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TESTING HEMP HURDS COMPOSITES WITH ALTERNATIVE BINDER

Composites based on natural fibres as organic filler are studied for several years because traditional building materials such as concrete are increasingly being replaced by advanced composite materials (fibre reinforced cement). The current trend in the construction industry is the effort to achieve sustainable development using rapidly renewable material resources instead of limited raw materials as well as using alternative materials. The need for development of promising and environmentally friendly materials is related to the industrial interest in the use of natural plant fibres as reinforcement into lightweight composites. The attention is given to hemp fibres as a substitute for synthetic fibers in lightweight composites due to their unique mechanical, thermal insulation, acoustic and antiseptic properties. Optimizing the adhesion of hemp plant fibre to the inorganic matrix in the composite is related to the modification of hemp fibers and/or the appropriate option and treatment of binder. In this paper, the attention is given to the study properties of composite based on hemp hurds (the woody part of hemp plant) as filler and alternative binder (MgO-cement). The hemp as a building composite component is rapidly renewable, carbon-negative, non-toxic, mildew-resistant and pest-free. Cement based on MgO seems to be a suitable binding agent for composites based on hemp hurds. Experimental work is focused on the study of thermal treatment of natural raw magnesite material for its subsequent use as an alternative binder component for lightweight composites and variation of composite mixtures based on hemp hurds and alternative binder focused on the MgO and SiO_2 component (silica sand and silica fume in variation). The evaluation of the physical and mechanical properties of hemp hurds composites with alternative binder is given. The results have shown that by incorporating hemp hurds into a magnesium oxide cement matrix it is possible to prepare materials with suitable thermal insulating properties usable in non-load-bearing structures.

Keywords: alternative binder, hemp hurds, lightweight composites, thermal treatment, physico-mechanical properties

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1. Introduction

Innovative building solutions for conserving non-renewable resources are connected with development of sustainable building materials based on renewable natural raw material resources. Technical hemp is becoming a major focus of green housing because of its energy-efficient cultivation as well as its health benefits to living. Due to the low density, biodegradability and high porosity of the hemp hurds, the combination of hemp and binder creates a building material with good thermal and acoustic insulation properties. Many studies on fibrous composites were carried out in order to understand the influence of various parameters, like binder nature, plant origin and fibre treatment on the mechanical properties of resulting composites [1-5].

The interaction of the fibres and mineral binder is very important factor in the development of composite mechanical properties [3].
Based on literature data and our previous research the binder nature is one of the key factors affecting the properties of lightweight composites based on hemp hurds [2, 6, 7]. Composite building material combining cementitious binders (limes and cement) with hemp hurds is generally referred to hemp concrete or hempcrete. Hemp hurds composites based on alternative binder MgO-cement have shown higher compressive strength values in comparison to composites with hydrated lime with cement addition [8].

The properties of hemp composites prepared with MgO-cement as alternative binder are dependent on the formation of M-S-H gel in composite system [9].

This article includes results of the hemp composite properties based on alternative binder MgO-cement. The impact of mixture variations on the physical and mechanical properties (compressive strength, density, water absorbability, thermal conductivity) of the hemp hurds composites hardened in indoor condition for a time period is studied.

2. Materials and methods

Technical hemp hurds used as filler into composites in this study is coming from Netherlands company Hempflax. This hemp sample contains more hurds material than bast fibres and used hemp material was polydispersive (wide particle length distribution 8-0.063 mm) with density 117.5 $kg.m^{-3}$.

MgO-cement was used as an alternative binder to hemp composites. MgO-cement as non-traditional binder consists of magnesium, silica and alkaline component. Caustic magnesite (CCM 85, SMZ a.s. Jelsava, Slovakia) with chemical composition MgO – 84%, Fe_2O_3 – 7.5%, CaO – 5.5%, SiO_2 – 1.0 %, Al_2O_3 – 0.2% was used as a magnesium component of MgO-cement. As silica component of alternative binder were used silica sand (Sastin, Slovakia) with the dominant component of SiO_2 (95-98 %) and silica fume (Istebne, Slovakia) with amorphous silica min. 85%. The variable component of the MgO-cement was an alkaline admixture in the form of sodium hydrogen carbonate $NaHCO_3$ (p.a) from Slovakia. Caustic magnesite has been milled in order to reduce its particle size in laboratory vibratory mill VM 4 for 5 minutes [10].

Experimental mixtures with original hemp hurds were prepared according to the recipe published in work [11] and its variations given in Table 1. The components of mixture were homogenized in dry way and then mixed with water addition. Standard steel cube forms with dimensions 100x100x100 mm were used for preparation of samples in accordance with the standard STN EN 206-1/A1 [12]. The specimens of fibrous composites were cured for 2 days in an indoor climate and then were removed from the forms. Curing was continued under laboratory conditions during 28 days.

Table 1. Experimental mixtures of hemp composites

Tabela 1. Doświadczalne mieszaniny kompozytów konopnych

Sample	Composition of mixture [vol.%]					
	Hemp hurds	MgO	Silica sand	Silica fume	$NaHCO_3$	Water
1	40	9,66	9,66	-	9,66	31
2	40	19,33	9,66	-	-	31
3	40	19,33	-	9,66	-	31

The physico-mechanical parameters were measured on hardened specimens under laboratory conditions. The resulting values are the average of three measurements. Density was determined in accordance with standard STN EN 12390-7 [13]. Thermal conductivity coefficient of samples, as the main parameter of heat transport was measured by the commercial device ISOMET 104 (Applied Precision Ltd., Germany). Short-term water absorbability (1h) was specified in accordance with the standard STN EN 12087/A1 [14]. Compressive strength of all fibrous composites under controlled conditions was determined as the maximum load per average cross-sectional area using the instrument ADR 2000 (ELE International Ltd., United Kingdom) in accordance with the standard STN EN 206 [12].

3. Results and discussion

As can be seen in Table 2, selected physical and mechanical properties of hemp-based composites vary depending on the mixture composition.

Density values after 28 days of samples hardening were ranged from 790 to 910 $kg.m^{-3}$. The lowest bulk density has the sample 3 prepared without alkaline component and with silica fume as the source of the silica component for providing binder hydration processes. This fact is due to the lower initial bulk density of silica fume. Compared to a sample with the same mixture composition made with silica sand as a source of silica component (sample 2), decrease in this parameter for sample 3 was observed by 20 %.

Table 2. Properties of experimental mixtures of hemp composites

Tabela 2. Właściwości doświadczalnych mieszanek kompozytów konopnych

Sample	**Density [kg.m^{-3}]**	**Thermal conductivity [W.m^{-1}.K^{-1}]**	**Water absorbability (1h) [%]**	**Compressive strength [MPa]**
1	890	0.195	22.4	1.55
2	910	0.205	19.8	2.85
3	790	0.190	17.5	3.15

The average thermal conductivity coefficient of all mixture samples is 0.197 W.m^{-1}.K^{-1}. This value confirms the possibilities of using prepared hemp - composites as insulating materials.

Study of sorption behaviour of fibrous composites is very important due to poor resistance to the moisture coming from organic nature of fibre [15]. The values of short-term water absorbability of samples ranged between 17.5 and 22.4%, with the lowest absorbability reached by sample 3.

The compressive strength of testing samples ranged from 1.55 MPa to 3.15 MPa, with the highest value of the strength parameter reaching by the sample with the lowest bulk density (sample 3) where the silica fume was used in the mixture as the source of silica component of binder. This active ingredient in the composite improves its strength parameter as described in the work [16]. The composite prepared with silica fume (sample 3) achieved a higher strength parameter compared to the composite prepared with silica sand (sample 2), due to the higher reactivity of the silica particles forming the M-S-H phases and the more compact structure of composite.

From this point of view, the mixture composition of sample 3 appears to be the most suitable.

4. Conclusion

This paper deals with composites based on hemp hurds as filler and alternative binder MgO-cement and variation of this MgO-cement composition (magnesium component, silica component and alkaline component). Comparison of the various composites mixtures showed that replacement of silica sand with more reactive silica fume in samples mixture demonstrated the possibility of its using in fibrous composites preparation with improved physic-mechanical properties. It has been shown that composites properties depend on the alternative binder mixture. Characteristics of hemp composites prepared with binder based on MgO predetermine this material as a sustainable and carbon – negative which can be applied as a non – load bearing material with good thermal – insulating properties.

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BADANIA KOMPOZYTÓW……………………………

Streszczenie

Tutaj streszczenie w jezyku polskim…………………………………………………………
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Słowa kluczowe: spoiwo alternatywne, konopne ???????, lekkie kompozyty, obróbka termiczna, cechy fizyko-mechaniczne

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