ABSTRACT

Rajabipour, Farshad, Ph.D., Purdue University, December 2006. Insitu Electrical Sensing and Material Health Monitoring in Concrete Structures. Major Professor: Jason Weiss.

Currently, several techniques are available to civil engineers for condition assessment and health monitoring of concrete structures. For example, different types of accelerometers, load cells, transducers, and strain gages are used to monitor the applied loads, displacements, stresses, strains, and vibrations of a structure. On the other hand, very few methods are available that enable health monitoring from a material durability viewpoint. Material health monitoring provides a valuable tool in assessing the current durability conditions of a concrete structure (i.e., diagnosis), determining if and what preventative measures need to be taken to reduce future maintenance (i.e., prescription), and evaluating the remaining life and the future performance of the material (i.e., prognosis).

In order to evaluate the durability performance, insitu measurements of concrete must provide insight into the microstructure and internal chemistry (e.g., ion concentrations) of the material. The objective of this research is development of a new material sensing and health monitoring system that is designed to measure several material properties and state parameters of concrete necessary for evaluation and prediction of the material's performance.

This sensing system is composed of three electrical conductivity-based sensors and a temperature sensor. The electrical sensors include a concrete conductivity (σ_t) sensor (that monitors setting and hardening of concrete and measures microstructural and

transport properties of the material), a pore solution conductivity (σ_o) sensor (that monitors changes in the internal chemistry of the system due to, for example, ion penetration or carbonation), and a conductivity-based relative humidity (RH) sensor (to monitor moisture transport, shrinkage, and the potential of moisture sensitive reactions such as ASR and corrosion inside the material). The temperature (T) sensor enables determination of the rate of hydration and strength development of concrete while it provides information needed for temperature calibration of the electrical sensors. In addition, an acoustic/ultrasonic sensor can be coupled with this system to add the capacity of damage (i.e., crack) monitoring inside the material.

This document provides a comprehensive description of several phases of the process used for development of the three electrical conductivity-based sensors. To develop the prototype of these sensors, the mechanism of electrical conduction inside concrete and similar porous materials must be well understood. Several composite conductivity models are studied in this research to describe changes in the electrical conductivity of hydrating cement systems and specimens exposed to drying. It is concluded that the electrical conductivity of concrete is a function of the composition (i.e., ion concentrations), volume fraction, and connectivity of the material's liquid phase (i.e., liquid filled capillary and gel pores).

In addition to hydration and microstructural variations, changes in the pore solution composition, temperature variations, and especially moisture variations are found to appreciably affect the conductivity measurements of concrete and as such, must be taken into consideration. It is shown that the combined measurements of the three conductivity-based sensors and the temperature sensor provide sufficient calibration information that enables determination of the desired material properties and state parameters of concrete.