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INVESTIGATION OF TMD AND TLD PERFORMANCE UNDER EARTHQUAKE EXCITATION, THE CASE OF 22-STORY RESIDENTIAL BUILDING

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Passive energy dissipation (PED) devices are a group of structural protective systems which are widely accepted by the engineering community. Passive control systems based on the structural response control are divided in two groups. The first group is used to reduce structural response by conversion of kinetic energy to heat and the second one by regarding the increased mass of oscillators, transfer energy among vibrational modes. The second group includes dynamic vibration absorber such as tuned mass damper (TMD), tuned liquid column damper (TLD) (Iemura et al., 2005).

In this paper, the effect of TLD and TMD to reduce structural response caused by seismic loads is presented. In order to compare damper performance, the 22 floors building of C6 located in the town Shahid Bagheri with 2.52 (rad/s) natural frequency and 1190 (ton) modal mass has been investigated using the Matlab/Simulink toolbox.

The mass rests on bearing that function as rollers and allow the mass to translate between the mass and the adjacent vertical support members which transmit the lateral "out-of-phase" force to the floor level, and then into the structural frame (Conner, 2000; Soong and Dargush,1997).

A Tuned liquid damper (TLD) consists of a tank partially filled with liquid (preferably water). The various mechanisms of the energy dissipation are viscous action of the fluid, wave breaking, and contamination of the free surface with beads and container geometry and roughness (Yalla, 2001).

The TLDs can be broadly classified into two categories: shallow-water and deep-water dampers. This classification is based on the ratio of the water depth to the length of the tank in the direction of the motion. A ratio of less than 0.15 is representative of the shallow water case. The deep-water damper has one drawback in the fact that a large portion of water does not participate in sloshing and adds to the dead weight (Yalla, 2001); therefore in this article shallow-water damper is used.

According to the same performance of TLD and TMD, the equation of motion of a multi-degree structure equipped by tuned dampers, and equation of motion of dampers under the seismic loads is as follows (Chang and Qu, 1998; Hochrainer and Ziegler, 2006):

$$(1+\mu_2)\ddot{x} + \mu_3\ddot{x}_d + 2\xi_s\omega_s\dot{x} + \omega_s^2 x = -L_j\ddot{x}_g \quad (1)$$

$$\mu_3\ddot{x} + \mu_1\ddot{x}_d + 2\mu_1\xi_d\omega_d\dot{x}_d + \mu_1\omega_d^2 x_d = -\mu_1\ddot{x}_g \quad (2)$$

Where $\ddot{x}$ ‹$\dot{x}$ ‹x ‹ξ_s and ω_s are the acceleration, velocity, displacement, damping and frequency of the structure respectively and $\ddot{x}_d$ ‹$\dot{x}_d$ ‹x_d ‹ξ_d and ω_d is the acceleration, velocity, displacement, damping and frequency of the damper, respectively.

$$L_j = \frac{\overrightarrow{\phi_j}^T . M_s . \vec{r} + \phi_{jk} . m_d}{\overrightarrow{\phi_j}^T . M_s . \overrightarrow{\phi_j}} \quad (3)$$

For the case of TMD, these coefficients can be expressed as:

$$\mu_1 = \mu \; ; \mu_2 = \ \phi_{jk}^2 . \mu \; ; \mu_3 = \ \phi_{jk} . \mu \qquad (4a, b, c)$$

$$\mu = \frac{m_d}{\phi_j^T . M_s . \phi_j} \quad \text{(In this study is assumed 2\%)} \qquad (4d)$$

$$\alpha_{opt} = \frac{\omega_d}{\omega_s} = \frac{1}{1+\mu} \; ; \xi_{dopt} = \sqrt{(3\mu/8(1+\mu))} \qquad (4e, f)$$

For the case of TLD, these coefficients can be expressed as follows:

$$\mu_1 = \frac{8}{\pi^3}\frac{L}{h}\tanh\left(\frac{\pi h}{L}\right) . \mu \; ; \mu_2 = \ \phi_{jk}^2 . \mu \; ; \mu_3 = \ \phi_{jk} . \mu_1 \qquad (5a, b, c)$$

$$\omega_d = \sqrt{\frac{\pi g}{L}\tanh\left(\frac{\pi h}{L}\right)} \qquad (5d)$$

Optimization of damping ratio is very necessary to increase the TLD effects. Chang and Gu (1999) have optimized design properties of TLDs.

$$\xi_{dopt} = \left[\frac{\sqrt{1+\mu_2} - \sqrt{1+\mu_2+\mu_3}}{2\sqrt{1+\mu_2}}\right]^{1/2} \qquad (6a)$$

In order to investigate the performance of dampers under earthquake excitations, in the current study four earthquake acceleration records were used as input ground motion: i.e. the Elcentro and Hachinohe records as far-field, and Kobe and Northridge as near-field time histories. Peak ground acceleration (PGA) has scaled to 0.3g, 0.5g and 0.8g as low, moderate and extreme levels. RMS of displacement, PI_RMS and PI displacement were used to compare the performance of dampers. Table 1 shows the result of damper performance under different earthquake excitations.

Table1. Percent reduction Response (PGA= 0.3, 0.5, 0.8)

		Elcentro	Hachinohe	Kobe	Northridge
TLD	PI_RMS	12	34	6	34
	PI_displacement	6	30	1	12
TMD	PI_RMS	16	37	8	37
	PI_displacement	7	32	1	14

Proportional to the obtained results, tuned dampers have better performance for reduction of RMS_displacement than reduction of maximum displacement. Compration between TMD and TLD showed that TMD is more effective for reducing the maximum displacement and RMS of selected structure. By comparing the results in accelerations PGA=0.3g, 0.5g and 0.8g, it is clear that if the optimal tuned dampers were designed, the dampers' effectiveness did not change as PGA increases.

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