

Implementation of recycled cellulosic fibres into cement based composites and testing their influence on resulting properties

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Abstract. Nowadays, the application of raw materials from renewable sources such as wood, plants and waste paper to building materials preparing has gained a significant interest in this research area. The aim of this paper is to investigate the impact of the selected plasticizer on properties of fibres composites made of cellulosic fibres coming from recycled waste paper and cement. Investigations were performed on specimens with 0.5 wt. % of fibre addition without and with plasticizer. A comparative study did not show positive influence of plasticizer on the density and thermal conductivity of 28 days hardened composite. The specimens after 1, 3 and 7 days of hardening with plasticizer exhibited the highest impact on compressive strength in comparison to composite without plasticizer but 28 days hardened specimens reached the same value of strength characteristic (41 MPa).

1. Introduction

Nowadays, the development of natural fibre reinforced composite based products to substitute traditional reinforcing materials (steel, glass, and polymer fibres) is becoming a trend in many fields of their application such as building construction, automotive, engineering etc. The main advantages of using natural fibres are the sustainability, low cost, low density as well as competitive specific mechanical properties [1]. There has been observed increase in the use of natural fibres for making new environmental friendly and biodegradable composite materials [2]. The increasing interest is in the utilization of recycled fibre materials as reinforcing element for building application. One of this potential material is waste cellulosic fibres that are obtained from wood, local annual plants, agricultural crops, industrial residues and waste paper, as well [1,3,4,5].

There are many factors that can affect the performance of natural fibre reinforced composites with inorganic or organic matrix. The properties of the natural fibre composites depend on the properties of matrix and fibres, adhesion of fibres to matrix at interface and their content and distribution in matrix. Another important factor influencing the composites properties is the processing parameters. Therefore, suitable processing techniques and parameters must be carefully selected in order to yield the optimum composite materials [2,6]. Cellulosic fibres are the most commonly used for composites reinforcement in organic or inorganic matrix to develop a natural fibre composite with appealing mechanical properties [2,7]. Composites based on natural cellulosic fibres offer environmental advantages such as reduced dependence on non-renewable energy and material sources, lower



greenhouse gas emissions, enhanced energy recovery, and the end of life biodegradability of components [7].

The objective of this work is to investigate the impact of plasticizer implementation on properties of cement composites based on 0.5 wt. % addition of recycled cellulosic waste paper fibres. Density, thermal conductivity after 28 days of hardening and compressive strength after 1, 3, 7 and 28 hardening days were tested. As a reference sample, the cement composite without fibres and plasticizer was prepared.

2. Materials and methods

2.1. Materials

The cellulosic fibres used in this study coming from different sources of recycled waste papers. These unbleached recycled cellulosic fibres (G-3/00T) were provided by Slovak company Greencel Ltd (Hencovce, Slovakia). Properties of grey recycled waste paper fibres G-3/00T with 80 % of cellulose content are shown in table 1.

Portland cement type CEM I 42.5 N, from Cement Factory Ltd. (Povazska cementaren Ladce, Slovakia), was used for preparing cement composites.

Standard silica sand was supplied by company Filtracni pisky Ltd (Chlum, Czech Republic) conforming with European standard STN EN 196-1 [8].

Water for the cement mixtures preparation was used conforming to standard STN EN 1008 [9].

Superplasticizer Glenium Sky 665 acquired from BASF The Chemical Company Ltd (Praha, Czech Republic) was used to adjust the workability of fibre cement mixtures in accordance with European standard STN EN 934-2+A1 [10].

Table 1. Properties of waste paper fibre Greencel.

Characteristic of cellulosic fibre	Max. length [μm]	Bulk density [kg/m ³]	Dry matter [%]	Ash [%]	Thermal conductivity λ [W/m.K]	Volume heat capacity x10 ⁻⁶ [J/m ³ .K]	Thermal diffusivity x10 ⁶ [m ² /s]
G-3/00T	1200	30-50	93	20	0.0595	0.1709	0.3478

2.2. Preparation of cellulosic fibres reinforced cement plasters

The fibre cement mixtures were prepared in accordance with European standard STN EN 196-1 [8]. In the mix design, the weight proportion of cement:sand:water was kept 1:3:0.55. The first set of cement mixture (RPC) was prepared with 0.5 wt. % recycled waste paper fibre addition. The second set (RPCP) had the same content of components, however there was added superplasticizer in amount of 0.5 wt. % from cement weight. Reference specimen (RF) (mixture without fibre and superplasticizer) was also prepared.

The soaking of recycled fibres and manual mixing in approximately 50 wt. % of water was the first step in the preparation of mixture. Next, remaining water, superplasticizer (only for the second set), the required amount of sand and the cement were mixed by mechanical stirring in a mixer. The fresh fibre cement mixture was cast into standard steel prism in the dimension of 40x40x160 mm. Consequently, consolidation was made for the mixture with paper fibres by a jolting apparatus and for the mixture with paper fibres and superplasticizer by a vibrating table, respectively. The samples were demoulded after 24 hours and cured for 3, 7 and 28 days in water bath (laboratory conditions + 20 °C). Each set of composite samples consisted of 3 prismatic bodies.

2.3. Methods of testing

Physical property, densities of fibre cement composites were calculated after 28 days of hardening (STN EN 1015-10/A1) [11].

The coefficients of thermal conductivity of hardened fibre cement composites were measured on surface specimens by using the commercial device ISOMET 2114 with surface probe.

The compressive strength of fibre cement composites was also tested according to the European standard STN EN 1015-11/A1 [12] by using the compression test machine (FORM+TEST Seidner & Co. GmbH, Riedlingen, Germany) after 1, 3, 7 and 28 days of hardening.

3. Results and discussion

3.1. Density and thermal conductivity of fibre cement composites

Table 2 reports the values of important parameters such as density and thermal conductivity of fibre cement composites as well as reference composite. While density of reference sample after 28 days of hardening reached 2244 kg/m^3 , specimens (RPC and RPCP) with the addition of recycled waste paper fibres in amount of 0.5 wt. % showed the decrease in density. The lowest value of density and its reduction around 6.8 % in comparison with reference sample had the RPC composite. Although the RPCP specimen containing superplasticizer and the same amount of cellulosic fibres than composite RPC, there was observed only slightly decrease (0.8 %) in comparison with the reference sample.

The lowest value of thermal conductivity (1.78 W/m.K) and its maximal reduction (34 %) of 28 days hardened fibre cement composites was found in the RPC specimen in comparison with reference sample (2.70 W/m.K). This trend was also observed in RPCP specimen with superplasticizer, however this reduction, compared with control specimen RF, was 11.4 %.

Generally, the fibre additions into matrix have positive impact on density and thermal conductivity of fibre cement composites, as well. Values of density and thermal conductivity decrease with increasing the fibre content in composites [13,14]. The incorporation of cellulosic fibres into matrix creates the voids and the heat-insulating properties are enhanced when density decreases [14].

Table 2. Density and thermal conductivity values of cement composites based on recycled waste paper fibre G-3/00T Greencel.

Sample	Density [kg/m^3]	Thermal conductivity [W/m.K]
RF	2244	2.70
RPCP	2227	2.39
RPC	2091	1.78

3.2. Compressive strength of fibre cement composites

The experimental results of compressive strength of cement composites based on recycled waste paper fibres after 1, 3, 7 and 28 days of hardening are shown in figure 1. From figure 1, it is obvious that there is observed increasing trend in the development of compressive strength values of cement composites containing recycled cellulosic fibres in the hardening time. The lower value of compressive strength after 28 days of hardening was recorded in the RPC fibre cement composite when compared with reference specimen RF. It was approximately decrease about 26 %. However, using superplasticizer into fibre cement matrix led to higher value of compressive strength of RPCP composite in comparison to reference sample. After 28 days of hardening, the composite with superplasticizer (RPCP) and reference sample reached slightly similar value of tested mechanical parameter.

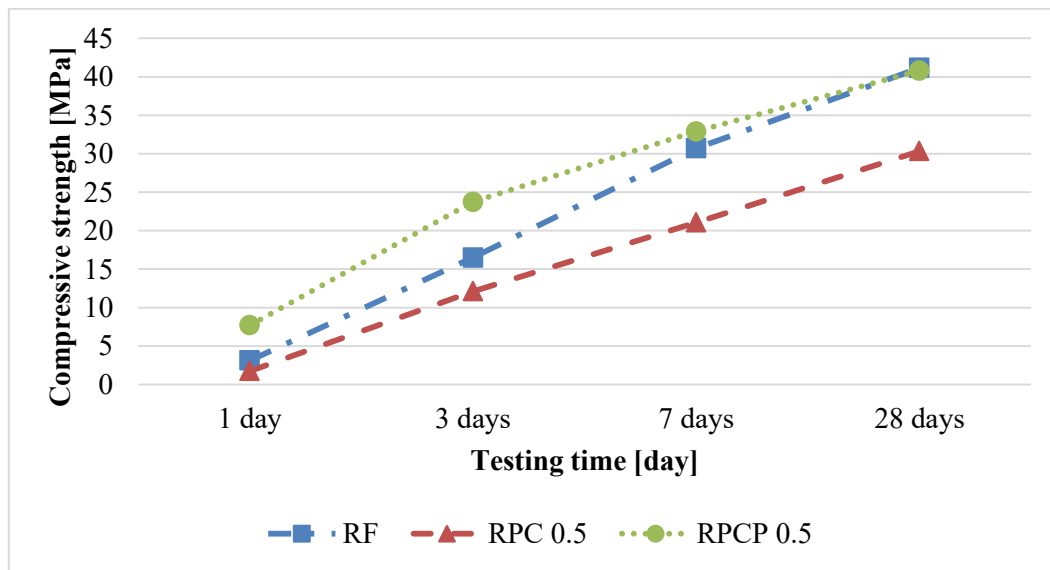


Figure 1. Compressive strength values of reference sample (RF) and cement composites based on recycled waste paper fibres tested after 1, 3, 7 and 28 days of hardening.

4. Conclusion

In this work, the influence of recycled waste paper fibres addition and superplasticizer on density, thermal conductivity and compressive strength of hardened cement composites based on recycled waste paper fibres was investigated. Two sets of fibre cement composites with the same amount of recycled waste paper fibres 0.5 % with and without superplasticizer were prepared.

Cellulosic fibres in the mixture have significant impact on resulting density and coefficient of thermal conductivity. In this case, incorporation of cellulosic fibres into the mixture shifts the results of tested parameters to better values of density (lighter in weight) as well as thermal conductivity of these composites. However, the composite with fibres and superplasticizer after 1,3 and 7 days of hardening showed higher compressive strength values than fibre composite without plasticizer, while the same strength parameter value of both of 28 days hardened composites was observed.

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