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Experimental and theoretical investigation of the acoustic performance of sugarcane wastes based material

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ABSTRACT

Agricultural residues present a challenge to the environment. Most of these residues are burnt in the farm causing several pollution hazards to the environment. There has been a lot of interest to find applications for these residues instead of burning them. One application can be using them as acoustic materials. This paper presents the results of the evaluation of the acoustic performance of the sugarcane wastes based material. This evaluation is made by measuring two acoustic parameters: the flow resistivity and the acoustic absorption coefficient. The manufacturing of multiple samples with different physical properties (sample thickness, fiber size, and resin content) allowed evaluating the effect of each property on the acoustical performance of the studied material. A comparison between experimental and theoretical results showed good agreement.

1. Introduction

Today, a greater attention has been given to the environment and public health which stimulated the research to develop new techniques to make use of the annually produced agricultural residues. Nowadays, various kinds of materials is being recycled from these wastes which sometimes called "green materials". Using this material – which based on agricultural residues – to make a new sound absorber or insulator is so interesting because it solves two environmental problems: noise and environmental pollution. Some of these materials have already been investigated: wood based materials [1], rice straw-wood based materials [2], hemp wastes based materials [3], tea-leaf fiber wastes [4], Bamboo [5], and Coconut coir fiber [6]. In Egypt there is a notable quantity produced of sugarcane which is used to manufacture sugar and to extract a juice, the waste of this operation is a fibrous material called "Bagasse". It remains as an ecologic problem because of its big quantity which is usually burned.

On the other hand, Noise pollution is considered to be one of the most common environmental problems which has become more complex and serious nowadays. In industry, absorbing and insulating materials have been widely used to attenuate the noise generated by various sources. Porous and fibrous materials such as glass wool, foam, and mineral fibers are used in multiple industrial applications to reduce noise in buildings, vehicles or manufacturing environments, etc. The characterization of sound absorbing properties of these materials showed that they have a good acoustic performance to obtain the acoustic comfort.

The objective of this paper is to discuss the measured acoustical properties of sugarcane wastes' based materials, and to present the characterization and modeling approaches adapted for this material. To evaluate the acoustical properties of samples, two methods have been elaborated: an experimental study to characterize the acoustical properties and the absorption efficiency of the proposed material, and a numerical study using an empirical model to predict the samples absorption coefficient based on its measured flow resistivity.

In the first section of the paper, the samples preparation process and physical characteristics of each sample are detailed. In the second section, the experimental setups for the measurement of the flow resistivity and the absorption coefficient are presented. An analytical model is developed to predict the absorption properties of these samples based on Delaney and Bazley theory. The effects of these physicals parameters on the flow resistivity and the absorption coefficient are analyzed. In the last part, both theoretical and experimental results are compared.

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2. Samples preparation

Sugarcane waste (bagasse) is the raw material selected for this study. Bagasse can be defined as the fibrous matter that remains after sugarcane stalks are crushed to extract their juice. The bagasse raw material (Fig. 1) is retrieved from a sugarcane shop in Cairo, then has been processed by drying, crushing, sieving it into different fiber sizes.

The following steps are supposed to produce the same test samples if followed:

1. The bagasse raw material is heated up in the oven (Fig. 2) and weighed periodically until its mass saturates to ensure the liquid content evaporation.
2. The bagasse material are cut down to shorter sections and then blended into the blender until it turns up to rough fibers, then these rough fibers are fed into the grinder until the fibers get finer.
3. The obtained sugarcane fibers are then sieved in the sieves set (Fig. 3) to get it classified into the following fiber sizes:
   a. Coarse fibers: the fiber size varies from 0.7 m to 1 mm (Fig. 4(a)).
   b. Medium fibers: the fiber size varies from 0.5 m to 0.7 mm (Fig. 4(b)).
   c. Fine fibers: the fiber size varies from 0.35 m to 0.5 mm (Fig. 4(c)).
4. According to the required sample density and sample thickness, the sample whole mass is calculated which is formed of fibers and resin. Then, based on the required resin content percentage of the whole sample mass, the fibers and resin masses are deduced. The resin content is composed of two substances: 90% of urea formaldehyde 65% concentrated and 10% of ammonium chloride as a hardener.
5. Then, the fiber mixture is molded using a piston and cylinder (Fig. 5) by applying pressure over a period of time. Fig. 6 shows a simple schematic of the process which involves filling a mold with sugarcane' wastes and resin is added in order to facilitate adhesion. Pressure is then applied to the top surface of the mold and kept for 10 min in order to gain sufficient strength to get the specified density, thickness and diameter. Finally the sample is heated up in the oven for six hours until it becomes hardened.
6. The final sample presented in Fig. 7 is then left to cool down before being ready for the measurement phase.
7. Sample holders (Fig. 8) of different lengths are used to plug the samples in, before attaching them to the test rig presented in the next section.

Fig. 1. Sugarcane wastes.

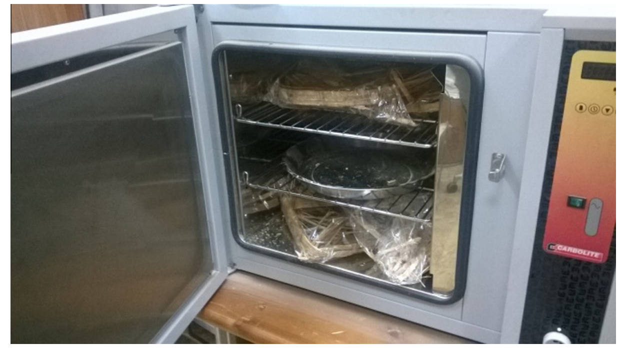

Fig. 2. Drying the sugarcane bagasse.

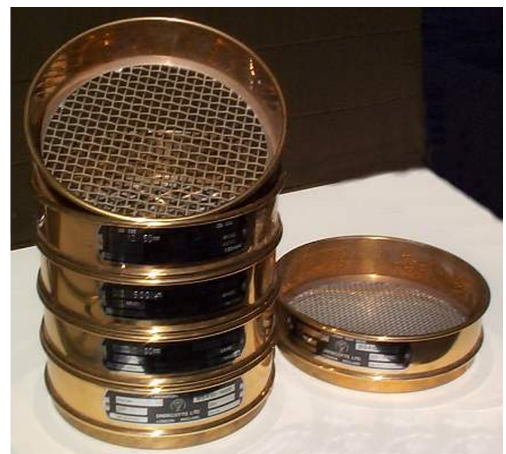

Fig. 3. Sieves set.

8. By varying the thickness, the fiber size and the resin content in the manufacturing process, five samples from the sugarcane wastes are obtained. These samples are presented in Table 1.

As observed in Table 1, obtained samples have the same resin with 20% content except the sample no. 5 with 15%. The thickness of these samples decreases from sample 1 to 5. The fiber size varies between 0.5 and 1 mm. This variation in sample parameters allows us to study each parameter's effect by comparing results of samples sharing two same parameters.

3. Experimental procedures

3.1. Measurement of the liner flow resistivity

The pressure difference through a fibrous material sample is a function of the air velocity traversing this material [7]:

$$\Delta P = P - P_0 = R_f \cdot v \quad (1)$$

P_0 is the atmospheric pressure, P is the pressure inside the duct, v is the air velocity and R_f is the flow resistance. The flow resistivity of the material σ is deduced then:

$$\sigma = \frac{R_f}{h} \quad (2)$$

With h is the sample thickness. The flow resistivity measurement is based, as presented in Eqs. (1) and (2), on the measurement of two parameters: the air velocity and the difference of pressure at the extremities of the sample ΔP. By changing the air velocity, the

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