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Sound insulation of slabs in dwellings

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Sound insulation of slabs in dwellings

Kęstutis Miškinis[1], Raimondas Bliudžius[1] and Andrius Buska[2]

[1] Institute of Architecture and Construction of Kaunas University of Technology, Tunelio str. 60, LT-44405 Kaunas, Lithuania
[2] JSC "ROCKWOOL", A. Goštauto 40B, LT-01112, Vilnius, Lithuania

kestutis.miskinis@ktu.lt

Abstract. The well-being and sleeping quality of people in dwellings depends on appropriate sound insulation efficiency of building structures. In individual apartments, airborne sound is produced by people talking and music playing, and impact sound is produced by people walking and falling of various objects on the floor. The inter floor slab separating the individual dwellings is intended for airborne and impact noise insulation, so special attention is paid to its design and installation. Since the composition of this structure is primarily determined by the structural requirements, the improvement of the sound insulation performance is mainly carried out by developing the damping interlayer materials. The stone wool plate has been modified reducing the fiber intertwining to obtain a more uniform fiber directivity, thus reducing its dynamic stiffness. Therefore, the aim of this study was to investigate the sound insulation efficiency of inter floor slabs with a new modification of stone wool damping interlayer in comparison with currently used mineral wool products. The experimental measurements in 50-5000 Hz frequency range were performed in construction site (real structures), the single-number quantities – weighted standardized level difference (D_{nTw}) and weighted normalized impact sound pressure level (L'_{nW}) with living adaption term (C) were determined and compared. The research results demonstrated that the modified stone wool with reduced fiber intertwining and lover organic content used for damping interlayer enables to improve living sound insulation of inter floor slab comparing with existing stone wool materials.

1. Introduction

Efficient sound insulation of collective dwellings has a strong influence on the quality of life of their occupants and for maintaining good neighbourly relations [1]. In individual apartments, airborne sound is produced by people talking and music playing, and impact sound is produced by scraping sound, footsteps and thumping from neighbours [2, 3]. During the conversation, the fundamental frequency of a typical adult man ranges from 80 to 180 Hz and that of a typical adult woman from 165 to 255 Hz, for children, around 300 Hz [4]. The current reference frequency for tuning musical instruments is 440 Hz [5]. People walking and falling of various objects on the floor also produces a low-frequency sound in rooms under the inter floor slab.

Reduction of the impact of noise generated in the building on people's health and well-being could be realized by means of building planning, technical solutions and used materials [6]. Various types of lightweight and heavyweight structures are used for an appropriate sound insulation realization [4, 5]. The composition of heavyweight inter floor structure is primarily determined by the structural requirements [7], therefore the improvement of their sound insulation performance is mainly carried out by developing the damping interlayer materials [8]. The most commonly used for this interlayer are porous fibrous materials, they have an original spatial structure, as their framework consists of interwoven fibres of different length and thickness, adhered together with an organic binder [9]. Mineral

wool products intended for structures with mechanical load, which include heavyweight inter floor structures, are produced by intertwining the fibre in such a way as to obtain the required compressibility and/or compressive strength with the least amount of fibre and organic binding material [10]. Such intertwining of mineral wool fibres is relevant for saving materials and energy resources, but it increases the dynamic stiffness of this material, which has a significant impact on the performance of impact sound insulation [3, 11].
Both stone and glass wool products are used for the damping interlayer of sound insulating structures. Stone wool has the advantage of greater mass, which has a greater impact on airborne sound attenuation, while glass wool has the advantage of more flexible fibre and its consistent longitudinal orientation, resulting in lower dynamic stiffness, which determines impact sound insulation properties [11]. The advantage of stone wool is also the smaller amount of organic binding material required to achieve mechanical strength, as it determines the combustibility classification of the material and the entire structure. Therefore, changes were introduced in the stone wool production technology, and the structure of stone wool panels was modified. In order to find out the achievements of stone wool modification, four heavyweights inter floor structures were installed in real buildings, as a damping layer using stone and glass wool products of conventional and modified structure. The air borne and impact sound performance of structures in 50-5000 Hz frequency range was measured. In order to evaluate the efficiency of living noise insulation, which is dominant in multi-apartment buildings [12], the single-number quantities – weighted standardized level difference (D_{nTw}) [13] and weighted normalized impact sound pressure level (L'_{nW}) [14] with and without living adaption term (C) were determined and analysed.

2. Structure, materials, method and equipment for investigation.

Four heavyweights inter floor slabs were installed in a real building for this experiment. The load bearing structure was hollow concrete slab 200 mm thickness (the mass - 280 kg/m^2), covered by 120 mm of sand 0-4 mm fraction (the mass -198 kg/m^2). For damping interlayer were used stone and glass wool products of conventional and modified structure (table 1). The sand-cement screed 50 mm thickness (the mass - 82.5 kg/m^2) was installed on the top of slab (figure 1).

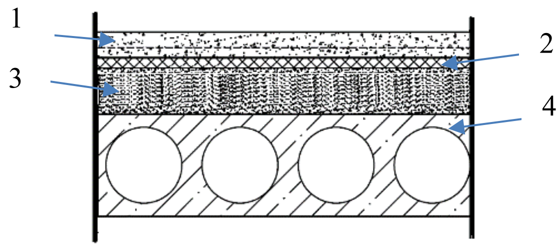

Figure 1. Cross-section of inter floor slab. 1 – sand/cement screed; 2 – damping interlayer (resilient material); 3 – sand interlayer; 4 – hollow concrete slab.

The damping interlayer of resilient materials was different in all structures. Designation of structures and properties of resilient materials determined in the laboratory are given in table 1.

Table 1. Designation of inter floor slabs and properties of resilient materials.

Slab marking	Resilient material	Thickness, mm	Density, kg/m^3	Dynamic stiffness, MN/m^3	Compressibility, mm	Compression strength, kPa	Organic content, %
NMW1	New stone wool	20	120	≤ 30	≤ 4	≥ 15	3,0
NMW2	New stone wool	30	120	≤ 16	≤ 4	≥ 15	3,0
EMW	Existing stone wool	20	120	≤ 34	≤ 4	≥ 20	3,5
EGW	Existing glass wool	20	85	≤ 20	≤ 4	≥ 20	9,0

The density of the existing and modified stone wool is the same - 120 kg/m^3, while the density of glass wool is lower, 85 kg/m^3. The dynamic stiffness of the 20 mm thick existing stone wool is 34 MN/m^3, and of the glass wool is much lower – 20 MN/m^3. The dynamic stiffness of 20 mm thick modified stone wool decreased to 30 MN/m^3, and of this 30 mm thick wool is the same as of glass wool - 20 MN/m^3. By reducing the fiber intertwining and organic content of the modified stone wool to 3%, its compression strength also decreased by 5 kPa, but compressibility of all products remained the same - ≤ 4 mm, which ensures the suitability of this material for use in heavyweight inter floor structures.
The volume of source and receiving rooms were from 25 m^3 to 30 m^3. The common areas of inter floor slabs were from 9 m^2 to 10.5 m^2. The surrounding structures (walls) were heavyweight made of hollow ceramic bricks plastered with cement-lime mortar (the mass per unit area was 198 kg/m^2). The source and receiving rooms were empty, without furnishing. The doors to the rooms were covered with panels to minimize the background noise level inside rooms. The measurements were performed after working hours to eliminate background noise influence.
The airborne and impact sound insulation measurements in the 50–5000 Hz frequency range were carried out in accordance with the LST EN ISO 16283-1 [15] and LST EN ISO 16283-2 [16] standards using a two-channel Nor1516 Building Acoustics system. The system is verified by an accredited metrological laboratory. For the measurements, a combination of two loudspeakers and five fixed microphone positions were used in both, the source and the receiving rooms.
For the evaluation of airborne sound insulation of inter floor slabs, weighted standardized level difference (D_{nTw}) and weighted standardized level difference with living adaption terms (D_{nTw}+C) according to the standard LST EN ISO 717-1 [17] were determined, because this single-number quantity leads to best evaluation of sound insulation [13]. D_{nTw} is the value of sound insulation of tested element in dB. The larger value of D_{nTw} is, the better sound insulation of tested element. Spectrum adaption term is value in dB, added to the single-number rating to consider the characteristics of particular sound spectra (living noise). The larger value of D_{nTw}+C is, the better airborne sound insulation of living noise of tested element.
For the evaluation of impact sound insulation, weighted normalized impact sound pressure level (L'_{nW}) and weighted normalized impact sound pressure level with living adaption term (respectively L'_{nW} +C) according to the standard LST EN ISO 717-2 [18] were determined to define a link between the insulation measured and the insulation experienced by the building occupants [14]. As impact sound source, taping machine Nor211A was used. L'_{nW} is the value of sound insulation of tested element in dB. The lower value of L'_{nW} is, the better sound insulation of tested element. Spectrum adaption term is value in dB, added to the single-number rating to take account of the characteristics of particular sound spectra (living noise). The lower value of L'_{nW} +C is, the better impact sound insulation of tested element of living noise.

3. Results and Discussion

3.1. Airborne sound insulation dependence on frequency
The measured standardized level difference dependence on frequency is presented in figure 2.

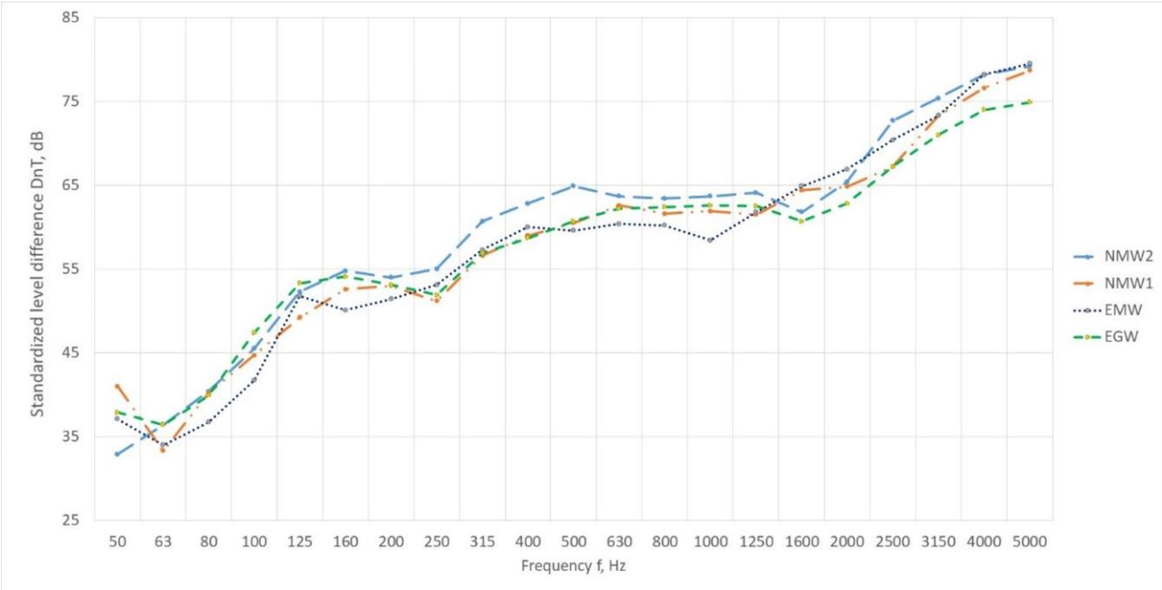

Figure 2. Standardized level difference dependence on frequency of inter floor slabs with different damping layer materials.

A comparison of the sound level of structures with 20 mm thick existing and modified stone wool damping interlayer at various frequencies showed that the airborne sound insulation did not change significantly, only low frequency range from 60 to 110 Hz could be distinguished, where the airborne sound insulation of the structures with modified stone wool increased. This should not have a significant effect on airborne sound insulation, as speech and music sounds are emitted in the higher frequency range. Comparing the graphs of the frequency dependence of the sound insulation of the structures with the existing stone and glass wool damping layers, the sound insulation of the structure with glass wool is more efficient in the lower frequency range, but worse in the higher frequency range, from 1300 to 5000 Hz. It is observed that the sound insulation of structures with 20 mm thick modified stone wool and conventional glass wool is very similar in the entire frequency range, and the sound insulation of the structure with 30 mm thick modified stone wool is greater than that of other structures in the range of 150-5000 Hz. This shows that the use for damping interlayer of stone wool, modified by reducing the fiber intertwining and the amount of organic binder, does not reduce, and even slightly improves the airborne sound insulation efficiency of heavyweight inter floor structures.

3.2. Impact sound insulation dependence on frequency

The measured normalized impact sound pressure level dependence on frequency is presented in figure 3.

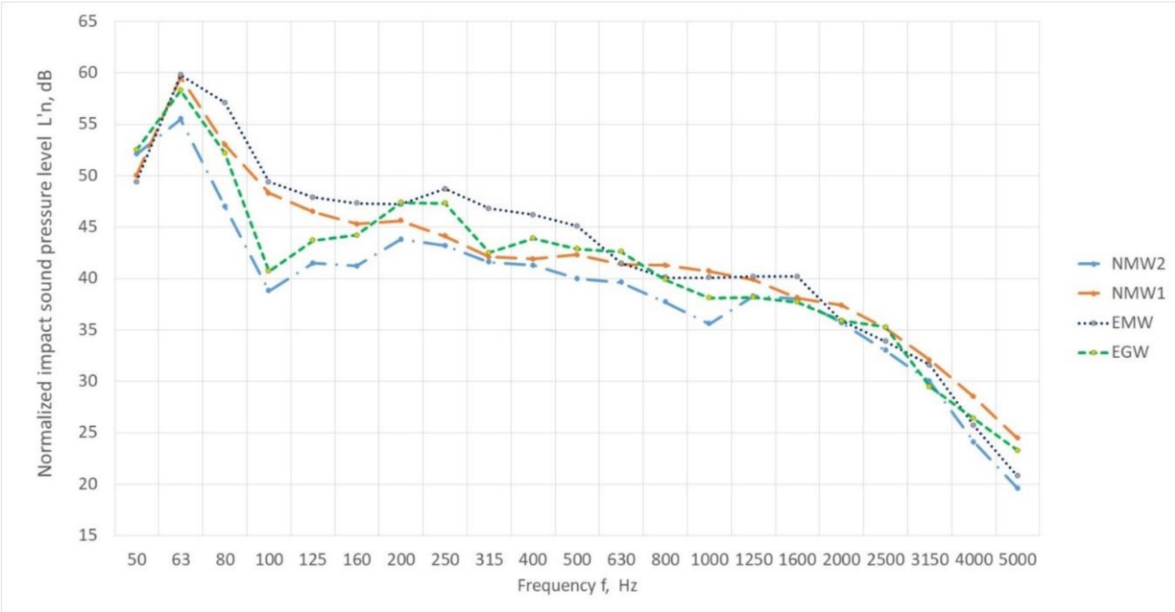

Figure 3. Normalized impact sound pressure level dependence on frequency of inter floor slabs with different damping layer.

The dependence of the impact sound pressure level on the frequency shows that the inter floor slab with glass wool damping interlayer in almost the entire frequency range isolates the impact sound better than the structure with the existing stone wool damping interlayer of the same thickness. The biggest difference in sound pressure level is visible in the low-frequency range (60-180 Hz), a little less - in the 250-600 Hz frequency range. A comparison of the sound insulation measurement results of slabs with existing and modified stone wool damping interlayers demonstrate the lower normalized impact sound pressure level of slab with the modified stone wool in the frequency range of 50-700 Hz, while the insulation efficiency remains similar in the higher frequency ranges. This shows that the use of modified stone wool will be effective in improving the impact sound insulation of the floor. The impact sound insulation efficiency of inter floor slab with modified stone wool approaches the efficiency of the structure insulated with glass wool. In the frequency range of 180-500 Hz, the slab with modified stone wool reduces impact sound even better, but its efficiency is much lower in the frequency range of 70-180 Hz. These impact sound level measurement results also confirm that the use for damping interlayer of stone wool, modified by reducing the fiber intertwining and the amount of organic binder, instead of conventional stone wool, obviously improves the impact sound insulation efficiency of heavyweight inter floor structures. The results of this measurement also show that use for damping layer 30 mm thick modified stone wool significantly improves the impact sound insulation efficiency of the floor in the entire frequency range studied.

3.3. Weighted standardized level difference

The airborne sound insulation values (single parameter) with and without spectrum adaptation term for living noise (C) were calculated for further analysis of the efficiency of stone wool modification increasing the airborne sound insulation of the inter floor slab (figure 4).

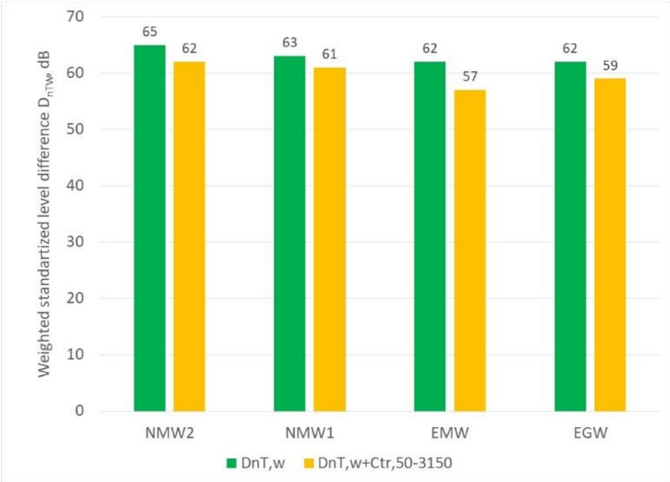

Figure 4. Weighted standardized level difference of inter floor slabs with different damping layers.

The results show that the weighted standardized level difference of structures with modified stone wool increases only slightly, compared to the structure with existing stone wool. However, then evaluating the spectrum adaptation term for living noise (C), this difference increases, showing that the slab with modified stone wool better isolates airborne living noise. The graph also shows that the weighted standardized level difference of the slabs with the existing stone wool and glass wool damping layer is the same - 62 dB, and with the spectrum adaptation term for living noise assessment - the sound insulation of the inter floor slabs with glass wool is of 2 dB higher. However, weighted standardized level difference of slab with the damping interlayer of modified stone wool becomes slightly higher than that of slabs with glass wool, and for sound insulation with the spectrum adaptation term for living noise, a small increasement of 2 dB is visible for slabs with modified stone wool. Increasing the thickness of the modified stone wool to 30 mm only by 1 dB increases the weighted standardized level difference with spectrum adaptation term for living noise (C) of the inter floor slab with this material, so it is not a rational decision to increase the airborne sound insulation value of this sound insulation single parameter of inter floor slab.

3.4. Weighted normalized impact sound pressure level

The weighted normalized impact sound pressure levels with and without spectrum adaptation term for living noise (C) are given in figure 5.

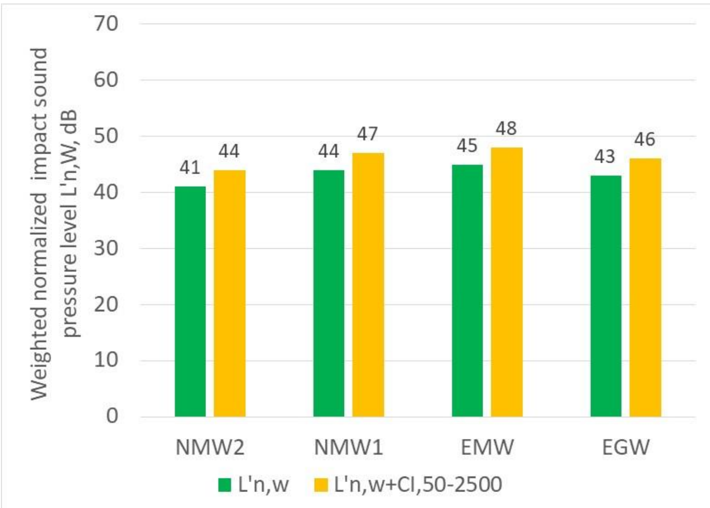

Figure 5. Weighted normalized impact sound pressure level of inter floor slabs with different damping layers.

The results indicate that the use of modified stone wool instead of the existing one improves weighted normalized impact sound pressure level of the slab by only 1 dB, and this is also by 1 dB lower than the values of slabs with glass wool damping interlayer. This shows that the modification of the stone wool by reducing fiber intertwining and the amount of organic binder, used in the damping layer of inter floor slabs is a positive direction of development of stone wool products not only in improving the impact sound insulation, but also in reducing raw material's consumption. The impact sound single parameter of the slab with a 30 mm thick damping layer show that this is a way to significantly increase the impact sound insulation of inter floor slab.

4. Conclusions

After analyses of standardized sound level difference dependence on frequency of inter floor slabs it was determined, that the use for damping interlayer of stone wool, modified by reducing the fiber intertwining and the amount of organic binder, does not reduce, and even slightly improves the airborne sound insulation efficiency of heavyweight inter floor structures. The much better advantage of modified stone wool in airborne sound insulation is demonstrated by weighted standardized level difference with spectrum adaptation term for living noise: airborne sound insulation of inter floor slabs with modified stone wool damping layer is even 4 dB higher than of slabs with existing stone wool, and 2 dB higher than of slabs with glass wool.

The impact sound insulation measurement results also confirm that the use for damping interlayer of stone wool, modified by reducing the fiber intertwining and the lower amount of organic binder, instead of conventional stone wool, improves the impact sound insulation efficiency of heavyweight inter floor structures, especially in low frequency range around 100 Hz. This should be efficient in reducing the impact sound caused by walking. However, the weighted normalized impact sound pressure level with and without spectrum adaptation term for living noise indicate, that the use of modified stone wool improves weighted normalized impact sound pressure level of the slab by only 1 dB, and this is also by 1 dB lower than the values of slabs with glass wool damping interlayer.

The results analysis also indicates that use for damping interlayer 30 mm thick modified stone wool significantly improves the sound insulation efficiency of the floor in 50-5000Hz frequency range, however, it also leads to the use of larger amounts of materials, which should be avoided following raw material saving purposes.

The general analysis of the results of the conducted airborne and impact sound research shows that the use of modified stone wool in the damping interlayer of heavyweight inter floor slabs improves its airborne and impact sound insulation properties, therefore, the structure of resilient materials should be further improved instead of increasing the thickness in damping layer, in order to achieve higher values of sound insulation of inter floor slabs.

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