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EVALUATION OF A NEW LIGHTWEIGHT INSULATION MATERIAL PREPARED BY HEMP SHIVES

BY

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Abstract. Hemp is today an important resource for food, clothes, furniture, and construction industries. These technical crops are known for their capacity of industrialization, because hemp can be used in totally for its elements. Seeds, fibres, tow and hemp hurds are the main elements that are obtained from hemp plant. With an annual rate of regeneration, hemp promises much for the construction sector, in a period in which buildings are considered having a biggest negative impact on the environment. Finding solutions for developing alternative materials is essential for building environment. Natural plants can be the solution for replacing the synthetic materials used in buildings. Therefore the present study concerns the identification of new materials that can give a proper hydrothermal and noise related comfort conditions also being able to meet the requirements of sustainable development. For this purpose, three formulae based on hemp shives and hydrated limes were investigated. Tests concerned noise and thermal properties were carried out.

Keywords: hemp; hydrated lime; sustainable development; absorption coefficient; thermal conductivity coefficient.

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1. Introduction

Recent research in the field of building materials focuses more and more upon developing products that can satisfy the requirements of thermal, noise and other forms of insulation and which can similarly be considered sustainable. The identification of such products could lead to getting a larger space in a building, by using a material which fulfils the requirements of more materials simultaneously (Philippe Glé *et al*., 2011) and at lower costs.

Hemp shives-based composite materials represent an important resource for the construction sector. These materials are regarded as ecological; they contribute to improving the energy efficiency of the buildings, absorb carbon dioxide and mitigate polluting emissions during the manufacturing process, while producing a limited amount of waste (Anna Arizzi *et al*., 2016).

At world level, according to Fig. 1, hemp production increased by about 800ha in the period 2010-2011, and remained almost constant from years 2011-2013, as mentioned in the data of the Food and Agriculture Organization of United Nations Statistics Division (FAOSTAT).

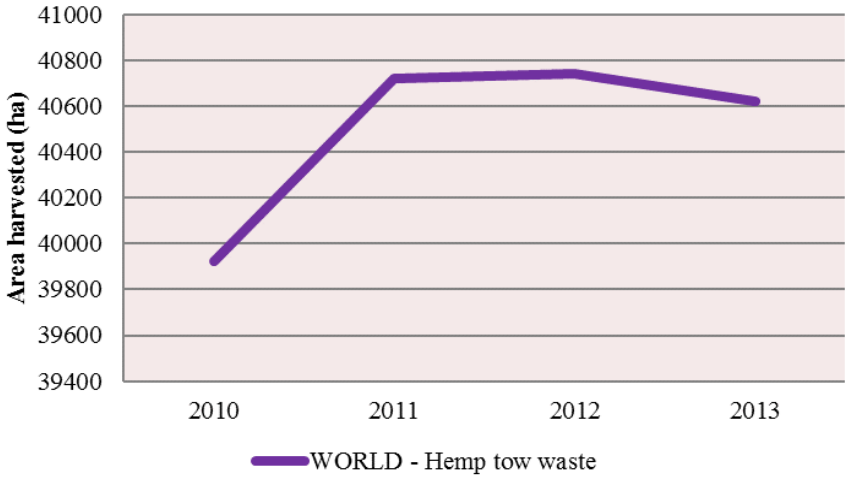
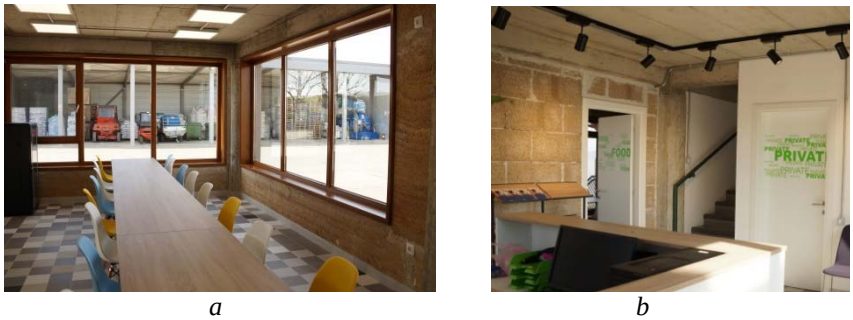


Fig.1 – WORLD hemp tow waste area, [ha].

In the field of constructions, the hemp shives are used as natural aggregates in products called hempcrete. The composition of this product is based on hemp shives and lime.

Hemp shives represent the wooden part of the hemp stem; it started to be used as a building material at the beginning of 1990's in France, to get a

more lightweight concrete. This kind of concrete is put into work by: spraying (Fig. 2 *a*) or in the form of hemp blocks (Fig. 2 *b*) (Paulien de Brujuin, 2012).



a *b*

Fig.2 – Hempcrete: *a* – spraying; *b* – blocks.

In the literature of the field, most studies concern the mixture of hemp shives and hydraulic lime. There are extremely few studies regarding hemp and a binder formed only from hydrated lime and the hydrated lime often comes together with other binders. There aren't complete and complex studies about the materials based on hemp and hydrated lime which can evaluate the physical and mechanical properties of the product (mechanical strength, thermal conductivity, reaction to fire, acoustic absorption coefficient and so on).

Nadezda Stevulova, in the paper Lightweight Composites Containing Hemp Hurds, found the following results:

a) formula 1 (hemp hurds 40%, hydrated lime 24%, portland cement 5%, water 31%)- the thermal conductivity coefficient is 0.111 W/mk, density – 1,040 kg/m^3, compressive strength – 0.3 MPa,

b) formula 2 (hemp hurds 40%, hydrated lime 24%, portland cement 2.5%, zeolite 2.5%, water 31%) – the thermal conductivity coefficient is 0.115 W/mk, density 1,070 kg/m^3, compressive strength 0.27 MPa,

c) formula 3 (hemp hurds 40%, hydrated lime 24%, zeolit 5%, water 31%) – the thermal conductivity coefficient is 0.110 W/mk, density 1,150 kg/m^3, compressive strength – 0.23 Mpa (Nadezda Stevulova *et al*., 2013).

Researchers from Lithuania stopped at the compressive strength values of two formulae including hydrated lime: formula 1 (water 600 ml, hemp hurds 200 gr., cement 200 gr., hydrated lime 200 gr., clay 200 gr.) and formula 2 (water 600 ml, hemp hurds 200 gr., cement 250 gr., hydrated lime 250 gr., clay 250 gr.), with values between 1.2,...,1.55 N/mm^2; from the thermal viewpoint, they do not go further because of the large amount of binders which increase sample density and negatively influence the magnitudes of the thermal conductivity coefficient (Giedrius Balčiūna *et al*., 2013).

Oliver Kinnane from Queen`s University, in his research Acoustic Absorption of Hemp-Lime Construction, presented two formulae whose binder is 70% hydrated lime and 30% GGBS, respectively 80% hydrated lime and 20% metakaolin. The values of the noise absorption coefficient in the two formulae range between 0.39,...,0.49, at frequencies from 500 to 2,000 Hz (Oliver Kinnane *et al*., 2016).

Benfratello and his team searched the development of hemp and lime products. The value of the thermal conductivity recorded for the hemp – binder composition (ratio 4:1 hydraulic lime: hydrated lime) was 0.14, with hemp covering 20% from the weight of the sample (Benfratello S. *et al*., 2013).

The French researchers were interested in the mechanical and thermal properties of hempcrete. It was found that the values of the thermal conductivity coefficient depend on product density, being recorded between 0.179 and 0.542 W/mk (Elfordy S. *et al*., 2008).

2. Materials

The present study aims at investigating the thermal and acoustic parameters for the three formulae developed from hemp shives (C) and hydrated lime (V).

In the composition of the three formulae, the content of lime and water was kept constant, and the variable was the volume of hemp. The variation of the hemp shives amount was proposed to be able to find out whether an increase of the organic matter in the samples affects the thermal and acoustic insulation parameters. In Table 1 are given the compositions, based on ratios of the three formulae.

Table 1
Mixing formulae composition

Composition	Hemp cm^3	Hydrated lime cm^3	Water cm^3
C1+V	1,000	1,000	500
C2+V	2,000	1,000	500
C3+V	3,000	1,000	500

The hemp shives are recommended to be used for thermal insulation composite materials because they have a porous structure and their pores are small. Hemp waste, another name for the shives, is a lightweight filler material, with two kinds of porosities, the porosity of the hemp shives internal particles and the porosity of the particles formed among the internal particles.

The 3-D tomographic method helped foreign scientists to define hemp porosity at 57%. The size of the pores formed inter particles depends on the texture of the shives and it is about 1 mm. The internal porosity of the hemp shives is formed from 15% of the pores of 70 μm and 85% of the pores of 400 μm (Giedrius Balčiūna *et al*., 2013).

3. Methods

Materials were tested with the required devices. The acoustic absorption coefficient for the materials was established with the help of the impedance tube or Kundt tube (Fig. 3), according to the standard SR EN ISO 10534-2:2002. The tube used for the tests belongs to the Transylvania University of Braşov.

Fig.3 – Impedance tube.

The thermal conductivity coefficient was tested in the laboratory of The Technical University of Cluj-Napoca, with a Thermofluxmetre, Fig. 4.

Fig. 4 – Thermofluxmetre.

Based on the thermal conductivity coefficient, one establishes the property of the material to convey the heat flux produced by the difference in temperature between the opposite faces of the building members in the material mass (Borlea, 2013).

4. Results

The thermal conductivity coefficient was determined by investigating three specimens. The form of the specimens was parallelepiped with the sizes of 150 × 150 × 30 mm. The results obtained applying hemp formula respectively hydrated lime formulas are given in Fig. 5.

The recorded values for the three formulae are close to each another, ranging between 0.16,…,0.17 W/mk. The sample with the smallest thermal conductivity value (C_3 + V) has a triple amount of hemp, but it does not fit into the values necessary to be considered as a thermal insulation material ($\lambda < 0.10$ W/mk).

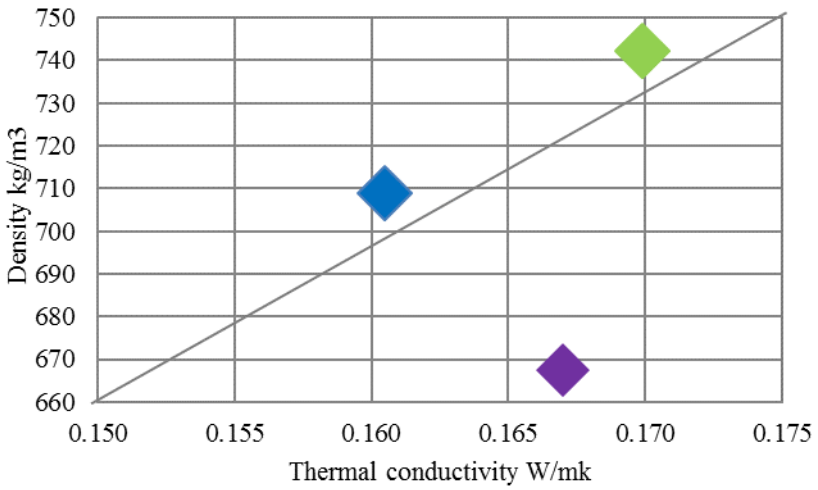


Fig. 5 – Density and thermal conductivity of new materials.

The investigation of the thermal properties of these formulae will go on, to reach a diminution of materials density and consequently to improve the thermal conductivity coefficients.

From the acoustic viewpoint, the determination of the sound absorption coefficient requires the building of two types of specimens for each individual

formula. The shape of the specimens is round, with the diameter of 100 mm for low frequencies and 28 mm for high frequencies, and a height of 30 cm.

Two curves generated with the values of the sound absorption coefficients were found and compiled with the Pulse software, to get a final coefficient value for the frequency range of 50,…, 6,400 Hz (Fig. 6).

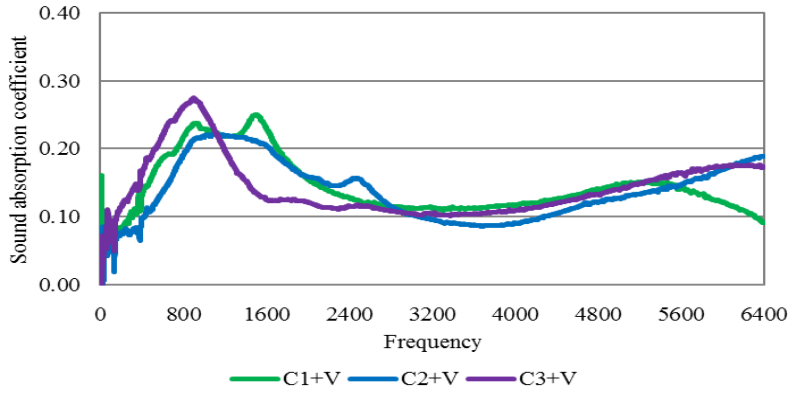


Fig. 6 – Acoustic absorption coefficient in the frequency range 0,..., 6,400Hz

In the case of sound absorption coefficient, the same situation as for thermal values is repeated, where the differences for the three formulae are very close. A larger amount of hemp (C_3 + V) has a more beneficial outcome compared to C_1+V and C_2+V in the frequency range 0,…, 1,600 Hz (Fig. 7).

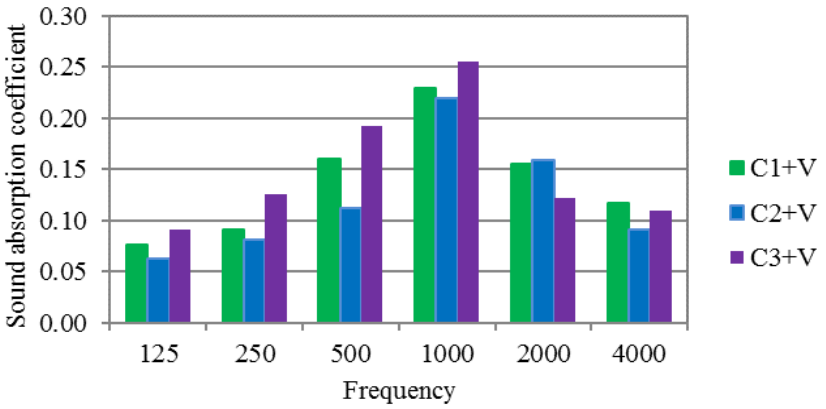


Fig. 7 – Acoustic absorption coefficients in standard frequency bands.

5. Conclusion

The impact of hemp-based composite materials upon the built environment becomes important because of the need to provide new and sustainable materials, better responding to the human-nature relationship.

The final form of the acoustic and thermal research on the three formulae of new materials highlights the fact that hemp shives mixed with hydrated lime can be a good building material. The formula who responded best in terms of thermal and acoustic properties was C3+V. However, future research should be continued to optimise products so that they respond better to the purpose for which they were developed.

Research will continue using non-destructive methods (non-invasive), to justify the physicochemical composition of the products studied.

Using optical microscopy (SEM) will allow identifying how individual components of materials are disposed and how internal connections help to achieve the desired performance.

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EVALUAREA UNUI NOU MATERIAL UŞOR PENTRU IZOLAŢII CU ADAOS DE CÂNEPĂ

(Rezumat)

Cânepa reprezintă astăzi o resursă importantă pentru industria alimentară, textilă, a mobilei şi a construcţiilor. Aceste culturi sunt recunoscute datorită procentului ridicat de industrializare, materia primă obţinută din planta de cânepă fiind utilizată în totalitate. Seminţele, fibrele, câlţi şi puzderia sunt principalele elemente care se obţin prin procesarea cânepii. Fiind o plantă cu un ritm de regenerare anual, cânepa promite mult pentru sectorul de construcţii, într-o perioadă în care clădirile sunt răspunzătoare de impactul negativ cel mai ridicat asupra mediului înconjurător. De aceea este esenţial dezvoltarea unor noi soluţii şi materiale alternative pentru mediul construit. Plantele naturale pot reprezenta soluţia potrivită pentru înlocuirea materialelor sintetice utilizate în prezent în sectorul de construcţii. Prin urmare acest studiu îşi propune identificarea de noi materiale care să răspundă cerinţelor termice şi acustice de confort necesare, dar în acelaşi timp să îndeplinească şi cerinţele dezvoltării durabile. Drept urmare au fost analizate trei reţete pe bază de puzderie de cânepă şi var hidratat, iar testele realizate asupra materialelor au avut cu obiectiv stabilirea proprietăţilor acustice şi termice.