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Tensile Performance of Fiber-Reinforced Cement Composites with Hybrid Fibers

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Abstract

Fiber-reinforced cement composites (FRCCs) can exhibit better tensile behavior such as strength, ductility and energy absorption capacity compared to plain cementitious composite. This paper describes the tensile performance of FRCC with hybrid fiber. For the hybrid fibers, polyvinyl alcohol (PVA) fiber and micro steel fiber (SF) were prepared. Direct tensile tests were conducted on the dumbbell-shaped specimens to examine the effect of hybrid fiber on the tensile strain capacity of FRCC. FRCCs showed gradually decreasing descending curve after peak stress due to fiber bridging action between cement matrices. Depending upon tensile strength of fiber and fiber volume fraction, FRCCs tended to exhibit better energy absorption capacities.

Keywords: FRCCs, Tensile performance, Energy absorption capacity

1 Introduction

Crack are developed in cement composite such as mortar and concrete because of weak tensile strength. To make up for this shortage of cement composite, steel reinforcement is used and it is called reinforced concrete (RC).

In recent, to simplify the complex reinforcement detail of RC member, reinforcing fiber is recognized as an alternative. Inclusion of fiber can improve tensile strength and strain capacities of cement composites that shows brittle failure under tension. It is well-known that fiber-reinforced cement composites (FRCCs) have good ductility and high energy absorption capacity in comparison to plain cementitious composite. There are so many research about effects of fiber and sand addition [1-2], shrinkage crack characteristics [3-4], fiber's pull-out behaviors [5]. Also, a research on analytical models to evaluate the effects of fiber [6] was performed.

This study aims to investigate the application of FRCC for grouting materials, and to evaluate the relationships between behavior characteristics and the mechanical properties of FRCC. For variable, PVA0.25%+SF0.25%, PVA0.50%+SF0.50%, PVA0.75%+SF0.75% of hybrid fiber volume fraction are considered. Based on the test results, this study aims to generate the basic source data which is needed to develop material constitutive models to predict the tensile cracking behavior characteristics of mass concrete under hydration heat stress.

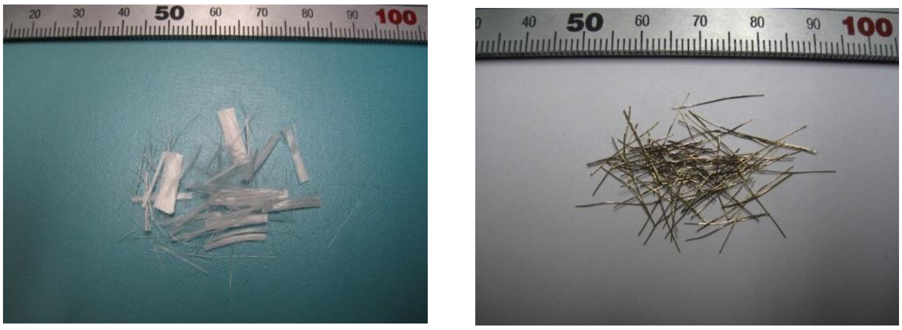
2 Test Program

Mix proportions of cement composites are shown in Table 1. In this study, water-cement ratio was set to 0.45 for the target compressive strength of 40 MPa at 28 days.

Table 1. Mix proportions of cement composites

Type	W/C	Unit weight (kg/m^3)					SP (kg)
		W	C	S	PVA	SF	
Mortar	0.45	334	743	1,114	-	-	-
PVA0.25+SF0.25					0.77	4.63	0.43
PVA0.50+SF0.50					1.53	9.25	0.85
PVA0.75+SF0.75					2.30	13.88	1.28

For reinforcing fibers, polyvinyl alcohol (PVA) fiber and micro steel fiber (SF) shown in Figure 1 were prepared. As listed in Table 2, the tensile strength and elastic modulus of SF are 61% and 415% higher than those of PVA, respectively.



(a) PVA (b) Steel fiber

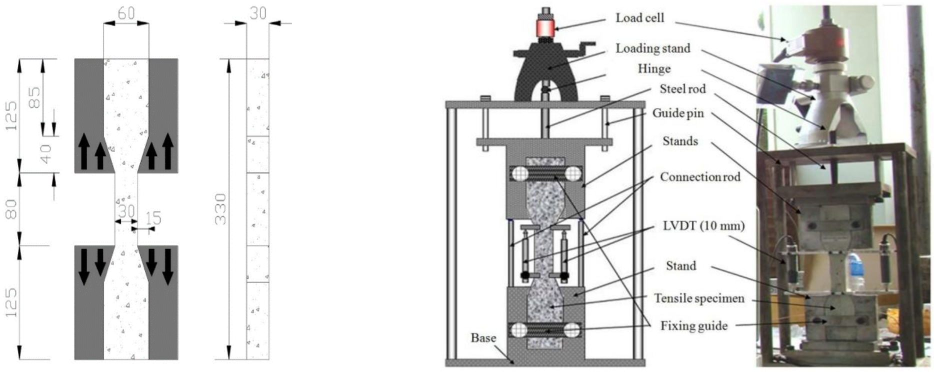
Figure 1. Fibers used in this study

Table 2 Mechanical properties of fibers

Fiber	Specific Gravity (g/cm^3)	Length (mm)	Diameter (mm)	Aspect ratio	Tensile strength (MPa)	Modulus of elasticity (GPa)
PVA	1.30	12	39	307	1600	40
SF	7.85	12-14	180-230	52-77	2580	206

For each mixture, prismatic (40 mm × 40 mm × 160 mm) specimens were cast for compressive strength test in accordance with KS L ISO 679 [7]. For tensile strength test, dumbbell shaped specimens were cast as shown in Figure 2(a).

Direct tensile load was monotonically applied on the dumbbell-shaped specimens to examine the effect of hybrid fiber on the tensile strain capacity of FRCC.



(a) details (unit: mm) (b) Test set-up

Figure 2. Direct tensile strength test

The tensile tests were performed by a displacement-control, as shown in Figure 2(b). The displacement of the central region was measured by average value of two linear variable differential transducers (LVDTs), and the tensile strain was calculated by dividing this measured displacement by the reference length of 100 mm.

3 Test Results and Discussions

Figure 3 shows comparison of compressive strengths of FRCCs. As shown in the figure, compressive strength of Mortar specimen was 43.53 MPa which is higher than specified compressive strength 40 MPa. FRCCs exhibited 6-19% higher compressive strength than Mortar specimen.

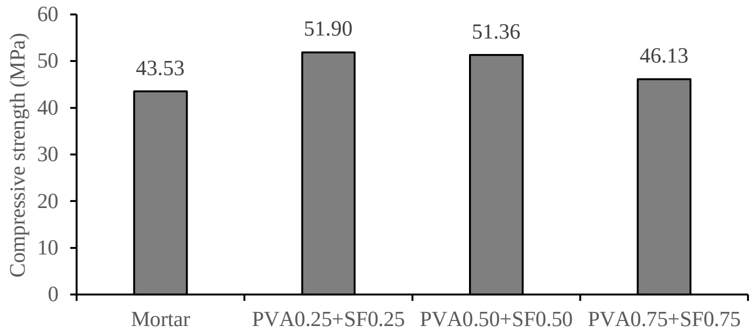
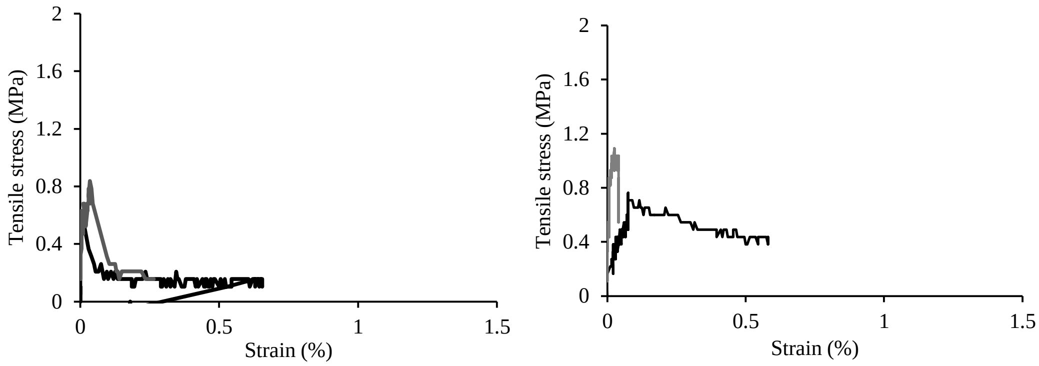
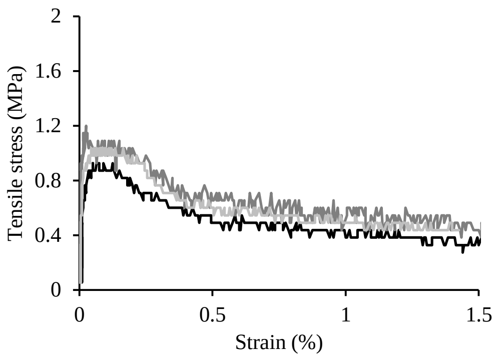


Figure 3. Compressive strengths of FRCCs

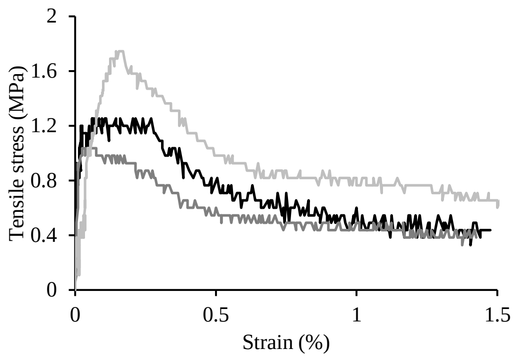
Figure 4 shows direct tensile stress-strain curves of FRCCs. Mortar specimens show brittle failure after initial cracking. PVA0.25+SF0.25 specimens exhibit similar tensile strength to Mortar specimen but show gradually decreasing descending curve. PVA0.50+SF0.50 specimens shows higher tensile strength and larger tensile strain capacity than PVA0.25+SF0.25 specimen. PVA0.75+SF0.75 specimens show partial strain-hardening characteristic after peak tensile stress due to fiber bridging action between cement matrices.



(a) Mortar (b) PVA0.25+SF0.25



(c) PVA0.50+SF0.50



(d) PVA0.75+SF0.75

Figure 4. Direct tensile stress-strain curves

Figure 5 shows dissipated energy of FRCC until final tensile failure. As stated above, due to fiber bridging action between cement matrices, PVA0.75+SF0.75 specimens shows the highest tensile deformation energy among all of the specimens. The tensile deformation energy tends to increase in proportion to fiber volume fraction in the cement composite.

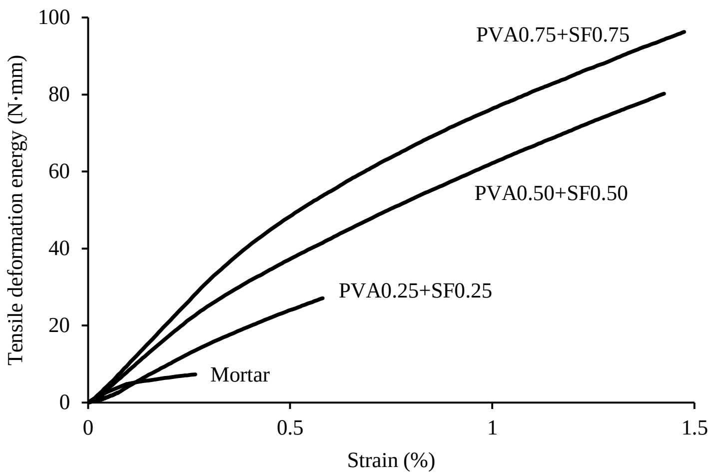


Figure 5. Comparison of tensile deformation energies

Figure 6 shows relationship between tensile strength and fiber-reinforcing (FR) index calculated as following equation.

FR index = Tensile strength of fiber (F_f) x Fiber volume fraction (V_f)

As shown in Figure 6, tensile strength of FRCC is influenced by both tensile strength of fiber and fiber volume fraction.

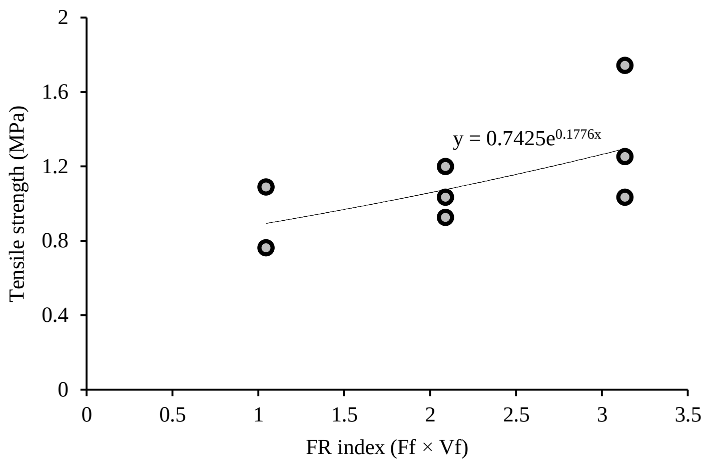


Figure 6. Relationship between tensile strength and FR index

4 Conclusion

In this study, direct tensile tests were conducted with variables of hybrid fiber volume fraction. Based on the test results, following conclusion are drawn.

1) As hybrid fiber volume fraction increases, FRCC exhibits higher tensile strength and larger tensile strain capacity due to fiber bridging action between cement matrices.
2) The tensile deformation energy tends to increase in proportion to fiber volume fraction in the cement composite.
3) Both tensile strength of fiber and fiber volume fraction affect to the tensile strength of FRCC.

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