Gym Noise Reduction: Two Case Studies

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ABSTRACT

Two case studies involving the reduction of structureborne noise due to use of boxing bags and the dropping of heavy barbells during deadlifts are presented. The boxing bag isolation varied from the usual installation method as the client wanted to suspend the boxing bags via framework suspended from the underside of the suspended concrete slab above. The deadlift isolation involved testing different rubber tiles on an on-ground concrete slab to reduce the structureborne noise moving laterally into the adjoining commercial tenancy. The results of in-situ testing are presented along with lessons learnt during the studies.

1 INTRODUCTION

The control of structureborne noise and vibration is a major consideration whenever a gym is located within a building containing other uses. These case studies address the most difficult problems associated with gyms – reduction of structureborne noise due to use of boxing bags and the dropping of heavy barbells during dead-lifts.

2 CASE STUDY 1: BOXING BAG ISOLATION

2.1 Background

The gym for Case Study 1 was located on the ground and mezzanine floors of a multi-storey office building. The 1st floor immediately above the gym was vacant and plans were made for the gym to lease that space. As a result, the gym would be operating directly underneath an office tenancy located on the 2nd floor.

The gym was a 'fight gym' and as such, boxing and Muay Thai dominated the classes and training. The extension to the gym on the 2nd floor contained a boxing ring along with 29 boxing bags suspended from the slab soffit along two sides of the tenancy. The building owners were concerned about structureborne noise associated with use of the boxing bags causing nuisance within the office tenancy on the floor above.

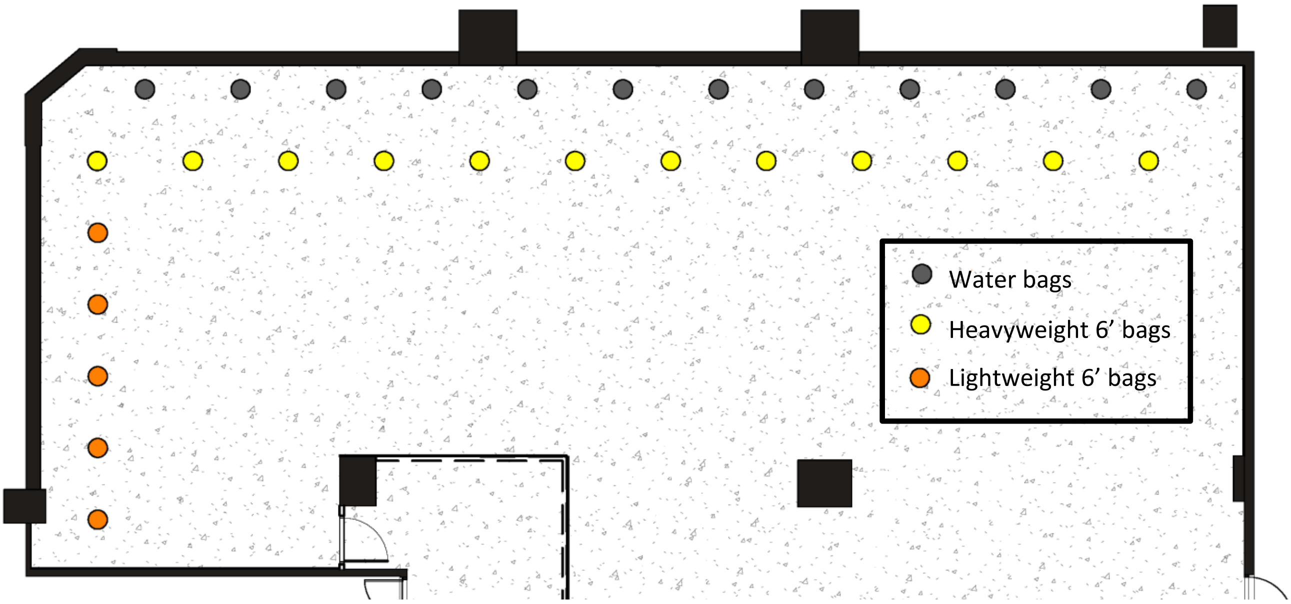


Figure 1: Boxing bag locations around perimeter of tenancy

2.2 The Problem

The gym owners wanted the boxing bags suspended from the slab soffit to create a clean and unimpeded training area. As a result, solutions involving the installation of a spring mounted lightweight floating floor and isolated boxing bag stands, as successfully implemented by Embelton (2021), could not be used. This required an analysis of the problem to determine what methods could be used to isolated the boxing bags, while ensuring that movement of the eye bolt from which the boxing bag was suspended was kept to a minimum. There would be three different types of boxing bags; a water bag (72 kg), lightweight 6' bag (45 kg) and a heavyweight 6' bag (77 kg).

A boxing bag dropper was designed by the project's civil engineers as shown in Figure 2. Originally a straight dropper was to be used as shown in Figure 2(a). However, due to the presence of fire sprinkler pipes and other services, the design had to be changed to incorporate an arm at 90º to the dropper as shown in Figure 2(b), with the length of the arm being 300 mm to 600 mm long to achieve the required spacing between the boxing bags.

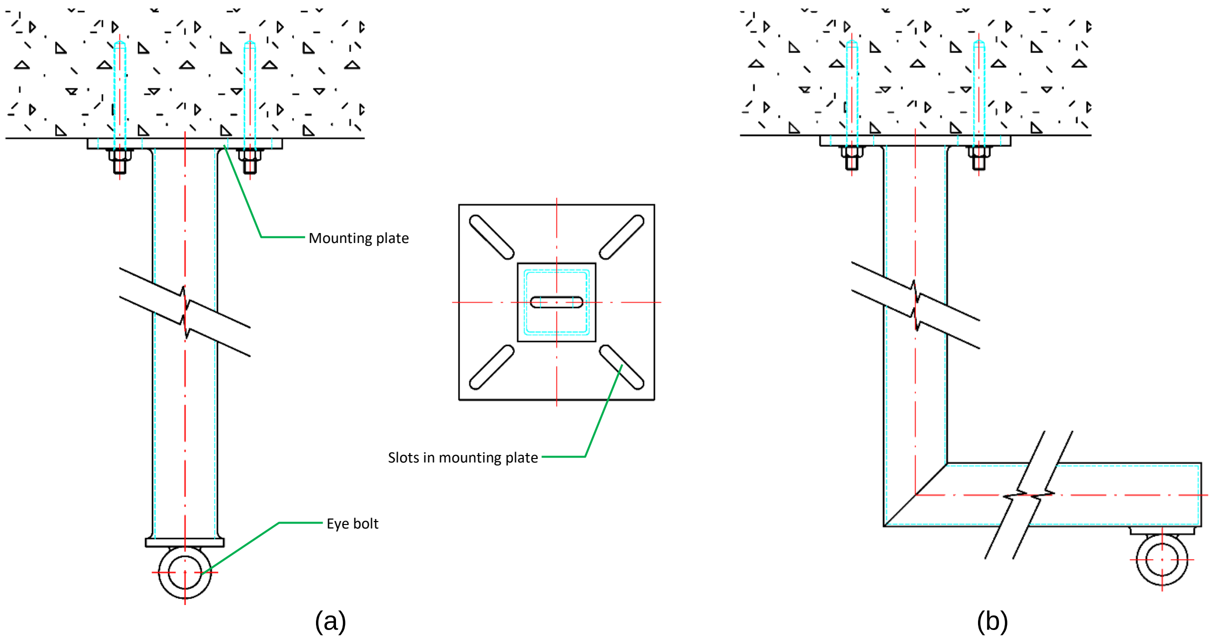


Figure 2: Original dropper designs

2.3 Design Criteria

There were no design criteria nominated for the boxing bag isolation performance. The building's managers stated that they "did not want use of the boxing bags to cause nuisance" in the tenancies above. In response, it was decided to look at the emergence of the transient peaks over the ambient background levels within the office tenancy, with the aim of keeping the transient peaks less than 5 dB above the background levels. As there was still a question over whether than criterion would be acceptable, the building's managers were encouraged to attend the testing so that they could hear first-hand the impact of the acoustic treatments.

2.4 Proposed Solution

Discussions were held with Embleton to determine potential upgrades to isolate the boxing bags. The main design requirements was to minimise movement of the eye bolt while maximising the level of vibration isolation. There was some concern about exciting the natural frequency of the suspended concrete slab, so consideration was given to maximising the low-frequency isolation. The upgrades included:

- Adding gussets to the dropper arm to increase the stiffness of the assembly as shown in Figure 3(a). Increasing the stiffness allows softer isolation pads to be reduced potentially increasing the low-frequency isolation performance while minimising the movement of the eye bolt.
- Structural isolation of the dropper using the arrangement shown in Figure 3(b).
- Increasing the size of the mounting plate, which will also allow the use of softer isolation pads.
- Increasing the size of the slots in the mounting plate to allow rubber sleeves to be fitted to the threaded rod to isolate it from the dropper.
- Suspend the boxing bags using a tension spring, with ropes instead of chains used to suspend the bag from the spring to reduce metal-on-metal contact.

The design advice was communicated to the site manager along with the caveat that to determine the optimal combination of upgrades, in-situ testing will be required.

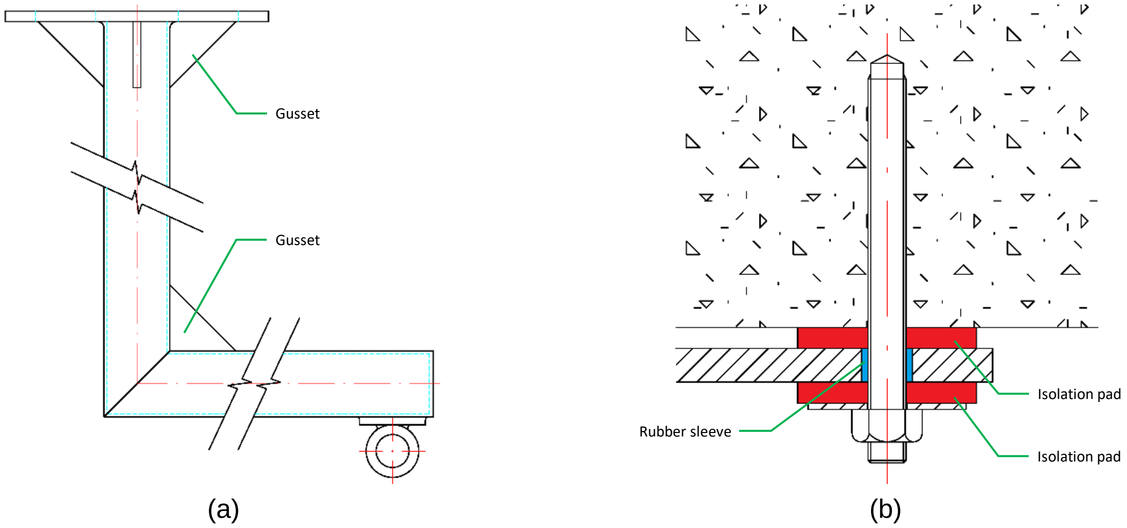


Figure 3: Proposed upgraded dropper design and isolation

2.5 Actual Solution

The design advice sent to the site manager was not forwarded onto the dropper manufacturer or the client. As a result, no modifications were made to the droppers and the droppers delivered to site matched the design shown in Figure 2(b). This created a number of issues with the installation:

- The slots were too small to allow rubber sleeves to be fitted to the threaded rod to isolate it from the dropper. As the mounting plates were machined before being welded to the dropper arms, the builder had to drill four holes in the mounting plate to allow the isolation sleeves to be fitted. This created alignment problems with the threaded rods fixed into the slab soffit. The builder was advised to use a multimeter to check to see it there was any metal-on-metal contact between the threaded rods and mounting plates – that was not done and as such, whether there was any bridging of the isolation pads or not is unknown.
- The mounting plate was the original size and there were no reinforcing gussets, which resulted in harder isolation pads having to be used.
- No consideration was given to the additional height that would be required to allow the use of a tension spring and ropes to connect the boxing bags to the eye bolt. Subsequently, the dropper arms had to be shortened by 300 mm to allow the use of springs and ropes.

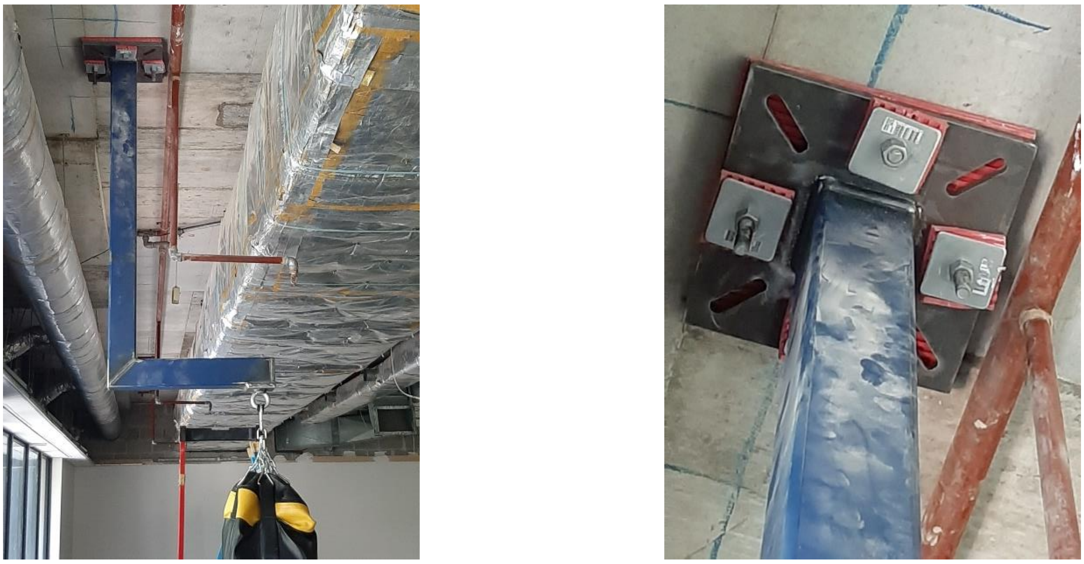
The dropper installation for the first series of in-situ tests is shown in Figure 4. Note the uneven loading of the isolation pads created by the moment arm of the dropper.

Rope was used to connect the boxing bags to the eye bolt as shown in Figure 5(a). The rope was chosen by the builder based upon its colour rather than any acoustic requirements.

A problem was raised by the gym owner regarding the use of tension springs. It was widespread practice for gym patrons to jump and hang off the boxing bags, adding impulsive loads of up to 120 kg. That additional mass could potentially cause the tension springs to fail and disintegrate, creating and occupational health and safety issue. A search could not find any suitable tension springs and as a result, use of a compression spring arrangement was suggested. A suitable spring arrangement was designed by Mason Industries for the prototype testing as shown in Figure 5(b), with the spring characteristics matched to that of the boxing bags. Dampers were also trailed to see whether damped springs perform better compared to undamped springs.

2.6 In-Situ Testing

As there was uncertainty in how the structureborne noise would propagate, the first part of the in-situ test focussed on measuring the background noise levels throughout the office tenancy on the floor above with the air-conditioning operating, followed by measurements of boxing bag noise with the air-conditioning turned off.



(a) (b)

Figure 4: Prototype dropper design and isolation

(a) (b)

Figure 5: Rope and spring isolation of the boxing bags

A single boxing bag dropper was tested and measurements made at ear height throughout the office tenancy. The highest levels of intruding noise were measured directly above the boxing bag and as such, that measurement position was used for the remainder of the in-situ testing.

The test method for the boxing bags involved having a trained kickboxer repeat the same punch and kick combination on the bag over a period ranging between 10 and 20 seconds. The kickboxer was allowed time to recover between each test and an observer was used to make sure that the punches and kicks were consistent. A minimum of six tests was conducted for each boxing bag configuration, with the results then arithmetically averaged.

The test results are presented in Figure 6. In Figure 6(a), (b) and (c) the results are compared against the background noise level within the tenancy. In Figure 6(a) and (b), the rubber sleeves to isolate the threaded rod from the base plate were not installed (the builder accidentally forgot to install them). The results for the water bags in Figure 6(a) showed that an improvement was achieved across the mid-frequencies by placing a thin rubber strip between the clip and eye bolt, with noise associated with use of that bag being just audible in the office tenancy. On that basis, it was deemed that the water bags will be adequately isolated once rope was used to connect and boxing bags to the eye bolt and the rubber sleeves were installed.

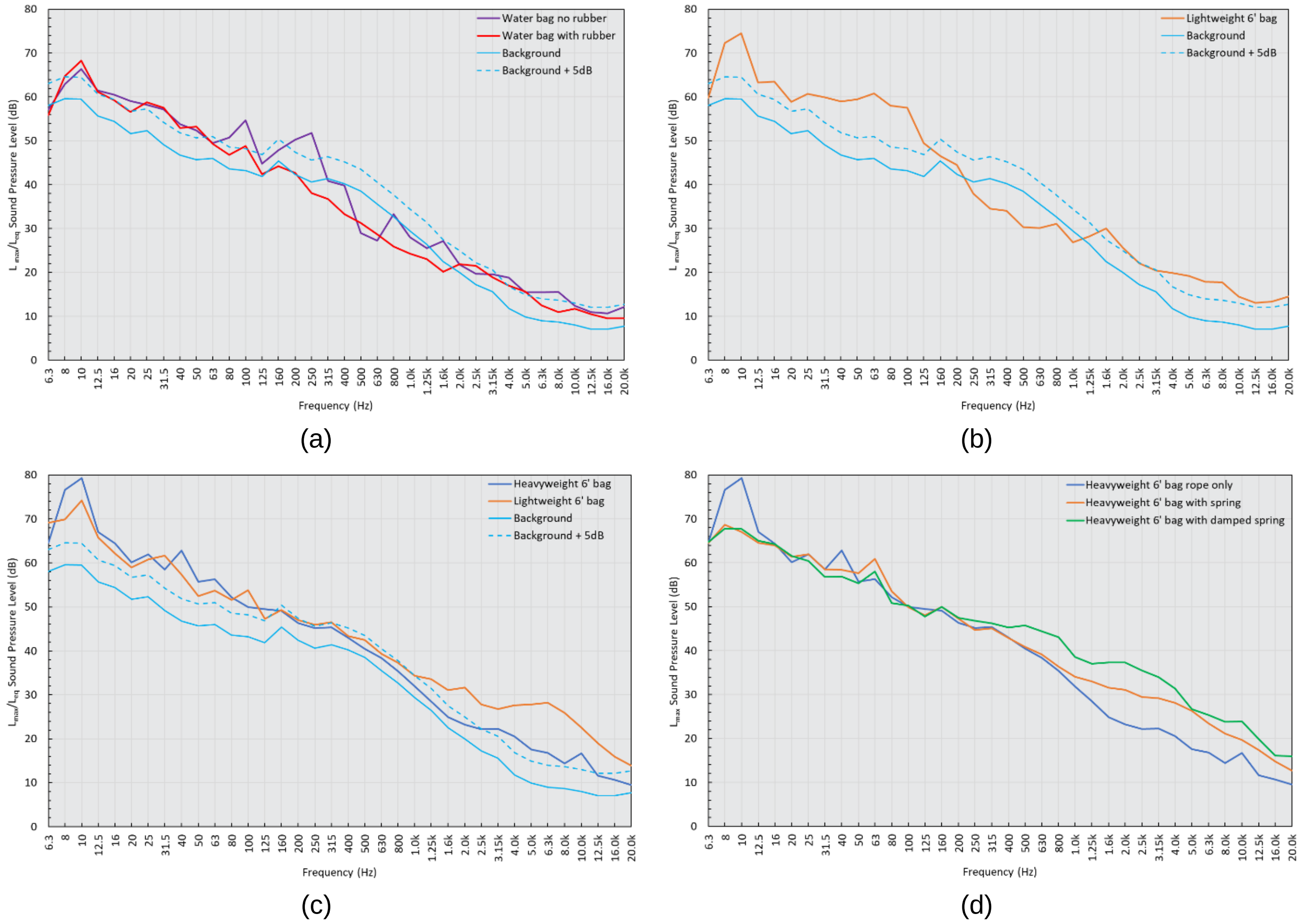


Figure 6: Test results

In Figure 6(b) the lightweight 6’ bag was connected to the eye bolt using chains and a carabiner clip. As the dropper was too long, the heavyweight 6’ bag could not be tested. The results show that isolation at lower frequencies is a problem, which was expected due to the methods available to achieve the isolation.

After the droppers were shortened the 6’ bags were tested using rope to connect the bag and eye bolt. Those test results are presented in Figure 6(c). The maximums in the range 6.3 Hz to 12.5 Hz are in the region of the resonant frequency of a typical suspended concrete slab. In is seen in Figure 6(d) that using a compression spring removes those maximums at the cost of a low isolation performance at higher frequencies. Using a damped spring resulted in a lower overall performance compared to an undamped spring. The springs were only able to be tested with the heavyweight 6’ bag, as the droppers were still too long to mount the lightweight bags.

2.7 Summary

The final isolation used for the boxing bags consisted of the rubber isolation pads and rope connecting the bags to the eye bolt. While the springs were found to be effective isolators at low frequencies, the subjective evaluation by the building managers indicated that they were not necessary. Given that additional modification would have been required for the droppers to the lightweight 6’ bags, a wait and see approach was adopted.

3 CASE STUDY 2: DROPPING OF HEAVY BARBELLS

3.1 Background

The gym for Case Study 2 was located within a converted mid-century single-storey warehouse building adjacent to a retail showroom. The gym and retail showroom were originally part of the same tenancy. To create two tenancies the building owner constructed a lightweight partition consisting of 10 mm plasterboard either side of a 92 mm steel stud between the floor and underside of the lightweight sawtooth roof. The gym had subsequently fixed a second layer of 10 mm plasterboard to their side of the partition, even though there was no acoustic insulation in the framing cavity.

Expansion joints in the on-ground concrete slab ran laterally across the building, with the gym and retail tenancy shared the same structurally-connected slab. During the gym fit out, Southside Fitness CGT15X30 flooring (15 mm thick) was installed. The gym conducted classes and allowed patrons to do deadlifts on that flooring. Impacts associated with weights being dropped caused nuisance within the retail tenancy and as such, complaints were made to the local authority.

A pollution control officer subsequently visited the tenancies and conducted in-situ testing with their cooperation. The gym owner provided a noise source by cleaning 60 kg barbell to shoulder height and dropping it onto the floor. Not surprisingly, the pollution control offer deemed the gym to be in breach of their Entertainment Venues Permit, which stated:

> *For all entertainment venues, the holder must ensure that activities carried out at the venue do not create a nuisance or intrude on the privacy of occupiers of adjacent properties.*

To demonstrate compliance, Council requested evidence that emitted L_{Amax} noise levels from the gym were less than BG + 10 dB within the retail tenancy.

3.2 The Problem

A site meeting revealed that the retail tenancy was likely to be experiencing a combination of airborne and structureborne noise. There were obvious gaps where the partition met the floor and roof that needed to be treated. The gym employed a builder to seal those gaps before in-situ floor isolation testing was conducted.

The gym had also purchased Pavigym Extreme S&S 22mm tiles to lay on top of the existing Southside Fitness CGT15X30 floor. Those tiles were purchased without any design input from an acoustic engineer. In an initial attempt to save money, the gym installed the tiles and invited the pollution control officer back for additional testing. Those tests showed that dropping the barbells still exceeded the $L_{Amax} \leq$ BG + 10 dB limit, at which point the gym acknowledged that design input and in-situ testing by an acoustic engineer was necessary.

3.3 In-Situ Testing

The initial plan was to conduct in-situ testing of various rubber tiles systems with and without a lightweight floating floor system as described in Hayne (2015). However, it was found that the floating floor samples provided by Embelton (around 1,200 mm x 1,200 mm) were too small to allow both the dropping of a barbell and the placement of weights (around 270 kg per sample) to simulate static loading. Hence testing was only conducted of different rubber tile products on the concrete slab.

The test sample consisted of an Olympic barbell loaded with four 20 kg weight plates and collars to create a 100 kg mass for dropping. The deadlifts were performed by the same person to ensure consistency, with the barbell being raised to a height of around 785 mm above the floor before being dropped. To ensure a consistent drop height, the deadlifter stood on a platform between the test samples that was adjusted to match the height of the samples.

A minimum of six deadlifts was performed for each floor system, with the maximum noise level recorded for each deadlift. A sound level meter was placed on the gym side of the inter-tenancy partition at a distance of 1,000 mm from the partition, while another sound level meter was placed within the retail tenancy at the service desk location, approximately 2,700 mm from the partition at ear level.

Several times during the testing the background noise levels were measured within the retail tenancy. An average background level of 45 dB(A) L_{Aeq} was measured, with the resulting limit being 55 dB(A) L_{Amax}. To separate the structureborne and airborne components of the noise, noise reduction testing was also conducted whereby pink noise was played through a speaker located at the lifting position within the gym and simultaneous measurements made at the sound level meter locations. The data were subsequently post-processed to determine the performance improvements and contributions due to structureborne and airborne noise.

Twelve tests were initially included in the test program as summarised in Table 1. As the gym had already purchased the Pavigym Extreme S&S 22 mm tiles, they were incorporated where possible into the floor systems. The test results are summarised in Table 2, with the airborne and structureborne components identified along with the structureborne noise reduction compared to the base concrete and existing Southside Fitness CGT15X30 floor.

Table 1: Summary of floor systems – first test program

Test	Floor System
1	Bare concrete
2	Southside Fitness CGT15X30 15 mm
3	Pavigym Extreme S&S 22 mm
4	Southside Fitness CGT15X30 15 mm + Pavigym Extreme S&S 22 mm
5	Southside Fitness CGT15X30 15 mm + 2 x layers Pavigym Extreme S&S 22 mm
6	Southside Fitness CGT15X30 15 mm + Pavigym Extreme S&S 22 mm + plywood + Pavigym Extreme S&S 22 mm
7	Regupol 4080 48 mm
8	Regupol 4080 48 mm + Pavigym Extreme S&S 22 mm
9	Southside Fitness CGT15X30 15 mm + Pavigym Extreme S&S 22 mm + Regupol 4080 48 mm
10	Regupol 4080 88 mm
11	Regupol 4080 88 mm + Pavigym Extreme S&S 22 mm
12	Southside Fitness CGT15X30 15 mm + Pavigym Extreme S&S 22 mm + Regupol 4080 88 mm

Table 2: Test results – first test program

Test	Component Level, L_{Amax} (dB(A))			Structureborne Noise Reduction (dB) Compared to…	
	Structureborne	Airborne	Total	Bare Concrete	Existing Floor
1	73.6	57.3	73.7	N/A	N/A
2	72.4	54.7	72.5	1.2	N/A
3	71.2	53.3	71.3	2.4	N/A
4	67.6	52.9	67.7	6.0	N/A
5	65.0	51.8	65.2	8.6	2.6
6	67.0	60.2	67.8	6.6	0.6
7	61.3	49.7	61.6	12.3	6.3
8	56.9	48.4	57.5	16.7	10.7
9	57.5	47.7	57.9	16.1	10.1
10	50.6	47.1	52.2	23.0	17.0
11	50.5	46.0	51.8	23.1	17.1
12	48.0	45.2	49.8	25.6	19.6

Even though the test results in Table 2 indicated is was possible to satisfy the design limit of 55dB(A) L_{Amax}, the gym requested a second test program of alternative flooring systems as detailed in Table 3. The second test program results are summarised in Table 4. Unfortunately the deadlifter from the first test program was unavailable and another person used who dropped the barbell from a lower height. In addition, the relationship between the gym and retail tenant had disintegrated to the stage where access to the retail tenancy was only allowed for a brief period of time, limiting the tests that could be completed. Hence the various products across the two test programs can only be compared in terms of their improvement over bare concrete. It can be seen that 2 x layers A1 Rubber 30 mm Olympact + Pavigym Extreme S&S 22 mm provides a similar level of structureborne noise reduction to Regupol 4080 88 mm + Pavigym Extreme S&S 22 mm.

Table 3: Summary of floor systems – second test program

Test	Floor System
1	Bare concrete
2	A1 Rubber 30 mm Olympact
3	A1 Rubber 30 mm Olympact + Southside Fitness CGT15X30 15 mm
4	2 x layers A1 Rubber 30 mm Olympact
5	2 x layers A1 Rubber 30 mm Olympact + Southside Fitness CGT15X30 15 mm
6	2 x layers A1 Rubber 30 mm Olympact + Pavigym Extreme S&S 22 mm
7	2 x layers A 1 Rubber 30 mm Olympact + 20 mm Olympact + Southside Fitness CGT15X30 15 mm

Table 4: Test results – second test program

Test	Component Level, L_{Amax} (dB(A))			Structureborne Noise Reduction (dB) Compared to Bare Concrete
	Structureborne	Airborne	Total	
1	72.3	57.3	72.4	N/A
2	69.1	51.0	69.2	3.2
3	64.9	51.2	65.1	7.4
4	59.2	47.1	59.5	13.1
5	57.6	47.4	58.0	14.7
6	54.8	47.8	55.6	17.5
7	51.4	45.4	52.4	20.9

During the testing subjective feedback was obtained from the retail tenancy about the various products, which influenced the final product selection made by the gym. As the level of structureborne (and airborne) noise depends upon the mass and height from which the weights are dropped, care was taken to avoid any statements claiming compliance would be guaranteed. In addition, the gym was advised to focus on upgrading the flooring to achieve an adequate level of structureborne noise isolation and take a wait-and-see approach about further upgrades to the inter-tenancy partition to mitigate airborne noise.

3.4 Summary

The in-situ testing determined that for on-ground concrete slabs rubber tiles can be a viable way of mitigating structureborne noise associated with deadlifts. However, the type of lifting has a direct correlation between the level of impact noise being experienced by the adjoining tenancy. A higher mass or dropping the same mass from a different height will change the momentum and hence the impulse causing the noise. As such, it was also recommended that during the opening hours of the retail tenancy, management of the gym should ensure that their members do not undertake extreme lifting activities, defined as deadlifting with a mass greater than 100 kg or dropping weights greater than 72 kg from shoulder height (around 1,500 mm above the floor).

ACKNOWLEDGEMENTS

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