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Lightweight floor screed with increased impact sound reduction

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Abstract Increasing users' requirements force to provide better and better solutions for reducing impact sounds. A lightweight floor screed can be a favorable solution for existing buildings with limited ceiling load capacity, where typical highly effective floating floors are too heavy to be used. In the paper further development of the impact sound reduction measurement method for small lightweight floor screed samples is presented. In order to protect the top layer of the sample from the hammers of the tapping machine, a thin concrete layer was coupled with the sample. What is more, a thin layer of sand below the sample was tested in order to improve the connection between the sample and the concrete floor. Based on obtained results, the concrete top layer and the sand bottom layer reduce slightly the effectiveness of the screed but decrease the uncertainty of the results significantly.

Keywords: impact sound reduction, lightweight floor screed.

1. Introduction

Acoustic comfort in buildings is a result of many different aspects. Air-borne and structure-borne sound insulations are the ones of the most importance. For air-borne sound insulation, it is relatively easy to provide values required by international standards even with a single layer partition, since it depends on the mass of the partition. On the other hand, providing effective structure-borne sound insulation is very challenging not only in industrial buildings but also public facilities and residential buildings. Low structure-borne sound insulation causes high noise, especially below the ceiling of the room where the noise is generated. Averaged noise generated by a tapping machine (impact sound source) is a basis for assessing the acoustic quality of the ceiling. Maximum permissible values of noise measured in a room adjacent to the room with the impact sound source are given in PN-B-02151-3 standard [1], where the parameter $L'_{\mathrm{n,w}}$ was defined. Selected values of $L'_{\mathrm{n,w}}$ are given in Tab. 1.

Table 1. Maximum permissible values of impact sound pressure level for selected room according to PN-B-02151-3 standard.

Location of the partition	Symbol	Unit	Value
Between dwellings in multifamily residentials	$L'_{\mathrm{n,w}}$	dB	≤ 55
Between a dwelling and a music club/an object with loud sound sources	$L'_{\mathrm{n,w}}$	dB	≤ 38
Between a hotel room and a music club	$L'_{\mathrm{n,w}}$	dB	≤ 43
Between a hotel room and a corridor	$L'_{\mathrm{n,w}}$	dB	≤ 55
Between a hotel room and an office	$L'_{\mathrm{n,w}}$	dB	≤ 58
Between classrooms	$L'_{\mathrm{n,w}}$	dB	≤ 58

To obtain the values given in Tab. 1, usually it is necessary to use a resilient layer on a heavyweight ceiling to reduce the impact noise transmission. Alternatively, multi-layered, highly sound-insulating suspended ceilings can be used in the receiving room. However, the noise reduction on the source side is always more effective as it is easier to reduce the noise transmitted through all possible paths.

International standard EN ISO 10140-1 [2] defines three categories of floor coverings used for the impact sound reduction: small specimens (including flexible coverings such as plastics, rubber, cork, etc.), which reduce vibrations locally, large specimens with rigid homogeneous surface materials, and stretched specimens, where flexible covering covers the floor from wall to wall.

The most effective ones are the large specimens (second category), with the resilient layer made of Styrofoam, mineral wool, or a dedicated material made of, e.g., foamed polyurethane with low dynamic stiffness. This kind of solution reduces impact sound by between 20 and 35 dB. A heavy floating slab must be applied on the resilient layer. The total mass of this kind of solution is usually too large for existing buildings with limited ceiling load capacity. Alternatively, a flexible floor covering can be used (first category acc. to [2]). This solution allows for achieving impact sound reduction of about 20 dB. Finally, for existing buildings without sufficient ceiling load capacity or stiffness, lightweight floor screeds can be used. Using lightweight aggregates, such as expanded perlite, foam glass, or expanded vermiculite reduces the density of the screed. With the right proportion of the lightweight aggregates and the binder it is possible to obtain the impact sound reduction of about 15 dB and meet the requirements for mechanical properties of floors given in the PN-EN 13813 standard [3].

In our previous paper [4], the development of the impact sound reduction measurement method for small samples of lightweight floor screeds was presented. The analysis of different positions of the receivers, different top layers of the sample as well as different measurements signals (sound or vibration) allowed to obtain repetitive and reliable results.

In this paper, a further development of the measurement method is presented. The results for samples of different densities and other important composition parameters are compared.

The measurement methods are presented in Section 2, while Section 3 contains results. In Section 4 the conclusions and further works are presented.

2. Measurement method

The measurement sample was prepared with the following assumptions:
- maximal thickness: 10 cm,
- maximal density in a dry state: up to 805 kg/m^3,
- dimensions: 500 x 900 mm,
- meeting the requirements of the standard PN-EN 13813 [3],
- minimum drying time: 28 days.

The dimensions of the sample and general assumptions of the measurement method were adapted to the method by Baruch et. al. [5] with the modifications given in [4]. Another adjustment of the method was the use of about 2 cm layer of concrete on the top of the measurement sample to protect lightweight screed against the hammers of the tapping machine (similar to the vinyl lining used before). Additionally, the hard concrete top layer dispersed the vibrations from the hammers to the lightweight screed more equally and made it more similar to the way it is used in real-life applications. On the other hand, the additional layer introduced another source of measurement uncertainty, since the connection between lightweight screed and the concrete layer was not perfectly homogenous.

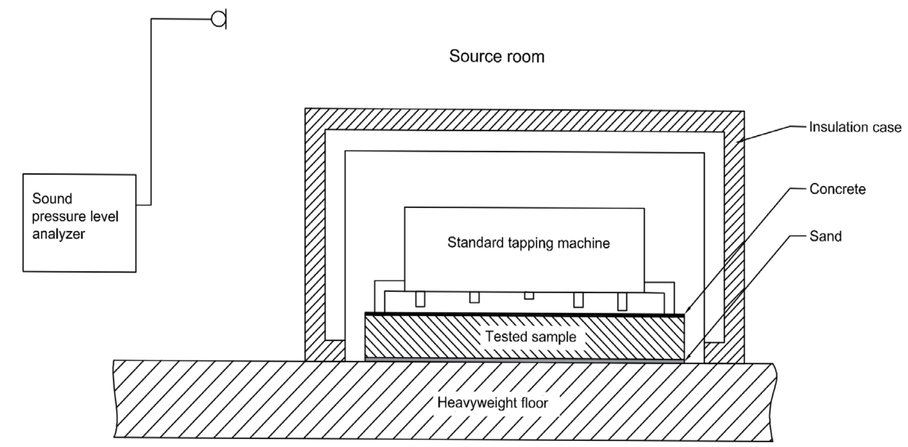

Figure 1. Setup for the improvement of the sound insulation ΔL measurement. The Concrete as well as Sand marked in the figure was used in selected measurements (Con and Sand subscript in Tab. 2). The microphone was placed in six different positions in the source room.

For some samples with the concrete top layer, the bottom layer of the sample was not equally adjacent to the heavyweight floor, since it was not perfectly flat due to the deformations ensuing from the production process. The samples were distorted while drying. In order to homogenize the measurements for all the measurement samples, some measurements were taken with a thin (about 5 mm thick) layer of sand applied between the measurement sample and the heavyweight floor.

All the results are based on the sound measurements in the same room as the impact sound source covered with the insulation case. The measurement setup is shown in Fig. 1.

In Table 2, measurement options are presented. The averaging time was 15 seconds, the number of microphone positions was six, equally distributed in the source room. For the selected options, the measurements were taken for three different densities (from the range 240 – 520 kg/m^3) of the samples.

Table 2. Measurement options. All parameters were obtained in 1/3 octave bands in the range 100 – 3150 Hz.

No.	Parameter	Measured parameter, dB	Additional vinyl layer	Top concrete layer	Bottom sand layer
1	$L_{S,Vin}$	L_{eq}	YES	NO	NO
2	$L_{S,Con}$	L_{eq}	NO	YES	NO
3	$L_{S,Con,Sand}$	L_{eq}	NO	YES	YES

3. Measurement results

In Figure 2 the results of the impact sound reduction for the lightweight floor screed with three different top covers are presented. As it was noted in [4], the unprotected top layer of the sample was permanently deformed by tapping machine hammers. The cavities under the hammers could increase the results. In the first option, the sample was covered with a vinyl with low impact sound reduction. The obtained results ($L_{S,Vin}$ in Fig. 2) were similar to the not-protected sample (L_S). For the characteristics presented in Fig. 2, ΔL_w parameter was 1 dB higher for the vinyl measurement. In the next step, a thin layer of concrete was applied on top of the sample. Despite the difference in ΔL frequency characteristics visible in Fig. 2 (solid line stands for Concrete top layer, while dashed line stands for vinyl top layer), the value of ΔL_w index was the same as for the sample without the top layer (both 5 dB).

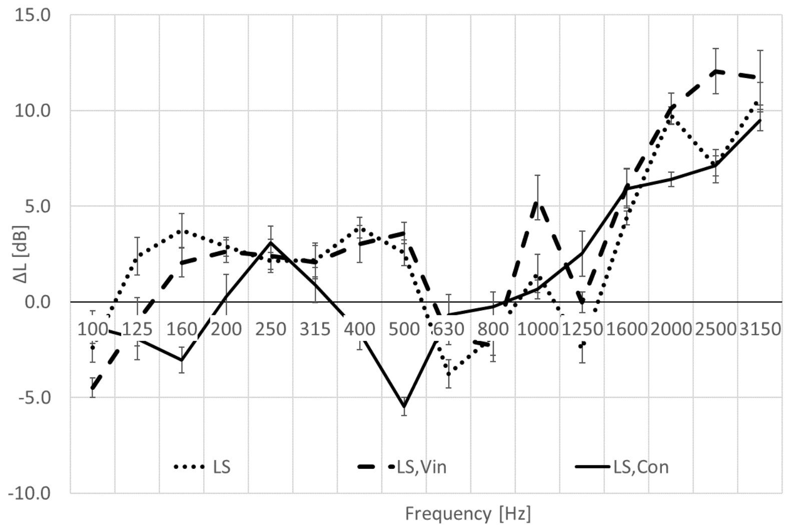

Figure 2. The influence of the top cover of the sample on *ΔL* results (with standard deviation). Measured parameter: L_{eq}. Solid line – with 2 cm concrete on top of the sample, dashed line – with the vinyl top layer, dotted line – without any top layer.

The concrete top layer caused slight deformations of some of the samples, which worsen the contact between the sample and the heavyweight ceiling. In order to improve the adherence and make the measurements more repetitive, an additional thin layer of sand was applied between the sample and the ceiling. The results for the measurement samples with different densities with and without the sand layer are presented in Fig. 3. For all samples, the frequency characteristics of the impact sound reduction with the sand layer show fewer local extremes which is especially visible for the mid-frequency range (315 –

1000 Hz). The extremes observed for the sample without the sand layer could be caused by inaccurate adherence of the sample and the heavyweight floor below. The sand homogenizes the connection and transmission of the vibration generated by the tapping machine through the sample to the heavyweight floor. This results in smoother characteristics.

For the sample with the lowest density (267 kg/m³), the weighted reduction in impact sound pressure level ΔL_w increased from 11 to 12 dB after using the bottom layer of sand. The frequency characteristic is higher for all frequency bands above 800 Hz. For other samples of densities 280 and 303 kg/m³, the impact sound reduction is lower with the sand layer for this frequency range by about 3 dB. The calculated ΔL_w values are also lower. For the 280 kg/m³ sample, ΔL_w was reduced from 10 to 9 dB, while for the 303 kg/m³ sample, ΔL_w was reduced from 10 to 8 dB.

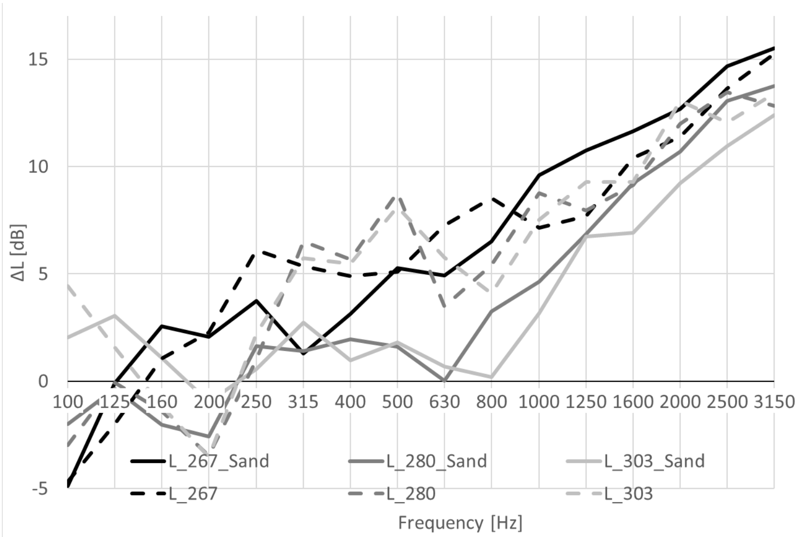

Figure 3. The influence of the bottom sand layer on ΔL results for different densities of lightweight screeds. Measured parameter: L_{eq}. Solid line – with sand, dash line – without sand. Values in legend stand for densities of the lightweight screed given in kg/m³.

Weighted reductions in impact sound pressure level ΔL_w for different densities of samples are presented in Fig. 4. Apart from the ΔL_w of samples presented in Fig. 3, there are also samples with much higher densities (about 520 and 600 kg/m³). All samples were measured in the same conditions (concrete top layer and sand between the sample and the heavyweight floor). The approximation with the logarithmic function gave the following equation:

$$\Delta L_w = -8.874 \ln \rho + 60.386, \tag{1}$$

where ρ stands for the density of the sample. Coefficient of determination $R^2 = 0.87$.

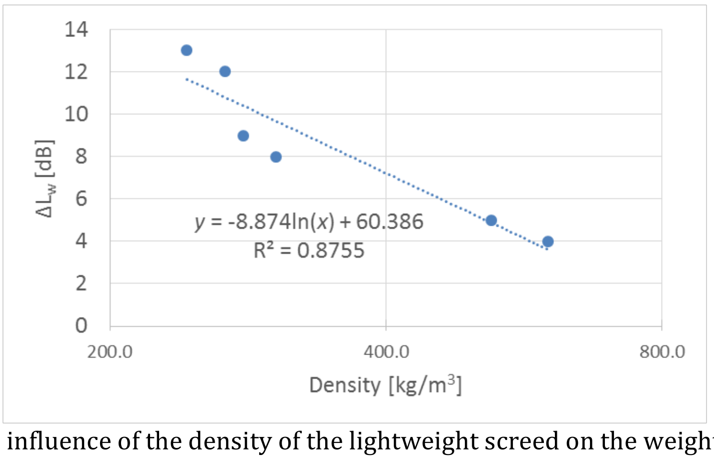

Figure 4. The influence of the density of the lightweight screed on the weighted reduction in impact sound pressure level ΔL_w.

4. Conclusions

The paper is a continuation of the work published in [4], presenting a modification of the measurement method of impact sound reduction for lightweight floor screeds. Because of the deformation of the samples by the hammers of the tapping machine, different methods of protection were tested. The results of vinyl protection presented in the previous paper are supplemented with the results for the sample with a thin (about 2 cm) layer of concrete. This solution apart from the mechanical protection, makes the sample more similar to its final application in buildings. Because of the sensitivity of the contact between the sample and the heavyweight floor, an additional layer of sand was considered to homogenize this adherence and improve the transfer of vibrations from the sample to the heavyweight floor.

Introducing a concrete top layer did not affect the weighted reduction in impact sound pressure level of the samples. Sand bottom layer corrected single-number quantity ΔL_w by ± 2 dB, smoothing the frequency characteristics of reduction in impact sound pressure level, especially for middle and high-frequency bands. The weighted reduction ΔL_w depends mainly on the density of the sample. Logarithmic function approximates the results with the coefficient of determination equal to 0.87.

In the next tests, it is planned to develop material and mechanical parameters to allow maximizing acoustic performance while keeping the required mechanical parameters of the floor. Numerical model of the sample will be calibrated with selected measurements [6] to find more parameters that can influence the acoustic performance of the lightweight floor screed.

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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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