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CHANGES IN THE PROPERTIES OF BIOCOMPOSITES CAUSED BY PHYSICAL MODIFICATION OF HEMP HURDS

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Abstract

Lightweight composites based on natural fibres as organic filler are studied for several years. Using renewable resources (like natural fibres) instead of non-renewable is very current topic in developed countries. The use of alternative and environmentally friendly materials like plant fibres from hemp, jute, sisal and the others as reinforcement for composite materials is attractive for the purpose of the construction. The great importance is attached to the industrial hemp, specifically to the woody part of hemp plant called hemp hurds as a reinforcement for composite materials for the purpose of construction. Hemp hurds composite is a prospective building material because of its unique properties (exceptional thermal insulation, antiseptic, acoustic and mechanical properties).

In this paper, the attention is given to the physical modification of hemp hurds (cooking in water for a time period) and to the preparation of the lightweight composites based on this organic filler and on alternative binder MgO-cement. Some important parameters (thermal conductivity, density, compressive strength, water absorption) of these hemp composites (made with modified and unmodified hemp hurds) were tested in dependence on the hardening time (28, 60, 90 days).

Key words

Defining characteristics; hemp hurds; lightweight composite; physical treatment

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1 INTRODUCTION

Nowadays, the growing trend in construction industry is to create a sustainable construction by minimizing the production of emissions and replacing the limited material resources for the renewable raw materials. A large group of renewable raw materials are materials of plant origin. Plant fibres from hemp, jute, sisal and the others are used for the purposes of the construction in the civil engineering.

The great importance is attached to technical hemp like a renewable and fast-growing source of cellulosic fibres. This material has significant environmental and economical advantages because it is a rapidly renewable and non-waste material. The technical hemp (Cannabis Sativa) is source of two types of fibres (Fig. 1); bast fibres (used mainly in the paper and textile industries) and woody fibres – hurds which is interesting for the construction industry [1]. The hemp hurds represents a waste material from hemp processing and is used as filler in lightweight composites.

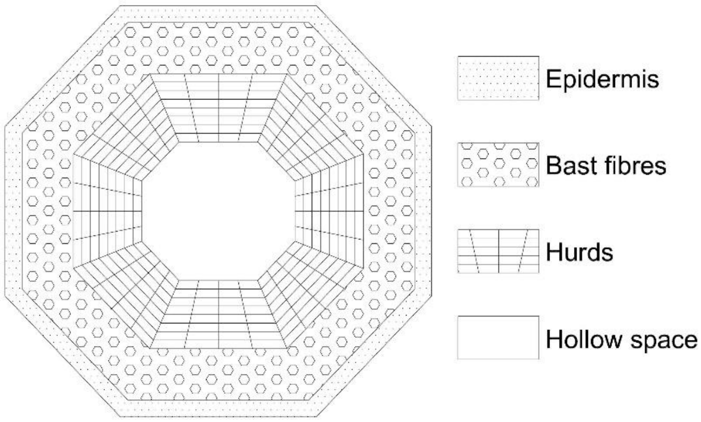

Fig. 1: Hemp stem – cross section

Combination of the lime-based binder and woody hemp fibres brings a new material - hemp concrete that is a perspective building material in the EU and it has to be used in combination with a load-bearing frame [1-3]. It enables to build sustainable buildings (for new buildings construction or existing buildings renovation) as filling material of a load-bearing structure. However, today hemp hurds can be used in high-quality products such as hemp concrete, fibre boards and composites with excellent thermal insulating, acoustic and antiseptic properties. However, high moisture sorption and heterogeneity of hemp fibres cause weak interface between the fibres and the matrix in composite system. Poor moisture resistance is connected with the presence of hydroxyl and other polar groups in structure what leads to their hydrophilic nature. Hemicellulose is responsible for moisture absorption [4]. In our previous work, some selected physical and mechanical properties of lightweight composites based on cellulosic natural materials such as hemp hurds and wood pulp as organic filler with different binder kinds were investigated [5].

The surface physical/chemical pre-treatment of natural fibres is necessary in order to optimize their adhesion to inorganic matrix in composites [6]. Based on the results of testing the chemically modified hemp hurds published in paper [7], changes in chemical composition of hemp hurds caused by removing impurities and amorphous components (pectin, lignin, hemicellulose), degradation of average polymerization degrese of cellulose and separation of bundles of fibers in the fibrils were observed.

According to literature [8], the interface is generally enhanced via an increased mechanical bonding between the fibre and the matrix when hemp fibres were treated.

In this paper, comparison of changes in properties of biocomposites based on MgO-cement as binder and untreated and physically treated hemp hurds in hardening time dependence is given.

2 MATERIAL AND METHODS

The technical hemp hurds slices (Cannabis Sativa L.) coming from the Netherlands company Hempflax were used as filler in experiments. This hemp hurds contains more hurds material than bast fibres. The used hemp material was poly-disperse with a wide mean particle length distribution (8 - 0.063 mm) and its density was 117.5 $kg \cdot m^{-3}$. The average moisture content of the hemp material determined by weighing of hemp sample before and after drying at 105 ºC for 24 h was found out 10.78 wt. %.

The estimated chemical composition of used hemp hurds is shown in Table 1. The content of holocellulose was determined by using the modified method according to Wisea. The quantitative determination of cellulose was performed by the Kürschner-Hoffer nitration method. The content of acid-insoluble (Klason) lignin was carried out by two-step hydrolysis of polysaccharides portion in sulphuric acid. Total ash content (mineral substances) was measured by combustion of sample. Toluene-ethanol extract containing mainly extractable waxes, fats, resins as well as water extractives was obtained by extraction in a Soxhlet apparatus for 6 – 8 h at 90 °C.

Tab. 1: Estimated chemical composition of hemp hurds

Percentage of components of hemp hurds	(%)
Cellulose	44.2
Hemicelluloses	30.3
Lignin	24.4
Toluene ethanol extract	3.5
Ash	1.4

The physical modification of dried hemp hurds was made by their thermotreatment in hot water (100 °C) for 1 h. Subsequently the hemp hurds slices were dried and their surface was obviously distraught and shredded.

For preparation of biocomposites based on hemp hurds was used alternative binder MgO-cement consisting of caustic magnesite obtained by low temperature decomposition of natural magnesite (CCM 85, SMZ a.s. Jelsava, Slovakia), silica sand (Sastin, Slovakia) with the dominant component of SiO_2 (95-98 %) and sodium hydrogen carbonate (p.a). Dry vibratory milled product of MgO (for 5 min) was used in binder mixture [9].

Experimental mixtures were prepared according to the recipe consisted of 40 vol. % of hemp hurds (unmodified as a referential material and physically treated), 29 vol. % of MgO-cement and 31 vol. % of water. 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 [10]. The 9 specimens of lightweight 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 (3 samples), 60 (3 samples) and 90 days (3 samples).

The density, thermal conductivity coefficient, compressive strength and water absorption were measured on hardened composites under laboratory conditions. Density was determined in accordance with standard STN EN 12390-7 [11]. The thermal conductivity coefficient of samples, as the main parameter of heat transport was measured by the commercial device ISOMET 104 (Applied Precision Ltd., Germany). The measurement is based on the analysis of the temperature response of the studied material to heat flow impulses. Compressive strength of all composites was determined using the instrument ADR 2000 (ELE International Ltd., United Kingdom). Water absorption (after one hour) was specified in accordance with the standard STN EN 12087/A1 [12].

3 RESULTS AND DISCUSSION

In this paper, the impact of physical modification of the hemp hurds slices and hardening time on selected physico - mechanical properties (density, compressive strength, thermal conductivity, water absorption) of biocomposites with alternative binder MgO-cement were studied. The results of testing parameters of hardened composites (after 28, 60, 90 days) are presented. As it can be clear from Figs. 2-4, the values of compressive strength, thermal conductivity coefficient and water absorption of hemp composites depend on the time of hardening as well as on the surface modification of hemp hurds slices.

The density values of biocomposites were ranged from 940 to 1120 kg•m^{-3}which places them into category of lightweight composites. Biocomposites based on physically treated hemp hurds have lower values of density in comparison to composites with untreated hemp hurds slices.
As it can be seen in Fig. 2, hemp composites based on untreated original hemp hurds have higher values of compressive strength (1.84 – 4.9 MPa) in comparison with composites based on treated hurds (1.12 – 2.74 MPa). The same behaviour of composites has been observed in the case of hardened specimens with chemically treated hemp hurds [13].

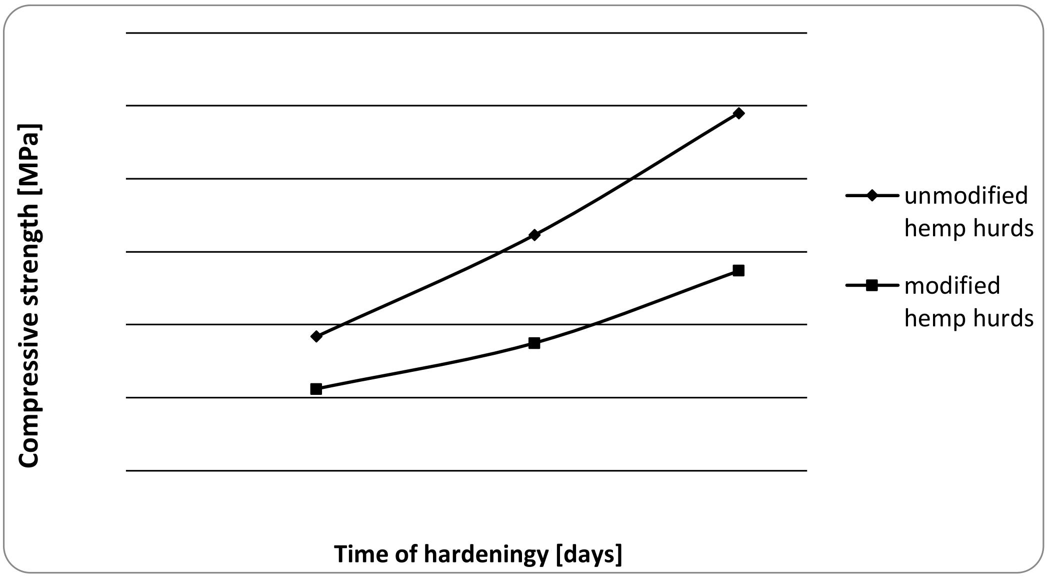

Fig. 2: Dependence of biocomposites compressive strength on time of hardening

The hemp composite samples based on physically modified hemp hurds have lower values of thermal conductivity coefficient (0.071-0.085 W•m^{-1}•K^{-1}) than composites based on original hemp slices (0.08-0.098 W•m^{-1}•K^{-1}). It seems that the thermal conductivity decreases with increasing hardening time (Fig. 3). The all measured values of prepared bicomoposites samples are in range acceptable for the thermal insulating materials.

The water absorption values of prepared composite samples, shown in Fig. 4, present decreasing water absorbability of composites based on hemp hurds with increasing time of hardening. Values of water absorption are in a range 13.9 – 26 % for biocomposites based on unmodified hemp hurds and in a range 10.7 – 16.1% for composite samples prepared from modified hemp hurds. Water absorbability in hardened composites is depended on internal porous system. The results confirmed that the absorbability is decreased over the time that may indicate the fact that hydration products of binder gradually fill the vacant interior spaces in the composite.

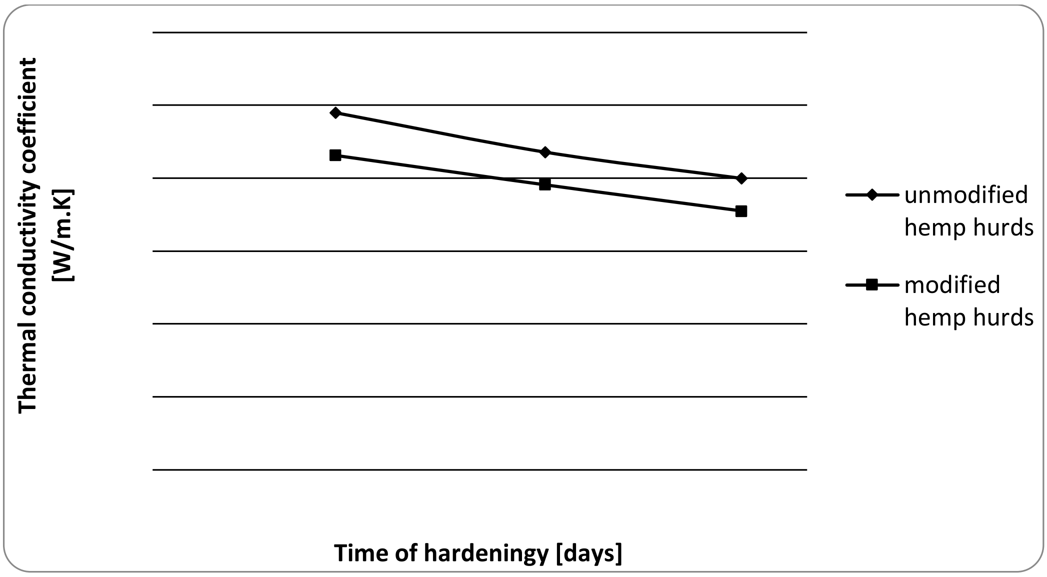

Fig. 3: Values of biocomposites thermal conductivity coefficient in dependence on time of hardening

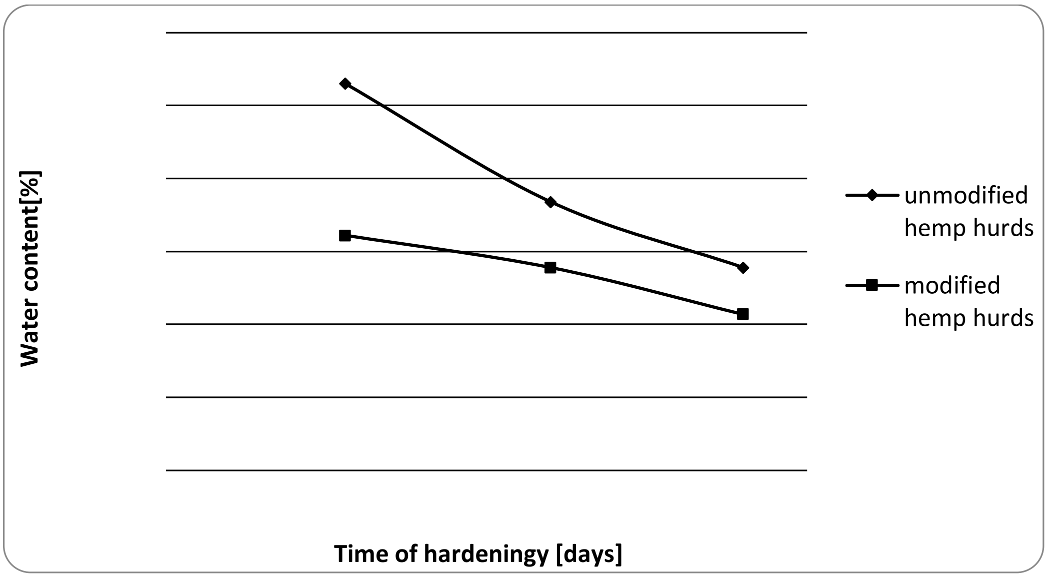

Fig. 4: Dependence of water content in biocomposites on time of hardening

As it can be clear from Fig. 4, the specimens with modified hemp hurds have observably lower values of water absorption than composites based on unmodified fibres. It means that the physical modification of hemp hurds reduced water absorption of the lightweight composites. According to literature data [14], the physical treatment changes structural and surface properties of the fibres but it does not extensively change their chemical composition. Assessment of changes in the properties of physically modified hemp hurds will be published in future research.

4 CONCLUSIONS

This paper deals with using hemp hurds as organic filler in unmodified and physically modified form into building materials. Thermo treatment (cooking in hot water) was used as a method for removal of organic and inorganic loosely bound contaminants from surfaces of hemp hurds. The influence of used method on hemp hurds slices and also of the specimens hardening time on the mechanical (compressive strength) and physical properties (density, thermal conductivity, water absorbability) of hardened composites was observed. Following conclusions can be given:

The compressive strength of biocomposites prepared with hemp hurds increased with increasing time of hardening. However, physical treatment of hemp hurds has negative impact on compressive strength of composites in comparison to composites based on untreated organic filler.

The values of thermal conductivity of composites prepared with unmodified and modified hemp hurds predetermine this material to its use like thermal insulation. The positive impact of increasing hardening time was also monitored.

Hot water treatment of hemp hurds affects the water absorption behaviour of hardened composites. Lower water absorption values were observed in the case of composites with physically treated surface of hemp hurds.

More investigations are needed to understanding and explanation the influence of natural fibres as filler in composites structure by using physical method.

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