UTILIZATION OF ORGANIC MATERIAL AS ADDITION TO CEMENT BASED PLASTERS

Nadezda Stevulova[1], Ivana Schwarzova[1]*, Viola Hospodarova[1], Jozef Junak[1]

[1]Institute of Environmental Engineering, Faculty of Civil Engineering, Technical University of Kosice, Vysokoskolska 4, 04200 Kosice, Slovakia

Abstract

The use of alternative and environmentally friendly materials like natural fibres from different plant sources and also recycled fibres as reinforcement for composite materials is attractive due to good mechanical properties and sustainability prerequisites for the purpose of the construction.
In the last decades, many studies deal with the use of organic materials and with utilization of natural fibres as replacement to synthetic fibres in reinforced composites, polymers and cement-based materials. Natural cellulose fibres are coming from different sources such as natural raw materials (hemp, flax, coir, wood) and waste raw materials (waste paper). The advantages of natural fibre-made composite are low density, low production cost of molded products and biodegradability.
In the commercial market, there has been a strong trend to produce environmentally friendly materials by using recycled paper and agro-waste fibres. In many studies, the recycling of various types of wood pulp and waste paper fibres for the production of fibre cement composites has shown a significant effect on the mechanical and physical properties.
This paper discusses the use of natural fibres as reinforcement in cement-based materials. The investigation of the properties of cement plasters with bio-based additives, that are applicable for exterior and interior environment, is given in this article. These materials were made of cement mortar containing lingo-/cellulose fibres coming from different sources (hemp hurds and waste paper). The investigation focused mainly on the effects of both fibres addition on the physico - mechanical properties of composite materials.

Key words

Cement based plasters; hemp hurds; organic material addition; physic-mechanical properties; recycled fibres; waste material.

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*Corresponding author: Tel.: +421-55-602-4278,
E-mail address: ivana.schwarzova@tuke.sk

1 INTRODUCTION

Nowadays, the natural plants become an alternative solution or source of fibrous material due to increasing population and industrialization along with better education. In a view to reduce the cost of production and the harmful destruction of our environment, so many research work has been carried out and still ongoing as to the possibility of using natural fibres for the development of high performance engineering products [1].

The development of cement based composites using recycled or recyclable organic material is very actively pursued due to the effort to develop sustainable concrete material. Natural fibre composites are proposed to substitute synthetic fibre composites due to several advantages such as biodegradability, renewability, recyclability, abundant, permeability, high degree of flexibility, hygroscopicity, non-toxicity, capability of giving up moisture, no release of substances harmful for health, non-irritation to the skin, no allergic effect, competitive mechanical properties, reduced energy consumption, less abrasiveness to processing equipment, and minimum waste disposal problems [2-4].

The use of agricultural wastes and recycled materials as reinforcement of composite materials is one of the most important targets in today's materials research [5]. The present research is concerned with the use of the wastes from the industrial hemp (Cannabis Sativa L.) and with the recycled waste fibres from paper making to manufacture fibre-cement products. Similar to other lignocellulosic fibres, hemp is biodegradable and environmentally friendly [6]. This fact, together with its high strength and durability and low density, explains the increase in the use of hemp fibres in the manufacture of composite materials. The most common material obtained from hemp is its fibres, especially the coarse ones which are extremely strong and durable. As the most valuable fibres are located in the phloem, they must often be separated from the xylem material ("hemp core"), which is considered a waste in the hemp industry [7, 8]. Many authors have studied the use of hemp fibres as reinforcement for building materials based on cement [7-10].

Reuse the agricultural by-products presents clear advantages from economic (costreducing) and ecological (resource-saving) perspectives [11]. Natural fibres offer an attractive alternative to many synthetic materials building with natural fibres presents diverse markets for farmers, reduces the emission of carbon dioxide and minimize the volume of waste in landfill. Furthermore, natural fibre source is renewable and considered being green and environmentally friendly [12].

The aim of this work is to study the influence of two types of waste lingo-/cellulosic fibres on physico-mechanical parameters of cement based plasters. Hemp hurds as a waste material coming from hemp stem processing and recycled fibres from waste paper are introduced in plaster specimen and their effect on physico-mechanical parameters is studied in dependence on the percentage of used fibrous material (2.0, 5.0 and 10.0 %).

2 MATERIALS AND METHODS

The raw material used for this study was the hemp hurds, waste from technical hemp stem processing, coming from the Netherlands Company Hempflax. This hemp material consisted of a large majority of core fibres (hemp hurds,) over bast fibres, and it also contained fine dust particles originating from the manufacturing grinding process (Figure 1a).

Original hemp hurds slices had wide particle length distribution (8–0.063 mm). The mean particle length of used hemp hurds was 0.94 mm and its density was 117.5 kg.m^{-3}. The average moisture content of hemp material determined by weighing of hemp sample before and after its drying for 24 h at 105 °C was found 10.78 wt%. The hemp hurds is constituted by 44.5% cellulose, 32.8% hemicelluloses, 21% lignin, 3.5% components soluble in toluene-ethanol extract and 3% ash.

Cellulose fibres from recycled paper (Figure 1b) - Greencel were supplied by Greencel Ltd. (Hencovce, Slovakia).

a)  *b)* 

Fig. 1: Organic material as addition to plasters: a) hemp hurds; b) recycled fibres

Two kinds of organic fibrous material – hemp hurds and waste paper fibres in various portions (2.0, 5.0 and 10.0 %) were selected for addition to cement based plaster samples. Portland cement CEM I 42.5 R (Holcim Slovakia a.s.) as binder and natural silica sand (fraction 0-1.0 mm) as filler were used into mixtures. Water for the cement mixtures preparation was used in accordance with standard STN EN 1008. Fresh reference plasters were prepared with Cement/Sand (C/S) weight ratio of 1:3 and Water/Cement (W/C) ratio of 0.75. Each batch of three test specimens consists of 450 ± 2 g of cement, 1350 ± 5 g of sand and 337 ± 1 g of water. Fresh cement based plasters with fibres were prepared with cement/(sand + fibres) weight ratio of 1:3. The fibre content was subtracted from the silica sand content which means that fibres were used as substitutions. The sand content was then adjusted based on mixing rule where the ratio water/cement is kept constant.

Preparation of fibre reinforced cement composites was carried out in two different ways. At first, the components of mixture with hemp hurds were homogenized in dry way and then mixed with water addition. At second, the recycled paper fibres were dispersed in water by mechanical stirring (approximately 50 wt. % of water). Subsequently, cement, sand and remaining amount of water were added, and mixing continues to allow uniform fibre dispersion in the mixture. After mixing, the plasters specimens were immediately poured into the standard steel block forms with dimensions 40 x 40 x 160 mm. The specimens were cured for 2 days in the indoor climate at approximately +18°C and then they were removed from the forms. After that time, the specimens were held under PVC foil for 26 days. For each measurement were prepared 3 samples.

The density of cement mortar composites were determined in accordance with standard STN EN 12390-7 [13] and STN EN 12390-3 [14]. Compressive and flexural strength of the all specimens under controlled conditions after 28 days of hardening was determined using the instrument ADR ELE 2000 (International Limited, United Kingdom) in accordance with the standard STN EN 206-1/A1 [15].

3 RESULTS AND DISCUSSION

For this study, various cement based plasters with organic material addition were prepared. Lignocellulosic hemp fibres and cellulose recycled fibres were added with different percentages (2.0 %, 5 % and 10 % wt. replacement of sand) into cement based plasters and a reference sample without fibres addition was prepared for comparison. The all physico-mechanical properties of composite samples were measured after 28 days of hardening.

One of the physical parameters - density was measured after 28 days of fibre-cement composite samples hardening. The density values of the all composite samples are shown in Table 1. It is evident that higher amount of fibres (hemp hurds and recycled paper) caused lower density of all samples in comparison to reference sample. Density of composites with fibres is in the range from 1981 $kg.m^{-3}$ to 1797 $kg.m^{-3}$ and for reference sample (without fibres addition) it is 2073 $kg.m^{-3}$. Decrease of density values are in the range 4.44 – 10.08 % in comparison with reference sample, samples with hemp hurds (8.88 – 13.31 %); samples with recycled paper (4.44 – 7.72 %). This is caused by amount of fibres, their nature and physical and chemical characteristics in accordance with our previous study [16].

Tab. 1: Density values of cement based plasters with organic material addition

Density [$kg.m^{-3}$]	**Percentage of fibrous material [%]**			
	0	**2**	**5**	**10**
Samples with hemp hurds	2073	1889	1864	1797
Samples with recycled fibres	2073	1981	1968	1913

Figures 2 and 3 show mechanical behaviour of cement based plasters with organic material addition in dependence on its various percentages in comparison with reference sample after 28 days of hardening. The flexural and compressive strength values of all mixtures are lower than value of reference sample. The compressive strength tends to increase with increasing fibre content up to a point where there is a decrease in compressive strength of samples due to phenomenon, when an excessive amount of fibrous material reduces the strength. In this case, as it is shown in Figures 2 and 3, there is recorded an increase of compressive strength up to 5% wt. content of hemp hurds and recycled fibres at 2.70 % and 6.33 %, respectively. The flexural strength values of plasters with recycled waste paper have similar trend in the development of compressive strength values (Figure 2b). However, in the case shown in Figure 2a flexural strength of plasters with hemp hurds have different course. There is recorded decreasing character in flexural strength of hemp hurds plasters (3.66 – 2.49 MPa).

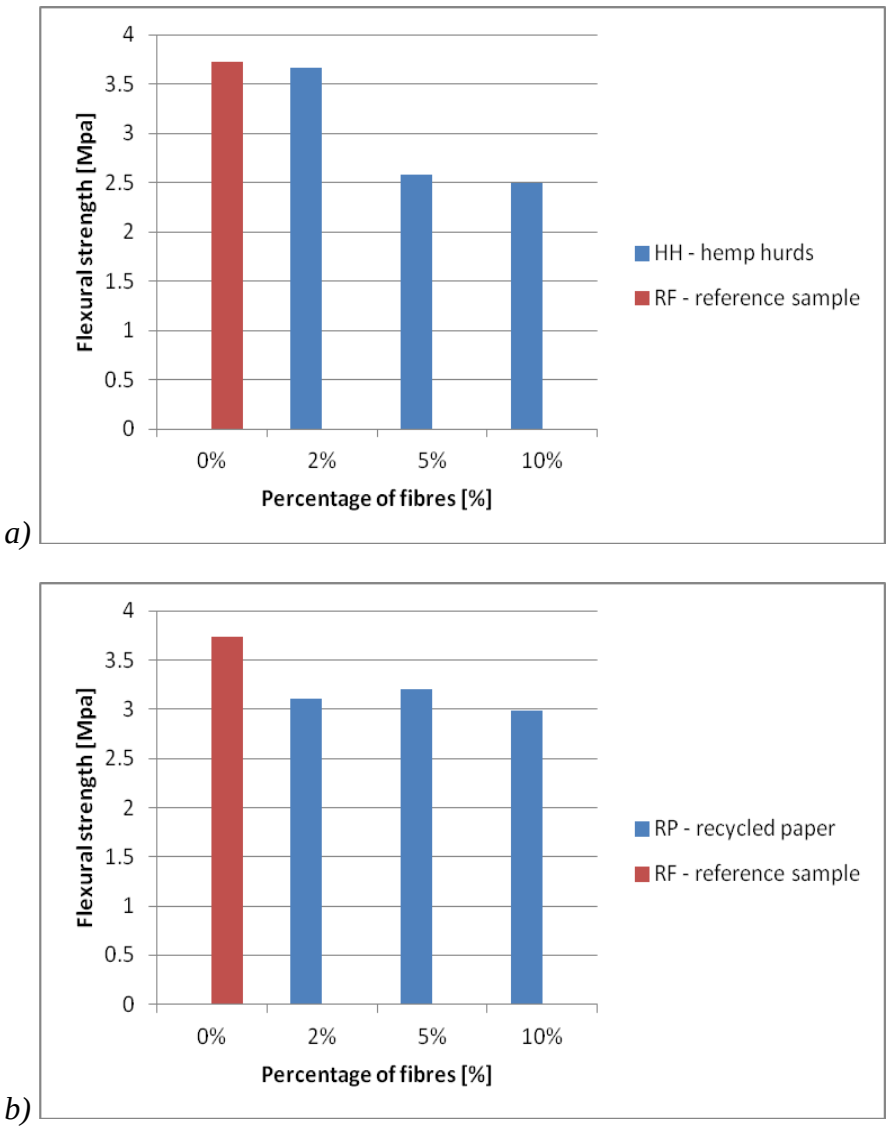

Fig. 2: Flexural strength of cement plasters after 28 days with a) hemp hurds; b) recycled paper addition in dependence on fibres percentage

The compressive strength values of cement pastes blended with various amount of fibres from hemp hurds and recycled paper are shown in Figure 3. These values are in range 15.68 – 18.00 MPa and compressive strength value of reference sample is 26.6 MPa. The compressive strength values of composite samples with hemp hurds and also with recycled paper fibres increases in dependence on amount of fibres addition. However, samples with fibres from waste paper reached higher values of compressive strength in comparison with hemp hurds samples. Differences in values of compressive strength are caused by the different nature and structure of used fibrous material. Natural fibres require higher water content in the production, which leads to lower density and reduced compressive strength. The mechanical properties of the cement based composite depend mainly on the content of fibres, their orientation and on the quality of load transfer between the reinforcement and matrix. The positive effect of fibres was observed mainly visually; the samples with fibres remained relatively compact at large strain [17].

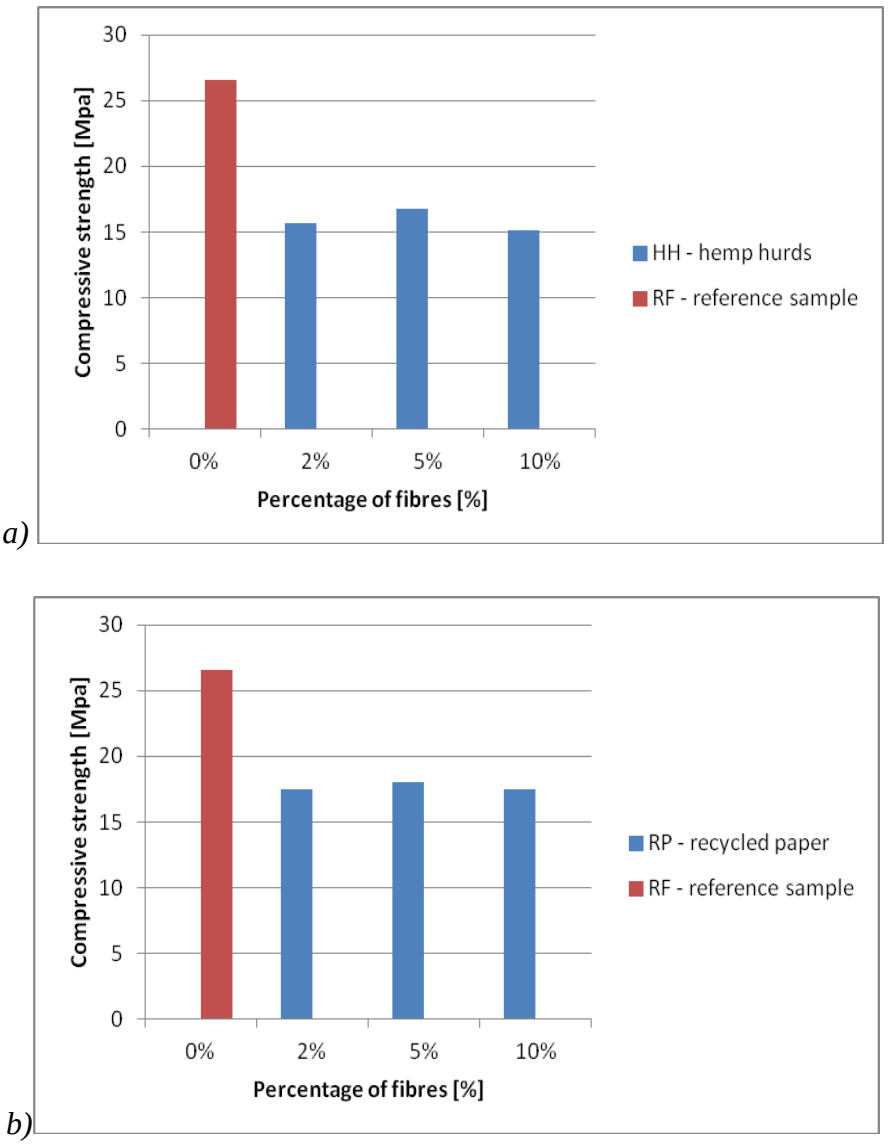

Fig. 3: Compressive strength of cement plasters after 28 days with a) hemp hurds; b) recycled paper addition in dependence on fibres percentage

The dependence between values of compressive strength and density of the all composite samples with organic material is depicted in Figure 4. The results show that the compressive strength of plasters with hemp hurds and waste paper varies moderately linearly with the density of plasters up to 5 % wt. used fibres into plasters. After that point, there is observed decrease of compressive strength and increase of density of bio-based plasters what is caused by using 10 % wt. of fibre replacement (i.e. more air voids and bad reducing of air voids).

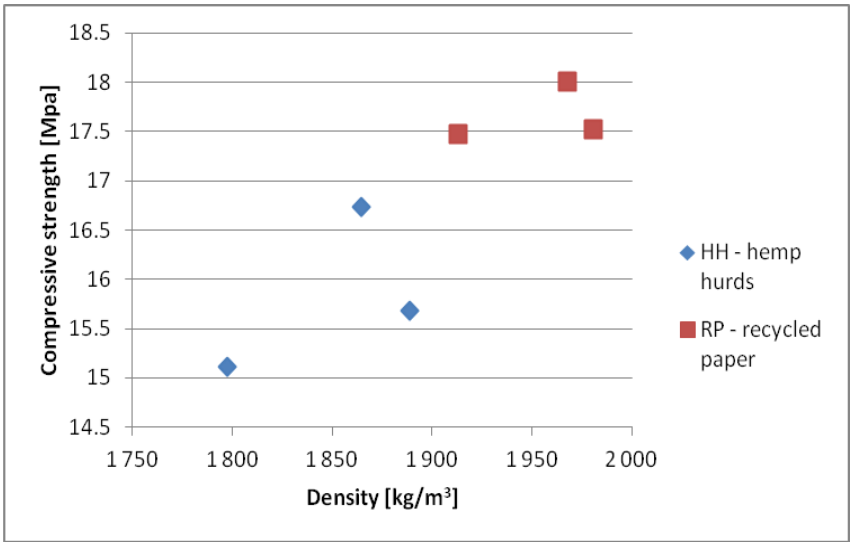

Fig. 4: Compressive strength of cement plasters after 28 days with organic material addition in dependence on composite density

4 CONCLUSION

The novelty of this paper lies in the use of waste materials (agricultural, paper making), particularly, technical hemp hurds an recycled fibres, as eco-friendly and renewable source of cellulose fibres in the manufacture of fibre-cement plasters.

The effect of waste cellulosic fibres addition on the physico – mechanical properties of cement based plasters was investigated in this paper. Furthermore, the effect of different fibre origin (hemp hurds and recycled waste fibres) and various portions (2.0 %, 5.0 % and 10 %) of fibre addition to the composite mixture were analyzed. Physical and mechanical properties (density, flexural and compressive strength) of 28 days hardened composite samples were tested. The measurements demonstrated that physical and mechanical properties depend on the fibre nature, structure, shape and amount of used fibrous organic material into cement based plaster mixtures. The density decrease of fibre-cement samples is mainly attributed to the fact that both types of fibres, hemp hurds and recycled waste fibres, are light in weight due to their porous structure and nature. The relationship between compressive strength and density of fibre-cement plaster samples was shown. Hemp fibres do not significant change the compressive strength but reduce the brittle breaking behaviour of the material. Hemp fibres lead to slightly reduced compressive strength compared with the pure cement plaster. This is mainly due to the strength loss of the fibres and the reduced density.

The performance is positive in terms of future use of lignocellulosic aggregates and cellulosic fibres into cement-based plasters. The cement based composites with fibres reinforcement are potentially contributing to sustainable development due to their environmental benefits.

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