Monumental Staircase Vibration Abatement Using a Tuned Mass Damper-2

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.

To lower the vibration level of a monumental staircase, one 500 lb tuned mass damper (TMD) was designed, fabricated, and appended to the structure. The natural frequency of the staircase was measured and used for tuning the TMD. Figure 1 shows the landing of the staircase with two of the measurement locations highlighted.

The first natural frequency was measured at 8.2 Hz and damping ratio at 2%.

Monumental aesthetically pleasing staircases have become a common addition to architectural designs in recent years. The long unsupported span, low mass, and low damping ratio of such iconic staircases normally cause vibration serviceability problems making them highly responsive to human-induced vibration.

The vertical forces generated by humans ascending and descending a stair are much more severe than forces generated while walking on a flat surface. Humans ascend and descend stairs at step frequencies up to 4 Hz, which is almost double the step frequency for walking on a floor. Thus, the second harmonic of stepping perturbation can match any natural frequency below about 8 Hz, which allows it to forcefully excite most grand staircases.

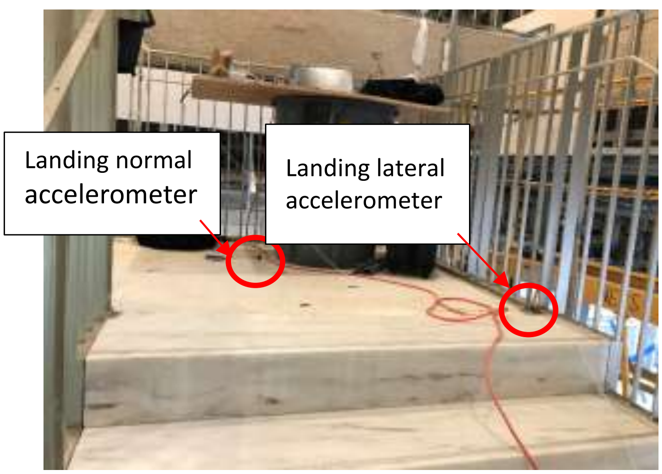

Figure 1 The landing of the nearly completed staircase

In Design Guide 11, tolerance limit of vibration acceleration for staircases subject to a normal descent by a 168 lb person is 1.5% of *g*. This limit is extended to 3% g for fast descents.

The TMD was installed in the cavity underneath the landing. Figure 2 shows the images of the TMD installed in the cavity underneath the landing and the TMD itself.

The blue traces in Figure 3 depict the power spectral densities (PSDs) and time traces of the measured landing acceleration without the TMD in place. The red traces in Figure 3 show the same measurements as those of blue traces, except with the TMD installed.

To increase the natural frequency of the staircase and yet avoid using the traditional means of stiffening such as using large stringers or placing posts underneath the landing, which would have taken away from the splendor and beauty of the structure, the staircase was suspended from the ceiling using to small diameter steel wire ropes. This suspension scheme increased the natural frequency of the staircase in vertical direction to above 8 Hz.

Figure 2 The TMD installed in the cavity underneath the landing

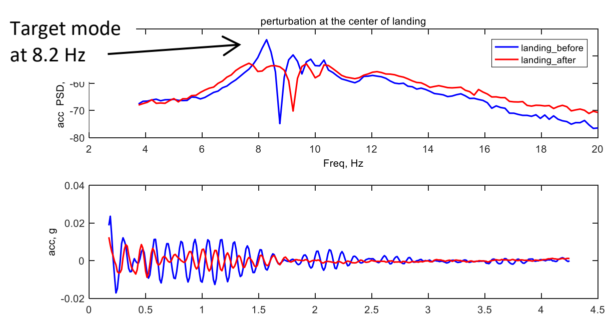

Figure 3 measured vibration without (blue) and with (red) the TMD

Comparison of the red and blue traces in Figure 3 clearly points to the effectiveness of e tuned mass damper in dampening its target mode, abating the vibration of the staircase.