IN-SITU TESTING OF GYM FLOOR IMPACT ISOLATION

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Abstract

In response to complaints about structure-borne noise, in-situ floor impact isolation testing was conducted of a gym floor. The gym was located on the ground floor of a multi-storey residential apartment building. The impact of free weights being dropped onto the existing gym floor was causing structure-borne noise to be clearly audible within residential apartments located up to six floors above the gym. Using a 42.5kg dumbbell dropped from the same height above the floor surface, the existing gym floor was tested along with various samples of rubber flooring mats and a timber floating floor. The airborne sound generated by the dumbbell impacts was measured in the basement directly below the ground floor test location to provide an accurate indication of the impact isolation provided by the various flooring systems. At the completion of the installation of the upgraded gym floor additional in-situ testing was conducted to evaluate the effectiveness of the completed floor.

1. Introduction

Floth Sustainable Building Consultants were commissioned to undertake an investigation into a regenerated noise problem in a residential apartment building. The regenerated noise was described by residents located throughout the building as consisting of a “banging” noise that was heard during the daytime, evening and night-time periods.

The regenerated noise problem commenced immediately after the opening of a 24-hour gym on the Ground Floor of the building. To conclusively show that the noise was due to operation of the gymnasium unattended noise logging was conducted at several locations throughout the building using time-synchronised noise loggers that were also set up to record sound files of major noise events. Based upon the logging results it was determined that the impact of free weights being dropped onto the floor in the Ground Floor gym was the cause of the regenerated noise problem.

To determine whether it was possible to reduce the level of generated noise in-situ testing was conducted of a range of rubber floor coverings with and without a floating floor in place. From these test results an appropriate upgrade was implemented for the gym floor in the free-weights area and post-installation acoustic testing conducted of the finished floor.

2. Base Building Design

The gym was located on the Ground Floor of a 20-storey residential building as indicated in Figure 1. It can be seen in this Figure that residential apartments are located on the floors above the gym, while below the gym was the Refuse Room and Basement Carpark.

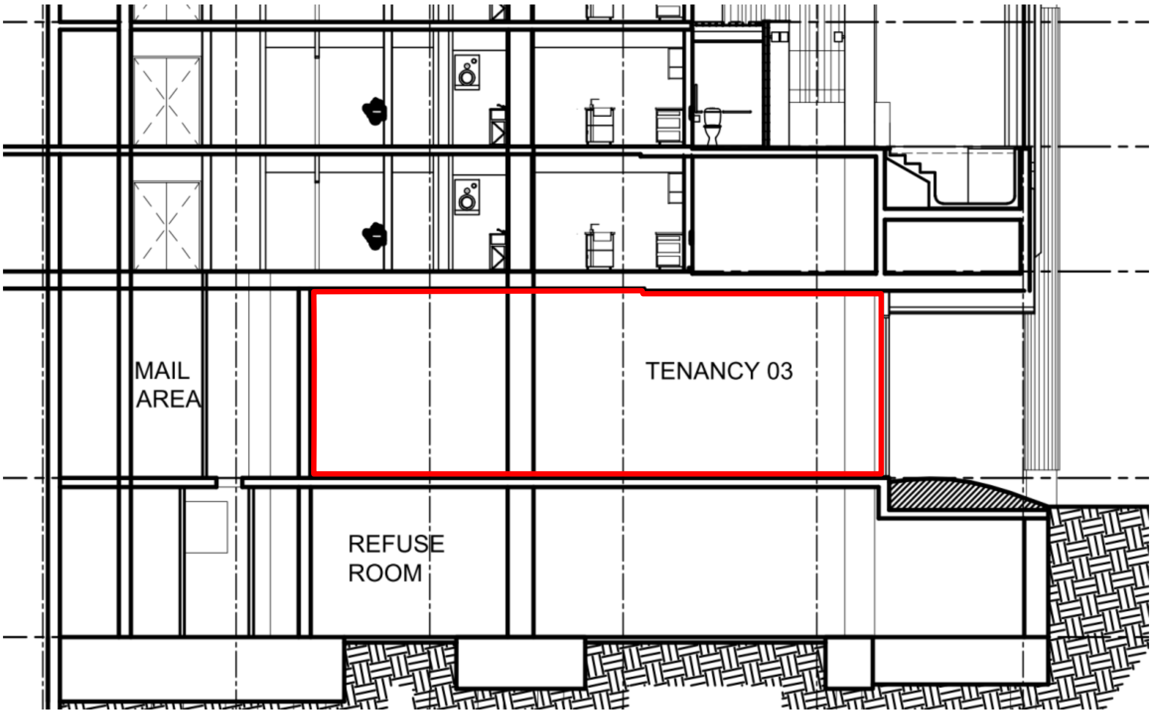


Figure 1. Section through building showing the gym location (in red) and apartments above

Originally intended to accommodate restaurant or retail uses, the suspended concrete slab in the vicinity of the free weights area was 210mm thick, utilised 40MPa concrete and was post-tensioned as shown in Figure 2. The columns supporting the building along which the structure-borne noise was determined to have travelled up into the residential apartments can be seen in Figure 2.

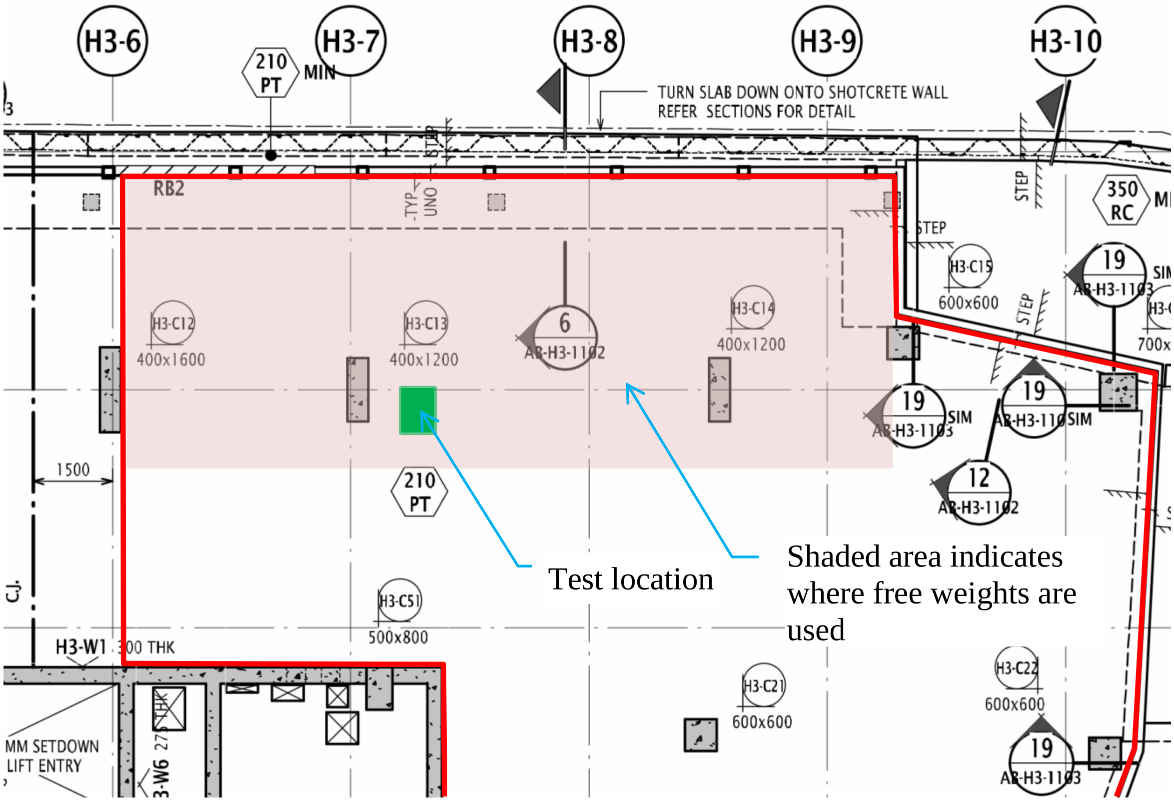


Figure 2. Structural details of the base building near the noise source

3. Tested Flooring Configurations

The flooring configurations that were tested are summarised in Table 1. Testing was conducted of the existing floor, the suspended slab without any floor coverings, product samples provided by Regupol and Embelton as described in Table 2 and the final installed floor at the completion of the investigation. Tests were conducted of the existing Everroll Core 8mm floor where it was adhered to the suspended concrete slab and when it was loose laid on top of the concrete to see whether the adhesive made a significant different in the impact isolation performance.

Table 1. Summary of test configurations

Test	Configuration Tested
1	Existing gym floor –Regupol Everroll Core 8mm (adhered to slab)
2	Regupol Everroll Core 8mm on slab
3	Bare slab with no floor coverings
4	Regupol FX75 on slab
5	Regupol E43 on slab
6	Regupol 6010 17/8mm Acoustic Underlay on slab
7	Regupol 6010 10mm Acoustic Underlay on slab
8	Embelton ImpactaMat 15mm 750 on floating floor
9	Embelton ImpactaMat 15mm 750 plus ImpactaMat 15mm 900 on floating floor
10	Regupol FX75 on floating floor
11	Regupol E43 on floating floor
12	Regupol 6010 17/8mm Acoustic Underlay on floating floor
13	Regupol 6010 10mm Acoustic Underlay on floating floor
14	Regupol Everroll Core 8mm on floating floor
15	Completed floor - Regupol FX75 on top of existing Regupol Everroll Core 8mm

Table 2. Physical properties of the rubber mat/tile products that were tested [1][2][3]

Product	Description	Thickness (mm)	Density (kg/m^3)
Regupol Everroll Core 8mm	Mat consisting of 80/20% blend of recycled content and selected coloured ethylene propylene diene monomer (EPDM) rubber chips	8	1,015
Regupol FX75	Tile consisting of polyurethane-bonded rubber fibres, solid coloured	75	520
Regupol E43	Tile consisting of polyurethane-bonded rubber fibres or granules, solid coloured	43	814
Regupol 6010 17/8mm	Dimpled mat made from selected recycled rubber particles bonded together with a highly elastic polyurethane binder	17 max. 8 min.	550
Regupol 6010 10mm	Mat made from recycled rubber particles bonded together with a highly elastic polyurethane binder	10	580
Embelton ImpactaMat 15mm 750	Mat made from recycled rubber particles bonded together with an elastic polyurethane binder	15	750
Embelton ImpactaMat 15mm 900		15	900

The floating floor sample measured 1.2m x 1.2m and consisted of two layers of 12mm structural plywood supported by Embelton NXS-14 damped springs at 300mm x 600mm centres (i.e.: 15 springs total). Figure 2 shows a schematic of the floating floor construction. The NXS-14 damped springs were screw fixed into the underside of the bottom layer of plywood. The top layer of plywood was not fixed to the bottom layer of plywood. No lateral restraints were applied to the floating floor sample.

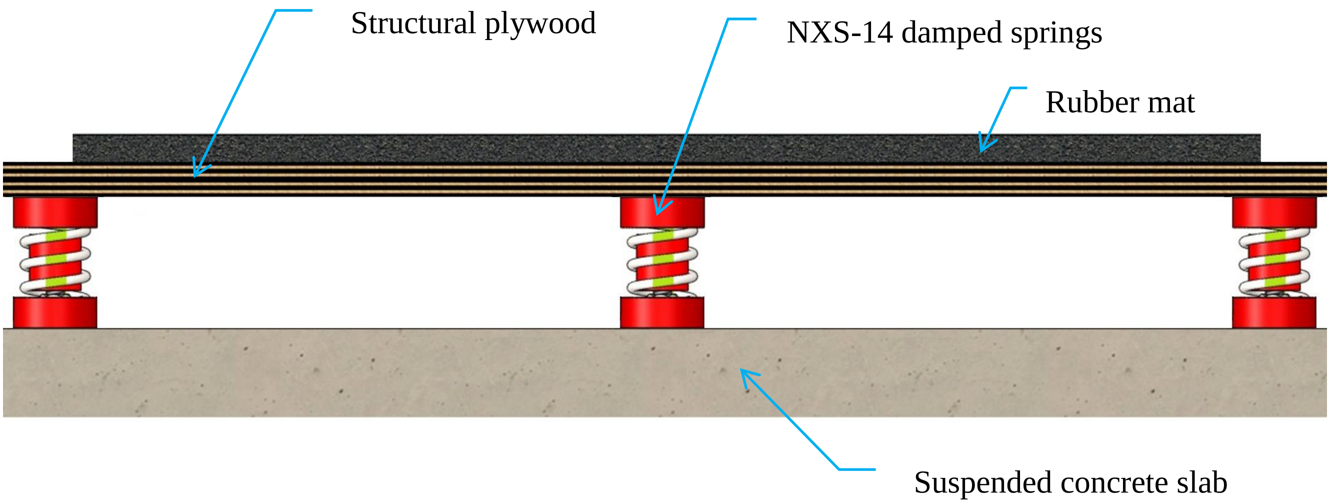


Figure 3. Floating floor construction (modified from [1])

The specifications of the Embelton NXS-14 damped springs are presented in Table 3. A dead load of 246.5kg representing around one-third of the maximum loading allowed on the floating floor in accordance with AS/NZS 1170.1 was applied [4]. It was observed during the testing that the concrete floor exhibited some unevenness and as such, it is possible that there was a small variation in the loading between individual springs.

Table 3. Embelton NXS-14 damped spring properties [1]

Product	Max. Load (kg)	Static Deflection (mm)	Spring Constant (kg/mm)
Embelton NXS-14	125	25	5.0

4. Methodology

4.1 In-Situ Testing

To conduct the in-situ testing the following methodology was used:

1. A test location was chosen that was above the Refuse Room located in the Basement (refer Figure 1). Testing above the Refuse Room allowed an enclosed receiver space to be used and minimised the impact of background noise on the measurement results.
2. The existing gym floor was tested before being pulled up to see whether the adhesive made a significant difference to the test results.
3. The concrete slab without any floor coverings was then tested to provide a reference level for each of the floor samples. Each of the subsequent floor samples were positioned and tested at the same location. For tests involving the floating floor a dead load was applied to simulate the typical loading placed on the surface by people and equipment.
4. A consistent impact was generated using a 42.5kg dumbbell that was rolled off the edge of a weights bench from a height of 420mm above the upper surface of each test sample as shown in Figure 4. Spacers were used under the legs of the weights bench to ensure a consistent height was maintained above each floor sample to account for the varying thicknesses of the test floors.

5. A Norsonic Nor140 Class 1 Precision Sound Analyser (serial # 1405077) was mounted on a tripod at a height of 1.5m above floor level in the Refuse Room directly below the test sample location. A Pulsar Model 105 Acoustic Calibrator was used to calibrate the Norsonic Nor140 before and after the measurements.
6. The Norsonic was used to measure the L_{max} noise levels in 1/3 Octaves for each impact. Between four and six impacts were generated for each test sample. The number of impacts was limited due to the timeframe given by building management for the testing to occur. In any instances where extraneous events were found to have occurred during the test, the test result was discarded and the test repeated. Extraneous noise sources that occurred during the testing included operation of the refuse chutes and multiple floor impacts due to the dumbbell rolling off the test sample after being dropped from the weights bench.
7. Background levels within the Refuse Room were measured to ensure that they did not influence the measurement results.

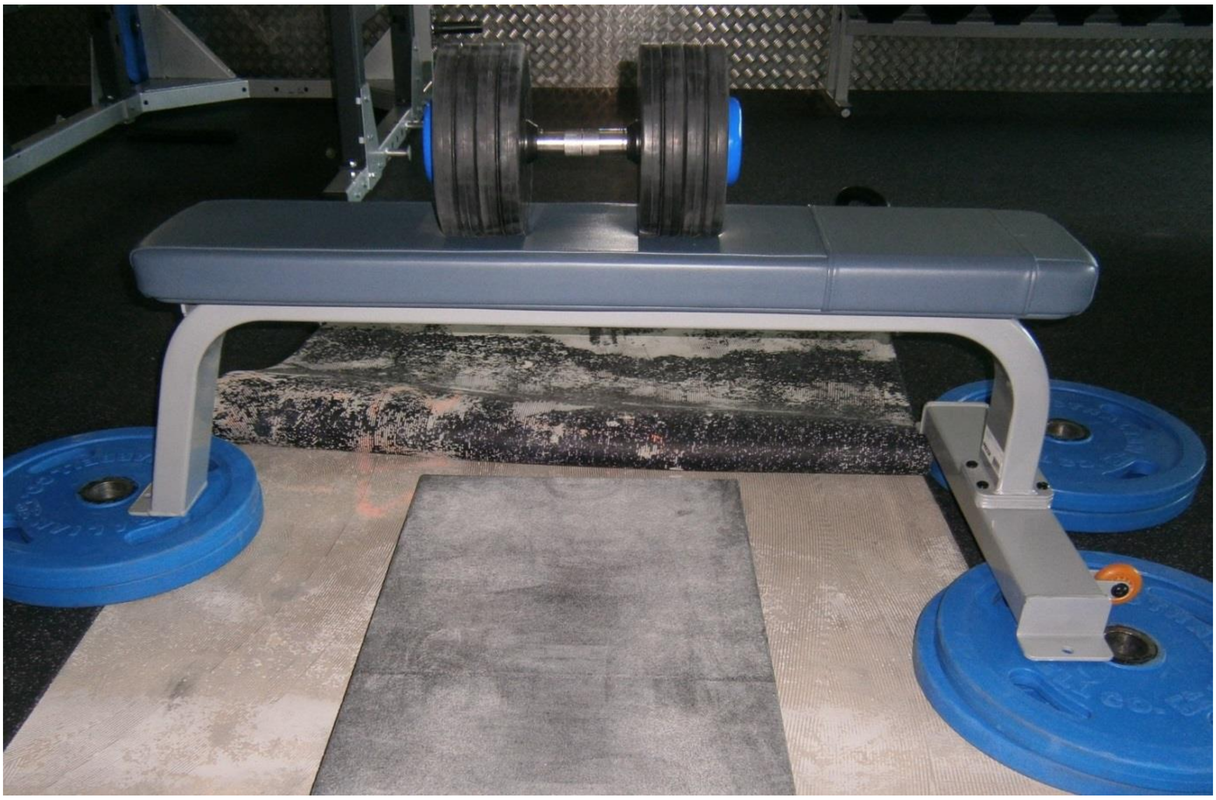


Figure 4. Test setup showing the 42.5kg dumbbell and 420mm high weights bench

4.2 Data Processing

Each data set was arithmetically averaged and adjusted to remove the influence of the background noise level within the Refuse Room. Where required, the adjusted sound pressure level for each floor covering was then subtracted away from the sound pressure level measured for the slab without any floor coverings to determine the sound reduction performance provided by each floor covering.

For each dataset the sound pressure level and/or the sound reduction has been presented between 10Hz and 10kHz. The volume of the Refuse Room was around 285m^3. Based upon this room volume there would be a greater uncertainty in the levels measured at frequencies below 100Hz [5]. However, given that great care was taken to ensure that the same test procedure and measurement location was used for each test the low frequency results are still considered to be valid for engineering design purposes.

5. Test Results

5.1 Reference Sound Pressure Level

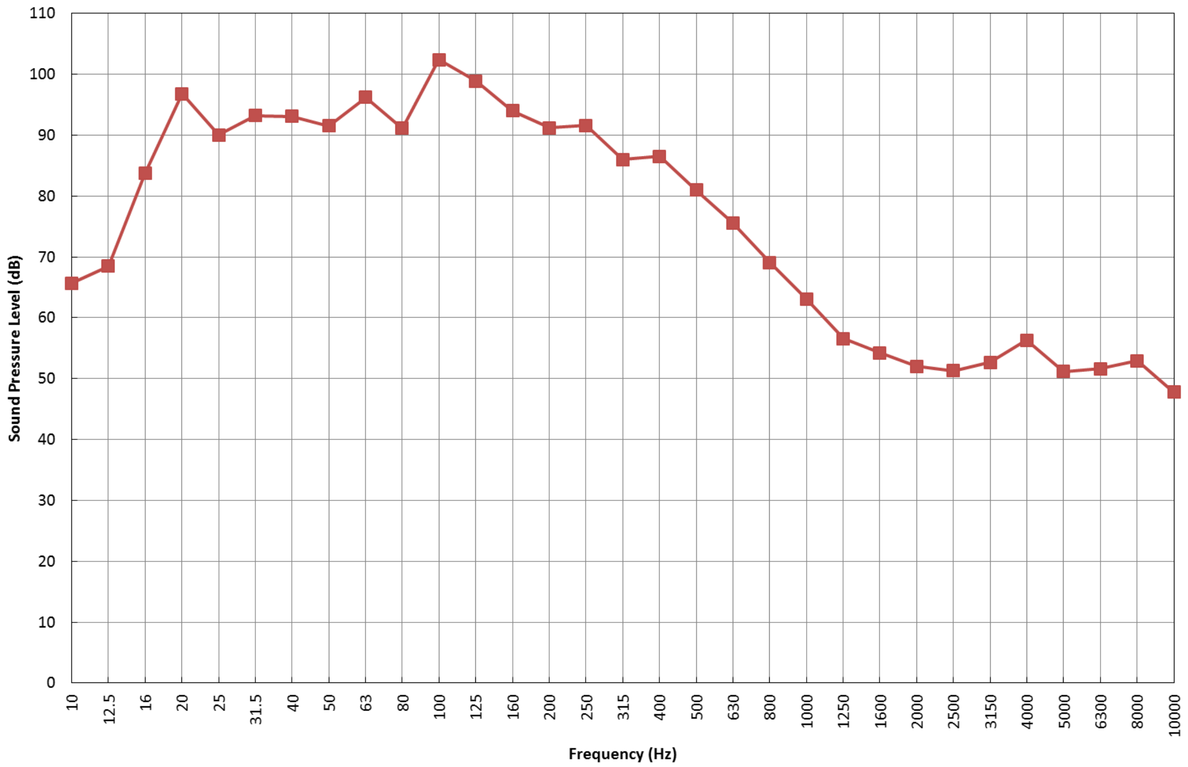
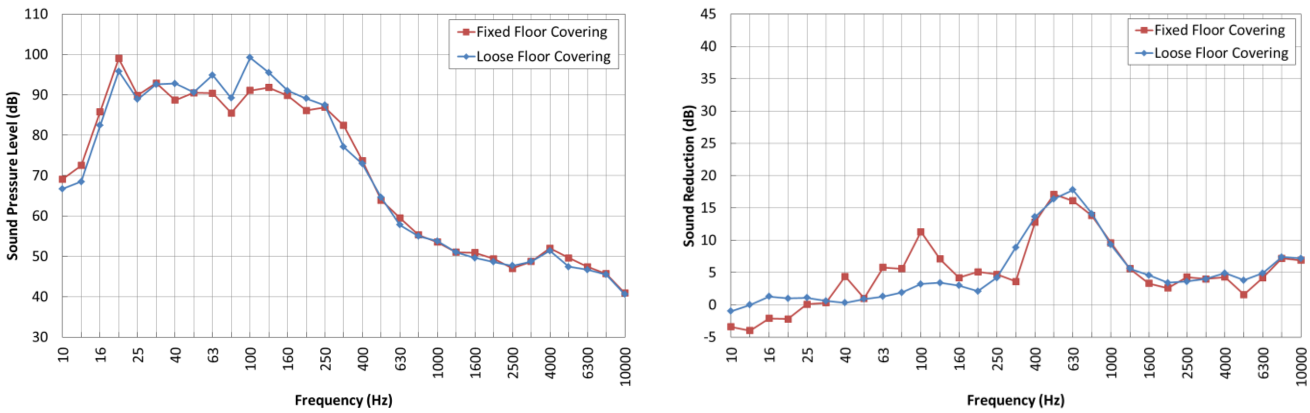


Figure 5. Reference sound pressure level due to the 42.5kg dumbbell being dropped directly onto the uncovered concrete slab

5.2 Impact of Adhesive



(A) (B)

Figure 6. Sound pressure levels (A) and the sound reductions (B) measured for Regupol Everroll 8mm adhered to and loose laid on the concrete slab

5.3 Rubber Products Placed Directly on Top of the Concrete Slab

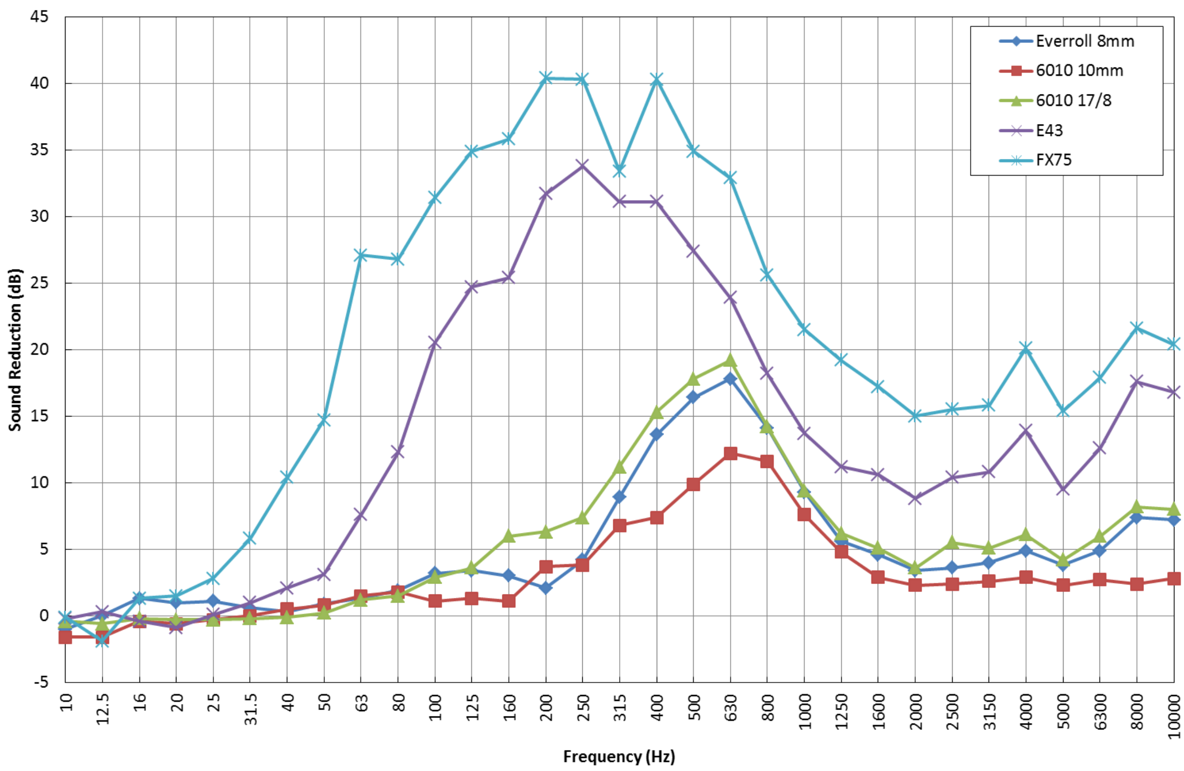


Figure 7. Sound reduction performances of the various rubber flooring products on top of the concrete slab

5.4 Floating Floor without any Floor Coverings

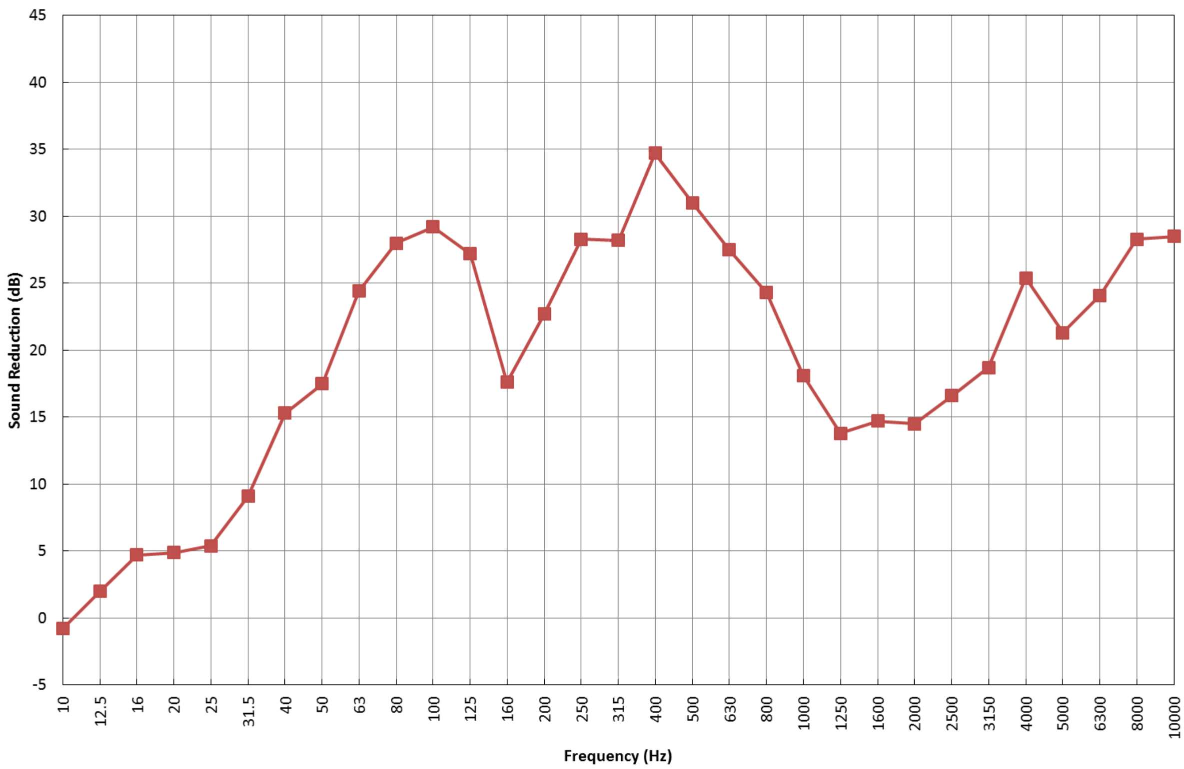


Figure 8. Sound reduction performance of the floating floor sample

5.5 Rubber Products Used in Conjunction with the Floating Floor

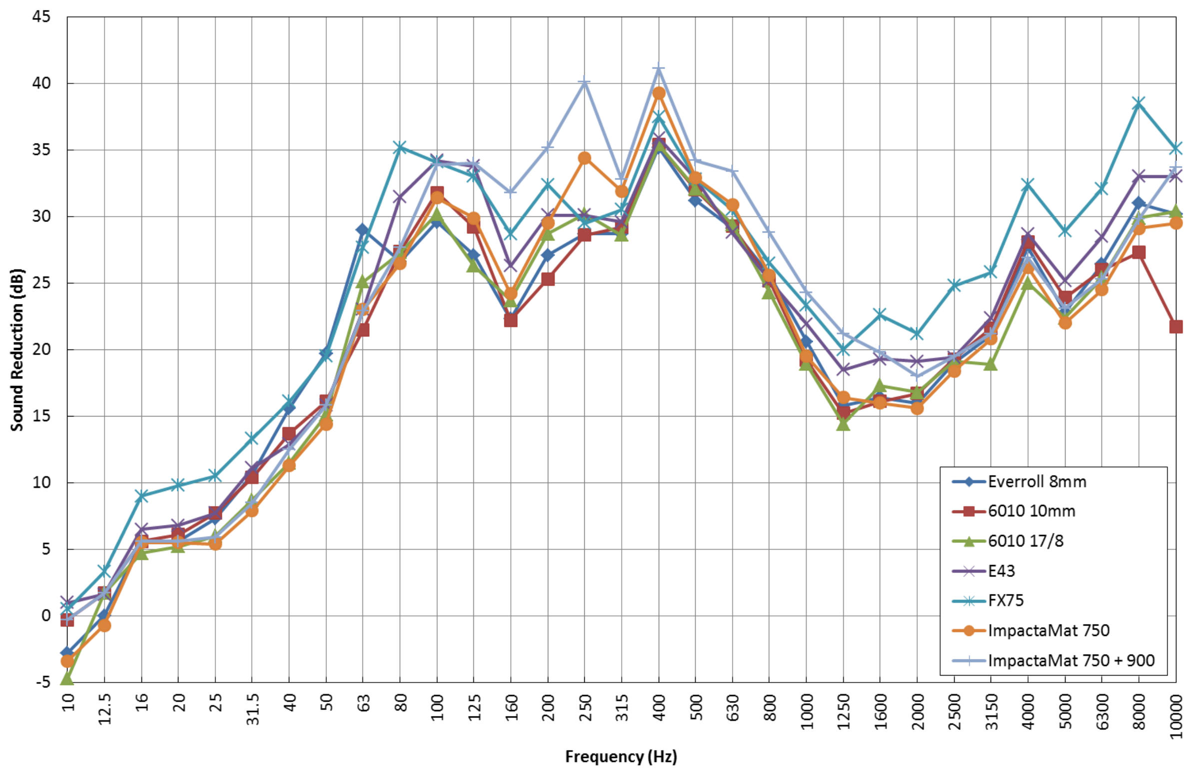


Figure 9. Sound reduction performances of the various rubber flooring products on top of the floating floor sample

5.6 Final Floor Installed in the Gym

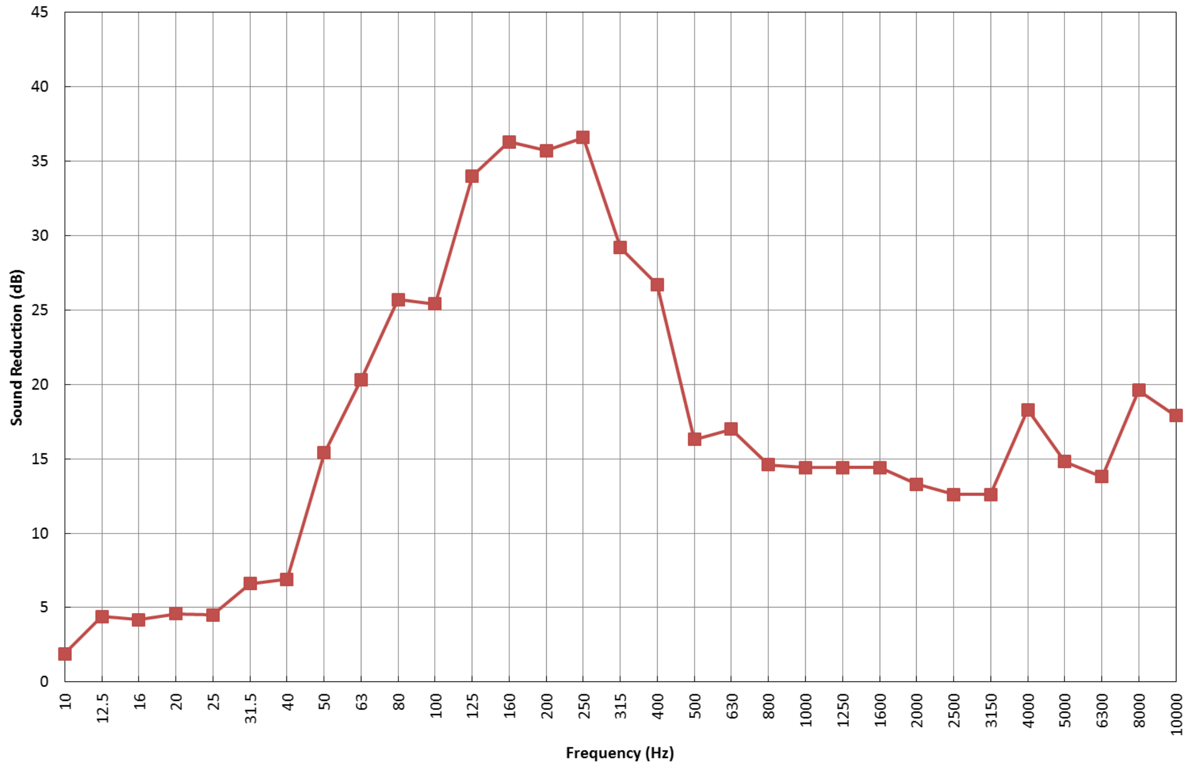


Figure 10. Sound reduction performances of the final installed floor (FX75 laid on top of existing Everroll 8mm floor)

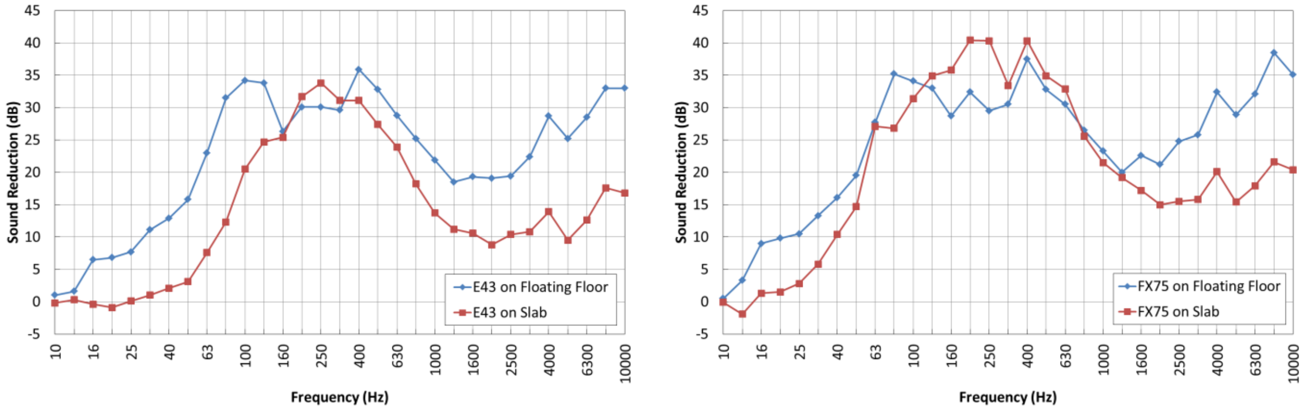
6. Discussion

Figure 6 presents a comparison of Everroll 8mm mat adhered to and loose-laid on top of the suspended concrete slab. It can be seen that across most of the octave bands there was a minimal difference between the measured sound pressure levels. When the sound reduction performance is calculated, the differences appear to be larger at 31.5Hz and 315Hz, however given the uncertainties involved in this type of testing, additional testing is still required to determine whether adhering the samples to the concrete slab makes a significant difference.

The sound reduction performances of the rubber mat and tile products placed directly on the concrete slab are compared in Figure 7. It can be seen in this figure that as expected the thicker tile products (E43 and FX75) performed significantly better than the thinner mat products. At low frequencies (<50Hz) all of the mat and tile products with the exception of the FX75 did not provide a significant sound reduction performance. This result is important when considering the installation of rubber matting or tiles in a gym, as the sound pressure levels presented in Figure 5 show that the dropping of heavy weights onto the floor produces a significant amount of sound energy in frequencies less than 50Hz.

It can be seen in Figure 8 that there is a dip in sound reduction performance at 160Hz and 200Hz for the floating floor. This dip is attributed to the failure to fix both layers of plywood together allowing the top layer of the plywood to resonate as the second modal frequency of the plywood floor is around 180Hz [6]. As such, the results presented in Figures 8 and 9 could be adjusted to remove this dip to provide a more accurate indication of the performance of a properly installed floating floor.

The sound reduction results presented in Figure 9 for the rubber mat and tile products on top of the floating floor show that all of the flooring systems achieve a similar sound reduction performance to each other, with no mat or tile product providing a consistent performance improvement across all of the octaves. A comparison between the sound reductions provided by the two rubber tile products (E43 and FX75) on the concrete slab and floating floor are presented in Figure 11. It can be seen that when used with the floating floor the low frequency and high frequency sound reduction performances are increased. In the mid-frequency region the sound reduction performances are similar no matter whether a floating floor is used or not.

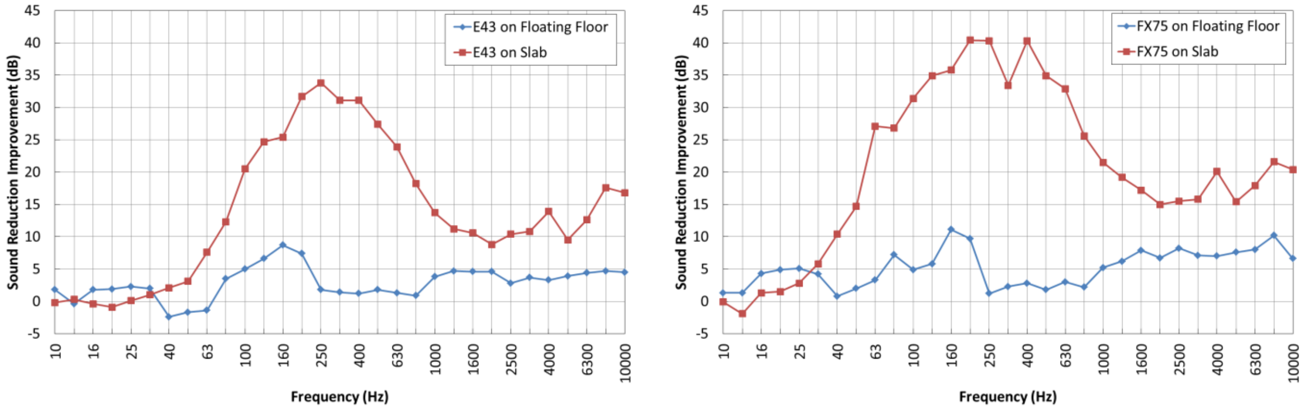


(A) (B)

Figure 11. Comparison of the sound reduction provided by (A) Regupol E43 and (B) Regupol FX75 mounted on the concrete slab and floating floor

Figure 12 presents a comparison of the sound reduction performance provided by the rubber tile products over the bare concrete slab and bare floating floor. It can be seen that using a rubber tile on top of a bare concrete slab provides a significant improvement in the sound reduction performance. However, going to the additional expense of using a rubber tile product on top of a floating floor may not be justified in many situations, as the additional performance improvement is on average 2.9dB for the E43 and 5.2dB for the FX75 products across the octave bands.

The sound reduction performance provided by the final installed floor is presented in Figure 10. Comparing the results in Figure 10 against those obtained for the FX75 in Figure 7 it can be seen that at 31.5Hz and above the FX75 sample sound reduction performance is generally equal to or better than that of the final installed flooring. The final floor as installed consisted of around 100m^2 of FX75 tiles loose laid on top of the existing 8mm Everroll flooring. The FX75 tiles were laid so that they were hard up against the walls and columns of the building, which through bridging may have resulted in the performance decrease compared to the FX75 sample test, which was located away from the walls and columns. Notwithstanding the reduction in performance, testing conducted on Level 1 of the building found that re-radiated structure-borne noise from the dumbbell being dropped on the floor was inaudible.



(A) (B)

Figure 12. Comparison of the improvement over the bare concrete slab and bare floating floor provided by the rubber products (A) Regupol E43 and (B) Regupol FX75

7. Conclusions

In-situ testing has been conducted of a number of rubber mat and tile flooring systems located on a concrete slab and a floating floor. The results have indicated that for a gym a thicker rubber tile type product is necessary to achieve a significant reduction in structure-borne noise, unless a rubber mat or tile is being used in conjunction with a floating floor. If used in conjunction with a floating floor, the rubber mat or tile that is used is less critical as the floating floor provides most of the impact isolation.

Acknowledgements

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References

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