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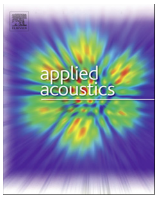

Acoustic absorption increase prediction by placing absorbent material in pieces

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ABSTRACT

We present the results of tests performed in a reverberation room measuring reverberation time with different acoustic absorbent materials in different layouts, compared to those results where the same material was placed as a single piece. With the analysis of the obtained data, a regression model is established in order to predict, for certain frequencies, the improvement produced in the reverberation time of a room, using the same amount of material by placing it in pieces separated from each other, instead of in one piece. The analysis also prove the sturdiness of the model.

1. Introduction

One of the strategies employed to limit the reverberating noise in the interior of an enclosure is to fit it acoustically including a certain amount of absorbent material in one or more surfaces.

These acoustic conditioning strategies are very commonly used because of calculation simplicity (performance prediction) and its simple execution. Many of the European acoustic regulations include limitations of reverberation time regarding the use and the volume of the enclosure or premises. Other countries replace the requirement by one on the calculated amount of applied equivalent absorption area [1,2].

The vast majority of these regulations base their prescriptions on the well known Sabine's equation, published in 1900 [3]:

$$T = 0.16\frac{V}{A}\ [\mathrm{s}], \tag{1}$$

where T is the reverberation time, in seconds, of a room with volume V in cubic meters and A is the equivalent absorption area in square meters. The equivalent absorption area gathers all the acoustic absorption capabilities of the room, for it is computed as the addition of the absorbent surfaces areas, S_i, each one multiplied by the absorption coefficient of the material of that surface: $A = \sum_i S_i \alpha_i$.

The limitations of Sabine's formula have been clearly recognized [4] and several improved formulations have been proposed. The most celebrated ones are slight modifications of Eq. (1), like the one proposed by Eyring [5] or that by Millington [6], both of which consider different forms of introducing the absorption coefficient within the equations. There are also attempts to modelize the reverberation time with non diffuse sound field, like Fitzroy's equation [7] or Arau-Puchades's equation [8]. It is well known that all these formulations consider only two properties of each absorbent surface, namely its absorption coefficient, which is an intrinsic property of the material, and the surface area. Therefore they cannot distinguish the effect of different layouts of the same amount of absorbent material. However, an extra absorption when the absorbent material is placed in patches rather than in one piece has been widely documented [9–13] and it has been attributed to lack of diffusion and to the so called edge effect. In the former case some research studies [14,15] have attempted to quantify the diffusion based on the dispersion coefficient and absorption coefficient of the walls. It is also known, in the latter case, and extensively studied [11,12,16], that the edge effect increases the measured absorption in a reverberation chamber due to the extra surface area that may be present because of the thickness of the sample under test. Other researchers have studied a similar issue [10,9,17,18] without finding a simply method that can predict the improvement produced in the time of reverberation in a room, using the same amount of absorbent material by placing it in separated pieces. All proposed research methods to give estimates of the acoustical properties of porous type absorbers are complex for practical use.

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Nevertheless placing the absorbent material in patches is a quite common situation in construction works, see Fig. 1, and notwithstanding the explanations offered in the references, not a simple account of the influence of these effects in the reverberation time has been reported. It is the goal of this paper to provide such a model, when feasible, and to explain the reason when it is not.

To that end we have measured reverberation times in a reverberation chamber with test samples in different layouts: in one piece as well as in several patches with a variety of separation gaps among them. In Section 2 we give a detailed account of the experimental procedure, while in Section 3 we report the results of the measurements followed by their statistical analysis which allow us to provide, when suitable, a simple equation to relate the reverberation time with the layout of the patches. Finally, in Section 4 we enumerate the conclusions of our analysis.

2. Method

We have chosen to measure the reverberation time under the same conditions specified by the ISO 354 standard [19] for the measurement of the absorption coefficient of an absorbent material. The method described in this standard measures the mean reverberation time in the reverberation room with and without the test sample. The equivalent sound absorption area is calculated from these reverberation time periods through Sabine's equation, Eq. (1), and then the absorption coefficient. The testing conditions prescribe a specific reverberation room size and shape, with controlled temperature and humidity. The testing sample must have an area between 10 m^2 and 12 m^2 and must be rectangular in shape with a width-to-length ratio between 0.7 and 1.

We have measured the reverberation time in bands of thirds of octaves of three different materials with similar thickness and in different positions. The tested materials have been:

- Material 1 (M1): non-woven polyester fiber 30 mm thick, in rigid planks with dimensions $1000 \times 500 \times 30$ mm and 30 kg/m^3 density.
- Material 2 (M2): 30 mm thick rock wool, in rigid planks with dimensions $1000 \times 600 \times 30$ mm and 100 kg/m^3 density.
- Material 3 (M3): melamine foam 30 mm thick, in rigid planks with dimensions $1000 \times 500 \times 30$ mm and 10 kg/m^3 density.

Firstly, the reverberation time with the materials in one piece is obtained, and then with the materials distributed in pieces with given separations among them. The samples used have a net area of 10 m^2 (in one piece), increasing the gross area through the separation surface between pieces in the different positions tested. As the pieces are separated, for each case, we compare the space occupied by the absorbent material and the gaps left when the planks are gradually distanced. In this way, different results are obtained for 100% of the occupied surface (all planks together in a single piece), 86%, 75%, 51% and 37% of the area occupied by the material. This ratio of net to gross area is the variable that we refer to as occupation throughout the paper.

The test samples are initially rectangular in shape, with a width/length ratio of 0.7 and are placed in such a way that every part is more than 1 m away from the edges of the reverberating room. This condition varies as the separation distance between the pieces increases, but in all cases a separation of at least 0.75 m is maintained (see Fig. 2).

In all cases, test sample pieces were allowed to reach a balance between the temperature and the relative humidity of the reverberating room before the tests. The relative humidity of the chamber ranged from 38% to 39% during the tests, and the temperature between 19.9 and 20.6 °C.

The interrupted noise signal method was used for measuring the reverberation time and the sound fall curves were measured from equivalent levels (using linear average) with integration times that vary between 20 ms for the third octave bands of frequency 100, 125 and 160 Hz and 10 ms for the other frequency bands. Readings were made in all cases, in third octave bands, as specified in the ISO 266 standard [20].

From the layout of the experiment one may expect different results at different frequency bands. Since the gaps between patches of the material range from 10 cm to less than 1 m, medium and low frequencies waves are expected not to notice the different layouts of the absorbent materials due to their long wavelengths. On the contrary, the effect should be noticeable in the high

Fig. 1. Suspended ceiling with discontinuous absorbent material.

Fig. 2. Test in reverberating room.