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Effects of cement on lignocellulosic fibres

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ABSTRACT

Lignocellulosic fibers are available throughout the world from different agro-forestry companies which could be utilized for the reinforcement in cement/fiber-based composites. The composites made from the lignocellulosic fibers compositing with the cement could be enhanced with numerous functionality and properties for using in construction and building sector. However, the proper selection of fibre is necessary to ensure better compatibility between the lignocellulosic fibres and cement. This research work investigates about the testing of sugar and tannin content and hydration of the cements with fibres. The Scanning electron microscope (SEM) images was investigated for the checking of fibre and cements existence in the matrix. The SEM analysis has further shown the regular distribution of fibers throughout the composite panels. This research would also help to identify the effects of different additives for improving the compatibility of cements and fibers on the cement bonded fibre boards.

INTRODUCTION

Recently, considerable efforts are seen with the researchers to develop cement bonded lignocellulosic fibre composites for affordable and fashionable infrastructures. But, the usage of natural fibre-based cementitious materials are still limited for durability issues along with the development of poor resistance against crack formations. So, different investigations are going on develop toughness and ductility of fibre reinforced cement-based composites (Yao et al. 2003, Savastano Jr et al. 2009). However, the incorporation of vegetable fibers (Hasan et al. 2020) could enhance the microstructure interactions between the cement and fibres in matrix. Nevertheless, cementitious composites exist outstanding potentiality for low-cost, superior compressive strength, low maintenance requirements, and attractive appearances (Wei et al. 2016). Furthermore, to fulfill the ever-increasing demands towards the sustainable structural composites, natural fibres (Hasan et al. 2020, Hasan et al. 2020, Hasan et al. 2020) are attracting the interests of the scientists continuously.

Compatibility is another critical problem for the production of fibre- based cementitious composites. The inorganic alkaline chemical component (cement) contains hydroxyl groups in the surface. On the other hand, fibres originated from the hardwood exhibits strong inhibition against the cement. Such problems are generated both in the cement setting and curation stages. However, inhibitory problems are quite less during the curation period of the hardwood (Pehanich et al. 2004). Exothermic hydration processes are strongly affected by the extractives of fibres with ordinary Portland cement which is the main reason for the incompatibility problems of wood fibres and cements (Castro et al. 2018). Although plant fibres are comprised of many chemical compounds but the sugar and tannin contents are mainly responsible for the inhibition of wood fibre and cement hydration and thus consequences on the strength. So, we have conducted sugar and tannin content tests of our lignocellulosic fibres extracted from different species of Hungarian plants and found our results were quiet satisfactory that no need any additional pretreatments to remove the impurities.

The effects on different ratios of cement/fibre mixing, storage environment for hydration temperature, time for hydration has significant influences for the reduction of hydration temperature and time. The usage of plant-based natural fibres has been enhanced for minimizing the costs of construction materials in terms of economic aspect to meet the consumer demands. However, the constituents of wood fibre and cement has made it challenging for the hydration problems and presence of impurities (sugar and tannin content). So, we have conducted this research to optimize these problems through analyzing the hydration of cements with different chemical ingredients. The SEM images were also analyzed to find out the fibre cement appearances in the matrix before and after the applying the loads.

MATERIALS AND METHODS

Materials

The lignocellulosic fibres used for this study was kindly supplied by a local Hungarian company (Kronospan-MOFA Hungary Ltd.). The fibers were used without any further pretreatment. The cement was kindly supplied by another local company of Sopron, Hungary (OPC CEM I 42.5). The chemical ingredients (water glass, montmorillonite, and $CaCl_2$) were purchased from Sigma Aldrich.

Methods

The sugar and tannin content of the fibres were investigated before starting the fibre board productions. The hydration rate of the chemical, fibre, and cement was also checked to ensure about the suitability of the fibre composites manufacturing. The cement bonded fibre boards were prepared by using compression moulding machine (G. Siempelkamp GmbH, Germany). Two fibre boards (WCF (water glass, cement, and fibre) 1 and WCF 2) were prepared from water glass (0.05 and 0.06), ordinary Portland cement, fibre (1), and water by varying the cements (2.5 and 3.5) in the matrix proportion. The dimensions of the composite boards were 400 mm X 400 mm X 12 mm. The applied pressure was 18.5 MPa for 24 h at normal temperature. The composited panels were then cured for another 28 days in room temperature. The SEM images were also taken by using Hitachi S-3400N instrument (Japan) at accelerating voltage of 20.0 kV for fibre boards and 20.0 kV for fractured composites.

RESULTS AND DISCUSSION

The sugar and tannin contents of the fibres were checked before starting the composites productions. The assessed tannin content of the fiber was around 0.25% which is within the standard range (upto 0.4% is considered as accurate). On the other hand, sugar content of the fibres were less than 0.5% according to our assessment which ensures that the fibres did not contain any unacceptable impurities that could appeal for further pretreatment (Sudin and Swamy 2006, Tibor L. Alpar- Éva Selmeczi 2012). It may be that the fibre supplying company has applied a boiling treatment before the production of fibers.

Table 2: Temperature versus time characteristics of different cementitious materials

Samples	$T_{(max)}$ (°C)	$T_{(min)}$ (°C)	$t_{(max)}$ (min)	$t_{(min)}$ (min)	$\frac{dT(T_{max-T_{min}})}{dt(t_{max}-t_{\min})}$
MPCF	26.1	20.3	9	1440	0.0041
WCF	23.6	20.2	5	1440	0.00237
CPCF	21.7	20.2	7	570	0.00266

When the water was added to the different samples (MPCF, WCF, and CPCF) the chemical reaction is started which brings a structural changes in the cementitious paste which turns to hard and rigid from the fluid mass with a generation of significant amount of heat (Wei et al. 2000). The temperature changing rate (dT/dt) and temperature versus time study were investigated for MPCF (montmorillonite + PDDA + cement + fibre), WCF, and CPCF ($CaCl_2$ + water glass + cement + fibre) as shown in Figure 6 and Figure 7. The Figure 6 shows the characteristics of temperature and corresponding time. The maximum temperature (26.1 °C) was found for MPCF and the time required to reach this temperature was 9 min. However, the highest temperature for WCF was 23.6 °C achieved at 5 min, and 21.7 °C for CPCF achieved at 7 min. It seems that, the hydration of cement requires the minimum time for WCF (WCF<CPCF<MPCF), whereas the highest time needed for MPCF. The addition of montmorillonite and $CaCl_2$ may increase the hydration time a little bit compared to the water glass. On the other hand, dT/dt value of WCF

(0.00237) is also comparatively lower than both CPCF (0.00266) and MPCF (0.0041). Some of the similar phenomenon was also reported by other researcher (Jo and Chakraborty 2015).

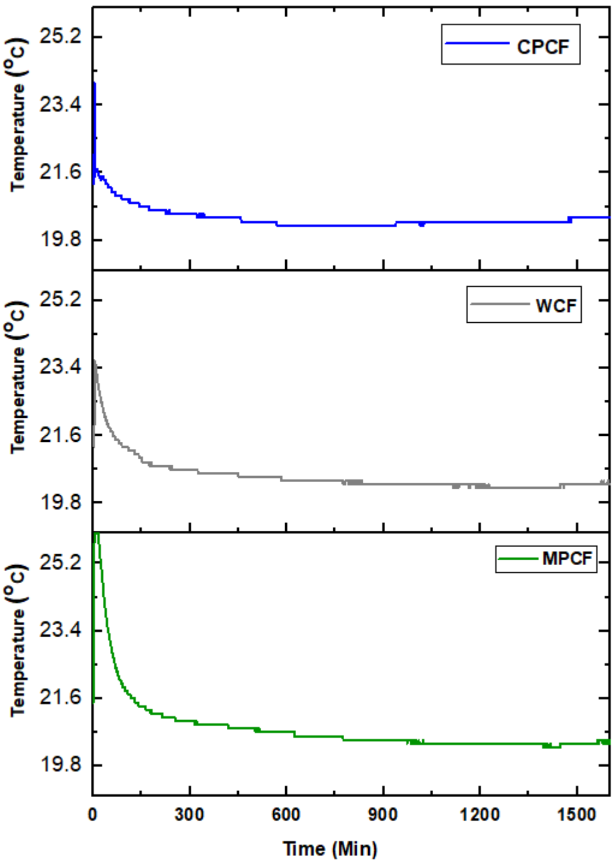

Figure 6: Time versus temperature curves for assessing the effects of different additives on cement hydrations

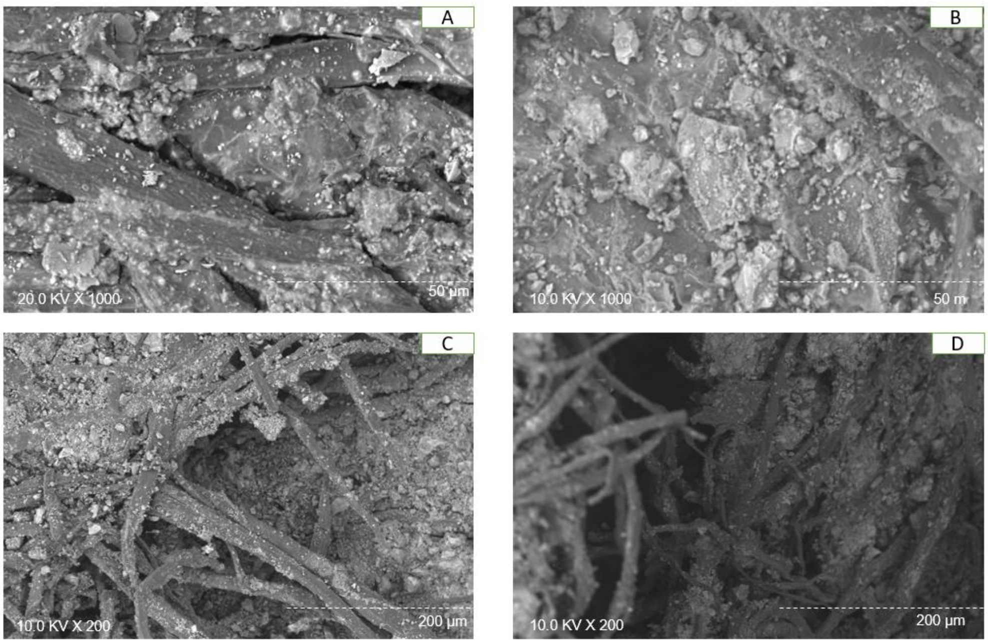

Figure 7: SEM images of (A) fibre board 1 (WCF), (B) fibre board 2 (WCF), (C) fracture of fibre board 1(WCF), (D) fracture of fibre cement board 2(WCF)

The SEM images (Figure 7) were used to visualize the samples for observing the structure and defects of the produced composite panels. The Figure 7 (A and B) exhibits the presence of uniformly distributed lignocellulosic fibres in the cementitious matrix. The Figure 7 (A) shows more presence of fibres in the composites maybe for the presence of less cement (2.3) than the Figure 7 (B) entailing 3.3 gm of cement. However, Figure 7 (C and D) shows the pull out and breakage of the matrix in composite system when the stress was applied. The similar phenomenon were also described by other researchers for wollastonite fibre-based cement composites (Tichi et al. 2019).

CONCLUSIONS

The sustainable green fibre cement composite has extremely high potentially to be applied for different structural applications. An investigation regarding the fibre cement composites compatibility is reported in this research. The sugar and tannin content of the fibre was investigated for finding out the pretreatment necessity. It is found that both the sugar and tannin contents were within satisfactory range that no need for fiber pretreatment. The optimum hydration rate was found through this study. It is seen that, WCF requires the minimum time to reach highest temperature compared to MPCF and CPCF. The SEM images has clearly shown the uniform distribution of fibres throughout the matrix. Afterall, this research would support for future works on developing more innovative, lighter weight, low-cost, and environment-friendly composite panels in building and construction sectors.

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