IMPROVING FLEXURAL PERFORMANCE OF ULTRA-HIGH-PERFORMANCE CONCRETE BY RHEOLOGY CONTROL OF SUSPENDING MORTAR

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PRESENTATION ABSTRACT

The fiber orientation in ultra-high performance concrete (UHPC) matrix was associated with the casting scheme. Due to the high viscosity and fluidity of UHPC, during the casting, the velocity gradient of the flow (shear flow) of fresh UHPC mixture drives the fibers to be oriented along the flow direction. Thus, fresh UHPC that is placed at one end of a prismatic beam can flow to the other end along the longitudinal direction can develop more favorable fiber orientation. UHPC specimens cast in such a proper way can exhibit more than 60% higher flexural strength than other UHPC specimens cast from the middle of the specimen. However, the casting scheme seem to have limited influence on the dispersion of the fibers in UHPC. On the other hand, the rheological properties of concrete demonstrated significant effects on the fiber orientation and dispersion. The mini-slump flow and plastic viscosity of UHPC should be controlled at a proper level to ensure that the material can develop adequate flowability without fiber segregation. Increase the plastic viscosity by using a viscosity modified admixture (VMA) can have two opposite effects on mechanical properties of the composite material. On one hand, increasing the plastic viscosity was found to improve fiber dispersion and thus increase tensile strength properties. On the other hand, increasing the plastic viscosity resulted in reduced mechanical properties by introducing more air voids. The optimum plastic viscosity needs to be determined to ensure both fiber distribution and flaws are at adequate levels to enhance tensile/flexural strength performance. Governing the dispersion and orientation of fibers through a suitable balance of rheological properties is a promising approach to achieve superior tensile/flexural strength , which can also allow for a reduction in fiber content So far, there has been a lack of studies on improving fiber distribution and mechanical properties of UHPC by controlling the rheological properties of the material. The effect of VMA content on the hydration kinetics of UHPC and steel-matrix interfacial properties has not been fully investigated. The objective of this study is to develop a robust and easy-to-apply approach to improve fiber distribution to enhance flexural performance of UHPC by controlling the rheological properties of the suspending mortar before fiber addition. The study seeks to establish correlations among the rheological properties of the suspending mortar, the resulting fiber distribution in the UHPC, and flexural performance of the corresponding UHPC.

As the VMA dosage was increased from 0 to 2.0%, the yield stress, plastic viscosity, , and mini V-funnel flow time of the suspending mortar and the corresponding UHPC were monotonically increased. The mini V-funnel flow time of the suspending mortar before fiber addition and the UHPC increased linearly with the VMA dosage, as shown in Figure 1.

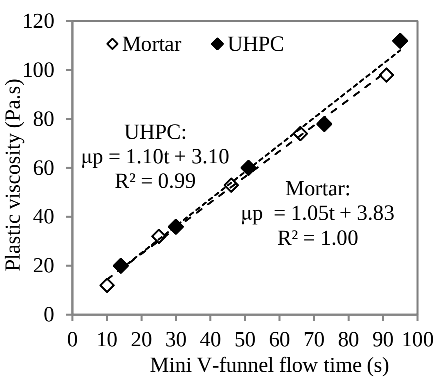

FIGURE 1 Correlation between mini V-funnel flow time (t) and plastic viscosity (μ_p) for suspending mortar (UHPC matrix) and UHPC.

The UHPC mixtures demonstrated higher plastic viscosity, yield stress, and flow time than the corresponding suspending mortar. During flow, friction and interlocking between the fiber and sand particles can increase the resistance to flow, thus increasing viscosity. Figure 1 also shows that the mini V-funnel flow time can be used as a simple and reliable indicator for the plastic viscosity of the suspending mortars and UHPC mixtures. The air content of the UHPC mixtures increased with the VMA dosage. This can be attributed to the increase in viscosity of the mortar that can lead to greater entrapment of air during mixing and placement.

The flexural strength and dissipated energy are plotted in relation to VMA dosage in Figure 2. The flexural strength was calculated in accordance with ASTM C1609. The area between the load-deflection curve and horizontal axis (from 0 to 3 mm of mid-span deflection) represents the dissipated energy. As the VMA dosage increased up to 1%, overall, the flexural strength and dissipated energy increased with the VMA dosage. As the VMA dosage increased from 1% to 2%, the flexural strength and dissipated energy decreased with the VMA dosage. Both

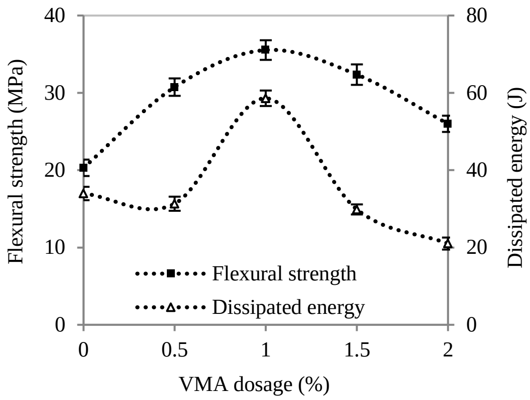

FIGURE 2 Flexural strength and dissipated energy of UHPC mixtures with different VMA dosages. The error bars represent the standard deviations of three specimens.

the flexural strength and the dissipated energy reached the highest values at the VMA dosage of 1%. This can be attributed to the optimum fiber distribution was guaranteed when 1% of VMA was used in the suspending mortar, which is explained in later section.

The uniformity of fiber distribution of the whole cross section was quantified using a fiber dispersion coefficient (α). Figure 3 plots the values of α (coefficient of fiber distribution) and η (coefficient of fiber orientation) determined by image analysis. The η approaches to 1 when all of the fibers are aligned perpendicular to the cross section, and η equals to 0 when all of the fibers are aligned parallel to the cross section. This coefficient expresses the deviation of the number of fibers in a unit area from the average number of fibersAs the VMA dosage increased from 0 to 1%, α increased from 0.45 to 0.86, thus improving the uniformity of fiber dispersion in the UHPC. However, when the VMA dosage increased from 1% to 2%, α decreased to 0.76, thus reducing the uniformity of fibers in UHPC. The incrase of VMA dosage from 0 to 2% increased η from 0.64 to 0.77. This indicates that increasing the viscosity of the suspneding mortar tended to make the steel fibers perpendicular to the cross section of the corresponding UHPC beam. However, the change in η is smaller than change in α.

The relationships among the mini V-funnel flow time of the suspending motar, fiber dispersion coefficient, and dissipated energy in flexure of UHPC mixtures are plotted in Figure 4. As the mini V-funnel flow time was increased from 10 to 46 s, both the fiber dispersion coefficient and dissipated energy increased. As the mini V-funnel flow time was increased from 46 to 91 s, both the dispersion coefficient and dissipated energy decreased. Both the highest fiber dispersion coefficient and dissipated energy were achieved at the mini V-funnel flow time of 46 s. Therefore, the highest fiber dispersion coefficient corresponded to the highest dissipated energy of the UHPC beam, which can be attributed to the improved bridge effect due to the improvement in the fiber distribution.

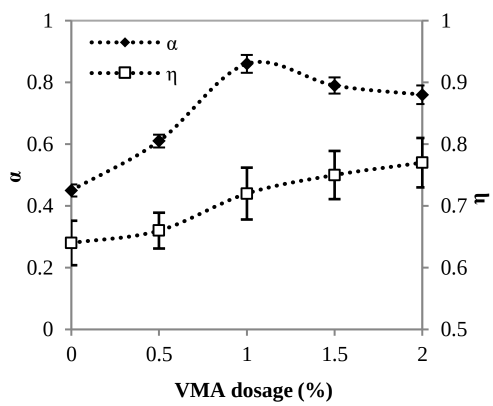

FIGURE 3 Relationships of fiber dispersion and orientation coefficients with the VMA dosage.

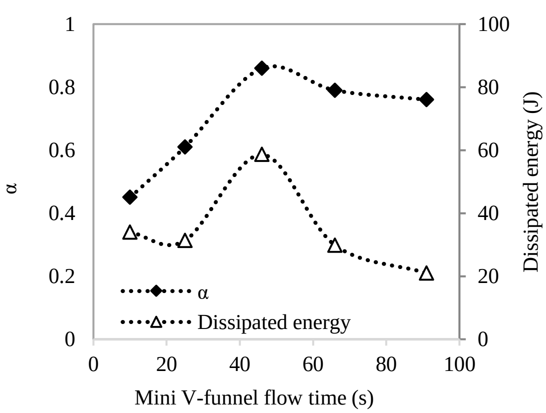

FIGURE 4 Correlation among flow time, fiber dispersion coefficient, and flexural toughness.