Comparative Measurements of Sound Insulation of Materials Placed in Small Size Acoustic Chamber

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Abstract – ***An original experimental set-up have been proposed for comparative measurements of sound insulation of building materials. As a sound source room is used a small size acoustic chamber, specially built in a real size room, which is utilized as the sound receiving room. The experimental results, obtained by this small size acoustic chamber test method are verified by standard field measurements and theoretical calculations using specialized Insul software. The agreement is very satisfactory. The described method appears to be intermediate between methods, using down - scaled acoustic chambers and real-size standard measurements. So it is concluded that it is a different and acoustically more favorable way for the aim of comparing the sound insulation properties of building elements.***

Keywords – ***Sound insulation, small size acoustic chamber, building acoustics, comparative measurements.***

I. INTRODUCTION

The small size acoustic chambers save space, time and costs, while providing sufficiently reliable results on the materials sound insulation by improving the details and accuracy of calculation methods and helping to optimize new building materials and materials combinations. Laboratory scaled models for measuring the sound insulation of small test elements have been built in various universities and testing institutes [1], [2], [3], [4]. Most of them have down-scaled dimensions of a standard laboratory for testing sound insulation according to the standard [5].

The accuracy of standardized laboratory measurements has also been discussed for a long time and various solutions have been proposed to reduce differences due to variations in their performance and measurement conditions. In addition, the standardized laboratory requires a minimum reverberation time of the receiving room.

One of the main challenges associated with down scaled chambers is to achieve a diffuse sound field in the chamber. Diffusion is a measure of the uniformity of the distribution of sound in the room and is characterized by two criteria: spatial diffusion and directed diffusion. Spatial diffuse reflection ensures uniformity in the distribution of sound energy at each point of the room. Usually reasonably long reverberation times improve spatial diffusivity. The reverberation time in a standardized laboratory for measuring sound transmission loss is in the range of 2 to 10 seconds, while down scaled chambers show a shorter reverberation time - less than 2 seconds and in some cases even shorter than 0.5 seconds [6], [7]. Directed diffusion is a measure of the randomness of the angles of incidence of sound waves and is improved by converting the regular geometric proportions of the room into an irregular shape with a comparable volume. The problem of small scaled chambers mainly with the creation of a diffuse field in the receiving room is well known.

In these studies, the small size acoustic chamber (built in the Physics Department of UACEG), used as a source room, was combined with a receiving room of a real size. In this way a better diffuse field is achieved and the formation of standing waves in the receiving room is avoided. These effects lead in the research to a good agreement of the measurement results, obtained by the small size acoustic chamber test method and in real conditions, which contributes to the successful application of the small size acoustic chamber in the comparative study of the sound insulation of building elements [8].

II. THE EXPERIMENTAL SET-UP USED FOR COMPARATIVE MEASUREMENTS OF MATERIALS SOUND INSULATION

In Fig.1 is presented the experimental set-up proposed for the comparative measurements of sound insulation of materials, placed in a small size acoustic chamber. The comparative measurements of sound insulation of materials are carried out in a real size room with a volume of 219 m^3 and not quite parallel walls. The original small size acoustic chamber, built in the room, is used as a sound source room. Therefore in the small size acoustic chamber is staged the appropriate sound source device.

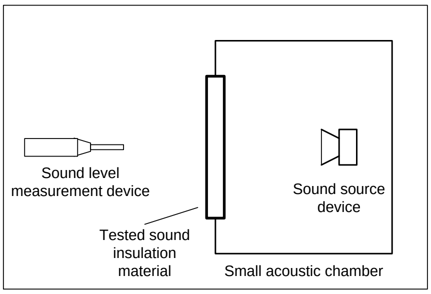

Fig.1. The experimental set-up, used for the comparative measurements of sound insulation of building materials

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The tested sound insulation material is placed in an opening on one side of the small size acoustic chamber. In the room, in front of the tested sound insulation material is mounted the sound level measurement device.

The general view of the proposed experimental arrangement to prepare the comparative measurements of sound insulation materials is presented as picture in Fig.2.

Fig.2. View of the experimental set-up used for the comparative measurements of sound insulation of materials

For the correct measurement of the sample's sound insulation the small size chamber partitions need to be well sound insulated. Therefore, in their construction a three-layer sandwich, consisting of two air gaps of different sizes and three types of solid panels were used, shown in Fig.3 as the corresponding construction of cross-section of the small size acoustic chamber wall.

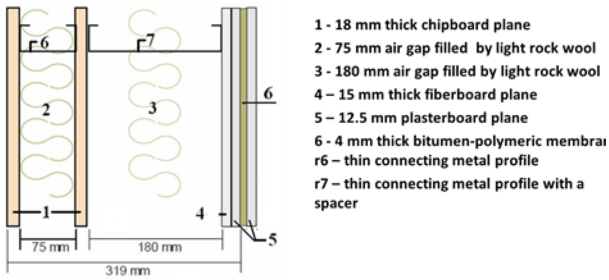

Fig.3. Cross-section of the small size acoustic chamber wall

Different air gaps determine different resonances of mass-spring-mass systems. Increasing the second air gap as180 mm, aims to improve the sound insulation in the low frequencies, which compensates to some extent the low weight of the barriers. Light mineral wool was used as a filer in the air gaps in order to improve the sound insulation in the middle and high frequency range. The panels, as it is shown in Table 1, are selected from materials with different volumetric density, thickness, Poisson's ratio and internal loss coefficient, in order to obtain different natural oscillation frequencies and correspondingly mismatched resonant frequencies. A cross-section of the layers of the small size chamber is shown in Fig.3. Chipboard, gypsum fiberboard and gypsum plasterboard planes were used, as well as a layer of bitumen-polymer membrane with a thickness of 4 mm and again gypsum plasterboard with a thickness of 12.5 mm. Thin-layer /0.5 mm/ profiles and spacers made of galvanized sheet metal were used for the load-bearing structure. The total wall thickness is 335 mm.

The parameters of the solid partition panels used in the construction of the small size chamber are given in Table 1. The partition walls of the chamber have produced a sufficient sound insulation index R_w of 60 dB, established experimentally in [8].

TABLE 1.

PARAMETERS OF THE SOLID PARTITION PANELS USED IN THE CONSTRUCTION OF THE SOUNDPROOF CHAMBER.

Material	Density	Elasticity Modula	Coefficient of Poisson	Coefficient of inner losses
---	kg./m^3	GPa	ν	η
Chipboard plane 18мм	662	3.00	0.36	0.018
Fiberboard 15 mm	1180	3,9	0.15	0.01
Plasterboard 12.5 mm	690	2.01	0.24	0.008

An original approximate modeling of the partition walls of the chamber has been performed with the specialized software Insul [9], [10]. A theoretical value of 60 dB sound insulation index is obtained, which is consistent with the experimental results.

Evaluation of sound insulation of materials with index R_w up to 50 dB is possible and for frequencies higher than 630 Hz due to the small internal size of the chamber.

III. RESULTS

A. Comparative studies of the sound transmission through samples of different building materials (plasterboard, OSB, metal sheet, plexiglas) using the small acoustic chamber test method

To investigate the abilities and limitations of the system a comparative measurement of sound transmission through light barriers has been carried out. For this purpose, a pink noise source with a sound pressure of 96.0 dB is placed inside the small size acoustic chamber. When measuring the sound transmission through the elements, the chamber opening is closed by the corresponding element.

The sound pressure level is measured in decibels with a calibrated Sound Level Meter of Pulsar Instruments brand at a distance of 0.70 m from the element. The frequency range from 600 Hz to 8000 Hz is investigated, due to the fact that the internal chamber size prevents the stable propagation of the lower frequencies. The measured signal in the receiving room maintains levels above the permissible difference with the background noise.

The sound pressure loss in the sample D(f) (Level Difference) in decibels is calculated as the difference between the sound pressure level of the source L_1 (f) in dB and the sound pressure level L_2 (f) in dB omitted by the sample for each terz-octave frequency by Eq. 1:

$$D(f) = L_1(f) - L_2(f) \qquad (1)$$

L_1 - average sound pressure level in the source room, dB

L_2 - average sound pressure level in the receiving room, dB.

The experimental results are represented by the curves on Fig.4.

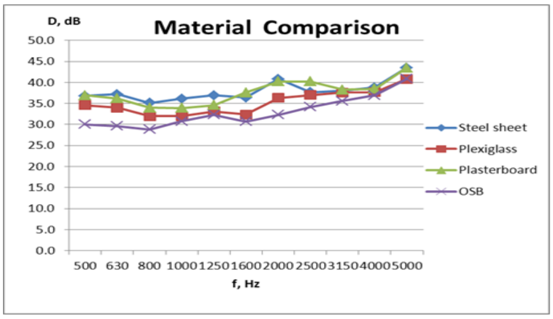

Fig.4. Curves of sound energy losses when passing through the samples - measured values

For frequencies above 1000 Hz the weakest among the studied materials as a sound insulator appears to be the OSB sample (ρ=640 kg/m^3, d=10 mm). Better than it is the Plexiglas sample (ρ=1190 kg/m^3, d=3 mm), and as relatively equally good sound insulators in the high frequency range are gypsum board (ρ=690 kg/m^3, d=12.5 mm) and sheet steel (ρ=7800 kg/m^3, d=1 mm) samples. This is a manifestation of the possibility to compare materials and materials combinations in regard to their frequency characteristics of the sound insulation.

B. Comparative studies of the sound transmission through samples of 10 mm OSB boards - measurements by a small acoustic chamber test method and in real conditions according to EN ISO 16283-1

The results on sound insulation for one definite material /OSB plate/, measured by the small size chamber test have been compared by standard field measurement and by theoretical calculations, using Insul software [9]. The parameters of the investigated 10 mm OSB plates are given on Table 2.

TABLE 2.

PARAMETERS OF THE OSB PLATES.

PROPERTY	TEST METHOD	UNIT	NOMINAL THICKNESS, mm
			6 до 10mm
Bending Strength - major axis	EN 310	N/mm^2	22
Bending Strength - minor axis	EN 310	N/mm^2	11
MOE in bending - major axis	EN 310	N/mm^2	3500
MOE in bending - minor axis	EN 310	N/mm^2	1400

The measurement of the sound transmission through the OSB samples by the small acoustic chamber follows the method, described in part A. The experimental curve of the frequency dependence of the sound insulation is presented on Fig.5.

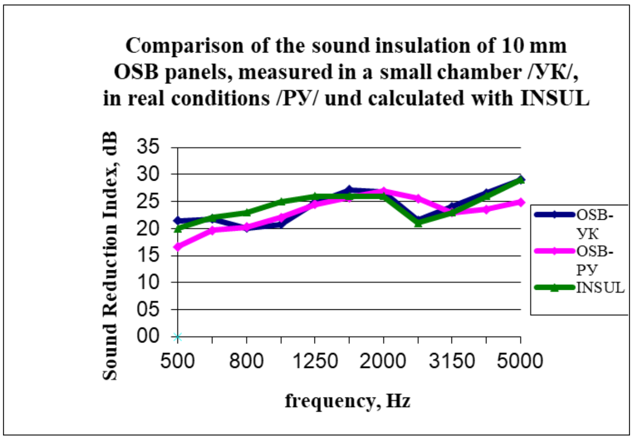

Fig.5. Curves of sound reduction index, measured by the small size chamber test, in real conditions and calculated by Insul software

The results are verified by measurements in reals conditions, second curve on Fig. 5, in accordance with the requirements of the standard EN ISO 16283-1 for on-site measurement of sound insulation in buildings and building elements [11]. The OSB 90/200 cm sample is placed and tightly attached to an opening between two rooms. Equipment according to the standard is used.

The sound reduction index R in dB is calculated by Eq. 2:

$$R = L_1 - L_2 + 10 \log(S/A) \qquad (2)$$

where:
L_1 is average sound pressure level in the source room, dB
L_2 - average sound pressure level in the receiving room, dB
S - area of the test specimen, m^2
A - equivalent sound absorption area of the receiving room, m^2.
The third graph on Fig. 4 represents the theoretical results, obtained by the specialized software Insul.

The results of the three graphs in Fig. 5 generally show a good match. The comparison between the values, obtained by the small chamber test and in real conditions show mismatch at low frequencies up to 630 Hz /due to the chamber limitation in this range/ and a very good agreement in the middle range frequencies /800 Hz - 2000 Hz/, which is important for the assessment of sound insulation of building materials. The results of the theoretical calculation, done by the Insul software, serve to further confirm the experimental results, obtained by the small size acoustic chamber test method.

IV. CONCLUSION

A small size acoustic chamber test method has been proposed for comparative measurements of the sound insulation of building materials. For the needs of the method small size acoustic chamber as a sound source room has been constructed, incorporated in a real size sound receiving room. The possibilities and limitations of this method are as follows:

- Estimates of sound insulation of materials for frequencies greater than **630 Hz** are possible. The limitation is due to the small internal size of the acoustic chamber.
- Sound insulation estimation for materials with sound insulation index $\mathbf{R_w}$ up to **50 dB** is possible. The value is determined by 10 decibels lower than the experimental and theoretical sound insulation of the chamber walls $\mathbf{R_w}$ **~ 60 dB.**

A procedure has been established for measuring the loss of sound pressure in decibels through samples of construction materials f.e.: **OSB, plasterboard, plexiglas, steel sheet**.

The results, obtained by the small acoustic chamber method, have been verified by both experimental measurements in real conditions according to EN ISO 16283-1 and by theoretical calculations using the specialized Insul software. The agreement in the middle range frequencies /800 Hz - 2000 Hz/ is very satisfactory.

Basic advantage of the proposed comparative measurements is that by applying them a correct choice of sound insulation materials can be made. The small size acoustic chamber test method can provide sufficient information on sound insulation of materials in the following cases: when there are no data on the materials sound insulation properties; the materials are under development or used in combination with coatings; calculations of multilayer elements do not give results with sufficient accuracy.

The proposed experimental method using as a small size acoustic chamber as a sound source room and a real size receiving room is a different and acoustically more favorable way in comparing the sound insulation properties of building elements.

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