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Continuing Prediction of Heavy/Hard Impacts on Resilient Sports Floors in Existing Buildings

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ABSTRACT

Previously we have presented a method to predict the acceleration from heavy/hard impacts in existing buildings to replace more traditional methods. The traditional methods for the assessment of noise and vibration due to heavy/hard impacts in an existing building can be cumbersome and time consuming, have low repeatability, and does not allow for evaluation of additional solutions not present at the time of testing. The new method consists of measuring on-site vibrational transfer functions, measuring a force pulse that a given weight will exert onto a resilient floor and then combining those elements to predict the vibration. This method can predict the acceleration or vibration in a building due to any arbitrary combination of impact source and resilient flooring. The new measurements obtained for this paper were conducted in a true field application in both narrow and one-third octave bands. The predictions obtained are compared to on-site weight drop measurements in order to qualify the predictive model.

Keywords: Vibration, Impact, Prediction

1. INTRODUCTION

The issue of heavy/hard impacts in buildings has been an issue for a number of years[1,2,3,4,5,8]. Currently, the assessment of the noise and vibration due to heavy/hard impacts in an existing building can be quite cumbersome. All of the potential floor coverings and the heavy/hard source need to be shipped to the site. Often impact sources are not sent to the site whatever type of mass happens to be present at the site is used to generate the heavy/hard impacts. Therefor there is often little reproducibility between measurements.

Overall, this testing regimen is quite arduous, time consuming, and not very repeatable. In recent years, the authors have built a drop tower to repeatedly test fitness flooring performance in a controlled environment[4,5] and presented a method to combine the results from the drop tower with on-site measured transfer functions to predict the vibration in buildings[8].

This paper shows that the method works in real field conditions. The method was previously shown to use a narrow band analysis, but it has now been shown to work as a one-third octave band analysis similar to what others[6] have suggested. That analysis used a method similar to the Delta IIC in ASTM E2179[7] but presented method using one-third octave band "transfer functions". Previously, only locally reacting fitness flooring was used. This paper shows that the method has some success for hybrid systems that combine locally reacting fitness floors with light weight floating floors.

2. Experimental Setup

2.1 Samples Tested

For this experiment, a total of five different fitness flooring systems were used that consisted of two different manufactures fitness flooring tiles, alone and in combination with the same light-weight floating floor systems. The combination fitness tiles and light-weight floating floors are referred to as hybrid solution. All solutions are summarized in Table 1.

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Table 1 – Summary of test specimens used in experiment.

ID	Product name	Material/specimen thickness	Material/specimen type
1	GenieMat® FIT70	70 mm (2 ¾”)	• Recycled rebounded crumb rubber tile
2	Apollo™	38 mm (1 ½”)	• Recycled rebounded crumb rubber tile
3	GenieMat® FIT70 GenieMat® FF25 GenieMat® FF70LDM	165 mm (6 ½”)	• Recycled rebounded crumb rubber tile • Patented recycled rebounded crumb rubber sheet with bilateral sinusoidal surface • Double plywood floating floor tile with low dynamic modulus isolators.
4	Apollo™ GenieMat® FF25 GenieMat® FF70LDM	133 mm (5 ¼”)	• Recycled rebounded crumb rubber tile • Patented recycled rebounded crumb rubber sheet with bilateral sinusoidal surface • Double plywood floating floor tile with low dynamic modulus isolators.
5	GenieMat® FIT70 GenieMat® FF70LDM	140 mm (5 ½”)	• Recycled rebounded crumb rubber tile • Double plywood floating floor tile with low dynamic modulus isolators.

2.2 Force Pulse

The force pulse was measured on the five different fitness flooring solutions with Pliteq’s proprietary drop tower shown in Figure 1. Two carriages are supported on low friction rails as to only allow one axis of motion. The upper carriage lifts the lower carriage to a selected height and releases it so that the lower carriage will impact the test specimen with close to free-fall like conditions. The lower carriage can be fitted with various load plates to adjust the mass of the lower carriage and impact foot shape can be changed to simulate different types of weight impacts. A load cell measures the impact force pulse. Narrow and one-third octave band analyses were conducted on the time signals. For this experiment, the drop height was set to 0.5 m (19.7 in) and the mass was 22.7 kg (50 lbs).

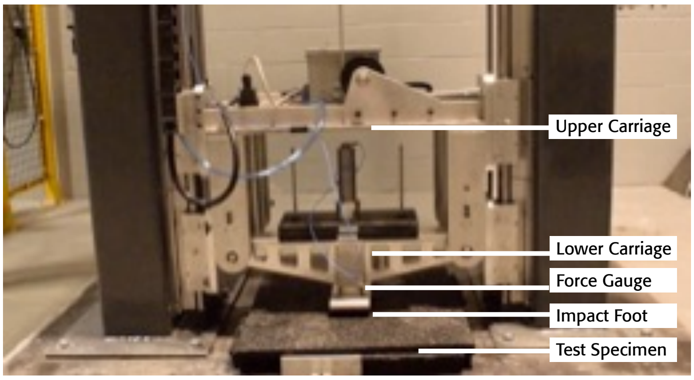

Figure 1 – Heavy/Hard Impact Drop Tower at Rest.

2.3 Field Measurements

The same type of fitness flooring tiles were installed on the 8th floor of the field location in Toronto, ON. A machined, semi-spherical mass was lifted to the same initial height above the fitness floor as it was when tested with the drop tower. It was released from rest and allowed to impact once before it was caught. (Figure 2)

Three accelerometers were placed on the same concrete slab as the fitness tiles as shown in Figure 3. The vibration at each accelerometer was measured due to drops on each of the different fitness flooring solutions.

Figure 2 – Field testing of fitness tiles with machined heavy/hard source

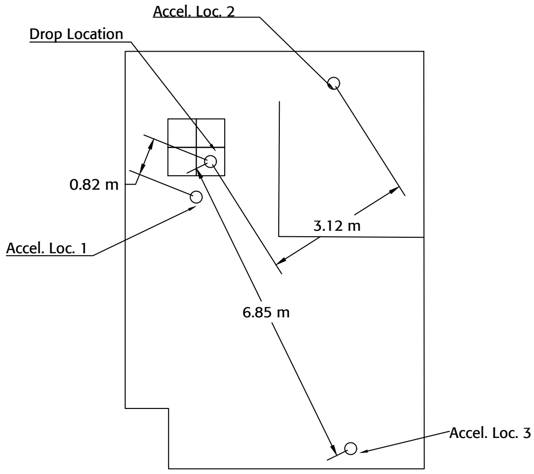

Figure 3 – Plan view of field-testing locations.

2.4 Transfer Function Measurement

An impact sledge hammer was used to impact the same locations as the heavy/hard impacts on the concrete slab. The force impulse and the resulting accelerations were measured, and narrow and one-third octave band analyses were conducted on the signals. The impact hammer input force and resulting vibration were used to calculate a transfer function in narrow band and one-third octave bands. These transfer functions were combined with the force pulses obtained from the drop tower to derive an estimated acceleration that can be compared to the actual measured vibration.

3. RESULTS AND ANALYSIS

3.1 Force Pulse Measurements

First, the force pulse on the five types of fitness flooring were measured with the heavy/hard impact drop tower, described above, with a lower carriage mass approximately equal to the machined heavy/hard source used in the field testing. Figure 4 shows the performance of three of the five

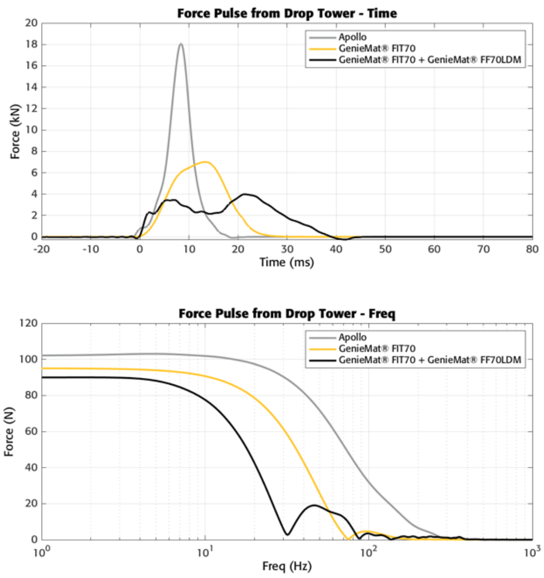

Figure 4 - Time and frequency response of the force pulse on three of the five fitness floors.

flooring solutions. Since the other two hybrid solution force pulses are very similar to hybrid solution force pulse shown they are left out of the analysis due to the limited scope of the paper. The lower the maximum force and longer the pulse width the better the fitness flooring does in decreasing noise and vibration. The frequency response of the fitness flooring solutions also changes such that the 3dB cutoff frequency of the apparent low pass filter decreases for solution with wider force pulse widths.

3.2 Field Measurement of Heavy/Hard Impacts

Figure 5 shows the data collected at location 3 for several consecutive impacts for three of the floor coverings. The figure shows the time history, narrow band and one-third octave band analysis for each floor covering. The data collected for the locally reacting tiles is very repeatable. While the data collected for the hybrid system shows slightly less repeatability. As expected, the amplitude decreased significantly as the impacts were on successively higher performing fitness flooring. The peak amplitude of the vibration response at location 3 on the GenieMat® FIT70, Apollo, and the GenieMat® FIT70 on GenieMat® FF70LDM was approximately 0.02 m/s^2, 0.07 m/s^2, and 0.013 m/s^2 respectively. This is approximately in proportion to the relative levels for maximum force measured on the drop tower. Both the narrow band and one-third octave analysis show the peak of acceleration occurred in the 10 to 200 Hz range.

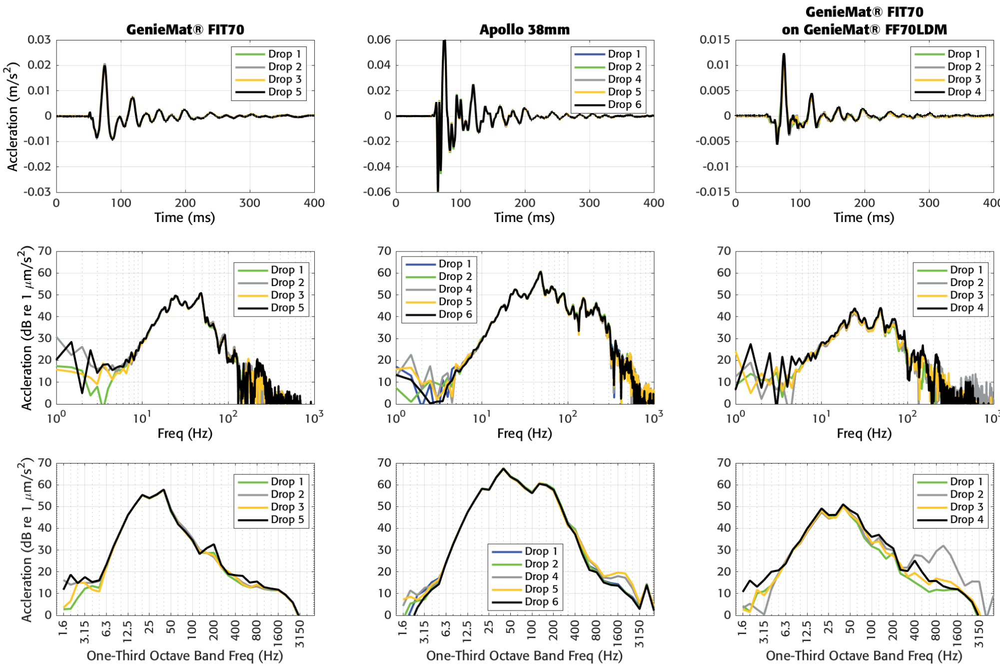

Figure 5 – Vibration response in time, (top row) narrow band (middle row) and one-third octave bands (bottom row) at location 3 due to heavy/hard impacts on GenieMat® FIT70 (left column), Apollo 38 mm (center column), and GenieMat® FIT70 on GenieMat® FF70LDM (right column).

3.3 Measurement of Transfer Function

The transfer functions were measured using an impact sledge hammer and several accelerometers. The sensors are listed in Table 2. The signal from the impact sledge hammer was used as the input signal to calculate the transfer function. The signals from the accelerometers were used as the output. The coherence of several impacts, along with the narrow and one-third octave band transfer function magnitude are shown in Figure 6.

Table 2 – Summary of sensors used.

Sensor Type	Sensor Make and Mode	Sensitivity
Impact Hammer	PCB065D50	0.23 mV/N (1 mV/lbf)
Accelerometer 1	PCB 353B03	10 mV/g
Accelerometer 2	Dytran 3055D2	100 mV/g
Accelerometer 3	PCB 393B05	10 V/g

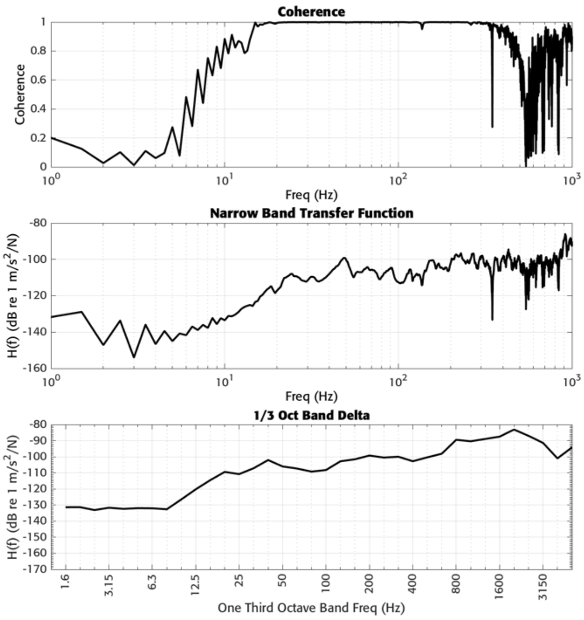

Figure 6 – Coherence, narrow and one-third octave band transfer functions for location 3.

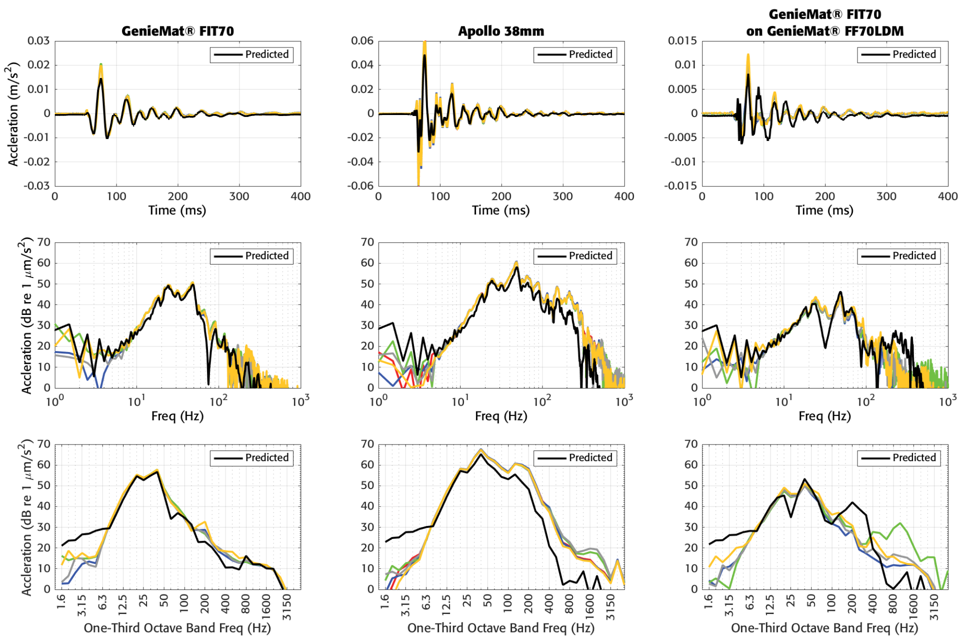

Figure 7 – Predicted results on top of measured data in time, (top row) narrow band (middle row) and one-third octave bands (bottom row) at location 3 due to heavy/hard impacts on GenieMat® FIT70 (left column), Apollo 38 mm (center column), and GenieMat® FIT70 on GenieMat® FF70LDM (right column).

3.4 Prediction of vibration due to heavy/Hard Impacts

The transfer functions were then combined with the force pulse data to calculate an estimated time history, narrow and one-third octave band vibration levels for each floor covering. The prediction results and measured values at location 3 for each flooring solutions discussed above are shown in Figure 7. In the frequency range when coherence is high (10 to 200 Hz) very good agreement is shown for the locally reacting flooring solutions. The predictions results for the hybrid flooring solutions are not quite as good but still show general agreement with measured values. The results can also be numerically converted into velocity as is more commonly used in building vibration. (Figure 8)

Below 10 Hz and above 200 Hz, the results do not match well. If techniques are developed to increase the coherence of the field measured transfer functions, the agreement between predicted and measured results would likely increase.

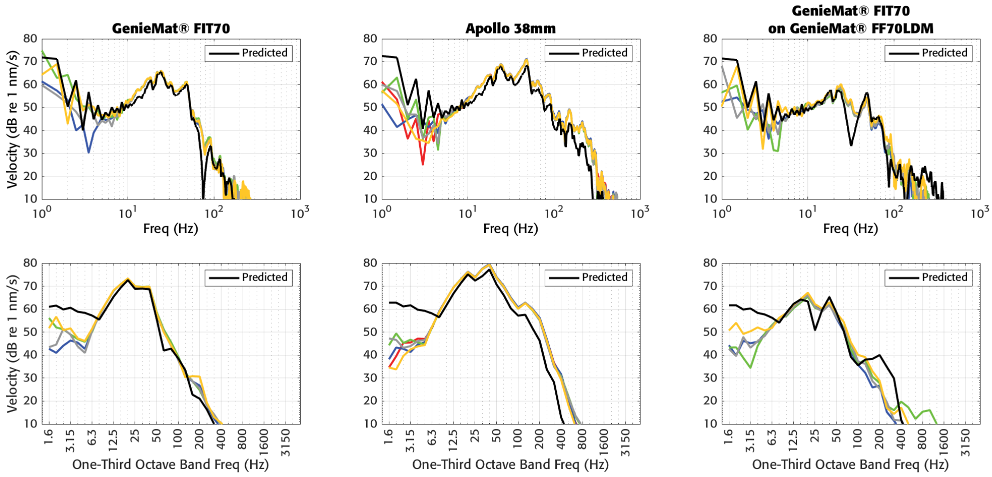

Figure 8 – Velocity prediction results in narrow band (middle row) and one-third octave bands (bottom row) at location 3 due to heavy/hard impacts on GenieMat® FIT70 (left column), Apollo 38 mm (center column), and GenieMat® FIT70 on GenieMat® FF70LDM (right column).

4. CONCLUSION

As previously shown, the force pulse of a heavy/hard impact source on fitness flooring can be measured in a controlled laboratory environment. A transfer function between the impact force at one location and the acceleration at a several other locations can be measured. This transfer function can then be combined with the laboratory measured force pulse to obtain an estimated time and frequency response. The analysis can be conducted in narrow or one-third octave bands. This calculated estimate shows good agreement with the in situ measured time and frequency response due to a heavy/hard impacts in the range of 10 to 200 Hz. Further work is needed to improve the methodology to include a greater frequency range. Addition work should be performed to test the methodology over larger distances and building types, and to extend the predictions to sound.

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