24th INTERNATIONAL CONGRESS ON SOUND AND VIBRATION
23–27 July 2017, London

IMPACT PERFORMANCE OF LIGHTWEIGHT GYM FLOORS USING 25KG AND 50KG WEIGHTS

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Gyms are a common source of complaints for adjacent tenancies due to vibration and impact related noise issues. In many cases it is impractical to install a concrete floating slab and therefore lightweight floor options are increasingly being used for retrofitting, due to cost effectiveness and ease of removal for change of tenancy. Difficulties arise when selecting suitable lightweight gym floor build-ups to achieve satisfactory noise and vibration reduction. This paper presents test data results for noise and vibrations levels of low and high density rubber installed directly onto a suspended slab, rubber mounts under plywood and damped spring mounts under plywood. Testing involved a 25kg and 50kg dumbbell being dropped separately ten times from 620mm height for each system. High density rubber installed exclusively was used as a baseline test. Damped spring mounts under plywood with 25mm rubber underlay and rubber impact tile, 75mm rubber underlay with impact tile, and 100mm rubber underlay with impact tile systems achieved the highest noise attenuation. In addition, damped spring mounts provided the greatest reduction in vibration.
Keywords: gym, vibration, isolation, weights

1. Introduction

Structurally isolated floors reduce noise and vibration transfer from various types of harmonic excitations and impacts. While heavyweight constructions are preferable for performance, lightweight isolated floors can be retrofitted, are cost effective and more easily removable for changes in tenancy. For this reason, they are commonly employed in gyms located in apartments, commercial buildings and hospitals. However, a lack of clarity exists around comparative performance in selection of lightweight floor build-ups due to the vast range of options for isolation layers.

This paper presents the acoustic and vibration testing method and results carried out on five commonly used gym floor types. Dumbbells were chosen in place of barbells for localised impacts and to reduce the possibility of twisting upon release to achieve more consistent drops. In addition, building floor systems for a barbell drop would be less practical as a larger surface area is required.

Typically gyms will provide dumbbells up to 50kg. 25kg was chosen as a common weight used in residential gyms and 50kg as an upper limit. Weights were dropped from a comfortable standing position height of 620mm. The aim of this paper is to provide a comparison of acoustic and vibrational performance between different lightweight gym floor systems. It should be noted that all materials are Embelton products.

2. Lightweight gym floors

The floor systems were characterised by two types; rubber mat systems laid onto the slab, and floating floor systems. The five test floor systems differing in materials used and finished height are as follows.

2.1 Baseline 15mm Impact Tile

- 15mm high density rubber top surface finish (approximately 800kg/m^3) 1.0 x 1.0 metre tiles installed directly onto 150mm concrete slab
- This was used as a baseline test, providing a typical minimum level of cushioning over the concrete slab

2.2 Rubber Underlay

- 25mm, 50mm, 75mm and 100mm low density rubber underlay (approximately 600kg/m^3) 1.0 x 1.0 metre tiles installed directly onto 150mm concrete slab
- 15mm high density rubber top surface finish

2.3 Rubber Mounts

- 10mm deflection rubber mounts installed onto 150mm concrete slab at 600 x 600mm spacing fixed to structural plywood
- 2 layers of 1200 x 1200 x 19mm structural plywood screwed together with rubber mounts fixed to underside
- 15mm high density rubber top surface finish
- Cavity filled with 25mm 32kg/m^3 polyester insulation
- 97mm overall free height

2.4 Damped Springs

- 25mm deflection damped springs installed onto 150mm concrete slab at 600x600mm spacing
- 2 layers of 1200 x 1200 x 19mm structural plywood screwed together with damped springs fixed to underside
- 15mm high density rubber top surface finish
- Cavity filled with 50mm 32kg/m^3 polyester insulation
- 147mm overall free height

2.5 25mm Rubber Underlay + Damped Springs

- 25mm deflection damped springs installed onto 150mm concrete slab at 600x600mm spacing
- 2 layers of 1200 x 1200 x 19mm structural plywood screwed together with damped springs fixed to underside
- 25mm low density rubber underlay on plywood
- 15mm high density rubber top surface finish
- Cavity filled with 50mm 32kg/m^3 polyester insulation
- 172mm overall free height

3. Equipment

3.1 Test facility

Testing was conducted at Embelton's onsite facility comprising of an isolated concrete slab and receiving room of approximately 80m^3 volume. Floor samples were built onto the 10.8m^2, 150mm thick 32MPa approximately 20Hz concrete slab. The slab is isolated by a rubber layer from the surrounding concrete structure to minimise the influence of wall flanking transmissions.

3.2 25kg and 50kg dumbbell

For a deadlift exercise, a weight can be dropped from a comfortable standing position at around knee height. Therefore, in the absence of international standards for heavy rigid impact testing, the chosen drop height was 620mm which was measured from a comfortable standing drop position. It was expected that a dumbbell would be more practical than barbells or kettlebells for occupational health and safety concerns for repeated weight drops.

3.3 Weight rack with hand winch

The weight rack had large steel feet for stability and rubber was adhered to the underside to minimise vibration due to dumbbell release. A hand winch was fixed to the rack to safely lift weights and a threaded rod allowed for height adjustment for consistent drops.

Figure 1: Weight rack with hand winch used to produce repeatable tests

3.4 Svantek 958A analyser and SV207A accelerometer

A Svantek 958A analyser was used with an SV60 microphone attachment for acoustic testing in 1/3rd octave bands. For vibration tests, a Svantek SV207A tri-axial accelerometer was placed at a 200mm fixed distance from the test floor area. Measurements were taken in the 1/3rd octave bands and weighted as presented in results.

4. Methodology

A 25kg and 50kg dumbbell were dropped 10 times for each test floor in the centre of the isolated floor system. Results were averaged to minimise measurement errors and variations. L_{max} was measured from the centre of the receiving room over 30 seconds between 20Hz to 20kHz using the Svantek 958A analyser. RMS acceleration levels on the concrete slab were measured over a 10 second interval. During analysis of the data, the RMS acceleration values were weighted according to BS 6472:2008 [1].

5. Results

5.1 Acoustic test results

Table 1: Single L_{Max} dB(A) attenuation values for 25kg and 50kg dumbbell drops

Floor System	25kg L_{Max} Attenuation dB(A)	Rank	50kg L_{Max} Attenuation dB(A)	Rank
Baseline 15mm Impact Tile	0.0	-	0.0	-
25mm Rubber Underlay	19.2	7	16	7
Rubber Mounts	20.7	6	21.7	6
50mm Rubber Underlay	26.2	5	22.0	5
Damped Springs	27.6	4	30.1	2
75mm Rubber Underlay	29.0	3	27.4	4
100mm Rubber Underlay	30.0	2	28.1	3
25mm Underlay + Damped Springs	31.6	1	30.8	1

All floor types yielded significant improvements to the baseline test, which measured L_{Max} of 91.0 dB(A) and 94.4 dB(A) for 25kg and 50kg drops respectively. At frequencies higher than 1kHz, all systems excluding the baseline test performed close to background noise. In the frequency spectrum of approximately 63 – 800Hz, the behaviour of the systems displayed no clear order, which may have been a result of room modal frequencies and fundamental frequencies of different components in build-ups. At frequencies below 50Hz (Figs. 2 and 3) however, there was a clear trend that was consistent with the hierarchy of attenuations listed in Table 1.

Relative to the baseline, damped springs with 25mm underlay resulted in the highest attenuation in both 25kg and 50kg of 31.6 dB and 30.8 dB respectively. While the absolute L_{Max} values for all test systems increased with the heavier weight, only the 25mm and 50mm rubber underlays yielded a worse relative noise reduction (Table 1 50kg L_{Max} Attenuation). In contrast, the damped spring system with no rubber underlay significantly improved with the 50kg weight drop, and recorded the second highest attenuation with respect to baseline testing.

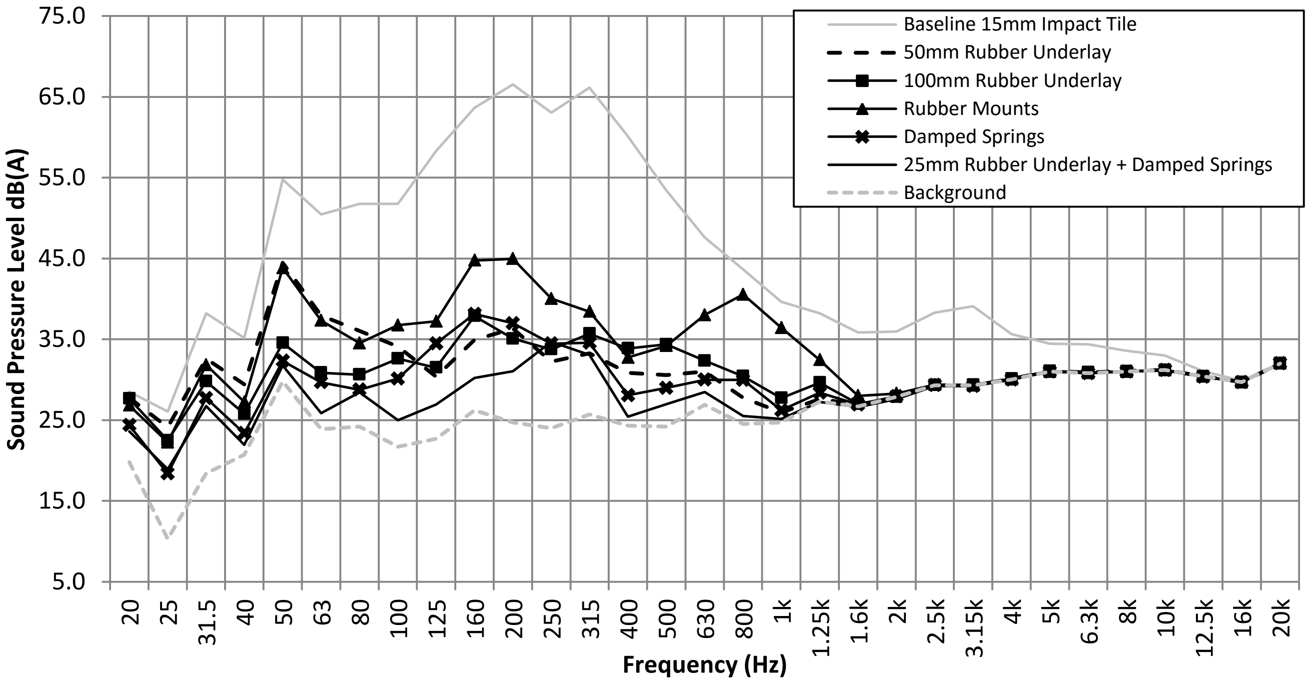

Figure 2: 1/3[rd] Octave L_{Aeq} for 25kg dumbbell drops

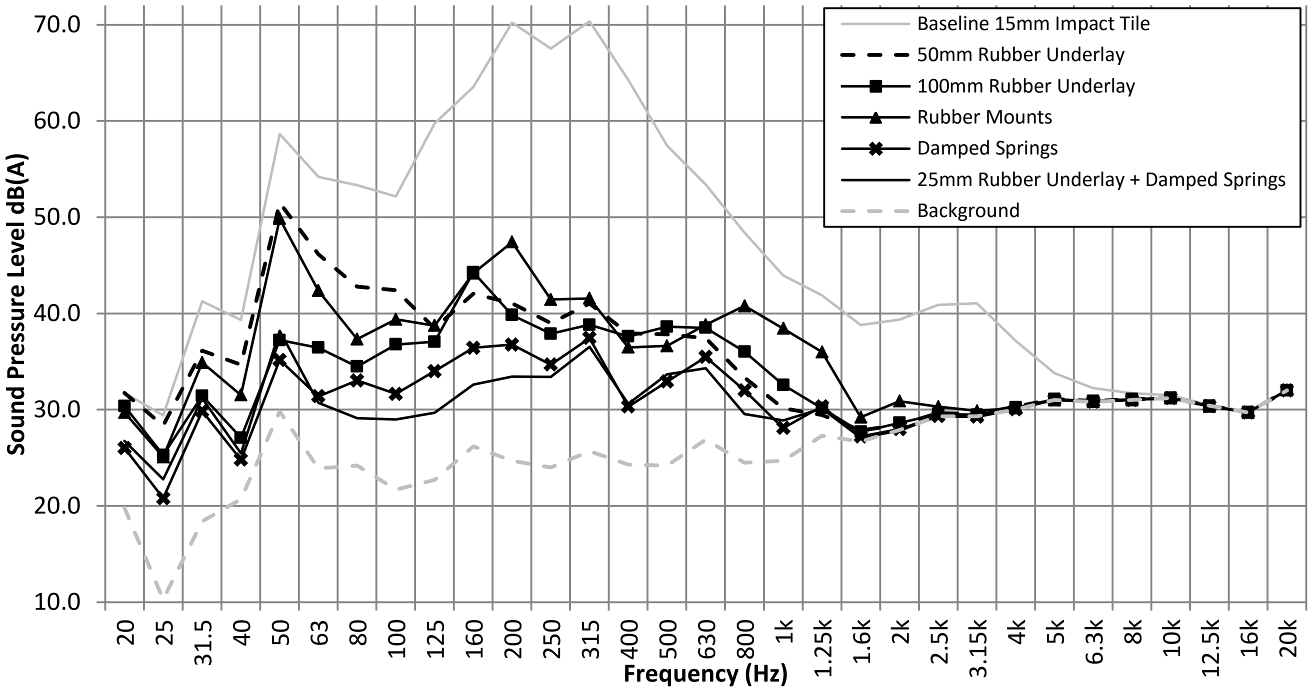

Figure 3: 1/3rd Octave L_{Aeq} for 50kg dumbbell drops

5.2 Vibration test results

Table 2: BS 6472:2008 Weighted RMS acceleration for 25kg and 50kg dumbbell drops

Build	25kg Weighted RMS acceleration (mm/s^2)	50kg Weighted RMS acceleration (mm/s^2)
Baseline 15mm Impact Tile	101.3	214.6
25mm Rubber Underlay	89.9	140.9
50mm Rubber Underlay	76.1	139.5
75mm Rubber Underlay	73.9	137.0
100mm Rubber Underlay	70.8	121.8
Rubber Mounts	64.2	104.7
Damped Springs	33.5	48.6
25mm Rubber Underlay + Damped Springs	25.0	45.1

Table 3: BS 6472:2008 Weighted RMS acceleration attenuation for 25kg and 50kg dumbbell drops

Build	25kg attenuation (dB)	50kg attenuation (dB)
Baseline 15mm Impact Tile	0.0	0.0
25mm Rubber Underlay	1.0	3.6
50mm Rubber Underlay	2.5	3.7
75mm Rubber Underlay	2.7	3.9
100mm Rubber Underlay	3.1	4.9
Rubber Mounts	4.0	6.2
Damped Springs	9.6	12.9
25mm Rubber Underlay + Damped Springs	12.1	13.5

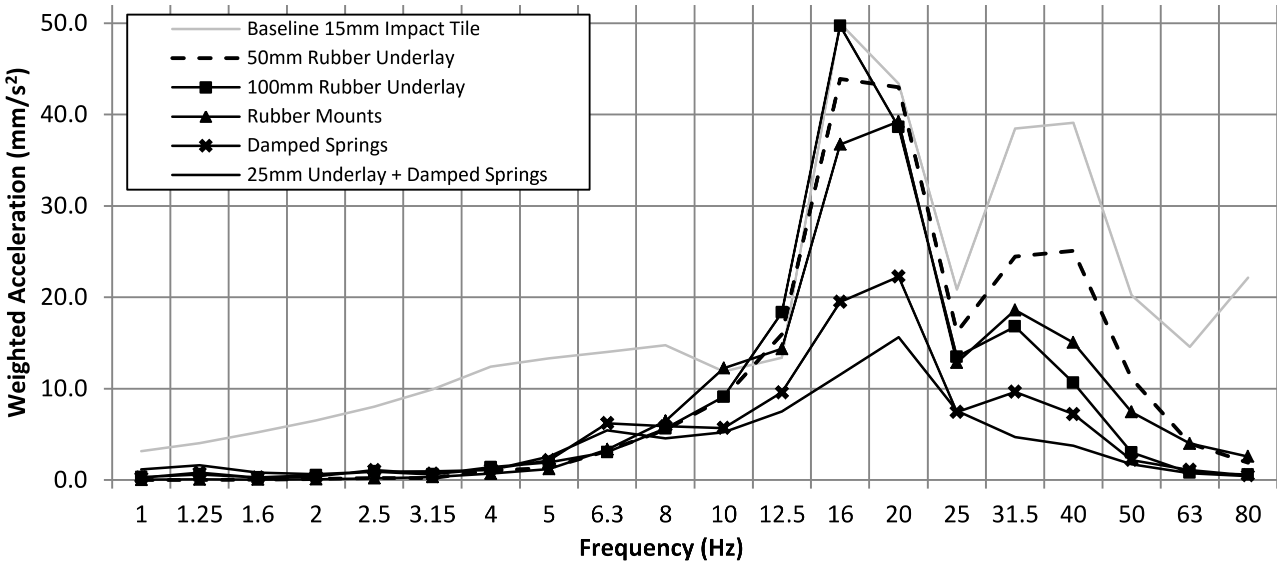

Figure 4: 1/3rd Octave L_{Max} for 25kg dumbbell drops

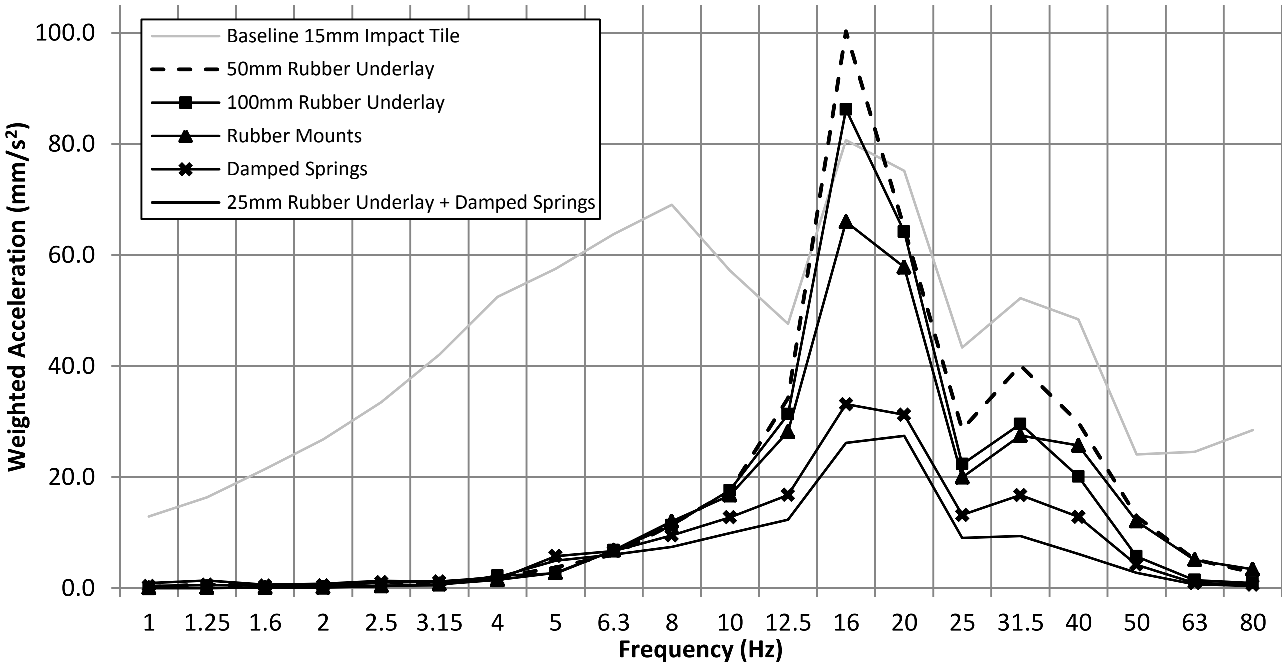

Figure 5: 1/3rd Octave L_{Max} for 50kg dumbbell drops

During testing, it was observed that for baseline and rubber underlay systems, the windows in the source room rattled and the lights in the receiving room flickered. In the case of damped springs and rubber mounts, this was not noticeable. From Figs. 4 and 5, a major peak was present at approximately 16 - 20Hz for all tests which was indicative of the concrete slab's fundamental frequency. The trends at 16 - 20Hz range distinguished the attenuation performance of systems shown in Table 3 and the absolute values for RMS acceleration were greater for all 50kg drops (Table 2). The baseline test resulted in 214.6mm/s^2 for the 50kg test which was over double that for the 25kg test. Consequently, attenuation for all other systems improved due to the poor performance of the baseline.

The damped springs with 25mm underlay yielded the best results in 25kg and 50kg testing with 12.1 dB and 13.5 dB attenuation respectively. The acceleration recorded for 50mm rubber underlay exceeded the baseline test in the 50kg test at 16 - 20Hz, while all other tests remained below baseline for both weights across the 1 – 80Hz frequency range. The damped spring floor with no underlay significantly improved in performance by 3.3 dB reduction to baseline between 25kg and 50kg testing, and was comparable to damped springs with underlay.

6. Analysis

With the increase of weight to 50kg, the noise attenuation of rubber underlays decreased with respect to baseline testing. Furthermore, the incremental improvements reduced with increasing rubber thickness. For 25kg testing, the damped springs with underlay provided 4.0 dB additional noise reduction compared to damped springs without underlay, whereas the 50kg test resulted in only a 0.7 dB difference in attenuation between the systems. These observations suggested that the rubber underlays were becoming over-compressed upon impact, providing a more rigid transmission path. Further testing can be done with varying weights on different thicknesses of rubber underlay to determine a trend for diminishing returns as well as identifying what loads and thicknesses cause amplification of an underlying concrete slab's fundamental frequency.

The rubber underlays provided minimal attenuation in vibration for 25kg drops. The improvement in attenuation for the 50kg test was mainly due to the baseline registering a poorer performance in weighted RMS, which was more than double that of the 25kg.

At the 16 - 20Hz slab fundamental frequency, low density rubber provided negligible vibration isolation in comparison to the baseline for 25kg drops, and amplified vibration for 50kg drops. This may have contributed to the observation during testing that the windows in the source room rattled and lights in the receiving room flickered. Suspended slabs in residential buildings are typically more flexible than 16 Hz [2][3], therefore greater slab amplitudes could be expected in residential gyms.

The rubber mounts acoustically performed similarly to 50mm underlay but provided only minor vibration improvements in comparison to rubber underlay systems. Unlike rubber underlays, the rubber mounts achieved higher levels of noise attenuation relative to baseline testing when the weight drop was increased. This may have been due to the greater dynamic deflection available to the rubber mounts. It was unexpected that this was not reflected in the vibration results.

Damped spring systems provided the highest noise attenuation relative to baseline for 50kg dumbbells of over 30 dB. The weighted vibration RMS values were less than half that of rubber underlays and rubber mounts, and less than 25% of the baseline test for 50kg testing. The addition of 25mm rubber underlay was providing little cushioning for 50kg dumbbells, indicated by the comparative vibration attenuation between the two damped spring floors. It was expected that increased vibration attenuation performance was related to lower stiffness in the isolators. This was evident with the 13 dB attenuation to baseline of 25mm deflection damped springs compared to 6 dB reduction of 10mm deflection rubber mounts.

7. Conclusions

Comparative performance of some common lightweight gym flooring options has been presented in terms of structure borne noise levels measured in an adjacent space and vibration of the underlying isolated concrete slab following a discrete impact. Not discussed throughout this paper are practical and subjective considerations such as cost, ease of installation, and comfort.

Overall, the damped springs, 75mm underlay and 100mm underlay systems provided significant and comparable attenuation acoustically. With regards to vibration however, damped springs outperformed all other systems significantly. The weighted acceleration RMS values for damped springs were less than 25% of the baseline. Rubber underlays reduced overall vibration levels with respect to baseline but amplified vibration at the underlying structure's fundamental frequency for 50kg tests. For this reason, in circumstances where vibration has been revealed to be an issue, it is unlikely that the use of rubber underlays will bear any significant improvement.

REFERENCES

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