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Effective sound absorption of acoustic panels in a diffuse and non-diffuse sound field

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Summary

This article compares the sound absorption efficiency of acoustic panels in a diffuse and non-diffuse sound field. The impulse response measurements were performed in the reverberation chamber and in one of the typical shoebox shaped classrooms with standard interior surface treatments (at STU Bratislava). The two investigated rooms had approximately the same volume and classroom were unfurnished. During the experiment, a number of absorbers (acoustic panels) were placed with different layouts in which their positions on the floor were varied. The selected acoustic panels consisted of mineral wool coated with plaster, and dimensions of 600x1200x50 mm. Subsequently, simulations were performed in CATT Acoustic software using calculated sound absorption properties of absorbers (acoustic panels) according to the Sabine's formula and the calculated results of different room acoustics parameters were compared with measured ones.

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Introduction

According to the standard ISO 354 the sound absorption coefficient of acoustic materials or other sound absorbers is measured in a special acoustic environment called reverberation chamber, which closely approximates the diffuse field ideal and fulfills the condition that the length of the longest straight line in the room (typically one of the diagonals) is smaller than 1,9 $V^{1/3}$, where V is the volume of the room in m^3 (typically 200 m^3). The calculation of the equivalent sound absorption area of the test specimen (A_T) is based on the measurements of reverberation time with and without sample. The A_T of the sample is then calculated according to the well-known Sabine formula. The sound absorption coefficient α_s is finally calculated as A_T/S, where S (m^2) is the surface of the specimen. In certain situations, due to diffraction effects of the sample edges α_s might reach values larger than 1. Sound absorption coefficient measured in diffuse field is therefore never expressed in percentage and must be distinguished from the theoretically defined sound absorption coefficient α (without superscript "s") that is expressing the ratio of a non-reflected to incident sound energy.

Placement of the specimens in the room depends on their dimensions and shape. By putting the specimens into the reverberation room, the room volume will decrease and the interior surface area will increase. In the calculation formula proposed in the ISO 354, only the volume of the empty space is used. This may also cause some uncertainties when measuring 3D absorbers without covered edges.

For most of the building materials that are intended for their usage in building interior, the sound absorption coefficient is measured in a diffuse field. However, α_s cannot be always successfully used as an input value of absorption in ray-based software, since the absorption coefficient in simulations cannot be larger than 1.

This article compares a measured equivalent sound absorption area (of absorptive samples) in a diffuse field with a situation in a classroom of similar volume. Later, several simulations with different sample layouts are performed. The input values of sound absorption coefficient are taken as calculated according to Sabine's formula. For octave bands where α>1, the value is taken as 0,99. The effect of local absorption in the reverberant room and the classroom is shown.

2. Description of the experiments

2.1. Description of the rooms

The reverberation chamber used in measurements has basic dimensions 10,72 x 5,82 x 4,1 with a volume V = 208 m^3. The non-diffuse sound field is represented by classroom B320 at the Slovak University of Technology in Bratislava. The dimensions of the classroom are 11,84 x 5,45 x 3,52 and the total volume is 227 m^3.

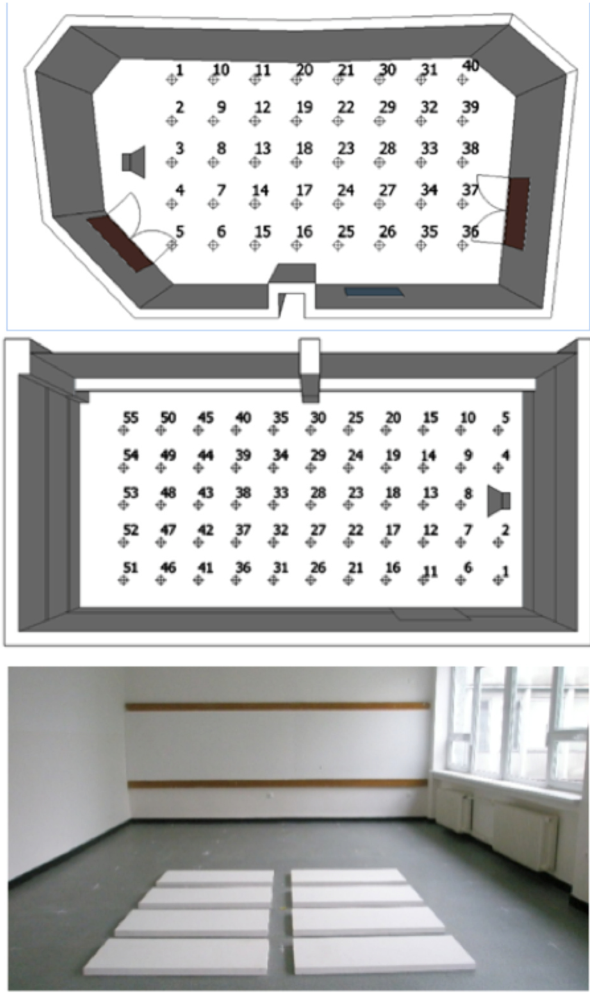

Figure 1 – Illustration of the loudspeaker – microphone(s) setup during the impulse response measurement in a reverberation room (upper picture) and in the classroom (lower picture)

2.2. Description of the specimens

The sound samples used for the study are simple panels from mineral wool with breathable plastic and with dimensions of 0,6 x 1,2 x 0,05 m. For this experiment, 8 or 16 panels were used.

A parametric study was made for both 8–pieces and 16–pieces options by varying the distance between the absorptive panels. For the sake of simplicity in this conference proceeding, we will show the results for situations where the panels were attached to each other (referred to as distance between specimens = 0) and situations with 200 mm distance between specimens. Panels were in all cases placed in the middle of the rooms.

3. Measurements

The loudspeaker - microphone setup as used in the reverberant room and classroom is illustrated in Figure 1. Measurements of impulse responses were performed for each combination of source-receiver.

3.1. Reverberation time

The average reverberation time as measured in the two rooms is given in the Figure 2.

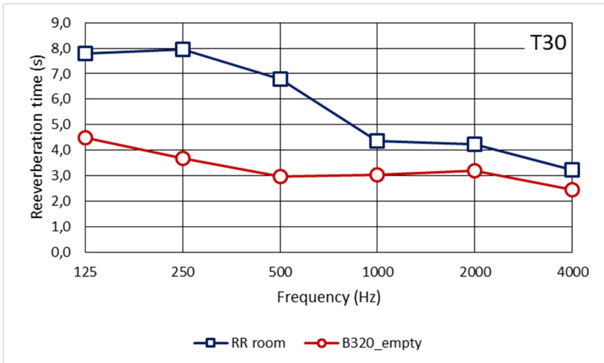

Figure 2 - Comparison of the average T_{30} in the empty reverberation room and in the classroom

In total, ten (10) different alternatives were measured and later simulated. All alternatives are summarized in Table I.

The equivalent sound absorption area was calculated from measurements in the reverberant room (RR) and classroom (B302) and consequently α_s was calculated as if it were measured in RR or in B320. Results are shown in Figure 3.

Results show that if sound absorption would be measured in the shoebox shaped classroom without furniture (instead of standardized diffuse field), the values at low frequencies (in our case study) would be overestimated and the values at high frequencies underestimated. The situation at low frequencies would require a more detailed investigation in terms of uncertainty of measurement at 125 and 250 Hz. At higher frequencies > 500Hz the reverberation time in the classroom was longer then presumed according to calculation with Sabine's formula. It is due to sound reverberation in the horizontal plane.

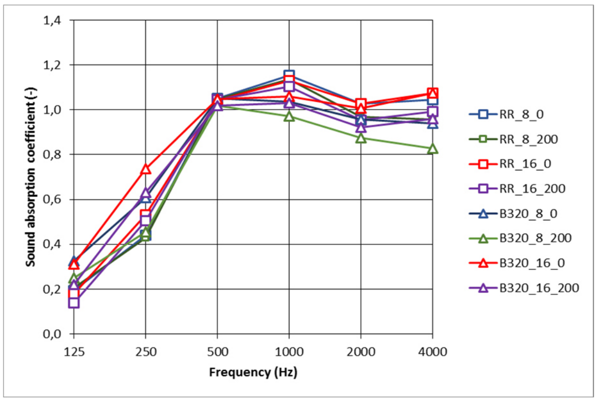

Figure 3 –Sound absorption coefficient αs calculated in different alternatives (in Reverberant room and classroom)

Table I. Names of the studied alternatives. The two first letters indicate the room: RR (reverberation room) or B320 (classroom). The first set of numbers refers to the number of panels and the second number expresses the distance between the panels

Alternative	Number of specimens	Distance between specimens [mm]
RR_empty	0	-
RR_8_0	8	0
RR_8_200	8	200
RR_16_0	16	0
RR_16_200	16	200
B320_empty	0	-
B320_8_0	8	0
B320_8_200	8	200
B320_16_0	16	0
B320_16_200	16	200

4. Simulations

4.1. Reverberation time

Simulations of the two measured rooms have been performed in CATT Acoustic version 8e, which uses a hybrid calculation method that combines the Image Source Model for calculation of the early sound reflections and a special kind of ray-tracing method with randomized tail-corrected cone–tracing for full detailed calculation. Scattered sound reflections are calculated according Lambert´s distribution [4]. The sound absorption coefficients used in the model surfaces are shown in Table II (based on in situ measurements). Note, that the values higher than 1 were to replace by the value 0,99 in the simulation.

Table II. Sound absorption coefficient of panels.

	125	*250*	*500*	*1000*	*2000*	*4000*
RR	0,178	0,477	1,047	1,130	0,995	1,017
B320	0,277	0,607	1,034	1,024	0,941	0,950

If we look at the reverberation time we will see, that the simulations correlate very well with the measurements, whereas using the Sabine formula would overestimate the efficiency of the sound absorption in the classroom. The differences between measurement and simulations were found larger in cases with 16 panels. The reverberation time results also do not show significant differences between the alternatives with different distributions of the absorptive panels in the room.

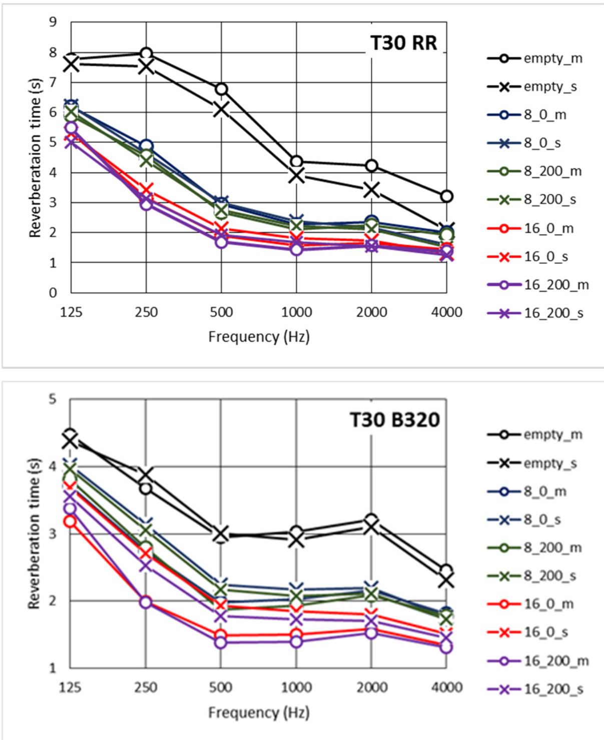

Figure 4 –Reverberation time at different measured at simulated alternatives in reverberant room and classroom

4.2. Strength

Figure 5 shows the simulated results of Strength as a function of distance from the sound source in the main axis of the room. Only little effect can be seen
between the variants with 0 and 20 cm distances between the absorptive panels.

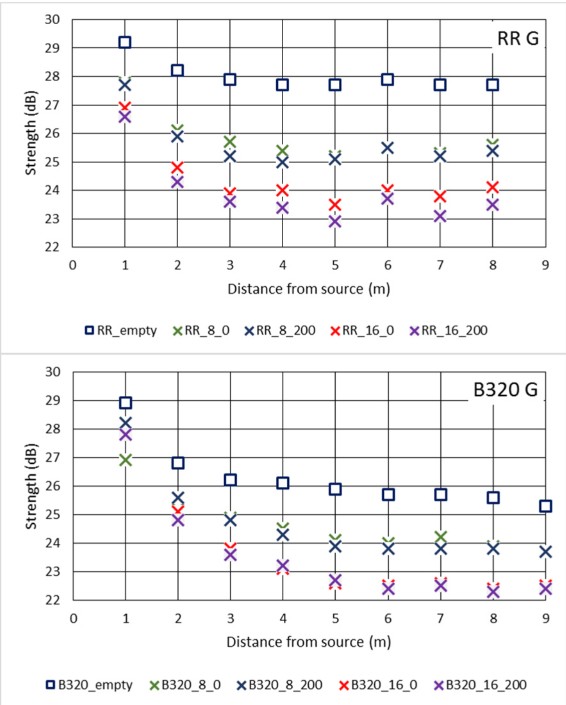

Figure 5 – Strength *G* (dB) values for the simulated alternatives in reverberant room and classroom.

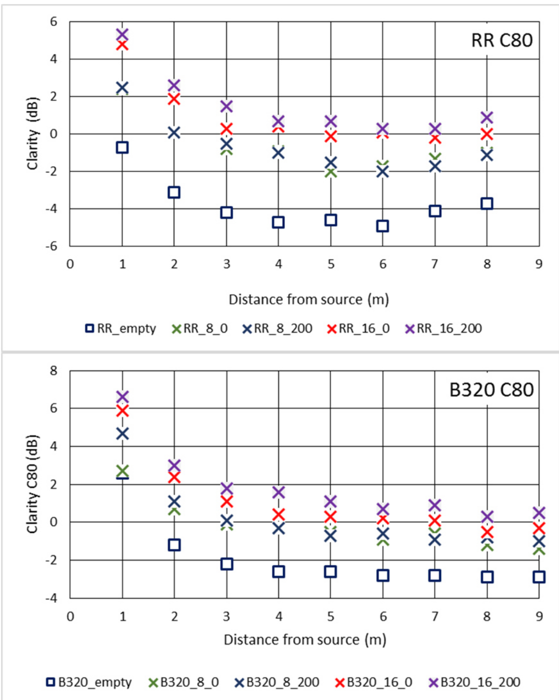

Figure 6 – Clarity C_{80} (dB) values for the simulated alternatives in reverberant room and classroom.

Conclusions

Based on the case study used for this article, it can be concluded that the sound absorption α_s will not cause a significant errors in the simulation of reverberation time if the values larger than 1 will be simulated as 0.99. A larger problem when predicting acoustic conditions in a non-diffuse room is the efficiency of sound absorption. It has been experimentally confirmed that the prediction of reverberation time in a classroom would fail when using Sabine formula and the absorption efficiency would be overestimated at middle and high frequencies.

The results of Strength and Clarity shows some effect of the position of absorption in a room. However these effects should be further and perceptually investigated in binaural simulations.

Acknowledgements

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