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The origin of early age expansions induced in cementitious materials containing shrinkage reducing admixtures

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ABSTRACT

Studies on the early-age shrinkage behavior of cement pastes, mortars, and concretes containing shrinkage reducing admixtures (SRAs) have indicated these mixtures frequently exhibit an expansion shortly after setting. While the magnitude of the expansion has been noted to be a function of the chemistry of the cement and the admixture dosage; the cause of the expansion is not clearly understood. This investigation uses measurements of autogenous deformation, X-ray diffraction, pore solution analysis, thermogravimetry, and scanning electron microscopy to study the early-age properties and describe the mechanism of the expansion in OPC pastes made with and without SRA. The composition of the pore solution indicates that the presence of the SRA increases the portlandite oversaturation level in solution which can result in higher crystallization stresses which could lead to an expansion. This observation is supported by deformation calculations for the systems examined.

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1. Introduction and background

Since their introduction approximately three decades ago, shrinkage reducing admixtures (SRAs) have been extensively advocated as a methodology for reducing shrinkage and cracking in cement-based materials [1–8].

While the majority of studies performed have reported reductions in drying shrinkage [1–3,6], other studies have evaluated the influence of SRAs on evaporation, plastic shrinkage, autogenous deformation and self-desiccation at early-ages [9–15]. Under drying conditions, the SRA is observed to increase the volume of pores that empty at a given relative humidity thus altering the humidity range over which capillary stresses dictate the shrinkage response [10,15]. On the other hand, under autogenous conditions, the reduction in the surface tension of the pore solution by the SRA reduces the development of capillary stresses and maintains a higher internal relative humidity in sealed systems resulting in a reduction in shrinkage [10,11,13,16].

Studies of autogenous deformations on cementitious materials indicate that the addition of an SRA can result in a period of expansion which in turn induces a compressive stress in the system [10,17]. This period of expansion, which initiates shortly after set provides a considerable benefit in shrinkage mitigation even at longer time scales [10,18]. The impact of the expansion in mitigating autogenous shrinkage is considerable, as the expansion can amount to up to 60% of the reduction in unrestrained shrinkage under sealed conditions [10,11]. This indicates that a large part of the reduction in autogenous shrinkage by SRAs arises from the expansion.

This study takes a multidisciplinary approach to examine hypotheses associated with the nature of the expansion observed in mixtures containing SRAs. The results have important implications in understanding the reduction in shrinkage and stress development and the risk of cracking observed in concretes containing SRAs and developing material property inputs for simulation models which aim to predict the risk of cracking in restrained concrete elements.

2. Materials, mixture compositions and mixing procedures

A Type I, ASTM C150 compliant, portland cement with a Blaine fineness of 360 m^2/kg was used in this study. The composition of the cement as determined using quantitative X-ray diffraction indicated a phase composition (mass-basis) of 59.2% $3CaO{\cdot}SiO_2$, 15.5% $2CaO{\cdot}SiO_2$,

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