ONLINE ISSN 2069-7430
ISSN-L 1841-4737

PRO LIGNO
www.proligno.ro

Vol. 9 N° 4 2013
pp. 510-518

COMPARATIVE STUDY OF THERMAL CONDUCTIVITY OF COMPOSITE MATERIALS WITH THE SAME PERCENTAGE OF HEMP HURDS EMBEDDED IN DIFFERENT CERAMIC RECIPES

Maria-Adriana GHERGHIŞAN
PhD Student – TRANSILVANIA University in Brasov – Faculty of Wood Engineering
Address: 1 Colina Universitatii Street, 500068 Brasov, Romania
E-mail: maria-adriana.gherghisan@unitbv.ro

Ivan CISMARU
PhD.Prof.Eng. – TRANSILVANIA University in Brasov – Faculty of Wood Engineering
Address: 1 Colina Universitatii Street, 500068 Brasov, Romania
E-mail: icismaru@unitbv.ro

Abstract:
This paper is analyzing the behavior of twelve specimens containing 5%, 10%, 20% and 30% hemp hurds that are embedded in three different ceramic recipes: cement-sand-lime, cement-plaster and plaster. Resistance to handling, transport and sanding is tested on these twelve boards. The remaining specimens are tested for thermal conductivity. The expected results are the correlations between the percentage of hemp hurds, ceramic recipes and the ΔT (difference between internal and external temperature).

Key words: *agro-wastes; hemp hurds; ceramic matrix; thermal conductivity.*

INTRODUCTION

Energy is transferred from more energetic to less energetic molecules, when neighbouring molecules collide. The conductive heat flow occurs in the direction of the decreasing temperature since higher temperature is associated with higher molecular energy (http://www.engineeringtoolbox.com). In this case, thermal energy is of a highly importance when a building material is designed.

In many countries, building energy consumption accounts for approximately 40% of the global energy demands, and the energy requirement for space heating and cooling of a building is approximately 60% of the total energy consumed in buildings, which accounts for the largest percentage of energy usage (Kaynakli 2011). This is why more of the new building materials are created in order to reduce energy consumption. The tendency is to design composites that contain organic wastes originated from the agriculture. The tests have shown superior thermal proprieties (Korjenic *et al.* 2011) and demonstrated that agro-wastes could be transformed in sustainable construction materials (Karade 2010, Madurwar *et al.* 2013).

Using hemp hurds, as embedding materials in ceramic matrix, brings the benefit of recovery of the agro-wastes resulted from the processing of the hemp fibres. The value of k=0.048W/m*K sets this material as being a good thermal insulator (www.cannabric.com).

Both thermal conductivity and mechanical properties increase with the mortar density (Elfordy *et al.* 2007) which demonstrates that with the increasing of hemp hurds percentage, the composite material resulted has good insulation properties and a decrease of mechanical strength is noted.

Inventions of composite structural members such as panels, boards or beams that comprise hemp hurds (Wasylciw 2003), gypsum panel that incorporates a plant fibre other than paper (Baer *et al.* 2012), fibre-reinforced cementious product comprising a cementious matrix reinforced with a combination of hemp fibres and mineral fibres (Pedersen 1983), hemp concrete mixtures and mortars (Rizza 2005), are only a few examples to demonstrate the orientation for using hemp as a building material.

OBJECTIVES

The main objective of this research is the achievement of a comparative study over the physical integrity and thermal properties for twelve composite materials.

This research aims to achieve a selection of workable recipes after testing for handling, transport and sanding strength. These viable specimens are then tested to obtain the thermal conductivity coefficient.

The final objective is to analyze the data obtained from the thermal tests of specimens for ΔT=10, 15, 20 25 and 30(°C) and correlation between resulted charts and the typology of recipes.

The novelty of this research is to perform a comparative study between three ceramic recipes containing different materials like cement, sand, lime and plaster, and four percentages of hemp hurds 5%, 10%, 20% and 30%, as shown in tables 2-4. It aims to highlight both primary resistance tests and thermal testing for external temperatures from -20°C to +15°C at ΔT=10-30(°C).

METHOD, MATERIALS AND EQUIPMENT

The twelve specimens are the resulting process of embedding of 5%, 10%, 20% and 30% hemp hurds in ceramic matrix based on cement, sand, lime and plaster. The characteristics and provenience of the raw materials used for these twelve specimens are presented in Table 1.

Table 1

Presentation of raw materials

Materials name	Materials description
Hemp hurds	Woody chips, dried, unsorted, undusted purchased from HUNGAROHEMP, Hungary
Cement	Siliceous cement Portland Structo Plus, produced by HOLCIM Romania SA
Sand	Sorted, washed and dried sand, NSP 0-1, 0-1mm, produced by BAUMIX SRL
Lime	Hydrated calcic lime CL70, produced by CARMEUSE HOLDING SRL
Plaster	Plaster for constructions ADERA BASIC, produced by LAFARGE ARCOM GHIPS SA

The specimens with 5%, 10%, 20% and 30% hemp hurds have been made respecting the technological scheme developed in Wood Engineering Faculty Laboratories.

Next phase is represented by testing specimens at handling and transport strength followed by a sanding operation, which is also an eliminatory phase before thermal testing. Both, the technological scheme and the eliminatory tests were presented in detail, in the article “Preliminary research concerning optimal percentage of hemp hurds for lining panels and filler materials in buildings”. (Gherghisan and Cismaru 2013).

The Tables 2, 3 and 4 provide a brief overview of specimens and results of primary tests, before thermal testing was performed.

Table 2

Table displaying cement-sand-lime recipes

Crt. Nr.	Specimen image and surface detail	Specimen notation / Preliminary testing resistance	Values obtained after sanding	
			Mass m(kg)	Density ρ(kg/m³)
1		5%hh-csl (hh=hemp hurds; csl=cement-sand-lime) Show resistance to handling, transport and sanding. Suitable for thermal testing	2,558	1254,40
2		10%hh-csl Show resistance to handling, transport and sanding. Suitable for thermal testing	1,791	995,00
3		20%hh-csl Show resistance to handling, transport. Structural failure during the sanding operation.	Eliminated recipes	
4		30%hh-csl Show no resistance to handling, transport.		

Table 3

Table displaying cement-plaster recipes

Crt. Nr.	Specimen image and surface detail	Specimen notation / Preliminary testing resistance	Values obtained after sanding	
			Mass m(kg)	Density ρ(kg/m³)
1		5%hh-cp (hh=hemp hurds; cp=cement-plaster) Show resistance to handling, transport and sanding. Suitable for thermal testing	1,952	1084,72
2		10%hh-cp Show resistance to handling, transport and sanding. Suitable for thermal testing	1,661	922,77
3		20%hh-cp Show resistance to handling, transport and sanding. Suitable for thermal testing	1,206	670,22
4		30%hh-cp Show no resistance to handling and transport.	Eliminated recipe	

ONLINE ISSN 2069-7430
ISSN-L 1841-4737

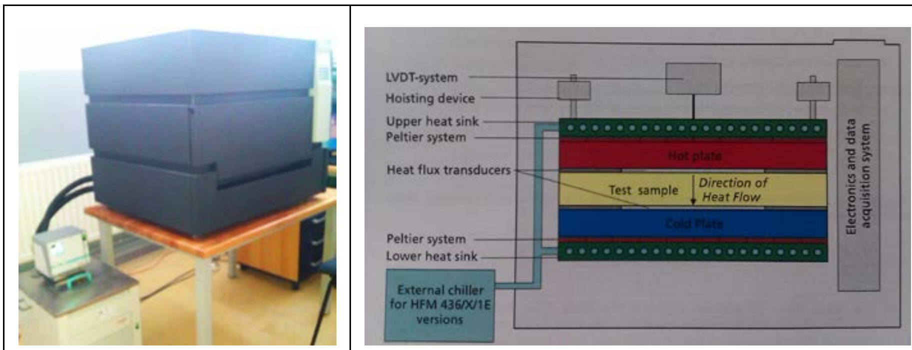
PRO LIGNO
www.proligno.ro

Vol. 9 N° 4 2013
pp. 510-518

Table 4

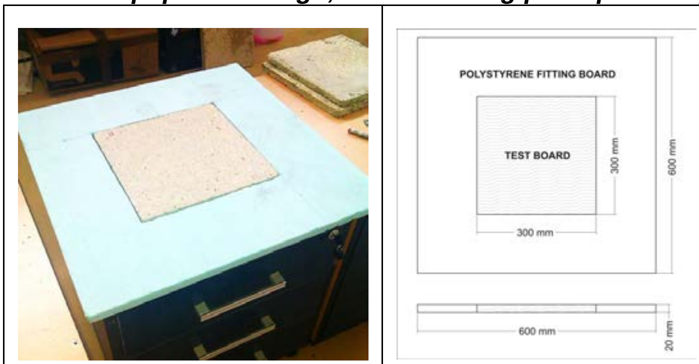
Table displaying plaster recipes

Crt. Nr.	Specimen image and surface detail	Specimen notation / Preliminary testing resistance	Values obtained after sanding	
			Mass m(kg)	Density ρ(kg/m³)
1		5%hh-p (hh=hemp hurds, p=plaster) Show resistance to handling, transport and sanding. Suitable for thermal testing	2,138	1187,77
2		10%hh-p Show resistance to handling, transport and sanding. Suitable for thermal testing	1,665	925,00
3		20%hh-p Show resistance to handling, transport and sanding. Suitable for thermal testing	1,200	666,66
4		30%hh-p Show resistance to handling, transport and sanding. Suitable for thermal testing.	0,847	470,72



a b

Fig. 1
HFM 436/6/1: a - Equipment image; b - Measuring principle of equipment.



a b

Fig. 2
Thermal testing assembly: a - Assembly of thermal testing; b - Sketch of thermal testing assembly.

ONLINE ISSN 2069-7430
ISSN-L 1841-4737
PRO LIGNO
www.proligno.ro
Vol. 9 N° 4 2013
pp. 510-518

After preliminary tests, nine specimens remain viable for establishing the thermal conductivity coefficient. Specimens testing was performed on HFM 436/6/1 equipment (Heat Flow Meter Instrument), acquired from NETZSCH Company, Germany, as it shows in Fig. 1.

Maximum surface for testing, according with HFM 436/6/1 size is a square of 60cm with thickness of specimen up to 20cm. Central sensory area is 25,4x25,4cm, meaning that the minimum testing surface is 30x30cm. The specimen smaller than maximum testing surface are incorporated into a frame of the same thickness with testing board, as it is seen in Fig. 2.

The specimens with 30x30x2cm were included in a polystyrene board. This assembly was placed between the two plates according with the testing program. The heat flow passing through specimen is measured by a heat flux transducer previously calibrated with a control sample provided by the equipment builder.

The polystyrene frame has the purpose to maintain the parallelism of the hot with cold plate during the tests, maintains the centred position for the tested specimen and an optimum air flux. The testing of the frame it is not necessary. During the tests, the sensors were set to acquire data from the centre of equipment, 24,5cm square.

Testing method.

For following tests, temperatures for inferior plate (T1): -20°C, -15°C, -10°C, -5°C, 0°C, +5°C, +10°C, +15°C, and ΔT=10, 15, 20, 25 and 30(°C) have been selected. With these data, hot plate temperature (T2) and Mean value (average) were obtained.

EXPERIMENTAL RESULTS.

All nine specimens were tested in the same laboratory conditions. The figures 3, 4 and 5 show the test results of the thermal conductivity coefficient k(W/m*K) for each specimen according with the testing program mentioned above.

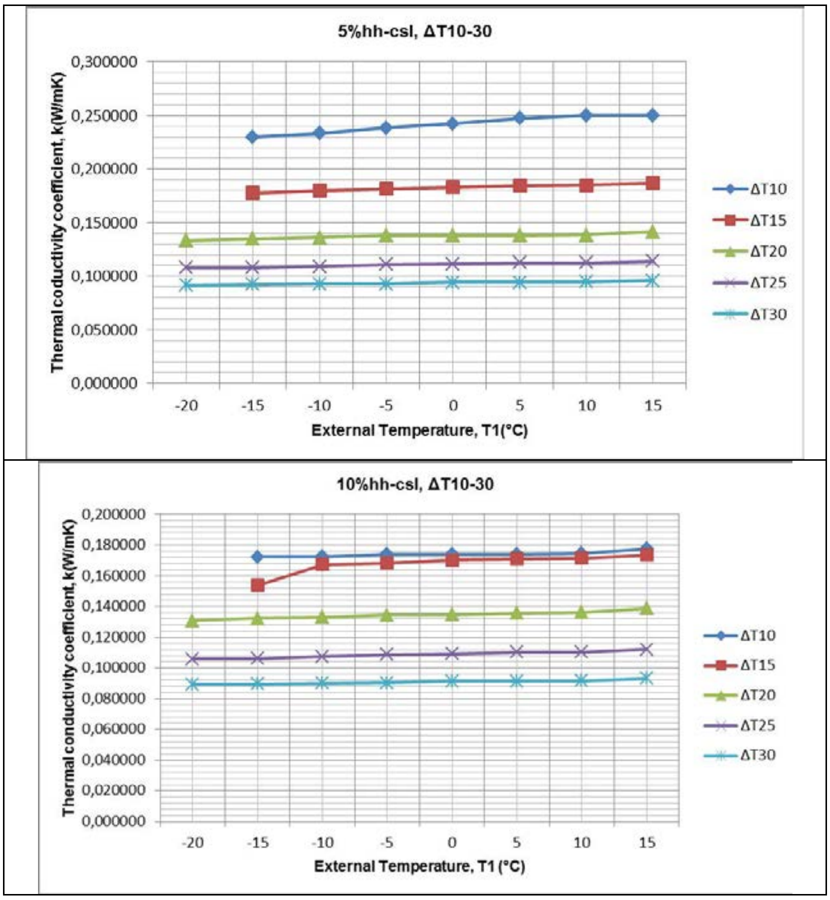


Fig. 3
General diagrams for specimen with cement/sand/lime matrix (csl).

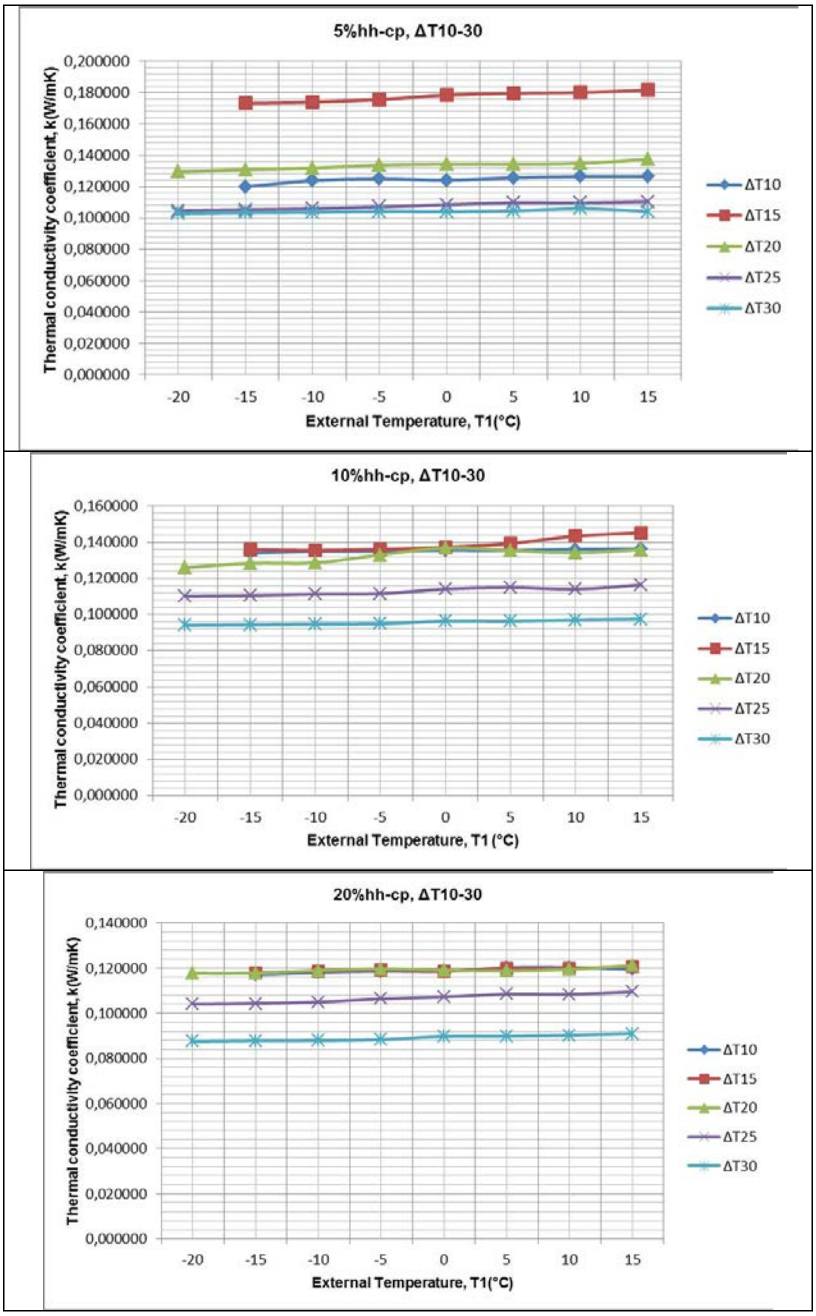


Fig. 4
General diagrams for specimen with cement/plaster matrix (cp).

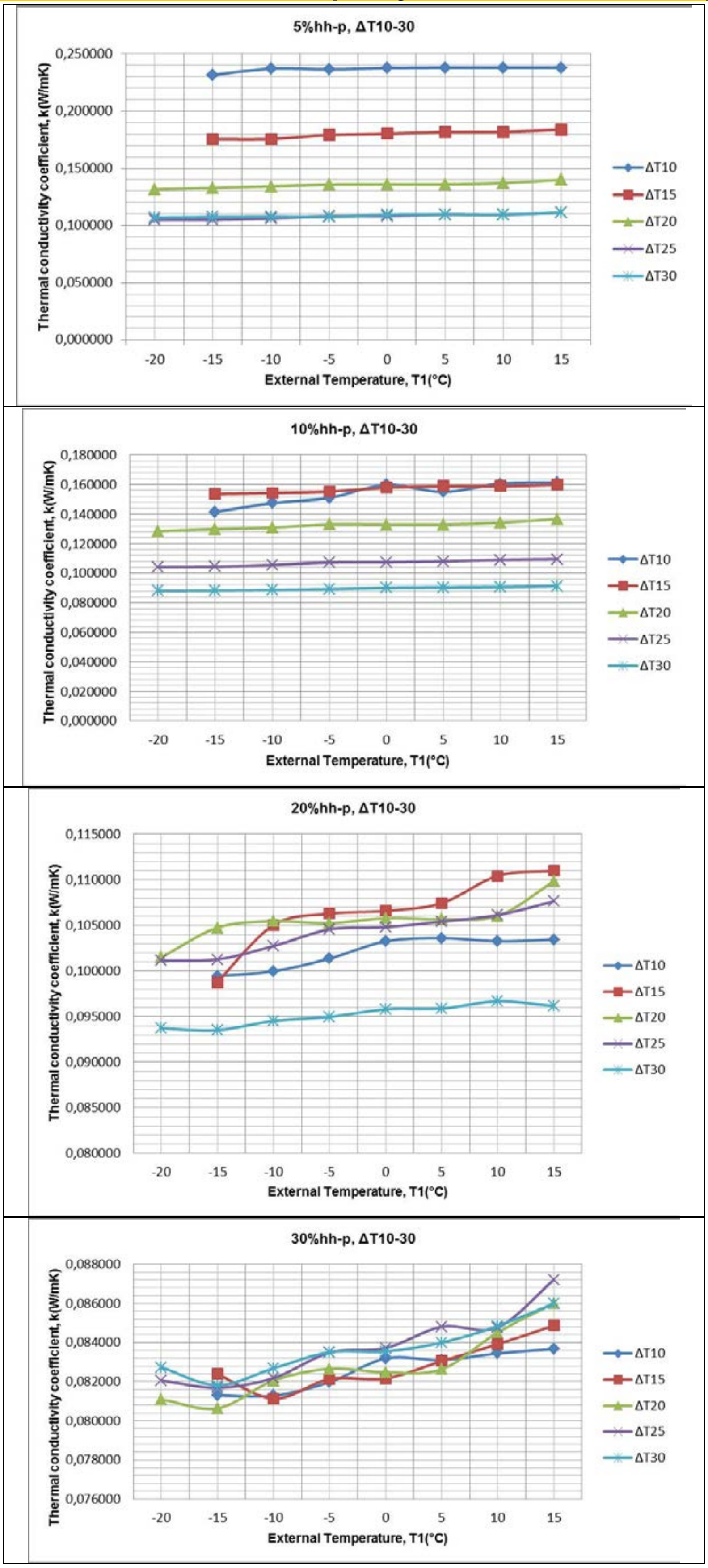


Fig. 5
General diagrams for specimen with plaster matrix (p).

External-internal temperature differences affect the value of k.

Decreasing of thermal conductivity coefficient is noticed, for the same specimen, during the ΔT10(°C) to ΔT30(°C) testing. Values drop from 0,240 to 0,095(W/mK), about 60%, for specimen 5%hh-csl. For 5%hh-cp, k values obtained were 0,176-0,140(W/mK), that means an approximately 20% decrease in value. For specimen 5%hh-p, values from 0,230 to 0,110(W/mK) are dropping with 52%.

With increasing of hemp hurds percentage, k is decreasing and the difference of value tested from ΔT10(°C) to ΔT30(°C) is smaller. Therefore for the matrix composed of 100% plaster, the k values are presented as following: 5%hh-p, 0,230-0,110(W/mK), 52% decrease in values, 10%hh-p, 0,150-0,090(W/mK) with 40% deacrese from ΔT10 to ΔT30. At 20%hh-p, values of k are in 0,102-0,095 range with 7% decreasing. The lowest value is obtained for specimen 30%hh-p, 0,083-0,082, almost 2%, and the diagrams are almost linear.

From 5% to 30%hh, the increase of k value for the same ΔT is noticeable especially for ΔT10 when the difference in value for thermal conductivity coefficient is dropping from 0,230(W/mK) for specimen 5%hh-p to 0,083(W/mK) for 30%hh-p specimen, that mean an increasing a value with approximately 64%. For the same specimen, tests for ΔT30 show an increasing of k with 25%, from 0,110(W/mK) for 5%hh-p to 0,082(W/mK) for 30%hh-p. k value is less influenced by the percentages of hemp hurds when testing large differences of temperatures (external-internal) and the differences are of the order of hundredths: 0,110(5%hh-p), 0,09(10%hh-p), 0,095(20%hh-p), 0,082(30%hh-p).

CONCLUSIONS

Over the thermal conductivity coefficient influences the concentration of hemp hurds and differences between the external and internal temperatures. Value of k grows with increasing directly proportional with outdoor temperature and decreases with increasing temperature range of exterior and interior.

Increasing the percentage of hemp hurds lowers the value of k, which proves the insulation properties of lignocellulosic material.

It needs to be taken into account, when design of hemp hurds containing structure, the maximum value of ΔT. The tests presented in this article which includes the ΔT from 10 to 30(°C), cover the temperature variations encountered throughout the year. For the future research this data will be used for the heat loss values and thermal heating systems determination.

It is noticed the low influence of the matrix structure over the thermal conductivity coefficient comparing with the hemp hurds influence. Testes show that the matrix with the lower value of k is matrix composed of cement and plaster followed by the 100% plaster matrix, compared for the same proportion of hemp hurds. There is the possibility of optimization based on the tests, of the structures which provide a minimum k. The optimization is made by combined analysis of the materials that are part of the composite structure.

The performed tests presents the guarantee of the values presented in this study, thanks to the performance of testing equipment from the laboratories of Wood Engineering Faculty, TRANSILVANIA University of Brasov.

ACKNOWLEDGEMENT

This paper is supported by the Sectoral Operational Programme Human Resources Development (SOP HRD), ID76945 financed from the European Social Fund and by the Romanian Government.

REFERENCES

Baer SC, Francis H, Gautam KS, Lerch MS (2012) Gypsum boards made with high performance bio-based facers and method of making the sample. United State Patent WO 2012/148964 A2

Gherghisan MA, Cismaru I (2013) Preliminary research concerning optimal percentage of hemp hurds for lining panels and filler materials in buildings. PRO LIGNO 9:61-70

Elfordy S, Lucas F, Tancret F, Scudeller Y, Goudet L (2008) Mechanical and thermal properties of lime and hemp concrete ("hempcrete") manufactured by a projection process. Construction and Building Materials 22:2116-2123

Karade SR (2010) Cement-bonded composites from lignocellulosic wastes. Construction and Building Materials 24:1323-1330

Kaynakli O (2012) A review of the economical and optimum thermal insulation thickness for building applications. Renewable and Sustainable Energy Reviews 16:415-425

Korjenic A, Petranek V, Zach J, Hroudova J (2011) Development and performance evaluation of natural thermal-insulation materials composed of renewable resources. Energy and Buildings 43:2518-2523

Madurwar MV, Ralegaonkar RV, Mandavgane SA (2013) Application of agro-waste for sustainable construction materials: A review. Construction and Building Materials 38:872-878

Pedersen P (1983) Fibre-reinforced cementitious product. United States Patent 1983/4373957

Rizza M (2005) Hemp concrete mixtures and mortars, preparations method and uses. United States Patent 2005/6913644 B2

Wasylciw W (2003) Hemp hurd composite panels and method of making. United State Patent US 2003/6641909 B1

www.cannabric.com/catalogo/cannahabitat_canamiza/dbc31_cannahabitat_technical_data_sheet.pdf. (available in March 2013)

www.engineeringtoolbox.com (available in March 2013)