# Comparative testing of Acoustic Isolation Properties of Mixed Cell Polyurethane (PUR) Elastomer in Lightweight Floating Floors


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*Abstract* – This paper examines the material properties of mixed cell polyurethane (PUR) elastomer as an acoustic isolator. This isolator achieves good acoustic isolation while requiring minimal floor cavity depth (whereas conventional isolators such as steel springs or rubber mounts typically deliver only one or the other). This paper presents comparative testing of cube shaped PUR isolators, damped springs and rubber mounts as part of a lightweight floating floor over a concrete slab. Field measurements of impact sound and vibration transmission through these floor systems were conducted using multiple methods, which include dropping heavy-hard impact objects of different mass and shape. The results show that floating floor systems with PUR isolators perform similarly to damped springs in terms of noise and vibration isolation. The material characteristics of PUR isolators are also examined, particularly those which make them cost-effective and suitable for conventional applications in lightweight floating floors.


## 1 INTRODUCTION

Acoustic isolation in lightweight floating floor systems is critical in multi-storey buildings to improve amenity for sensitive receivers (residents or other occupants). Over the last decade, springs and rubber mounts are the most commonly used isolators to reduce impact and noise vibration in lightweight floating floor systems in Australia. However, their use is typically a trade-off between minimising floor cavity depth and acoustic performance, with rubber mounts allowing small cavity depths (nom. 50mm) at the cost of acoustic performance, while steel springs typically deliver superior performance at the cost of a large floor cavity to accommodate for their 100mm free height. Minimising the floor cavity depth is one way that building designers tackle challenges associated with cost and space efficiency in multi-storey buildings. To this end, we consider mixed cell polyurethane (PUR) elastomer isolators as a valuable alternative in addressing such design challenges due to their high acoustic performance and compactness which achieves a minimal floor cavity depth, maximising height within internal spaces at a lower overall cost.

## 2 LIGHTWEIGHT FLOOR SYSTEMS TESTED

This paper presents the comparison of a 50mm thick PUR isolator with the two most conventional systems in this space, damped springs and rubber. The rubber mounts tested were of similar height to the PUR mounts, and the springs were 82 mm in height, to aid comparison. Two types of floor systems were tested for each type of isolator: the bare plywood platform with no surface finish, and the platform with a PUR shock absorber and rubber topping. The floor finishes chosen were a layer of 15mm high density rubber mat over 25mm G-Fit Advanced polyurethane (PUR) shock absorption layer, which were expected to mimic a real-world gym floor system commonly used and considered to be cost effective in the local industry. During the tests, a total of 100kg of sandbags were used to keep the platform stable to hold down the floor finishes on top of the plywood platform. Details of the floor systems tested are presented in the tables and diagrams in the following sections.

## 2.1 Polyurethane (PUR) mounts under plywood

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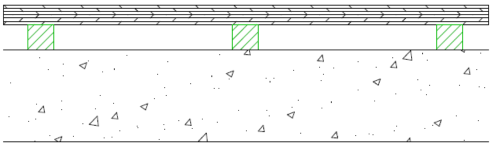
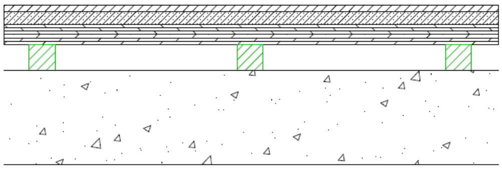
|  |  |
| Polyurethane mounts under bare plywood:<br>• 50mm thick AFB60 Getzner Sylomer polyurethane (PUR) acoustic floor blocks (AFB) installed onto 180mm concrete slab spaced at 400mm x 600mm centres.<br>• 2 layers of adhered 1200mm x 1200mm x 19mm structural plywood<br>• No top surface finish<br>• No ceiling installed | Polyurethane mounts under bare plywood with top surface finish:<br>• 50mm thick AFB60 Getzner Sylomer polyurethane (PUR) acoustic floor blocks (AFB) installed onto 180mm concrete slab spaced at 400mm x 600mm centres.<br>• 2 layers of adhered 1200mm x 1200mm x 19mm structural plywood<br>• 15mm high density rubber mat over 25mm G-Fit Advanced PUR shock absorption layer<br>• No ceiling installed |

## 2.2 Damped spring mounts under plywood

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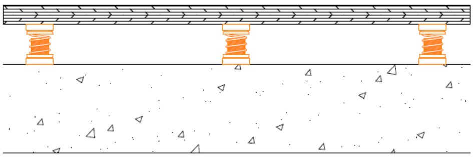
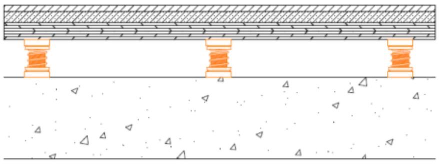
|  |  |
| Damped springs under bare plywood:<br>• 82mm thick Isotop springs with PUR damping tube onto 180mm concrete slab, spaced at 400mm x 600mm centres.<br>• 2 layers of adhered 1200mm x 1200mm x 19mm structural plywood<br>• No top surface finish<br>• No ceiling installed | Damped springs under bare plywood with top surface finish:<br>• 82mm thick Isotop springs with PUR damping tube onto 180mm concrete slab, spaced at 400mm x 600mm centres.<br>• 2 layers of adhered 1200mm x 1200mm x 19mm structural plywood<br>• 15mm high density rubber mat over 25mm G-Fit Advanced PUR shock absorption layer<br>• No ceiling installed |

## 2.3 Rubber mounts under plywood

| | |
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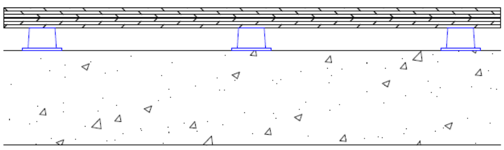
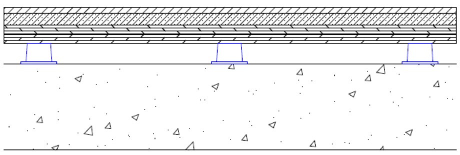
|  |  |
| Rubber mounts under bare plywood:<br>• 45mm thick Embelton NRD2 rubber mounts installed onto 180mm concrete slab, spaced at 400mm x 600mm centres.<br>• 2 layers of adhered 1200mm x 1200mm x 19mm structural plywood<br>• No top surface finish<br>• No ceiling installed | Rubber mounts under plywood with top surface finish:<br>• 45mm thick Embelton NRD2 rubber mounts installed onto 180mm concrete slab spaced at 400mm x 600mm centres.<br>• 2 layers of adhered 1200mm x 1200mm x 19mm structural plywood<br>• 15mm high density rubber mat over 25mm G-Fit Advanced PUR shock absorption layer<br>• No ceiling installed |

# 3 INITIAL METHODOLOGY (TEST A)

The initial testing was undertaken as part of a larger test involving over 20 floor configurations comprising of various finishes and isolators. A range of commonly used spring mounts were tested It was observed that all the floor systems with the spring mounts exhibit similar performance. For the purposes of this technical paper, we present the results of the Isotop spring as a representative spring isolator to show comparative impact performance with PUR mounts and rubber mounts.

## 3.1 Test facility

Testing was undertaken at Renzo Tonin & Associates' field test facility comprising of a 180mm bare concrete slab and a fully enclosed receiver room below of loadbearing brick wall construction, with a volume of 90m$^3$ and floor to soffit height of 2.4 metres. The total floor area of the test facility is 35m$^2$. All weights were dropped on the same point of the test facility, on the 1.44m$^2$ plywood and the same area for the bare slab tests. The underside of the concrete slab was exposed in the receiving room, and impact tests were performed on the bare slab to determine the delta $L_{AFmax}$, to quantify the improvement of the isolated floor systems of interest.

The natural frequency of the concrete slab is 11Hz, which was measured in the validation test (Test B).

## 3.2 Testing methodology and equipment

Currently, there are no set national or international standards that detail best practice for field measurements of noise and vibration transmission through floor systems using heavy-hard impact objects. In the absence of such standards, the following measurement methodology was undertaken, and further refined in Test B. For the lightweight floor systems 2.1 and 2.2, and the bare concrete slab, the impact noise was generated by a 20kg cast iron weight plate with a continuous curved impact surface. To ensure repeatability, a purpose-built vertical duct was used to control height and prop orientation. A series of five weight drops were carried out via manual dropping through a vertical duct for each test. Table 1 summarises the drop heights for this noise source with the corresponding input energy.

*Table 1 - Drop heights, mass and corresponding input energy*

| Mass (kg) | Height (mm) | Equivalent Input Energy(J) | Energy Level |
|---|---|---|---|
| 20kg | 250 | 49 | Low |
| 20kg | 500 | 98 | Mid |
| 20kg | 1000 | 196 | High |

Three unattended NTI XL2 Analysers were used to record noise levels for each impact, with microphones set at 0.77m, 1.15m and 1.5m above ground level. The microphones were distributed in the receiver room as much as practical, so that they were at more than 1 metre away from each other and from room boundaries. Each noise monitor was set to record broadband and spectral noise descriptors and measure impact noise over at 0.1 second intervals. The energy-average maximum impact sound pressure level $L_{i,p,F}$ max (dB) was determined from the 3 noise monitors with microphones at different heights. This method results in a spatial average of noise levels in the receiver room and reduces the effects of room modes on the results.

## 3.3 Acoustic Test Results

### 3.3.1 Results at AAAC frequencies of interest

According to the Association of Australasian Acoustical Consultants *Guideline for Acoustic Assessment of Gymnasiums and Exercise Facilities*, the frequencies of interest for impulsive noise emission to receiver rooms are between 31.5 Hz to 250 Hz, which are the octave bands containing the impulse energy (Association of Australasian Acoustical Consultants, 2022). The following graphs present the comparative performances between the springs and PUR mounts at these frequencies.

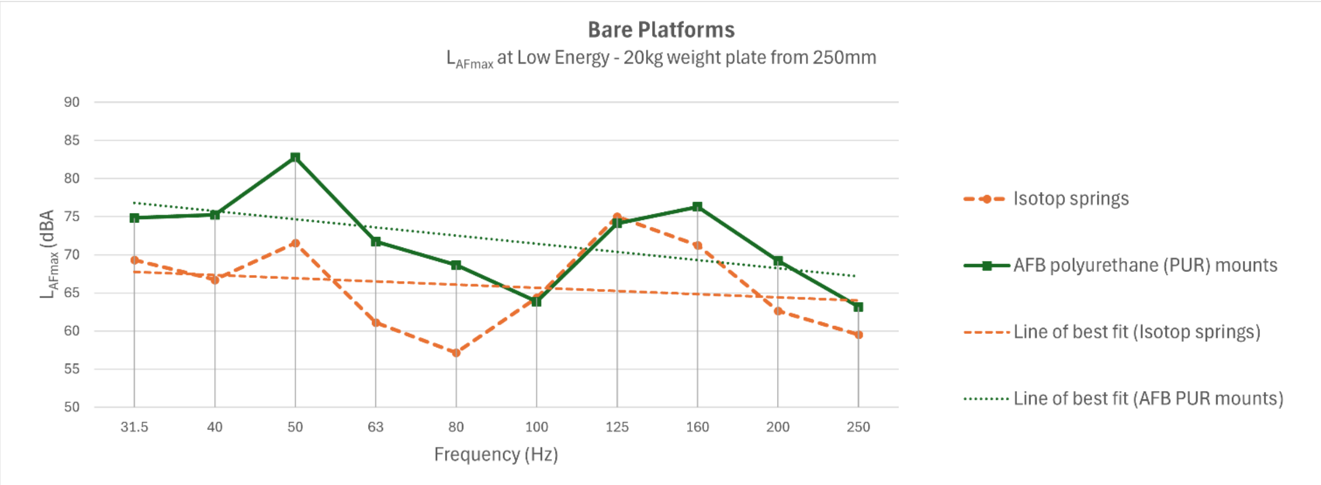



*Figure 1 – Comparative $L_{AFmax}$ for bare floor systems 2.1 and 2.2 at low energy*

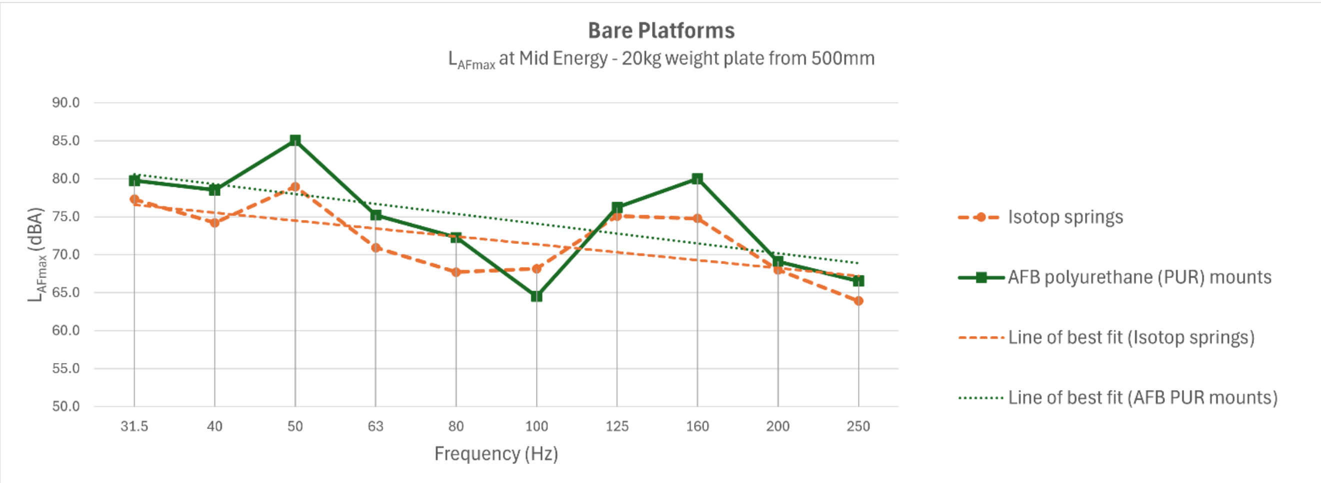



*Figure 2 – Comparative $L_{AFmax}$ for bare floor systems 2.1 and 2.2 at mid energy*

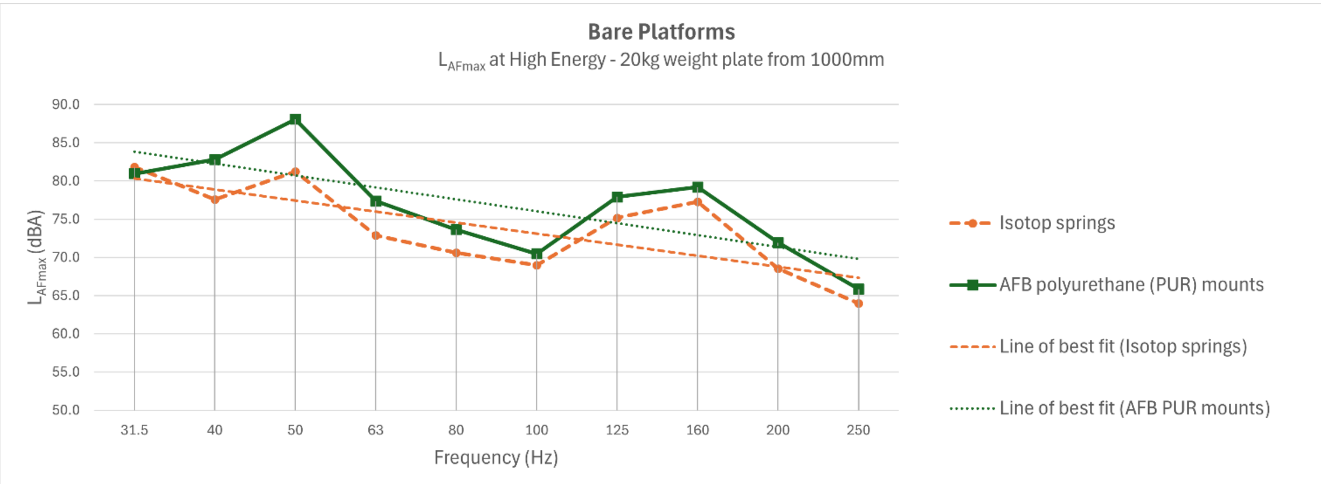



*Figure 3 – Comparative $L_{AFmax}$ for bare floor systems 2.1 and 2.2 at high energy*

### 3.3.2 Overall delta $L_{AFmax}$ results

The delta $L_{AFmax}$ was derived from subtracting the $L_{AFmax}$ noise level of the floor system from the $L_{AFmax}$ of the bare concrete slab, at each energy level. The higher the delta $L_{AFmax}$, the better the acoustic performance. The results in Figure 5 demonstrate that the PUR mounts perform better than springs at all energy levels for the finished floor platforms.

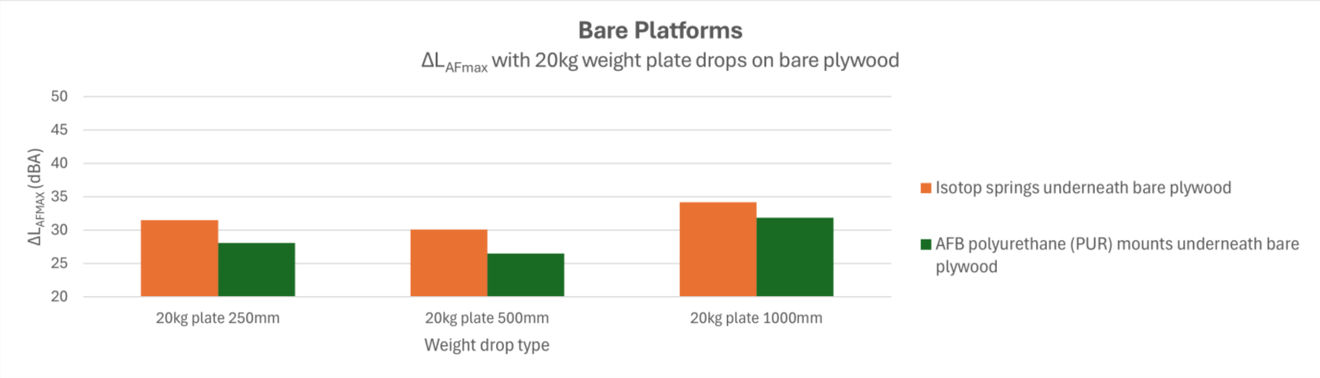



*Figure 4 – The delta $L_{AFmax}$ comparison of springs and PUR mounts underneath bare plywood platform*

However, the 25mm G-Fit Advanced topping also comprises of polyurethane material, which would influence the overall result. The improvement in performance is exhibited by the PUR mounts at high energy level in the bare platform test, providing a similar attenuation to that of springs, with a difference of 2 dB.

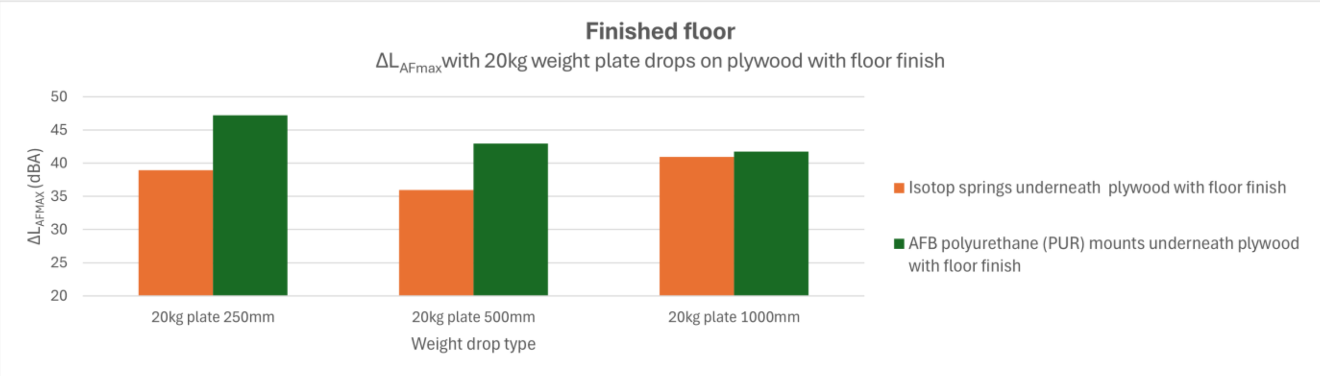



*Figure 5 – The delta $L_{AFmax}$ comparison of springs and PUR mounts underneath the platform with a floor finishes*

## 3.4 Test A discussion

The 1/3 octave spectrum graphs show that the performance of the PUR elastomer mounts increases as more energy is applied onto the floor system, approaching the performance of the spring mounts. This is due to the 'shape factor' as well as the modulus of elasticity (or stiffness) of the isolators, which can significantly influence their performance under dynamic loading. The shape factor is how much an elastic bearing can bulge under specific loads and has an influence on the stiffness of the material.

As shown in Figure 6 (Getzner Werkstoffe GmbH, 2019), the modulus of elasticity of the PUR mounts decreases as the specific load increases and continues to decrease when it enters its dynamic range of use. The decrease in the modulus of elasticity means that the PUR bearing gets softer as the load is increased. As it gets softer under higher energy level, the cube shaped PUR mounts bulge horizontally and deflect outwards and absorb more energy within the air bubbles of the mixed cell elastomer. In comparison, the stiffness of spring mounts remains constant with increased loads, with the potential energy stored in the coil of the spring while it is compressed vertically. As such, PUR mounts can achieve greater compactness and a performance close to the 82mm springs, despite having a lower thickness of 50mm.

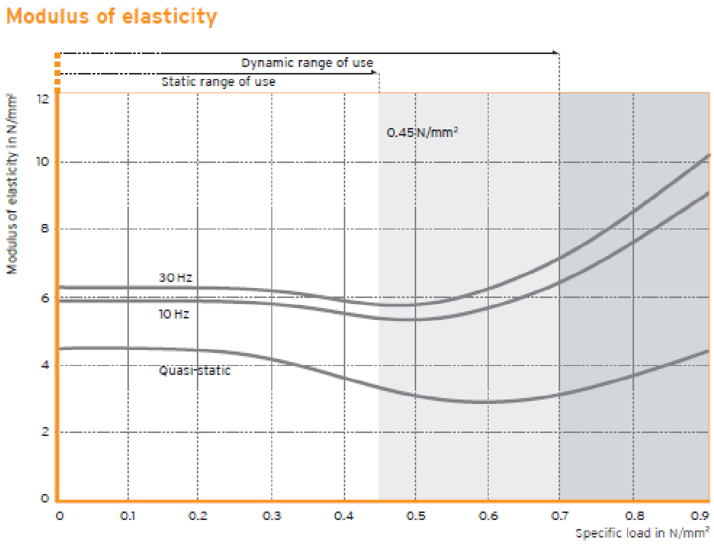



*Figure 6 – Load dependency of the modulus of elasticity for PUR isolators showing the relationship between the modulus of elasticity (N/mm$^2$) and the specific load (N/mm$^3$)*

The results demonstrate that PUR mounts perform similarly to springs under the bare platform configuration and with a floor finish. Further testing was required to support this observation from the initial testing. Since the thickness of the PUR mounts used were 50mm, it was pertinent to test a conventional isolator of similar thickness for comparison, so 45mm rubber mounts were introduced to further testing. According to literature (LoVerde, J., et al., 2015), the geometry of noise source should be spherical for best repeatability, which was implemented in the validation test outlined in the following section.

# 4 VALIDATION TEST (TEST B)

## 4.1 Refinement of methodology

A 24kg modified kettlebell with a spherical impact surface was introduced into this validation test and dropped on all floor configurations to test the performance of all three types of isolators. As shown by LoVerde, J., et al., 2015, spherical contact surfaces create repeatable impacts, compared to the non-uniform surface of typical gym equipment (eg. dumbbell). To create the spherical contact surface, handles were removed, and a hook was added to the other side. Images of the original kettlebell and the modified version used for Test B shown in Figure 6.

This modified kettlebell is used to validate drops using the weight plate in Test A. The method of dropping the modified kettlebell was refined by introducing a pulley system in this test in lieu of the manual drops done in Test A. The pulley system incorporated a releasable clip attached to the weight to best control the weight drop condition in a repeatable manner, as well as assist in the lifting of the weight for testing.


*Figure 7 - The original 24kg kettlebell (left) and modified kettlebell with a spherical impact surface (right)*

This series of validation tests were undertaken in the same testing facility as Test A. Weight drops using the 20kg weight plate were repeated for lightweight floor systems with 45mm thick high density rubber mounts as the isolator for information and comparison. A heel drop test was also conducted to determine the natural frequency of the concrete slab used at the test facility.

## 4.2 Testing methodology

For the lightweight floor systems 2.1, 2.2, 2.3, and the bare concrete slab the impact noise was generated by the 24 kg modified kettlebell at the following heights. A series of five weight drops were carried out via the pulley drops for each test.

*Table 2 - Drop heights, mass and corresponding input energy*

| Mass (kg) | Height above finished floor level (mm) | Equivalent Input Energy(J) | Energy Level |
|---|---|---|---|
| 24kg | 250 | 59 | Low |
| 24kg | 500 | 118 | Mid |
| 24kg | 1000 | 235 | High |

Three unattended NTI XL2 Analysers were placed in the same locations as in Test A with microphones set to the same heights (0.77m, 1.15m and 1.5m above ground level), and recorded noise levels for each impact. The heel-drop test and jumping test was carried out with a 79 kg person falling free onto the concrete slab in one location. 10 jumps and 10 heel-drops were applied to reduce uncertainty, and were carried out in accordance with the method demonstrated by Mohd Azaman (Mohd Azaman, N.A., et al., 2018). The acceleration responses were measured using accelerometers placed on the underside of the concrete slab connected to a Soundbook.

## 4.3 Acoustic test results

### 4.3.1 Results at AAAC frequencies of interest

The graphs below show that the performance of the PUR elastomer mounts increases and approaches the performance of the spring mounts, as more energy is applied onto the floor system, with their performance increasing from 125Hz to 250Hz.

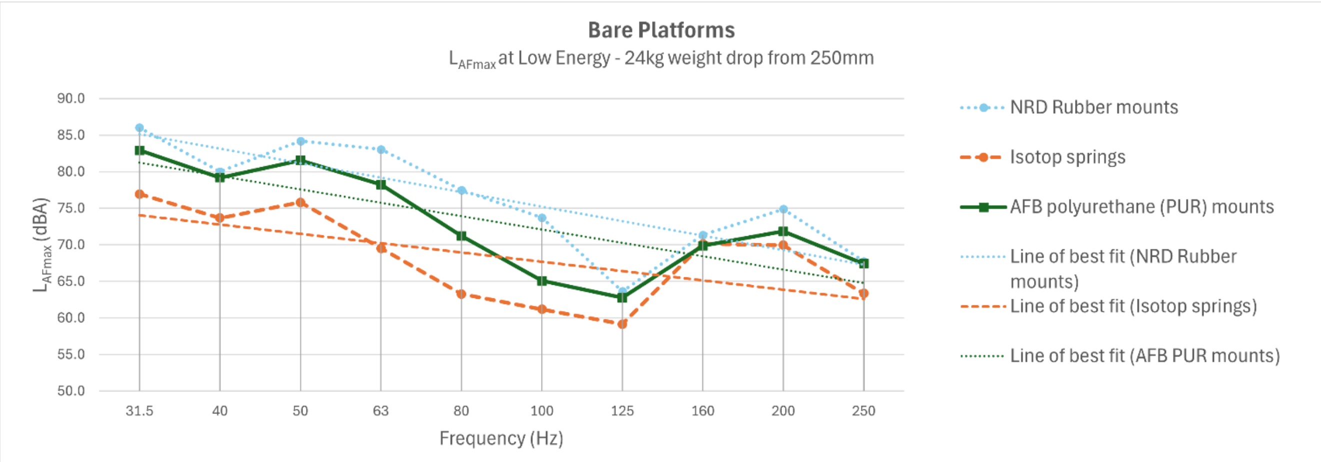



*Figure 8 - Comparative $L_{AFmax}$ for bare floor systems 2.1, 2.2 and 2.3 at low energy*

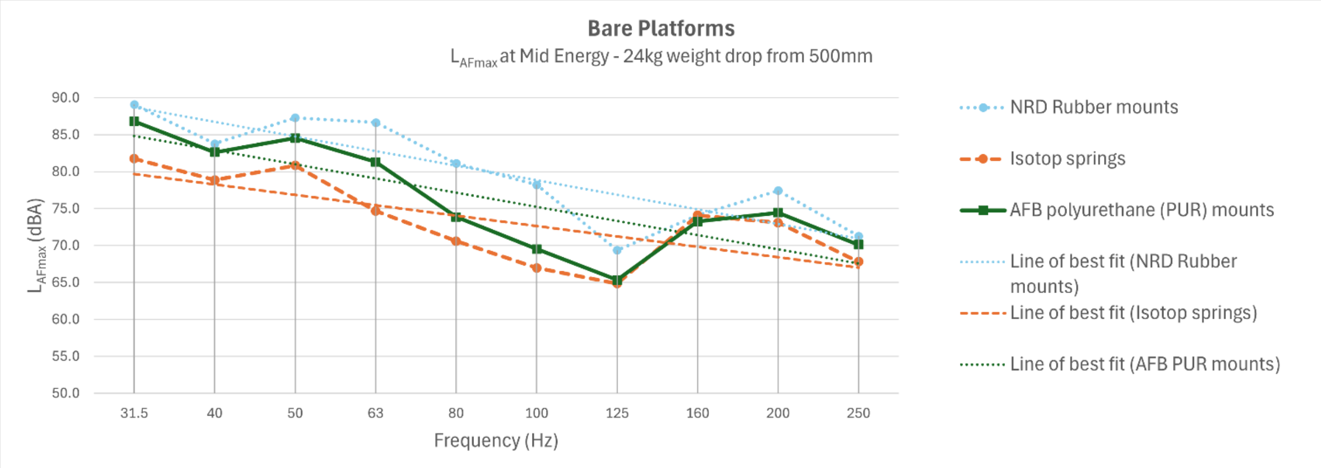



*Figure 9- Comparative $L_{AFmax}$ for bare floor systems 2.1, 2.2 and 2.3 at mid energy*

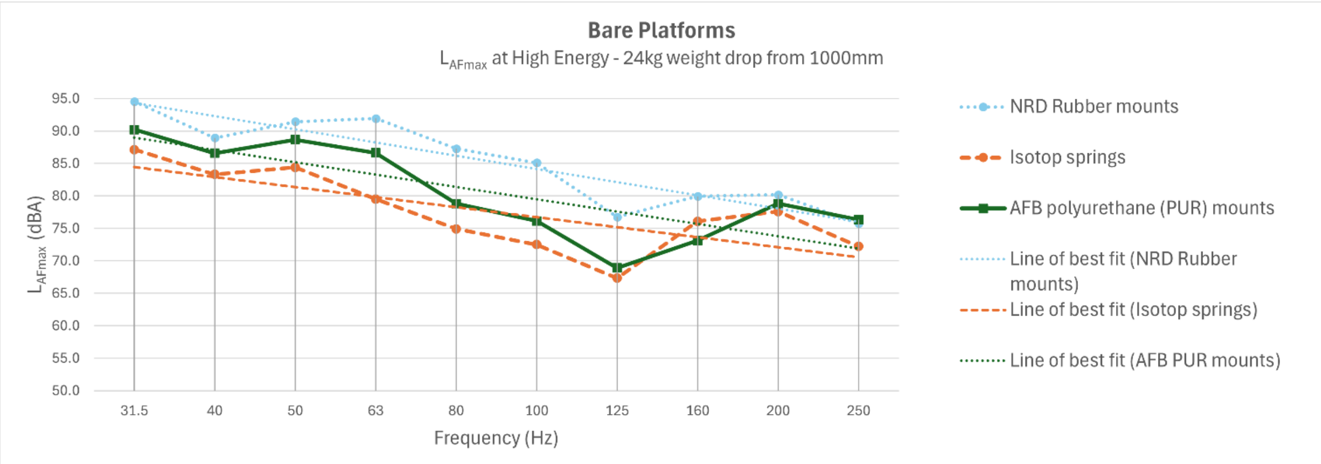



*Figure 10 - Comparative $L_{AFmax}$ for bare floor systems 2.1, 2.2 and 2.3 at high energy*

### 4.3.2 Results at 1/3 octave frequencies

Under high energy impact on the bare plywood platform, the damped springs provided the greatest attenuation with 26% reduction, and the PUR isolators provided 25% reduction from bare concrete slab, as illustrated in Figure 11. The rubber mounts provided an overall 23% reduction. While the overall damping efficiency of the PUR mounts is only slightly lower than that of springs, their lower height (higher spatial efficiency) within the floor-floor space can make it the most practical option for fit-out projects where there are limitations with floor-ceiling height, which can be more cost-effective. Note that the peaks at 11 Hz indicate the natural frequency of the bare concrete slab, and the isolators start to provide attenuation from 20Hz and beyond this frequency.

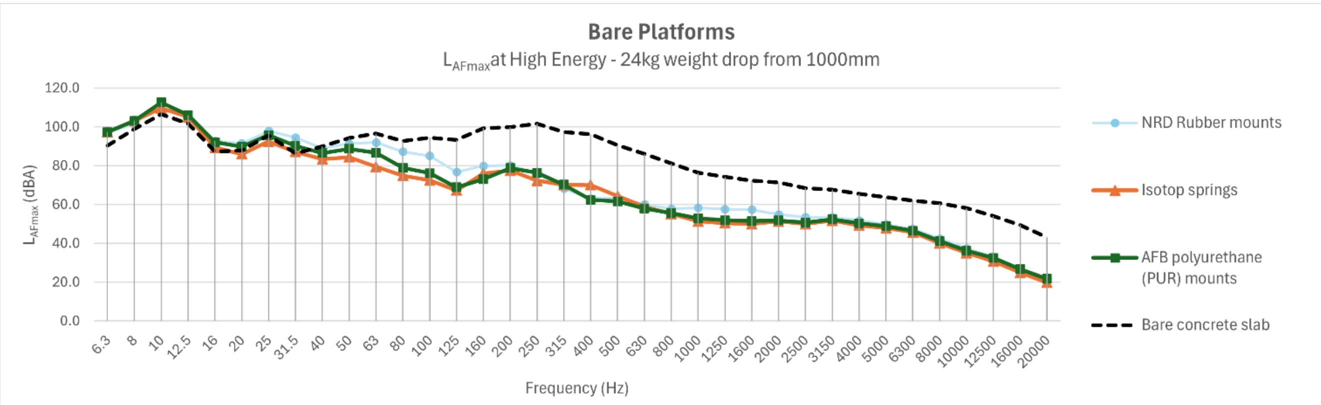



*Figure 11 - Comparative $L_{AFmax}$ for bare floor systems 2.1, 2.2, 2.3 and bare concrete slab at high energy*

## 4.4 Test B discussion

The impact test results from the 24kg modified kettlebell dropped via the pulley system validates the initial findings in Test A using the weight plate via manual dropping. PUR mounts perform comparably to spring mounts under high energy dynamic loading while having a closer thickness to the rubber mounts.

The repeatability of the kettlebell has been shown to be very good, and the drop method of the pulley system has proven to be reliable for both the weight plate and the kettlebell. Source repeatability and dropping method are analysed in the figures below to compare and evaluate the accuracy of the pulley drops in Test B against the manual dropping method in Test A, using results monitored by the microphone set at 1.15 metres high for the PUR mounted finished floor platform. As shown in Figure 13 and 14, the five pulley-assisted drops at high energy level are more highly correlated than the results shown in Figure 12. This shows that the refinement of the dropping method and validation testing was necessary. Furthermore, the pulley-assisted 20kg weight plate drops are grouped tighter than the 24kg kettlebell drops, particularly in the lower frequencies. This analysis indicates that the drops using a weight plate with a curved impact surface is considered reliable as long as the drop method is mechanically assisted and as controlled as possible.

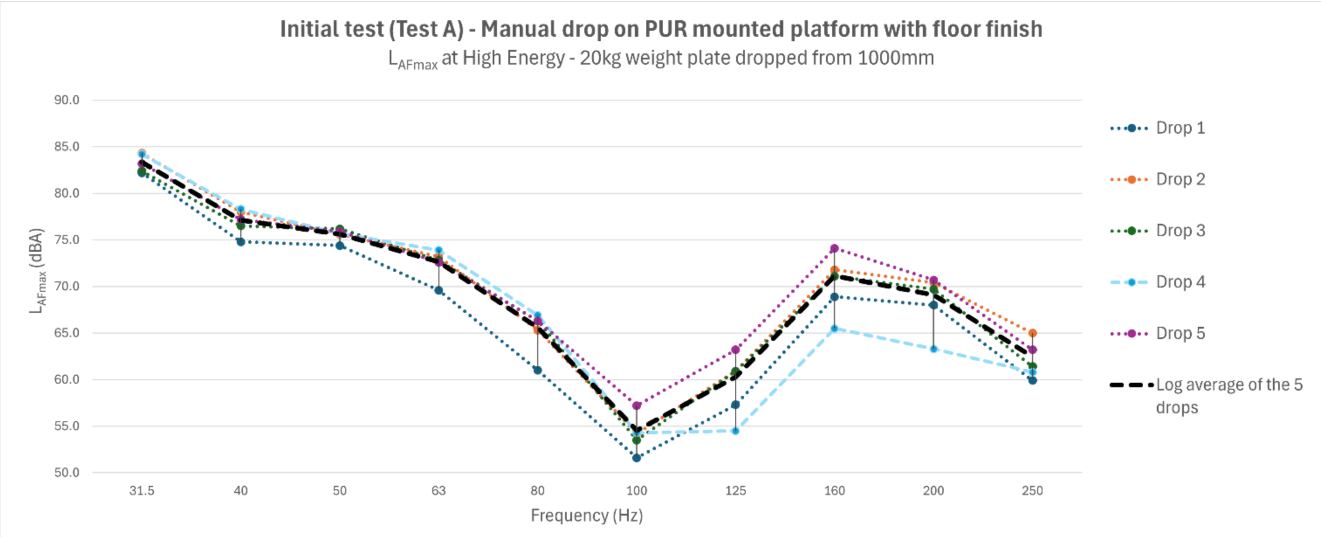



*Figure 12 - $L_{AFmax}$ results for 20kg weight plate dropped manually on PUR mounted finished floor at high energy*

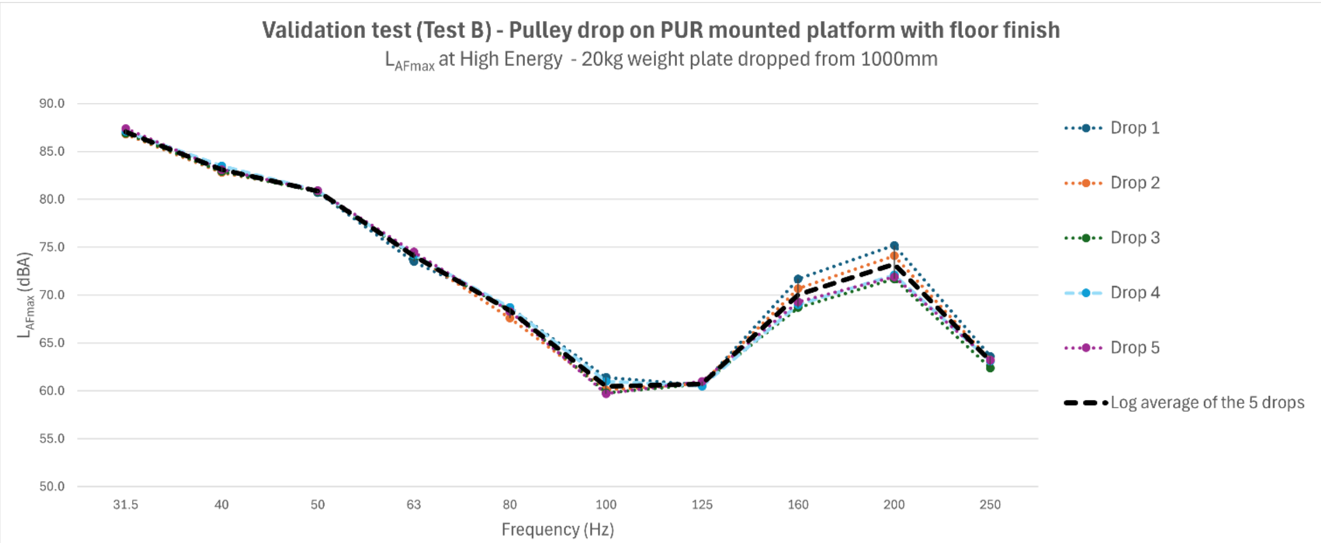



*Figure 13 - $L_{AFmax}$ results for 20kg weight plate dropped via pulley on PUR mounted finished floor at high energy*

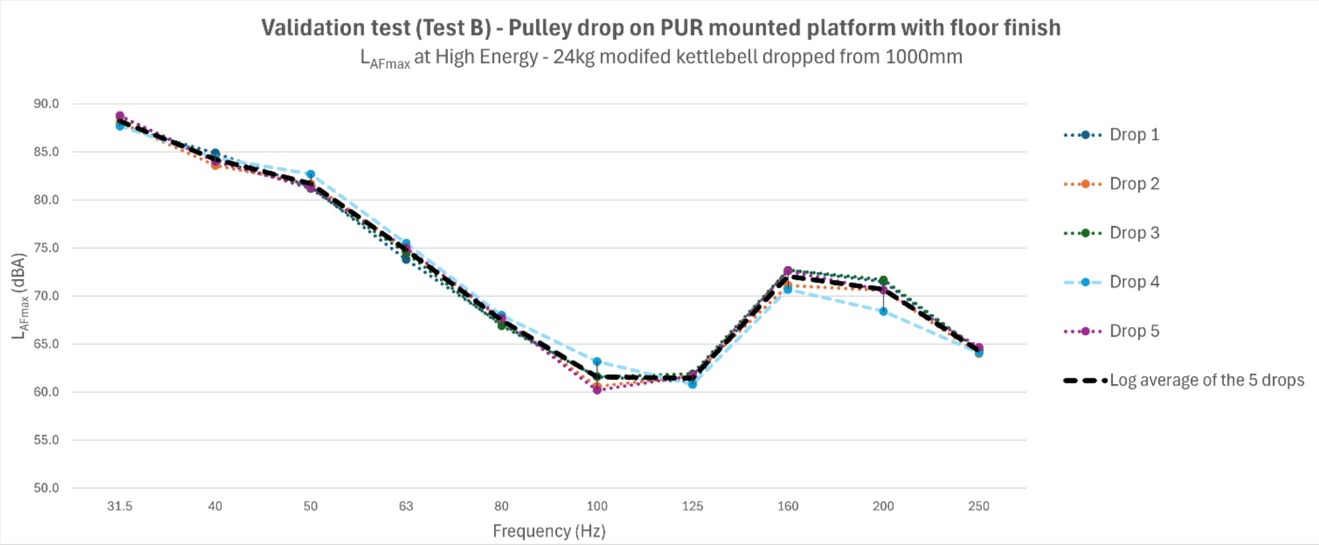



*Figure 14 - $L_{AFmax}$ results for 24kg kettlebell dropped via pulley on PUR mounted finished floor at high energy*

## 5 CONCLUSION AND FUTURE RESEARCH

PUR elastomer isolators are a valuable alternative to damped spring mounts and rubber bearings in lightweight floating floors. Their compactness and capability to perform similar to springs that have greater thickness, make PUR mounts a practical solution to the challenges of floor cavity depth and room height limitations in the fit-out of tenancies within buildings, particularly for the development of gymnasia and fitness rooms. This gives designers more flexibility and achieves spatial efficiency for a performance similar to damped spring mounts and greater than rubber bearings, which can lower overall project costs.

This paper demonstrates acoustic testing done on a cube shaped PUR mount, so further research can be done on PUR bearings of different thicknesses and shapes (cuboid, cylindrical and hollow cylindrical). Further testing is to be done in newer buildings and bare concrete slabs of different fundamental frequencies. Data retrieved from the pulley assisted drops using an Olympic style weight plate proved to be reliable, provided that the weight dropping and lifting method is mechanically assisted. There is potential for more research in evaluating the validity of this noise source for acoustic testing, and the source repeatability using drop rigs.

## 6 ACKNOWLEDGEMENTS

The first author wishes to acknowledge Renzo Tonin and Associates for the provision of the field test facility and resources; and Nicholas Peters and Renzo Pombuena for their involvement in the field tests documented in this paper. They also thank Getzner Vibration Solutions for their technical support and provision of the PUR isolators and damped spring mounts used throughout the testing.

## REFERENCES

Association of Australasian Acoustical Consultants. (2022). *Guideline for Acoustic Assessment of Gymnasiums and Exercise Facilities Version 1.0.* www.aaac.org.au.

Getzner Werkstoffe GmbH. (2019, June). *Sylomer® SR 450 Data Sheet.* Retrieved August 2024

LoVerde, J., et al. (2015). *Investigation into a Standardized Test Method for Measuring and Predicting Heavy Weight Impact Noise Transmission.* Internoise 2015, San Francisco, CA, US.

Mohd Azaman, N.A., et al. (2018). *Investigation of Concrete Floor Vibration Using Heel-Drop Test.* Journal of Physics Conf. Ser. 995 012027. doi:10.1088/1742-6596/995/1/012027