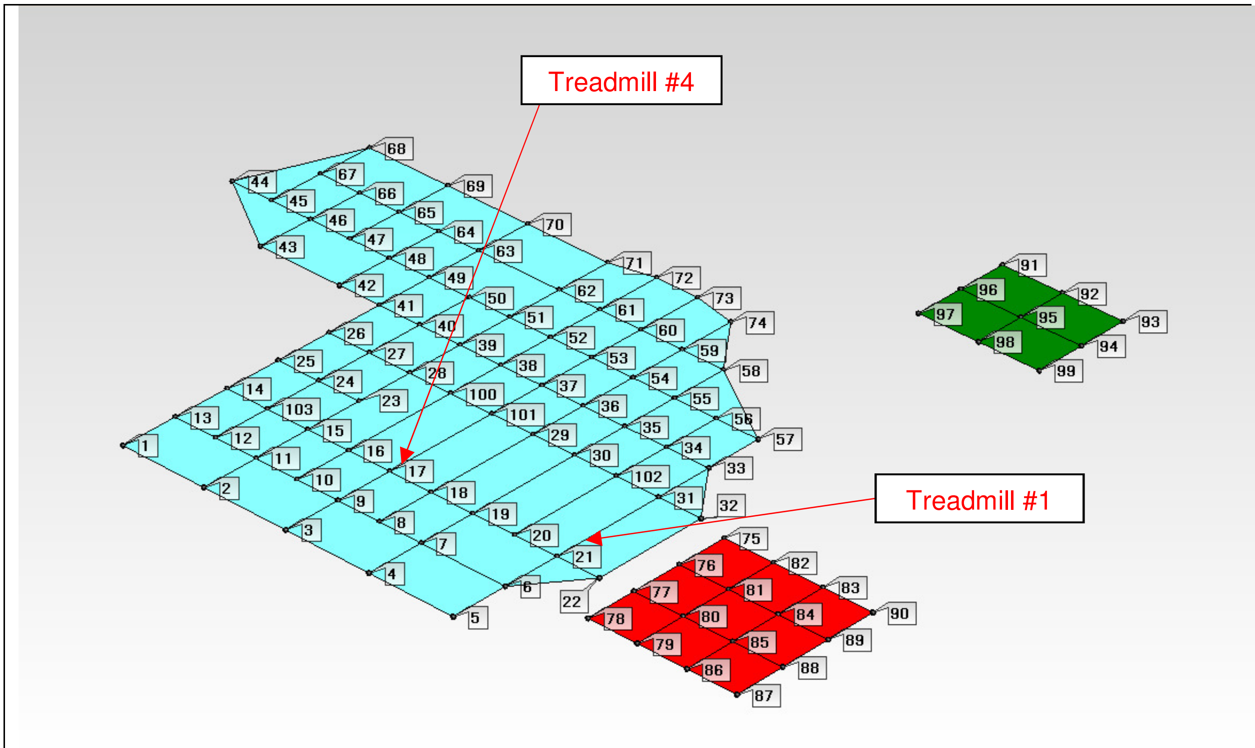
Case History: Floor Vibration

This case history summarizes an investigation involving excessive vibration levels of the 29th floor exercise center of the executive offices of a major corporation. The primary complaint was excessive floor vibration occurring in adjacent executive (CFO) offices and conference rooms during noon lunch time when office staff would use treadmills in the exercise center. Unfortunately, existing vibration isolation pads under each treadmill were not sufficiently reducing floor vibration. All of the floor areas in the exercise center, offices and conference rooms were covered with short nap/pile carpeting. One restriction was no modifications could be made to the carpet or interior office spaces for this investigation, and this investigation was to be conducted at night when the building was empty.

Since carpeting could not be modified or removed, a methodology of maximizing vibration transmissibility though the carpeting was developed. Sensor mounting systems were evaluated using carpet samples, seismic accelerometers, and different coupling methods during impact transmissibility measurements. Several coupling methods were examined, including various furniture spikes and such, but the method that yielded best transmissibility results (broadband and linear frequency response) was stud mounting each seismic accelerometer to a 10”x10”x1” steel plate (29 pounds) laid flat on the carpet.

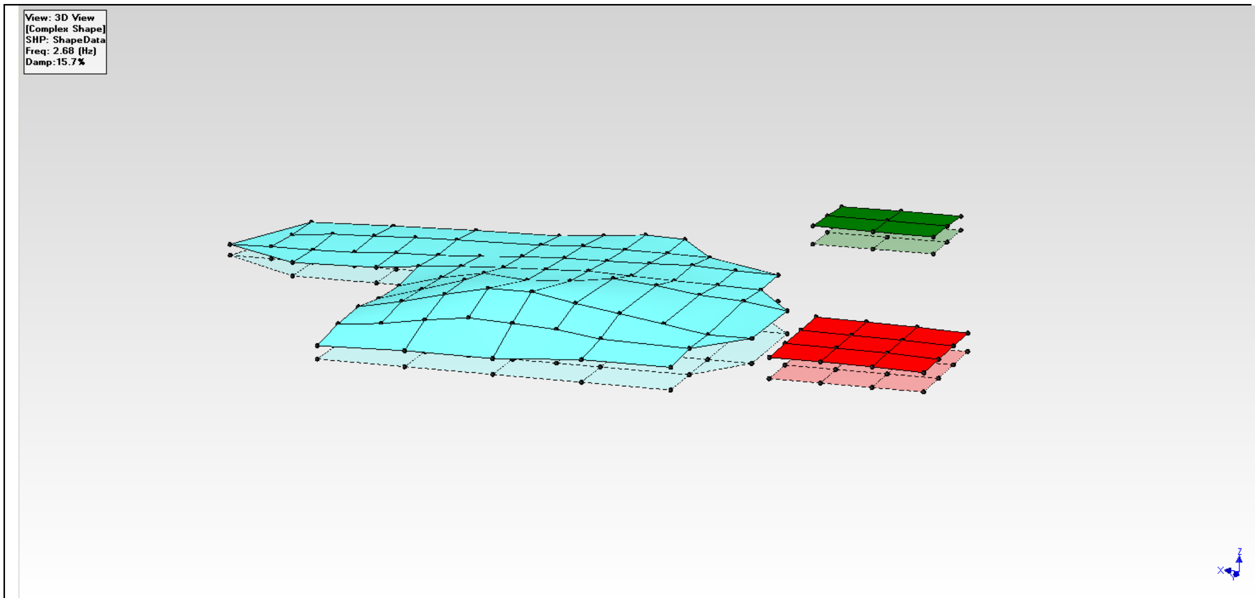
To investigate the root cause for these excessive levels, vibration measurements were conducted to characterize floor motion within the exercise center, adjoining offices and conference room while a treadmill was in operation. An operating deflection shape (ODS) analysis was conducted to characterize floor motion while a treadmill was running. To simplify these measurements and analysis, only one (1) treadmill was in operation during the testing. The #4 treadmill was used throughout the vibration measurements for the operating deflection shape analysis. For this ODS, one reference seismic sensor (IMI 626B02) was attached to a steel plate and located on the exercise center floor where vibration levels appear to be greatest. For these measurements, the reference sensor was positioned in front of the operating treadmill #4. This sensor was used as an amplitude and timing reference for the other three roving seismic sensors (IMI 626B02). These three sensors were also attached to large steel plates and were moved about the floor. Vertical floor vibration measurements at each floor location were obtained in this manner. These vibration measurements included frequency response measurements or functions, called FRF’s. The FRF’s contain information concerning how each of the three sensor locations moved/vibrated relative to the reference sensor. After completing the ODS, additional vibration measurements were also made while treadmill #1 was in operation, for a comparison. From the operating deflection shape measurements, floor vibration was characterized and corrective actions were developed to reduce unwanted vibration levels in the conference room and nearby office.

To generate the necessary floor vibration energy, a technician volunteered to run on the treadmill during each vibration measurement. A constant running speed of 7 mph was maintained (2.7Hz foot-fall frequency) during each measurement. Same technician was used throughout these measurements to try to maintain “repeatable” vibratory loading. Now that’s a committed volunteer!



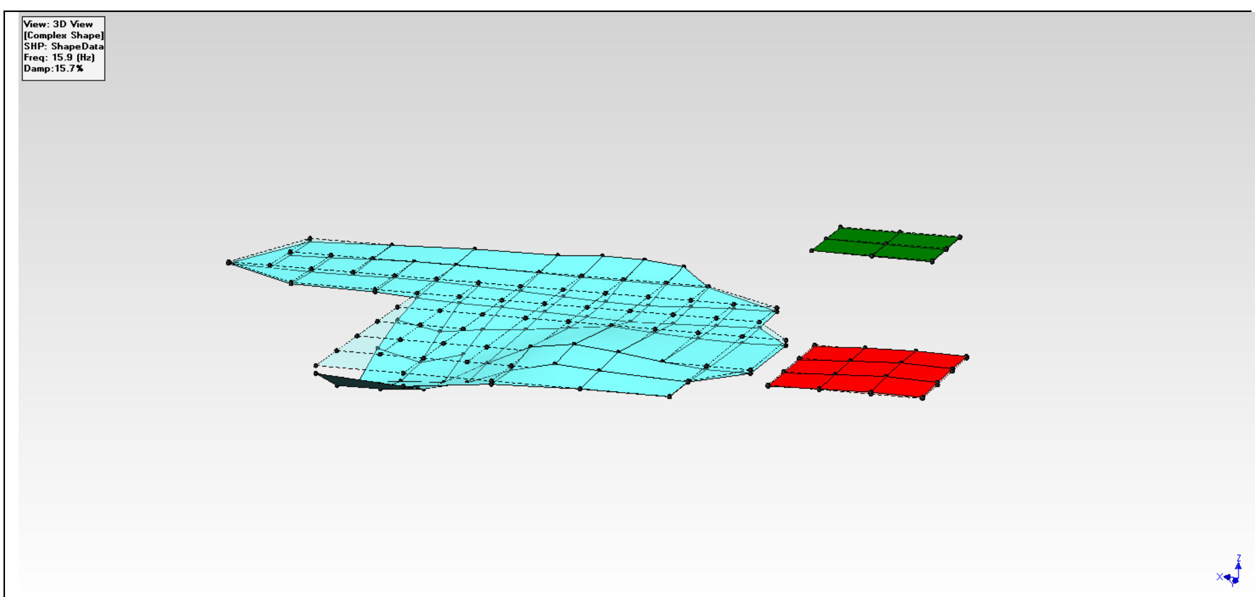
ODS Analysis Model: Exercise Room (cyan), Executive Office (green), Conference Room (red), Treadmill #4 (location 17), Treadmill #1 (location #21)

Typical vibration levels adjacent to treadmill #4 (location 17) during normal operation (about 7 mph, foot fall frequency 2.7Hz) were approximately 0.0115 inches peak-to-peak (11.5 mils peak-to-peak). Typical vibration levels in the nearby office (Adjacent to the desk, facing the door) were approximately 7.3 mils peak-to-peak. Operating deflection shape analysis at 2.7 Hz. (treadmill foot-fall frequency) showed a vertical bouncing (trampoline) or membrane motion in the exercise room, office and conference room floors.



Operating Deflection Shape, 2.7Hz, Deflections not to Scale

In contrast to the low frequency motion at foot-fall frequency, an additional ODS at 15.9 Hertz was also analyzed. This frequency was selected because the FRF's (Frequency Response Functions) from exercise center floor vibration measurements suggested that a structural resonance might be present. The peak deflections at 15.9Hz were primarily confined to the area surrounding treadmill #4, with very little relative motion occurring in the conference room or nearby office. Therefore, these 15.9Hz deflections were not of immediate concern.



Operating Deflection Shape, 15.9Hz, Deflections not to Scale

Vibration levels in the nearby office dropped to approximately 5.4 mils peak-to-peak when treadmill #1 (treadmill closest to the wall, location 21) was in operation instead of treadmill #4. This was approximately a 26% reduction in vibration level compared to when the treadmill #4 was being used. This change can be attributed to moving the treadmill to a location of higher floor stiffness adjacent to a vertical steel support column within the wall, and also moving the treadmill away from the center of the “drum head” membrane of the exercise center floor.

The ODS analysis at 2.7Hz suggested that a slight improvement in nearby office and conference room vibration levels could be achieved by relocating some of the treadmills closer to exercise center walls, away from these adjacent rooms. In particular, relocating treadmills adjacent to walls with vertical support beams. Given the constraint of the existing floor structure, locations 13, 14, 25, 26, 41, 42, and 43 appeared to be the best spots for the treadmills (with regards to reducing floor vibration). These locations are closest to vertical structural supports of the building and were farthest from the office and conference rooms. A reduction in office vibration of approximately 38% was measured by relocating these treadmills.