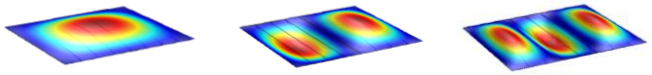
Multi-mode vibration Control of a Floor System Using Tuned Mass Dampers

Tuned mass dampers (TMDs) are tuned damping devices commonly used for dampening the vibration of a structure at a particular resonant frequency. TMDs come in various configurations. The commonality between all of them is their make-up which includes an inertia element (mass) suspended by an energy dissipating (damping) device and a restoring (resilient) element.

The composite floor system of a large multi-purpose room on the third floor of the admission building at a state university, exhibited noticeable vibration caused by walking. The composite floor system consists of three long and narrow bays.

The vibratory attributes of the floor system established by numerical analyses and measurement revealed the presence of three modes contributing to the perceptible vibration of the floor; the shapes of these modes are shown in Figure 2.

Figure 1 The admission building



Mode 1 at 6 Hz Mode 2 at 7 Hz Mode 3 at 9.4 Hz

Figure 2 The first three modes and their corresponding natural frequencies of the floor system

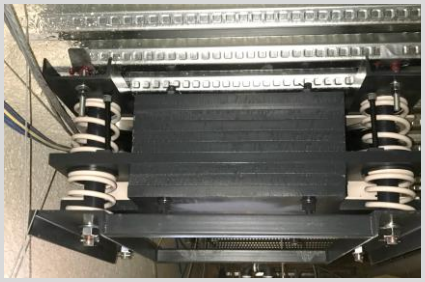
In mode 1, also known as the 'trampoline mode', the entire floor vibrates with the peak of vibration at around the center of the floor. When the floor vibrates with mode 2 pattern, half of the floor goes up and the other half goes down, with a quiet (nodal) line in the middle of the floor. This pattern of vibration, has the nodal line in the middle of the room. Mode 3 divides the floor in 3 segments (along the bay lines) with one segment (bay) moving in one direction and the other two moving in the other direction. Depending on the location and the walking pace of the walker, two or all three of these modes could be excited, making the floor vibrate at their corresponding frequencies.

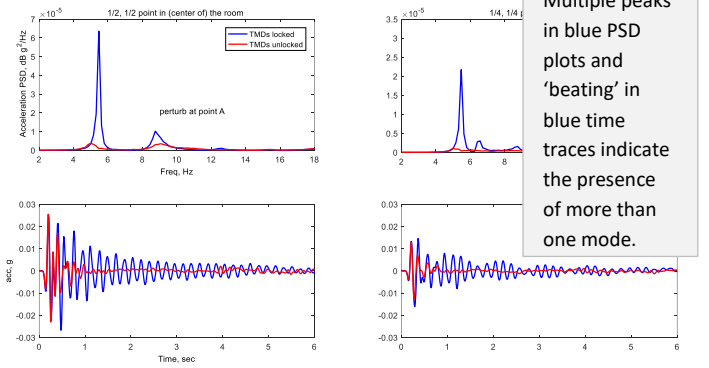
Three pairs of tuned mass dampers (TMDs) targeting the three modes of vibration were designed using the dynamic parameters of the floor system, namely natural frequencies and modal shapes, evaluated by numerical analyses and verified by measurement.

The TMDs were fabricated, shipped to the job site, and installed underneath the floor system at locations where their target modes have the highest vibration level. Following the installation, the TMDs were commissioned and fine-tuned.

Floor vibration without and with the TMDs operational were measured; the results are presented in Figure 3 with blue and red traces relating to the TMDs locked and unlocked, correspondingly.

Two 600 Kg TMDs targeting mode 1, Two 450 Kg TMDs targeting mode 2, and two 300 Kg TMDs targeting mode 3 were installed underneath the floor. One of the installed TMDs is shown below





Multiple peaks in blue PSD plots and 'beating' in blue time traces indicate the presence of more than one mode.

Figure 3 Power spectral densities (PSDs) and time traces of measured acceleration at the center of the floor (the left plots) and the ¼ , ¼ point (the right plots) in response to heel drop perturbation at the center of the room.

Comparison of the red and blue traces in Figures 3 clearly points to the effectiveness of the tuned mass dampers in adding substantial amount of damping to their three target modes, quieting the vibration of the floor system.