Ing. Lucia Kidalova, Ing. Jozef Junak, PhD., prof. RNDr. Nadezda Stevulova, PhD.

Technical University of Košice,
Civil Engineering Faculty, Institute of Architectural Engineering

HEMP AS UNCONVENTIONAL MATERIALS FOR A SUSTAINABLE CONSTRUCTION

У контексті питань, пов'язаних з навколишнім середовищем, рівень зацікавленості дослідників у біоматеріалах швидко зростає завдяки їх перевагам, як в поновлюваність ресурсів, низька вартість, біорозкладання тощо. Є багато можливостей використання природних сировинних матеріалів для виготовлення біокомпозитів. Описано експериментальні дослідження композитів на основі прядива (пеньки) з метою визначення фізико-механічних властивостей цих композитів. Часткові результати вказують на можливість використання бетонів на основі прядива (пеньки) як не несучих навантаження будівельних матеріалів.

Ключеві слова: волокна, композит, міцність на стиск.

In the context of environmental issues, bio-based materials are attracting increasing levels of research interest, because of their numerous advantages: renewable resource, low cost, biodegradability and so on. Natural raw materials have a lot of possibilities utilization in biocomposites preparing. This paper describes in an experimental study of hemp composites with regard to physico-mechanical properties of composites. Partial results indicate the potential using of hemp concrete such as non-load bearing building materials.

Key words: hemp shives, composite, compressive strength.

Introduction. The term industrial hemp is applied to varieties of Cannabis Sativa that have been specifically produced by plant breeders to have a tetra hydro cannabinnol (THC) level of 0.2% or less. Hemp is a 'bast' fibre crop with two constituent parts: a fibre sheath around a woody core called shiv, shive or hurd [1]. Hemp cultivation in Europe has increased from approximately 5000 hectares in 1993 to over 15,000 hectares in 2004 [2]. This rapid growth is continuing: 30,000 tones of hemp hurd/shiv were produced in 2003. In 2005, 60,000 tones of hemp straw were processed in France [3]. Hemp is growing also on the increase in Ireland and hemp-processing facilities are planned.

Hemp fibre is used increasingly in the automotive sector, primarily in the manufacture of internal door panels and other parts. Demand for hemp products is also growing in construction where the shives is used as an energy efficient building material and the fibre is used as natural fibre insulation. The composite material combines fast-growing renewable and carbon sequestrating plant-based aggregates (hemp shives) with a lime-based binder to form a lightweight material that is suited to various construction applications, including solid walls, roof insulation and under-floor insulation and as part of timber-framed building. It also offers good thermal and acoustic performance and the ability to regulate internal relative humidity through hygroscopic material behaviour, contributing to healthier building spaces and providing effective thermal mass [1]. In our previous paper [4], the effect of using different binding agents (hydrated lime, cement, zeolite) in combination with hemp shives in composites was examined. Our research is also focused on the use of MgO as cement replacement in composites based on hemp shives [5, 6] because MgO has rich resources in our country. This material was also studied with emphasis on comparison influence of thermal loading, water absorption on mechanical, thermal and structural properties of composites. In this paper, we studied mixtures with two different of volume percentages of hemp shives in regard to comparison of strength characteristics.

Materials and methods. Hemp (specifically hemp shives) as unconventional natural material used in this study was supplied from Hungarohemp Rt, Nagylak, Hungary. The density of dried hemp shives was 115 kg.m-3 and mean particle diameter was 33.68 mm. Granulometric composition of hemp shives is given in Table 1.

Table 1

Granulometric composition of hemp shives

Fraction [mm]	Mass yield [wt.%]
+ 40	35.6
40 - 25	18.3
25 - 20	20.63
20 - 16	2.5
16 - 10	10.3
10 - 7.1	5.64
7.1 - 6.3	2.63
6.3 - 5	1.5
- 5	2.9

MgO-cement as binder was used and consists of caustic magnesite obtained by low temperature decomposition of natural magnesite (CCM 85, SMZ a.s. Jelšava, Slovakia), silica sand (Šaštín, Slovakia) with the dominant component of SiO_2 (95-98%) and sodium hydrogen carbonate ($NaHCO_3$) p.a. Granulometric composition of caustic magnesite and silica sand are given in Table 2.

Table 2

Granulometric composition of MgO and silica sand

Fraction [mm]	Mass yield [wt.%]	
	MgO	Silica sand
0.5 - 1	18.25	14.75
0.25 - 0.5	34.75	63
0.125 - 0.25	30	19.75
0.063 - 0.125	13.5	2
- 0.063	3.5	0.5

The effect of MgO milling has been investigated in order to reduce its particle sizes. Dry milling was carried out in laboratory vibratory mill VM 4 with in times of 5 - 60 minutes. The particle size analysis of the milled products was carried out on the laser granulometer Helos with dry dispersion unit Rodos (Sympatec, Germany). The specific surface area of powders was determined by the standard B.E.T. method using the equipment Gemini 2360 (Sy-lab, Austria). Product of milling after 5 min was chosen as the most available for next research and its mass yield of fraction under 5 μm was 53.02 wt.% and mean particle diameter was 6.852 μm.

Components content in experimental mixtures is given in Table 3. Mixture I.1 and II.2 were prepared according to recipe published in [7] and [8], respectively. The mixture I.2 and II.1 are a modification of previously mentioned mixtures. The mixtures were prepared in the labour mixer and the standard steel cube forms with dimensions 100mmx100mmx100mm were used to preparation of samples. Next day the composites were taken out of the forms and cured under laboratory conditions according to standard rules. Compressive strength (equipment ELE ADR 2000) and density after 28 days of hardening were determined. Three replications were used for each property.

Table 3

Components content in experimental mixtures

Mixture	Composition of mixture [vol.%]		
	Hemp shives	MgO-cement	Water
I.1	40	29	31
I.2	60	19	21
II.1	40	22.5	37.5
II.2	60	15	25

There were also prepared mixtures with 40 vol.% hemp shives and 29 vol.% MgO-cement (binder), but this binder was not contained silica sand and contained half the amount of NaHCO3 and MgO was milled or unmilled.

Results and discussions. Figures 1 and 2 show the results of density and compressive strength of hardened composites with different ratio of hemp shives. The composites I.1 and II.1 containing 40 vol.% hemp shives reached the highest compressive strength. The obtained data show that the compressive strength decreases with percentage reduction of hemp shives (filler). Same dependence is observed in the case of density. Figure 3 show compressive strength of hardened composites without silica sand. Results show that higher values of compressive strength achieved mixture with milled MgO. Density values of composites were 1190 and 1150 kg/m3, respectively. Obtained results with MgO-cement show higher values compared to traditional binder (hydrated lime) in the same mixture, where the compressive strength was from 0.3 to 0.33 MPa [5].

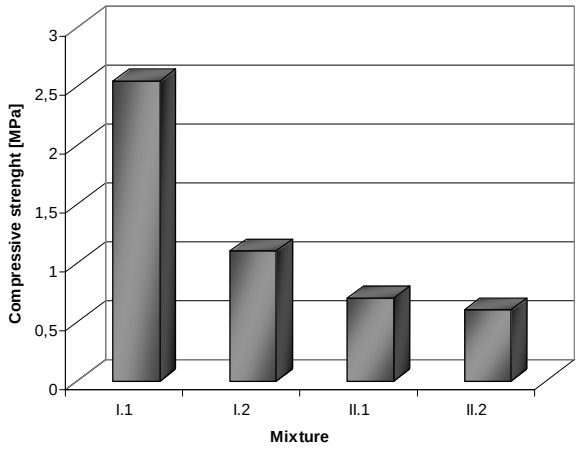

Figure 1. Compressive strength of 28 days hardened composites

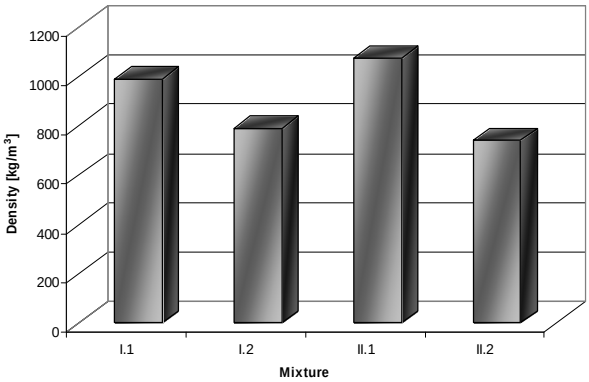

Figure 2. Density of 28 days hardened composites

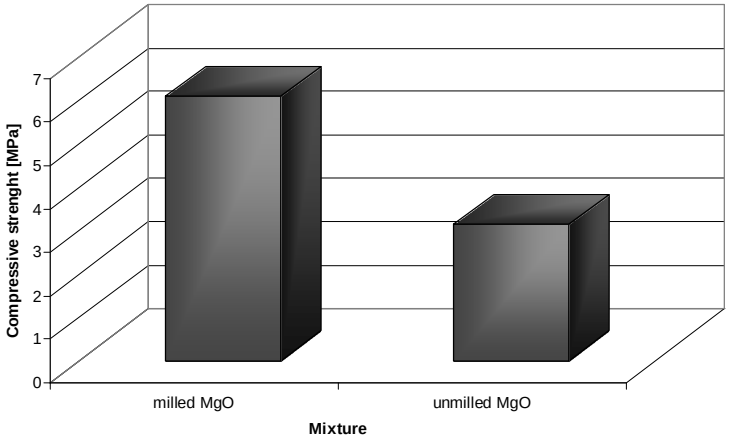

Figure 3. Compressive strength of 28 days hardened composites

Conclusion. Our experiments were focused on comparison of filler amount influence on the resulting composite strength. Mixtures with 40 vol.% of hemp shives have highest values of compressive strength in both but it is necessary to orientate on other mechanical parameters. With respect to obtained results, application of MgO-cement as binder in composites based on hemp shives appears to be a suitable alternative instead traditional binder (hydrated lime). This materials have also relatively low density compared with normal concrete, thus it is suitable material for insulation materials or non-load bearing building materials.

Acknowledgements. The authors are grateful to the Slovak Grant Agency for Science (Grant No. 1/0498/09) for the financial support of this work.

1. BEVAN R., WOOLLEY T. Hemp lime construction. A guide to building with hemp lime composites. Bracknell: IHS BRE Press, 2008. 2. NOVA INSTITUTE. http://www.novainstitute.org (27/05/2011). 3. EUROPEAN INDUSTRIAL HEMP ASSCOCIATION. http://www.eiha.org (27/05/2011). 4. KIDALOVA L., STEVULOVA N., TERPAKOVA E., HELCMAN M. Effective utilization of alternative materials in lightweight composites, // Chemical Engineering Transaction. 2011 – vol.25 – P.1–6. 5. KIDALOVA L., STEVULOVA N., TERPAKOVA E., SICAKOVA A. Use of magnesium oxide-cement binder in composites based on hemp shives // Journal of Environmental Science and Engineering, 2011 – vol.5, No 6, p. 736–741. 6. STEVULOVA N., TERPAKOVA E., KIDALOVA L., PRIGANC S., ESTOKOVA A., HELCMAN M. Hemp as potential component in sustainable construction. Proceeding of Matbud. – Krakow: Politechnika Krakowska, 2011 – P. 387–394. 7. BYDZOVSKY J. Utilization of rapidly renewable raw materials in building materials. In Proceedings of the 12th International Scientific Conference. – Brno, 2009. – P. 43–46 (in Czech). 8. ALLIN S. Building with hemp, Rusheens. – Kenmare: Seed press, 2005.