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THERMAL INSULATING PANELS MADE OF RECYCLED MATERIALS

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Abstract:
The present paper investigates the thermal performance of panels made of the following raw materials: wood fibres (WF) and recycled materials such as recycled polyethylene crumbs (PE) and acrylonitrile butadiene styrene shavings (ABS) resulted in the edge banding operation of melamine faced particleboard. Sizes and physical properties (bulk density, thermal conductivity coefficient and moisture content) of the raw materials used for the particleboard manufacturing were first investigated. Based on the results, thermal insulating panels with thicknesses of 18 mm and a target density of 300kg/m^3 were manufactured in the laboratory conditions and tested for the determination of the thermal conductivity coefficient, using HFM 446 Lambda Series Heat Flow Meter. The mixed panels WF:PE:ABS had various participation rates (in %), namely 5:5:90, 10:10:80, 15:15:70, 20:20:60, and 25:25:50. Six temperature gradients (ΔT) between 5ºC and 30ºC were set between two plates through the material to be measured. Thus, the experiment simulates the indoor and outdoor temperature conditions for the cold and warm seasons. The indoor temperature was set for the hot plate (upper plate) to 20ºC and the outdoor temperature was set for the cold plate (bottom plate) in the range of -10ºC to 15ºC. The results show that with the increase of ABS share from 50% to 90%, the value of thermal conductivity coefficient decreases and the thermal performance of the panel increases. The analysis of the results show that the thermal conductivity coefficient (λ) experimentally determined depends on the gradient of temperature. Thus, with the increasing of gradient of temperature, which corresponds to an outdoor temperature (T1) specific to cold season and ranging between -10ºC and 0ºC, the value of thermal conductivity coefficient (λ) increases, which means that the thermal insulating performance of the panels decreases. The recorded values of λ varied between 0.0472W/mK and 0.0568W/mK. These values recommend the investigated panels as thermal insulating ones and the best performance was recorded for the panels containing 90% ABS, having the lowest values of λ for all temperature gradients.

Key words: *panels; recycled plastic; thermal conductivity coefficient; air humidity; temperature gradient.*

INTRODUCTION

Plastics are extremely useful and versatile materials used in a various range of products such as consumer goods, packaging, automotive and construction. Low-density polyethylene (LDPE) is used in large amounts to make very useful consumer items such as carrier bags and fast food packaging (Goodship 2007). Latterly, the amount of plastics ending up in the waste was increasing with the increase of purchasing of goods from the supermarkets and excess use of plastic bags. Many countries have banned plastic bags due to public concern over the serious negative impact on the environment and agriculture (Moharam & Maqtari 2014). Romania is now aligned to the new trend, but vast quantities of plastics need to be recycled. LDPE is a thermoplastic material, so one way of recycling it is to re-melt and reprocess it in small granules which can be further mixed with virgin polyethylene and obtain other products.

Acrylonitrile-Butadiene-Styrene copolymer (ABS) is another thermoplastic material widely used in appliance housings, automotive, electrical wires and furniture, due to its resistance and toughness. Research is focused on finding methods and technologies to produce new products using recycled plastics or allowing them to be recycled together (Liu & Bertilsson 1999, Gao 2002, Gent *et al.* 2009, Grigore 2017, Valavanidis 2018). A waste resource of ABS from furniture industry results as shavings in the edge banding process of melamine faced particleboard. ABS banding edge is finally removed by a levelling operation in order to remove the excess of 1-2mm of ABS edge. This resource is intented to be used as recycled material in the present research.

In literature, wood fiber based materials in the dry state are considered as thermal insulators (Vololonirina *et al.* 2014, Veitmans & Grinfelds 2016). Made from soft wood or hard wood (especially beech wood), wood fibers are compared by several researchers with glass wool in different conditions, and it is concluded that wood fiber insulation performed similar to glass wool (Gevinga *et al.* 2015).

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In this study recycled ABS in the form of shavings resulted from particleboard's edge banding process and recycled LDPE granules together with wood fibres (80% softwood and 20% hardwood) are investigated as potential materials to be used for thermal insulating panels. In these composites, both thermoplastic ABS and LDPE are intented to be used as matrix and wood fibres as fillers. The thermal and physical properties of these raw materials and finaly the thermal behaviour of composite panels resulted from these materials are investigated in this paper. Thermal conductivity coefficient was used to characterize the thermal performance of the raw materials and of the composite panels.

OBJECTIVE

The objective of the present research is to investigate recycled materials such as ABS waste, recycled LDPE granules and wood fibres (WF) as potential raw materials for designing and manufacturing of thermal insulating panels. For this purpose, different participation rates of the investigated materials were used to manufacture composite panels in the laboratory conditions. The resulted panels were tested for thermal insulation capacity by using heat flow meter equipment for the determination of thermal conductivity coefficient (λ).

MATERIAL, METHOD, EQUIPMENT

The materials used in designing and development of thermal insulating panels are presented in Fig. 1, and they are wood fibres (WF), acrylonitrile-butadiene-styrene waste particles (ABS) and recycled LDPE granules (PE), with various participation rates.

a b c

Fig. 1.
Materials used for the manufacturing of thermal insulating panels
a – wood fibres (WF); b – ABS waste; c – recycled LDPE (PE).

WF were provided by Kastamonu Romania S.A.as a mixture of 80% resinous wood and 20% beech wood. ABS waste was collected in the exhaust bags of the edge banding machine from the production facility of Wood Engineering Faculty in Brasov, Romania, and the recycled PE was purchased from a Romanian company. Sizes and physical properties of the raw materials are presented in Table 1.

The bulk raw materials were first investigated for their thermal insulation performance and afterwards they were used for composites manufacturing in the laboratory conditions. For the determination of bulk density of the materials, wooden frames with internal dimensions of 410mmx410mmx32mm were used. The inside volume of the frame was filled in with the respective materials without pressing the contents, weighing before and after filling the frame. The investigated materials are presented in Fig. 2.

Density was calculated as the ratio between the weighed mass and the calculated volume of the interior frame.

Table 1

Properties of the raw materials used for the manufacturing of thermal insulating panels

Raw material	Bulk density, in kg/m^3	Moisture content, in %	Sizes, in mm		
			Length	Width	Thickness
Wood fibres (WF)	65.973	3.06-3.15	0.08-1.08	0.05-0.5	0.1-0.3
ABS (shavings)	77.604	-	2-16	1-2.5	0.2-0.5
Recycled polyethylene (granules)	595.981	-	3.37	4.5	3

The sizes of the granules and shavings were measured using the caliper. The moisture content of WF was determined using the UM 2000 Laboratory Moisture Meter.

a **b** **c**

Fig. 2.

Bulk materials used for the preparation of thermal insulating panels and the frames used for calculating the bulk density; a – wood fibres; b – ABS shavings; c – PE granules.

The target density of the panels was of 300 kg/m^3. Various ABS, R and WF participation rates were used for the composites (Table 2).

Table 2

Composites prepared for thermal investigations and various participation rates of ABS, R and WF.

Code no.	Target density (kg/m^3)	WF (%)	PE (%)	ABS (%)
WF-PE-ABS 1	300	5	5	90
WF-PE-ABS 2	300	10	10	80
WF-PE-ABS 3	300	15	15	70
WF-PE-ABS 4	300	20	20	60
WF-PE-ABS 5	300	25	25	50

After mixing the raw materials for 5 minutes using a mixer, the resulted composition was poured into wood frames with sizes of 420mmx420mmx16mm. Before pressing the mats, they had initial thicknesses of 50mm - 60mm. Each mat in the frame was covered by a thermo-resistant foil before introducing it in the hot press, in order to prevent sticking of the composition with the hot press. The pressing temperature used in the hot press was of 160ºC and the pressing time was 20 minutes without applying a pressure from the plates. The panels were afterwards conditioned for 48 hours and sized to 300mmx300mmx16mm.

Both bulk raw materials and panels were investigated for their thermal performance according to European standards DIN EN 12667: 2001 and ISO 8301: 1991, by determining the thermal conductivity coefficient (λ). The equipment used for the test was the heat flow meter HFM 436 Lambda (Netzsch, Selb, Germany). The amount of heat that passes from the hot plate to the cold plate through the tested material is automatically determined by the equipment. The equipment was first calibrated according to the temperature gradients, which were set between the two plates through the material to be measured. The thermal conductivity coefficient (λ) was automatically calculated by the equipment software based on Fourier's Law. In Table 3 the temperatures set to simulate the outdoor and indoor climate are presented. The indoor temperature (T2) was set to 20ºC and the outdoor temperature (T1) varied between -10ºC and 15ºC. The average of three measurements was reported as result.

Table 3

Temperatures set on HFM 436 Lambda equipment for the determination of thermal conductivity coefficient (λ)

Test no.	Temperature T1 (ºC)	Temperature T2 (ºC)	ΔT = T2-T1 (ºC)	Tm =(T1+T2)/2 (ºC)
1	-10	20	30	5
2	-5	20	25	7.5
3	0	20	20	10
4	5	20	15	12.5
5	10	20	10	15
6	15	20	5	17.5

Both humidity and temperature sensors were introduced in the bulk raw materials in the vecinity of hot plate and cold plate, in order to determine the humidity variations in the remaining air voids between the particles, granules or fibers, along with the temperature variations induced by the test protocol (Fig. 3).

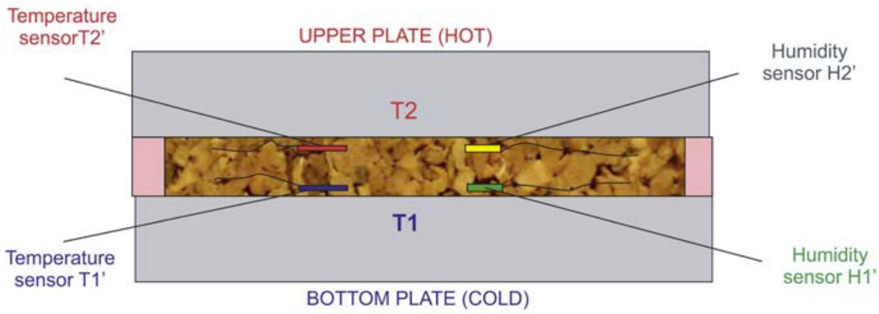

Fig. 3.
Placement of the sensors during the experiment.

The results are expected to give indications of the intensity of the humid air movement with the increase or decrease of the temperature.

RESULTS AND DISCUSSION

Mean values and standard deviations of the thermal conductivity coefficient (λ) experimentally determined for bulk raw materials are presented in Fig. 4. The lowest value of λ was recorded for WF (0.0398W/mK), but ABS recorded also a good value (0.0417W/mK), which means that these materials have good thermal insulation properties. Instead, recycled PE recorded high values of λ. Its' role is to melt and form the matrix for WF and ABS, but this raw material is expected now to increase λ of the designed composite panels.

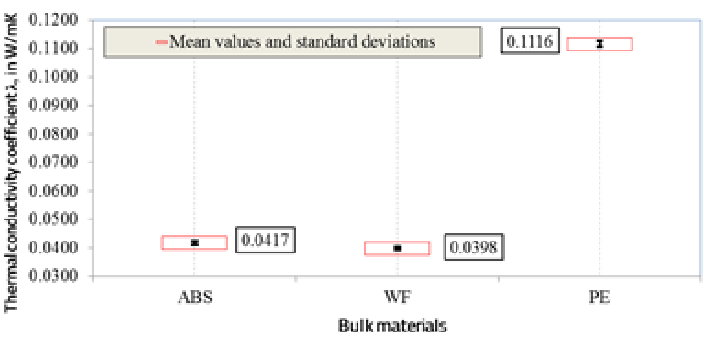

Fig. 4.
Thermal conductivity coefficient experimentally determined for bulk raw materials.

Previous research (Brenci *et al.* 2018) have shown that the successive cooling and heating phases during the testing cycle have influence on the thermal behaviour of the materials, perceived as oscillatory variation of thermal conductivity. Inside bulk materials there is not only pure thermal conductivity, but convection heat losses due to the local temperature differences and moisture transfer phenomena. For this reason, the behaviour of the raw materials used for thermal insulating panels was investigated by measuring temperatures and air humidity during the experiment. The results are presented in Fig. 5

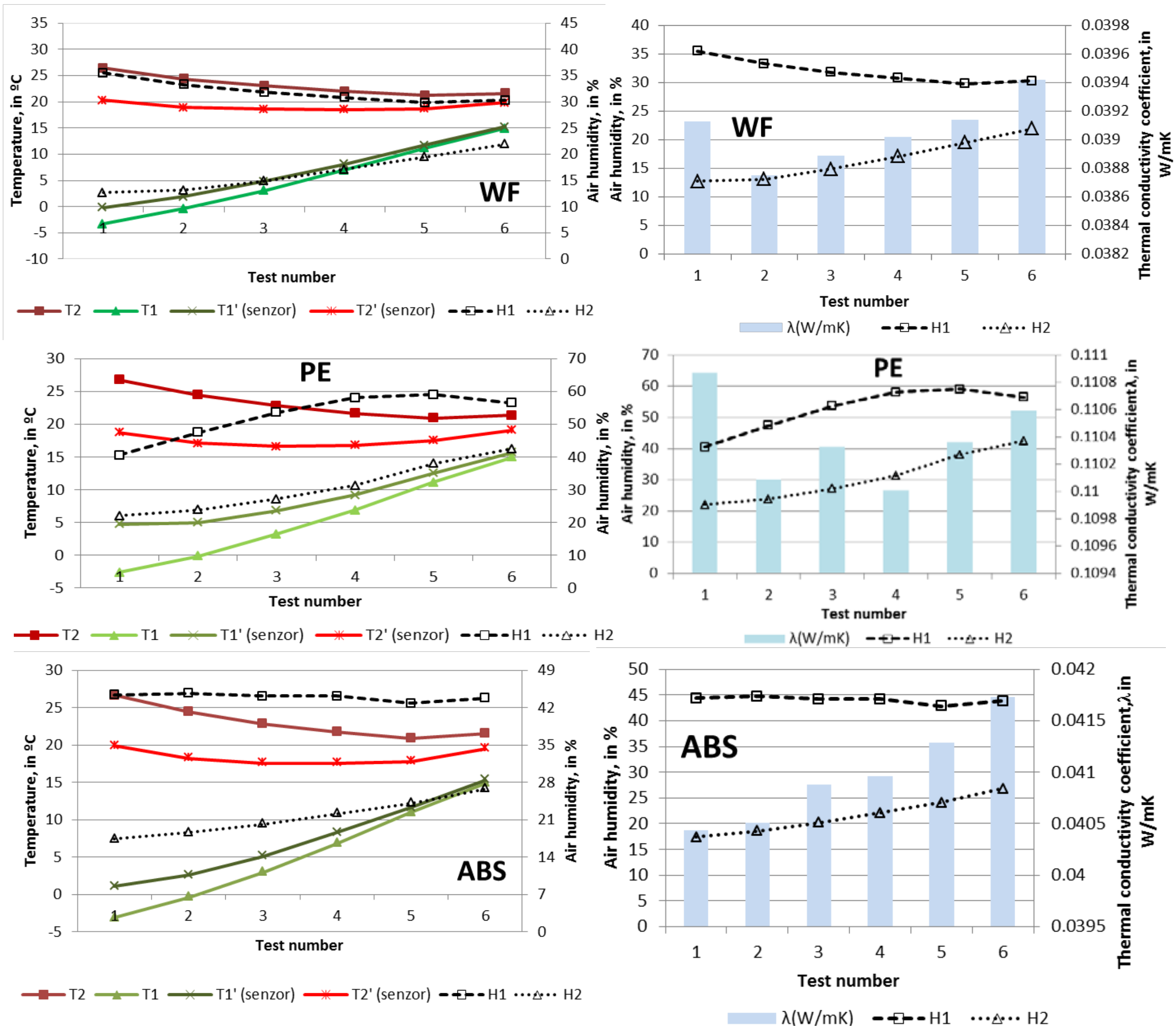

Fig. 5.
Variations of temperatures, air humidity and thermal conductivity coefficient during the experiment.

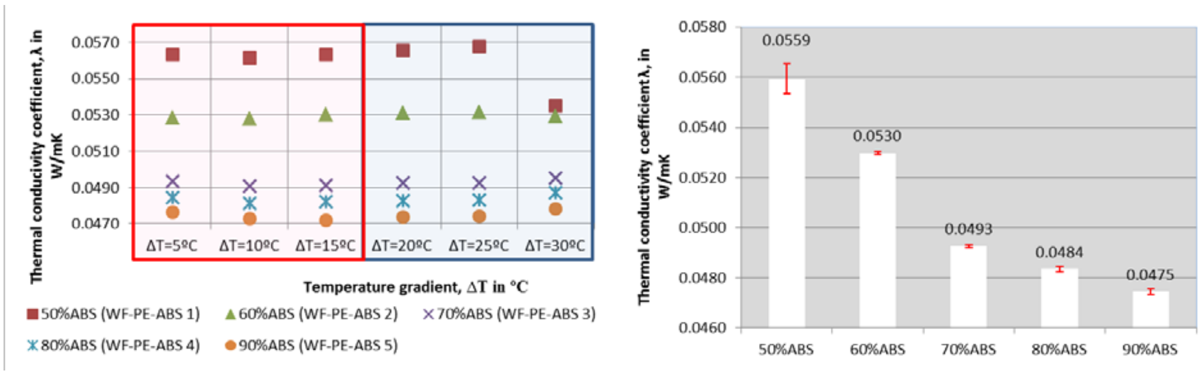

Fig. 6.
Thermal conductivity coefficient of the thermal insulating panels.

Evolution of measured temperatures and air humidity both in the area of cold plate and hot plate is shown in the graphs in Fig. 5 (left) for bulk materials. For ABS and WF, the air humidity in the hot plate area increases and simultaneously decreases in the cold plate area, fact that explains an intensification of humid air movement from the cold plate to the hot plate and the occurrence of the convection phenomena. It results in an increase of λ values, as seen in Fig. 5 (right). For PE, an increase of humid air was noticed both in the area of cold plate and hot plate. In this case, PE behaves as a vapour barrier, blocking the humid air transfer from one plate to the other. No rule is observed for the oscillation of λ in this case.

The influence of the thermal performance of the raw materials upon the thermal conductivity coefficient of WF-PE-ABS panels with various participation rates of the components can be seen in Fig. 6. Thus, it was noticed that with the increase of temperature gradient, λ also increases (Fig. 6 left). The mean values of λ on the right (Fig. 6) show that with the increase of equal PE and WF participation rates, the thermal performance of the panel decreases, due to the high value of λ for PE component.

CONCLUSIONS

The objective of the research was to design and test thermal insulating panels made of recycled materials. The results show that the thermal properties of the raw materials have influence on the thermal performance of the composite panels. Bulk ABS waste and wood fibers proved to have a low value of λ, but PE recorded a 2.8 times higher value than for ABS. PE behaves as a matrix of the composite. The higher PE content, the more resistant panel was obtained, but lower thermal performance. Instead, the higher ABS content, the better performance was obtained (λ = 0.0475W/mK) for the panels. The analysis of the results shows that the thermal efficiency of the composites decrease with the decreasing of outdoor temperature. The potential of using recycled materials such as ABS, PE and WF to manufacture thermal insulating panels is promising. Water permeability and water absorption tests of the panels presented in this paper are in progress, in order to complete the present research.

REFERENCES

Brenci LM, Cosereanu C, Zeleniuc O, Georgescu SV, Fotin A (2018) Thermal Conductivity of Wood with ABS Waste Core Sandwich Composites Subject to Various Core Modifications. BioResources 13(1):555-568.

DIN EN 12667: 2001 Thermal performance of building materials and products - Determination of thermal resistance by means of guarded hot plate and heat flow meter methods - Products of high and medium thermal resistance, German Institute for Standardization Berlin, Germany.

Gao F (2002) Handbook of plastics recycling. F La Mantia (ed). Rapra Technology, Shrewsbury UK, ISBN 1-85957-325-8. DOI: 10.1002/pi.1323

Gent MR, Menendez M, Toraño J, Diego I (2009) Recycling of plastic waste by density separation: prospects for optimization. Waste Manag Res 27:175-187. DOI: 10.1177/0734242X08096950

Gevinga S, Lundea E, Holmeb J (2015) Insulation materials for the building sector: A review and comparative analysis. 6th International Building Physics Conference, IBPC 2015, pp. 1455-1460. Elsevier Ltd.

Goodship V (2007) Plastic recycling. Science Progress 90(4):245–268. Doi: 10.3184/003685007X228748

Grigore ME (2017) Methods of Recycling, Properties and Applications of Recycled Thermoplastic Polymers. Recycling 2(24). Doi: 10.3390/recycling2040024

ISO 8301: 1991 Thermal insulation - Determination of steady-state thermal resistance and related properties - Heat flow meter apparatus, International Organization for Standardization Geneva, Switzerland.

Liu X, Bertilsson H (1999) Recycling of ABS and ABS/PC blends. Journal of Applied Polymer Science 74(3):510–515.

Moharam R, Maqtari MAA (2014) The Impact of Plastic Bags on the Environment: A field Survey of the City Of Sana'a And The Surrounding Areas, Yemen. International Journal of Engineering Research and Reviews 2(4):61-69. Available at: www.researchpublish.com

Valavanidis A (2018) Technological Challenges in Plastic Recycling. Can technological innnovation tackle the problem of plastic waste? Scientific Reviews, available on www.chem-tox-ecotox.org/ScientificReviews

Veitmans K, Grinfelds U (2016) Wood fiber insulation material. Research for Rural Development 2:91-98.

Vololonirina O, Coutand M, Perrin B (2014) Characterization of hygrothermal properties of woodbased products – Impact of moisture content and temperature. Construction and Building Materials 124(63):223-233.