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Comparison of seismic performance of variably baffled TLD and the optimal TMD

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ABSTRACT: In this study, to improve the efficiency of TLD, a Variably Baffled Tuned Liquid Damper (VBTLD) has been used. The baffles are so that they divide the tank into three equal parts when they are fully closed. Furthermore, when they are open or partially closed, they can serve as some obstacles and improve the energy dissipation parameters. When this damper meets an excitation with a specific frequency, the baffles can be tuned to make the frequency of sloshing equal to that frequency. VBTLD used in this paper could be set for the frequency range from 1.73 to 3 times of a specific frequency. Compared to a simple TLD, VBTLD can be tuned to a range of frequencies to improve the performance of structure against external excitation. At first, the benchmark building was modeled in OpenSees, then the performance of the device was verified by previous test results. To examine the performance of VBTLD, Tuned Mass Damper (TMD) with optimal parameters was used in this study. Results showed that when the baffles are at the best angle, VBTLD with water depths of 42 mm has maximum response reduction for the numerical model subjected to the Kobe earthquake at intensities of 2, 4, 6, and 8% of the initial maximum acceleration of the earthquake (PGA=0.87g). The improvement of structural behavior compared to the optimal mass damper at maximum acceleration are respectively 23.1, 22, 14.6, and 10.5%, while for damper with water depths of 63 mm, they are respectively 8.17, 9.5, 6.7 and 6.8%.

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1. INTRODUCTION

Vibration control of structures against periodic loads such as wind, earthquake, and traffic can be performed using passive, semi-active and active control systems. Tuned liquid damper (TLD) is often utilized as a passive control system to mitigate the structural vibrations. Common TLDs should be tuned with the main frequency of structure in the first mode because it is not possible to change the characteristics of TLD during its performance. However, in this research, the new system of Variably Baffled Tuned Liquid Damper (VBTLD) is utilized.

The liquid in TLDs produces the damping and control forces via i-laminar and turbulent movement of fluid ii-colliding with the tank walls, making a pressure difference and wave breaking, which results in an extra shear force on the tank bottom. The resultant force is applied to the structure opposite to the vibration direction. While in tuned mass dampers, the mass inertial force is the only deterrent force against the structural movement. Installation of baffles inside the TLD tank will change the fluid traveling time in the tank. Also, the baffles act as some obstacles and increase the energy dissipation.

In this paper, a new kind of TLD equipped with rotatable baffles was compared to an equivalent tuned mass damper. The TLD has eight vertical baffles which can be fixed at desired angles. The eight baffles are ordered at two rows each contains four baffles. Also, the baffles are flat, smooth and rigid and are installed to balance the damper's frequency to counteract the structural vibrations at various frequencies. Figure 1 shows the new system of variably baffled tuned liquid damper (VBTLD).

2. MODELING OF THE STRUCTURE AND NUMERICAL STUDIES

To investigate the baffled liquid damper performance, an equivalent tuned mass damper is utilized. One of the common methods of passive structural control against earthquake and other excitations is to use tuned mass damper systems. These dampers consist of three parameters of mass, damping, and stiffness. Tuned mass dampers often reduce the amplitude of the responses via affecting a single mode, which is usually the first mode. As the parameters of tuned mass dampers are constant during the vibration, it is important to tune them accurately [2]. To find the optimized values for the parameters of tuned mass dampers using numerical models, numerous dynamic analyses are needed. So, the volume of essential calculations is very large! In this research, some relations which are emphasized in previous studies are utilized to tune the values of damping and optimized frequency.

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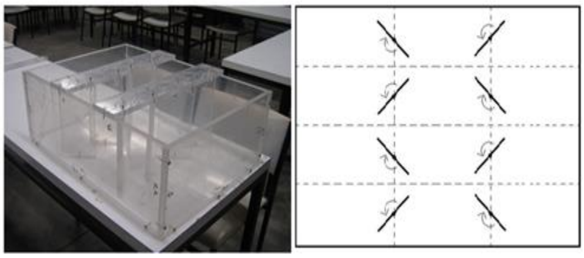

Fig. 1. The new system of variably baffled tuned liquid damper (VBTLD) [1].

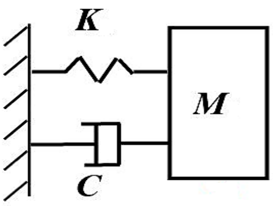

Fig. 3. The tuned mass damper modeled in the OpenSEES.

Fig. 2. The 5-story benchmark structure [3].

The mentioned damper was installed on a 5-story benchmark structure. The 5-story benchmark structure has been designed and manufactured by the Sydney University of Technology in Australia and is one of the reference models registered by the international association of structural control (IASC). The researchers set down their analytical and experimental algorithms on a benchmark structure and improved their findings by comparing them to each other. The structures plan has 1.5 m length (2@0.75 m) and 1.0 m width (1@1.0 m). The beams are made of 75×75 mm^2 hollow box sections with a thickness of 4 mm. The columns are made of 25×25 mm^2 square steel sections. The 5-story benchmark structure is shown in Figure 2.

In performed experiments in the laboratory, the heights of stories were considered to be 0.72 m. The total mass of the structure without additional mass was 352.5 kg. The connections of the structure were pinned at 1th and 3rd stories and fixed at other stories. To adjust the vibration frequency of the structure, additional masses of 127 kg and 617 kg were added to the 4th and 5th stories, respectively.

3. MODELING OF THE TUNED MASS DAMPER

The viscose damping element was used to model the damping of the equivalent tuned mass damper in OpenSEES. Also, an element with elastic stiffness was used to model the stiffness, and the ZeroLength element was used to assign the damping and stiffness to the tuned mass damper on the roof. This element has connected the stiffness and damping of the tuned mass damper between the roof and the mass of tuned mass damper. The governing equations of mass dampers in MATLAB were utilized to validate the behavior of modeled tuned mass damper in OpenSEES with its real dynamic performance. Figure 3 shows the tuned mass damper modeled in the OpenSEES.

4. EARTHQUAKE RECORD USED FOR TIME-HISTORY ANALYSIS

To investigate the seismic behavior of the structure equipped with VBTLD, the structural model was subjected to the Kobe earthquake, Hanshin station, 1995. The Kobe earthquake was applied to the structure with PGA of 2%, 4%, 6%, and 8% of the main PGA. The performance of the structure equipped with VBTLD under these excitations was compared to that of equivalent TMD at its optimum condition.

5. CONCLUSIONS

In this study, to improve the efficiency of TLD, a Variably Baffled Tuned Liquid Damper (VBTLD) has been used. This damper is composed of a tank and eight rotatable baffles inside. The baffles are so that they divide the tank into three equal parts when they are fully closed. Furthermore, when they are open or partially closed, they can serve as some obstacles and improve the energy dissipation parameters. When this damper meets an excitation with a specific frequency, the baffles can be tuned to make the frequency of sloshing equal to that frequency.

To examine the performance of VBTLD, Tuned Mass Damper (TMD) with optimal parameters was used in this study. Viscose and stiffness elastic elements respectively have been used for damping and stiffness of TMD modeling. To study the seismic performance of the structures equipped with VBTLD and TMD, the Kobe earthquake record in Hanshin station was used.

Despite common TLDs, VBTLD can be tuned at a frequency range of 1.73-3.00 Hz. The achieved results from excitation of such controlled structure show that utilizing a damper with a water depth of 42 mm under PGA of 2%, 4%, 6% and 8% of the main PGA has reduced the structures displacement response by 23.1%, 22%, 14.6% and 10.5% respectively. These values for the damper with a water depth of 63 mm are 8.2%, 9.5%, 6.7% and 6.8%, respectively.

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