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Feasibility Study for Detection and Quantification of Corrosion in Bridge Barrier Rails

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Abstract
Three non-destructive technologies were evaluated for their abilities to detect and quantify corrosion damage in reinforcing steel used in bridge barrier rails.

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Feasibility Study for Detection and Quantification of Corrosion in Bridge Barrier Rails

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tech transfer summary

Three non-destructive technologies were evaluated for their abilities to detect and quantify corrosion damage in reinforcing steel used in bridge barrier rails.

Background

The US transportation system is at the heart of our economic prosperity, providing the network for the movement of people and products. We rely on our roadways and bridges for safe passage in a time-efficient manner.

Problem Statement

Availability for traffic places strict demands on inspection methods in terms of speed and reliability in ensuring that the time to complete an inspection is minimized and that results provide sufficient, quantitative information to enable repair and replacement decisions.

Multiple technical challenges that are involved with the nation's aging infrastructure can be addressed by nondestructive evaluation methods. One such challenge involves detecting corrosion damage to the reinforcing steel and U-bolts that anchor concrete barrier rails to the bridge decks of structures.

Moisture and chloride ions reach the reinforcing steel or U-bolt anchors along the cold joint between the rails and the deck and cause general corrosion that can weaken the performance of the anchors and ultimately the barriers.

Research Description

This project evaluated the feasibility of three technologies—x-ray radiation, ground-penetrating radar (GPR), and a magnetic flux leakage (MFL) approach using a giant magnetoresistance (GMR) sensor—for detection and quantification of corrosion of embedded reinforcing steel.

A set of controlled samples containing pristine reinforcing steel with and without epoxy, and reinforcing steel with 25 percent and 50 percent section reduction, were embedded in concrete at 2.5 in. depths.

The controlled samples were used to develop each of the three methods. Two of the techniques, GPR and MFL, were also used in a limited field test on the Iowa Highway 210 Bridge over Interstate 35 (I-35) in Story County, Iowa.

Key Findings

Primary conclusions for each of the three methods are as follows.

- Radiographic inspection provides a visual image of the position and condition of the reinforcing steel. Proper selection of the source is needed to ensure penetration of the x-ray energy through typical thicknesses of concrete. Several detector options are available including film and digital detectors.

  Hesitancy has existed with use of radiography because of cost and health safety concerns (i.e., protection zones are needed to prevent inadvertent radiation exposure to humans). However, modern digital x-ray detectors reduce the exposure time and use less radiation, thereby increasing the cost-to-benefit ratio for this method.

- An MFL sensor was designed and fabricated using GMR sensors. Laboratory tests showed a monotonic decrease in signal response with material loss, which indicates the ability to quantify corrosion damage in standalone reinforcing steel.

  Interference can occur when other reinforcing bars are in close proximity, so application of this technique requires independent knowledge of the location of the bars. Future sensor designs could combine an eddy current sensor with the MFL measurement to address this issue.

  The sensor was also used to inspect 18 reinforcing bar locations on the Iowa 210 Bridge over I-35. Of the 18 locations, 13 showed a stronger off-deck response than measurements near the cold joint, indicating suspect conditions.

- GPR was also applied to quantitative detection of corrosion damage. Use of GPR for locating reinforcing steel in concrete is well-documented. With this project, techniques were developed to detect corrosion damage using laboratory samples and then applied to inspection of 88 reinforcing bars on the Highway 210 Bridge, moving beyond location of reinforcing bars to condition assessment.

  The method compares the response in a known undamaged region to the response near the cold joint. Of the 88 reinforcing bars, 11 were found to be anomalous. Agreement was found between the GPR and MFL results for those locations that were inspected using both methods.

Implementation Readiness and Benefits

Each of the methods considered in this research provide useful and complementary information. GPR methods provide a rapid approach to identify reinforcing steel that has anomalous responses. The MFL technique provides similar detection responses but could be optimized to provide more quantitative correlation to the actual reinforcing steel condition.

The GPR or MFL methods could be used to identify areas of concern. Radiography could then be used to give a visual image of the actual condition at those points, providing the final guidance needed to plan bridge maintenance actions.

Use of modern, digital x-ray detectors would further improve the speed and cost of x-ray inspection, making this a more attractive option than in prior film-based radiography studies. Further improvements could result from the use of backscatter x-ray methods, which is a topic recommended for future study.

The benefits of actual visual evidence of the reinforcing steel condition could lead to more-effective decisions regarding bridge maintenance actions and ensure that scarce infrastructure resources are used where they are needed most.

The final report for this research includes a more thorough discussion of conclusions, recommendations, and future research.