ABSTRACT

Castro, Javier. Ph.D., Purdue University, March 2011. Moisture Transport in Cement Based Materials: Application to Transport Tests and Internal Curing. Major Professor: Jason Weiss.

The durability of concrete subjected to aggressive environments depends largely on the transport properties of the concrete. These transport properties are influenced by the volume of pores as well as the connectivity of the pore network. Three main mechanisms can be used to describe transport in cementitious systems: permeability, diffusion and absorption. Permeability is the measure of the flow of water under a pressure gradient. Diffusion is the movement of ions due to a concentration gradient. Absorption can be described as the ability to take in water by means of capillary suction. It is important to note that absorption occurs on a much faster time scale than diffusion.

A large fraction of concrete in service is only partly saturated and the initial ingress of fluid is influenced, at least in part, by capillary absorption. As such, fluid (water) absorption has been used as an important factor for quantifying the durability of cementitious systems and it is being increasingly used by specifiers and in forensic studies to provide a parameter that can describe an aspect of concrete durability. For this reason the water absorption test is the focus of the first part of this thesis. The influence of preconditioning and initial moisture content was assessed as it relates to the water absorption test measurements. The results confirm that the test is considerably affected by the relative humidity of the samples before starting the test, which if not properly accounted for can lead to a misunderstanding of the actual absorption behavior. It was also observed that the conditioning procedure described in ASTM C1585 is not able to eliminate the "moisture history" of the samples. As such modifications to the standard test procedure are suggested. Further, the absorption behavior was investigated when salts were present in the samples or as a part of the absorbing fluid. Tests were performed on concrete using different aqueous solutions containing deicing salts. The rate of fluid absorption was generally lower for aqueous solutions containing deicing salts than it was for water (with the exception of low concentrations of NaCl). The change in the rate of aqueous fluid absorption was proportional to the square root of the ratio of surface tension and viscosity of the absorbed fluid. Experimental data indicates that concretes that had previously been exposed to deicing solutions can also exhibit reduced rate of absorption, even if water is the fluid being absorbed.

The second part of this thesis is focused on the internal curing for concrete and its effect on the transport properties. The increased propensity for shrinkage cracking in low water-to-cement ratio (w/c) concrete has inspired the development of new technologies that can reduce the risk of early-age cracking. One of these is internal curing. Internal curing uses pre-wetted lightweight aggregate (LWA) to supply "curing water" to low w/c paste as it hydrates. Significant research has been performed to determine the effects of internal curing on shrinkage and stress development; however, relatively little detailed

information exists about the effects of internal curing on fluid transport properties such as water absorption. In order to determine the mixture proportions for internally cured concretes information about the water absorption and water desorption properties of the lightweight aggregate is needed. Unfortunately, these properties are not easy to obtain accurately. This work studies the absorption and desorption properties of commercially available expanded shale, clay and slate lightweight aggregates. This research determines these properties so that they can be efficiently used in proportioning concrete for internal curing. Further, it was shown that by normalizing the results general trends on material behavior can be obtained that are quite useful in proportioning the mixtures. After characterizing the properties of the aggregates to be used for internal curing, this research examines the absorption of water into low w/c mortar specimens made with pre-wetted lightweight aggregates. These results indicate that the inclusion of LWA can reduce the water absorption of mortar specimens. This observation was reinforced with electrical conductivity measurements that exhibited similar reductions. In addition, this work analyzes the potential use of internal curing in concrete systems with *w/c* higher than normally used (*w/c* of 0.30, 0.36, 0.42 and 0.45) to increase the durability of the concrete. Test results show that internal curing can be useful to improve the durability of concretes prepared with this wider range of *w/c*. The benefits of using internal curing on the transport properties can be explained by an increase in the hydration of the cement. This was assessed using isothermal calorimeter, internal relative humidity, scanning electron microscopy and an atomic force microscopy. Further, in addition to reducing the porosity, the increased hydration appears to reduce the tortuosity by preferentially hydrating the interfacial regions around the lightweight aggregate.