Assessment of Acoustic Properties of Biodegradable Composite Materials with Textile Inserts

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The paper focuses on the experimental evaluation of acoustic properties of biodegradable composite materials with textile inserts used for products with a protective role in the urban habitat. The materials used in this study are obtained from mixed wood and textile waste bonded together with ecological binders. In order to determine the absorption and reflection coefficients, the samples were tested using the impedance tube Bruel & Kjaer type, 4206 A, with a frequency range between 100 - 3200 Hz. It was concluded that the tested specimens have shown a high absorption coefficient for the frequency range between 800 – 2800 Hz. It was also noticed that the values of absorption coefficient depended on the type and quantity of binders. Based on the experimental results, the composition of the tested materials will be improved in the future in order to obtain a good absorption of the sound at low frequencies.

Keywords: absorption, reflection, composite, frequency, impedance tube

The sound absorption is one of the most important acoustical properties of the porous materials used for sound insulation products having the role of sound barriers, walls, road surfaces [1]. Depending on the type of materials and products, the range of frequencies and applications, the measurement methods of absorption coefficient vary and they can be: the impedance tube method, ultrasound method, extended surface method, guard tube method or reverberant room method [2]. One of the widely used methods to determine the acoustic properties (absorption coefficient, impedance ratio, reflection coefficient) is the international standardized impedance tube method.

In order to improve the acoustic absorption of materials and attenuate the noise from industry or urban traffic, different systems were developed based on recycling solid waste (sterile municipal waste, wood chips, waste polystyrene, slag or fly ash with polymer matrix). In unused form these residues could harm the environment [3]. Another type of materials such polyester fiber, glass fiber and urethane foam were researched in order to determine the sound transmission loss both theoretical and experimental [4]. The variation of sound absorption coefficient carried out by Kundt's tube was determined for the following materials: porous textile material, latex plate, rigid plate consisting on textile waste, synthetic leather glued on textile support [5, 6].

This paper focuses on the assessment of the acoustical properties of new composite structures based on wood chips and textile waste bonded together with ecological binders. In previous work, the density and thermal conductivity coefficient were determined for each structure and compared with the expanded and extruded polystyrene values [7].

Experimental part

Materials and methods

In this study were used green and biodegradable materials, found as inserts of wood (flakes or fibers) and textiles (wool or jute) and binders as wheat flour, clay or ecological acrylic copolymers as can be seen in figure 1. In the first stage, these types of materials obtained as agglomerated structures were formed in wooden molds and then were prepared for measurements of sound absorption coefficient.

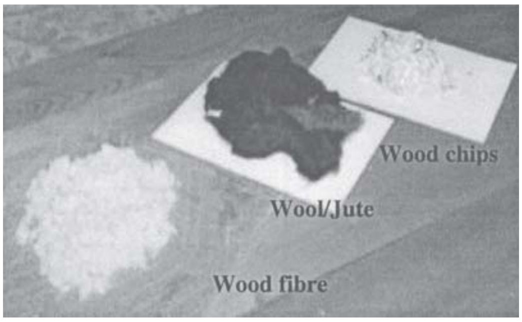

Fig. 1. The row materials used to obtain the biodegradable composites

The characteristics of composite materials are presented in table 1. The differences between samples consist on the quantities of raw materials or the type of binders, which conduct more or less to the compaction of the particles. The basic of these materials is represented by wood flakes and wool. The binder and the amount of binder in the composition are different. All samples were obtained in the same laboratory conditions, including the pressure parameter.

To determine the absorption coefficients, the set-up measurement chain presented in figure 2, was used. First, the equipment without samples was prepared, in order to configure the microphones and to calibrate them using the calibration function from Pulse soft [8-10]. Then, each sample was properly inserted into the tube and the measurements started (fig. 3). The generated noise was connected to the amplifier and the tube filter emitted the set signals. The emitted signal and reflected signal were

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Table 1
CHARACTERISTICS OF AGGLOMERATED STRUCTURES

Code	Content and amount		Properties
	Inserts, in g	Binders	Density, ρ kg/m^3
A1	Wood flakes 150 g, Wool 150 g	40% White acrylic copolymer (Paint), 60% water	197.89
L1	Wood flakes 150 g, Wool 150 g	400ml Ecologic acrylic copolymer (lacquer)	157.88
L2	Wood flakes 150 g, Wool 150 g	400ml Ecologic acrylic copolymer (lacquer)	193.16
L3	Wood flakes 150 g, Wool 150 g	800 g Clay solved in 500 ml water	626.73
G5	Wood flakes 150 g, Wool 150 g	600 g Gyps solved in water	415.52
G12	Wood flakes 100 g, Wool 100 g, Wood fibers 100 g	1000 g Gyps solved in 900 ml water	656.75
PAL 1	Wood chips (Particleboard - commercial)	Formaldehyde	700.00
PAL 2	Wood chips (Particleboard - commercial)	Formaldehyde	720.00

captured by microphones and transmitted to Pulse hardware and displayed with the Pulse soft.

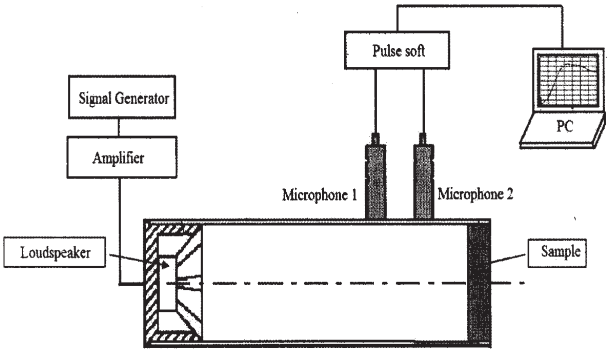

Fig. 2. The experimental set-up


Fig. 3. Capture image during the measurements

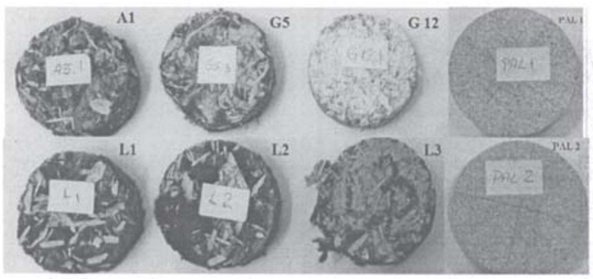

Fig.4. The agglomerated structures with different composition

Table 2
THE INPUT DATA

Tube	Characteristics
Type	Medium
Microphone Spacing:	0.0318 m
Distance to Sample from Mic. 2	0.0635 m
Distance to Source from Mic. 1	0.37 m
Diameter:	0.064 m
Lower Frequency Limit:	100 Hz
Centre Frequency (Hz):	1600
Generator	
Waveform:	Random
Signal Level:	1.414 Vrms
Pink Filter:	Off

For the experimental tests, the samples were cut into specimens with a diameter of 63.5 mm and the thickness in the range between 20 – 30 mm (fig. 4).

The input data from the project set-up are presented in table 2 and they are established automatically by soft in the calibration stage.

Due to the influence of the environment upon the measurements accuracy in situ, the tests were performed in the same environment conditions (atmosphere pressure - 1035.00 hPa, temperature - 28.00°C, relative humidity - 46,00%, velocity of sound - 347.89 m/s, density of air - 1.195 kg/m^3, characteristic impedance of air: 415.8 Pa/(m/s)).

Results and discussions

The sound absorption coefficient indicates what amount of sound is absorbed in the actual material and depends on the frequency type. In figure 5 the variation of sound absorption coefficient against the frequency is presented, for different materials. The maximum values of absorption coefficient are marked on the chart. It can be noticed that the composition of tested materials have influence on the sound absorption. From the acoustical behaviour point of view, the samples can be grouped in three cathegories:

- the sample A1, L1, L2 and G5 are described by high absorption of sound for the frequency range between 1000 – 3200 Hz.

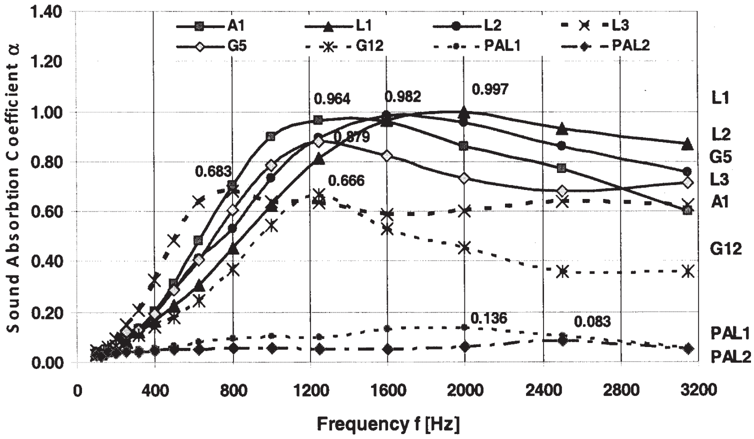

Fig. 5. The comparison of sound absorption coefficient for different materials

Table 3
ABSORPTION CLASSES [9]

Absorption coefficient α	Sound Absorption Class
1,00 – 0,90	A
0,85 - 0,80	B
0,75 – 0,60	C
0,55 – 0,30	D
0,25 – 0,15	E
0,10 – 0,00	Not classified

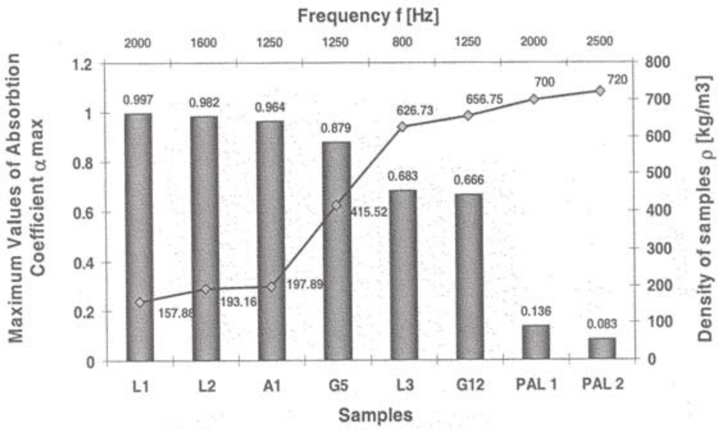

Fig. 6. The variation of sound absorption coefficient versus density of materials

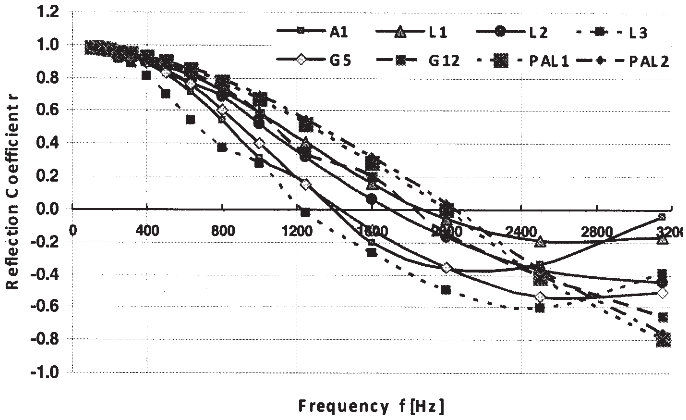

Fig. 7. The comparison of sound reflection coefficient for different materials

- the sample L3 which contains clay solved in water as a binder, presents a relative constant absorption of sound for the frequency spectrum ranged between 800 to 3200 Hz, but at a medium value of the absorption coefficient.

- the lowest absorption was recorded by samples PAL 1 and PAL 2, for all frequencies.

According to the absorption classes described in the international standard ISO 11654 (table 3), the new tested materials belong to class A (L1, L2, A1), class B (G5), class C (L3, G12) in opposite with PAL 1 and PAL 2 which can be not classified [11].

Figure 6 shows the variation of sound absorption coefficients against the density of the tested materials. First, the maximum values of absorption coefficients were selected from previous charts and then were compared to the variation of density. So, the increasing of the value of the density of materials leads to the decreasing of the absorption coeficient. For example, the samples L1, L2 and A1 have low density (range between 150 to 200 Kg/m^3) and high absorption (over 0.9). For high densities as PAL 1 and PAL 2 have (ρ=700...750 kg/m^3), the absorption capacity of materials is lower.

The reflection coefficient determined for the tested materials is presented in figure 7. The most reflective materials are the composites PAL 1 and PAL 2, characterized by flat and smoth surfaces and a high degree of compaction of wood particles and chips.The tendency of all materials is to have a negative value of the reflection coefficient for the frequencies in the range of 1200 – 3000, which correspond to the maximum acoustical absorption.

In figure 8 the chart of impedance ratio is presented, where the most important variation of impedance against the frequency in the range of 100 – 400 Hz can be observed.

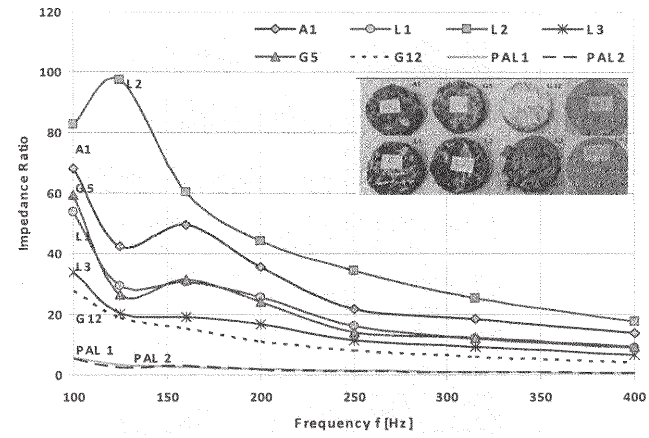

Fig. 8. The comparison between the impendance rations for tested materials

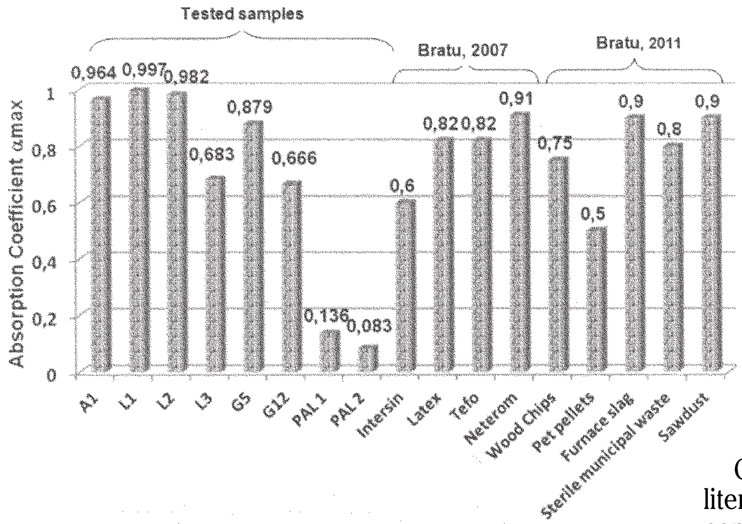

Fig. 9. Comparison between experimental and literature results

It can be noticed that by increasing the frequency 4 times, the impedance ratio decreases 4 times. At high frequencies, the impedance decreases to zero, no matter of the materials of the sample.

Conclusions

The experimental investigation aimed to determine the acoustical properties of new materials obtained by waste textile and wood residues. These materials were designed for assuring a good acoustic and thermal insulation. Eight types of materials were tested. The composition of binders (matrix) had a great influence upon the acoustical properties of the samples (absorption coefficient, impedance ratio, reflection coefficient). Concerning the sound absorption coefficient, the sample A1 (white acrylic copolymer), L1 and L2 (ecological acrylic copolymer) and G5 (Gyps solved in water) presents a very good sound absorption at high frequencies, fact that recommends the materials for sound insulation application. The other ones, as PAL 1 and PAL 2 are, have recorded a lower value of absorption coefficient against the frequency. An interesting acoustic behaviour was performed by sample L3 (clay solved in water), due to its relative constant sound absorption at different frequencies, even the sample recorded only a medium value of absorption (around 0.683 at 600 Hz). For this reason, the research results of composites A1 (white acrylic copolymer), L1 and L2 (ecological acrylic copolymer) and G5 (Gyps solved in water) concluded to the fact that they can be used for sound absorbent panels for highways, railways and airports. The study of sample L3 made of wood flakes, wool and clay binder can be continued in order to improve the sound absorption for a large frequency domain.

Comparing the experimental results with others from literature (fig. 9), it can be noticed that the biodegradable composite materials with textile inserts as new structures, present a very good absorption capacity that will be used for future researches regarding their applications. The other materials studied by Bratu, 2007 and Bratu 2011 are composites based on residues as textile waste, synthetic leather, wood chips, pet pellets, furnace slag and sterile municipal waste [3-5].

Acknowledgments: This paper is supported by the Sectorial Operational Programme Human Resources Development (SOP HRD), financed from the European Social Fund and by the Romanian Government under the contract number POSDRU POSTDOC-DD, ID59323- Transilvania University of Brasov, Romania.
We are also grateful to ICECON Romania, manager Prof. Polidor Bratu who facilitates the measurements.

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Manuscript received: 16.01.2012