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Impact Sound Reduction Measurement Method for Lightweight Floor Screed

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Abstract Development and implementation of a new product in the form of a lightweight screed with high impact sound reduction require a lot of measurements of different aggregates of lightweight elements and filling. The manufacturing process influences the final parameters of the solutions as well. This is why a method was developed, that allowed a comparison of many different samples within one measurement session. The measured samples must therefore be small and easy to move. In the paper, various possibilities of impact sound reduction measurements were analyzed being different variants of the normative methods and those existing in the literature on the subject. Based on the obtained results, it was shown that for lightweight floor screeds, sound pressure level measurement is more reliable than vibration acceleration measurements. The top vinyl layer used between the tapping machine and the sample did not influence the results significantly and protected the sample from being distorted by the tapping machine hammers.

Keywords: lightweight floor screed, tapping machine, vibration, impact sound reduction

1. Introduction

Impact noise in buildings is produced mainly on floors by people walking or objects falling and hitting the floor. It is transmitted through the structure of the building and can be radiated not only to the room next to the sound source but also on the other side of the building. That is why its reduction is the most effective on the source side, by limiting the penetration of vibrations into the structure of the building. Attempting to reduce structure-borne sound on the listener's side is usually ineffective and/or much more expensive. Being highly irregular and impulsive, impact noise can lead to considerable discomfort [1] and even crime [2].

The existing legislation protects the users of multistorey buildings by introducing maximum sound levels that can be transmitted from the neighboring apartment, public corridors, as well as technical and service rooms of the buildings [3]. The impact noise is generated primarily on the floor surface, hence the structure of this element has a decisive impact on meeting the legal requirements. The most important feature of the slab is to ensure an appropriate load capacity, hence the elements of high stiffness are usually used. This kind of material efficiently transmits structure-borne noise to other rooms', so it cannot be used solely. Obtaining sufficiently low levels of impact sounds requires the use of additional floor layers reducing the amplitude of vibrations penetrating the building structure. The most common and effective solution is to use a floating floor. It consists of two layers – floating slab and resilient underlays. The use of an appropriately low dynamic stiffness of the resilient underlays and high mass of the floating slab allows for a low value of the resonance frequency of the entire system, and thus high efficiency in damping vibrations in the full range of human hearing. The use of floating floors is, unfortunately, often impossible in the case of existing buildings with a limited ceiling load capacity or where it is not possible to significantly increase the existing floor level and thus reduce the volume of the room. The most popular method of reducing impact noise in such a situation is a light floor layer, e.g. a carpet with an integrated damping layer. In the case when the floor needs to be leveled or its stiffness is too low, lightweight floor screeds can be considered as an alternative to the traditional floating floor. The much lower density of this type of solution allows it to be used in the case of ceilings with a much lower load-bearing capacity. Light screeds owe their low density to the use of lightweight aggregates such as expanded clay, expanded perlite, foam glass, or expanded vermiculite. By selecting the appropriate proportions and type of aggregate and binder, it is possible to obtain the desired acoustic and mechanical properties. The development of a recipe and implementation of a lightweight screed with such properties is the subject of a research and development project by J.P. Cover sp. z o.o. At the initial stage of the project, it was necessary to develop a measurement method that would allow controlling acoustic parameters of screeds at the subsequent stages of designing aimed at the desired mechanical and acoustic effects.

The method of measuring the improvement of impact sound insulation is described in the ISO 10140-1 and ISO 10140-3 standards [4,5]. It requires the use of standard coupled chambers and a reference floor, on which a 10-12 m^2 sample is mounted. A simplified variant of the measurement that can be performed without the reference floor is presented in the ISO 16251-1 standard [6]. The method uses a small measurement sample and is based on vibration measurements on the surface of a concrete block instead of measuring the sound pressure level in the receiving chamber. The method gives correct results for soft floor covering acting locally (vinyl with or without flexible underlayers, linoleums). It was also validated for the floating floors [7]. Another variant of simplified measurements for a small sample was presented in the work of Baruch et. al. [8]. The measured quantity was the sound pressure level in the room with the tapping machine. The extraction of tapping machine hammers structure-borne sounds was possible thanks to the use of an air-borne sound insulation case for a tapping machine and a tested sample. The correctness of the proposed method was supported by calculations using the Statistical Energy Analysis (SEA) and measurements made for different floor coverings and different heavyweight floors on which the coverings were applied.

This article presents the results of research and analysis of various modifications of the existing methods of measuring impact sound reduction, allowing for the selection of the best method for analyzed sample type. Results for sound and vibration were compared and different localizations of microphones were analyzed. As the results depend on the top layer of the screed, a comparison between the vinyl floor covering and thin foil was made. The description of the samples is presented in Section 2. Measurements methods are presented in Section 3, while Section 4 contains results. In Section 5 some conclusions and further works are presented.

2. Measurement sample

The assumption for the development of a lightweight screed was to obtain a single-layer structure 10 cm thick with a high improvement of impact sound insulation and meeting the requirements for mechanical properties given in the PN-EN 13813 standard [9]. Low sample density (in a dry state up to 850 kg/m^3) was obtained thanks to the use of lightweight aggregates. Their mechanical properties made it possible to obtain significant elasticity and damping of the screed, which allowed for vibration damping and thus a significant improvement of impact sound insulation. Therefore, the samples cannot be unequivocally classified into any of the categories listed in the ISO 10140-1 standard [4]. Based on preliminary measurements, the number of different samples that need to be analyzed, and the results presented in [7,10], it was decided to analyze small samples.

Based on the available research room and equipment, the dimensions of samples for acoustic tests were determined to be 500 x 900 x 100 mm. The samples were cast in a mold in a dedicated location in the test room. Measurements were taken at least 28 days after the samples were cast, allowing the material to fully bond. Each sample was poured on a thin foil, which did not affect the sound transmission and allowed the sample to be moved to a different location. During the project implementation, several dozen different samples were planned to be measured, hence it was necessary to select a measurement method that would meet all the requirements.

3. Measurements method

The measurement of the improvement of the sound insulation ΔL was performed based on the method described in [8]. The measuring stand is shown in Fig. 1.

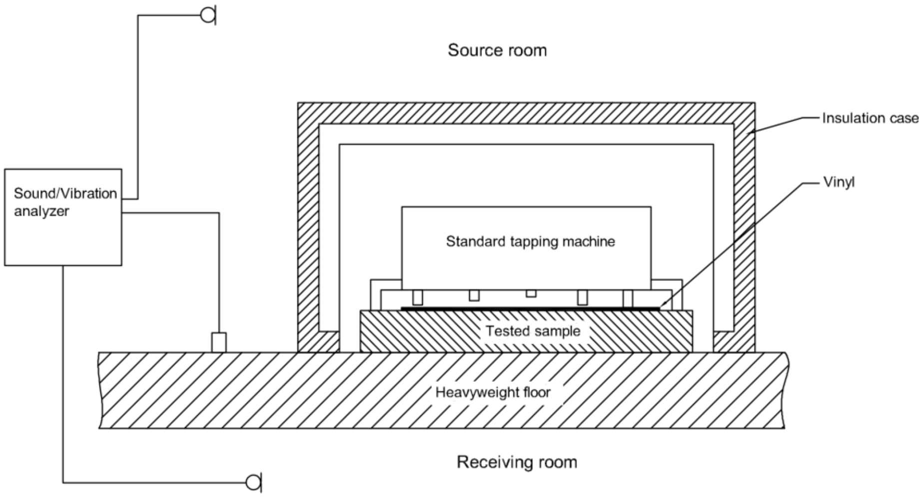

Fig. 1. Setup for the improvement of the sound insulation ΔL measurement. The vinyl layer marked in the figure was used in selected measurements (Vin subscript in Tab.1.). The accelerometer and microphone were placed in six different positions (microphone in the source or receiving room).

Because the mechanical properties of lightweight floor screeds differ from those of the materials verified during the method development, several measurement options were analyzed to obtain reproducible results.

Measurements were made for two different measurement samples for various setups and analyzed parameters. The starting point for the measurements method was the publication by Baruch et. al [8], i.e. the measurement of the sound pressure level in the source room (room with the sample and the tapping machine) after isolating the noise generated by hammers hitting the underlay with a highly sound-insulating case (Tab. 1., parameter $L_{S,C}$). As a result, the noise that was measured was generated in the vast majority by vibrations of the floor under the screed and the walls surrounding the room. In a further variant, the noise was measured in a room below the one on which the floor screed was used ($L_{S,C,B}$). The measurement option is similar to the ISO 1040-3 standard method differed only with the size and the type of the heavyweight floor. Due to the possible flanking transmission of the source and receiving rooms, the airborne noise of the hammers was reduced by using the same case as above for a tapping device and a measured sample.

Lightweight screed due to its mechanical properties cannot be used without the final (top) layer. For options where hammers were directly (of through thin foil) hitting the screed, it was noticed that the sample is permanently deformed at the point of impact of hammers. To eliminate this phenomenon, and to simulate real usage of a screed, a vinyl lining (thickness 5 mm) with a low improvement of impact sound insulation was used. Options, for which vinyl lining was used are described in Tab. 1. With "Vin" in subscript (e.g. $L_{S,Vin,C}$). That solution limited the impact force and increased the surface area of the hammer's impact.

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

Lp.	Parameter	Measured parameter, dB	Transducer localization	Additional vinyl layer	Insulation case
1	$L_{S,C}$	L_{eq},	source room	NO	YES
2	$L_{S,C,B}$	L_{eq}	receiving room	NO	YES
3	$L_{S,B}$	L_{eq}	receiving room	NO	NO
4	$L_{S,Vin,C}$	L_{eq}	source room	YES	YES
5	$L_{Vib,C}$	L_a	source room	NO	YES
6	$L_{Vib,Vin,C}$	L_a	source room	YES	YES

The tests were carried out using both the microphone signal (measurement of the equivalent sound pressure level L_{eq}, in the table the values described with the "S" in subscript) and the accelerometer (measurement of the vibration acceleration level L_a, in the Table described with the "Vib" subscript) placed in various locations. The averaging time was 15 seconds, the number of microphone/accelerometer positions was six. The sample was placed at different locations within one room. For each variant, the measurement was repeated with the same layout but without the floor underlay. The influence of the underlay for the exemplary measurement variant was calculated as

$$\Delta L_{S,Vin,C} = L_{0,S,Vin,C} - L_{S,Vin,C} \quad (1)$$

where $L_{0,S,Vin,C}$ is the equivalent of the measurement of the $L_{S,Vin,C}$ but without the measurement sample. Single-number values were determined following ISO 717-2 [11].

Before the measurements, the acoustic treatment of the research room was carried out. On two perpendicular walls, sound-diffusion structures with low absorption coefficient for medium and high frequencies were installed. This allowed increasing the diffusion of the sound field in the room [12], which resulted in greater uniformity of the value of the sound pressure level in different positions of the room and the lengthening of the reverberation time in the room [13].

4. Measurement results

Figure 2 shows a comparison of the improvement of the impact sound insulation measured in the receiving room for the option with and without the sound-insulating case for the tapping machine. In the case of laboratories divided by a reference ceiling, which has high air-borne noise insulation between the source and receiving chambers, the dominant noise in the receiving room is the one generated by vibrations of the ceiling and walls, i.e. structure-borne noise. In the case of the room where the measurements were carried out, the airborne sound insulation was not sufficient. The use of the sound-insulating case for the tapping machine increased the impact sound insulation of the tested foundation, in particular for high frequencies - above 1000 Hz. For low and middle frequencies, both the screed and the insulating case did not have a significant impact on the structure-borne sounds in the lower room – the values fluctuated in the range of +/- 2.5 dB. The differences in the values did not affect the single-number quantity – in both cases, it was equal to 7 dB.

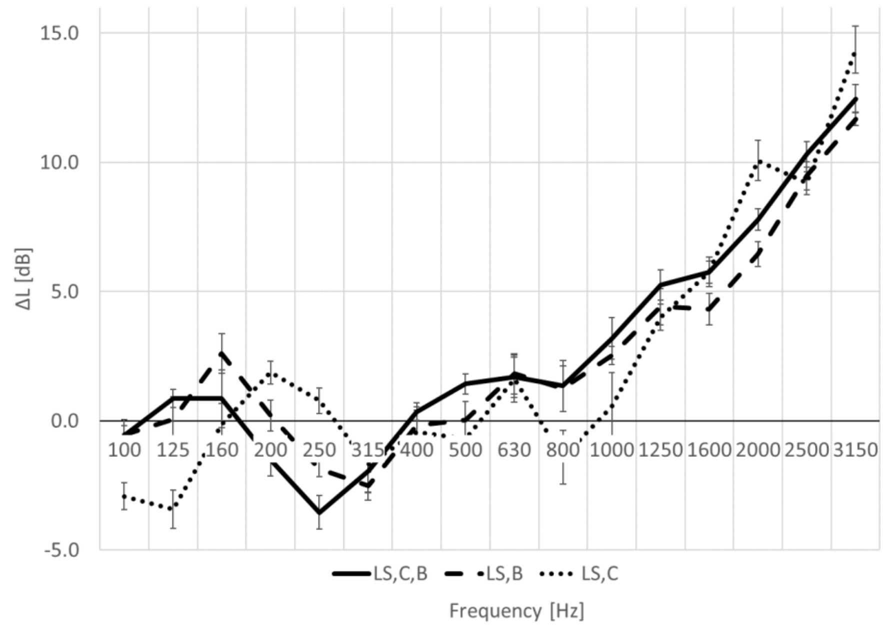

Fig. 2. The influence of the insulation case and receiving room localization on ΔL results (with standard deviation). Measured parameter: L_{eq}. Solid line – with the insulation case, measured in receiving room, dash – without the case, measured in the receiving room, dotted – with the case, measured in the source room.

The frequency characteristic of the improvement of the impact sound insulation for the measurement in the same room (parameter $L_{S,C}$) differs from the other curves in Fig. 1. by a greater number of local extrema (e.g. for frequencies 800 and 2000 Hz). However, it should be noted that the single-number quantity was the same for all options: 7 dB.

For another measurement sample, a comparative analysis of the frequency characteristics of ΔL obtained based on the measurements of various acoustic signals was carried out: acceleration level – L_{Vib} and sound pressure level (L_S). In Fig. 3. the values obtained for the sample covered with a thin vinyl lining ("Vin" subscript) and without this element are compared. The air-borne sound insulation case (subscript "C") was used in each case. Higeher values were obtained for measurements with the use of an additional layer of vinyl (used in both – with and without sample measurements). Although sound and vibration based characteristics are similar (especially for mid and high frequencies), standard deviations for sound are much smaller (below 1 dB) than for vibrations (around 2 dB, and even 5 dB for mid frequency bands).

Frequency characteristics of parameter $L_{\mathrm{S,C}}$ of first (Fig. 2) and second (Fig. 3) sample differs mainly at low frequency range. Second sample (Fig. 3) due to different density and material fraction has two resonances (around 160 and 500 Hz) improving the impact sound insulation at that frequency range.

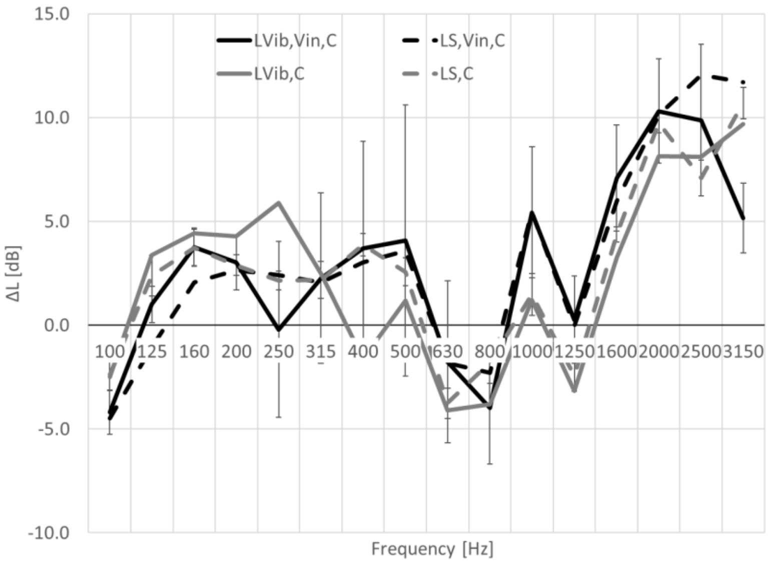

Fig. 3. The influence of the measured parameter (S – sound, Vib – vibration) and an additional layer of vinyl (Vin) on ΔL results. Standard deviation given for $L_{Vib,Vin,C}$ and $L_{S,C}$ only.

Based on the analysis of the obtained results (Figs. 2 and 3), a decision was made to measure with the use of the sound insulation case, in the same room where the measuring sample was placed (the source room) with the use of an additional top layer of a vinyl lining. In this configuration, the measurement of vibration acceleration and acoustic pressure gave similar values with much smaller standard deviation of sound pressure level based measurements.

5. Conclusions

The paper presents an analysis of various possibilities of measuring the improvement of impact sound insulation for lightweight screeds. Due to the mechanical properties of the screed and its target use, it was necessary to adapt the engineering method described in [8]. Using various measurement samples, taking into account the characteristics of the insulation improvement and the single-number quantities obtained based on [11], it was shown that for a given type of sample it is possible to measure vibration acceleration or sound pressure level in the same room with the sample and the tapping machine. Therefore it is necessary to use the sound-insulating case. Due to the fragility of the measurement samples and its final use, it was proposed to use an additional surface layer that does not significantly affect the results obtained based on the sound pressure level and improved vibration-based results. For measurements with an additional vinyl top layer, the values obtained from the measurements of sound pressure and vibrations were similar in terms of both frequency characteristics and single-number quantities. Based on standard deviation of ΔL analysis, sound pressure level measurements were selected as biased with smaller uncertainty.

In the next tests, it is planned to develop a test method for lightweight ceilings described in ISO 10140-3 [5] and to use other top layers to check how they affect the insulating performance of the screed itself and the parameters of the entire floor structure.

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Additional information

The authors declare no competing financial interests.

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