Study of sound absorption and reflection coefficients and thermal conductivity of porous composite material obtained from household glass waste and burnt rice grains husks

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Abstract: *The coefficients of sound absorption and reflection in the frequency range up to 2 kHz, here respectively 0.2 and 08, as well as the coefficient of thermal conductivity, here below 0.027, of a new porous composite material were studied. The material was obtained from ground household glass waste and rice grains husks burned at temperature from 4000C to 7000C. The results show that the material has good sound reflectivity and low thermal conductivity, which makes it suitable for the manufacture of modules for thermal and sound insulation.*
Keywords*: SOUND ABSORPTION, SOUND REFLECTION, THERMAL INSULATION, SOUND INSULATION*

1. Introduction

Composite materials are specific technological products whose characteristics depend on the components that make them up. In the present study, the sound absorption, sound reflection and thermal conductivity of porous composite material (PCM) obtained from ground household glass waste and rice grains husks burned at temperature from 400^0C to 700^0C [1] were studied.

Due to its valuable properties, PCM finds wide application in the field of construction and marine engineering. PCM has good sound insulation, high thermal insulation and heat resistance, high strength and excellent corrosion resistance. It is important to note that both components that make up the composite material are household and bio-waste released in huge quantities and constituting a problem for the countries where they are produced and accumulated. The utilization of these two types of waste for energy and environmentally efficient material will have a positive effect in various areas of industry.

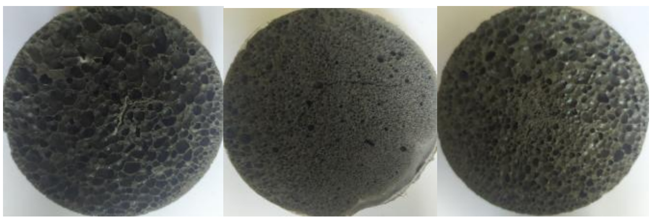
The production of the material and its useful properties are due to the ash obtained by burning rice grain husks. With proper observance of the technological conditions of combustion, such as heating rate and maximum heating temperature, ash containing nanosized SiO_2 is obtained, while rapid burning results in incomplete burning and coke production. The composite material is non-combustible and non-flammable.

The study of sound absorption, sound reflection and thermal conductivity of the material will contribute to its application in construction industry as it will allow for the proper calculation and sizing of various building modules. The modules are obtained by performing the foaming in moulds or by foaming blocks of the material from which modules are later obtained by machining.

2. Experiments

2.1. Materials

The aim of the study is to determine experimentally the coefficient of sound reflection and absorption and the coefficient of thermal conductivity of samples made of bio products. The subject of study are 5 samples shown in Fig.1. The dimensions of the samples are: diameter 80 mm and height from 12 to 20 mm.



Sample No 1 ***Sample No 2*** ***Sample No 5***

Sample No 8 ***Sample No 11***

Fig. 1. Pictures of the studied samples.

3.2. Determination of the coefficients of sound reflection and sound absorption

To determine the acoustic properties of the developed materials, an interferometric method is applied at zero angle of incidence of the sound wave [2,3]. The measuring instrument is a cylindrical interferometric tube with acoustically rigid walls. At one end of the tube is positioned a speaker which creates a flat sound wave in the tube, and at the other - a reference sample of material with high sound reflection. The tests are performed within the frequency range from 100 Hz to 2,000 Hz. A diagram of the experimental setup is presented in Fig. 3. The test samples are placed in front of the reference sample which is made of lead. The frequency of the generator is set to obtain resonance frequencies. A microphone is moved to measure the sound pressure P in the areas of the minimum (Pmin) and maximum (Pmax) pressure of the standing waves formed in the tube. A computer sound analysis system RTA 168 and a Multi Instruments data collection program were used.

Several measurements were made in the peaks and troughs of the standing waves at each resonant frequency of the system for each studied sample. The values are recorded and statistically processed. The coefficients of standing waves n (1), sound absorption (4) and sound reflection R (2, 3) are calculated by the dependences (1-3) [3]. The coefficient of standing wave n is given by:

(1) n = (Pmax/ Pmin)

The coefficient of sound reflection R is determined by the relationship:

(2) R=(n-1)/(n+1)

The squared-magnitude of the coefficient of sound reflection denotes the power Rp that is reflected:

(3) $$R_p = \left(\frac{n-1}{n+1}\right)^2$$

The coefficient of sound absorption α is given by the equation:

(4) $$\alpha = 1 - R_p = \frac{4n}{(n+1)^2}$$

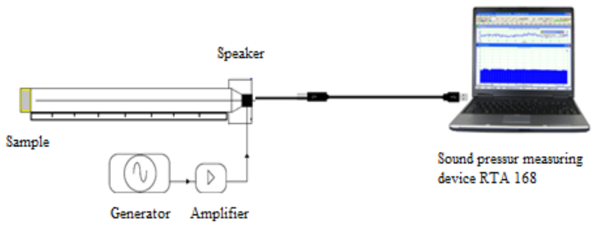


Fig. 2. Diagram of the experimental setup for measuring sound reflection and absorption

2.3. Results of measurements of sound reflection and absorption coefficients

The results of the measurements of sound and absorption coefficients in the frequency range up to 2 kHz Hz are shown in Fig. 3 a, b, c, d and e for the tested samples Nos 1, 2, 5, 8 and 11. In Fig. 4 are shown the average values of the coefficients for the material from which the test specimens were cut and the lead reference sample, which is characterized by a large sound reflection. The mean values of sound reflection and sound absorption coefficients in the whole frequency range up to 2 kHz are 0.8 and 0.2, respectively. The tested samples have good sound reflectivity.

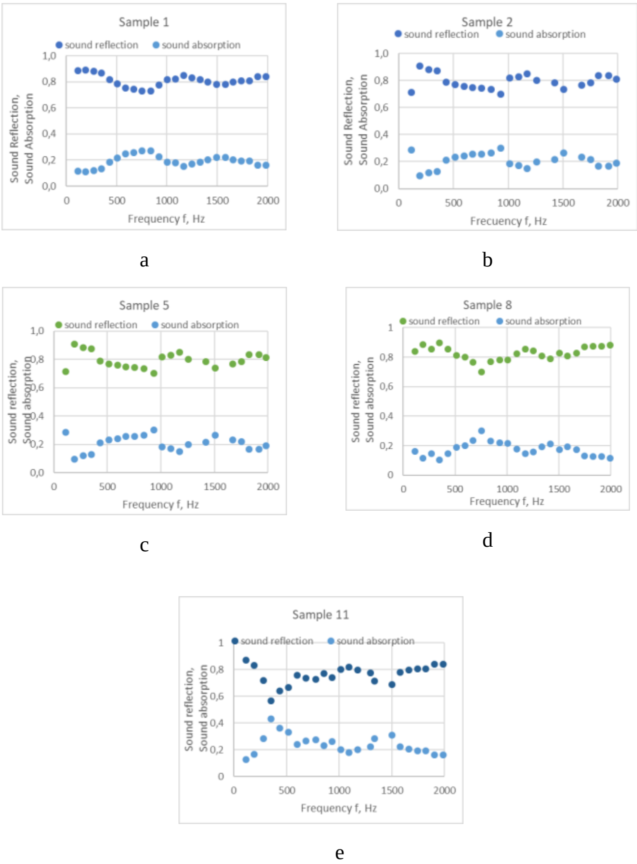


Fig. 3. Sound reflection and absorption coefficients for frequencies up to 2 kHz.

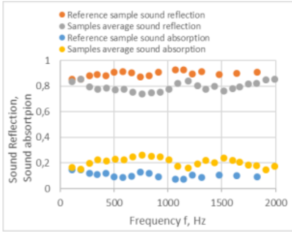


Fig. 4. Average values of the reflection and absorption coefficients for the studied test samples and the lead reference sample

2.4. Determination of the thermal conductivity coefficient

A comparative method using cylindrical reference samples [4] was applied to measure the thermal conductivity. A reference sample (h_R = 20 mm, D = 80 mm), a test sample, a second reference sample (h_R = 20 mm, D = 80 mm) and a cooler were placed sequentially on the heater. The diameters of the reference samples and the test sample are the same (D = 80 mm). The system is insulated using a low thermal conductivity material. The diagram in Fig. 5 illustrates the implementing the comparative method.

The following designations are used: 1 – heater, 2 and 4 – cylindrical shape reference samples made of high thermal conductivity material (steel), 3 – test sample (composite material), 5,6,7 and 8 – type K thermocouples, 10 – thermometer-data logger (device for recording temperatures change over time – 4-channel CENTER 304 type K thermometer.

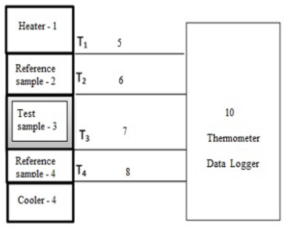


Fig. 5. Diagram for implementing the thermal conductivity measurement

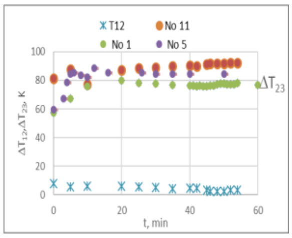


Fig.6. Changes in the surface temperatures of the reference sample (2) and the test sample (3) during the measurements of test samples Nos 1,5 and 11

The amount of heat Q conducted through a material of thickness h at a temperature difference ΔT for a time interval τ through an area s is determined by the dependence:

(5) $$Q = \lambda . s . (\Delta T / h),$$

where λ is the coefficient of thermal conductivity of the material.

In stationary thermal mode, the amount of heat transferred from the heater through the reference sample to the test sample and the second reference sample, both of which have the same area, is the same:

(6) $$Q = \lambda_R \frac{\Delta T_{12}}{h_R} = \lambda_X \frac{\Delta T_{23}}{h_X} = \lambda_R \frac{\Delta T_{34}}{h_R},$$

where λ_R is the coefficient of thermal conductivity of the material of the reference sample, λ_X is the coefficient of thermal conductivity of the test sample, ΔT_{12} is the temperature difference between the surfaces of the heater (1) and the reference sample (2), ΔT_{23} is the temperature difference between the surfaces of the reference sample (2) and the test sample (3), ΔT_{34} is the temperature difference between the surfaces of the test sample (3) and the second reference sample (4).

The coefficient of thermal conductivity λ of the material of the test sample is determined by the formula:

(7) $$\lambda = \lambda_R \frac{\Delta T_{12}}{\Delta T_{23}} \frac{h_X}{h_R}$$

In Fig. 6 are shown the difference in the surface temperatures of the reference sample (2) and the test sample (3) ΔT_{23} during the measurements of the tested samples № 1,5 and 11, which are 76 K, 85 K and 90 K respectively.

The ratios λ/λ_R (λ_R =40 K W/m.K) for samples Nos1 (h_X = 16 mm), 5 (h_X = 20 mm) and 11 (h_X = 15mm) are 0.026, 0.014 and 0.027 respectively. The thermal conductivity coefficients of the studied samples are low and they can be used as thermal insulation materials.

The results show that the material has good sound reflectivity and low thermal conductivity, which makes it suitable for the manufacture of modules for thermal and sound insulation.

3. References

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