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Technical note

# Experimental and theoretical considerations on sound absorption performance of waste materials including the effect of backing plates

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ABSTRACT

The acoustic human comfort includes the protection from noise and it is closely related to the sound absorption concept. The paper presents an experimental study on sound absorption coefficients, including transmission, for some combined materials: waste materials (rubber particles, polypropylene, crumbled plastic, wood flour, jute and cord fabrics) with different backing plates (plasterboard, oriented strand board - OSB, polystyrene). The tests were realized following the impedance tube method (ISO 10534-1:1998 standard), except for that the end of the tube was inserted into an anechoic room. The effect of this "backing room" on the samples sound absorption performances is discussed. Also, the experimental results emphasize the influence of the combined materials placed in series on the sound absorption performances and promote the idea of environmentally friendly solutions in their improvement.


## 1. Introduction

The technological development of all the industries (automotive, construction, environmental and equipment manufacturing) that creates powerful and noisy systems requires more efficient and cheap sound absorptive materials in order to achieve the acoustic human comfort. This is connected to the sound absorption concept. Absorption coefficient quantifies how much sound is absorbed by the material and transmission through it. When the sound reaches the material, its energy is absorbed and reflected, depending on the sound absorption performance of the material [1]. For instance, the buildings walls and roofs constitute the backing for different materials that need to have a high absorption coefficient, as wool glass, foam or mineral fibers and their composites.

There are studies that reinforce the idea of the use of some materials combinations, resulting in different structures of thickness and density, influencing the sound absorption properties of the new created material [2,3]. Recently, human health and environmental protection have become another major requirements leading to natural materials use in practical applications. Therefore, another series of experimental studies on sound absorption coefficient focuses on some natural materials and their combination (bamboo fiberboard, coconut fibers, and tea leaf fibers) [4,5]. As a result, good sound absorption coefficients similar to those for metallic foams or sinterized materials were reported.

This paper experimentally investigates and then compares the sound absorption coefficients including the transmission to behind of several samples consisting of waste materials (rubber particles, polypropylene, crumbled plastic, wood flour, jute and cord fabrics) with different backing plates (plasterboard, oriented strand board - OSB, polystyrene). The samples (considered combined materials placed in series) were tested in an anechoic room using the ISO 10534-1:1998 standard. The testing procedure was modified in that the anechoic room represents the "backing itself" of the tube, replacing the rigid wall from the standard procedure. As the materials sound absorption properties are very dependent on the way the material is mounted, the investigation of the material absorptive performance in a certain position in space is of interest.

The sound absorption study of some materials based on different backing plates, in different combinations, highlights the possibility of cheap and efficient constructive solutions to provide better absorptive materials.

## 2. Experimental investigation

### 2.1. Method and material

The absorption coefficient of a material varies with frequency and with the angle at which the sound wave strikes the material.

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When sound waves hit a surface, as energy conservation, (Fig. 1), it can be expressed [6]:

$$E_i = E_r + E_a + E_t \quad (1)$$

The absorption coefficient is defined as ratio of absorbed energy to incident energy:

$$\alpha = \frac{E_a}{E_i} \quad (2)$$

Also, the absorption coefficient, $\alpha$, can be defined as the ratio of all energy not reflected to incident energy:

$$\alpha = 1 - \frac{E_r}{E_i} = \frac{E_a + E_t}{E_i} \quad (3)$$

Absorption coefficient measurements usually are made in a reverberant room, according to the ISO 354:2003 standard [7]. Using this standard, it has been reported influences of sample placement in the room and sample edge effects on the accuracy of the measurements [8].

As well, it is used the standing wave tube technique, presented in part 1 of the ISO 10534:1998 standard [9] and the transfer function method described in part 2 of this standard. The first part of the standard settles the measurements of the ratio of peak to minimum amplitude in a standing wave tube in order to determine the magnitude and phase of the pressure reflection coefficient, and then the sound absorption coefficient, $\alpha$. The second part of the standard describes the use of the transfer function $H$ between two spaced microphones and also spaced from sample in order to get pressure reflection coefficient, $r$ [10,11]. ISO 10534:1998 standard can be applied if there are no reflected waves resulting from other systems than the tested samples, meaning that measurements based on these methods have to be carried out in open spaces or rooms that have sound insulation [12]. The measured upper frequency is limited to the plane waves frequencies which can travel in the tube depending of the sound speed and the tube diameter [6].

None of these procedures allows making measurements in situ, furthermore the experimental methodologies are quite different, and so the obtained values for the sound absorption coefficients have a great dispersion from an author to another [13].

To summarize, we may consider that the sound absorption coefficient obtained from the reverberation room method is the ratio of the absorbed energy by the test sample to the incident sound energy, while the sound absorption coefficient measured in an impedance tube is defined as the ratio of the non-reflected sound energy to the incident sound energy [14].

The standard impedance tube method supposes that the sample is backed by a rigid termination/wall. If the rigid backing is replaced by an anechoic termination, then the measured sound absorption coefficient obtained for this case includes both the energy dissipated inside the material and the energy transmitted through the material and propagated to the anechoic terminal.

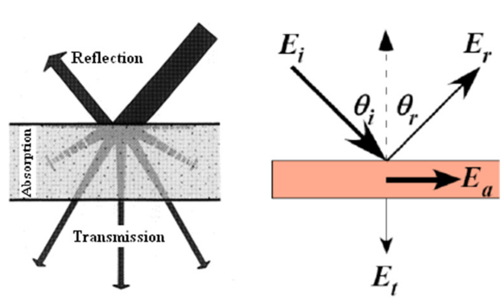


**Fig. 1.** Sound energy conservation.

When the sample is backed by a rigid plate this latter term disappears and the sound absorption coefficient rating is the same as that for the standard impedance tube method defined by the corresponding ISO standards [14].

Taking into account that we have in the department an anechoic room, we performed our experimental work based on a modified impedance tube method (ISO 10534-1:1998 standard). The anechoic end of the impedance tube is the anechoic room itself.

In practical cases, the energy dissipated inside a material when it is directly mounted on a wall is close to the result from the standard tube configuration [14]. As well, a lot of materials can be freely-hanging in space and the sound transmission loss through the material must be considered. Therefore, it can be of interest for practical situations to explore the effect of the anechoic cavity, as backing, in order to estimate the sound absorption coefficient values.

Fig. 2 presents the experimental setup for the sound absorption coefficients. It consists of: signal random generator, microphone, soundmeter connected with the microphone and NIDAQ board, laptop with LabVIEW soft compatible with National Instruments DAQPad for data processing. The signal generator connected to the loudspeakers emits waves travelling to the other end of the tube, where the tested samples are well fastened.

The samples are realized from different combinations of waste/recycled materials (plastic, wood flour, rubber, polypropylene, jute fabric, cord fabric) bonded on backing plate made of some usual construction materials for room walls and roofs (plasterboard, polystyrene, OSB-oriented strand band). The bonding solution is a water-based agent, ecological and without chemical reactivity.

Therefore, some materials are layered together to make a new structure in practice and it is necessary to get the acoustic properties of the whole structure. The total reflected sound wave at the interface of two or more layers of materials is the summation of the infinite number of reflections at the surfaces [14]. In a standard configuration, the material is backed by a rigid wall. It can be considered as two layers of materials placed in series with the reflection coefficient of the second one equal to unity [14]. We can think about this standard configuration as a particular case of the general situation when the end of the tube has an anechoic termination. The anechoic room is the back cavity replacing the rigid wall from the standard procedure.

In the impedance tube the waves are reflected back from the sample and received by the microphone measuring the incident and reflecting sound pressure. The samples with a diameter of 10 cm were prepared according to the tube size and the third octave analysis with LabVIEW soft is performed in frequencies band ranging from 63 to 2000 Hz.

The tested samples are noted:

The appearance characteristics of the tested samples are depicted in Fig. 3.

### 2.2. Experimental results and discussions

We have measured the sound pressure level dB(A), A weighted, of incident and reflected wave, using the LabVIEW soft with the *third-octave analysis* tool. Values are usually provided in the literature at the standard frequencies of 125, 250, 500, 1000 and 2000 Hz [15].

Specifications for this tool included in LabVIEW library are defined by ANSI and International Electrotechnical Commission (IEC) standards and the results are fully compliant to the international standards (ANSI S1.11-2004 and the IEC 1260:1995 standards). The absorption coefficient under a certain frequency is determinate according to ISO 10534-1:1998 standard. Each sample was tested 3 times and the averaged values are considered.