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Evaluation of Performance of Tuned Liquid Damper Attached to Scaled Model

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Abstract: *In this research, the performance of tuned liquid damper attached to single degree freedom steel model have been evaluated during lateral movement, by free vibration analysis. Awater tank mounted on test model containing water of certain depth, serves as tuned liquid damper (TLD). A method of logarithmic decrement have been used to find the damping ratio of test model from its free vibration response. The properties of structural model, with and without tuned liquid damper have been compared. It was found that tuned liquid damper increases the damping ratio of structural model by virtue of which it helps in reducing response of structure during lateral movement.*

Keywords: *Damping ratio, free vibration test, single degree freedom, tuned liquid damper (TLD), water tank.*

I. INTRODUCTION

Dampers are the devices that are added to the structure in different ways in order to reduce its lateral movement caused because of some external excitation, i.e. wind and earthquake. Passive dampers are considered more suitable way to do this because of its effectiveness and do not require any external source of energy[1]. Tuned liquid damper (TLD) is a passive energy damper, which is water containing body mounted on top level of the building. It can reduces displacement of structure subjected to ground motion by increasing its damping ratio. Damping ratio is that property of structure by virtue of which it dissipated energy of its lateral movement [2].

In Past, most of the experimental and numerical studies have been conducted to evaluate the properties of structure with tuned liquid damper. Tuned Liquid Damper was also have been tested under different ground motion. Some significant ways were introduced to evaluate the properties of such system and it was concluded that TLD works in more effective way by installing it at the top level of building. Further in order to achieve better performance, the TLD should be designed so that the period of TLD remains same as natural time period of structure. The period of TLD is defined by the sloshing time period of water in it[3].Bhattacharjee et al. conducted an experiments on scaled model of structure-TLD system under different ground motion. The performance of TLD for different tank orientation have been evaluated at different water depths for wide range of forcing frequencies.The vibration response of structure have been studied in each case. It was determined that the specific depth of water is always needed in tuned liquid damper so that it can effectively decrease the response of building during lateral movement [2]. Chen et al. conducted study on simple pendulum type model that simulate the long period structures. The free vibration analysis have been used to find the ability of TLD system in controllingresponse of structure [4].

In this study, performance of tuned liquid damper attached to the single degree freedom, steel model have been assessed in term of damping ratio by using free vibration analysis.

II. MATERIALS & METHODS

2.1 Experimental setup

Figure1 shows a test model of TLD, in which a water tank is mounted on steel model. Steel model is consist of a diaphragm, four supporting columns and a base plate. While the water tank made of transparent acrylic sheet, attached to the diaphragm of steel model.The scaled model with tuned liquid dampers is designed keeping in view the design parameters and experimental conditions. A data acquisition system consist of controller (computer), data logger and sensor (accelerometer) attached to diaphragm have been used to record the response data of test model during experiment.

2.2 Testing procedure

A free vibration test is performed on test model with and without TLD. Model with TLD contains 7cm depth of water in tank while model without TLD contains empty tank. In each case, the structure is initially excited by unidirectional small jerk. Response of structure is recorded in term of acceleration with the help of data acquisition system.

Fig 1: Experimental setup of test model.

III. ANALYSIS

The free vibration data in both the cases have been converted to the required units and are plotted as shown below.Figure 2 and 3 shows the free vibration response of test model, with zero depth of water and 7cm depth of water respectively.

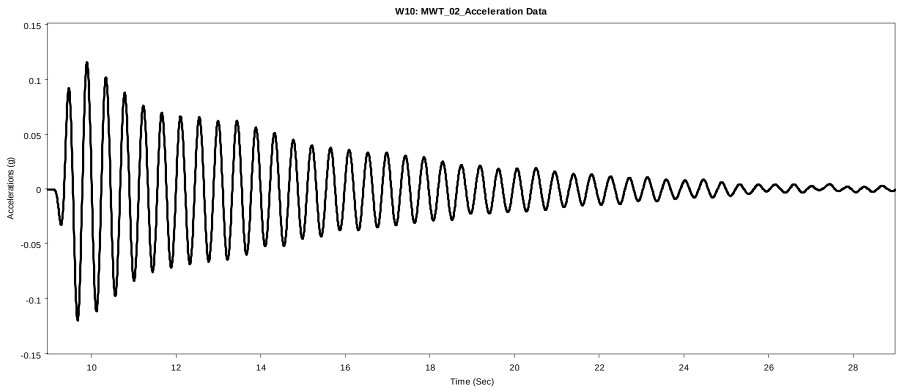

Fig 2: Acceleration response of test model without TLD under free vibraiton.

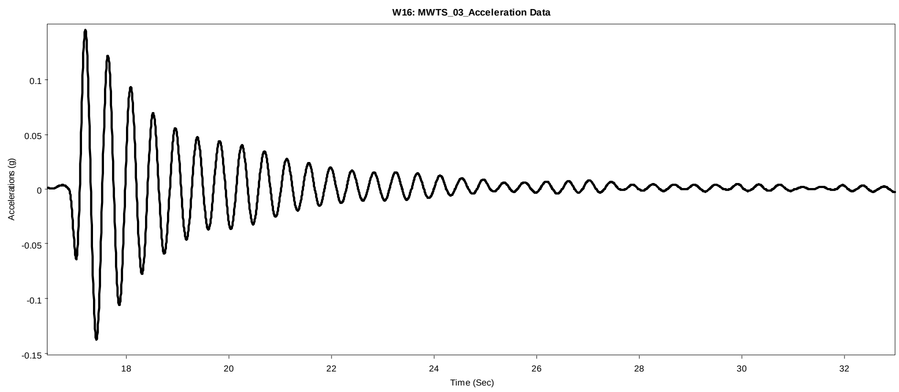

Fig 3: Acceleration response of test model with TLD under free vibration.

The damping ratio is evaluated with logarithmic decrement method. A mathematical formula of this technique is given as

$$j= \frac{\sqrt{1-\zeta^2}}{2\pi\zeta} \ln\left(\frac{u_1}{u_{j+1}}\right) \tag{1}$$

Where,
ζ = Damping ratio
J = Number of cycles
U_1 = Response value at initial cycle
U_{j+1} = Response value at $(j+1)^{th}$ cycle

Following figure and numerical equation explains this technique, applied to the free vibration response of test model without TLD.

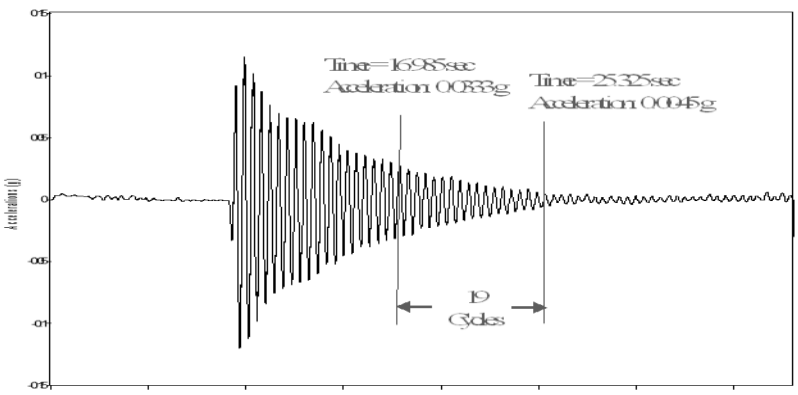

Fig 4: Free vibration response analysis by logarithmic decrement method.

$$19= \frac{\sqrt{1-\zeta^2}}{2\pi\zeta} \ln\left(\frac{0.0333\ g}{0.0045\ g}\right)$$

Damping ratio, ζ=0.01677=1.68 %

Similarly, this method is applied to the free vibration response of test model with TLD at water depth of 7 cm. The damping ratio in this case was found to be 2.24%.

IV. CONCLUSIONS

From the result analysis it can be concluded that TLD at certain depth of water can increase the damping ratio of structure by 33%. By virtue of this property, TLD is helpful in reducing response of structure during lateral movement. Further, the logarithmic decrement method was found effective for the evaluation of damping ratio of structure with tuned liquid damper.

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