ACOUSTIC CHARACTERISTICS OF DIFFERENT MATERIALS USED IN CONSTRUCTION.

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ABSTRACT

This work presents experimental measurements of the normal absorption coefficient and of the normal acoustic impedance in some noise absorbers used in construction, and also bulk foam for comparison. For that we use an impedance tube. We have compared the results obtained for different thickness and air cavity depths between the sample and the rigid end of the tube. We have also prepared a new absorber material formed by a resonator (multiperfored plaque) on a bulk foam rubber. The absorbent characteristics of this material are better than those presented by commercial noise absorbers actually used in construction.

INTRODUCTION

As it is well known, porous materials are typical in noise control. The sound frequencies with interest for construction are those between 100 Hz and 4000 Hz (following the N.B.E. C.A.-88 norm) [1]. Due to that we present measurements of the absorption coefficient of porous materials in the frequency range mentioned.

The noise absorbent capacity of a material is determined from two types of techniques [2,3]. From acoustic ones we can measure the absorption coefficient as well as the acoustic impedance, while with non-acoustic experiments we can determine other properties, as the resistance to airflow or the shape factor. We have used the acoustic method of transfer function to measure the normal absorption coefficient and the acoustic impedance relative to air [2], using a multianalyzer composed by an impedance tube type 4206 from Brüel & Kjær, with two microphones and software PULSE 6.0 version. The measurements were done according the norm ISO 10534-2.

The materials used are three different commercial foam rubbers (usually used in false ceiling), two different bulk foam rubbers (that used for package), and one manufactured noise control material, also used in construction. The aim for choosing bulk foam rubber is due to its homogeneity, relatively big porous and low cost [4-6].

EXPERIMENTAL PROCEDURE

We have directly measured the normal acoustic impedance and the normal absorption coefficient using the random excitation technique, which description appears in several papers [1,2].

The impedance tube used has an internal diameter of 100 mm, which can be reduced to 29 mm with another tube that can be coupled to the first one. This allows us to cover a broad range of frequencies because the large tube covers frequencies between 100 Hz and 1600 Hz, while the small one covers the range between 500 and 6400 Hz. The tube has in an end a loudspeaker (in random mode) and in the other a movable piston, it also has two microphones placed in fix and known positions.

To perform the measurements of the normal impedance, it is necessary to establish the reference plane with precision [3-6], for that the samples have been fitted against the movable piston to exactly have the adequate distance between the surface of the sample and the nearest microphone. The samples fit exactly the diameter of the tube closing any air gap. After visual inspection of the samples mounted, the tube was closed tightly with the sample placed in one end. A random signal was generated from the loudspeaker, and the transference signal between the microphones is measured using the two channels fast Fourier's transform. For some measurements we create an air cavity between the sample and the movable piston, to study its influence on the results. The experimental technique has been described in a previous paper [7].

All the samples were cut from a plane sheet in circular slices according with diameters of the impedance tubes, and attached to the movable piston. The manufactured material sample was greased around the border with vaseline to close any air gap and so to obtain a coherence of exactly 1.00 along the frequency range in the measurements. We have used two different samples of each type to verify the reproducibility. The two commercial foam samples have been also measured for both sides to verify the influence of some visible differences between them, it is negligible within the experimental uncertainties. In Table I are shown the density, thickness of the samples and the depth of the air cavity used.

Table I. Properties of the materials tested and depth of the air cavity (Lf means only for low frequency).

	Comm. foam 1	Comm. foam 2	Comm. foam 3	Bulk foam 1	Bulk foam 2	Manufactured material
Density ($kg\cdot m^{-3}$)	78.8	108.3	76.4	19.8	19.2	231.3
Thickness (mm)	26.8	22.1	40.0	24.0	18.5	14.8
Air cavity (mm)	50 & 100	50 & 100	50 & 100 Lf	-	-	100, 150 & 200 Lf

EXPERIMENTAL RESULTS

In Figs. 1, 2 and 3 we show the measured acoustic impedance ratio for the three types of commercial foam rubber used. These results are normalized to the air characteristic impedance and are plotted in the range of $^{1}/_{3}$ octave. In these three figures we can observe that the imaginary part of the normalised acoustic impedance tends to null for the frequencies where the absorption coefficient is maximum, this fact is predicted by theories for an absorbent material and normal incidence. As observed in Figure 3 for sample 3, the imaginary part gets null at two frequencies (2000 Hz and 5000 Hz), which corresponds to two peaks of maximum absorption for this sample (see Figure 4 below).

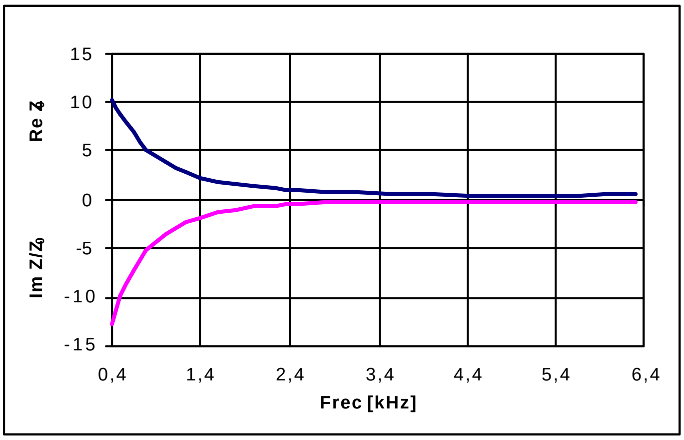

Figure 1 Real and Imaginary parts of impedance ratio for sample 1 of commercial foam.

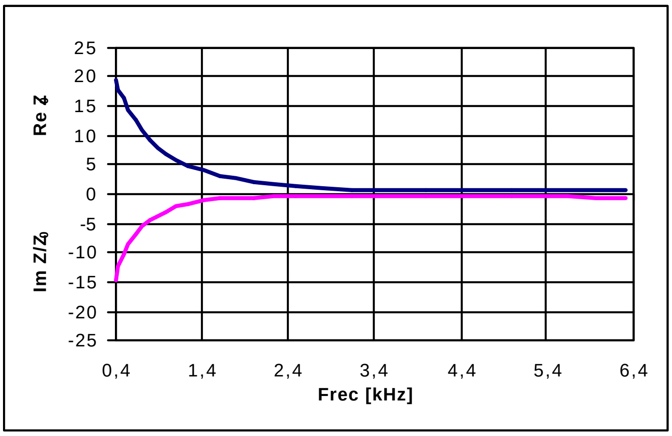

Figure 2 Real and Imaginary parts of impedance ratio for sample 2 of commercial foam.

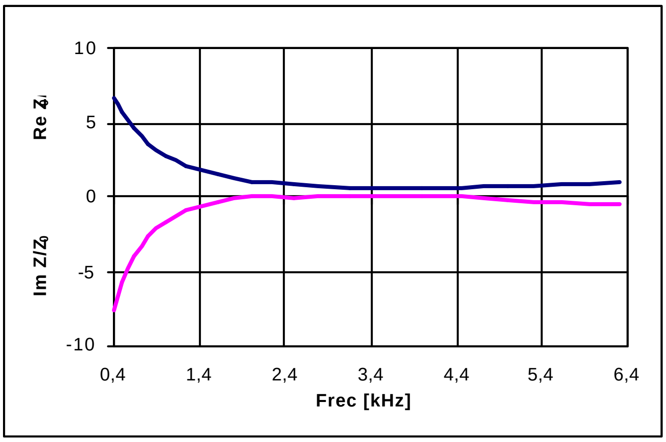

Figure 3 Real and Imaginary parts of impedance ratio for sample 3 of commercial foam.

The influence of the thickness of the commercial foam samples on the absorption coefficient is shown in figure 4. We can observe that there exists a displacement of the maximum of absorption towards low frequency with the increase of the thickness. Although, the thinnest sample presents better noise absorption in the range from 2500 Hz to 4000 Hz.

On the other hand, figure 5 shows the normal absorption coefficient measured for the two samples of bulk foam rubber. Here, we observe that up to 4000 Hz the absorption is better for the thickest sample 1, but at higher frequencies the result is opposite. The noise absorption quality is quite good for this bulk foam samples, but worse than that of the commercial foam samples.

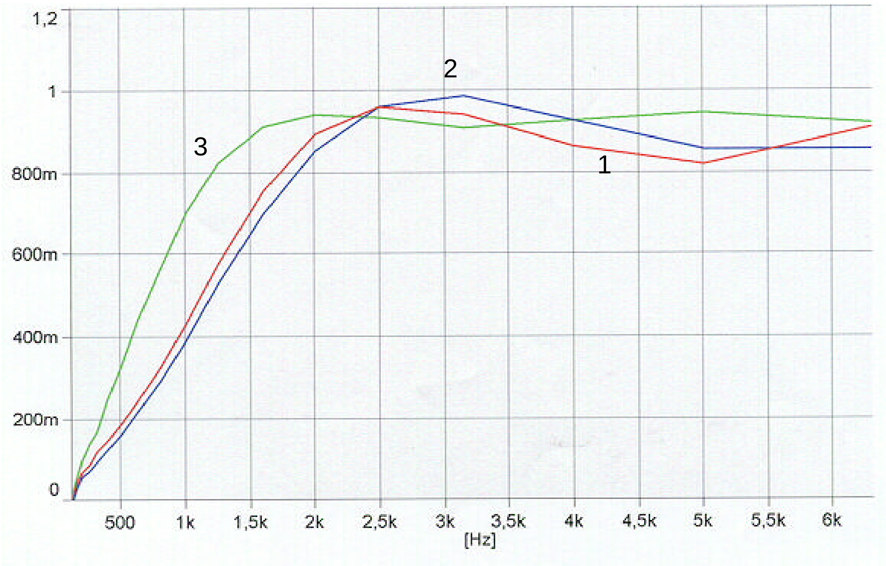

Figure 4. Absorption coefficient for the three samples of commercial foam rubber studied versus frequency in $^{1}/_{3}$ octave. Red curve 1 corresponds to sample 1, blue curve 2 to sample 2 and green curve 3 to sample 3. See Table I for details.

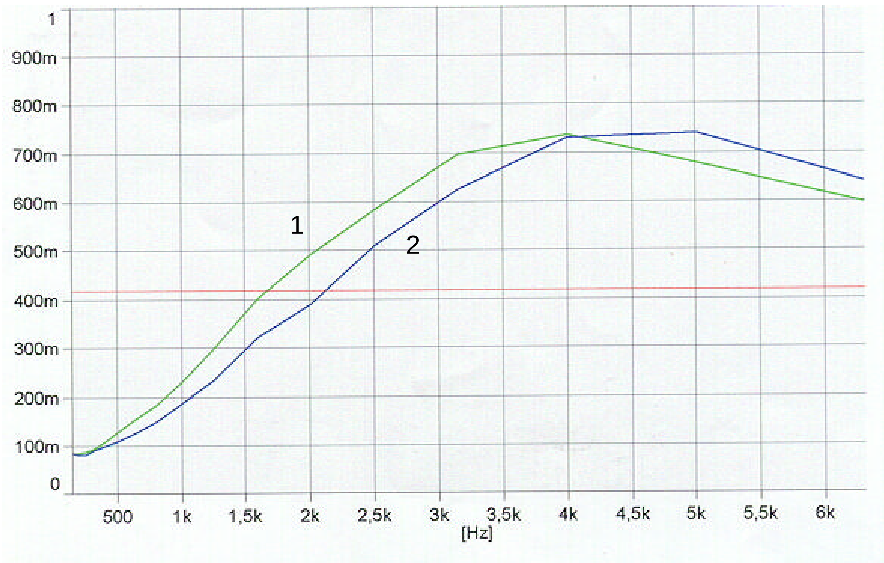

Figure 5. Absorption coefficient for the two samples of bulk foam rubber studied versus frequency in $^{1}/_{3}$ octave. Green curve 1 corresponds to sample 1 and blue curve 2 to sample 2. See Table I for details.

The normal absorption coefficient of the manufactured material increases about linearly from 0.05 at 100 Hz up to 0.54 at 1000 Hz, as observed in Figure 6. For higher frequencies its value is almost constant and lower than 0.55. To observe the influence of the air cavity in the absorption coefficient we have measured this sample with air cavities of 50 mm, 100 mm and 200 mm. The air cavity has influence at low frequency but not at high frequency as expected. The maximum influence of the air cavity appears for frequencies around 400 Hz, where the absorption coefficient increases with the depth of the air cavity.

Finally, we have placed a multiperfored plaque over the tested material bulk foam 2. The plaque is made of metal with 1 mm thickness, the holes have 1.5 mm diameter and form a square arrive, resulting a hole density of 11.1 holes per square cm. It has a thin veil in its back surface (that on the foam sample), and works as a resonator. In Figure 6 we show the normal absorption coefficient of this covered sample for low frequency, and for comparison we also show the absorption coefficient of the manufactured material. Both absorption coefficients increase linearly from 0.05 at 100 Hz to 0.45 at 800 Hz, but while that of the manufactured material stabilize at around 0.55 at 1000 Hz, the absorption coefficient of the covered sample follows increasing up to 0.9 at 1600 Hz. This resonator placed over the foam could be used for ceilings due to its low cost compared with manufactured material or current mineral wool noise absorber. For practical applications we must take into account possible close of pores due to contamination, and also its flammability.

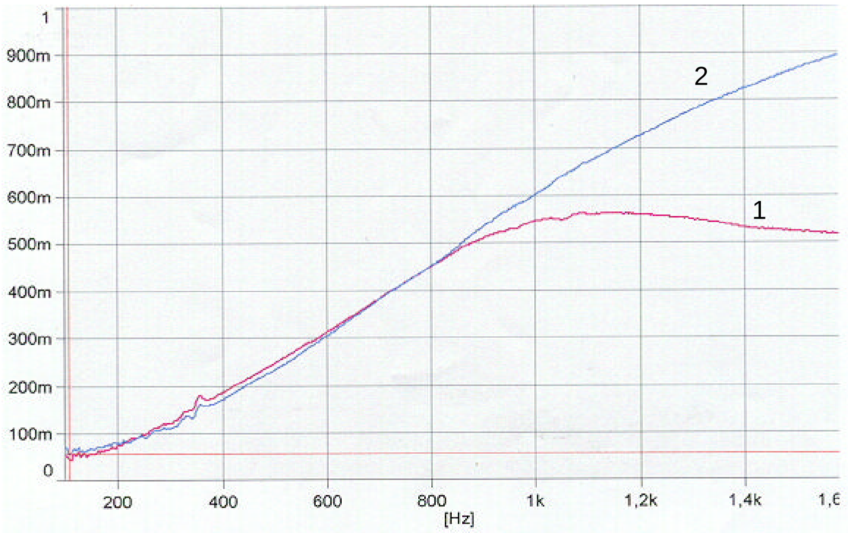

Fig. 6. Absorption coefficient of covered sample (blue curve 1) and manufactured material (red curve 2) versus frequency. See text for details.

CONCLUSIONS

This work presents measurements of the normal absorption coefficient and the acoustic impedance in some noise absorbers used in construction, and also bulk foam for comparison. The final goal will be to measure the characteristic impedance from the two cavities method. To do that with good precision it is necessary to measure more different air cavity depth. In construction, the commercial foam is used for false ceiling, glue to the framework and covered by lime or textile (with or without air cavity in between).

The commercial foam presents high values of absorption, being more than 60% for frequencies up to 600 Hz for sample 3 (the thickest one) and 1000 Hz for samples 1 and 2 (without air cavity and normal incidence).

The presence of an air cavity between the sample and the rigid wall increases the absorption coefficient value. Thus, a commercial foam sample of 22.4 mm thickness increases its noise absorption from less that a 40% without air cavity to 70% with an air cavity of 50 mm. To obtain that absorption value without air cavity we must use the thickest commercial foam of 40.0 mm.

The manufactured material is usually used in construction to form false ceilings (with an air cavity) in many offices and even classrooms. In this material the acoustic absorption is very low for low frequency and it has its maximum (64% without air cavity and normal incidence) at 6300 Hz. The absorption coefficient is poorly affected by the presence of air cavity at high frequency (from 2000 Hz to 4000 Hz), but it does affect at low frequencies (mainly from 100 Hz to 315 Hz).

The acoustic absorption of the bulk foam rubber covered with the multiperfored plaque is much better than that of the manufactured material, reaching a value of 0.9 at 1600 Hz. The absorption coefficient value of this material is higher in 0.2 from 1000 Hz to 1600 Hz respecting the manufactured one.

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