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Improvements in Acoustical Performance of Lightweight Floating Floors for Gym/Sports Applications

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Summary

Gyms, fitness spaces and health clubs in general, built within residential/commercial buildings, pose a great challenge for integration into their environment and are a well-known conundrum to acoustical consultants. Multi-disciplinary gym activities (such as running on treadmills, jumping, and weight lifting) generate a large range of noise and vibration in terms of the induced energy level and the frequency content. This makes finding an efficient isolation solution difficult. For gym activities with a combination of structural and air borne-noise, at both low and high frequencies, acousticians may propose a heavy concrete floating floor. However, in an existing building where the extra weight of a new concrete slab/screed or the extra built up height is not feasible, a lightweight wooden floor system may be necessary. Gym floor isolation using lightweight solutions, especially where a variety of impact levels occur, remains quite challenging for acousticians. A set of laboratory and in-situ testing has been performed where the isolation performance of different lightweight floor setups have been examined under different drop weight energy levels. In addition, the influence of floor covering and the addition of damping layers have been investigated. The isolation performance was defined in terms of transmission loss by comparing the vibration level in a frequency range from 5 to 2000 Hz measured on the reference concrete slab, with and without the floor isolation systems. Results of these tests show that a heavy concrete floor setup performs slightly better at the low frequencies but the damped light weight floor setup results in the best overall performance.

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1. Introduction

Floating floors are employed as a solution for noise and vibration problems where the transmission loss of existing structural floor is not sufficient to mitigate the generated noise and vibration.
Concrete or wet floating floors mounted on elastomeric pads are the most common type of floor isolation systems. The concrete floors can show a high level of structure and air-borne noise isolation providing an extra mass in the vibration system, figure 1a.
For the zones where a wet floor is not permitted to constructed or added to the existing floor because of structural stability issues or limited room height, a lightweight or dry floating floor can be proposed. Lightweight floors are cost effective and fast and easy to install or remove.

The dry floor system consists of 2-3 layers of wooden or cement board mounted on elastomeric pads, figure 1b. For Gyms application with different source of vibrations/excitations, both heavy and light floors can be employed.
The most challenging application of lightweight floors in gyms is for the control of vibration in drop weight and haltering zones where for example, a drop of a 10 kg dumbbell from 1.0 m onto the floor can generate a significant impact with a wide range of frequency content, depending on the contact surface condition (floor covering). In addition, in drop weight zones, the floating floor must have enough strength against the high loads and impact stress and deformation.
Generally, acoustic performance of floating floors can

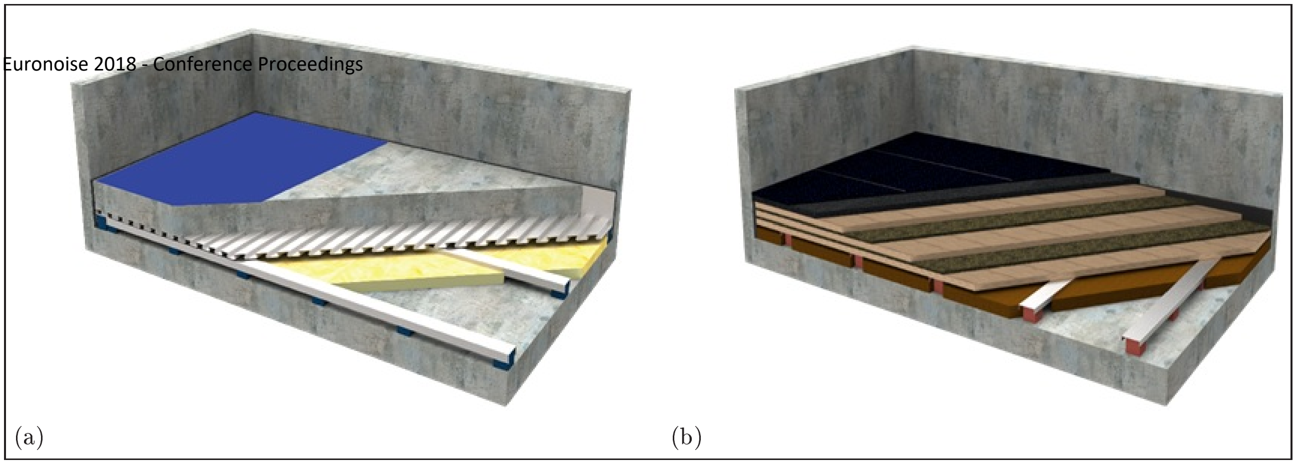

Figure 1. Scheme of (a) CDM-LAT wet floor and (b) CDM-LAT dry floor.

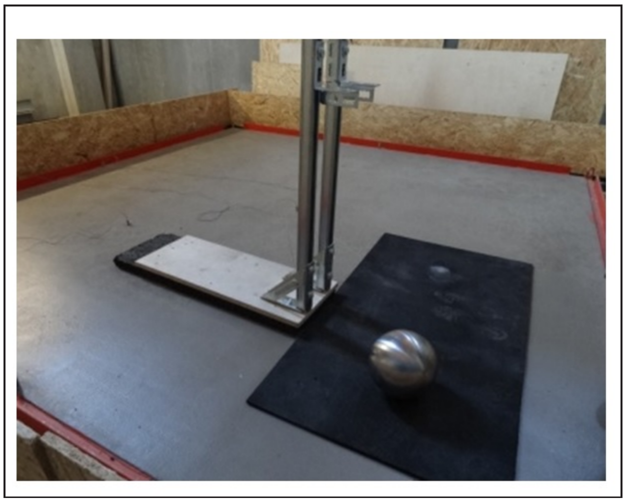

Figure 2. Drop weight test room.

Table I. Drop heights and weights and corresponding energy.

Drop type	Weight	Height	Impact energy
1	10 [kg]	0.80 [m]	79 [J]
2	10 [kg]	2.00 [m]	196 [J]
3	30 [kg]	0.80 [m]	235 [J]
4	30 [kg]	2.00 [m]	589 [J]

be determined using standard tests in terms of airborne and impact sound insulation i.e. Rw and Lnw [3, 2]. Although, a tapping machine, which is used for the standard impact noise insulation test (Lnw), may generate a measurable impact on the floor, the level of induced impact energy as well as the frequency content of the excitation, is not comparable with that of a dropped dumbbell on the floor.
The generated structure borne noise due to the impact in the adjacent spaces depends on the floor covering, resonance frequency of the isolation system (floating floor mass and isolation pad stiffness) and the structural floor vibration modes.
In this study, the effect of dumbbell impacts on the floor has been tested using a wide range of impact energies by varying masses and heights, representative of the activities performed in the haltering zone. The tests has been performed in the ITECONS laboratory in Portugal, [4].
This paper aims to investigate and measure the role of each dry floor characteristics on the acoustic performance of the entire floor system.

2. Drop weight test

Different dry floor setups have been examined under different drop weight energy levels in which the influence of floor covering, floor structure flexibility, air void height, and damping layers have been investigated.
The repeatability of the test was guaranteed by controlling the drop energy (the weight x the drop height) by means of a drop stand, figure 2.

The floors have been tested under different drop weight impacts using two different steel balls of 10 and 30 kg, dropped from different heights of 0.80 and 2.0 m, table I.

2.1. Measurement setup and configuration

The floor systems were installed on a overlying thick structural floor of 3.65 m$\times$ 3.65 m (about 13 m^2) which has been decoupled from the ground floor by means of low frequency springs. Figures 3 and 4 show the scheme of floor configurations.
The heavy floating floor is a 70 mm-thick concrete slab. First, the isolation system consisting of galvanized guide C-channels and resilient CDM-pads (CDM-LAT system) is installed. Then, ply sheets (the frame work) are placed and fixed on the channels and the concrete is poured on this wooden frame work.

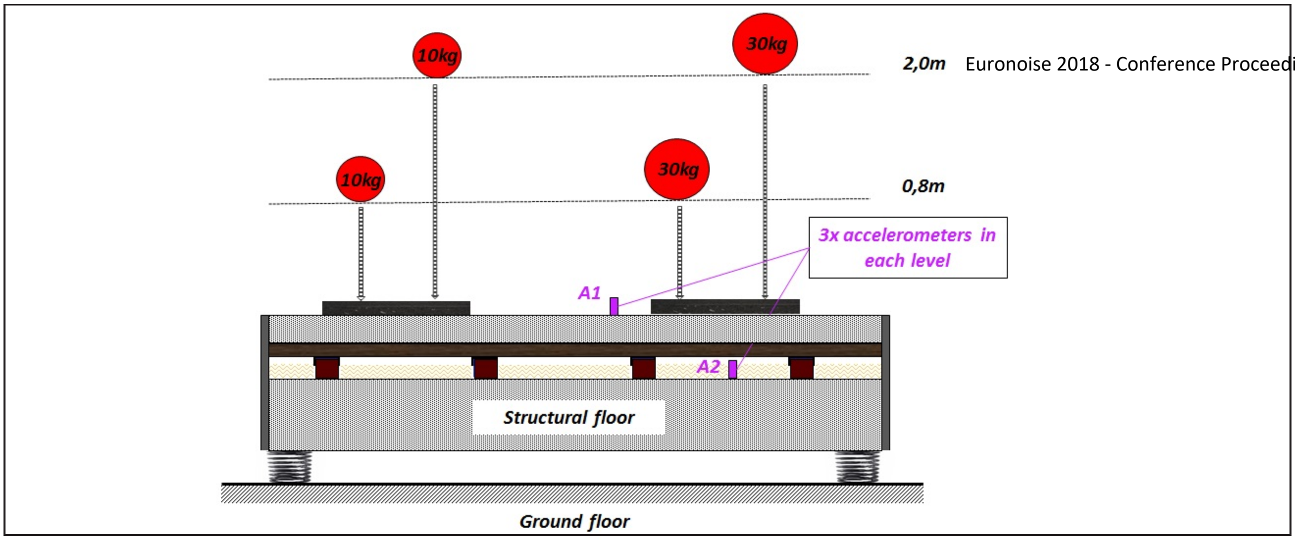

Figure 3. Drop weight test configuration for a heavy floor.

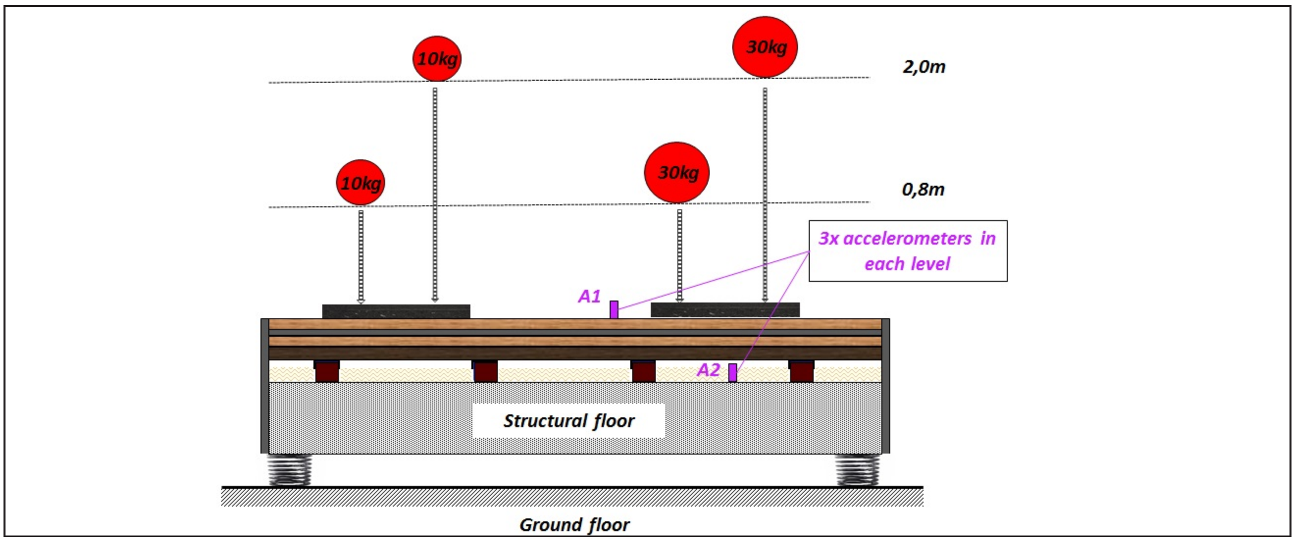

Figure 4. Drop weight test configuration for a lightweight floor.

Table II. Heavy floor configurations.

<table>
<tr><th>Setup</th><th>Isolation system</th><th>Over height</th><th>Mineral wool</th><th>Floor type</th><th>Floor extra layer</th></tr>
<tr><td>H1</td><td rowspan="4">CDM-LAT-50</td><td rowspan="3">70 mm</td><td>——-</td><td rowspan="6">OSB18 + Concrete 70mm</td><td rowspan="2">——</td></tr>
<tr><td>H2</td><td rowspan="5">30 mm</td></tr>
<tr><td>H3</td><td>Damp layer</td></tr>
<tr><td>H4</td><td>0</td><td rowspan="3">——</td></tr>
<tr><td>H5</td><td>CDM-LAT-30</td><td>70 mm</td></tr>
<tr><td>H6</td><td></td><td>0</td></tr>
</table>

To consider the effect of air-gap stiffening ,the perimeter of the floor system was laterally covered/sealed by a layer of closed-cell foam.
The dry floors were composed of 2 or 3 layer of wooden boards. To stop bouncing of the floor and to rapidly attenuate the free vibration of floating floor after each impact, a thin CDM-DAMP-5 layer was placed between each two wooden boards, figure 5.

Six heavy floors (H1 to H6) and nine lightweight floors (L1 to L9) have been tested. Tables II and III provide the details of the different setups/solutions of isolation floors.

2.2. Measurement results

The vibration levels were measured by means of six 100mv/g accelerometers. Three accelerometers are in-

Table III. Lightweight floor configurations.

Setup	Isolation system	Over height	Mineral wool	Floor type	Floor extra layer
L1	CDM-LAT-50	70mm	——	PW19+OSB18+(CDM-DAMP-5)+OSB18	——
L2			30mm		
L3			——		(CDM-DAMP-5)+OSB18
L4			30mm		
L5		0			——
L6					(CDM-DAMP-5)+OSB18
L7	CDM-LAT-30	0	30mm	PW19+OSB18+(CDM-DAMP-5)+OSB18	——
L8					(CDM-DAMP-5)+OSB18
L9	CDM-LAT-50			PW19+OSB18+ACUSEAL+ OSB18	——

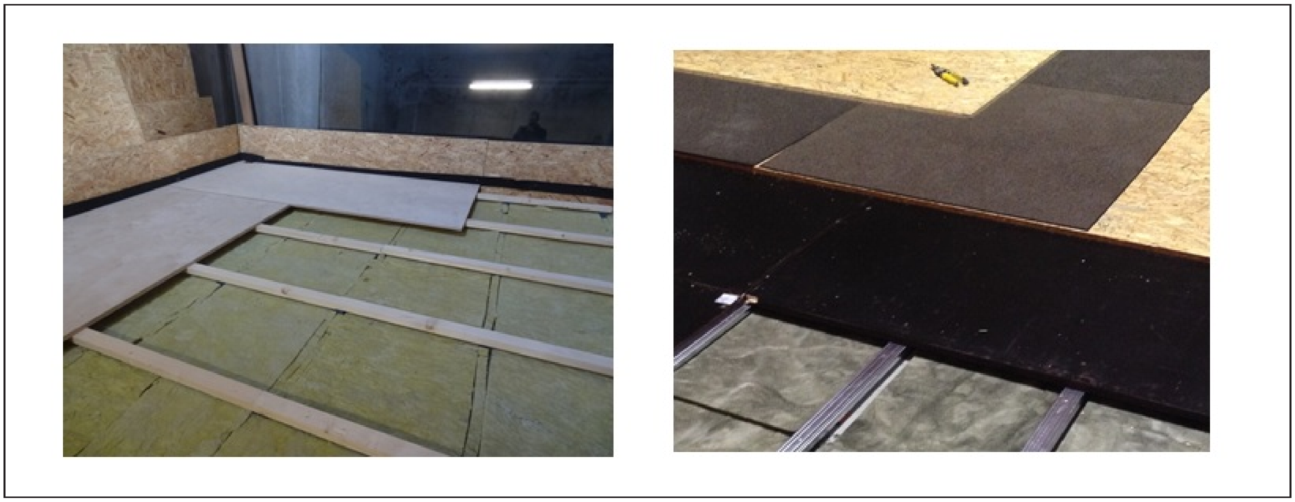

Figure 5. Installation of the lightweight floor.

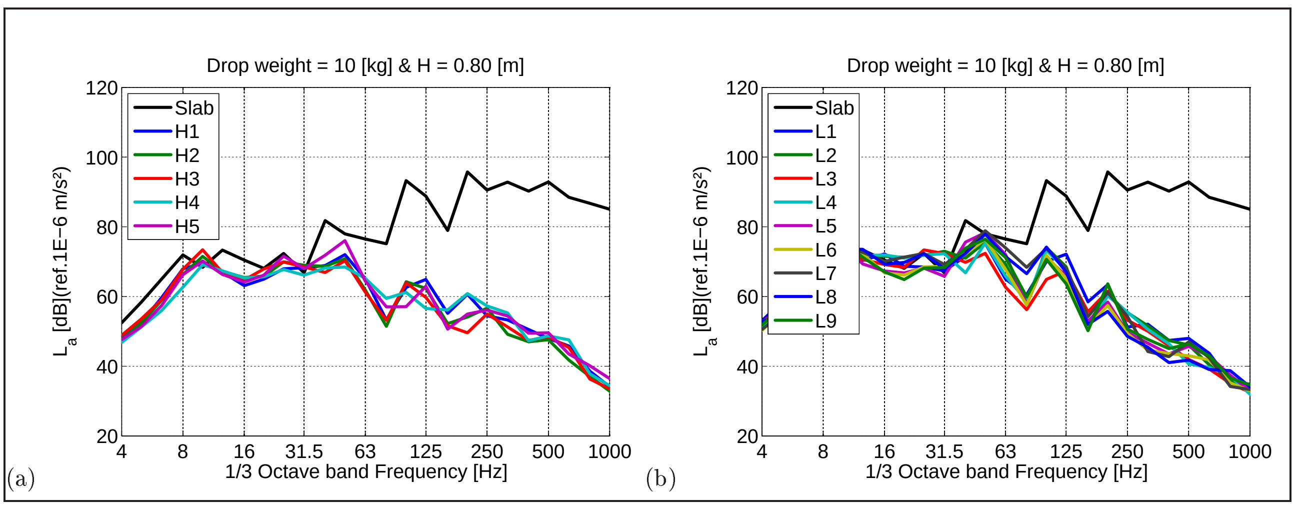

Figure 6. Vibration level measured at bare slab due to impact of 10 kg dropped from 0.80 m above the floor in different isolation floor configurations: (left) Heavy floor (right) lightweight floor.

stalled on the floating slab and three accelerometers are installed under the bare concrete slab (structural floor).The sampling frequency of 4 kHz was selected to cover the entire content of the impact energy up to 2000 Hz. In the following, the measured vibrations (as an average of three accelerometers) are presented in dB with a reference acceleration of 1×10^{-6} m/s^2. The isolation performance was defined in terms of transmission loss by comparing the vibration level in a frequency range from 10 to 2000 Hz measured on the reference concrete slab, with and without the floor isolation systems. Figure 6 shows the results of whole measurements all together. Results show that a heavy concrete floor setup performs slightly better at the low frequencies but the damped light weight floor setup results in the best overall performance.

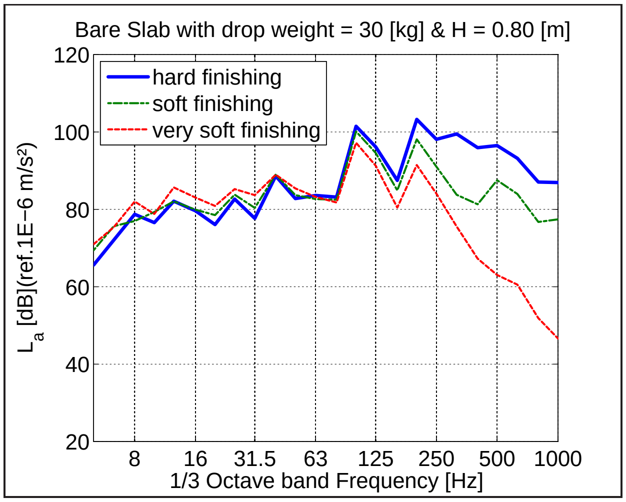

Figure 7. Vibration level on bare slab without an floor isolation system using different floor coverings.

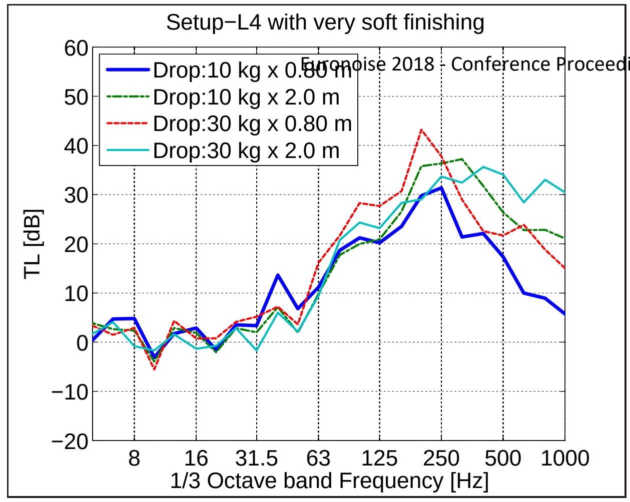

Figure 9. Transmission loss obtained for the lightweight floor L4 at different impact energies.

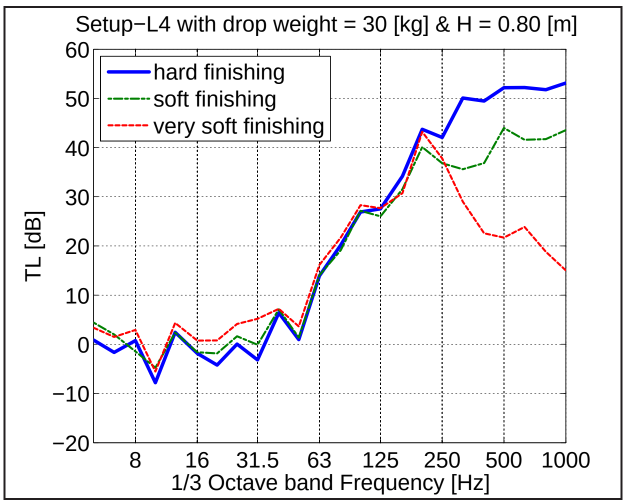

Figure 8. Transmission loss obtained for dry floor setup L4 in combination with different floor coverings.

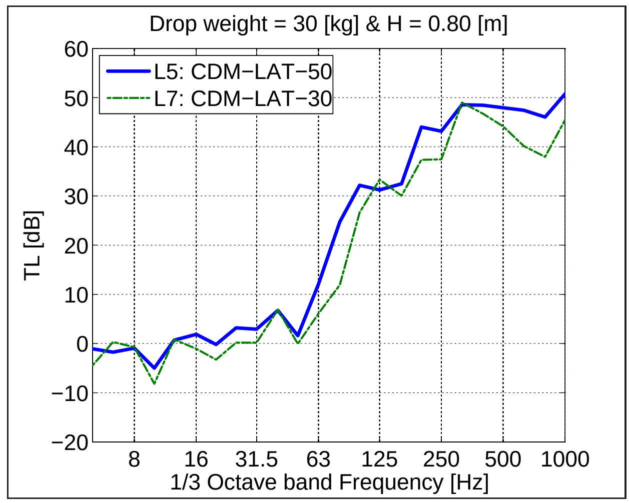

Figure 10. Transmission loss obtained for lightweight floor setups L5 and L7 with different isolation pad stiffness's.

2.2.1. floor covering

Floor coverings with three different dynamic stiffness's have been tested: (1) very stiff covering (a thin Linoleum sheet), (2) soft (10 mm-thick rebonded rubber sheet), (3) very soft (30 mm-thick rebonded rubber sheet). The floor finishing (covering) plays two important roles: (1) to protect the floor surface against direct contact and eventually a structural damage and (2) to control and reduce the transmitted impact energy.

In all of the tests, the floor finishing was placed under the drop zone only and did cover the entire floor surface. Therefore, the weight of floor covering has no contribution into the floor dynamic system.

First, the influence of floor covering on the bare slab is investigated. Figure 7 shows the level of vibration on bare slab using different floor coverings. Results clearly show that the floor coverings are acoustically efficient only at frequencies higher than 125 Hz. This confirm the fact that the application of floor covering alone is not sufficient for mitigation of structure-borne noise at low frequencies. Figure 8 shows how the acoustic performance has been significantly improved when the floor covering effect is combined with a floor isolation system.

2.2.2. Impact energy effect

Since the elastomeric pads and the floor covering materials behave non-linearly at higher loads (i.e. hardening behavior), they may show different dynamic behavior and consequently different acoustic performances under higher impacts. Figure 9 shows the transmission loss obtained for the lightweight floor L4 under different impact energies. As expected, a difference of 5 to 15 dB was found between the results obtained at the lowest and highest impact. In addition, it has been found that the proposed lightweight floor setup shows a significant performance even under very high impact beginning at 63 Hz.

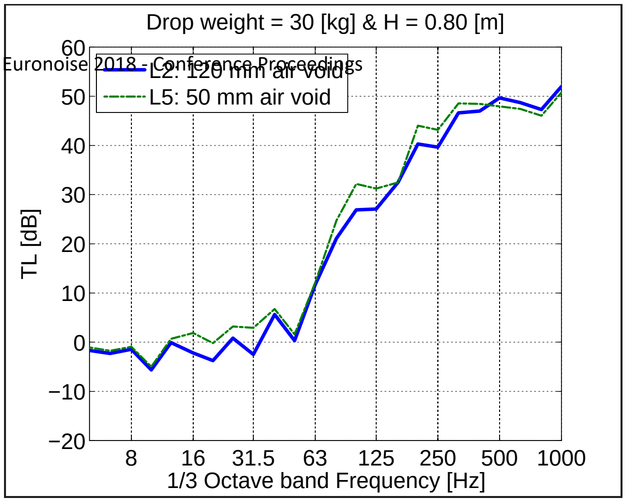

Figure 11. Transmission loss obtained for for lightweight floor setups L2 and L5 with different air gap heights.

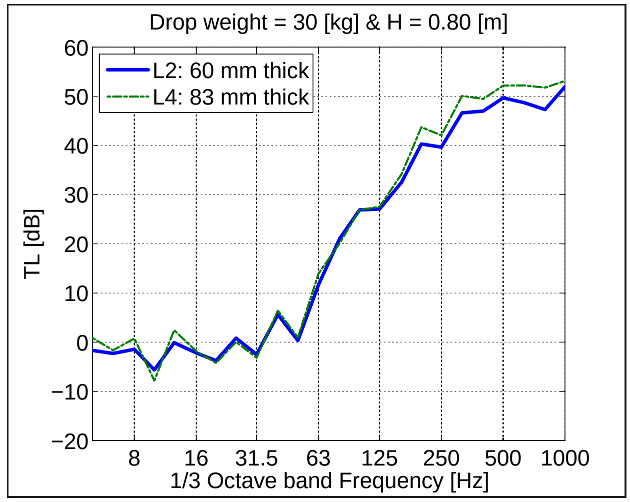

Figure 12. Transmission loss obtained for for lightweight floor setups L2 and L4 with different floor thicknesses.

2.2.3. Isolation pad stiffness

To investigate the influence of pad's stiffness on the floor performance, results of two solutions L5 and L7 with similar structure but with different isolation solutions CDM-LAT30 and CDM-LAT50, are compared. Although CDM-LAT30, with a resonance frequency of about 12 to 15 Hz, is stiffer than CDM-LAT50, with a resonance frequency of about 8 to 10 Hz, a difference of only 2 to 3 dB was found. In addition, both setups start showing a considerable performance beginning 31.5 Hz, figure 10.

2.2.4. Air void effect

The other parameter that may influence the acoustic performance of floating floors, is the height of air void. When the air volume between the floating and structural floor can not be evacuated easily, which may happen in large rooms, the air-gap stiffening affects the resonance frequency of the system and can significantly reduce the acoustic performance of the isolation system. The air void height depends on the height of isolation pads and if required, can be increased using packers under the pads.
The air gap cavity is generally filled by mineral wool to absorb the sound reverberation that may improve the air-borne and impact noise insulation as well, [1]. Influence of air-gap stiffening has been shown in figure 11. A comparison has been made between results of two setups L2 and L5 with different air void height of 120 and 50 mm, respectively. However, both solutions show similar performances and no significant difference has been found.

2.2.5. Floating floor bending stiffness

In general, a stiff floor performs better than a flexible one. Considering comfort of occupants, the deflection to span ratio of a floating floor should not be higher than 1/250. The deflection/flexibility of dry floors are controlled by the number of wooden boards and channel stiffness. Furthermore, to control the floating floor vibration due to running or dancing activities, the floor must be designed such that its natural frequency being greater than the dominant frequency of excitation frequency (greatest harmonics).
To investigate the effect of bending stiffness of lightweight floors on their acoustic performance, a comparison has been made between the results of floor setup L2 with three layers of wooden board and that of floor setup L4 which has an extra layer i.e. structurally stiffer, figure 12.
Results show an improvement of about 2-3 dB at frequencies higher 150 Hz.

3. CONCLUSIONS

In this study, different floating floor solutions with different configurations have been tested and the influence of floor covering, floor bending stiffness, damp layers between the wooden boards and air void height have been investigated.
Results of this experimental investigation show that:

- The light and heavy setups can give similar performance in free weight drop zones in gyms.
- Even the light versions, if well tuned in stiffness, damping and layers mix, can offer a better performance at higher frequencies.
- In lightweight floors, the mix of floor layers and damping play an important role on the final performance.
- Using a floor finishing is not sufficient for mitigation of structure-borne noise at low frequencies.
- The proposed lightweight floor solutions show a considerable performance from 50 Hz with an efficiency of about 25 dB compared with that obtained by resilient floor finishing solutions alone .However, a combination of floating floor together with a floor finishing results in a better overall performance.

References

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