Florida Department of Transportation Research

Impedance-Based Detection of Corrosion in Post-Tensioned Cables: Phase 2 Extension of Sensor Development

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In post-tensioning construction, steel cables running through PVC pipes buried in concrete construction components are subjected to a high level of tension and then secured. This gives the component significant strength, allowing bridge spans to be longer, reducing the number of vertical supports, and saving construction dollars. Post-tensioning has been used in many significant bridges in Florida, including the Sunshine Skyway Bridge. In several of these bridges, inspections have revealed corrosion of post-tensioning cables, which could compromise the structure, but because of the placement of the cables, corrosion can be difficult to detect. Studies of this problem concluded that a nondestructive technique to test for corrosion and corrosion risk in post-tensioned bridge components was needed.

The Ringling Causeway in Sarasota is one of many critical bridges in Florida that employ post-tensioned concrete components.

In this project, University of Florida researchers used electrochemical impedance spectroscopy (EIS) to detect corrosion in steel post-tensioning cables. In this method, a sinusoidal current is applied to the concrete surface in a range of frequencies. Researchers sought to design a sensor which uses EIS to monitor the integrity of the steel and grout in a post-tensioned system.

The researchers traveled to the Ringling Causeway Bridge and the Sunshine Skyway Bridge. At the Ringling Bridge, they observed shear cracks in the concrete girders and bulges in the tendons due to failed strands. They noted tendon placement and other issues relevant to sensor design.

Conventional impedance experiments were conducted with the steel used in post-tensioned cables, ASTM A416M, in simulated pore solutions. Experiments were conducted in aerated and de-aerated solutions that contained chlorides. Contactless impedance experiments were performed on fabricated tendons containing either a proprietary grout or hydrated Portland cement paste as the filler with one steel strand. These studies determined the appropriate perturbation mode and frequency range, as well as a useful electrode configuration and how frequency influenced which part of the steel was detected.

Mathematical models were developed to interpret both conventional and contactless impedance measurements. For conventional measurements, a model was developed to fit the impedance of the steel and simulated pore solution interface, which incorporated a porous film model and accounted for anodic and cathodic impedances. For contactless measurements, finite element simulation determined that the polarized area of steel changed with frequency and that the sensing location was directly beneath the working and counter electrodes.

In preliminary testing, the sensor was found to be sensitive to the condition of the steel under the current-injecting electrodes. Six inches between these electrodes worked well for a three-inch diameter, single strand tendon. Spacing between electrodes could be smaller for tendons encasing multiple strands. Initial silver/silver chloride electrodes were eventually replaced with iridium oxide-coated titanium.

Project results are promising for development of a nondestructive test for corrosion and corrosion risk in post-tensioned bridge components. This will allow more thorough testing and earlier detection of potential problems, thus protecting Florida's considerable investment in its bridges.

Project Manager: Ronald Simmons, FDOT Materials Office
Principal Investigator: Mark Orazem, University of Florida
For more information, visit http://www.dot.state.fl.us/research-center