CELLULOSE FIBRES AS SECONDARY RAW RESOURCES USE IN SUSTAINABLE BUILDINGS MATERIALS

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ABSTRACT

Nowadays, due to the increase of awareness on environment, productions of waste from any sectors (industry, construction industry and agriculture) are significant. Therefore, it is important to devote more attention to this area. The material recycling is growing trend in development of building materials and some waste materials can be used in construction as secondary raw materials. The green awareness and focus of sustainability has supported the overall recycling culture. Secondary raw materials are used for production new sustainable building materials and it helps to conserve non-renewable sources of raw materials. These renewable raw materials are based on plant fibres.

Cellulose fibres are environmentally friendly sources of renewable raw materials. Large quantities of lignocellulosic waste (vegetable fibres, wood pulp and pulp from waste paper) are being generated worldwide. An investigation concerning the potential use of the cellulose fibres from waste paper as construction materials is essential in order to gain an insight into their behaviour and properties. The use of lightweight cellulose pulp as reinforcement in building materials is an interesting strategy for managing these by-products, from the point of view of their mechanical properties, environmental and social-economic impact.

The characterization of cellulosic fibres in a pulp form from waste paper and their use into cement composites is presented in this paper. Fibres are as a partial substitution of filler in the mixture. The selected technically important parameters (density and compressive strength) of 28 days hardened composites with two types of cellulosic fibres and with three additions were tested. Density and compressive strength of hardened composite varied with cellulosic fibres content.

Keywords: pulp, waste, recycled paper, cellulose fibres, material recycling

1. Introduction

An increasing worldwide shortage of wood resources, there has been a strong trend to produce composite products using recycled paper, non-wood plant materials and agricultural residues. Among the possible alternatives, the development of pulp and paper industries and bio-composites using recycled paper is currently at the centre of attention of researcher for some value-added products (Ashori et al., 2011).

The use of waste fibres as reinforcement in cement composites has enormous potential in the field of recycled materials utilization for civil construction. The composites based on recycled fibres in optimised form present an acceptable behaviour in comparison with fibre cement produced with virgin wood cellulose fibres. The availability of non-commercial fibrous wastes also supports their potential utilization throughout sustainable methods of production of building components (Savastano et al., 2005). Due to the need of reducing costs, considerable research efforts have been carried out during the last years to explore the potential of fast growing and cheap fibre alternatives (hemp, kenaf, sisal and recycled paper) (Tonoli et al., 2010). A combination of interesting mechanical and physical properties and their environmental benefits has been the main driver for their use as alternatives for conventional reinforcements.

One of the great waste material groups is fibrous biomaterial originating from plants. It is fast renewable material. The main component of this substance is cellulose. Cellulose fibres exhibit a set of important advantages, such as wide availability at relatively low cost, biorenewability, ability to be recycled, biodegradability, non-hazardous nature, zero carbon footprint, and interesting physical and mechanical properties (low density and well-balanced stiffness, toughness and strength) (Ardanuy et al., 2015). Cellulosic fibres provide adequate stiffness, strength and bonding capacity to cement-based matrices for substantial enhancement of their flexural strength, toughness and impact resistance (Tonoli et al., 2010).

Applications of cellulosic fibre reinforced cement composites are basically addressed to the non-structural building of thin walled materials, mainly thin-sheet products for partitions, building envelope or ceilings flat sheets, roofing tiles and pre-manufactured components in general (Roma et al., 2008). As is shown in many papers (Le et al., 2015), such composites have lower environmental impact especially in regard to the carbon footprint. Comparing to cellular concrete, the building with the cellulosic fibres cement composites can reduce energy consumption up to 45% (Colinart et al., 2012).

The main objective of this study is to explore the potential use of cellulose fibres from wood pulp and waste paper into the cement composites as an alternative building material. The variation of physical and mechanical properties of 28 days hardened cellulosic composites in terms of fibres amount is investigated.

2. Materials and methods

2.1. Materials

The cellulose raw material for this study was cellulose fibres - Greencell from wood pulp and recycled paper which were supplied by Bukoza Invest spol. s.r.o. (Hencovce, Slovakia). Two types of cellulose fibres were tested and their physical and chemical properties are shown in the Table 1.

Table 1: Physical and mechanical properties of Greencel cellulose fibres

Cellulose fibres	Cellulose content [%]	Bulk density [kg/m^3]	Max. length [µm]	Dry matter [%]	Ash [%]	pH	Colour
GW-500	99.5	60-80	500	93	0.5	6±1	white
G-700T	80	40-70	600	93	20	7±1	grey

The binding agent was employed Portland cement CEM I 42.5 R (Holcim Slovakia a. s.). Natural silica sand of the fraction 0–0.6 mm was used as filler into mixtures. Water for the cement mixtures preparation was used in accordance with standard STN EN 1008.

2.2. Preparation of composites

Experimental mixtures consisted of cement CEM I 42.5 R, sand, water and cellulose fibres were prepared according to the recipe given in the Table 2. The cellulose fibres substituted 0.2%, 1% and 5% weight of filler (sand). In the first alternative of experiments, fibres from wood pulp (GW-500) were used. A partial sand replacement by fibres from waste paper (G-700T) was performed in the second experimental set. Reference sample was prepared without cellulosic fibres addition. Water-cement ratio (w/c) was 0.75 for each sample.

Preparation of fibre reinforced cement composites was carried out in two stages. At first, mixing the pulp fibres with water addition (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. The standard steel block forms with dimensions 40 mm x 40 mm x 160 mm were used for preparation of specimens. The bodies were cured for 2 days in the indoor climate at approximately +18 °C and then they were removed from the moulds. After that time, the specimens were held under PVC foil for 26 days. After 28 days of hardening, the cement composites were weighed and their density and compressive strength were tested.

Table 2: Composition of prepared mixtures

Mixture samples		CEM I 42.5 R	Sand	Water	Cellulosic fibres (wt.%)	
					GW-500	G-700T
1.alternative	WP1	*	*	*	0.2	-
	WP2	*	*	*	1.0	-
	WP3	*	*	*	5.0	-
2.alternative	RP1	*	*	*	-	0.2
	RP2	*	*	*	-	1.0
	RP3	*	*	*	-	5.0
Reference mixture		*	*	*	-	-

2.3. Testing methods

28 days hardened composites according to standards STN EN 12390-7 and STN EN 12390-3 were tested. Compressive strength of all composites was determined using by the instrument ADR 2000 (ELE International, England). The mean values of density and compressive strength of each specimen were calculated as the average of the three measured values.

3. Results and discussion

As shown in Table 3, density values of composites based on two types of cellulosic fibres were lower in comparison to reference sample. While density of composite samples in the first experimental set was not influenced by fibrous amount in specimens, density of the second set of composites based on fibres from recycled paper shows a growing trend in the dependence on increasing share of cellulosic fibres in specimens.

Table 3: Density and compressive strength of composites

Sample	Density [kg/m^3]	Compressive strength [MPa]
WP1	1940	13.84
WP2	1945	17.79
WP3	1945	18.72
RP1	1947	18.51
RP2	1935	16.28
RP3	1955	21.85
RF	2096	26.44

The variation of the compressive strength values of composites with different amount of cellulosic fibres is evident (Table 3). These reached about 52-83 % of strength parameter value for reference composite. The results show that compressive strength increases with an increasing fibres content in followed range up to 5 wt.%. This confirmed known fact that wood fibre content is the major factor affecting properties of composites.

Composites of the second set show higher values of strength parameter (16.28-21.85 MPa) when compared to compressive strength values of the first set (13.84-18.72 MPa). This fact can be explained by the different nature of surface fibres. Similar results were obtained in paper (Kidalova et al., 2014) where impact of unbleached and bleached wood pulp on cement composites properties was studied. In the case of cellulosic fibres from wood pulp, no active centres are present on the surface of fibres due to bleaching process and therefore interaction between surface fibres and cement particles is weaker.

Figure 1 illustrated linear relationship between the compressive strength and density of composites based on two types of cellulosic fibres.

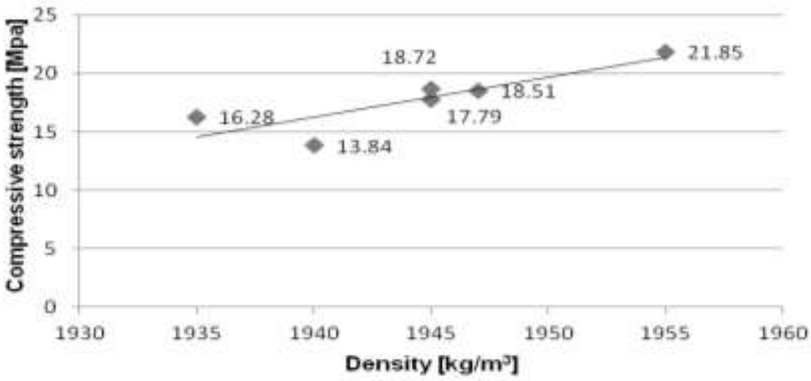

Figure 1: Dependence of compressive strength on density of the composites with cellulose fibres from wood pulp and recycled paper

4. Conclusions

In this paper, using of two types of cellulose fibres (originating from bleached wood pulp and recycled paper) in various portion (0.2; 1 and 5 wt.%) in cement composites were investigated. Some important properties of 28 days hardened composites such as density and compressive strength were tested. The results showed that density and strength parameter values are varied in dependence on share of cellulosic fibres in specimens as well as on nature of surface fibres. There is a need to research the influence of cellulose fibres properties and their incorporation on further properties of cement composites in order to obtain correct information for manufacturing of sustainable biocomposites with added value.

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