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Research on Obtaining Biocomposite Structures with Sound Absorbing Properties

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Abstract*: The paper addresses the methodology for obtaining biocomposite structures from waste, with sound-absorbing properties, such as: thuja shells, walnut shells, pistachio shells, beech sawdust, pumpkin seeds shells and sunflower seeds shells. The experimental analysis carried out considers the study of the sound-absorbing properties held by the proposed new biocomposite materials, by determining the value of the sound absorption coefficient, reflection coefficient, impedance ratio, using the Kundt tube. The interpretation of the results obtained from the evaluation of biocomposites shows that they have sound-absorbing properties. Consequently, sound-absorbing panels with soundproofing properties can be made from these materials, which can be used in industry, transportation, construction, etc. as well as for decorative purposes in spaces such as cinemas, malls, spas, etc.*

Keywords*: waste, sound-absorption, biocomposite materials, impedance tube*

1.Introduction

Human society is currently facing many problems such as: the effect of climate change, the deterioration of the quality of the external environment, globalization and the economic crisis, due to the process of social and economic development [1].

The amount of waste generated by human activities is a major issue that has been brought to public awareness ever since 1970, when it was found that waste treatment methods, such as incineration and storage, are not effective. Recycling waste is an efficient method of protecting the external environment. The main reasons for using the recycling method are the economic advantage and the decrease in the amount of natural raw materials used in human activities [2].

Waste management is a key global issue, generated by the increase in its quantity. The treatment of waste by storage in storage facilities, called landfills, which do not comply with the minimum requirements imposed by law, the discharge into watercourses and uncontrolled incineration, generate some major risks, both for the environment and public health [3]. Waste is not only a potential source of pollution but also a source of new raw materials. Like waste, the harmful effects of noise are an important component of environmental pollution. Noise pollution affects the well-being of millions of people every day and can lead to serious health issues such as hearing loss and stress [4]. The different frequencies and intensities of sounds are a stress factor to which people are constantly exposed: during the daytime and at night, in their homes, on the street or at in the workplace [5]. Therefore, it is necessary to reduce the noise level and the amount of waste, for both economic and social reasons. Composite materials could provide a solution for noise and waste reduction.

In order to ensure adequate acoustic comfort, measures to reduce noise pollution are necessary. At the same time, an economic advantage would be obtained since reducing the noise level leads to productivity growth as a result of the increase of an individual's intellectual concentration capacity. Extensive research has been conducted in the field of biocomposite materials used to obtain sound-absorbing panels to reduce noise levels [6].

The development of technical solutions for the production of sound-absorbing biocomposite materials is advancing. The fundamental goal is to establish innovative technical solutions for modular

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structures made of biocomposite materials capable of simultaneously satisfying three functions for structural noise and vibration, respectively: the function of absorbing noise in the high-frequency spectrum, the function of isolating noise in the spectrum of low frequencies and the function of damping structural vibrations. To improve the acoustic absorption of materials and attenuate the noise, different systems were developed based on recycling solid waste [7].

Biocomposite materials present a major advantage, respectively they can be used in almost any field, because their properties can be modulated. Researchers' efforts are oriented towards obtaining new materials, designing equipment for their processing and development of processing technologies. Biocomposite materials are characterized by [8]: low coefficient of expansion about metals, high shock resistance, high durability in operation, superior vibration damping capacity, high safety in operation, low energy consumption in processing, compared to metals, resistance to corrosion, thermal stability, high temperature resistance, the high coefficient for noise absorption etc.

The purpose of this experimental research is to obtain biocomposite materials from waste and to determine their acoustic properties (absorption coefficient, reflection coefficient, impedance ratio). It would reduce the amount of waste available globally and at the same time reduce noise pollution. Sound-absorbing panels can be made out of these materials used in various industries, to reduce noise levels, or for decorative and sound-absorbing purposes, in crowded areas such as cinemas, malls and spas [9,10].

From the theoretical research conducted in the field, it can be concluded that the value of the absorption coefficient of biocomposite materials is directly influenced by their thickness and the nature of the materials used [11, 12]. Also, the absorption coefficient is influenced by the reinforcement elements present in the composition of materials [13 - 15]. Considering the problems generated by the high noise level, it can be said that the discovery of new composite materials with sound absorption properties is a priority for the field of research and development [16].

2.Materials and methods

2.1. Description of the materials and methods used

The biocomposite materials were made of:

- basic materials (waste): thuja shells, walnut shells, pistachio shells, beech sawdust, pumpkin seeds shells and sunflower seeds shells (Figure 1);
- additive materials: cement or plaster.

The waste was ground in a laboratory mill and mixed with the additive materials and water. The ratio of base materials/additives was 50% - 50%. Water was added to obtain a homogeneous mixture. The casting has been realized in a molding device with the following dimensions: diameter of 63 mm and height of 20 mm. Strengthening has been realized in 48 h at room temperature.

Figure 1. Experimented materials

To determine the absorption and reflection coefficients and the impedance ratio, six types of circular-shaped samples were made (Figure 2):

P1_20 - Thuja shells + cement
P2_20 - Walnut shells + cement
P3_20 - Pistachio shells + plaster
P4_20 - Pumpkin seeds shells + cement
P5_20 - Sunflower seeds shells + cement
P6_20 - Beech sawdust + plaster

Figure 2. Biocomposite materials obtained

Depending on the sound absorption coefficient obtained from the individual analysis of the 6 experimental samples, they were distributed by sound absorption class. A composite material with good sound-absorbing properties has a value $\alpha = 1$ or close to 1 and the percentage of absorption at this value must be maintained over a wide frequency range. According to the international standard, the materials are classified into classes of sound absorption depending on α (Table 1)

Table 1. Absorption class depending on coefficient α [17]

Sound absorptiom class	The absorption coefficient, α
A	1.00-0.90
B	0.85-0.80
C	0.75-0.60
D	0.55-0.30
E	0.25-0.15
No class	0.10-0.00

2.2. Equipment used

To determine the sound absorption coefficient, reflection coefficient, impedance ratio for the biocomposite materials obtained, the method of Kundt impedance tube is used (Figure 3), according to a standardized method [18]. The necessary equipment consists of: an acoustic interferometer tube, a sample holder, microphone probe, a device to process the signal from the microphone, a mobile device to move and put into position the microphone, speakers, a sinusoid signals generator and a thermometer.

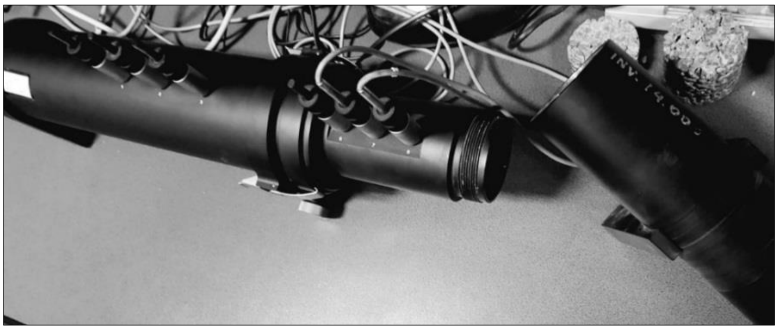

Figure 3. Equipment used for the analysis of biocomposite materials obtained

The values of these coefficients were determined for the frequency band width 0÷3200 Hz. The data from the experiment were acquired and processed by Bruël&Kjær PULSE Platform type 7758 [19].

3.Results and discussions

The sound absorption coefficient indicates what amount of sound is absorbed in the actual material and depends on the frequency values [20]. The data obtained by measurements were processed and the graph of the dependence of the medium absorption coefficient - frequency was made, for all six samples (Figure 4).

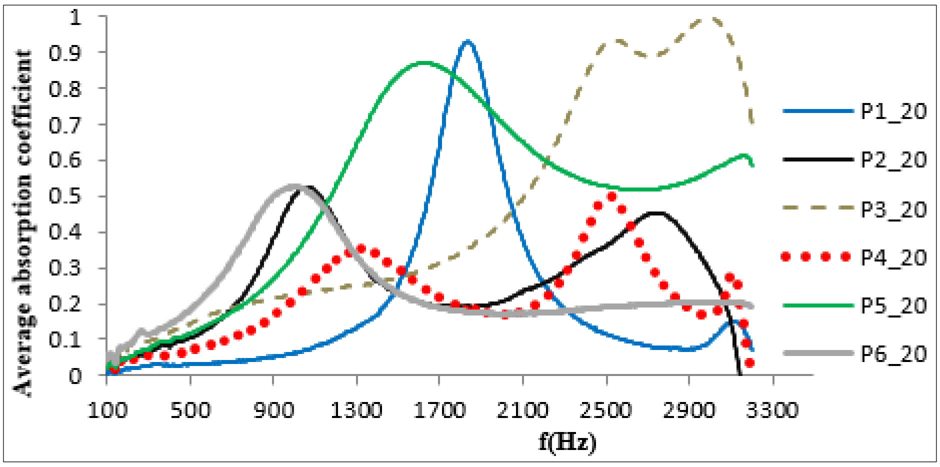

Figure 4. The variation of the medium sound absorption coefficient for the samples P1_20 – P6_20

The sample P1_20 displayied obtained after the experimental determinations a medium absorption coefficient α = 0.929. The medium absorption coefficient shows a progressive increase from 400 Hz to 1800 Hz, at which point it begins to decrease.

For the sample P2_20 the absorption coefficient increases from 400 Hz to 1000 Hz and the maximum value is α = 0.526; from 1000 Hz it begins to decrease. The coefficient increases again from 1900 Hz to 2800 Hz, but the threshold reached does not exceed 0.45.

Following the experimental determinations, the sample P3_20 obtained an absorption coefficient of $\alpha = 0.995$. The absorption coefficient increases from 400 Hz to about 3000 Hz, at which point it begins to decrease.

The maximum value of the absorption coefficient is α = 0.5 for the sample P4_20. The absorption coefficient increases from 400 Hz to 1300 Hz, at which point it begins to decrease, but the value does not exceed 0.35. Between 2100 Hz - 2800 Hz the coefficient increases again, reaching the maximum value, then begins to decrease.

The sample P5_20 obtained a medium absorption coefficient of more than α = 0.85. The absorption coefficient increases progressively from 400 Hz to about 1600 Hz, then begins to decrease.

The sample P6_20 obtained an absorption coefficient of more than α = 0.5. The absorption coefficient begins to increase from 400 Hz to 1200 Hz, then decreases.

Figure 5 shows, in descending order, the maximum values of the medium absorption coefficient on the studied material.

Depending on the acoustic behavior, the samples can be grouped into three categories:

- class A of sound absorption - the samples P3_20 and P1_20 are described by high absorption of sound for the frequency range between 2500 - 3000 Hz, respectively around the frequency of 1800 Hz;
- class B of sound absorption - the sample P5_20 for the frequency spectrum between 1400 to 1800 Hz;

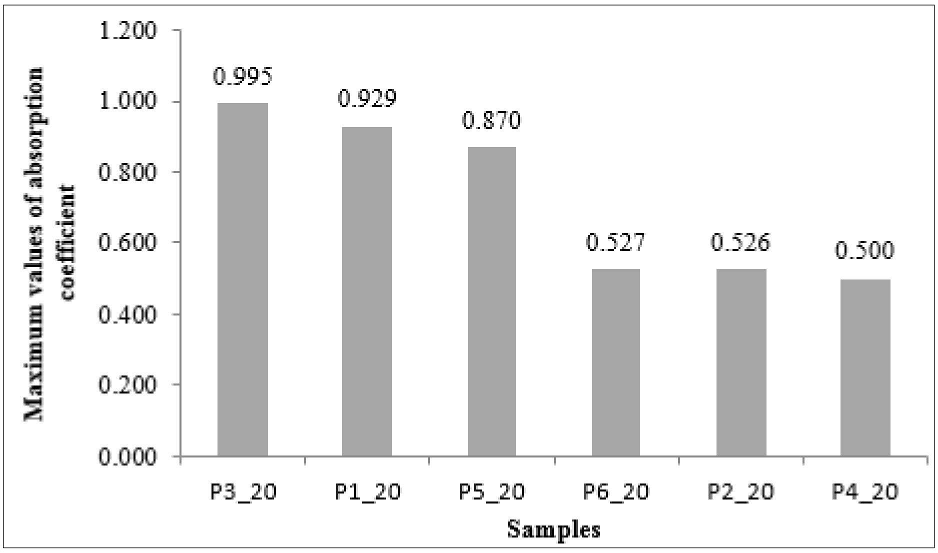

Figure 5. The maximum values of the medium absorption coefficient for tested samples

- class D of sound absorbtion - the samples P6_20, P2_20, P4_20 have the same sound absorption coefficient, for the frequency range between 800 - 1300 Hz (P6_20, P2_20), respectively 2300 - 2700 Hz (P4_20).

The reflection coefficient determined for the tested materials is presented in Figure 6. The most reflective material is the P4_20. It can be observed that these materials are characterized by a high reflective coefficient - over 0.6 for the frequency range between 100 - 1000 Hz. All materials tend to have a negative value of the reflection coefficient for high frequencies.

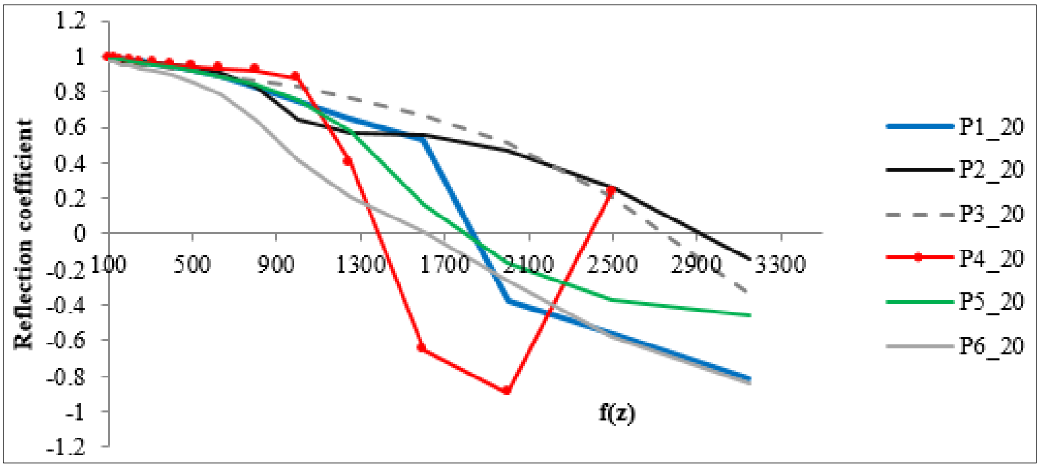

Figure 6. The reflection coefficient versus frequency

Figure 7 represents the variation of impedance ratio depending on frequency. The most important variation of impedance ratio can be observed in the range of 100-1100 Hz. For all samples, the impedance decreases to zero, at high frequencies.

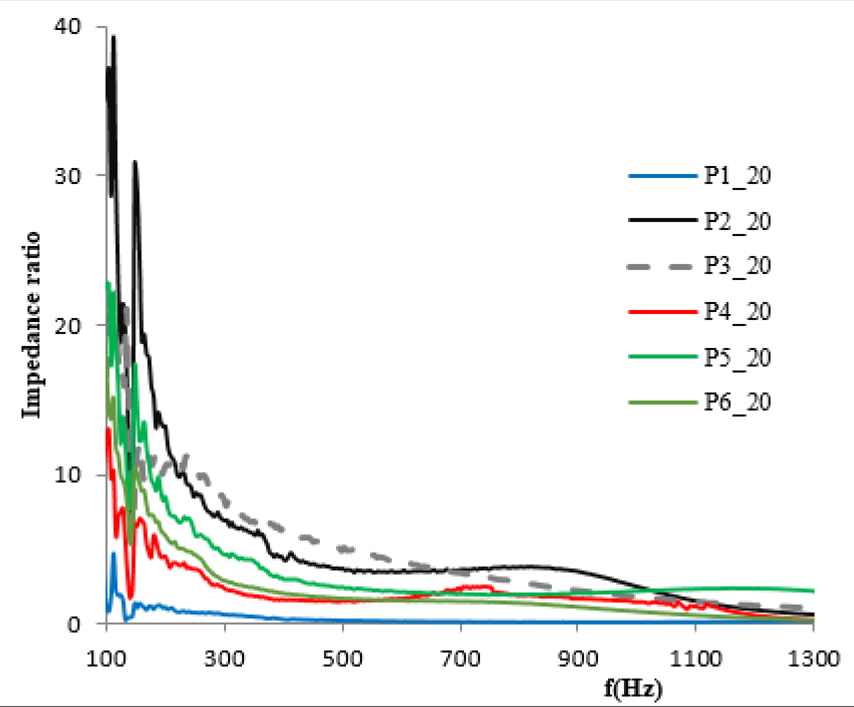

Figure 7. Variation of impedance ratio versus frequency

4.Conclusions

The experimental research aimed to obtain biocomposite materials from waste and to determine their acoustic properties. Six types of circular-shaped samples were tested. The sample P3_20 (pistachio shells + plaster) and P1_20 (thuja sheels + cement) present a very good sound absorption at high frequencies, which recommends them for sound insulation application.

Also, sample P5_20 (sunflower seeds shells + cement) has a good sound absorption coefficient, falling into class B of sound absorption. The other ones, such as P6_20 (beech sawdust + plaster), P2_20 (walnut shells + cement) and P4_20 (pumpkin seeds shells + cement), have recorded a lower value of the absorption coefficient against the frequency.

The study of these samples can be continued to improve sound absorption for a wide frequency range. The development of these new biocomposite materials with high sound absorption properties contributes to reducing the amount of waste and protecting the environment.

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