ASSESSMENT AND COMPARISON OF SOUND INSULATION OF SELECTED PARTITION CONSTRUCTIONS IN TWO WOODEN BUILDINGS

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Abstract: Acoustic comfort in an inhabited building is an important aspect from the point of view of a person's quality of life, especially in the hotels and the buildings for the temporary accommodation facilities. When evaluating the sound insulation of the partition walls and ceilings, measurements carried out in buildings are decisive, which can confirm the suitability of the material composition used and its correct application in the wooden building. The work deals the evaluation of the airborne and impact sound insulation of the partition constructions of a different thickness and material composition between the rooms in two different residential houses. The results of the airborne sound insulation measurements showed that, even after considering the required spectrum adaptation terms, the requirements of the standard STN 73 0532-2:2024 were not met in the first building, but they were met in the second building. The results of the impact sound insulation measurements showed that the requirements of the new standard STN 73 0532-2:2024 were not met in the first building after considering the required spectrum adaptation term $C_{i50\text{-}2500}$ but were met in the second building after considering all required spectrum adaptation terms.

Keywords: Building acoustics, Sound insulation, Standardized level difference, Standardized impact sound pressure level, Wooden buildings

1. INTRODUCTION

The building should be designed in such a way that the noise and vibrations affecting the users do not exceed the noise level that would endanger their health or make sleep and relaxation impossible. Investigating the acoustic characteristics of the partition constructions from the point of view of sound insulation is a very typical topic in the 21st century already in the project preparation phase. During the approval of the wooden constructions, measurement of noise level, both inside and outside, as well as the measurement of sound insulation of the partition constructions is becoming very popular [1].

Technical progress in the measurements and simulations currently allows not only a better assessment of existing structures, but also the prediction of their soundproofing properties at the design stage. Based on the prediction, it is possible to solve various details of the structures, identify the acoustic bridges, and help develop acoustically composite constructions. Sound insulation cannot be ensured only by increasing the thickness of a certain material, but only by a conceptual solution [2].

The acoustics of wooden constructions is affected by several factors. Soundproofing of the partition walls in wooden buildings can be affected by material layers, their properties, and the layer arrangement as well as the method of joining the partition with other elements of the wooden constructions.

The airborne sound transmission through the walls of lightweight structures (wooden buildings) is also affected by the material processing [3]. The acoustic comfort in buildings is also influenced by the composition of the floor structure, which should largely eliminate noise propagation between individual floors. The impact sounds are influenced by the mechanical properties of the floor, such as mass and stiffness [4]. Wooden house could reduce the impact sounds more than a concrete house due to its sound-absorbing properties [5]. Nowotny and Nurzyński suggest different evaluation methods of heavy standard floors and lightweight structures [6]. The development of new methods based on a more objective assessment of the sound insulation of building constructions is constantly relevant [7, 8].

From this point of view, a clear advantage of wooden constructions is the possibility of selecting materials with the required soundproofing provided at a lower wall thickness. However, acoustically multiple constructions of wooden buildings usually have a problem eliminating low-frequency noise due to the lower surface density of the materials compared to, for example, reinforced concrete constructions.

Standardized level difference parameter was chosen for evaluating the airborne sound insulation, measured according to STN EN ISO 16283-1:2014 [9]. Standardized impact sound pressure level was chosen for evaluating the impact sound insulation, measured according to STN EN ISO 16283-2:2021 [10]. These parameters provide a straightforward link to the subjective perception of noise level in buildings.

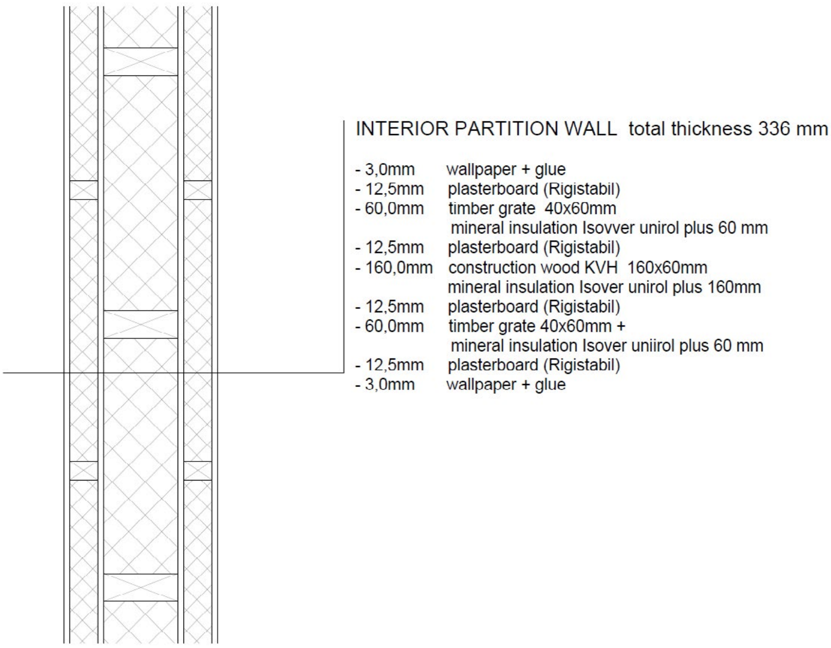
2. DESCRIPTION OF OBJECTS AND METHODS

The on-site measurements of airborne and impact sound insulation between two rooms were carried out according to the standard STN EN ISO 16283-1:2014 and STN EN ISO 16283-2:2021. The evaluation of the measurements was carried out according to the standards STN EN ISO 717-1:2021 [11] and STN EN ISO 717-2:2021 [12]. These standards include the evaluation of parameters measured by an A-weighting filter and inclined to the extended evaluation of sound insulation in the frequency interval from 50 Hz to 5 kHz.

The airborne sound insulation of the partition walls between the mirror-oriented separate accommodation units was evaluated. The 1st building has a larger living room, connected to an "L"-shaped entrance corridor, without internal equipment and with an air conditioning unit. The 2nd building has smaller bedrooms of the same volume, with full interior furnishings and accessories. The composition and thickness of the wall layers in the objects is shown in Fig. 1.

The impact sound insulation of the ceilings between the mirror-oriented separate accommodation units under each other, bedrooms along with interior furnishings and accessories, was evaluated. Curtains and bed mattresses were missing in the 1st building. The composition and thickness of the ceiling layers in the assessed objects is shown in Fig. 2.

1st building



2nd building

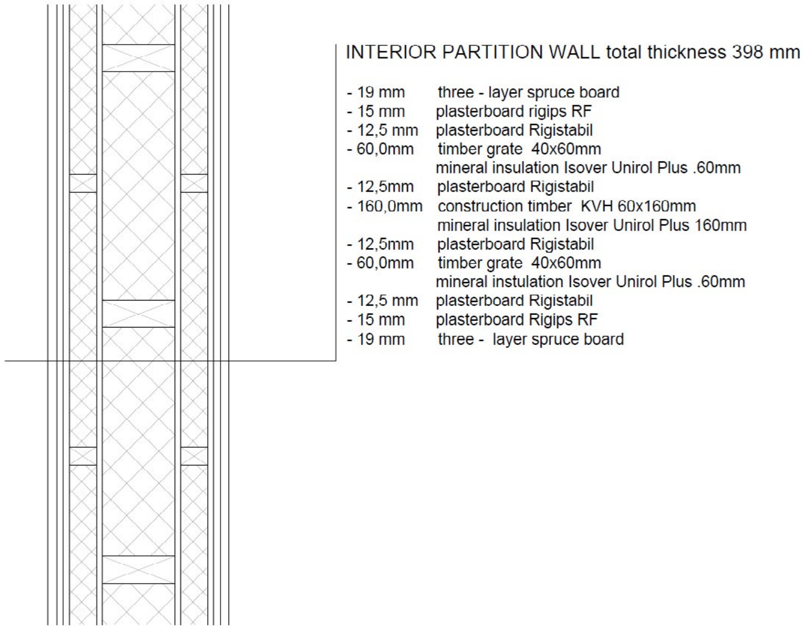
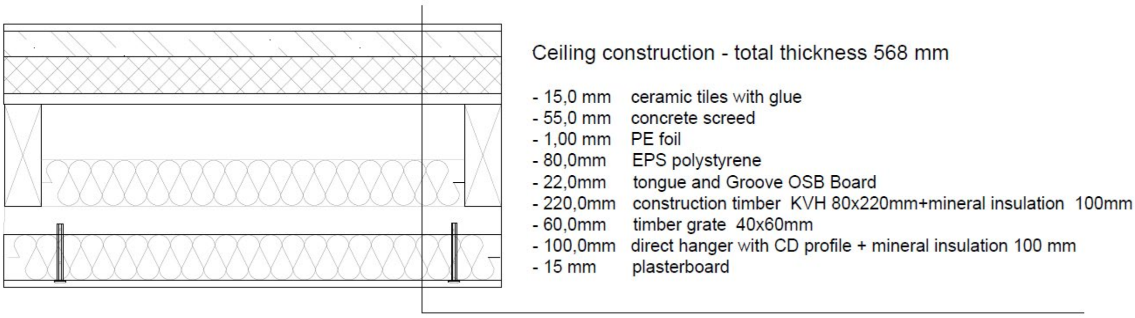


Fig. 1: Composition of the partition walls of the residential houses

1st building



2nd building

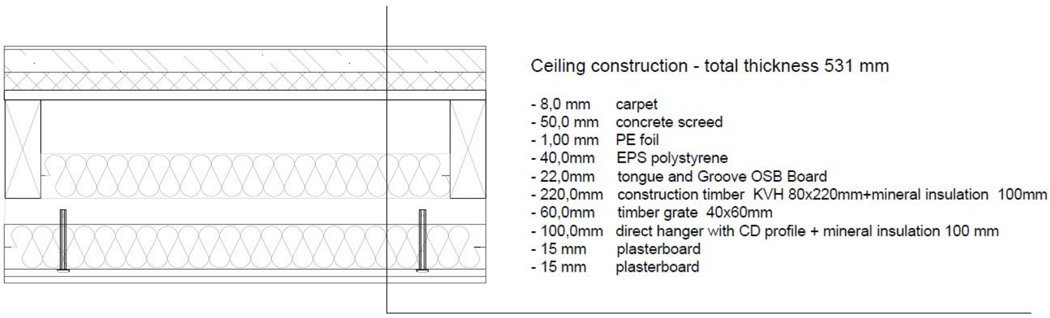


Fig. 2: Composition of the ceilings of the residential houses

The measuring equipment (Fig. 3) consisted of certified instruments and software from the Brüel & Kjær. The measurement system includes the omnidirectional sound source with the stand Type 4292-L; impact sound generator Tapping Machine Type 3207; Power Amplifier with wiring Type 2734-A; Hand-held analyser Type 2270 with a license for measuring parameters of building acoustics; software Measurement Partner Suite BZ5503 and Building Acoustics Partner; laptop.

The results of the evaluation of airborne sound insulation between apartment partitions in the 1st building are in Tab. 1 and Fig. 4. The reverberation time in the receiving room reached high values: at f = 63 Hz, T_{30} = 1.52 s; at f = 1 kHz, T_{30} = 1.57 s. The weighted sound reduction index R_w with a value of 53 (-13; -22) dB was determined for this object using prediction software. After conversionted to the weighted apparent sound reduction index R'_w (correction for flanking transmission: k_1 = 5-8 dB), it was evaluated at (45-48) dB, i.e. partition wall meets the minimum requirements of the STN 73 0532-2:2024 [14].

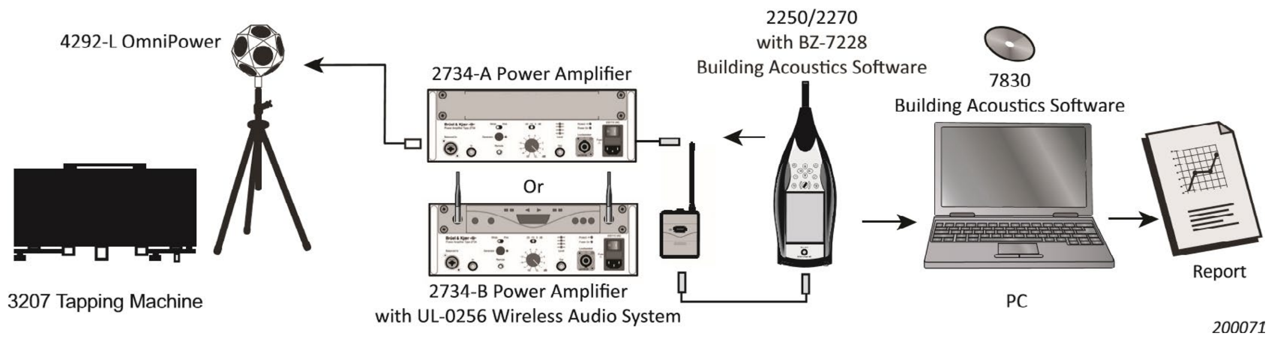


Fig. 3: Scheme of the measuring set [13]

3. RESULTS AND DISCUSSION

During the measurement in the 1st building, a high level of background noise was identified, affecting acoustic comfort. Noise of various frequencies was generated by the movement of air and fluid through the pipes and ducts of the air conditioning units. The central conditioning unit is located on the roof. The noise caused by the air conditioning units consisted mainly of audible frequencies in the sound insulation frequency band (125 – 5000) Hz and reached a background noise level in the range of (13 - 34) dB. In the second building, the background noise level was measured in a lower range of (4 - 20) dB.

The results of the evaluation of airborne sound insulation between the apartment partition in the 2nd building are in Tab. 1 and Fig. 4. The reverberation time in the receiving room reached acceptable values: at f = 63 Hz, T_{30} = 0.67 s; at f = 1000 Hz, T_{30} = 0.32 s.

The weighted standardized level difference $D_{nT,w}$ of the partition wall in the 1st building meets the standard STN 73 0532-2:2024 requirements. However, after considering all recommended spectrum adaptation terms (+C; C_{tr}), the requirement stated in the valid STN 73 0532-2:2024 standard is not met.

Residential houses	**1st building**	**2nd building**
Requirement of standard (walls)	$D_{nT,w} \geq 47$ dB	$D_{nT,w} \geq 47$ dB
Weighted standardized level difference	$D_{nT,w}$ (C; C_{tr}) = 49 (-5; -13) dB	$D_{nT,w}$ (C; C_{tr}) = 61 (-1; -5) dB
Spectrum adaptation terms / $D_{nT,w}$ + C; C_{tr}	C = -5 dB / 44 dB $C_{50\text{-}5000}$ = -4 dB / 45 dB C_{tr}; $C_{tr50\text{-}5000}$ = -13 dB / 36 dB	C = -1 dB / 60 dB C_{tr} = -5 dB / 56 dB $C_{50\text{-}5000}$ = -3 dB / 58 dB $C_{tr50\text{-}5000}$ = -14 dB / 47 dB
Comparison with the standard (+ C; C_{tr})	**Does not meet**	**Meet**

Tab. 1: The weighted standardized level difference with spectrum adaption terms $D_{nT,w}$ (C; C_{tr}) of the walls and evaluation according to the STN 73 0532-2:2024

1st building: $D_{nT,w}$ (C; C_{tr}) = 49 (-5; -13) dB

2nd building: $D_{nT,w}$ (C; C_{tr}) = 61 (-1; -5) dB

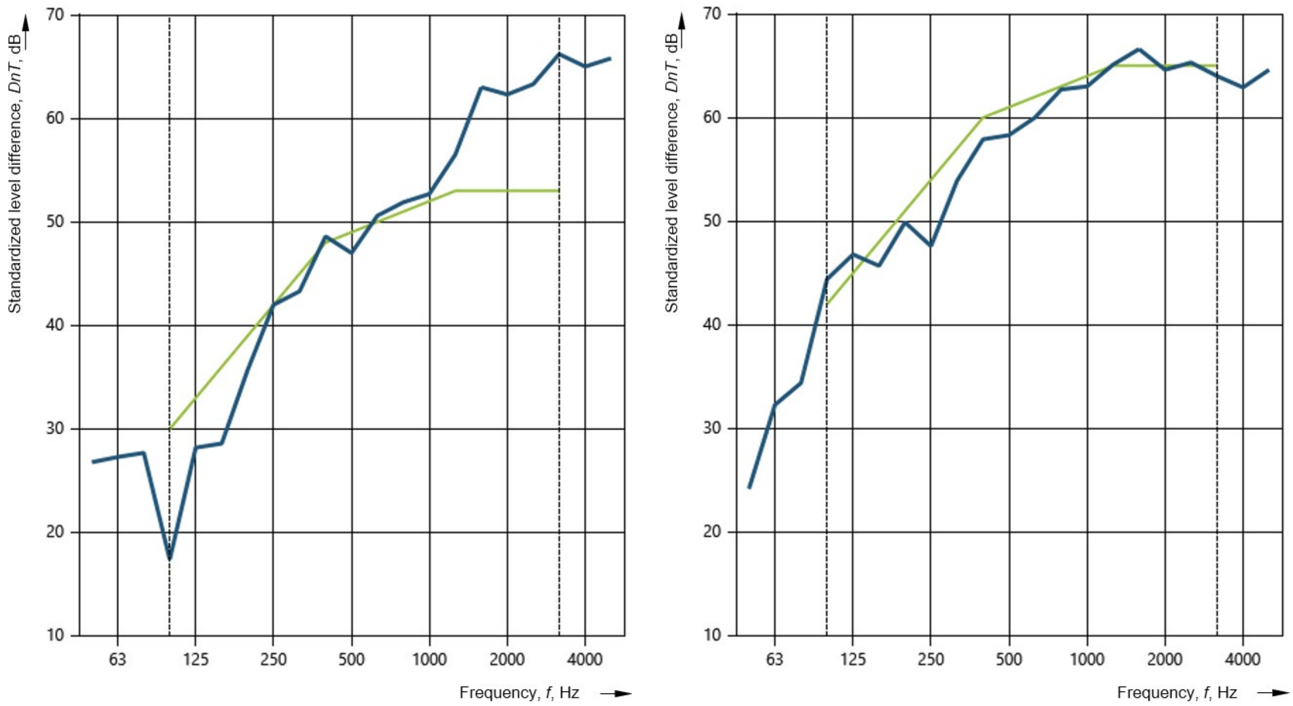


Fig. 4: Graphs of the standardized level difference dependence D_{nT} in 1/3-octave frequency band

In the 2nd building, the requirement stated in the standard STN 73 0532-2:2024 was met even after taking into all spectrum adaptation terms. The following contributed to meeting the requirements of the standard:

Increasing the wall thickness by adding: 19 mm thick three-layer spruce bioboard E1 and 15 mm thick fire protection plasterboard Rigips® RF 15 consisting of a special, reinforced gypsum core encased in cardboard. The boards were added to both sides of the wall. The three-layer spruce board causes fragmenting soundwaves. The pores disrupt the sound wave passage through the wood. Higher frequency waves are reflected and lower frequencies absorbed, so the sound transmission to the next layer of the wall is lower. Plasterboard Rigips® RF 15 is a material with high area density (13.5 kg·m^{-2}), which contributed to the improvement of sound insulation.

Partition wall consists of materials of different thicknesses and densities. So, at low frequencies, there is no in-phase vibration of individual large-area plates as a whole, since each plate has a different resonant frequency, which significantly affects the final value of $D_{nT,w}$. As shown in Fig. 4, where the directional curve is optimal.

The furniture was placed in the rooms as well as curtains and carpets.

The results of the evaluation of impact sound insulation between apartments in both buildings are in Tab. 2 and Fig. 5. The reverberation time in the receiving room of the 1st building was lower at the low frequencies and higher at the high frequencies: at f = 63 Hz, T_{30} = 0.69 s; at f = 1 kHz, T_{30} = 1.03 s.

The reverberation time in the receiving room of 2nd building reached higher values in lower frequencies, but adequate values at the higher frequencies: at f = 63 Hz, T_{30} = 0.80 s; at f = 1000 Hz, T_{30} = 0.48 s.

The weighted standardized impact sound pressure level $L'_{nT,w}$ of the ceiling in the 1st building meets the standard STN 73 0532-2:2024 requirements. However, after considering recommended spectrum adaptation term ($+C_{i50-2500}$), the requirement stated in the valid standard STN 73 0532-2:2024 is not met.

In the 2nd building, the requirement specified in the new Slovak standard was met even after considering all spectrum adaptation terms.

The measurements in the 1st building indicated a negative impact of low frequencies on the acoustic comfort.

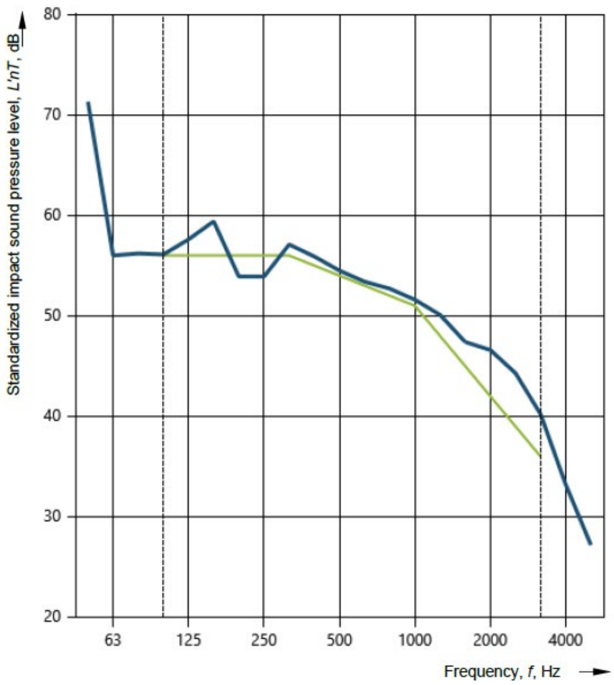
Residential houses	**1st building**	**2nd building**
Requirement of standard (ceilings)	$L'_{nT,w} \leq 55$ dB	$L'_{nT,w} \leq 55$ dB
Weighted standardized impact sound pressure level	$L'_{nT,w}(C_i) = 54 (-3)$ dB	$L'_{nT,w}(C_i) = 36 (4)$ dB
Spectrum adaptation terms / $L'_{nT,w} + C_i$	$C_i = -3$ dB / 51 dB $C_{i50-2500} = 4$ dB / 58 dB	$C_i = 4$ dB / 40 dB $C_{i50-2500} = 14$ dB / 50 dB
Comparison with the standard (+ C_i)	**Meet (C_i)** **Does not meet ($C_{i50-2500}$)**	**Meet**

Tab. 2: The weighted standardized impact sound pressure level with spectrum adaption terms $L'_{nT,w}(C_i)$ of the ceilings and evaluation according to the STN 73 0532-2:2024

The results of the sound pressure level measurements indicate that the soundproofing needs to be evaluated individually, it would be appropriate to consider all additional impacts.

The evaluation of the impact soundproofing of the ceiling with a single value descriptor, the weighted standardised impact sound pressure level $L'_{nT,w}$, showed a significantly lower

1st building: L'nT,w (Ci) = 54 (-3) dB



2nd building: L'nT,w (Ci) = 36 (4) dB

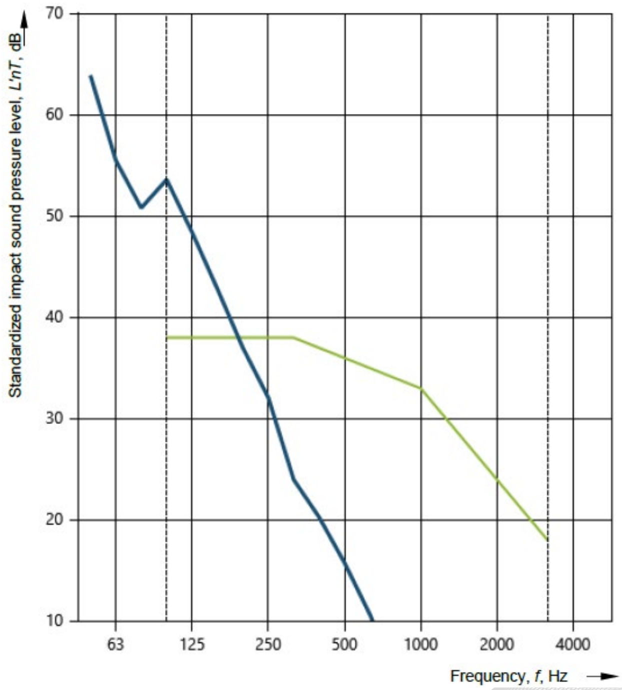


Fig. 5: Graphs of the standardized impact sound pressure level L'_{nT} dependence in 1/3-octave frequency band

value in the 2nd building. Better impact sound insulation in the 2nd building was achieved:

- By placing a soft layer, such as carpet, on the floor, while in the 1st building, ceramic tiles were glued to the floor. The carpet absorbs impact noise, mainly medium to high frequencies (sound absorption coefficient in the frequency range 500 Hz - 4 kHz is α = 0.14 - 0.30 and higher) and very effectively reducing impact sound transmission to rooms below. On the other hand (1st building), ceramic tiles have a hard surface that reflects sound waves (α = 0.01 – 0.03 in the frequency range 125 Hz to 4 kHz), can contribute to higher reverberation in the source room and to high sound pressure levels in the receiving room.
- Two layers of 15 mm thick plasterboard, flexibly mounted in the room below, have a better effect than one 15 mm layer in the 1st building. Double plasterboard increased the effectiveness of soundproofing of the ceiling.
- In both rooms, furniture (fully furnished), curtains and carpets were placed, i.e. higher sound absorption.

4. CONCLUSIONS

The results of measurements of airborne and impact sound insulation in two wooden buildings confirmed the influence:

- of the material composition, thickness of the partition structure and ceiling structure,
- of mechanical and physical properties of used materials,
- of the materials order in the partition and ceiling structures.

$D_{nT,w}$ of the partition wall in the 1st building meets the standard STN 73 0532-2:2024. After considering all recommended spectrum adaptation terms (+C; C_{tr}), it is not met. In the 2nd building, the standard STN 73 0532-2:2024 requirement was met even after considering all spectrum adaptation terms.

$L'_{nT,w}$ of the ceiling in the 1st building meets the standard STN 73 0532-2:2024. It is not met after considering the spectrum adaptation term (+$C_{i50-2500}$). In the 2nd building, the requirement specified in the new Slovak standard was met even after considering all spectrum adaptation terms.

Low-frequency noise is difficult to control. Therefore, the weighted standardised level difference with spectrum adaptation terms, i.e. $D_{nT,w}$ (C; C_{tr}), and weighted standardised impact sound pressure level with spectrum adaptation terms $L'_{nT,w}$ (C_i), can be an important parameter for the judgment of sound insulation in wooden buildings and of the building elements.

The legislation in Slovakia does not require measurements of the sound insulation partition walls and ceilings during the building construction, mainly wooden buildings. However, these measurements have shown the importance and justification of such measurements. Due to the increasingly frequent use of lightweight partition constructions (including wooden buildings), it is shown that the evaluation of sound insulation should also include measurement in low frequencies, i.e. below 100 Hz.

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