ABSTRACT

Mohammad Pour-Ghaz. Ph.D., Purdue University, August 2011. Detecting Damage in Concrete Using Electrical Methods and Assessing Moisture Movement in Cracked Concrete. Major Professor: Jason Weiss.

The service life of concrete structures is directly related to their ability to impede fluid ingress. The service life of concrete infrastructure is drastically affected by presence of cracks. Cracks provide preferential paths for fluid ingress, resulting in acceleration of degradation processes. Therefore, information about the location and the extent of damage is necessary for accurate service life prediction of infrastructure.

In this thesis electrically-based methods are developed and used to detect the time of cracking and location of cracks in concrete elements. These methods include the use of electrically conductive thin films at the surface of concrete elements and use of electrically conductive concrete materials. These methods are utilized to detect and quantify damage in both small-scale laboratory specimens and large-scale structures. In addition, acoustic emission is used to detect and quantify damage in concrete materials. Acoustic emission has been used in this work to quantify damage that occurs at material level and also detect and quantify damage in large structures.

In addition to detecting and quantifying damage in cement-based materials and elements, this thesis studies moisture transport in concrete materials. In this thesis, physical measurements and numerical simulations have been used to study unsaturated flow in saw-cut geometries and drying of concrete materials.

This study begins by developing an electrically-based method to detect the time of cracking and the location of the cracks. This method uses an electrically conductive thin film that is applied to the surface of the cementitious materials. The electrical resistance of this film is monitored as the substrate cracks. A sudden increase in the electrical resistance of the thin film corresponds with the time of cracking. To facilitate rapid and simultaneously interrogation of the response of multiple conductive thin film elements, a frequency selective circuit (FSC) has been developed. The accuracy of the thin film method is examined by using acoustic emission measurements, image analysis, and strain measurements using strain gages on restrained concrete elements.

In the second phase of this study, the developed electrical sensing methods are used to detect and quantify damage in buried pipelines. In addition to conductive thin films, electrically conductive concrete is developed and used. These electrically-based methods are used along with acoustic emission and magnetic sensors to obtain information about progression of damage in buried segmented concrete pipelines in the vicinity of permanent ground displacement. Using these methods it was observed that the majority of the damage to the pipe segments was localized at the joints, especially the bell sections while the damage to the spigots was minimal. The damage extended away from the joints in the pipe segments in the immediate vicinity of the fault line. Telescoping (i.e., crushing of the bell-and-spigot) was a primary mode of failure.

In the third phase of this work, acoustic emission is used to detect and quantify damage in cement-based composites due to volume change of aggregates and due to aggregate expansion caused by alkali silica reaction (ASR). Use of acoustic emission to detect and quantify damage due to ASR is especially attractive since the assessment of potential for alkali reactivity in concrete materials can be difficult and time consuming using traditional length change measurements. In this phase continuous and simultaneous length change measurements on potentially reactive aggregates were performed. Length change measurements were performed along with acoustic emission measurements to compare the results and provide insight to the mechanism of ASR. The results indicate that use of acoustic emission is a potential method for rapid assessment of damage due to ASR.

Finally, in the fourth phase of the present study, using numerical and experimental methods, moisture movement in cement-based materials in the form of unsaturated fluid transport and drying is studied. The effect of fluid properties on unsaturated fluid transport and drying of cement-based materials is investigated. In dealing with unsaturated flow, a great emphasis is placed on saw-cut geometries. The saw-cut geometry has well-defined boundary conditions, and can be used to provide insight to flow in crack-like geometries. In addition to unsaturated flow and drying of cement-based materials, in this section pressure plate apparatus is used to characterize porous light weight aggregates that are used for internal curing of concrete. The use of pressure plate enables characterizing light weight aggregates at very high relative humidities where application of gravimetric methods becomes very difficult.