ABSTRACT

Lucero, Catherine L. M.S.C.E., Purdue University, May 2015. Quantifying Fluid Transport in Cementitious Materials Using Neutron Radiography. Major Professor: W. Jason Weiss.

A portion of the concrete pavements in the US have recently been observed to have premature joint deterioration. This damage is caused in part by the ingress of fluids, like water, salt water, or deicing salts. The ingress of these fluids can damage concrete when they freeze and expand or can react with the cementitious matrix causing damage. To determine the quality of concrete for assessing potential service life it is often necessary to measure the rate of fluid ingress, or sorptivity. Neutron imaging is a powerful method for quantifying fluid penetration since it can describe where water has penetrated, how quickly it has penetrated and the volume of water in the concrete or mortar. Neutrons are sensitive to light atoms such as hydrogen and thus clearly detect water at high spatial and temporal resolution. It can be used to detect small changes in moisture content and is ideal for monitoring wetting and drying in mortar exposed to various fluids.

This study aimed at developing a method to accurately estimate moisture content in mortar. The common practice is to image the material dry as a reference before exposing to fluid and normalizing subsequent images to the reference. The volume of water can then be computed using the Beer-Lambert law. This method can be limiting because it requires exact image alignment between the reference image and all subsequent images. A model of neutron attenuation in a multi-phase cementitious composite was developed to eliminate the need to have a reference image. The attenuation coefficients for water, un-hydrated cement, and sand were directly calculated from the neutron images. The attenuation coefficient for the hydration

products was then back-calculated. The model can estimate the degree of saturation in a mortar with known mixture proportions without using a reference image for calculation.

Absorption in mortars exposed to various fluids (i.e., deionized water and calcium chloride solutions) were investigated. It has been found through this study that small pores, namely voids created by chemical shrinkage, gel pores, and capillary pores, ranging from 0.5 nm to 50 μm, fill quickly through capillary action. However, large entrapped and entrained air voids ranging from 0.05 to 1.25 mm remain empty during the initial filling process. In mortar exposed to calcium chloride solution, a decrease in sorptivity was observed due to an increase in viscosity and surface tension of the solution as proposed by Spragg et al 2011. This work however also noted a decrease in the rate of absorption due to a reaction between the salt and matrix which results in the filling of the pores in the concrete.

The results from neutron imaging can help in the interpretation of standard absorption tests. ASTM C1585 test results can be further analyzed in several ways that could give an accurate indication of the durability of the concrete. Results can be reported in depth of penetration versus the square root of time rather than mm^3 of fluid per mm^2 of exposed surface area. Since a known fraction of pores are initially filling before reaching the edge of the sample, the actual depth of penetration can be calculated. This work is compared with an 'intrinsic sorptivity' that can be used to interpret mass measurements.

Furthermore, the influence of shrinkage reducing admixtures (SRAs) on drying was studied. Neutron radiographs showed that systems saturated in water remain "wetter" than systems saturated in 5% SRA solution. The SRA in the system reduces the moisture diffusion coefficient due an increase in viscosity and decrease in surface tension. Neutron radiography provided spatial information of the drying front that cannot be achieved using other methods.