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Influence of the laboratory measurement method of the reduction of transmitted impact noise by covering floors on a heavyweight standard floor on the result

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Abstract The article presents the results of laboratory measurements of the reduction of transmitted impact noise ΔL by floor coverings on a heavyweight standard floor. The tests were carried out for a floating floor with EPS T insulation in two thicknesses: 43/40 mm and 22/20 mm. Each test was carried out for two types of screed: cement and anhydrite. The tests were repeated for an additional screed load simulating furniture load and without load. An attempt was made to determine the impact of the lack of load on the test result and to check whether a small difference in the weight of the screed significantly affects the result.

Keywords: impact noise, impact sound insulation, covering floors, reduction of impact sound pressure level.

1. Introduction

Acoustic comfort is one of the main criteria that is taken when making decisions about the purchase of new apartments [1, 2]. Impact sounds, which are a variety of structure-borne sounds, are the basic factor that reduces acoustic comfort in modern residential buildings [3, 4]. The floating floor is the main element that limits the propagation of impact sounds. In residential buildings, it is an essential element to ensure protection against noise from the neighbourhood. The floor pressure plate, together with the elastic material, ensures the reduction of vibrations generated when using the floor [5, 6]. The Cremer-Vera theoretical model [6, 7] is commonly used in calculations, e.g., in the ISO 12354-2 standard [8]. Research experiments indicate discrepancies between the values based on calculations with respect to the experimental values. For example, the impact of floor layer on the accuracy of laboratory measurements of the reduction of transmitted impact noise ΔL [9] was analysed. The authors of the paper attempted to recognise the impact of the aging of the elastic layer on its effectiveness on reducing impact sounds in a floating floor [10]. The purpose of laboratory measurements of the reduction of transmitted impact noise ΔL was to determine the effect of changes in the thickness of the elastic layer, changes in the thickness and type of screed pressure plate, and to determine the effect of the load simulating furniture on the measurement result.

2. Methodology

The work was carried out in the Laboratory of the Department of Building Engineering and Building Physics at the Faculty of Civil Engineering of the Silesian University of Technology. The method of measurements, test stands and apparatus complied with the standards [11-15].

2.1. Terms and definitions

Basic terms and definitions necessary in view of the subject discussed in the article are presented below.
Normalized impact sound pressure level L_n in decibels:

$$L_n = L_i + 10\log\frac{A}{A_0}, \tag{1}$$

where L_i is the impact sound pressure level measured in the receiving room by using the standard tapping machine in accordance with EN ISO 10140-5:2021-10 [8], in decibels, A is the measured equivalent absorption area of the receiving room, in square metres, A_0 is the reference equivalent absorption area with A_0 = 10 m^2.

Reduction of impact sound pressure level ΔL improvement of impact sound insulation reduction in normalized impact sound pressure level resulting from installation of the test floor covering, which is evaluated from:

$$\Delta L = L_{n,0} - L_n, \tag{2}$$

where $L_{n,0}$ is the normalized impact sound pressure level in the absence of floor covering, in decibels, L_n is the normalized impact sound pressure level when the floor covering is in place, in decibels.

Weighted reduction of impact sound pressure level ΔL_w, which is evaluated from:

$$\Delta L_w = L_{n,r,0,w} - L_{n,r,w} = 78 - L_{n,r,w} \tag{3}$$

where $L_{n,r}$ is the calculated normalized impact sound pressure level of the reference floor with the floor covering under test, in decibels, $L_{n,r,0}$ is the defined normalized impact sound pressure level of the reference floor, in decibels, ΔL is the reduction in the impact sound pressure level, in decibels, $L_{n,r,w}$ is the calculated weighted normalized impact sound pressure level of the reference floor with the floor covering under test, in decibels, $L_{n,r,0,w}$ is obtained from $L_{n,r,0}$ accordance with [8], in decibels.

Calculated weighted reduction of impact sound pressure level ΔL_w, according to PN-EN ISO 717-2:2021-06 [15]:

$$\Delta L_w = 13\log(m') - 14.2\log(s') + 28.5 \text{ dB} \tag{4}$$

where m' is mass per unit area of ana element, in decibels, $L_{n,r,0}$ is the defined normalized impact sound pressure level of the reference floor, in kg/m^2, s' dynamic stiffness per unit area, in MN/m^3.

2.2. Laboratory characteristics

The measurements were made in laboratory test facilities in which sound transmission via flanking paths is suppressed. A method is specified that uses the standard tapping machine to simulate impact sources like human footsteps when a person is wearing shoes. This method is applicable to heavyweight types of floors (reinforced concrete slab th. 14 cm) with all types of floor coverings. Figure 1 shows the test chambers separated by a ceiling.

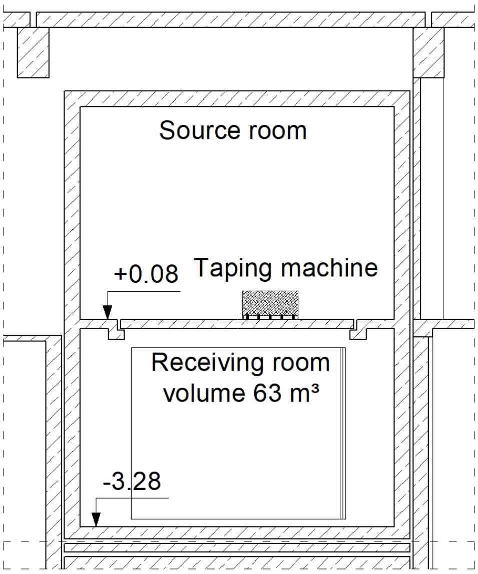

Figure 1. Section through the reverberation chambers separated by a model reinforced concrete ceiling, on which floor samples were mounted.

2.3. Object characteristics

Measurements of the reduction of transmitted impact noise by covering floors were carried out for 4 samples. Various thicknesses of EPS T sound insulation and two types of screed were used. Additionally, each of the samples was tested with and without furniture load simulation (9 x 25 kg/11,35 m² ≈ 20 kg/m²) according to [11]. Figure 2 shows all variants of floor covering. Table 1 shows the sample number, the type of elastic layer (insulation thickness), the type of screed, and the test method (with and without a load-simulating furniture according to [11]).

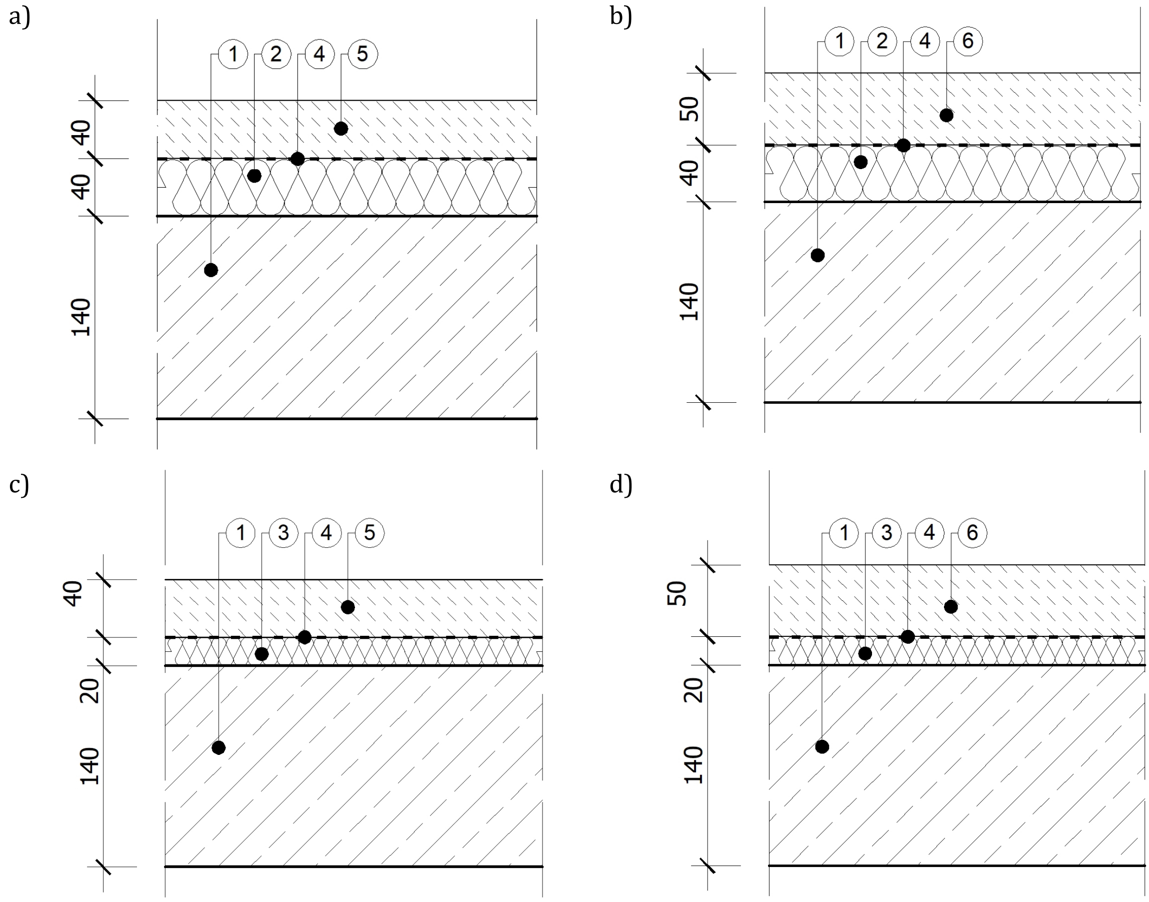

Figure 2. Floor covering variants: a) variant 1, b) variant 2, c) variant 3, d) variant 4.
Materials: 1) reinforced concrete reference ceiling 140 mm, 2) EPS T 43/40 mm, 3) EPS T 22/20 mm, 4) PE foil 0.2 mm, 5) anhydride screed 2000 kg/m³, 40 mm, 6) cement screed 2000 kg/m³, 50 mm.

Table 1. The sample number, the type of elastic layer, the type of screed, and the test method.

Sample no	Screed	Resilient layer	Load
1A	Anhydrite 40 mm	EPS T 43/40	No
1B	Anhydrite 40 mm	EPS T 43/40	Yes
2A	Cement 50 mm	EPS T 43/40	No
2B	Cement 50 mm	EPS T 43/40	Yes
3A	Anhydrite 40 mm	EPS T 22/20	No
3B	Anhydrite 40 mm	EPS T 22/20	Yes
4A	cement 50 mm	EPS T 22/20	No
4B	Cement 50 mm	EPS T 22/20	Yes

Figure 3 show the examples of floor coverings in the source room during the measurements: a) sample1A (anhydrite 40 mm), b) sample 2A (cement 50 mm).

a)

b)

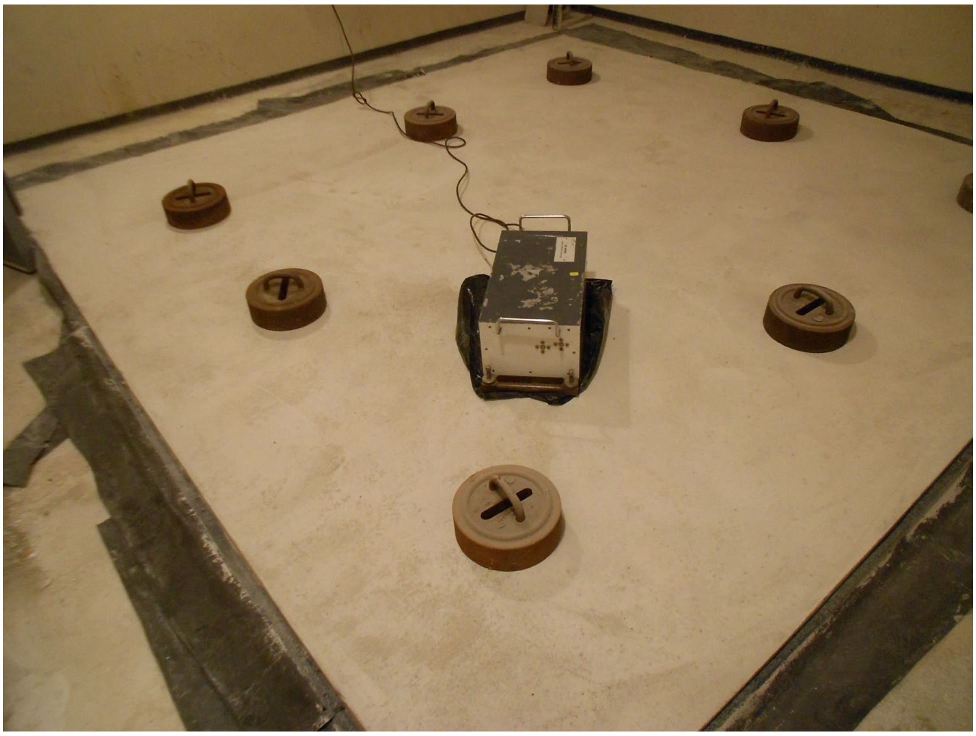

Figure 3. View of the examples of floor coverings in the source room during the measurements: a) sample1A (anhydrite 40 mm), b) sample 2A (cement 50 mm).

3. Results and discussion

Figure 4 shows the measurement results for the reduction of the impact sound pressure level ΔL as a function of frequency for: a) floor covering without load, b) floor covering with load 20 kg/m^2 according to [11]. Additionally the legend contains the results in the form of a single-number weighted reduction of the impact sound pressure level ΔL_w.

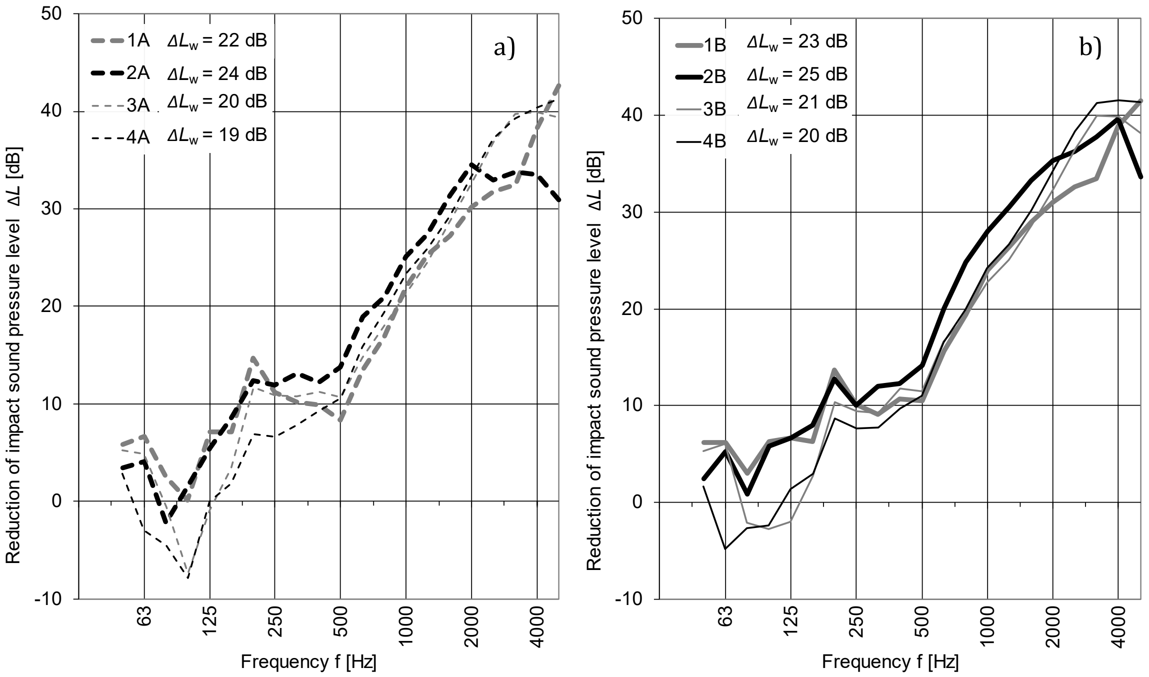

Figure 4. Laboratory measurements of the reduction of the impact sound pressure level ΔL in the 1/3 octave frequency bands for: a) floor covering without load, b) floor covering with load 20 kg/m^2 .

The results presented (Figs. 4a and 4b) in the range of 50 ÷ 400 Hz confirm the generally known dependence that the smaller the thickness of the elastic material, the lower the reduction of the impact sound pressure level ΔL (assuming that the thickness of the elastic material changes while its type remains without changes). Above the frequency of 500 Hz for the floor with cement screed, the situation does not change (samples 2 and 4) and we still observe the effect of reducing the thickness of EPS T on the decrease of ΔL (sample 4 vs. 2). However, for a floor with a thinner anhydrite screed, the lower thickness of EPS T polystyrene does not cause a decrease in the ΔL value, which may be surprising (sample 3 vs. 1). This also affects the weighted reduction of the impact sound pressure level ΔL_w. For the EPS T 22/20 mm board, despite the use of a lighter 40mm anhydrite screed, the floors 3A and 3B obtained a higher ΔL_w value of L_w (respectively, ΔL_w = 20 dB and 21 dB) than 4A and 4B with a 50 mm cement screed (respectively, ΔL_w = 19 dB and 20 dB), which may come as a big surprise. Figure 5 shows the same results as Figure 4 but grouped to show the effect of load simulating furniture according to [11]. On the basis of them, it can be concluded that the additional load significantly reduces the negative impact of the resonant frequency of the system (marked with a red circle). This is particularly noticeable in the case of the thinner EPS T 40 mm elastic material (3B vs. 3A and 4B vs. 4A). Not only has the frequency low been reduced, but the resonance has shifted towards lower frequencies. This is, of course, a very beneficial phenomenon, but unfortunately, in the case of unfurnished rooms, the actual acoustic comfort may significantly differ from that designed using laboratory test values on a loaded floor. The increase in the reduction of the impact sound pressure level ΔL translates into a weighted reduction of the impact sound pressure level ΔL_w. For each floor, the value of ΔL_w increased by 1 dB due to the use of load-simulating furniture. This is not a significant value, but the change in the ΔL characteristic L described earlier is more disturbing.

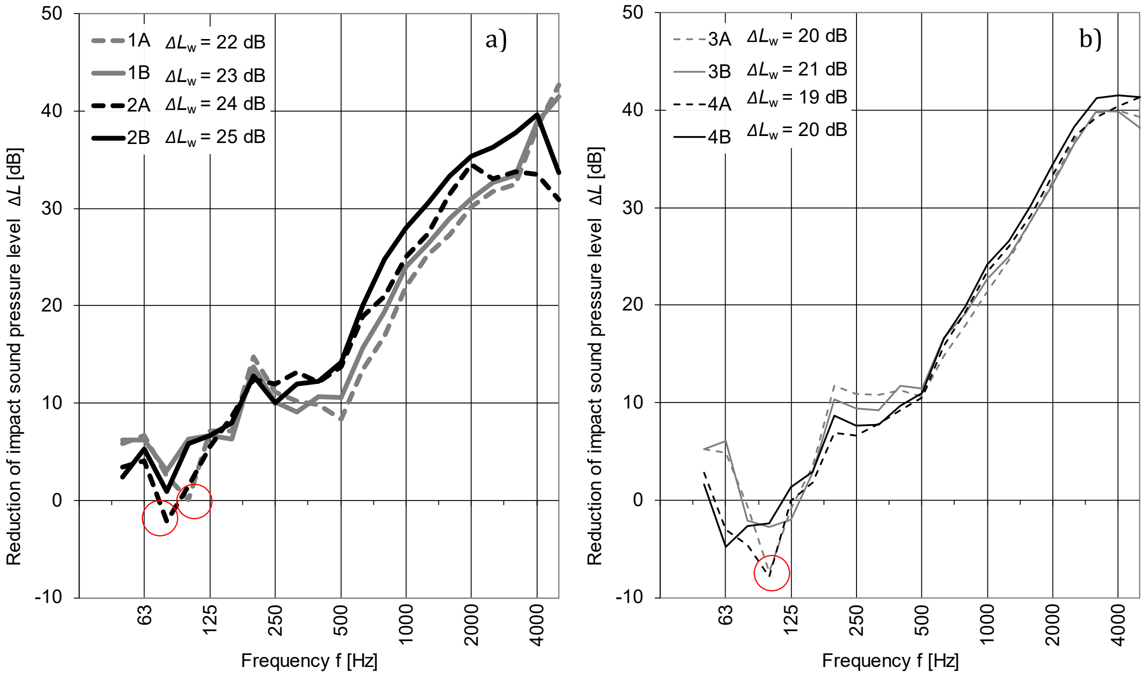

Figure 5. Laboratory measurements of the reduction of the impact sound pressure level ΔL in the 1/3 octave frequency bands for: a) floor covering with EPS T 44/40 mm, b) floor covering with EPS T 22/20 mm.

The results obtained may come as a surprise. In the wide frequency range of 100 Hz ÷ 630 Hz, there was a significant decrease in sound insulation, while for the remaining frequency range it increased. A comparison of the apparent sound reduction index as a function of frequency indicates a radical change in its characteristics. The negative impact of the work carried out for stage 2 on sound insulation between rooms is confirmed by the results presented in the form of the $R'_{A,1}$ indices in Fig. 4. The value of the $R'_{A,1}$ index for variant 3 and stage 2 was 44 dB, which means a decrease compared to stage 1 by up to 6 dB. According to the author of the article, the reasons for the above change should be sought in the implementation of new, additional installation ducts through the walls, or possibly in the incorrect construction of the raised floor (lack of expansion joints between the floor and walls). The influence of the suspended sound-absorbing ceiling in the source room and the furniture on the change of sound insulation parameters should be excluded. Table 2 summarises the complete results of field measurements carried out for all variants of the wall, both for stage 1 and stage 2.

Table 2 presents the EPS T values of the dynamic stiffness declared by the manufacturer of expanded polystyrene panels. On their basis, a weighted reduction of the impact sound pressure level ΔL_w was calculated. according to formula (4). The values calculated in this way were compared with the results of the laboratory tests (columns 3 and 4). The difference (column 5) indicates a significant discrepancy between the calculation and the measurement results. The probable cause may be a difference between the quality of EPS T available for sale and tested for the determination of s' by the manufacturer. This problem was pointed out by the author in an earlier work [16]. Table 2 also presents the dynamic stiffness determined on the basis of formula (4) using the value of ΔL_w determined in laboratory tests (column 6). The results differ not only from those declared by the manufacturer, which is obvious in the information presented context of the previously (columns 2 and 6). There is also a difference between the values s' determined for the same type of EPS T but different screed: sample 1B → s' = 38 MN/m^3 and sample 2B → s' = 34 MN/m^3 and 3B → s' = 53 MN/m^3 and sample 2B → s' = 78 MN/m^3 (column 6) imperfection of the formula (4). The above remark seems to apply in particular to the case of insulation with a small thickness.

Table 2. Properties of polystyrene panels.

Sample no	s' [MN/m³] 1)	ΔL_w [dB] 2)	ΔL_w [dB] 3)	difference (3 – 4)	s' [MN/m³] 4)
1	2	3	4	5	6
1B – EPS T 43/40	10	31,3	23	8,3	38
2B – EPS T 43/40	10	32,6	25	7,6	34
3B – EPS T 22/20	20	27,1	21	6,1	53
4B – EPS T 22/20	20	28,3	20	8,3	78

1) Based on the manufacturer's declaration EPS T.
2) Calculated according to formula (4).
3) Laboratory tests (Fig. 4 and Fig. 5).
4) Approximated on the basis of formula (4) and values laboratory tests ΔL_w 3).

4. Summary

Based on the results presented from laboratory measurements of the reduction of transmitted impact noise by floor coverings on a heavy-weight standard floor, the following conclusions can be drawn. The results for the cement screed confirm the generally known relationship that the lower the thickness of the resilient material, the lower the reduction of the impact sound pressure level ΔL. In the case of anhydrite screed, a deviation from this rule was observed for frequencies above 500 Hz. For the EPS T 22/20 board, higher ΔL values were obtained than for the EPS T 43/40 board, which may be surprising. The above anomaly is also reflected in the single-number weighted reduction of the impact sound pressure level ΔL_w . For the EPS T 22/20 mm board and the lighter 40 mm anhydrite screed, a higher ΔL_w value was obtained (ΔL_w = 20 dB and 21 dB, respectively) than the floor with the EPS T 22/20 mm board and the heavier cement screed 50 mm cement screed (ΔL_w = 19 dB, respectively) and 20 dB). The results show that for plates with a small thickness (high dynamic stiffness *s*'), the mass of the pressure plate is less important than for the elastic material with "good" properties. The reason may be the too low screed mass, which does not sufficiently load the elastic material and the results are worse than indicated by theoretical calculations made in accordance with PN-EN ISO 12354-2: 2017-10 [8]. Tests carried out without an additional load simulating furniture indicate that the additional load significantly reduces the negative effect of the resonant frequency of the system (Fig. 5). In the case of unfurnished rooms, the actual sound insulation parameters can significantly differ from the parameters calculated at the design stage based on the values for the floor with laboratory load. The article also presents the weighted reduction of the impact sound pressure level ΔL_w w calculated on the basis of the dynamic stiffness declared by the manufacturer of EPS T-expanded polystyrene panels. The calculated values differ significantly from the results of laboratory tests. The probable cause may be the difference between the quality of EPS T used in laboratory tests ΔL_w and that tested by the manufacturer to determine *s*' or imperfections in the formula (4). The above remark may apply, in particular, to the case of insulation with a small thickness and high dynamic stiffness.

Additional information

The authors declare: no competing financial interests and that all material taken from other sources (including their own published works) is clearly cited and that appropriate permits are obtained.

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