Implementation of a Pilot Continuous Monitoring System: Iowa Falls Arch Bridge

tech transfer summary

This type of monitoring is likely to be mandated by the federal government in the near future on specialty bridges, so the need for this pilot project was even more critical.

June 2015

RESEARCH PROJECT TITLE
Implementation of a Pilot Continuous Monitoring System: Iowa Falls Arch Bridge

SPONSORS
Iowa Department of Transportation
(InTrans Project 10-371)

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Background and Problem Statement

As part of designing, constructing, and maintaining the bridge infrastructure in Iowa, the Iowa Department of Transportation (DOT) has, in recent years, focused efforts on investigating the use of new high-performance materials, new design concepts and construction methods, and various new maintenance methods. These progressive efforts are intended to increase the lifespan of bridges in meeting the Iowa DOT objective of building and maintaining cost-effective and safe bridges.

Bridge testing and monitoring has been beneficial in helping with these innovative efforts, and in providing important information to evaluate the structural performance and safety of existing bridges. The Iowa DOT testing and monitoring program, in coordination with the Bridge Engineering Center (BEC) at Iowa State University, collects performance data to compare with design-based structural parameters to determine if the structural response is appropriate. The data may also be used to "calibrate" an analytical model that may be used to provide a more detailed structural assessment (e.g., a load rating to determine safe bridge capacity).

Diagnostic testing has also been used to help identify deterioration or damage or to assess the integrity of an implemented repair or strengthening method. In cases where the Iowa DOT has investigated the use of innovative materials (high-performance steel, ultra-high-performance concrete, fiber-reinforced polymers, etc.) and design/construction methods, they have used testing as part of a program for evaluating bridge performance.

Iowa Falls Arch Bridge, which the researchers instrumented during and after construction for installation, implementation, and operation of the pilot continuous monitoring system

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The Bridge Engineering Center (BEC) is part of the Institute for Transportation (InTrans) at Iowa State University. The mission of the BEC is to conduct research on bridge technologies to help bridge designers/owners design, build, and maintain long-lasting bridges.

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The most challenging research program cooperatively undertaken by the Iowa DOT Office of Bridges and Structures and the BEC has been related to developing a structural health monitoring (SHM) system to determine the real-time and continuous structural condition of a bridge. One example of such work aimed to develop an SHM system to identify crack development in fatigue-prone areas of structural steel bridges.

With the maturity of the use of quantitative information, the next step in the evolution of bridge monitoring for the Iowa DOT is to implement monitoring systems that not only assess targeted structural performance parameters, but systems that can also be applicable in assessing general condition (both structural and nonstructural) using multiple sensors and sensor types and to do so in near real-time.

While the bridge monitoring efforts that have taken place since the early 2000s have provided very valuable information to the Iowa DOT, it became clear that developmental work was needed to allow bridge monitoring to become part of everyday bridge condition monitoring.

Prior to the initiation of this project, the data have either been immediately used to make decisions regarding bridge condition/behavior/etc., and then provided in report format, or analyzed autonomously with the outputs coming in the form of general information. The missing piece has been the creation of a mechanism to provide the autonomous data analysis coupled with means and methods for storing the data such that they can be accessed later by Iowa DOT engineers.

Goal and Objective

The goal of this work was to move SHM one step closer to being ready for mainstream use by the Iowa DOT Office of Bridges and Structures. To meet this goal, the objective of this project was to implement a pilot multi-sensor continuous monitoring system on the Iowa Falls Arch Bridge such that autonomous data analysis, storage, and retrieval can be demonstrated.

Project Description

- Technical information search with a focus on architecture of similar multi-sensor operating systems
- Design of the long-term monitoring system (sensors, SHM operating system, and focus on how to merge diverse datasets and format to provide data in implementation format for Iowa DOT staff)
- Implementation (i.e., installation and maintenance) of the long-term monitoring system on the Iowa Falls Arch Bridge for one year
- Development of report on the bridge monitoring system, the proof-of-concept, web-based data visualization and retrieval system, the continued development of the BEC Assessment Software (BECAS), etc.

Conclusions

The challenge with this work was to develop the open channels for communication, coordination, and cooperation of various Iowa DOT offices that could make use of the data. In a way, the end product was to be something akin to a control system that would allow for real-time evaluation of the operational condition of a monitored bridge.

Development and finalization of general hardware and software components for a bridge SHM system were investigated and completed. The hardware system focused on using off-the-shelf sensors that could be read in either “fast” or “slow” modes depending on the desired monitoring metric. As hoped, the installed system operated with very few problems.

In terms of communications—in part due to the anticipated installation on the I-74 bridge over the Mississippi River—a hardline digital subscriber line (DSL) internet connection and grid power were used. During operation, this system would transmit data to a central server location where the data would be processed and then archived for future retrieval and use via the described database, visualization, and retrieval tools.

Implementation Readiness

The pilot system was developed for general performance evaluation purposes such that it could be easily adapted to the Iowa DOT’s bridges and other monitoring needs. The system was developed allowing easy access to near real-time data.

It was observed that the biggest hurdle to widespread use of a system like this is storage of historical data. With data being collected at relatively high rates, a very large volume of data is collected on a daily basis. Although, from an operational perspective, this is not an insurmountable problem, there are difficulties associated with physically storing this much data.

The project team recommends that the Iowa Falls Bridge SHM system be integrated into normal operations on a graduated trial basis to prepare for the upcoming I-74 bridge construction and SHM system installation. The motivation for this integration is to identify areas for practical improvement and to demonstrate the value added by such systems.

Integration steps were outlined and it’s expected that the process—including system testing and verification—could be completed in 18 months or less.

Implementation Benefits

Implementing a multi-sensor, continuous monitoring system in this project serves as a prototype for use on other bridges. The overall benefit from this pilot study is that the architecture of a continuous monitoring system was developed that can be implemented on any bridge type to evaluate general performance.

The monitoring system will provide data that are continuous, routinely accessible by Iowa DOT staff, and readily and directly implementable by the Iowa DOT for timely decision making. The researchers emphasize that the sensor systems used in this project can be used on multiple bridge types without difficulty.