

Field measurements of airborne sound insulation between office rooms

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Abstract The article presents the results of field measurements of apparent sound insulation between office rooms separated by a lightweight skeleton wall with plasterboard cladding and mineral wool filling. The tests were carried out in the same office rooms, but the connection method of the wall with the façade post was changed. Thanks to this, the impact of the connection method of the wall with the post on sound insulation between the rooms was determined. In addition, the measurements were repeated for the "best" connection variant, but only after the completion of the finishing stage of the rooms. The finishing works consisted in the construction of raised floor and suspended ceiling, laying floor covering and furnishing. Additional service ducts between the rooms were also made during this stage. The effect of these works had a significant impact on the reduction of sound insulation. The article presents potential causes of this phenomenon.

Keywords: apparent sound insulation, airborne sound insulation, lateral transmission, improvement of sound insulation, office building.

1. Introduction

The requirements for airborne sound insulation for internal walls in a building are defined by the provisions of the standard [1] and, in general, by the provisions of the Construction Law [2] as well as by the regulation [3]. For the existing buildings, verification of the requirements can be carried out using field measurements [4, 5], by direct comparison of the results with the requirements [6-8]. At the design stage, checking the requirements involves the need to perform calculations in accordance with the applicable standard model [9]. The most common solution used for walls separating office rooms involves lightweight structures on a steel skeleton frame with plasterboard cladding and mineral wool filling. The above group of solutions has, in most cases, sound insulation parameters confirmed by laboratory tests. Theoretically, the task of choosing a wall adequate to the requirements seems to be uncomplicated. In reality, however, it often turns out that the results of field measurements significantly differ from the values predicted at the design stage. The expected accuracy of calculations using a model in the case of massive buildings, expressed in terms of standard deviation, is about 1.5 dB [4]. The above predictions are confirmed by comparative studies of field research outcome with the results of calculations [7, 8, 10, 11]. In the case of lightweight walls, the expected accuracy is lower and depends to a large extent on the correctness of the data entered regarding sound insulation, including the flanking normalized level difference $D_{n,f}$ for the façade [12, 13]. At this point, it should be noted that the availability of this parameter for façade systems is very limited. The quality of workmanship is also a very important factor. In the context of the above facts, the results of field tests of sound insulation appropriate for variant solutions for the connection of stud wall with the façade post can be a significant contribution to the knowledge in the field of design and optimization of such project realizations.

2. Methodology

The field measurements were carried out using the methodology contained in the standards [4], referred to in Annex 1 to the Regulation [3]. While carrying out the research, the provisions of the current standard [5] were additionally taken into account, although it was not yet included in the Annex to the Regulation.

2.1. Terms and definitions

Basic terms and definitions necessary in view of the subject discussed in the article are presented below. Apparent sound reduction index R' in decibels:

$$R' = L_1 - L_2 + 10 \log \frac{S}{A}, \quad (1)$$

where L_1 is the average sound pressure level in the source room in decibels, L_2 is the average sound pressure level in the receiving room in decibels, S is the area of separating element in m^2 , A is the equivalent sound absorption area in the receiving room in m^2 .

Weighted apparent sound reduction index R'_w is the apparent airborne sound reduction determined in the standard frequency range of $100 \div 3150$ Hz, reduced to a single-number value in accordance with the method specified in ISO 717-1:2021-06 [14].

The spectrum adaptation indexes C and C_{tr} should be used to account for the diversity of spectra of noise sources (such as pink noise and traffic noise) and to evaluate sound reduction curves in accordance with the method specified in ISO 717-1:2021-06 [14]. The two spectrum adaptation indexes, separated by a semicolon, should be given in parentheses after the single-number weighting factor. In order to determine whether the requirements are met by an element or partition in a building, in accordance with the PN-B-02151-3:2015-10 standard [1], an appropriate rating of sound reduction indexes should be used, $R'_{A,1}$ for internal partitions and $R'_{A,1}$ or $R'_{A,2}$ for external partitions (depending on the noise spectrum):

$$R'_{A,1} = R_w + C, \quad (2)$$

$$R'_{A,2} = R_w + C_{tr}, \quad (3)$$

where $R'_{A,1}$ is the weighted apparent sound reduction index with spectrum adaptation term 1 in decibels, $R'_{A,2}$ is the weighted apparent sound reduction index with spectrum adaptation term 2 in decibels.

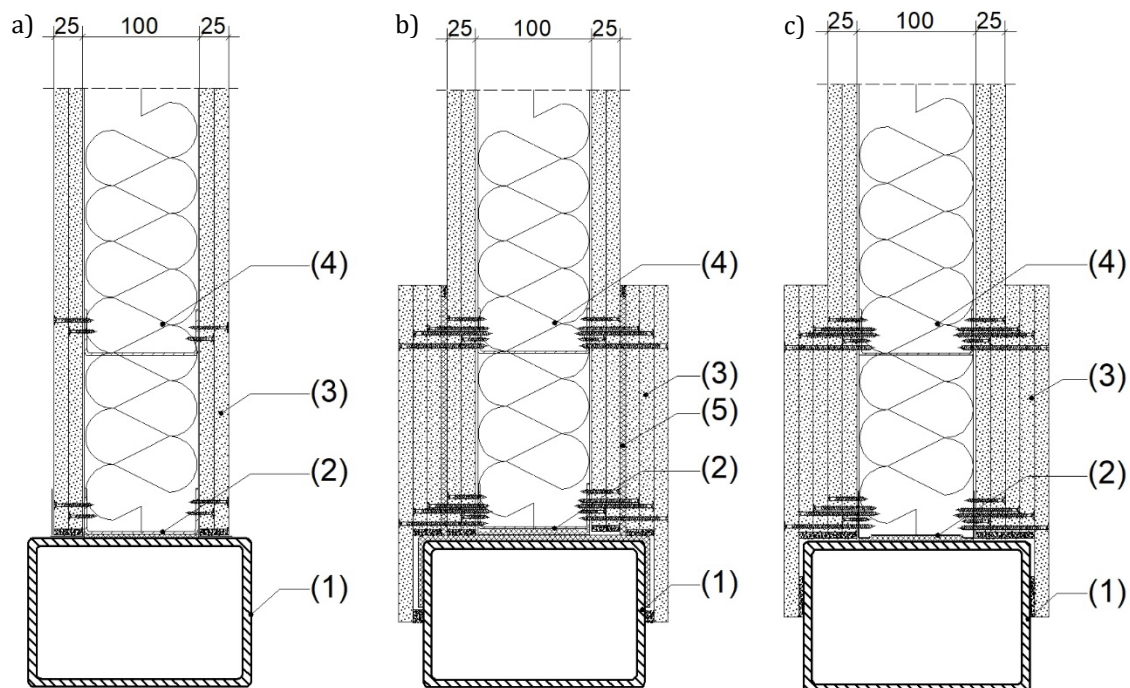


Figure 1. Section through the stud wall at the connection point with the façade post. The drawing shows three different connection ways of the wall with the façade post: a) variant 1, b) variant 2, c) variant 3.

Elements and materials used in the joints: 1) façade post, 2) steel profile systems with acoustic tape, 3) plasterboard, 12.5 mm, 4) mineral wool, 100 mm thick, 5) thick rubber, 5 mm thick.

2.2. Object characteristics

Field measurements of apparent airborne sound insulation were carried out in selected rooms located in an office building. The system of test rooms separated by a wall made in the system technology of a lightweight skeleton/stud wall with plasterboard cladding and mineral wool filling was subjected to assessment using field measurements of sound insulation. The wall in question was previously tested in the laboratory. During laboratory measurements of sound reduction index, it yielded the following result: $R_w(C;C_{tr}) = 62 (-2;-5)$ dB. The field tests were carried out for different connection variants of the same wall, with the façade post and for two stages of room finishing, which differed, among others, in the number of 'penetrations' into service ducts. Figure 1 shows three connection variants of the wall with the façade.

Figure 2 shows a fragment of the projection of an office building with the layout of office rooms separated by a stud wall, for which the measurements of apparent sound reduction index were carried out. The arrow indicates the direction of the measurement (from the source room to the receiving room).

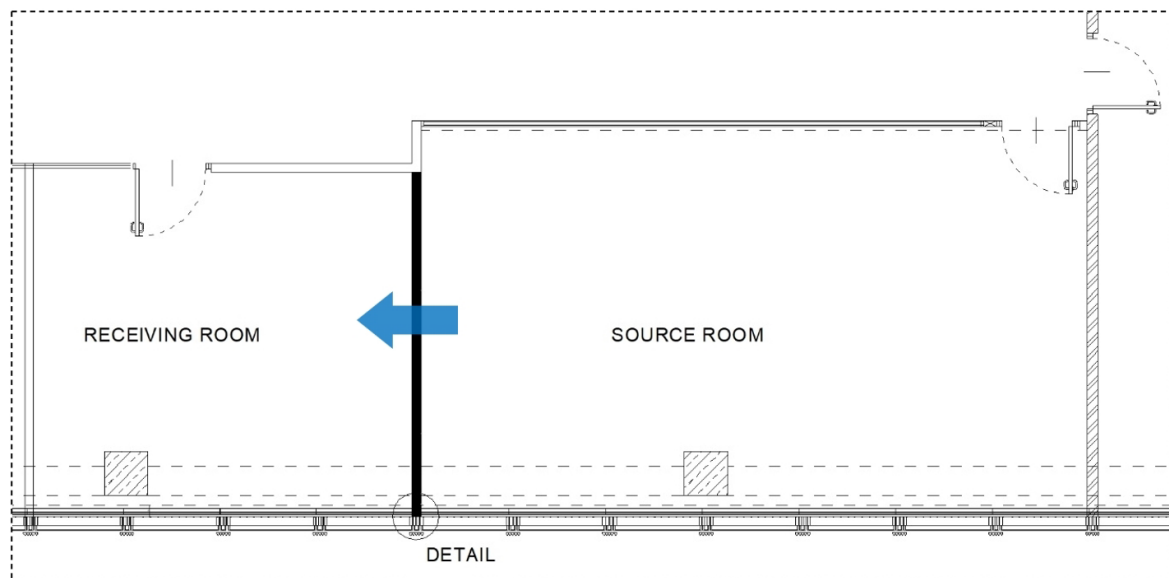


Figure 2. Fragment of the projection of the office building with a layout of rooms separated by a stud wall, for which the measurements of apparent sound reduction index were carried out.

The building was not used at the time of the measurements. At the same time, all construction works in the building were suspended for the duration of the measurements. The measurements were carried out for two stages of room finishing presented below:

- Stage no. 1 (variant 1, variant 2 and variant 3 of wall connection with the façade): the rooms had no doors (door openings for the time of the measurement were secured with specially prepared elements made of plasterboards and mineral wool), no floors on the ceiling slabs, no suspended ceilings, the rooms had sanitary installations whereof ducts were distributed under the ceiling slab between the rooms, the rooms were not furnished.
- Stage no. 2 (variant 3 of wall connection the with the facade): rooms had doors, raised floors were made on the ceiling slabs, the source room had a sound-absorbing suspended ceiling, while the receiving room had no suspended ceiling, the rooms had sanitary installations, the ducts of which were distributed under the ceiling slab between the rooms (compared to stage 1, the number of installations and penetrations through the walls was increased), the rooms were furnished.

Figures 3 and 4 show the view of the rooms during the measurements.



Figure 3. View of the wall in the receiving room. From left: stage 1 and stage 2.



Figure 4. View of the wall in the source room. From left: stage 1 and stage 2.

2.3. Requirements

In terms of the requirements for sound insulation, standard [1] in the regulation [3] is applicable. Table 1 presents the requirements for airborne sound reduction indices for internal walls in office buildings according to PN-B-02151-3:2015-10 [1]. The requirements that are most important from the viewpoint of the article are marked in red.

Table 1. Required sound reduction of selected internal partitions in a multi-family residential building according to [1].

Separating element	Index ratio
A wall without doors between the office rooms and a wall between the office rooms and the corridor	$R'_{A,1} \geq 40$ dB
A wall between conference rooms, including rooms of similar	$R'_{A,1} \geq 48$ dB

3. Results and discussion

Figure 5 shows the measurement results for stage 1, for the apparent sound reduction index R' as a function of frequency for all three variants of the wall-facade connection (Fig. 1). In addition, the graph shows the results of laboratory measurements of the sound reduction index R of the stud wall pattern. Apart from the description of the measurement, the legend contains the results in the form of single-number indices $R'_w(C; C_{tr})$ and $R_w(C; C_{tr})$.

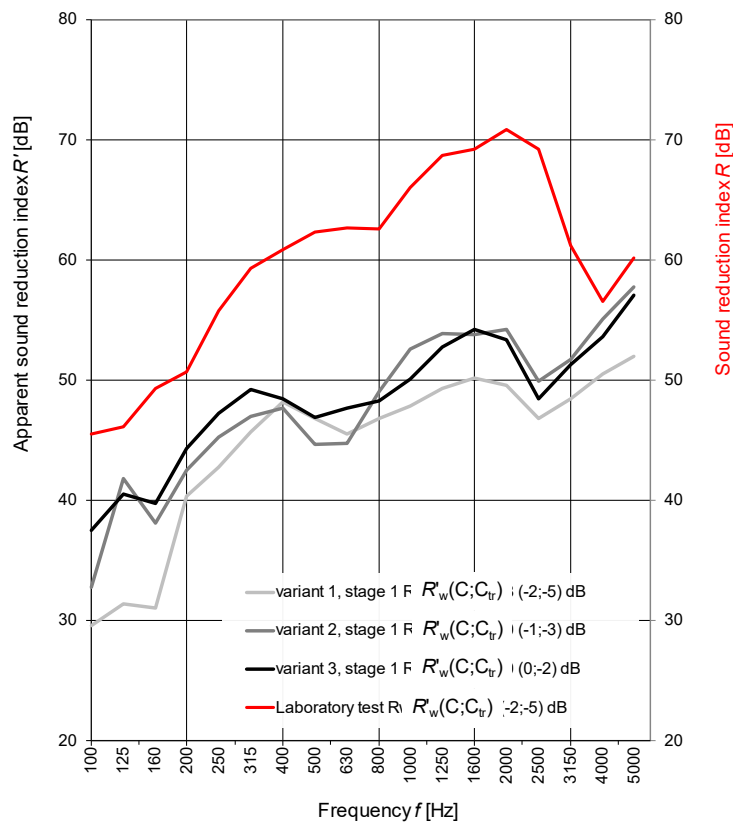


Figure 5. Results of field measurements of apparent sound reduction index R' for stage 1 and for all three variants of the wall-facade connection, and laboratory measurements of sound reduction index R of the wall pattern in 1/3 octave frequency bands.

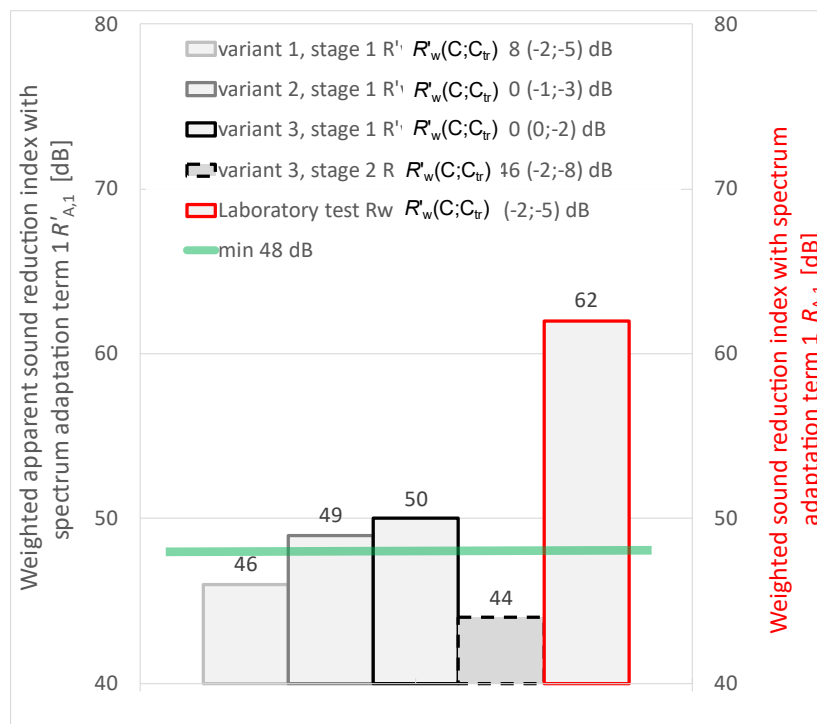


Figure 6. Measurement results in the form of $R'_{A,1}$ index for the tested room layouts separated by a ceiling slab, compared with the requirements for multi-family buildings $R'_{A,1} \geq 48$ dB (Table 1).

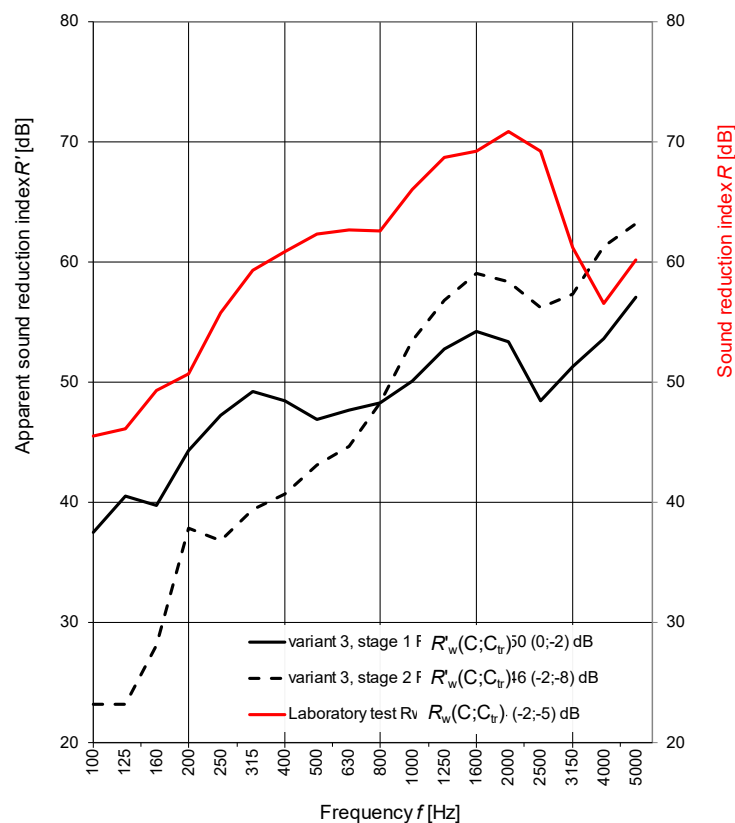


Figure 7. Results of field measurements of apparent sound reduction index R' for stage 1 and stage 2 involving the best way to connect the wall to the façade (variant 3) and laboratory measurements of the sound reduction index R of the wall pattern in 1/3 octave frequency bands.

Based on the results, it can be concluded that variant 1 is characterized by the lowest sound reduction. It concerns the wall connected at the front with the façade post. This solution is the simplest and least labor-intensive of all three tested variants, but the measurement results clearly show that this method of connection results in a significant decrease in sound insulation in relation to the parameters of the wall determined in laboratory tests. The next two tested variants of the wall (variant 2 and variant 3) are characterized by much better sound insulation than variant 1. It should be noted that the tests concerned the same arrangement of rooms separated by the same wall. Only the method of wall connection with the façade post was modified in line with the information presented in Fig. 1. Additional three-layer plasterboard construction was used along the entire height of the façade post. In variant 2, in addition to variant 3, a layer of vibration insulation in the form of rubber was applied. The construction of the façade post resulted in an increase in sound insulation practically in the entire measured frequency range of 100 Hz ÷ 5000 Hz. Noteworthy is the fact that variant 3 had the highest sound insulation. This means that the use of an additional rubber layer did not bring the expected results and this layer in the considered case (variant 2) turned out not only to be redundant, but also slightly lowered sound insulation as compared to variant 3. The above conclusions are confirmed by the results presented in the form of $R'_{A,1}$ indices in Fig. 6. The implementation of additional façade post construction (variant 2 and variant 3) resulted in an increase in sound insulation as compared to the basic solution (variant 1), respectively by the value of $\Delta R'_{A,1} = 3$ dB and $\Delta R'_{A,1} = 4$ dB, where $\Delta R'_{A,1}$ is an improvement indicator in the rating of apparent sound reduction index by additional lining placed on the source and the receiving sides of the façade post. The rise of sound insulation obtained for variants 2 and 3 made it possible to meet the requirements of the standard [1] for walls separating conference rooms in office buildings (Table 1). The requirements determined by the $R'_{A,1}$ index for this case are at least 48 dB, while the values obtained during the measurement were, respectively, $R'_{A,1} = 49$ dB for variant 2 and $R'_{A,1} = 50$ dB for variant 3. This value is lower by 12 dB than the value of $R_{A,1} = 62$ dB obtained for the pattern of this wall in laboratory tests. This means that such are the "losses" of sound insulation related to the transmission of indirect sound between rooms. For variant 3, for which the "best" sound insulation was achieved, the measurements were repeated after the finishing of the office rooms (stage 2). Figure 7 shows the results of these measurements in terms of apparent sound reduction

index R' . The results are presented for stage 1 and stage 2 (before and after finishing of the office rooms). In addition, the graph shows the results of laboratory measurements of the sound reduction index R of the stud wall pattern. The legend, apart from the description of the measurement process, contains the results in the form of single-number indexes $R'_w(C; C_{tr})$ and $R_w(C; C_{tr})$.

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 works carried out for stage 2 on sound insulation between rooms is confirmed by the results presented in the form of $R'_{A,1}$ indices in Fig. 4. The value of $R'_{A,1}$ index for variant 3 and stage 2 was 44 dB, which means a decrease compared to stage 1 by as much as 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 summarizes the complete results of field measurements carried out for all variants of the wall, both for stage 1 and stage 2.

Table 2. Summary of results of all field measurements.

Variant of wall-facade connection	Laboratory tests $R_w(C; C_{tr})$ [dB]	Stage 1 $R'_w(C; C_{tr})$ [dB]	Stage 1 $R'_w(C; C_{tr})$ [dB]
Laboratory test	64 (-2;-5)	—	—
Variant 1	—	48 (-2; -5)	—
Variant 2	—	50 (-1; -3)	—
Variant 3	—	50 (0; -2)	46 (-2; -8)

4. Conclusions

The results of field tests of apparent airborne sound insulation between office rooms described in the article differ significantly from the results of measurements obtained in laboratory conditions. In the first stage, the lowest insulation was obtained by variant 1. The value of the $R'_{A,1}$ indicator was only 46 dB compared to the laboratory value $R_{A,1} = 61$ dB. The change in the connection method of the wall with the façade through the casing with a gypsum plasterboard of the façade post allows for an increase in the value of the $R'_{A,1}$ index by 4 dB (variant 3). The use of an additional layer of rubber did not bring the expected results (variant 2). Rubber turned out to be useless and resulted in a slight decrease in insulation compared to variant 3. The value of the $R'_{A,1}$ index obtained for finished rooms and for the entire number of installations is lower than the value of the $R_{A,1}$ index obtained in laboratory tests of the wall pattern by 18 dB (variant 3 and stage 2 $R'_{A,1} = 44$ dB). The results of field measurements indicate a significant impact of longitudinal sound transmission through the facade of the building and penetration of the walls by service ducts. The limited computational possibilities in terms of taking these phenomena into account at the design stage mean that the results of field measurements for variant solutions of the connection of the stud wall with the façade post presented in the article can provide a significant assistance in designing and optimizing such implementations.

Additional information

The author(s) 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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