ABSTRACT

Jones, Wesley A. M.S.C.E., Purdue University, May 2014. Examining the Freezing and Thawing Behavior of Concretes with Improved Performance through Internal Curing and Other Methods. Major Professor: W. Jason Weiss.

Internally cured (IC) concrete has been emerging over the last decade as an effective way to improve the performance of concrete. IC holds promise for producing concretes with an increased resistance to early-age cracking and ultimately enhancing the durability of structures. It is a simple and effective way to ensure proper hydration of cementitious material in high performance concrete mixtures; mixtures in which traditional, external, curing can be ineffective. IC supplies water that is necessary to relieve stress buildup from chemical shrinkage and in turn helping to prevent early age shrinkage cracking.

The first part of this thesis presents and evaluates nine mixtures; two of which are standard mixtures that replicate Colorado DOT Class H and Class D (bridge deck and structural, respectively) mixtures and seven of which are altered standard mixtures to incorporate IC methods by use of pre-wetted lightweight aggregates (LWAs). Investigation into the fresh, mechanical, shrinkage, and transport properties of these mixtures is performed. This portion demonstrates the benefits of IC concrete mixtures through a variety of performance testing methodologies and provides insight to designing IC mixtures, such that these benefits can be fully utilized.

Values for slump, air content (by the pressure and volumetric methods), and unit weight are reported for the fresh properties of the mixtures. Compressive strength and elastic modulus at 28 and 56 days are reported for the mechanical properties. Autogenous, restrained, and drying shrinkage tests were performed. IC mixtures prevented autogenous shrinkage and caused expansion (or swelling) in the system. Restrained shrinkage showed that IC concrete reduced the residual stress buildup in the material. IC mixtures demonstrated improved drying shrinkage performance, as water is present to maintain a higher internal relative humidity. In addition, IC concrete was shown to reduce the chloride diffusion coefficient and tortuosity compared to standard mixtures, which is attributed to increased hydration. Overall, it is clear that IC is an effective and beneficial method for concrete mixtures.

While IC concrete has shown great promise for increased performance in concrete, some concerns have been raised regarding the potential for water to remain in the pores of the LWAs. This could create issues in freezing that otherwise may not be present, such as additional damage from the un-used water expanding during a freezing. Freezing of IC mixtures could have potential to shorten the service life of structures, opposing the benefits gained from using IC concrete.

The second portion of this thesis presents an experimental approach to evaluate the freezing and thawing behavior of IC concrete. An investigation into the use of LWA, as well as super absorbent polymers (SAPs), for IC concrete exposed to cyclic freezing and thawing environments has been performed by quantitatively showing the freeze-thaw durability for these mixtures. The results suggest that properly air entrained IC concrete with a reasonable w/c (approximately 0.48 or less) have no issues in resisting cyclic freeze-thaw action. However, "excessively" IC mixtures may perform poorly in freeze-thaw environments. SAP IC mixtures that *include* an air entraining admixture demonstrate no issues in freezing and thawing tests. SAP mixtures that *do not include* an air entraining admixture have demonstrated poor performance in freezing and thawing.

Other issues related to the freeze-thaw performance of concrete are caused by exposure to deicing salts. These are used to lower the freezing temperature of water on concrete surfaces, in turn preventing ice formation and increasing transportation safety. However, salts are partially responsible for issues that develop in pavement. One way to prevent damage is to seal the faces of the concrete surface to help repel the fluid. However, a proper testing method for quantifying chloride rejection of sealers during thermal cycling does not exist.

The final portion of this thesis examines the penetration of chlorides in hardened concrete due to interaction with salts that have potential for deterioration. The objective of this portion is to develop a testing procedure to assess the impact of sealers, pore blockers, and water repelling materials to delay or prevent chloride solution ingress. Presented is a testing methodology, which closely replicates concretes field exposure to fluids containing salts. Furthermore, a phenomenon coined as chloride pumping is presented. This is presumed to expedite the absorption of chlorides in concrete that are exposed to freezing conditions.