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Laboratory Evaluation of the Airborne Sound Insulation of Plasterboard Sandwich Panels Filled with Recycled Textile Material

Svetlana T. Djambova, Natalia B. Ivanova, Roumiana A. Zaharieva

***Abstract*—**Small size acoustic chamber test method has been applied to experimentally evaluate and compare the airborne sound insulation provided by plasterboard sandwich panels filled with mineral wool and with its alternative from recycled textile material (produced by two different technologies). An original small-size acoustic chamber is used as a sound source room. It has been specially built in a real-size room, which is utilized as a sound receiving room. The experimental results of one of the recycled textile material specimens have demonstrated sound insulation properties similar to those of the mineral wool specimen and even superior in the 1600-3150 Hz frequency range. This study contributes to the improvement of recycled textile material production, as well as to the synergy of heat insulation and sound insulation performances of building materials.

***Keywords*—**Airborne sound insulation, heat insulation products, mineral wool, recycled textile material.

I. Introduction

THE experimental laboratory evaluation of airborne sound insulation of building elements is important from several aspects:

- *for better living comfort*: The measures against the harmful effects of noise are measures to increase the comfort of life. The quality of life is a main topic not only in the European programs Horizon [1], but also among the Bulgarian state priorities. There are excellent results in the field of thermal insulation and energy efficiency, but in terms of sound comfort there is still much to be desired.
- *for architectural construction practice*: In architectural construction practice, attention is paid to noise insulation mainly in the construction of specialized premises/near airports, highways, production premises, operator cabins, etc. The more common noise from bathrooms and elevators in public and residential buildings is frequently ignored and considered normal.

Manufacturers of materials often have in their catalogs data on the sound insulation index of materials, but in practice combinations of materials are used, for example sandwich panels, which have a total sound insulation index different from the sum of the indices of the participating materials. This also requires a measurement or at least an evaluation of the sound insulation of the building elements.

- *as a verification of any theoretical calculation method*: The use of soundproof chambers for practical verification of the parameters of partition elements is extremely important for building acoustics. There are significant deviations of calculations of the sound energy transmission losses, which also depend on boundary conditions of the element, angle of incidence of the sound wave, atmospheric conditions, etc. There are also difficulties in theoretical calculations when collecting exact values for certain parameters of the specific material (elasticity modulus, Poisson's ratio, internal losses coefficient). Due to the listed features, experimental measurements of specimens are an important mandatory check for any calculation method used.

Sound insulation and other characteristics are generally considered separately from a regulatory and a research point of view. However, they are combined in the use of the structures, which makes the dependence among the different physical characteristics of materials a wide field for research and optimization.

In this paper a combination of thermal insulation and sound insulation performance of sandwich panels with filling of two types of innovative Recycled Textile Material – RTM1 and RTM2 (produced by two different technologies) is sought [2]. RTM1 and RTM2 have been created within the framework of project BG161PO003-1.1.05-0270-C0001 [3] as a sustainable response to the need of environmental protection, by solving the problem of textile waste to a large extent, by contributing to the energy efficiency of building and to the circular economy and by creating new jobs and offering cheaper thermal and sound insulation. With the help of the laboratory small size acoustic chamber, the soundproofing qualities of sandwich panels filled with RTM1, RTM2 and mineral wool have been evaluated and compared.

II. Experimental Set-Up and Procedure for Evaluation of the Airborne Sound Insulation of the Specimens

Laboratory scaled models for measuring the sound insulation of small test elements have been built in various universities and testing institutes [4]-[7]. The applied small size acoustic chamber test method [8] for comparative measurements of sound insulation of building materials is intermediate between

S. T. Djambova is with the Physics Department, University of Architecture, Civil Engineering and Geodesy, Sofia, 1164 Bulgaria (corresponding author, phone: +359-2963-5245-505; e-mail: std_fhe@ uacg.bg).

N. B. Ivanova is with the Physics Department, University of Architecture, Civil Engineering and Geodesy, Sofia, 1164 Bulgaria (e-mail: bobeva_fhe@uacg.bg).

R. A. Zaharieva is with the Department of Building Materials and Insulations, University of Architecture, Civil Engineering and Geodesy, Sofia, 1164 Bulgaria (e-mail: zaharieva_fce@uacg.bg).

methods, using down-scaled acoustic chambers and real-size standard measurements. An original small size acoustic chamber, specially built in a real size room, is used as a sound source room. The real size room is utilized as the sound receiving room. The facility is located in the Physics Department of the University of Architecture, Civil Engineering and Geodesy (UACEG) and has been thoroughly described in the Annual of UACEG [9].

The experimental set-up proposed for the laboratory evaluation of the airborne sound insulation of materials, placed in a small size acoustic chamber, is presented in Fig. 1. The measurements are carried out in the 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, holds the appropriate sound source device.

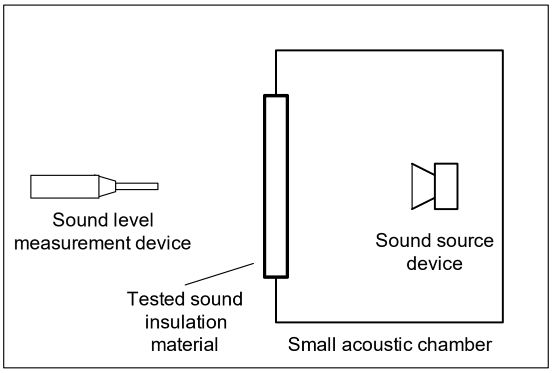

Fig. 1 The experimental set-up, used for the comparative measurements of sound insulation of building materials

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

For the correct measurement of the specimen's sound insulation, the small size chamber partition walls must be sufficiently soundproofed. The partition walls of the chamber have produced a sufficient sound insulation index R_w of 60 dB, established experimentally in [9]. Evaluation of materials sound insulation with index R_w up to 50 dB is possible. The correct frequency range is determined to be above 630 Hz since the internal chamber volume of 0.61 m^3 prevents the stable propagation of the lower frequencies.

III. Comparative Evaluation of Sound Insulation of Sandwich Panels with Different Fillings

A. Materials and Specimens

Specimens of type "Sandwich" with two plasterboard sides and a fibrous filling material between them are used. Plasterboards are of type "A" according to EN 520 with a thickness of 12.5 mm. The surface density of one plasterboard side is about 7 kg/m^2. Conventional wall insulation rock wool of surface density of 4.2 kg/m^2 is used as a filling material for the evaluation of the acoustic performance of the control specimen.

The main raw material for the production of both RTM1 and RTM2 is textile waste from two sources - production of clothes (pre-consumer waste) and old clothes (post-consumer waste). The composition of RMT1 and RTM2 consists of the following recycled fibers (in % by mass): cotton - about 20% ± 5%; wool and polyacrylonitrile - about 45% ± 5%, of which wool is less than a third; other synthetic fibers (polyamide, viscose, polyester, polypropylene) - 20% ± 5%; bi-component polyester fibers - 15% ± 5%. RTM1 is produced by the thermally bonded nonwoven, while for the RTM2 an additional folding has been applied, i.e. so-called STRUTO technology. In both cases, one-sided lamination was applied with a thin polyester felt, having a surface mass of 100 g/m^2. The main characteristics of RTM1 and RTM2 are presented in Table I. The surface densities of RTM1 and RTM2 in non-loaded state are lower than that of the mineral wool - 1.6 kg/m^2 for RTM1 and 1.9 kg/m^2 for RTM2, while the surface densities of the specimens are as follows: 18.2 kg/m^2 for the control specimen, and 15.6 kg/m^2 and 15.9 kg/m^2 for the specimens filled with RTM1 and RTM2 accordingly.

TABLE I
MAIN PARAMETERS OF THE USED MATERIALS

Characteristics, units	Method	Mineral Wool	RTM1	RTM2
Density (at 50 Pa), kg/m^3	EN 1602	70	40	42
Thickness (at 50 Pa), mm	EN 823	60	40	45
Coefficient of thermal conductivity $\lambda_{10, dry}$, W/mm.K	EN ISO 6996	0.034	0.039	0.041
Vapor diffusivity μ	EN 12086	1	3	4

B. Method

The comparative evaluation of the sound insulation of sandwich panels, filled with mineral wool or innovative recycled textile material, has been made for the frequency range from 500 Hz to 8000 Hz. A method of measuring the difference in sound pressure levels before and after the tested specimen is applied. Every specimen is exposed to a high sound pressure level of 93 dB from the side of the noise radiating room, matching the chamber. In the measurement, the sound is generated from a computer file of pink noise, amplified by a digital amplifier and distributed by loudspeakers. The high sound pressure level is measured at three different positions in the chamber volume and averaged.

The sound pressure level, transmitted by the investigated specimen, is measured from the side of the quiet receiving room at 70 cm from the chamber also for three different positions of the sound level meter and averaged for each specimen. Sound pressure levels are measured in decibels by a calibrated Sound Level Meter of Pulsar Instruments brand. The measured signal in the receiving room maintains levels above the permissible difference with the background noise.

Sound insulation by frequency is represented by the difference between incident and transmitted sound pressure level for each specimen, measured at the middle frequency of each third-octave in the range.

The sound pressure loss in the specimen *D(f)* (Level Difference) in decibels is calculated as the difference between the sound pressure level of the source *L1(f)* in dB and the sound pressure level *L2(f)* in dB omitted by the Specimen for each third-octave frequency by (1):

$$D(f) = L1(f) - L2(f) \quad (1)$$

L1 - average sound pressure level in the source room, dB; *L2* - average sound pressure level in the receiving room, dB; *f* – frequency of the sound wave.

IV. Measurement Results

The specimens examined from left to right in Fig. 3 are:

1. 12.5 mm plasterboard sandwich panel with RTM1 filling - 15.6 kg/m^2 total
2. Sandwich panel of plasterboard 12.5 mm with mineral wool filling 4 cm - 18.2 kg/m^2 total
3. 12.5 mm plasterboard sandwich panel with RTM2 filling - 15.9 kg/m^2 total.

Specimen size is: 56.5cm x 53.5 cm. Air temperature in the receiving room is 24 °C.

The results of the airborne sound insulation assessment of the different specimens are summarized in Table II. For the middle third octave frequencies in the range from 500 Hz to 8000 Hz, sound pressure loss for each specimen is presented.

Fig. 4 shows a comparative evaluation of the sound insulation of the Specimen with RTM1 filling and the Specimen with Mineral Wool filling for the frequency range 500 Hz-8000 Hz.

Fig. 5 graphically presents the comparative evaluation of the airborne sound insulation of the Specimen with RTM2 filling and the Specimen with Mineral Wool filling for the range from 500 Hz to 8000 Hz.

V. Conclusion

- The specimen filled with RTM1 material is inferior to the specimen filled with mineral wool in terms of sound insulation, except in the frequency range of 1600 Hz-2500 Hz.
- The specimen with material RTM2 demonstrates sound insulation properties similar to those of the specimen including mineral wool, and in the area 1600 Hz-3150 Hz it even surpasses it.

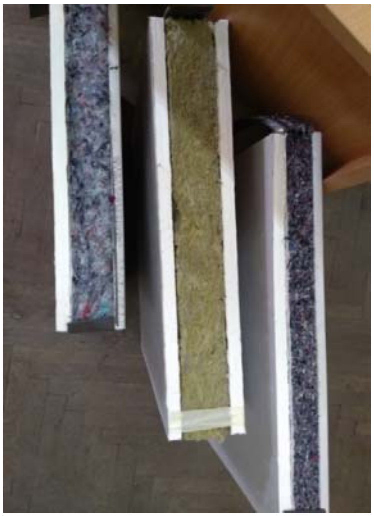

Fig. 3 Photograph of the examined specimens

TABLE II
EXPERIMENTALLY MEASURED SOUND INSULATION OF THE SPECIMENS IN DECIBELS BY FREQUENCY

f, Hz	Mineral Wool	RTM1	RTM2
500	46.4	43.4	46.4
630	47.5	43.6	46.5
800	47.7	45.4	47.4
1000	50.2	49.1	50.3
1250	50.5	49.2	50.0
1600	48.2	48.1	48.4
2000	48.6	48.7	49.6
2500	46.0	46.4	47.0
3150	48.4	47.3	48.9
4000	51.3	49.2	50.3
5000	51.5	49.6	51.5
6300	52.3	47.8	52.4
8000	52.5	44.0	50.6

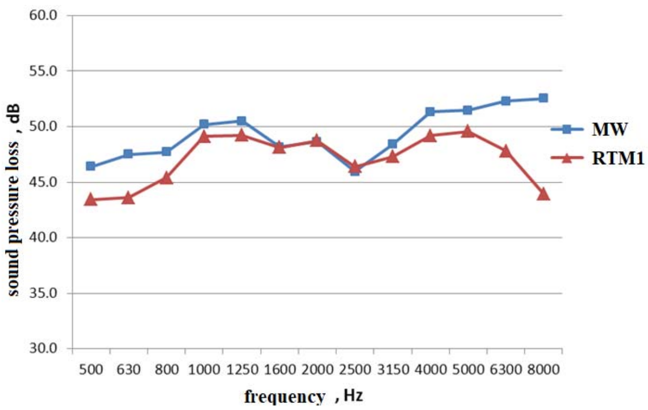

Fig. 4 Sound insulation of Specimens RTM1 and Mineral Wool

Obviously the STRUTO technology of preparing the RTM2 filling has given better results in terms of sound insulation than the technology of preparing the RMT1 filling for the specimen.

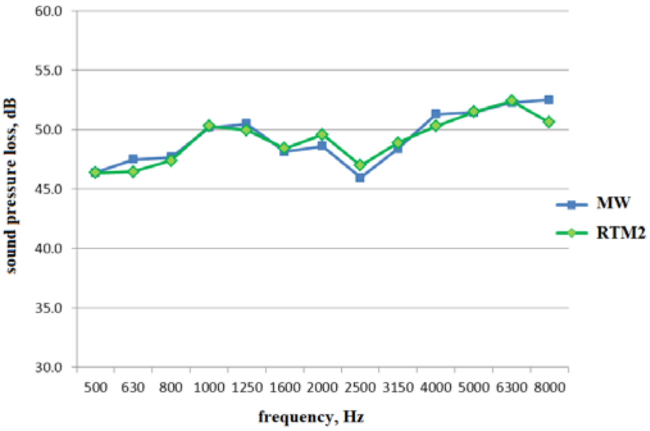

Fig. 5 Sound insulation of Specimen RTM2 and Specimen Mineral wool

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Svetlana T. Djambova, Assoc. Prof., Dr. in Physics, Head of the Physics Department in UACEG, Master Degree in Engineering Physics in Sofia University, Ph.D. and research carrier in the Bulgarian Academy of Sciences – Institute of Solid State Physics. Research fellowship also at University of Virginia, USA and Research Corporation of Virginia – Radford, Virginia.

Natalia B. Ivanova, PhD, Eng. Ph.D. Thesis: *Comparative Study Of Sound Insulation Of Building Elements By Small-Scaled Acoustic Chamber* in University of Architecture, Civil Engineering and Geodesy /UACEG/, Faculty of Structural Engineering, Department of Building Materials and Insulations. Graduated Building Physics at the University of Applied Science, Stuttgart, Germany. Master in Civil Engineer, UACEG, Sofia, Bulgaria.