Hz.

Now according to second principle the density of the model (ρm) should be equal to the density of the prototype (ρp).Density of the prototype structure (ρp) is determined as follows:

ρp = mass of prototype/volume of prototype

= 47623.80 / (14×3.25×3.25)

= 322.05 Kg/m3

Therefore the mass of the structural model (Mm) is estimated as

Mm = ρm × Vm

= 322.05 × (1.080×0.25×0.25)

= 21.738 Kg

The elements of segment and piece of scale down steel model is inferred in such a manner that the heaviness of model almost equivalents to 21.738 Kg as required by reenacted laws. Considering all over the subtleties of G+ 3 scale down steel model is worked out. The subtleties of scale down models are as per the following:

Sr. No.	**Content**	**Description**
1	No. of stories	G+3
2	Storey Height	270mm
3	Grade of Steel	Fe250
4	Bay width	250 mm
5	Slab thickness	5 mm
6	Size of Column	12mm X 12mm

Table 3: Geometric and material properties of scale down steel model

A typical G+3 scale down steel model is given in Figure 1.

Fig 1: A typical G+3 scale down steel model

5. Shake Table and Experimental Setup of Shake table

Shake Table is a most fitting exploratory set up for the expectation of seismic conduct of different structural building structures. Basic models are legitimately exposed to dynamic excitations looking like those normal to be experienced in an ongoing seismic tremor occasion. It is conceivable to reasonably mimic the impact of seismic powers on the test structures on Shake Table. The full powerful stacking property makes Shake Table testing a compelling instrument in the examination field. There are two critical difficulties for embracing the Shake Table.

Fig 2: Shake table

Fig 3: Shake table

An exploratory investigation is done so as to approve the crucial common recurrence of a model. The downsized steel model clarified in segment 4.3 is utilized for the study. The research facility set up is produced for fixed base condition without tuned fluid damper. There are 4 quantities of accelerometers used to get the information. Accelerometer no. 1 is at base of Shake Table (Actuator), no. 2 and 3 are at piece level and accelerometer no. 4 is at rooftop level of scale down model. This 4 accelerometer are associated with information procurement framework which converts the simple sign to computerized signals. To demonstrate the advanced sign information procurement framework associated with the workstation. Kampana programming is utilized to get the aftereffects of try. The trial arrangement and situations of accelerometers are appeared in Figure 3.

6. Proportioning of TLD

The TLD are portrayed by three noteworthy proportions in particular tuning proportion, mass proportion and profundity proportions. A TLD that decreases the basic reaction altogether for the given arrangement of estimations of these proportions might be considered as appropriately planned.

6.1 Tuning ratio

As the name suggests, tuning ratio of a TLD, is the ratio of the fundamental, linear sloshing frequency. Generally a tuning ratio of unity or very close to unity is considered to be optimum.

6.2 Depth ratio

Most of the earlier studies have restricted this value to less than 0.3. The depth ratio, which is the ratio of depth of the water h to the tank length L, is a significant parameter for defining the effectiveness of the rectangular TLD. Different water depth ratios (1.5 and 2) were considered. The corresponding responses of the structure have been shown in figure no.5.9 and 5.10. The figure shows the relationship between the excitation frequency ratio & displacement and excitation frequency ratio & acceleration respectively.

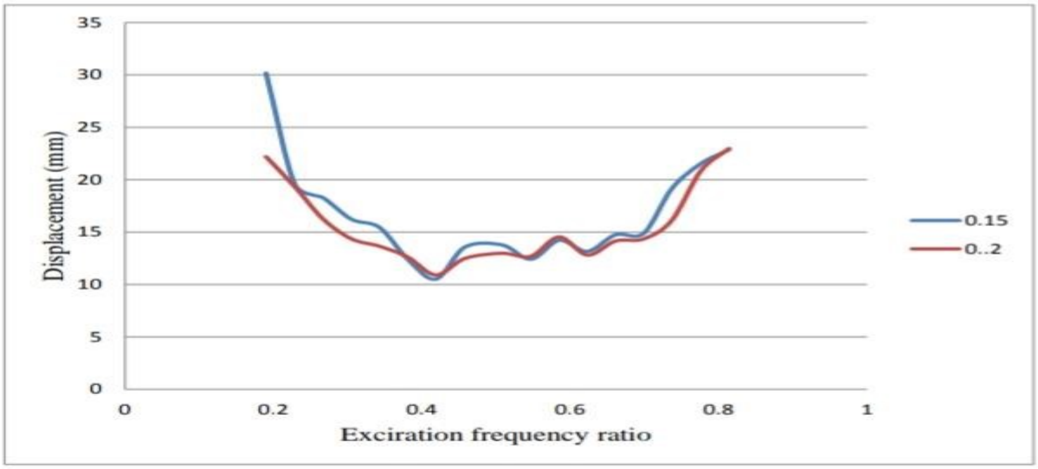

Fig no. 5.9: Displacement responses of a model with different depth ratio

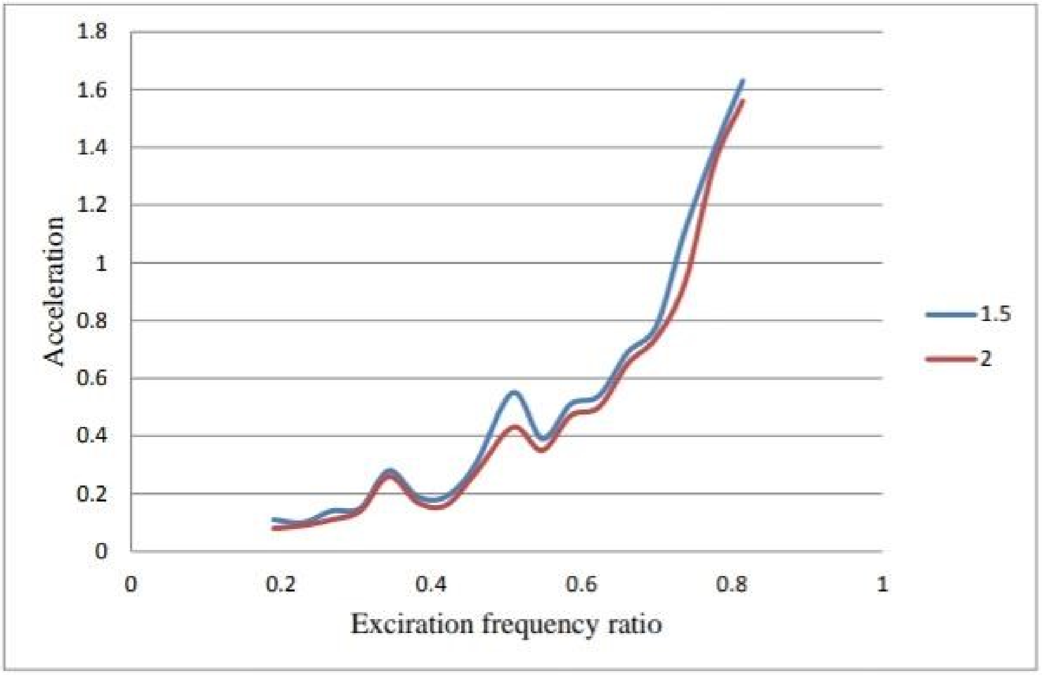

Fig no. 5.10: Acceleration responses of a model with different depth ratio

6.3 Mass ratio

The mass ratio is the ratio of the mass of water in the containers to the mass of the structure itself. In order to make sure that TLD do not influence the dynamic characteristics of the structure and also due to the practical limitations of space on the roof of the structure to place dampers, a mass ratio of 4% was considered in this case. The mass ratio, which is the ratio of the mass of water in the containers to the mass of the structure itself, is a significant parameter for defining the effectiveness of the rectangular TLD. Different mass ratios (4, 6.5 & 7) were considered. The corresponding max response of the structure has been shown in figure no. 5.7 and 5.8. The figure shows the relationship between the excitation frequency ratio & displacement and excitation frequency ratio & acceleration respectively.

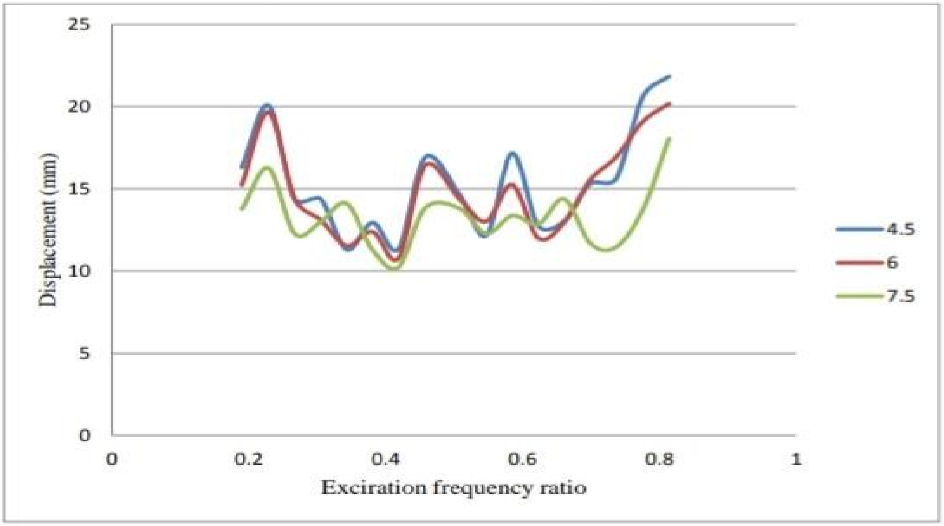

Fig no. 5.7: Displacement responses of a medel with different mass ratio

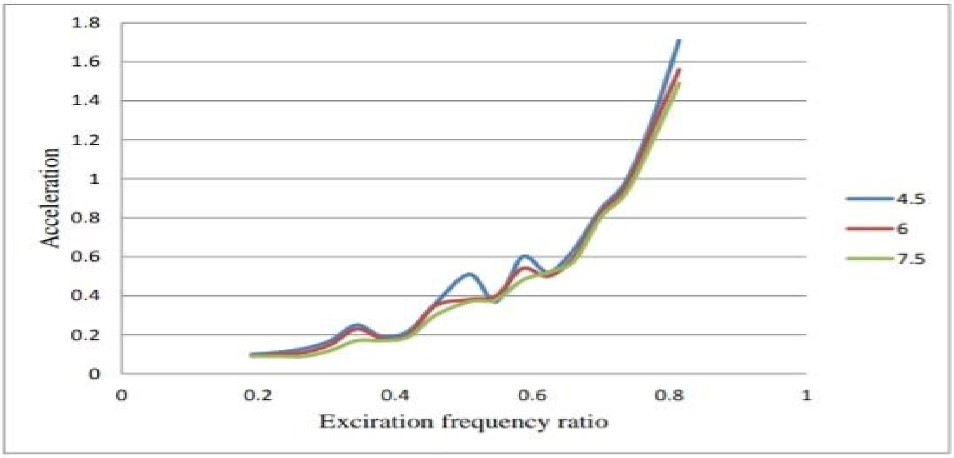

Fig no. 5.8: Acceleration responses of a model with different mass ratio

6.4 Excitation frequency ratio

The frequency ratio of a rectangular TLD is the ratio of the fundamental linear sloshing frequency to the natural vibration frequency of the structure.

7. Design of TLD

From the investigation, the principal recurrence of the structure was evaluated to be around 2.13 Hz relating to structure material properties. Since it was chosen to consider tuning proportion as solidarity, for a water profundity proportion of 0.1.42 and f = 2.13, the length of the tank comes to around 120 mm. Along these lines in this test, a compartment with length of 120 mm was utilized with a water stature of 30 mm. The complete mass proportion for this situation turned out to 4%. The test model of tuned fluid damper utilized for this examination is made by utilizing the acrylic material. For the examination two distinctive TLD are structured. As per the proportioning parameters the components of TLD are fixed. The TLD measurements are 210X120X400 mm and 210X80X400 mm as appeared in table no. 5.5. This TLD are arranged at the top degree of the basic model. The TLD"s are appeared in fig 5.4

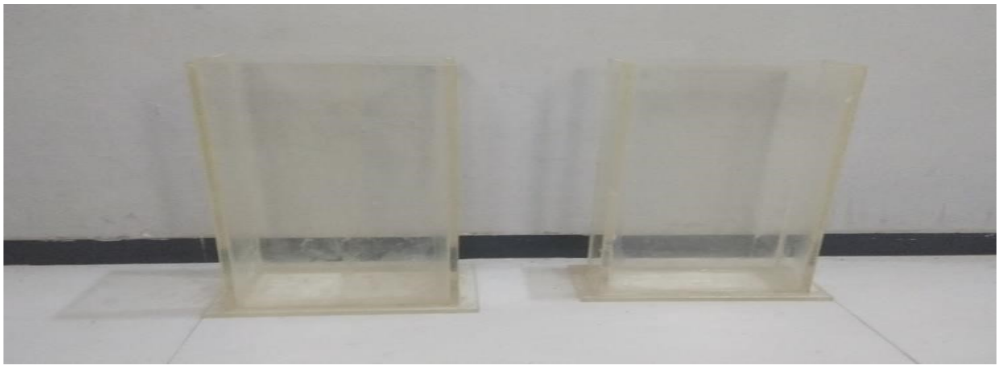

Fig 4: Tuned liquid damper

8. Input Data to Shake Table

The primary goal of the test is to locate the normal recurrence of the model. In Shake Table distinctive information movement can be given, for example, sine, sine clear, arbitrary, Time chronicles, and so forth. Sine Sweep test is given as the information movement to the steel model. The reason for a sine range test is to recognize characteristic frequencies of the test model. In this test a sinusoidal info with consistently differing recurrence is connected to the structure. The recurrence covers the run for which the edge structure is to be qualified. The level of consistent state reverberation reaction acquired relies upon the scope rate. The substance of a sine scope test is that the base excitation information comprises of a solitary recurrence at some random time. The recurrence itself, in any case, is changed with time. The sine range test may start at a low recurrence and at that point breadth to a high recurrence, or the other way around. So as to get regular recurrence of steel model, the model was exposed to a step by step expanding unidirectional consonant excitation (sine range wave) with abundance +/ - 2 mm and recurrence rate in the scope of 0.0 to 0.3 Hz.

9. CONCLUSION

A relatively extensive experimental study is conducted on the implementation of a TLD to control a structure's harmonic reaction. The experimental findings indicate that for harmonic movements a correctly constructed TLD can considerably decrease the structure reaction. In graphic and tabular forms, the impact of tuned situation on structural reaction with and without TLD is assessed and displayed.

The following conclusions are made from the study:

1. The structure's response is determined by considering the structure with and without TLD. During the research, several frequency ratios of excitation were regarded. It is noted that the structure under harmonic loading with TLD has less vibration reaction than the structure under harmonic loading without TLD. TLD is effective in reducing the response of the structure when tuning ratio is near to unity.
2. Different mass ratios of the structure have been considered to evaluate the effectiveness of TLD. The reduction in the displacement is significant as the mass ratio increases. The increase in mass ratio increases the efficiency in the displacement reduction, while the considerable mass of the water that needs to be employed. It is suggested that 4.5% mass ratio can be recommended as the optimum value.
3. Different water depth ratios are considered for the TLD to evaluate the performance of the structure. It is observed there exists an optimum water depth ratio corresponds to the minimum response amplitude. The optimum water depth ratio is found to be 0.15. In case of the higher water depth ratio no significant reduction in response amplitude is observed for higher depth ratios. The TLD having a higher water depth ratio does not slosh as much as that for low water depth ratios.
4. From this study, it can be concluded that properly designed TLD with efficient design parameters such as tuning ratio, depth ratio and mass ratio is considered to be a very effective device to reduce the structural response.

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