Iowa State University
Center for Nondestructive Evaluation

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

tech transfer summary

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RESEARCH PROJECT TITLE
Validation Study for Detection and Quantification of Corrosion in Bridge Barrier Rails

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This study showed that ground penetrating radar and magnetic flux leakage sensors can be used to detect and quantify corrosion of embedded reinforcing bars and other anchoring components.

Objective

The aim of this project was to validate the use of two nondestructive evaluation (NDE) methodologies—ground penetrating radar (GPR) and magnetic flux leakage (MFL)—to detect material loss in bridge barrier rail reinforcing steel to improve on current bridge barrier rail inspections.

Problem Statement

The ability to provide quantitative information about the condition of embedded reinforcing bars and other anchoring components is lacking, despite the availability of instrumentation and inspection service providers that aid in position verification. Without quantitative information regarding the extent of degradation, condition-based decisions regarding the repair or replacement of reinforced structures are not possible.

Project Description

This project evaluated the feasibility of two technologies, GPR and a MFL approach that used a giant magnetoresistive (GMR) sensor, to detect and quantify corrosion in embedded reinforcement bars.

Rail section of the Iowa Highway 210 bridge over I-35 during the 2017 inspection

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The researchers set aside a third method initially listed in the proposal, radiography, after discussion with the Iowa Department of Transportation (DOT) and Iowa State University's Center for Nondestructive Evaluation (CNDE). The expense and potential public relations issues were felt to outweigh the benefits of the method, given that the plan called for exposure of the reinforcing steel for measurement of material loss.

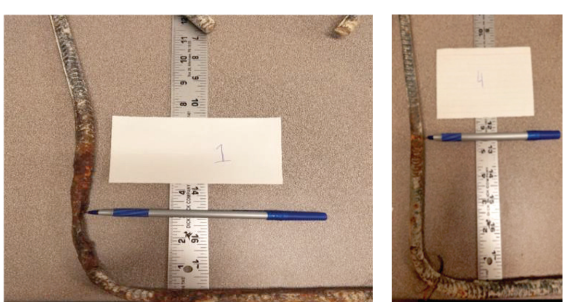
Researchers performed tests using the two methods on two sets of control samples: a set of bare reinforcing steel samples with 0%, 25%, and 50% material loss, and a set of control samples containing pristine reinforcing bar and bars with 25% and 50% section reductions that were embedded in concrete at a 2.5 in. depth. The team further tested the techniques used in the laboratory in a limited field trial on the IA 210 bridge that serves as an overpass of I-35 in Story County, Iowa.

An unfortunate lack of communication between the contractors working on the barrier rail replacement at the site and the research team resulted in the destruction of the initially inspected reinforcing steel, from both the 2012 phase of the program and the more recent data collection periods. However, the team acquired reinforcing steel bars from the north side of the same bridge, and assessed the amount of corrosion that unprotected reinforcing steel can experience.

Key Findings

- Each of the methods considered in this research project provided useful and complementary information. GPR offered a rapid approach to identifying reinforcing steel that had anomalous responses. The MFL technique supplied similar detection responses but can be better optimized to provide a more quantitative correlation to the actual reinforcing steel condition.

- The research team developed techniques to detect corrosion damage using laboratory samples, and then used them to inspect 88 reinforcing bars on the IA 210 bridge. Of the 88 reinforcing bars inspected, 11 were found to be anomalous. The team found agreement between the GPR and MFL results for the locations inspected using both methods.



Two of the reinforcing bars inspected with one near the end of the bridge and the drain (left) and one closer to the center of the bridge (right), where less water flows into the cold joint resulting in less corrosion

- Laboratory tests with the MFL sensor showed a monotonic decrease in signal response with material loss, indicating the ability to quantify corrosion damage in standalone reinforcing steel. Time constraints limited MFL tests on the bridge; however, the team used the sensor to inspect 18 reinforcing bar locations, and 13 showed a stronger off-deck response than the measurements near the cold joint, indicating suspect conditions.

Recommendations for Future Research

The ability to use GPR for quantifying corrosion could be improved with more study, particularly in the field. Researchers could perform a short-term project to test a barrier rail slated for repair by measuring corrosion at three points: prior to repair, the exposed reinforcing steel, and the repair made to the barrier rail.

Once a full validation of the potential for GPR testing in measuring material loss of reinforcing steel is available, a GPR unit could be modified to provide more instantaneous feedback on the condition of the steel's material loss to more quickly assess whether to repair or replace existing barrier rails.

No commercially available MFL system equipped to measure material loss currently exists. While the laboratory system like that used in this project demonstrated some success, it can be difficult to manage, and it is susceptible to fluctuations in the voltage and current that power the many components needed to create the system. There is a need for further research and development of a more environmentally sturdy model of equipment to make this method of inspection available for widespread use.

Future studies could build on advances in radiography. Past researchers have been hesitant to use radiography because of cost and health safety concerns, but modern digital x-ray detectors reduce the exposure time and use less radiation, thus increasing the benefit-to-cost ratio for this method.

Implementation Readiness and Benefits

The research demonstrated the use of GPR and MFL sensors can aid in the detection of material loss in reinforcing steel of a barrier rail. The technologies developed in this study will help move beyond the location and detection of reinforcing bars to the ability to assess their condition, but more equipment improvements are needed to further advance their use outside the laboratory.