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Monitoring the Early-Age Shrinkage Cracking of Concrete with Superabsorbent Polymers by Means of Optical Fiber (SOFO) Sensors

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1 Introduction

Shrinkage in concrete structures has been the focus of many studies, and lately, a lot of attention has been given to autogenous shrinkage. The autogenous shrinkage occurs in all kinds of concrete structures in different levels. In ordinary concrete structures (with water-to-cement ratio above 0.42) it is not such a prominent phenomenon but it may increase the risk of cracking, especially when supplementary cementitious materials are used (Jian *et al*., 2014; Wu *et al*., 2017). Recently, a lot of research has been developed aiming to use superabsorbent polymers (SAPs) to reduce/mitigate shrinkage in cementitious materials, most of it at mortar or paste level (Jensen, 2008; Snoeck, 2015; Tenório Filho *et al*., 2018) all showing that a dosage of SAPs in the range of 0.2-0.6% with respect to the cement mass should be enough to considerably reduce or completely mitigate the deformation due to autogenous shrinkage.

SAPs are a natural or synthetic water-insoluble 3D network of polymeric chains cross-linked by chemical or physical bonding. They possess the ability to take up a significant amount of fluids from the environment (in amounts up to 500 times their own weight) (Mechtcherine and Reinhardt, 2012). Once in contact with the mixing water of the cementitious material, the SAPs absorb and retain a certain amount of the water (depending on their absorption capacity), later on acting as water reservoirs for the system, keeping its levels of internal relative humidity high for a considerable time frame.

Up to now, most of the studies investigating autogenous shrinkage of concrete have relied on test methods based on linear measurements performed with the use of length transducers placed on the top surface of prismatic specimens. For the case of concrete structures, the crack formation or presence of internal voids and discontinuities might lead to different responses in different locations. For that reason, the use of long-gauge deformation sensors allows a more global and precise understanding of the material/structure under investigation.

2 Experimental Program

In this paper, embedded long-gauge deformation sensors based on low-coherence interferometry in optical fiber (SOFO) sensors are used to investigate the influence of SAPs on the autogenous shrinkage of concrete. The material response due to shrinkage deformation is also evaluated using a demountable mechanical strain gauge (DEMEC). The experimental program consisted of the shrinkage measurement of concrete specimens with and without SAPs by means of manual DEMEC and automatic SOFO measurements. All tests were performed on concrete mixtures produced with cement type CEM III-B 42.5N – LH/SR (CBR, Belgium); a polycarboxylate superplasticizer (Tixo, 25% conc., BASF, Belgium, at a constant dosage of 1.8 % in relation to the cement mass); sea sand 0/4 (absorption of 0.4% in mass); sea sand 0/3 (absorption of 0.3% in mass); limestone 2/20 (absorption of 0.5% in mass) and a commercial superabsorbent polymer identified as SAP1 (cross-linked acrylate copolymer produced by bulk polymerization, mean particle size (d_{50}) of 360 μm and absorption capacity of 22 g/g in concrete). Shrinkage measurements were performed on prismatic specimens (100 mm x 100 mm x 400 mm) for 28 days with DEMEC and SOFO sensors.

3 Main Findings

The SAP-containing concrete (effective water-to-cement ratio of 0.46 and total water-to-cement ratio of 0.57) showed a complete mitigation of the shrinkage strain during the whole time of testing. In contrast to that, two reference concrete mixtures with effective water-to-cement ratio of 0.46 and 0.57 showed shrinkage during the whole test. Both the DEMEC and the SOFO sensor methods reflected the different behaviors of the reference mixture and the SAP-containing mixture with respect to the shrinkage strain. With the SOFO sensors, it was also possible to identify the moment of internal cracking, which was later on confirmed with microscopic analysis of the specimens.

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