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ECO-COMPOSITES DESIGNED FOR THERMAL AND ACOUSTIC INSULATION OF BUILDINGS

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Abstract: *The paper aims to present a series of new composites that may be used for the thermal and acoustic insulation of buildings. The new composite structure is made from glued chips and wood fibres, hemp flakes, wool and reed fibres. The paper describes how the composites were made, and the methods used to determine the heat transfer coefficient and the acoustic absorption. The main purpose of this article is to promote these types of ecological materials which may replace in the near future, the materials that damage the human health and the environment.*

Key words: *ecological composites, thermal conductivity, sound absorption, insulation.*

1. Introduction

The "green" planet we live on has to be maintained by eliminating the most disturbing elements with unwanted "domino" effects on both human health and the environment.

At European level, buildings account for approximately 40% of the final energy consumption, and 36% of the emissions of greenhouse gases [14]. The consequence of this fact has led to the imposition of measures by the European Union, which stipulates that the Member States should ensure that "by 31 December 2020 all new buildings are buildings whose energy consumption is nearly zero" and " after 31 December 2018, new buildings occupied and owned by public authorities are buildings whose energy consumption is nearly zero" [14].

According to the World Health Organization, noise is considered to be a stress factor that severely affects the health of humans [11] being responsible for the occurrence of sleep disorders, cardiovascular disease, high blood pressure, myocardial infarction and tinnitus.

The centralized global medical data indicate that 12% of deaths are caused by ischemic heart disease, 9.6% of them by cerebrovascular disease and 1.6% of them by hypertension [12]. As regards the children of school age, the prolonged exposure to noise causes cognitive disorders [12]. The excessive exposure to noise also leads to the occurrence of tinnitus, which can cause sleep disturbances, depression, inability to work,

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frustration etc. [12].

In order to mitigate these undesirable effects, a possible solution to be applied is to insulate the buildings by using materials with high thermal and acoustic performances. Polystyrene is a thermal insulating material typically used for buildings, due to its affordable price and the low density, compared to other materials.

The World Health Organization Report in 2007 labeled polystyrene as a possible carcinogenic material, placed in the third risk group. According to the "Norms of fire safety of buildings", polystyrene is in "E" risk group, defined as a highly flammable material, which can withstand the maximum temperature of 75°C. Another drawback is that of not being a recyclable material, its degradation period being up to 400 years [1].

These drawbacks have determined the researchers to find new insulating products made from environmentally friendly materials that neither affect the health of humans, nor intervene as pollutants to the environment.

Studies on the composites containing hemp in their structure have shown that their acoustic properties [3], improve as the particle size decreases. For the composites having wood chips and fibers mixed with wool and jute in their structure [2], the sound absorption capability proved to be superior to other wood-based materials.

In the case of studies on the thermal insulation capacity of various materials, it has been demonstrated that an increase in the density of the composites made from bamboo fibers, leads to the determination of a higher thermal conductivity coefficient [6].

Other studies have shown that eco-materials can be successfully used in both acoustic and thermal insulation of buildings. Thus, research on biodegradable composites [5] showed that the panels containing textile fibers, wood chips and wood fibers in their structure performed on low values of the coefficient of thermal conductivity ($\lambda = 0.0412$W/mK).

This article presents a series of research works performed with a view to developing new composite materials for thermal and acoustic insulation, intended to replace traditional materials.

2. Objective

The main objective of the paper refers to the method to obtain new structures of composite using eco-materials such as: reed, wood fibres, wood chips, hemp particles, and also to determine both the coefficient of the thermal conductivity and the sound absorption of these composites, as well as to show whether or not they can be used as building materials for thermal insulation and sound absorption.

3. Method, Material and Equipment

The composite panels were made from the following environmentally friendly materials: wood chips and fibres, hemp and reed particles, wool waste, embedded in cement dissolved in water (Table 1).

The materials were mechanically mixed for a better homogenization of the structure; they were afterwards placed in wooden forms of 450mm x 450mm x 30mm and cold pressed for 24 hours. The composites thus obtained were heat dried for 5 hours in a press whose platens were heated in a range between 40°C and 50°C.

The equipment used to determine the coefficient of thermal conductivity was HFM436 Lambda (Figure 1) and the other one used to determine the sound absorption coefficient was Kundt tube (Figure 1b).

Table 1

Eco-materials used for manufacturing environmentally friendly composites

Code no.	Eco-materials [%]	Adhesive [%]	Density [kg/m^3]
P1	8.8% wood chips and 4.4% wool waste (total = 13.2%)	cement 47.3% dissolved in water 39.5%	729.16
P2	7.2% wood fibers and 3.5% wool waste (total = 10.7%)	cement 38.3% dissolved in water 54%	677.08
P3	4.4% wood chips, 4.4% wood fibers and 4.4% wool waste (total = 13.2%)	cement 47.3% dissolved in water 39.5%	733.33
P4	2.5% wood chips, 6.3% hemp particles and 4.4% wool waste (total = 13.2%)	cement 47.3% dissolved in water 39.5%	718.75
P5	6.3% wood chips, 2.5% hemp particles and 4.4% wool waste (total = 13.2%)	cement 47.3% dissolved in water 39.5%	708.33
P6	4.4% wool waste and 8.8% reed particles (total = 13.2%)	cement 47.3% dissolved in water 39.5%	716.33

Fig. 1. *Equipment used for experiment: a – HFM436 Lambda; b – Kundt tube*

In order to determine the coefficient of thermal conductivity, the panels were cut at dimensions of 400mm x 400mm x 30mm, and the sound absorption coefficient of the panels was obtained using samples cut at a diameter of 100mm.

The measurement of the thermal conductivity was done according to ISO 8301/1991 [8] and DIN EN 12667:2001 [9]. Thus, all the panels were tested for six values of the external temperature (T1) and a constant temperature difference, ΔT=20°C (Table 2).

In order to determine the sound absorption coefficient, a noise level of 75dB and a band of low frequencies in the range of 50-1390Hz were used.

4. Results and Discussion

The coefficients of thermal conductivity and sound absorption are analysed bellow.

Measurement points of the thermal conductivity Table 2

Temperature of the bottom plate T1 [^{0}C]	Temperature of the upper plate T2 [^{0}C]	ΔT = T2-T1 [^{0}C]	Temperature average $\frac{T1+T2}{2}[^0C]$
-20	0	20	-10
-15	5		-5
-10	10		0
-5	15		5
5	25		15
10	30		20

4.1 Coefficient of Thermal Conductivity

The results of the thermal conductivity coefficient determined from the experiments are shown in Table 3 and Figure 2. Following the results of the thermal conductivity coefficient of the six panels (Figure 2), each measured in six points (measuring conditions), one can notice that the lowest values of the coefficient of thermal conductivity were obtained for the composites P2 and P5, which means that they perform better as insulators.

The presence of the wood fibres in the structure of P2 panel determines a better insulation capacity than in the case of mixing wood chips and hemp particles (P5 panel).

For the composites P1 and P4 were recorded the highest values of the thermal conductivity coefficient, suggesting the lowest thermal insulation properties. Comparing the experimental results of the panels P3 and P6, one can notice that wood fibers and chips are not as good as reed particles for the performance of the thermal insulation of the resulted composites. Comparing panels P4 and P5, one can see that the structures are similar, except the amounts of wood chips and hemp particles. One can also notice that a greater amount of wood chips (panel P5) improves the thermal insulation property compared to the panel P4. Comparing the results of thermal conductivity coefficient (Figure 2) with density of all tested panels (Table 1), it can be noticed that a decreased density is usually but not necessarily associated to an increase of thermal insulation performance.

Table 3

Variation of the values of the thermal conductivity coefficients for the different types of experimental panels in the six measuring points (representing different measuring conditions as detailed in Table 2)

Panel type	Thermal conductivity coefficient λ [W/m*K] / measuring points					
	1	2	3	4	5	6
P1	0.097699	0.096065	0.099344	0.099790	0.099596	0.104011
P2	0.078481	0.081599	0.081575	0.083904	0.085780	0.087307
P3	0.092939	0.094164	0.096357	0.096435	0.098301	0.101044
P4	0.094784	0.097396	0.092992	0.100848	0.096339	0.106589
P5	0.083116	0.085049	0.086681	0.087484	0.088299	0.090738
P6	0.089080	0.089561	0.085723	0.092258	0.091153	0.096599

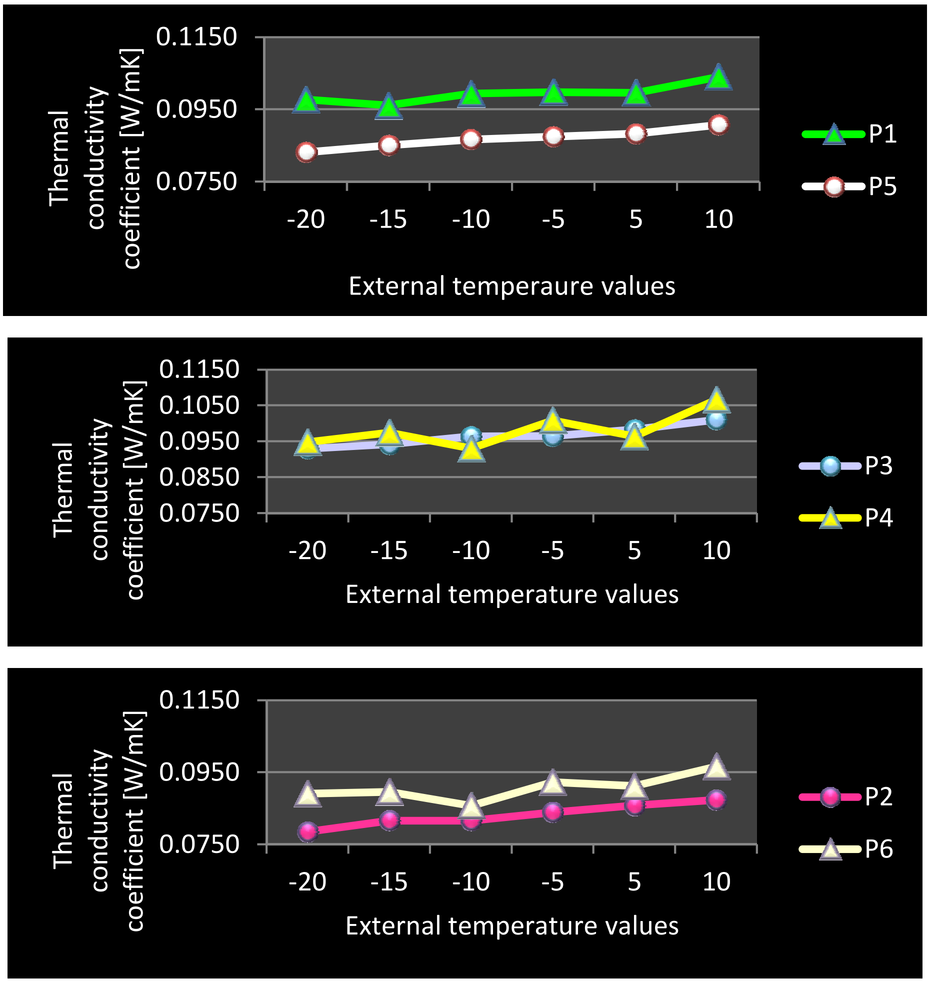

Fig. 2. *Diagram of the thermal conductivity coefficient*

4.2. Sound Absorption Coefficient

Analyzing the graphs in Figure 3, one can see that the panels P1, P2 and P3 have the average value of sound absorption coefficient in the range of 0.8 ÷ 0.9, the highest value being recorded for composite P3 (α = 0.870212) in the frequency range of 650 ÷ 950Hz.

In case of panel P4, the average sound absorption coefficient varies between 0.7 ÷ 0.8 for the frequency range of 650 ÷ 1050Hz. For panel P5, a higher value of the sound absorption coefficient was registered in the frequency range of 600 ÷ 850Hz, with a maximum value of 0559. In the frequency range of 850-1150Hz, a declined curve is observed, but for a frequency above 1150Hz, a peak of 0.649297 is reached. The explanation for such a situation can be attributed to the heterogeneity of the considered composite structure.

For the composites having in their structure the same materials (wood chips, hemp particles and wool) one can notice that a larger amount of wood chips and a smaller amount of hemp particles (in case of panel P5) provides a smaller acoustic insulation capacity than that of panel P4, which has a lower content of wood chips and a higher content of hemp particles.

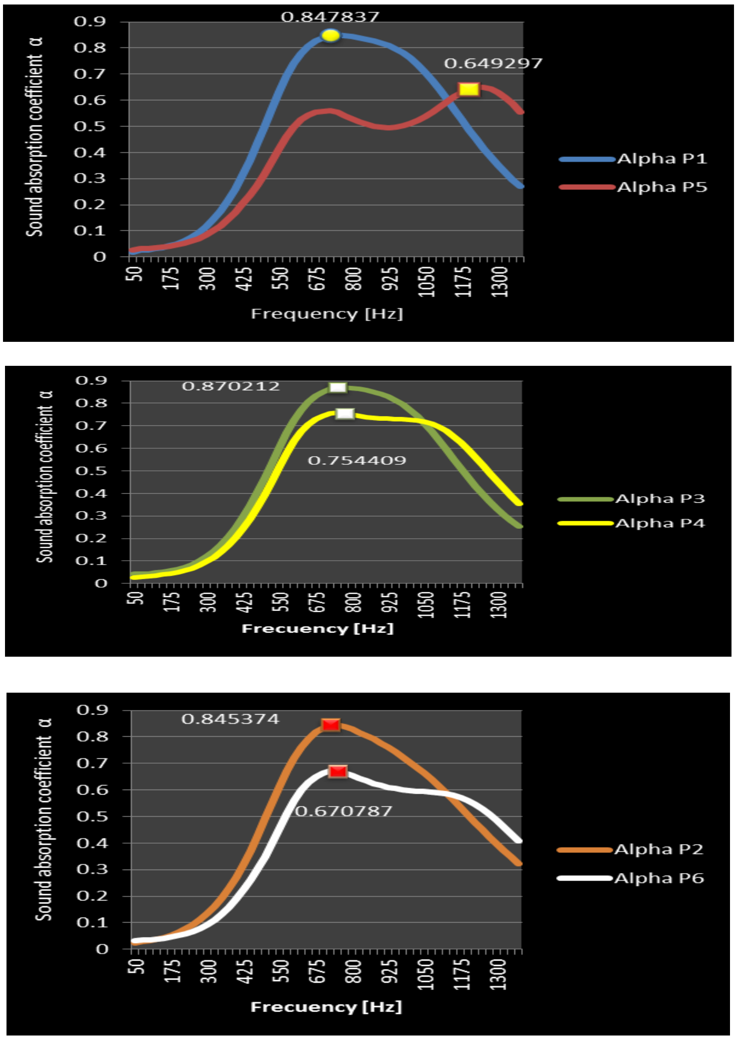

Fig. 3. *Measured values of the sound absorption coefficients*

The provisions of SR EN ISO 11654 [10], impose a classification of sound insulating materials. Thus, the composites analyzed in the paper may be classified as follows: panels P1, P2 and P3 in class B and panels P4, P5 and P6 in class C.

5. Conclusions

The analysis of the results of the two investigations, leads to the following conclusions:

- with a view to manufacturing a series of new eco-composite materials, the research presented in this paper, submits green products with higher coefficients of thermal conductivity, than those of polystyrene (λ = 0.036 ÷ 0046 W/mK) [7], but preferably to be used in the thermal insulation of buildings and civil engineering, because of the polystyrene drawbacks;
- the presence in the composite structures of the wood chips, wood fibres, wool and hemp particles led to good results

of the thermal conductivity coefficient, the top panel being P2;

- the determined values of the acoustic absorption coefficient resulted in the highest values recorded at 750Hz for both P1 and P3 structures;
- for panel P5, which has the lowest value of the acoustic absorption coefficient, the structure consisting of a higher amount of wood particles and a lower value of hemp particles proved to be non-efficient;
- a decreased density is usually but not necessarily associated to an increase of thermal insulation performance, and such comparison should be made on panels with similar composition;
- taking into account that the materials having the thermal conductivity coefficient up to 0.1W/mK are considered to be good thermal insulators, it can be concluded that all the panels studied in this paper meet this requirement [11];
- using ecological materials (wood chips and fibres, wool waste, hemp and read particles) in proportions of 10.7-13.2% in the composites structure, resulted in acceptable values of the thermal conductivity coefficient (λ = 0.078-0.089 W/mK), which is a clear positive result compared to other composites which had only 5% of hemp particles (λ=0.130-0.142 W/mK) [4];
- among the six composite materials presented in this paper, the composite panel P2 proved to be a possibly successful material to be used for thermal and acoustic insulation of industrial and civil buildings.

The results presented in the paper are a part of the research area covered by the author, and the analyses carried out have shown that the main disadvantage of these panels, is the high density. A solution for a further research is to use other than ceramic adhesives, obtaining thus lighter panels.

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