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# THE INFLUENCE OF ECOLOGICAL MATERIALS EMBEDDED INTO COMPOSITES UPON THE THERMAL INSULATING CAPACITY

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***Abstract:***
*The paper presents the results of a research performed in order to design and manufacture composites that embed in their structure ecological raw materials, such as wood chips and hemp hurds. The thermal conductivity was determined for a temperature difference (ΔT) of $20^0$C between the cold plate and warm plate and the measurements were done in eight points. The results showed that the best insulating composite material was obtained for the structure containing equal shares of wood chips and chopped hemp.*

***Key words:*** *composite panels; wood chips; hemp hurds; thermal conductivity; thermal insulation.*

## INTRODUCTION

The actual need of environment protection due to the emissions of pollutants coming from industry, transport and other areas has influenced the decision of the researchers to find composites with low emissions of pollutants. In this area, the composites with a high insulation capacity are investigated in the conditions of using ecological materials in their structure.

According to the statistics of European countries (http://epp.eurostat.ec.europa.eu/statistics_explained/index.php?title=File:Final_energy_consumption,_EU-27,_2010_(1)_(%25_of_total,_based_on_tonnes_of_oil_equivalent).png&_filetimestamp=20121012130317), the household and industrial energy consumption in 2010 was about 52%, a worrying fact with regard to the large amount of carbon dioxide emissions into the atmosphere.

The scientists are looking for solutions in this direction, studying effective and ecological solutions for thermal and sound insulation of the buildings, a first step for a healthier and cleaner environment. A solution for ecological raw materials in the structure of composites could be the waste materials from agriculture, forestry and wood processing. Thus, the valorization of hemp hurds in a mixture with lime chips, is a solution for composites with a thermal conductivity coefficient of 0.0899 ÷0,1408W/m*K (Benfratello *et al*. 2013). The increasing hemp hurds content in the structure of composites with binding materials such as cement or gypsum had as result the increas of the thermal insulating capacity of the composites (Gherghişan and Cismaru 2013). The presence of other materials as wood chips, wool fibres and chopped reed embedded in mineral and acrylic binding materials (Brenci *et al*. 2013) could lead to other viable solutions, having in mind that all above mentioned materials are ecological ones, without a significant impact on the environment and health. Some researchers on biodegradable composites (Olărescu and Coşereanu 2011) found that the lowest value of the thermal conductivity coefficient (ʎ=0.0412W/m*K) was registered for the panels containg wood chips, wool fibers and wood fibers.

The present paper shows the results of the research performed by the authors in order to obtain ecological composites containing wood chips and hemp hurds in their structure, having the property of thermal insulating material. The present study is a continuation of the investigations in this field, the final aim being an optimum structure that could meet the requirement of thermal insulation of the buildings.

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**OBJECTIVES**

The main objective of the paper is to show the results of the study regarding the influence of various ecological materials embedded in the structure of composites at diffrent ratios, upon the thermal insulating property of the composite material.

**METHOD, MATERIALS AND EQUIPMENT**

In order to manufacture the composites, hemp hurds and wood chips were used as reinforcing materials. They were embedded with varios ratios into seven composite structures, where gypsum has been used as binding material.

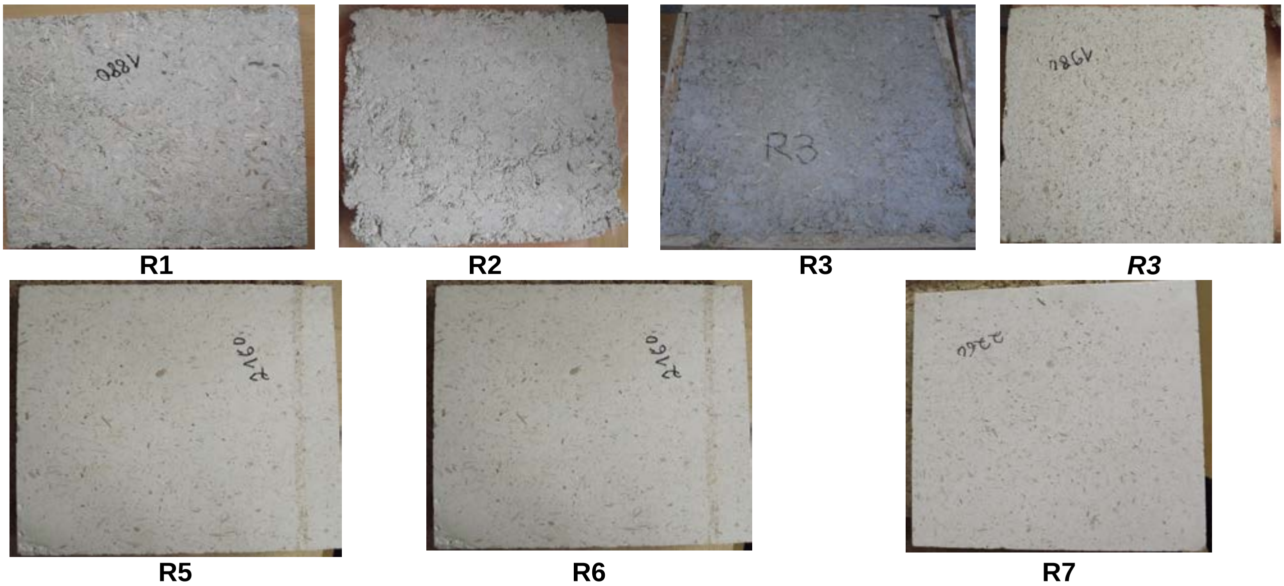


***Fig. 1.***
***The composite panels manufactured in the laboratory conditions.***

For the seven composite panels were given code numbers from R1 to R7. All panels were manufactured in the laboratory conditions.

The distribution of the materials into the seven structures is as follows: composites R1, R3 and R5 have the same ratio of wood chips and hemp hurds, namely 7.3%, 6.3% and 3.2% respectively; the composites R4 and R6 have only wood chips as reinforcing materials, namely 12.6 and 6.4% respectively and R7 contains only 6.4% hemp hurds. The composites R3, R4, R5, R6 and R7 have the same content of gypsum as binding material. The water amount decreased for the composites mentioned above, as follows: a maximum amount for panel R4, a smaller amount for panels R5, R6, R7, the amount of water decreasing successively for panels R2, then R3 and finaly R1.

The manufacturing process in the laboratory conditions was as follows: the wood chips and hemp hurds have been weighed, they were mixed with gypsum and water and then poured into wooden moldings with sizes of 350x380x20mm. Afterwards they were pressed for 10 minutes long (Table 1). After conditioning the panels (Fig. 1), they were cut at the final sizes of 300x300mm and calibrated for a final thickness of 20mm. Finally they were weighed again and the density was calculated as the ratio between the mass and the volume. (Table 2).

The thermal conductivity coefficient was measured (according ISO 8301/1991-08-01 and DIN EN 12667:2001), on HFM436 Lambda equipment, German manufacturer (Fig. 2.), being in the endowment of the research laboratory of the Wood Engineering Faculty in the frame of the ICDT Research Institute of the Transilvania University of Braşov.

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*Table 1*

***The pressing parameters***

| Code number | Pressure [bari] | Time of pressing [min] |
|---|---|---|
| R1 | 70 | 10 |
| R2 | 200 | 10 |
| R3 | 40 | 10 |
| R4 | 70 | 10 |
| R5 | 50 | 10 |
| R6 | 50 | 10 |
| R7 | 50 | 10 |

*Table 2*

***The characteristics of the composites***

| Code number | Sizes of the panels[mm] | | | Volume [m$^3$] | Mass [kg] | Density [kg/m$^3$] |
|---|---|---|---|---|---|---|
| | L | l | h | | | |
| R1 | 300 | 300 | 20 | 0.00245 | 2.557 | 1044.00 |
| R2 | 300 | 300 | 20 | | 1.09 | 420.00 |
| R3 | 300 | 300 | 20 | | 2.123 | 866.67 |
| R4 | 300 | 300 | 20 | | 2.695 | 1100.00 |
| R5 | 300 | 300 | 20 | | 2.94 | 1200.00 |
| R6 | 300 | 300 | 20 | | 3.074 | 1255.00 |
| R7 | 300 | 300 | 20 | | 2.611 | 1066.00 |

Taking into consideration that the final sizes of the panels were 300x300mm, and the sizes of the equipment plates were 600x600mm, a special frame made from polystyrene was added during the measurement all around the panels. It is to be mentioned that the added material had not negative influence upon the measured values of the thermal conductivity coefficient.

***Fig. 2.***
***HFM 436 Lambda equipment.***

*Table 3*

***The upper and lower plate temperatures corresponding to the eight measurement points***

| The measuring points | Temperature of lower plate T1 [$^o$C] | Temperature of upper plate T2 [$^o$C] | ΔT=T2-T1 [$^o$C] | Average (T2+T1)/2 [$^o$C] |
|---|---|---|---|---|
| 1 | -20 | 0 | 20 | -10 |
| 2 | -15 | 5 | 20 | -5 |
| 3 | -10 | 10 | 20 | 0 |
| 4 | -5 | 15 | 20 | 5 |
| 5 | 0 | 20 | 20 | 10 |
| 6 | 5 | 25 | 20 | 15 |
| 7 | 10 | 30 | 20 | 20 |
| 8 | 15 | 35 | 20 | 25 |

The panel and the added frame were placed between the hot plate and the cold plate of the equipment. The thermal flow is oriented in the equipment from the upper plate to the lower plate. The measurements were performed in the eight points for a temperature difference (*ΔT*) of $20^0$C (Table 3), according to ISO 8301/1991.

The testing data are displayed by the equipment software and automatically saved at the end of the test as .txt files. In Table 4 the values of the thermal conductivity coefficient in the case of the seven composite panels are presented.

*Table 4.*

***Thermal conductivity coefficient in case of the seven tested composite panels***

| Code number | Thermal conductivity coefficient λ [W/m*K] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Point 1 | Point 2 | Point 3 | Point 4 | Point 5 | Point 6 | Point 7 | Point 8 |
| **R1** | 0.138949 | 0.139764 | 0.141134 | 0.141219 | 0.141248 | 0.141299 | 0.143014 | 0.145228 |
| **R2** | 0.139753 | 0.140449 | 0.141847 | 0.142057 | 0.142081 | 0.142202 | 0.143967 | 0.146189 |
| **R3** | 0.139289 | 0.141041 | 0.142293 | 0.142573 | 0.142493 | 0.142641 | 0.144419 | 0.146662 |
| **R4** | 0.143458 | 0.144283 | 0.145489 | 0.145661 | 0.145654 | 0.145736 | 0.147627 | 0.149851 |
| **R5** | 0.144853 | 0.144973 | 0.146107 | 0.146605 | 0.146446 | 0.146746 | 0.148462 | 0.150808 |
| **R6** | 0.144293 | 0.143722 | 0.143937 | 0.143760 | 0.143951 | 0.143831 | 0.145653 | 0.147965 |
| **R7** | 0.129881 | 0.141356 | 0.142469 | 0.142605 | 0.142549 | 0.142658 | 0.144550 | 0.146804 |

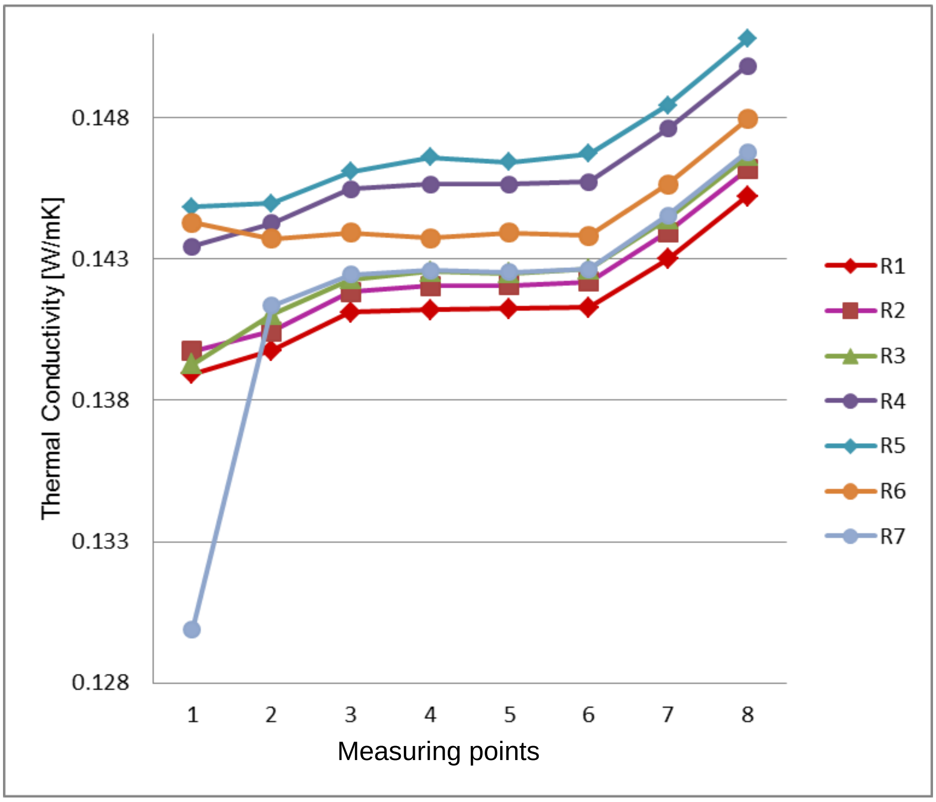


***Fig. 3.***
***Diagram of the thermal conductivity coefficient measured for the seven tested composite panels.***

By analyzing Fig. 3, one may notice that the measured values of the thermal conductivity coefficient for the seven panels were quite high compared to the admitted maximum value of 0.10W/mK according to the norm C107/0-2002. The trend was similar for the tested panels, excepting the composite R7 in point_1 (T1=-$20^0$C and T2=$0^0$C) where lower values were registered compared to the other six panels. The composite panel R1 had the lowest values of the thermal conductivity coefficient, and R5 was in an opposite position with regard to thermal conductivity coefficient. Composites R1 and R2, containing equal amounts of wood chips and hemp hurds, namely 7.3% and 3.6% respectively, registered different values of the thermal conductivity coefficient, smaller in case of R1 panel.

Even if R1 and R3 panels contain the same amounts of ecological reinforcing materials and binding material, the exceeding amount of water in R3 panel conducted to higher measured values of thermal conductivity coefficient.

In case of R6 and R5 panels, the double amount of wood chips embedded in R6 structure had a positive influence on the thermal insulation capacity of that panel. Thus, the values of thermal conductivity coefficient were lower for R6 compared with R5 structure (3.2%).

Panels R4 and R6 contain only hemp hurds, the highest rate of this material being embedded in structure R4. In this case, the thermal conductivity coefficient was lower in case of R4 structure. Panels R6 and R7 respectively contain the same amount of ecological material, wood chips for the first one and hemp hurds for the second one. This fact proves that the hemp hurds embedded in the composite R7 are better insulating components than wood chips embedded in composite R6.

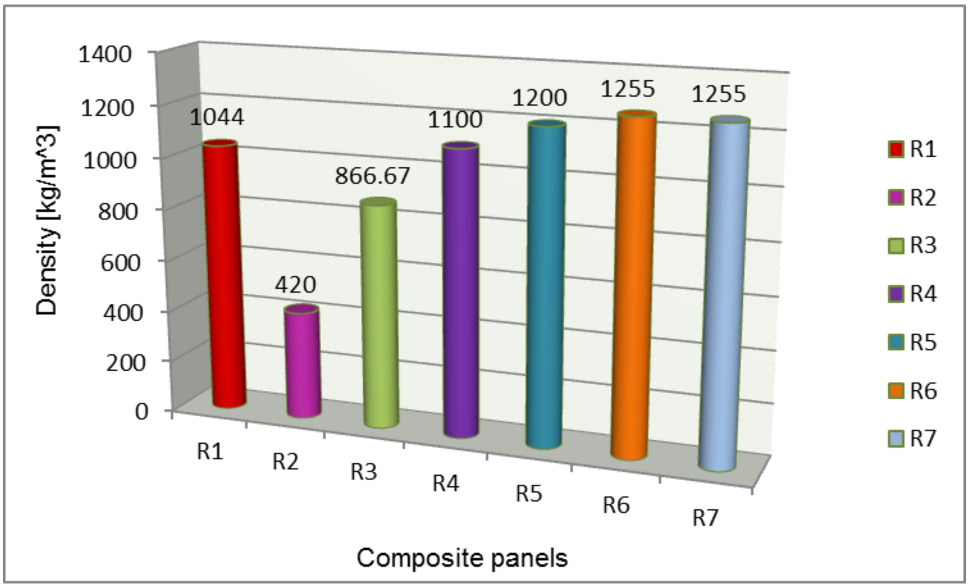


***Fig. 4.***
***The density of the seven composites.***

By analyzing Fig. 3 and 4, it was concluded that a decrease of the density of the composites does not influence the decrease of the thermal conductivity coefficient.

**CONCLUSIONS**

The best results in terms of the lowest values of the thermal conductivity coefficient λ have been registered in all measured points for structures R1 and R2. In change, panel R2 was more fragile at manipulation compared with R1 panel.

In case of panels R6 and R5, containing the same amount of water and gypsum, a double amount of wood chips (in case of R6 panel) brings better results than the equal ratios of wood chips and hemp hurds (as in case ofi R5 panel). So, R6 is a better thermal insulating panel than R5.

A higher content of water brings negative influences upon the thermal conductivity coefficient, even if the composition of reinforcing and binding materials is the same one. This is the case of R3 and R1 composites.

If the gypsum and water content are in equal rates, than the higher amount of hemp hurds brings a better insulating capacity, as in the case of panels R7 and R5.

For R6 structure, fluctuations of λ coefficient were registered. That could be caused by the non homogeneous structure of the panels.

The decreasing of the density did not affected the thermal conductivity coefficient in terms of decreasing it.

Even if the thermal conductivity coefficient values (λ=0.129881÷0.150808 W/mK) were higher than that of polystyrene (λ=0.036÷0.046W/mK, Yucel *et al*. 2003), and also the densities were higherthan that of polystyrene (ρ = 10÷30kg/m3, Yucel *et al*. 2003), the ecological content of the studied composites brings an important advantage.

Taking into consideration that the materials having the thermal conductivity coefficient up to 0.25W/mK are considered to be good thermal insulators, it can be concluded that all the panels studied in this paper meet this requirement.

A disadvantage of the studied composites is the high values of the densities. This fact will allow the authors to continue their research in order to obtain lighter and more effective panels in terms of thermal insulating capacity.

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