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OFFICE OF TRANSPORTATION SYSTEM MANAGEMENT

TECHNICAL SUMMARY

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PROJECT COST:
$71,950

The Cedar Avenue Bridge is a steel tier-arched bridge over the Minnesota River, chosen because it is fracture-critical but has no history of cracking.

Continuous Monitoring of Fracture-Critical Steel Bridges

The bridge monitoring system developed in this project will help provide MnDOT with advance warning of structural distress in fracture-critical bridges, helping to prevent bridge collapse and keep the traveling public safe.

What Was the Need?

While not inherently unsafe, a fracture-critical bridge has a structural component whose failure could lead to bridge distress and possibly bridge collapse. Consequently, these bridges must be regularly inspected, with increasing frequency as they age. To help determine when inspections are needed, MnDOT is developing a bridge health monitoring system that uses electronic instrumentation to provide advance warning of potential failure by detecting early signs of structural distress.

In the first phase of this project, completed in 2010, researchers helped MnDOT design a bridge health monitoring system that detects acoustic emission—stress waves caused when cracks form and propagate in the steel components of a bridge. To deploy and test the system, researchers selected the Cedar Avenue Minnesota Highway 77 Bridge in Burnsville, Minnesota, a fracture-critical steel bridge that has no history of cracking since it was brought into service in 1979. The bridge is a major commuting thoroughfare in the Minneapolis-St. Paul area. Researchers then developed a computer model of the bridge to plan the optimal placement of sensors as well as an implementation plan and installation procedures.

A second phase of this project was needed to deploy and test this system on the Cedar Avenue Bridge.

What Was Our Goal?

The objective of this project was to test and optimize an acoustic emission monitoring system to detect cracking in fracture-critical steel bridges.

What Did We Do?

Researchers began by acquiring acoustic emission monitoring equipment and evaluating it in the laboratory to ensure its functionality and compliance with MnDOT specifications. The system, selected in Phase I of this project, is a Sensor Highway II Smart Remote Monitoring system manufactured and sold by MISTRAS Group, Inc. Researchers also acquired a number of acoustic emission sensors for deployment on the bridge and solar panels with battery backup to provide energy for the system. Then they installed this equipment on the Cedar Avenue Bridge and conducted field tests to calibrate it. They also developed procedures for using manufacturer hardware and software to collect and process the bridge monitoring data for a health assessment of the bridge.

Researchers further calibrated the system using laboratory tests to characterize the kinds of acoustic emission signals that would be produced by the fracturing of three 24-inch deep steel beams. The purpose of these tests, designed to be deployable to the field for in situ tests in steel bridges, was to define waveform signatures of crack formation and propagation that can be used to discriminate cracking from false signals in the data. False signals can come from various causes, including impact from traffic, rain and friction at bolted connections.

Finally, researchers collected and evaluated acoustic emission data from the Cedar Avenue Bridge for a 22-month period (January 14, 2011, to October 30, 2012).

continued

"Since the collapse of the I-35W bridge in Minnesota, many states are interested in developing a bridge health monitoring system that will help engineers address the many challenges of managing infrastructure and ensure the longevity and safety of our bridges."

—Moises Dimaculangan,
MnDOT Bridge Rating Engineer

"Establishing a method to monitor fracture-critical steel bridges will help MnDOT manage its bridge inventory more efficiently and keep travelers safe."

—Arturo Schultz,
Professor, University of Minnesota Department of Civil Engineering

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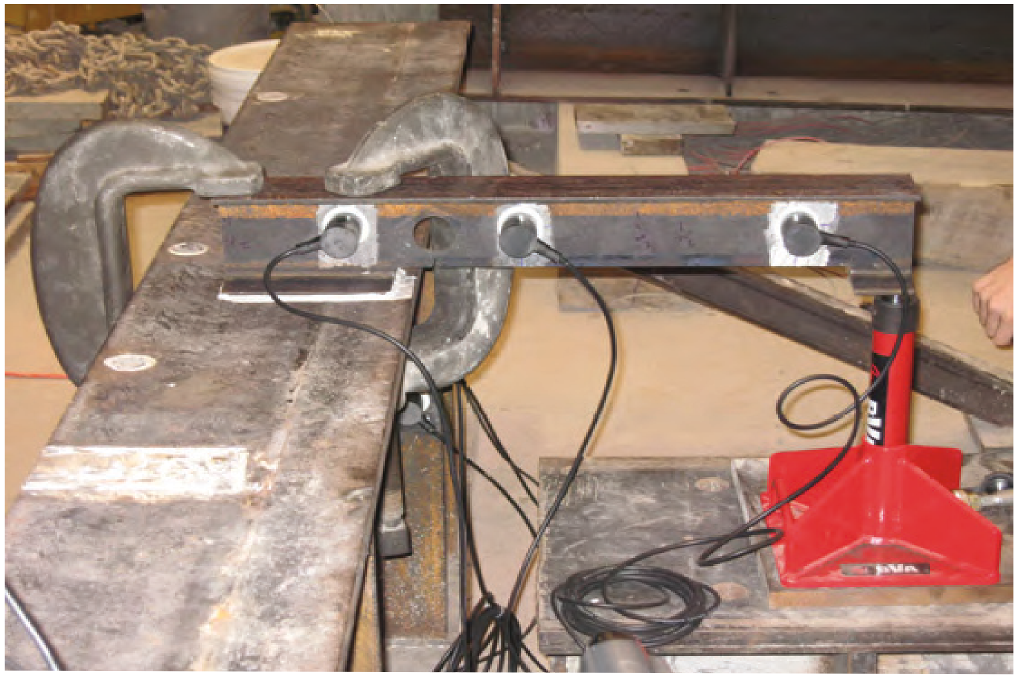

To help distinguish real monitoring events from false alarms, researchers conducted tests to capture acoustic emission data caused by brittle fractures in steel beams using the same bridge health monitoring system currently being used at the Cedar Avenue Bridge.

What Did We Learn?

Overall, the project demonstrated that commercially available acoustic emission technology could be used for global monitoring of a steel bridge to identify crack formation and propagation. As expected, analysis of acoustic emission data from the Cedar Avenue Bridge showed no evidence of fracture.

The final report provides a framework for selecting appropriate acoustic emission equipment and formulating effective data processing methods for assessing the formation and growth of cracks in steel bridges. Unlike previous applications of acoustic emission technology to steel bridges, where the sensors were concentrated in areas where fracture was expected, the system developed here utilizes distributed sensors at large spacing to globally monitor a large portion of a steel bridge.

One lesson learned from this project is that solar panels should not be used as an energy source because they are not sufficiently durable and reliable to meet the significant power demands of the system.

What's Next?

MnDOT will continue to monitor the Cedar Avenue Bridge using the system developed in this project. Researchers also recommend further investigation into acoustic emission data analysis methods as well as using the system developed in this project to monitor another steel bridge, one that has a history of cracking.

This Technical Summary pertains to Report 2014-15, "Acoustic Emission Monitoring of a Fracture-Critical Bridge," published March 2014. The full report can be accessed at http://www.dot.state.mn.us/research/TS/2014/201415.pdf.