Second International Interactive Symposium on Ultra-High Performance Concrete
Extended Abstract (no paper submission)

Comparison of Shrinkage-Reducing Methodologies of Ultra-High Performance Concrete

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Material Characterization
Shrinkage Control of UHPC

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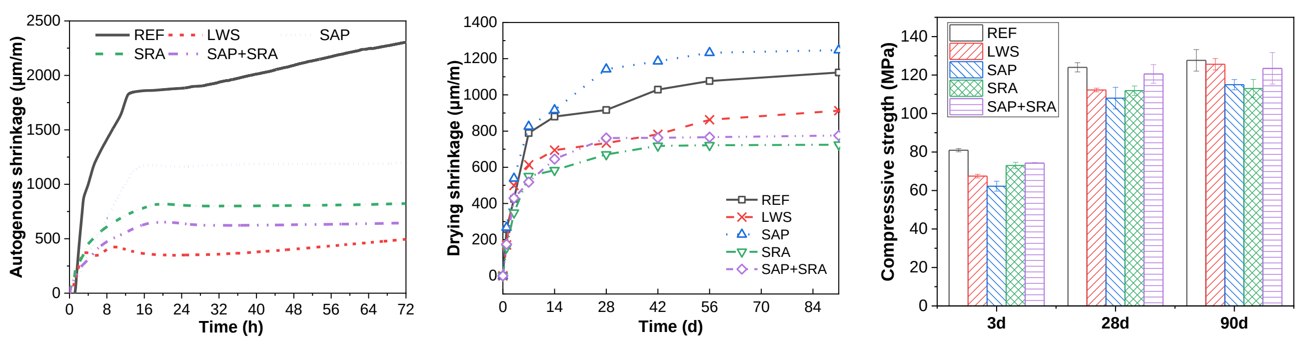
Extended Abstract

Despite its superior mechanical properties in the hardened state, ultra-high performance concrete (UHPC) is susceptible to high autogenous shrinkage compared to high performance concrete given the high binder content and low water-to-binder ratio (w/b). Such shrinkage can increase the risk of cracking at early age and cause impairment of durability, bond, and structural integrity.

Based on previous research carried out by the authors on UHPC, optimal types of pre-saturated lightweight sand (LWS) used at 15% sand replacement, by volume, 0.6% superabsorbent polymer (SAP), by mass of binder, and 2% shrinkage-reducing agent (SRA), by mass of binder, were used to investigate the individual and combined effects of these materials on UHPC performance. UHPC made with 0.18 w/b and 20% and 25% fly ash and silica fume replacements, respectively, were tested to compare the effect of different shrinkage-reducing methodologies on autogenous shrinkage (ASTM C1698), drying shrinkage (ASTM C596), and compressive strength (ASTM C109). In general, the incorporation of 15% LWS led to the best overall effect on autogenous shrinkage mitigating followed by UHPC made with SAP and SRA, as shown in Fig. 1. The incorporation of 15% LWS and 0.6% SAP was shown to reduce the loss of internal relative humidity (IRH). On the other hand, the addition of SAP increased the drying shrinkage compared with the reference UHPC made without any shrinkage mitigating materials. However, the UHPC incorporating with SRA had the lowest drying shrinkage.

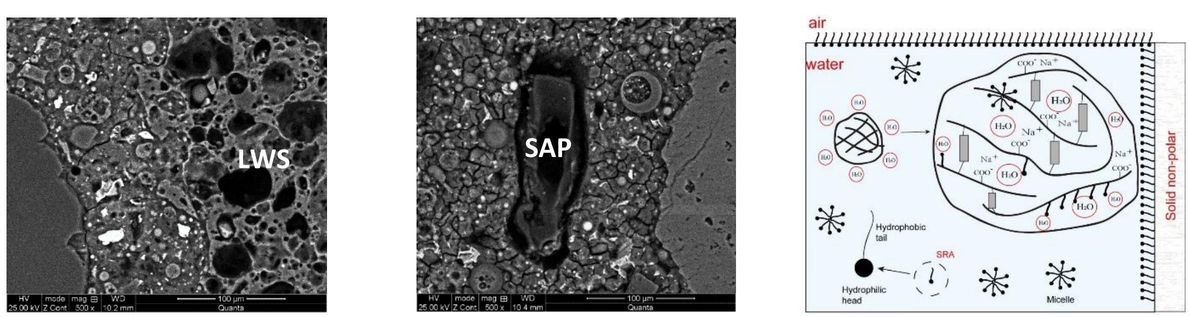
The three shrinkage mitigation methods had some adverse effect on compressive strength at 3d, which can attribute to residual pores left behind by the SAP and porous LWS, as shown in Fig. 2a and 2b. The use of SRA can hinder cement hydration, which had a reverse effect on the enhancement of mechanical properties due to internal curing. However, the use of LWS had a non-significant impact on compressive strength at later ages given the net effect of internal curing on reducing capillary porosity and densifying the transition zone at various interfaces.

In order to control the negative effect of SAP on drying shrinkage, the combination of SAP and SRA was used. The hybrid system with a low dosage (0.3%) of SAP and a high dosage (2%) of SRA, by mass of binder, exhibited the lowest autogenous shrinkage, as the coupled materials had roles in maintaining high IRH and reducing surface tension. The interaction of SAP and SRA can be explained by two mechanisms: the interaction between SRA molecules and the functional groups on the polymeric network of SAP hydrogels, as well as the reduced chemical potential of water, as shown in Fig. 2c. The addition of SRA and SAP, in a hybrid system, lowered the water absorption capacity of the SAP. In addition, an increase in SAP dosage was not beneficial in lowering the surface tension of pore solution since this led to increased demand for SRA in the pore solution to maintain the surface tension at a constant level.



(a) autogenous shrinkage (b) drying shrinkage (c) compressive strength

Fig. 1 Effect of various shrinkage-reducing methods on performance of UHPC



(a) LWS (b) SAP (c) SAP and SRA

Fig. 2 Microstructure of LWS and SAP in UHPC and mechanism of SAP and SRA