Investigation of Chloride Penetration in Shrinkage-Compensating Cement Concretes

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Shrinkage-compensating cement (a.k.a., Type K expansive agent) is a calcium sulfoaluminate cement with the ability of providing volume expansion during early age, primarily due to the formation of ettringite. In this way, Type K cement concrete can greatly enhance the volume stability of concrete, increase the serviceability of structures, and thus develop an optimized solution for issues regarding the highway and building infrastructure deterioration. Despite the past studies on the strength, shrinkage, and hydration of shrinkage-compensating cement concretes, there was no systematic investigation to understand the performance of this type of concrete under exposure to aggressive agents, particularly chloride ions. To address this gap, a comprehensive testing program was established in this study to evaluate the mechanical, transport, and dimensional stability properties of concretes made with various dosages of Type K expansive agent (i.e., from 0% to 22.5% by weight of total cementitious materials). This includes compressive strength, drying shrinkage, rapid chloride penetration, rapid chloride migration, surface electrical resistivity, and absorption tests. Both helium and mercury intrusion porosimetry analyses were also conducted to further support the experimental test results with the findings related to the distribution of pores. The results of this study confirmed the benefits of using Type K expansive agent (up to a certain dosage) in terms of increased compressive strength and reduced drying shrinkage. However, it was revealed that the permeability of concretes made with this type of cement is adversely affected. The pore volume of the concrete mixtures that contained 15% Type K expansive agent was more than 50% higher than that of the control mixture. Also, the resistance of concrete to the penetration of chloride ions was found to be reduced with increasing the dosage of replacement of portland cement with Type K expansive agent. Partial replacement of portland cement with Type K expansive agent was found to lead to the development of shrinkage free, low permeability concrete mixtures if supplementary cementitious materials are included. This was confirmed in the concrete mixture that contained 15% Type K expansive agent and 7.5% silica fume after a holistic investigation of compressive strength, drying shrinkage, chloride penetration, and absorption characteristics of a wide range of mixtures. Upon completing the necessary experiments on the improved mixtures, this study reported how low-shrinkage concretes with low susceptibility to chloride penetration can be developed with the promise of application in a wide variety of transportation infrastructures exposed to harsh environmental conditions.

Keywords: Shrinkage-Compensating Cement Concrete; Type K Expansive Agent; Chloride Penetration; Mechanical and Transport Properties; Supplementary Cementitious Materials