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MECHANICAL PROPERTIES OF A NEW INSULATION MATERIAL BASED ON *Miscanthus x Giganteus*

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Abstract

This paper deals with a brand new cost-effective, ecological and energy-efficient insulation material application based on Miscanthus x Giganteus with a reduced cement binder amount enriched with a smaller quantity of zeolite. In order to increase energy efficiency, the use of cement was minimized, as it is considered an extremely energy-inefficient material whose production requires large amounts of thermal energy, accompanied with high carbon dioxide emissions. As the physical-mechanical properties of thermal insulation are of crucial importance the paper deals with physical-mechanical properties of this material. The experimental part consisted of preparation of four mixtures with different component mass ratio, and determination of their physical-mechanical properties. The sample that showed the highest values of compressive and bending strength simultaneously was taken into thermal conductivity control tests. The thermal conductivity was measured by steady state conditions. The proposed composite material showed certain potential for practical and eco-friendly use.

Keywords: Energy efficiency, Insulation, *Miscanthus x Giganteus*

INTRODUCTION

The construction sector is one of the sectors with many problems in the field of environmental protection and sustainability, exploiting non-renewable resources, land use, energy consumption etc. [1]. It is one of the important segments of sustainable development and involves the use of eco-friendly and energy- and resource-saving construction materials.

This study deals with application of a brand new insulation material based on *Miscanthus x Giganteus* which is expected to be cost-effective and environment-friendly, as well as energy-efficient. In order to increase energy efficiency, the use of cement binder was minimized, since it is considered as an extremely energy-inefficient material consuming large amounts of heat for its production, with high carbon dioxide emissions [2]. Also, the use of this new material might significantly contribute to buildings energy efficiency, generally. For the purpose of this research, *Miscanthus x Giganteus* fibres were used instead of standard component materials. *Miscanthus x Giganteus*, also known as ”Elephant Grass“ or ”Chinese reed“, belongs to the family of grasses with many features of reed [3]. Originating from Asia, it was cultivated in Europe in the last century. During the vegetative season it can grow up to about 3 m in height and during this period the first yields are achieved, while for the complete establishment of plantations it takes up 3 to 6 years. After this period, a continuous rate of yield is achieved over a period up to 25 years without any demanding cultivation technologies during this period, making this plant extremely economical and easy to use [3]. Since manufacturing process is short, it has less carbon dioxide emissions, requiring lower energy consumption comparing to production of mineral wool or some synthetic organic (polymer) insulation materials [4]. Due to the morphological structure, a piece of stem provides a continuous process of micro-condensation and evaporation and has a certain level of self-thermoregulation, difficult to achieve with synthetic materials [5].

The standard thermal insulation materials have a thermal conductivity less than 0.06 W/(m·K) [6], such as already mentioned mineral and glass wool or expanded and extruded polystyrene [4]. The utilization capacity of *Miscanthus x Giganteus* products as insulating material could be expected, based on data of similar natural insulation such as hemp, wood or wood by-products, reed, straw, cotton, flax, etc. The insulation materials based on natural fibres have the thermal conductivity in the range of 0.038 – 0.090 W/(m·K) [4,7-9]. The investigation of insulation from the almost forgotten natural fibres have the great expansion due to its economical suitability and sustainability demands [4]. The new investigated material based on *Miscanthus x Giganteus* could be utilized as an insulation material or as a filler with satisfying thermal properties that might serve as cost-effective and environmental-friendly addition or replacement of conventional insulating materials, where it is possible.

MATERIALS AND METHODS

The new insulation materials based on *Miscanthus x Giganteus* were tested for physical, mechanical and trial thermal properties. The binder used for samples was a mixture of gypsum (3-5%), calcite (35-45%), slag (5-10%) and cement clinker (residue up to 100%). The prepared binder contained a reduced amount of cement clinker in relation to commonly used cement types. It has been enriched with a smaller quantity of synthetic zeolite. Zeolite shows good pozzolanic properties in alkaline medium, insulation properties (could be used in insulation coatings) and well absorbent performance [10]. It absorbs water and gasses, resulting in faster drying minimizing mold generation risk and release of unpleasant odours.

Although the thermal conductivity is the most important parameter of the insulating material, this study in the first place deals with physical and mechanical parameters which also have significant importance. The experimental part consisted of preparation of insulation material mixtures with different component mass ratio, determination of some physical parameters, mechanical properties investigations – compressive and bending (flexural) strength determination in the batch experiments and trial thermal conductivity tests.

Preparation of new mixtures for insulation material

The first experimental part was the preparation of four composite insulation material mixtures (marked I – IV) with the different component mass ratio, shown in Table 1. In order to prepare mixtures, *Miscanthus x Giganteus* chopped fibres, mineral binder, powdered zeolite and a sufficient quantity of water providing satisfactory workability, were used.

Table 1 *Mixture composition (mass ratio)*

Sample	$m_{Misc.}$ [g]	$m_{Bind.}$ [g]	$m_{Zeol.}$ [g]	$m_{Water.}$ [g]
I	300	420	180	360
II	400	420	180	360
III	300	480	120	360
IV	200	480	120	360

Miscanthus x Giganteus was previously air-dried for one month in the summer period, then fine-cut and shuffled. The chopped fibres were used with granulation of 300 mm with some possibly remaining pieces of long thinner fibres that could easily vertically pass through the sieve of this diameter. For the preparation of composites, the mentioned dry binder, powder zeolite and a sufficient quantity of water for incorporation into molds were used.

It is important to note that in the previous studies, *Miscanthus x Giganteus* proved to be resistant to the alkaline medium and the presence of silica. This information was important because the composite mixtures were prepared by mixing biomass and alkaline binder [11]. On the other hand, resistance to silicon dioxide is essential due to the subsequent usage and contact with standard construction materials such as, for example, mortar or concrete.

Determination of physical properties

The second part of the investigation was the determination of density, as the customary important physical characteristic. Low density means higher material' porosity and better insulation quality due to higher content of air which poorly conducts the heat [12].

It should be noted that there are other important physical parameters, such as absorption, water vapour diffusion resistance, thermal expansion coefficient, resistance to fire, chemical and biological stability, non-toxicity etc., which were not the part of this preliminary research.

The total (γ_u) and initial (after removing from the moulds) density (γ_0), as well as the density of the sample after drying during 90 days (γ_{90}) were defined according to equitation [13]:

$$\gamma_x = m_x / V_x \text{ [kg/m}^3\text{]} \quad (1)$$

where γ_x, m_x and V_x are corresponding density, sample mass and sample volume, respectively for each series sample.

Determination of mechanical properties

The third part of the experimental study was the investigation of mechanical properties by determination of compressive and bending strength in batch experiments. All mechanical tests were conducted in duplicate on 100 mm cubic samples, and in triplicate on prismatic samples (40x40x160 mm), shown in Figure 1. All results were presented as mean values.

Figure 1 *Samples for mechanical properties testing*

RESULTS AND DISCUSSION

Tables 2 and 3 show the mean values of density measured on cubic and prismatic samples.

Table 2 *Densities of cubic samples*

Sample	γ_u [kg/m^3]	γ_0 [kg/m^3]	γ_{90} [kg/m^3]
I	1205	1131	661
II	1298	1189	601
III	1223	1200	664
IV	1200	1135	619

Table 3 *Densities of prismatic samples*

Sample	γ_u [kg/m^3]	γ_0 [kg/m^3]	γ_{90} [kg/m^3]
I	1195	1086	715
II	1164	934	711
III	1211	1101	726
IV	1269	1285	851

Densities of all samples have higher values then mineral and glass wool or expanded and extruded polystyrene [12].

In addition to low density, it is important that the material has satisfactory mechanical properties.

The values of compressive strength of all samples were pretty different. For cubic samples, i.e. mixtures I and IV values were the highest (1.150 and 1.116 MPa, respectively). However, the values obtained on leftovers ("halves") of prismatic samples (remained after the bending test) only mixture IV showed satisfactory results (1.349 MPa). All results for compressive strength are shown in Figure 2a and b.

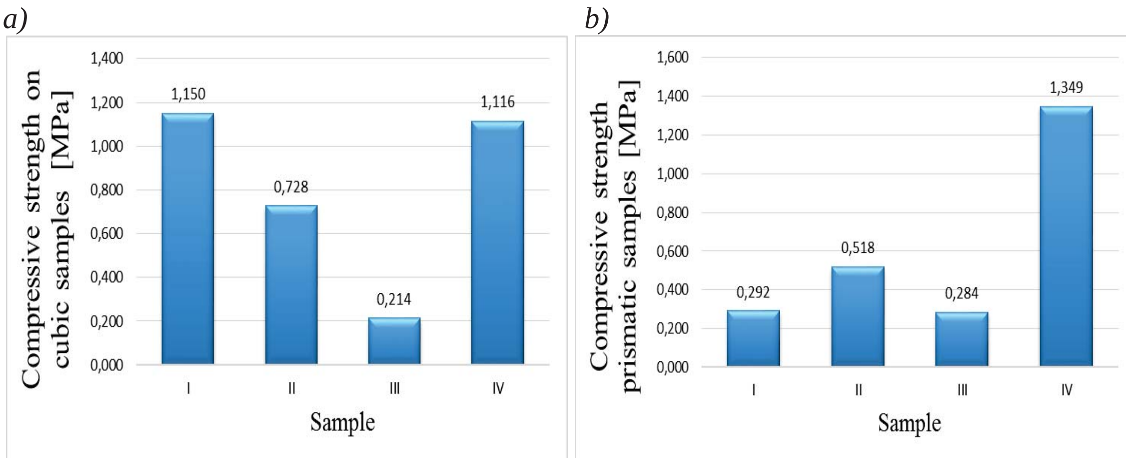

Figure 2 *Compressive strength [MPa]: a) on cubic samples; b) on halves from prismatic samples*

The similar trend was observed on prisms, priory subjected to bending test. Only mixture IV showed acceptable strength results with value of 0.631 MPa (Figure 3).

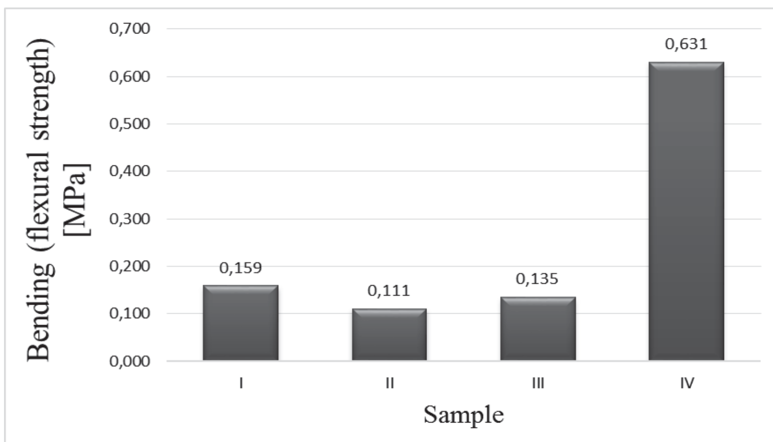

Figure 3 *Bending strength on prismatic samples [MPa]*

Since the mixture IV showed the highest values of compressive and bending strength simultaneously, only this mixture was taken into account for further thermal conductivity control tests. For thermal conductivity control tests, panel samples 500x500x70 mm were made (Figure 4). After drying up to a constant mass the selected panel had a thickness (width) of approximately 60 mm, and was tested.

Figure 4 *Sample for thermal conductivity determination*

The mean values of laboratory measured thermal conductivity for mixture IV panel, under the stationary thermal state conditions, were in the range 0.08 – 0.10 W/(m·K).

CONCLUSION

This research was conducted in order to prepare and investigate physical-mechanical properties of a brand new economical, ecological and energy-efficient insulation material. The four new mixtures based on *Miscanthus x Giganteus* fibres with a reduced cement binder amount and zeolite which shows good pozzolanic and absorbent properties, were prepared. In order to increase energy efficiency, the use of cement was minimized, since it is considered as an extremely energy-inefficient material, as well as high carbon dioxide emitter during its production. The utilization of this new material might significantly contribute to energy efficiency in construction sector.

The determination of densities has shown that all samples have higher values then mineral and glass wool or expanded and extruded polystyrene, i.e. smaller material' porosity.

The results of mechanical investigation on two cubic samples have shown good properties during determination of compressive strength, but only one mixture (mixture IV) has showed acceptable strength results for both strength tests (compressive and bending) with values 1.349 MPa and 0.631 MPa, respectively. Since only mixture IV showed the highest values of compressive and bending strength simultaneously, this mixture was taken into account for thermal conductivity control tests. The mean value of laboratory measured thermal conductivity was in the range 0.08 – 0.10 W/(m·K).

According to these results, examined composite material showed expected potential. It can be further enhanced with possible modification of its composition and preparation method in order to promote an additional reduction of its thermal conductivity.

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REFERENCES

[1] S. Proietti, P. Sdringola, U. Desideri, *et al*., Energy and Buildings; 64 (2013) 463–472.

[2] B. Skenderovic, M. Kekanovic, Construction materials, AGM book, Belgrade (2011), p.292.

[3] I. Lewandowski, C. Clifton-Brown, O. Scurlock, *et al*., Biomass and Bioenergy; 19 (2000) 209–227.

[4] M. Pfundstein, R. Gellert, M. Spitzner, *et al*., Insulating Materials – Principles, Materials, Applications, Aumüller Druck Regensburg, *Available on the following link:*https://www.degruyter.com/downloadpdf/books/detail.9783034614757/detail.9783034614757.fm/detail.9783034614757.fm.pdf, *Accessed on:* 20 December 2017.

[5] Z. Dzeletovic, N. Mihailovic, Dj. Glamoclija, *et al*., Agricultural Technology; 3 (2009) 9–16.

[6] ASHRAE, 2017, Handbook – Fundamentals, Chapter 26: Heat, Air, and Moisture Control In: Building Assemblies – Material Properties, *Available on the following link:* http://edge.rit.edu/content/ C09008/public/2009%20ASHRAE%20Handbook, *Accessed on:* 21 December 2017.

[7] V. Lekavicius, P. Shipkovs, S. Ivanovs, *et al*., Latvian journal of physics and technical sciences; 1 (2015) 38–51.

[8] F. Asdrubali, F. D'Alessandro, S. Schiavoni, Sustainable Materials and Technologies; 4 (2015) 1–17.

[9] K. Nagl, M. Barbu, T. Schnabel, *et al*., ProLigno; (2015) 181–186.

[10] S. Sircar, A. Myers, Handbook of Zeolite Science and Technology, Marcel Dekker, Inc., New York (2003), p.1184.

[11] E. Boix, F. Georgi, P. Navard, Industrial Crops and Products; 91 (2016) 6–14.

[12] M. Muravljov, Construction materials, Građevinska knjiga, Belgrade (2007), p. 397.

[13] D. Zakić, A. Savić, A. Radević, *et al*., Praktikum za vežbe i repetitorijum iz građevinskih materijala 1, Akademska misao, Beograd (2016), p.104.