CZASOPISMO INŻYNIERII LĄDOWEJ, ŚRODOWISKA I ARCHITEKTURY
JOURNAL OF CIVIL ENGINEERING, ENVIRONMENT AND ARCHITECTURE
JCEEA, t. XXXII, z. 62 (3/II/15), lipiec-wrzesień 2015, s. 75-81

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NEW BIOCOMPOSITES BASED ON HEMP HURDS

The development in the field of building materials tending to biocomposites made from natural resources is increasing worldwide. Natural fibre-reinforced composites are attractive due to their environmental and economic advantages. Natural fibres such as kenaf, jute, hemp and sisal are combined with inorganic matrix (based on conventional and/or non conventional material) in biocomposites for their application in building industry. A great importance in Europe has technical hemp as sustainable and fast renewable resource of lignocellulosic fibres with high specific strength, which can be utilized as filler/reinforcement material in composites.
This paper presents the results obtained from an experimental study of the mechanical and physical properties of biocomposites prepared with Portland cement as a binder and chemically treated and untreated hemp hurds as a filling agent.

Keywords: lignocellulose fibres, lightweight composites, surface treatment, mechanical properties, physical properties

1. Introduction

Agriculture offers a broad range of commodities materials. Plant-based materials have been used traditionally for food and feed, however, renewable biomaterials can be used for both bioenergy and bioproducts and are a possible alternative to synthetic products. In recent years, there has been a resurgence of interest for the use of renewable materials such as plant fibres, also called ‘‘lignocel-

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lulosic fibres'', due to increasing environmental concerns along with the unique characteristics of these fibres. These include abundant availability, renewability, biodegradability, as well as reduced weight, increased flexibility, greater moldability, reduced cost and sound insulation. Lignocellulosic fibres if compared with today's most used synthetic fibres offer the advantage of lesser health hazards and of course lower cost. Agricultural crops' residues and lignocellulose waste materials can be avaluable source of lignocellulosic fibres, which can be used to reinforce lightweight composites. Biocomposites have future commercial application that would unlock the potential of these underutilized renewable materials and provide a nonfood-based market for agricultural industry [1].

Fibrous hemp is a plant that easily adapts to new vegetation conditions and is characterized by a rich diversity of forms. It is a phytosanitary plant and therefore it can be introduced into each crop rotation, practically after any plant. Hemp generates about 10-15 tons of biomass per hectare. 1 ha of hemp absorbs about 2.5 tons CO_2, which results in a significant reduction of greenhouse effect [2]. The most essential advantage of hemp as an energetic raw material, compared to fossil fuels, is a considerable reduction of CO_2 emission to the atmosphere. Carbon dioxide emitted during biomass combustion is absorbed in the process of photosynthesis and utilized for plant growth in the process of vegetation.

Although there are some studies on hemp hurds use into lightweight composites since the beginning of the nineties of the last century, there are still many gaps in knowledge of these new building materials. In order to stimulate their commercial production, the research must lead to a deeper understanding structure and interface between fibrous fraction and matrix particles forming composite. It enables to construct sustainable buildings (new buildings or existing buildings renovation) where hemp hurds is used as filling/reinforcing material in a load-bearing structure. This new building material so called ''hemp concrete'' allows to reduce very significantly the ecological footprint of materials in the building due to storage of approximately 35 kg of CO_2 per square meter of wall built with a thickness of 25 cm over 100 years [3].

The scope of our previous paper was to study the influence of filler and binders volume portion [4] and milling condition of alternative binder component on selected properties of hemp-composites. The mean particle length of hemp hurds, chemical composition changed by treatment and binder nature as the most important parameters controlling the mechanical properties of composites were investigated [5-7].

The objective of this work is to process initial and chemically treated hemp hurds in order to evaluate and compare their application suitability into cement-based composite.

2. Materials and Methods

2.1. Raw materials

2.1.1. Filler

Hemp is an annual plant which provides two materials used in civil engineering: hemp hurds (fibrous fraction from the inner woody core) and hemp fibres (bast fibres).

The original material studied in this paper is hemp hurds coming from the Netherlands Company Hempflax. Used hemp hurds had wide particle length distribution of particles (8-0.063 mm). The mean particle length was calculated to 1.94 mm. Bulk density of hemp material was 117.5 kg•m^{-3}. Average moisture content of used hemp hurds was determined by weighing the sample before and after drying in an oven at 70°C until a constant moisture content; 10.78%.

The second sample used in experiment was hemp hurds chemically modified in alkaline environment. Dried original hemp hurds were soaked in 1.6 M NaOH solution during 48 h and then neutralized by 1% vol. acetic acid. Hemp hurds were then washed with water until the pH value was 7.

2.1.2. Binder

Conventional binder Portland cement CEM I 42.5 N was used for the preparation of composites. Characteristic properties of cement are in Table 1.

Table 1. Characteristic properties of used cement

Tabela 1. Charakterystyczne właściwości użytego cementu

Portland cement CEM I 42,5 N			
density (kg/m^3)	*specific surface area (m^2/g)*	*mean particle size (μm)*	*compressive strength after 28 days of hardened (MPa)*
3050	*0.610*	*29.90*	*52.1 ± 1.3*

2.2. Specimens preparation

The fresh mixtures for preparation of composites consisted of 40 vol. % of hemp hurds (modified or unmodified), 29 vol. % of binder and 31 vol. % of water. For preparation of composite specimens, the standard steel cube forms with dimensions 100mm x 100mm x 100mm were used. The specimens were cured for 2 days in the indoor climate at approximately +18°C and then removed from the moulds. After that time, the specimens were wrapped in a polyethylene foil during 28 and 60 days.

2.3. Methods

For hardened composites, following properties were measured: the density, thermal conductivity coefficient, compressive strength and water absorption. Density was determined in accordance with standard STN EN 12390-7 [8]. The thermal conductivity coefficient of samples, as the main parameter of heat transport was measured by the commercial device ISOMET 104 (AP Germany). The measurement is based on the analysis of the temperature response of the studied material to heat flow impulses. The heat flow is induced by electrical heating using a resistor heater having direct thermal contact with the surface of the sample. Compressive strength of all composites was determined using the instrument ADR ELE 2000 (Ele International Limited, United Kingdom). Water absorption (after one hour in indoor climate) was specified in accordance with the standard STN EN 12087/A1 [9].

3. Results and Discussion

During the laboratory study, physical and mechanical properties of composites based on chemically treated (alkalization) hemp hurds were compared to referential composite with initial (unmodified) hemp hurds. Changes in water absorption, thermal conductivity coefficient and compressive strength values of composites with chemically modified hemp hurds in comparison to referential composites after 28 and 60 days of hardening are shown in Table 2.

Table 2. Characteristic of physical and mechanical properties of 28 and 60 days hardened composites

Tabela 2. Charakterystyczne fizyczne i mechaniczne własności stwardniałego kompozytu po 28 i 60 dniach

sample	*hardening time (days)*	*water absorption (%)*	*thermal conductivity coefficient ($W \cdot m^{-1} \cdot K^{-1}$)*	*density (kg/m^3)*	*compressive strength (MPa)*
referential	*28*	*13.96*	*0.380*	*1557*	*6.87*
modified		*9.26*	*0.350*	*1616*	*6.98*
referential	*60*	*13.20*	*0.206*	*1527*	*6.67*
modified		*10.20*	*0.320*	*1581*	*11.90*

The obtained results indicate that alkaline treatment of hemp hurds influences the properties of composites. One of the recorded concequences of chemical modification of organic filler is decrease in its hydrophility. Values of water content of 28 and 60 days hardened specimens with modified hemp hurds are lower by 23 and 34 wt.% than the those of referential composites. This is the result of the lower porosity due to better interfacial bonding between the organic filler and inorganic matrix. Measurements show that values of thermal conductivity coefficient are in the range 0.206-0.380 $W/m^{-1} \cdot K^{-1}$.

These conductivity values of hemp hurds cement-based composites are higher in comparison to MgO-cement based composites [10]. The influence of chemical treatment of hemp hurds on values of thermal conductivity coefficient was not confirmed. Density of monitored samples ranged 1527-1616 kg/m^3. As shown in Tble 2, composites based on chemicaly modified hemp hurds had a slightly higher density values in comparison to composites based on unmodified hemp hurds after 28 and 60 days of hardening. Higher values of compressive strength were determined for samples with treated hemp hurds too. This is accordance with [11], where chemical modification of hemp hurds led to cleaning the surface repulped of hurds slices and improvement of the adhesion between the fibers and inorganic matrix. The study of hemp hurds properties after alkaline treatment in [5] confirmed changes in defibrillation of bundles, chemical and phase composition, cellulose crystallinity and degree of cellulose polymerization. Compressive strength values of composites increase with increasing hardening time, as shown in Table 2. 60 days hardened sample based on chemically modified hemp hurds reaches the highest value of compressive strenght of 11.9 MPa that could be considered to be sufficient for the load bearing material [12].

4. Conclusion

This paper evaluates the technical importat parameters of novel lightweight biocomposites based on hemp hurds (unmodified and chemically modified in NaOH) and cement matrix. Based on the results of this study, the following conclusions can be drawn:

- water contents of 28 and 60 days hardened composites with alkaline treated of hemp hurds slices were almost a quarter to a third lower in comparison to those of untreated ones due to the lower porosity of composites associated with better interfacial bonding between the organic filler and inorganic matrix
- density and compressive strength values of 28 and 60 days of hardened composites with alkaline treated hemp hurds slices were higher as compared to referential specimens, due to an improvement of the compactibility of cement particles with hemp hurds surface and forming the denser and compacter structure of composite
- the influence of chemical treatment of hemp hurds on values of thermal conductivity coefficient was not confirmed.

Acknowledgements
The authors are grateful to the Slovak Grant Agency for financial support of the project VEGA1/0277/15.

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NOWE BIOKOMPOZYTY NA BAZIE WŁÓKIEN KONOPNYCH

Streszczenie

Trendy rozwoju w dziedzinie materiałów budowlanych skłaniają się w stronę biokompozytów z zastosowaniem materiałów odnawialnych. Kompozyty wzmacniane włóknami naturalnymi są atrakcyjne z powodu ich zalet uwzględniających ekologiczne i ekonomiczne aspekty. Biokompozyty przeznaczone do zastosowań w budownictwie, składają się z naturalnych włókien, takich jak ketmia konopiowata, juta, konopie czy agawa są związane z matrycą nieorganiczną (opartą na konwencjonalnych i/lub niekonwencjonalnych materiałach). Ogromne znaczenie w Europie mają konopie techniczne jako ekologiczny i szybko odnawialny zasób włókien lignocelulozowych o wysokiej wytrzymałości, które mogą być wykorzystywane jako wypełniacz i materiał zbrojący w kompozytach.

Artykuł prezentuje wyniki badań doświadczalnych właściwości mechanicznych i fizycznych biokompozytów przygotowanych na bazie cementu portlandzkiego jako spoiwo, oraz włókien konopnych nie modyfikowanych i modyfikowanych chemicznie jako wypełniacz.

Słowa kluczowe: włókna lignocelulozowe, kompozyty lekkie, obróbka powierzchniowa, własności mechaniczne, właściwości fizyczne

Przesłano do redakcji:8.06.2015
Przyjęto do druku:1.12.2015

DOI: 10.7862/rb.2015.141