Rhythmic Perturbation and Floor Vibration

Any repetitive perturbation (such as movement in a rhythmic fashion) not only carries power at its fundamental frequency, but also at its higher order harmonics (integer multiples of its fundamental frequency). Figure 1 depicts such a perturbation (with the frequency of 2.4 Hz) both in time and in frequency domains. Note that such perturbation can correspond to dancing or any other rhythmic human activity with the repetition of 2.4 steps/sec. In addition to the fundamental frequency, the first and 2nd order harmonics of this perturbation are highlighted in Figure 1(b).

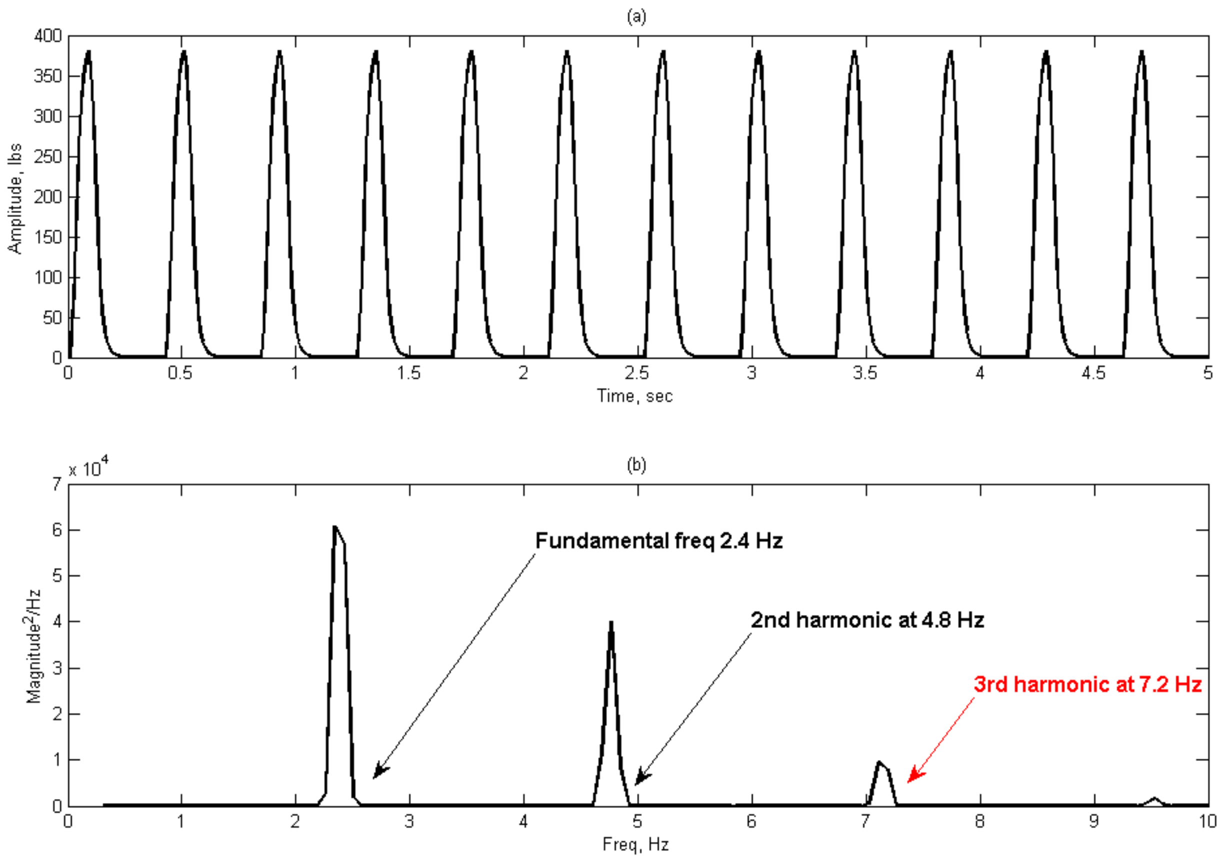

Figure 1 Time trace (a) and power spectral density (b) of a 2.4 Hz rhythmic perturbation

The blue (dashed line) trace in Figure 2 depicts the excessive vibration induced by the above-mentioned rhythmic perturbation to a floor system with the first resonant frequency of 7.2 Hz which happens to match the 3rd harmonic of 2.4 Hz repetitive human activity.

The black (solid line) trace in Figure 2 shows the vibration of the above-mentioned floor in response to the same rhythmic perturbation as the one shown in Figure 1, except at a slightly slower pace, i.e., 2.2 steps/sec. Comparison of this vibration to the one caused by a 2.4 step/sec rhythmic perturbation depicted in blue/dashed line trace of Figure 2 shows that a slight change in the rhythm of such perturbations have a profound effect on the severity (many folds increase in amplitude) of vibration when that slight change makes one of high order harmonics of perturbation match one of the resonant frequencies of the floor system. This explains the reason behind having excessive vibration in one event and not in another event.

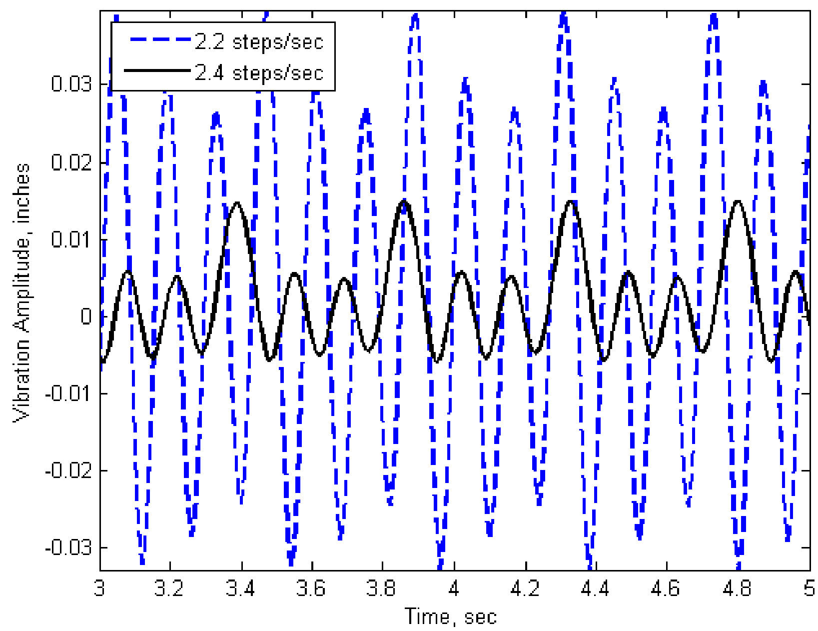

Figure 2 The vibration response of a floor to a 2.2 Hz (black trace) and 2.4 Hz (blue trace) rhythmic perturbation

As stated above, when one of the higher order harmonics of a repetitive perturbation caused by rhythmic motion matches one of the dominant resonant frequencies of a floor, it makes the floor to resonate excessively. Although stiffening the floor and/or adding mass to it could address the issue, but they are not attractive solutions especially for the floor system in a building which is already built.

Note that a floor system, like any other complex structure, has many resonant frequencies. Normally the first one (or the first two) of these resonances (occurring at low frequencies) is (are) the most dominant and cause perceptible vibration. This does not mean that the floor systems (and the rest of the structure for that matter) vibrate at their dominant, low resonant frequencies, only; such structures vibrate at high resonant (and forcing) frequencies as well, but the level of vibration at these frequencies is too low to be perceived as annoying vibration.

An alternative treatment to abate the perceptible vibration of the floor system at its dominant resonant frequencies, is adding more damping to the floor. The red trace in Figure 3 shows the positive impact of tuned damping on abating the resonant vibration of a floor subject to rhythmic perturbation.

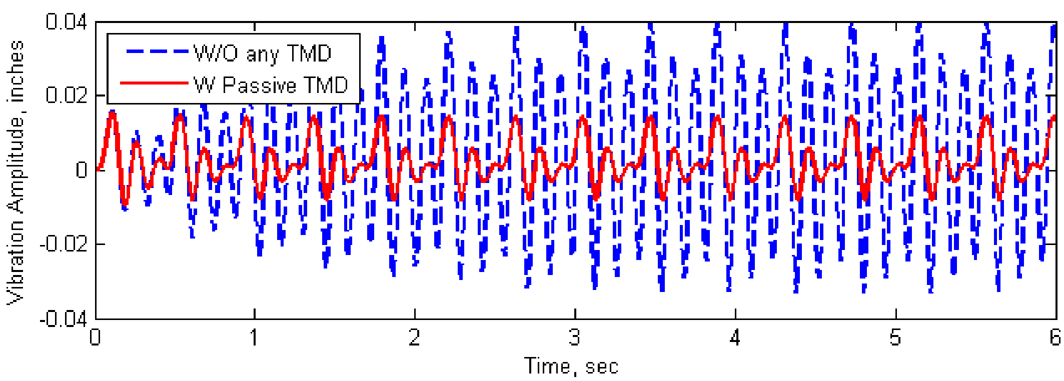

Figure 3 The vibration response of a floor without (blue trace) and with (red trace) of tuned damping