Microscopic and absorption properties of modified pulp fibre reinforced cementitious composites

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INTRODUCTION

The durability of cementitious composites has a very critical influence on service life. Most durability threats in structures made with cementitious composites are related to the ease of moisture penetration into the composite. Therefore, having a cementitious composite with lower permeability is an effective way of ensuring a more durable structure. On the other hand, fibres can be incorporated into cementitious composites to improve its ductility. Recently, more alternative eco-friendly fibres, such as vegetable fibres, are being developed to reinforce cementitious composites. The development of these eco-friendly fibres is anticipated to create a pathway to develop greener cementitious composites with higher performance. Therefore, it is paramount to observe how the incorporation of these eco-friendly fibres will affect not only the mechanical properties of cementitious composites but also its durability. In order to increase the application of greener materials in the construction industry, this study was carried out to observe the effect of two engineered Kraft pulp fibres on the major durability properties of cementitious composites.

EXPERIMENTAL PROGRAM

The binder used for all mixtures is general use limestone (GUL) cement conforming to CSA A3001 [1]. The fine aggregate employed has a maximum particle size of 5mm, fineness modulus of 2.63 and specific gravity of 2.51. The coarse aggregate used has a maximum nominal size of 19mm and specific gravity of 2.55. A poly-carboxylate high-range water reducing admixture (HRWRA), conforming to type A and F of ASTM C494 [2], was used to adjust the workability of the mixtures. Two types of modified pulp fibres similar to the one used by Booya et al. [3] alongside an unmodified fibre (UF) with 0.8 mm length were used for this study. The modified fibres are mechanically modified fibres (MF) and chemically modified fibres (CF) with fibre lengths of 1.8 mm and 2.1 mm, respectively.

Three concrete mixtures incorporating UF, MF and CF were made with a water-cement ratio of 0.35 and aggregate to cement ratio of 3.5. The fibre content in all mixtures was 2% as this amount has been found by other studies [4] to be optimum. However, an additional mixture with no fibre was made as control (C). To enhance effective dispersion of the pulp fibres, the fibres were first mixed with water (and HRWRA when needed) using a blender. Then, the cement and aggregates were dry mixed in a high-speed mixer before the premixed solution of water and fibre were slowly added, while the mixing continued. A FEI Quanta 200 FEGS scanning electron microscope (SEM) was used to study the fibre structure, fibre-matrix interface and microstructural properties of the mixtures using secondary electron images. The durability tests carried out are sorptivity in accordance with ASTM 1585 [5] and water absorption in accordance with ASTM 642 [6].

RESULT AND DISCUSSION

Water Absorption and Sorptivity

One of the ways to assess the durability of a composite is the water absorption and sorptivity test. The water absorption capacity of a composite shows the approximate number of pores that water can penetrate into, while the sorptivity test shows the rate in which a composite can absorb water in one direction. The higher the absorption and sorptivity, the lower the quality of the composite in terms of durability. Figure 1 and 2 present the water absorption and sorptivity results of the mixtures respectively. Sorptivity and absorption of mixtures incorporating the fibres are higher than that of the control at all ages. This observation is similar to the findings of Roque et al. [7]. It is interesting to note that at 90 days, there is an insignificant difference in the sorptivity of mixtures incorporating fibres and that of the control (Figure 2). The higher absorption and sorptivity of fibre mixtures incorporating these fibres might be caused by higher interconnected pores resulting from the incorporation of the fibres.

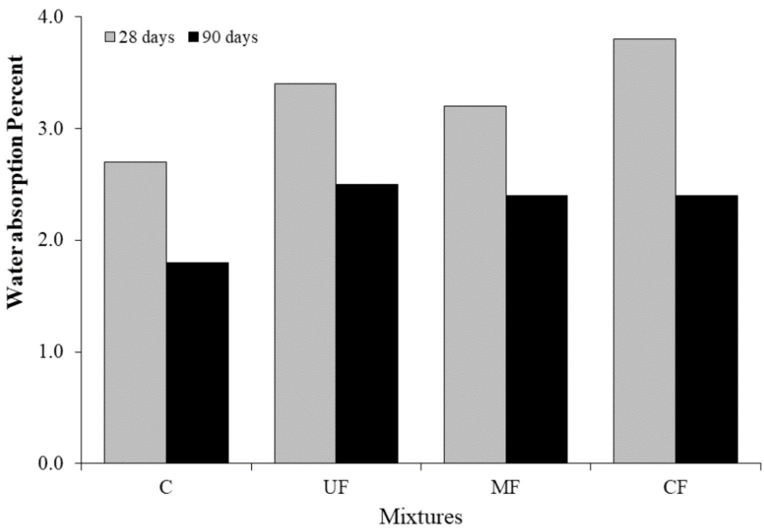


Figure 1: Water absorption at different ages

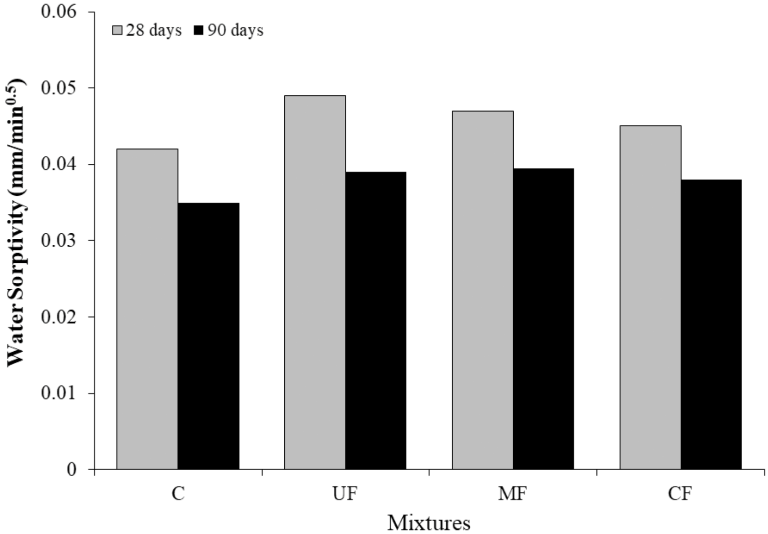
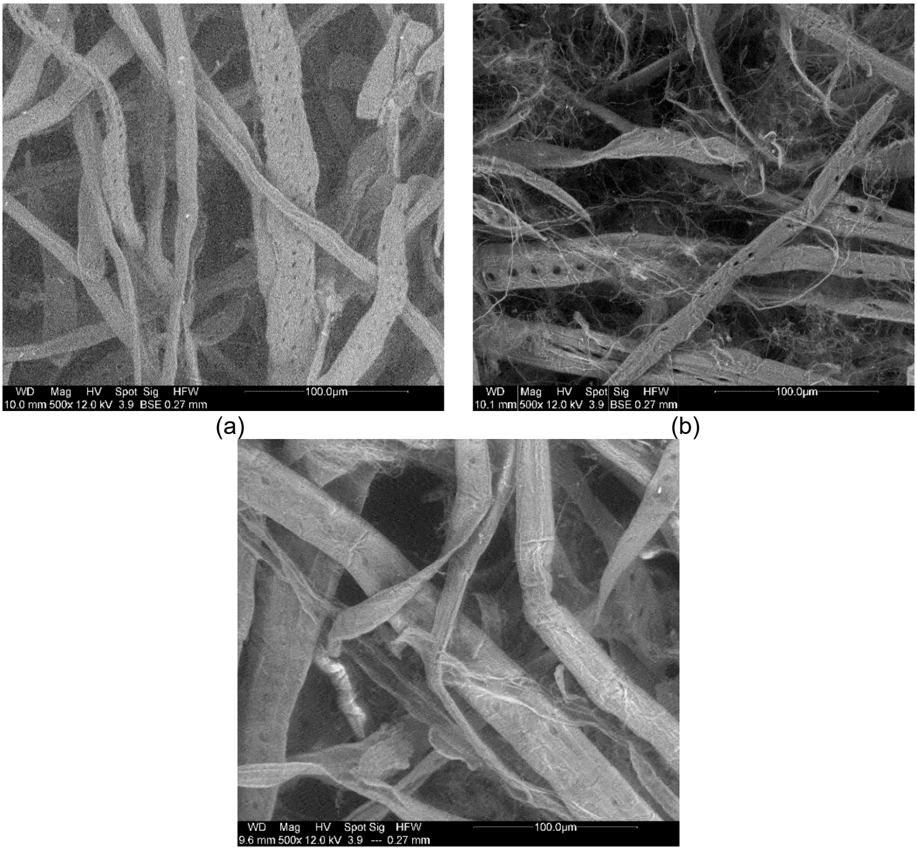


Figure 2: Water sorptivity at different ages

Scanning Electron Microscopy (SEM)

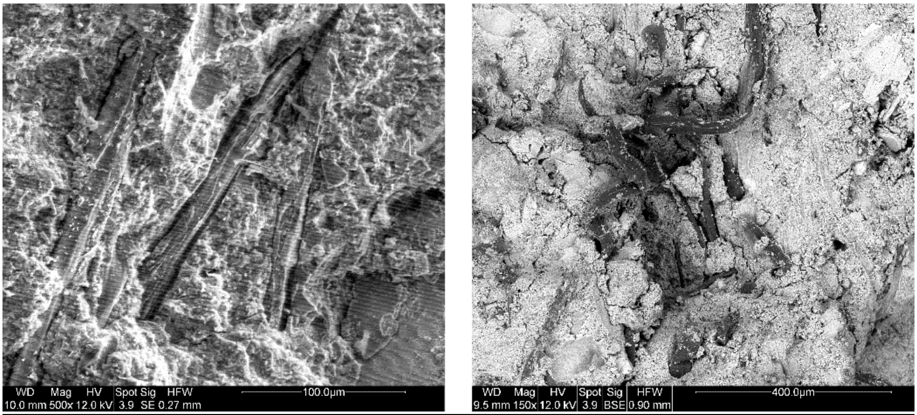
SEM investigations were carried out on all pulp fibres used. The observations are presented in Figure 3a-c which are similar to the pulp fibres used by Booya et al. [3]. It was observed from the figures that the modified pulp fibres (Figures 3b-c) have fibrils accumulated on its surface, whereas no fibrils were found on the surface of UF (Figure 3a).

SEM images of MF and CF embedded in the cementitious matrix are presented in Figure 4. From these images, it is evident that a good bond exists between the fibres and the cementitious matrix. Moreover, the figures show a densified interfacial transition zone (ITZ). These observations are further confirmed by the fact that fibre rupture occurred as opposed to debonding. Though microscopic investigation shows no ettringite formation around the fibre's ITZ, some ettringite was observed in the pores of the specimen made with MF, as shown in Figure 5. This might be a result of supplementary sulphate in the composite [8].



(c)

Figure 3: SEM images of fibers (a) UF, (b) MF, and (c) CF [3]



(a) (b)

Figure 4: SEM images of fiber reinforced mortars with Kraft pulp fibers, (a) MF, and (b) CF [3]

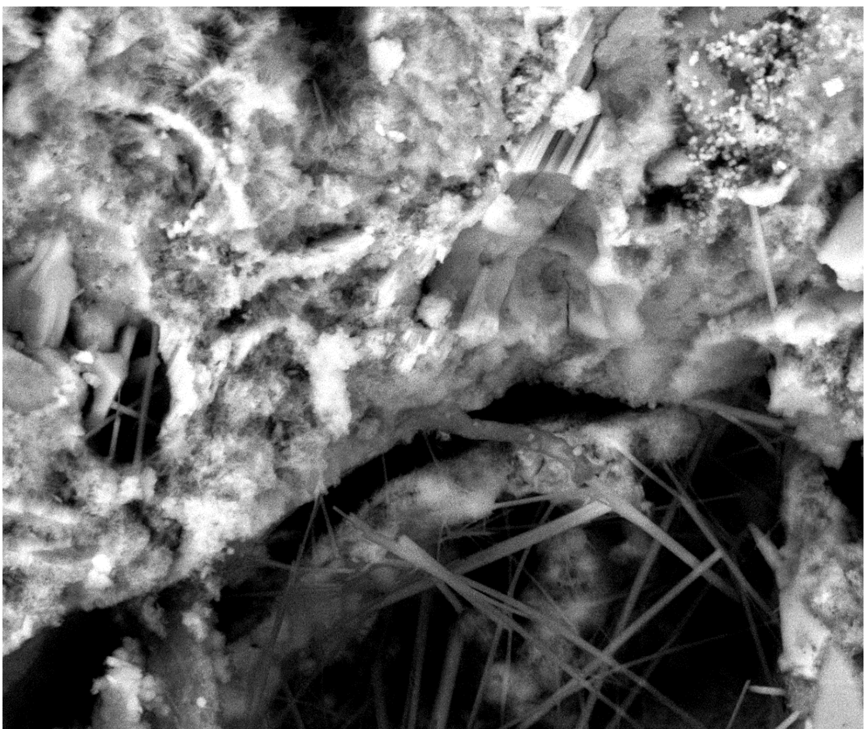


Figure 5: Needle shaped ettringite in composites containing MMF at x4000

CONCLUSIONS

The following conclusions can be made based on the experimental resulted presented herein. It should be noted that the conclusions may be limited to the scope of work.

Incorporation of modified pulp fibres increased the permeability properties in terms of water absorption, and water sorptivity of the cementitious composites when compared to that of the control. However, the observed values showed that the results are still within permissible limits and can be used for practical large-scale applications.

Fibrils on the surface of MF and CF improved the bonding and ITZ between the fibres and cementitious matrix.

An extended study is needed to improve the durability of composites incorporating these fibres by using supplementary cementitious materials as partial replacement of cement. Also, the effect of fibre content on the mechanical and durability of the composites needs a dedicated study.

REFERENCES

[1] CSA A3001, Cementitious materials used in concrete, Canadian Standards Association. Mississauga, Ontario. (2013) 1-292.
[2] ASTM C494, Standard specification for chemical admixtures for concrete, ASTM International. West Conshohocken, Pennsylvania. (2015) 1–9.
[3] E. Booya, H. Ghaednia, S. Das, H. Pande, Durability of cementitious materials reinforced with various Kraft pulp fibres, Construction and Building Materials, 191(2018). 1191-1200.
[4] M. Khorami, E. Ganjian, comparing flexural behaviour of fibre-cement composites reinforced bagasse: Wheat and eucalyptus, Construction and Building Materials. 25 (2011) 3661–3667.
[5] ASTM C1585, Standard test method for measurement of rate of absorption of water by hydraulic - cement concretes, ASTM International. West Conshohocken, Pennsylvania. (2013) 1–6.
[6] ASTM C642, Standard test method for density, absorption, and voids in hardened concrete, ASTM International. West Conshohocken, Pennsylvania. (2013) 1-3.
[7] L.G. Roque PE, Kim N, Kim B, Durability of fibre-reinforced concrete in Florida environments. Technical report submitted to Florida department of transportation. (2009)
[8] B.J. Mohr, J.J. Biernacki, K.E. Kurtis, Microstructural and chemical effects of wet/dry cycling on pulp fibre-cement composites, Cement and Concrete Research. 36 (2006) 1240–1251.