No. 0092-04-14 March 2005

PUTTING RESEARCH TO WORK

BRIEF

Smart Systems for Bridge Structural Health Monitoring

Bridges represent significant investments in Wisconsin's highway transportation network. They must stand strong and provide service for many years in the face of often unpredictable stresses, such as loading and environmental conditions. Traditionally, state departments of transportation have relied on periodic visual inspections to identify deterioration or damage to bridges. However, recent research suggests that visual inspections may not reliably identify all defects in a timely manner.

What's the Problem?

Advanced structural health monitoring is an emerging field in which nonintrusive damage detection devices are integrated into a structure to monitor the entire bridge or individual members. These technologies can extend the useful life of bridges by allowing deterioration or damage to be identified earlier, before major rehabilitation is required.

While a number of SHM technologies exist, a thorough compilation of the technologies does not. Such a synthesis would provide WisDOT with an effective tool to use in investigating these valuable technologies.

Research Objectives

Researchers' goal was to locate and synthesize information on advanced SHM technologies, with a specific interest in systems with "smart" attributes. A smart technology is one in which the system reports on the condition of a structure by making engineering-based judgments without requiring human intervention, providing early warning of dangerous conditions. Smart systems can provide real-time continuous sensing, advanced remote sensing, and self-diagnostic and decision-making functions. The investigators sought to assess the applicability, capability and viability of the technologies for effective short- and long-term monitoring of new and existing bridges.

Methodology

Researchers' tasks included:

• Identifying the information necessary to effectively monitor a structure and to select an appropriate monitoring approach. Researchers created an SHM Technology Evaluation Form to aid in assessing the technologies.

• Collecting information on SHM technologies that are currently being used with at least some success by other agencies.

• Identifying and evaluating emerging technologies with potential applications in bridge monitoring.

The Technology Evaluation Form summarizes the capabilities and applicability of each technology, providing enough information to facilitate preliminary assessments of the systems. The form details the type of structural changes each system monitors, the operational and environmental conditions under which the system can be used, as well as economic considerations and system limitations.

To collect information, researchers reviewed technical reports and other literature and contacted manufacturers and developers. Volume II of the final report provides completed evaluation forms for 100 technologies.

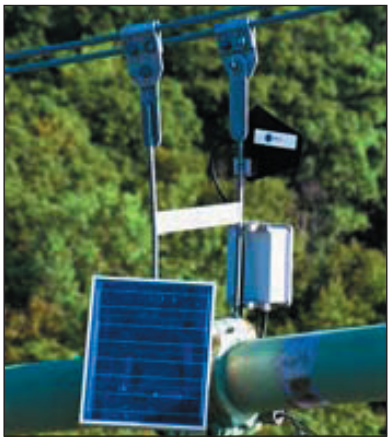
Investigators also conducted a survey to identify how state bridge owners are using smart SHM technologies to manage their inventory. A short online questionnaire was developed, and requests to complete the survey were sent by WisDOT to the state bridge engineer in all 50 states plus the District of Columbia and Puerto Rico. A copy of the survey is presented in the appendix to the final report.

Investigator

"SHM is a rapidly emerging field with the potential to produce significant cost savings. This study provides much-needed direction on these technologies."

–Brent M. Phares
Iowa State University
bphares@iastate.edu

Not shown:
Terry J. Wipf,
Lowell F. Greimann



Advanced structural health monitoring devices like the SoundPrint acoustic monitoring system (photo courtesy of Pure Technologies Ltd.) can identify deterioration and damage before major repairs are needed.

Results

The results of the survey showed that most of the respondents (15 of 20) did not have experience with smart SHM technologies. However, researchers found one smart system that is used by other DOTs, and identified several other technologies with potential applications in bridge management. Researchers divided the SHM technologies and products into four categories:

• **Smart SHM systems.** Although there are several technologies with "smart" attributes, researchers were able to identify just one system that satisfied the definition of "smart" used in this project—the SoundPrint system. Manufactured by Pure Technologies Ltd., SoundPrint uses acoustic sensors to determine if a wire break has occurred in a prestressed concrete or cable-supported structure. Several other SHM systems classified as smart by developers are currently being crafted.

• **State-of-the-art SHM systems.** These systems incorporate what are considered to be the most advanced or newest technologies that may not be widely used in bridge evaluation. They generally possess some, but not all, of the attributes of smart systems. Examples include systems using fiber optic sensors and real-time kinematic global positioning system technology.

• **Other SHM components.** These SHM components are considered to be advanced, but have not been integrated into a complete SHM system. They may form the basis for configuring an SHM system, and include several sensor types as well as strategies for data acquisition and processing, communication, and data management.

• **Emerging SHM technologies.** SHM systems and component technologies currently in development include wireless sensors for corrosion monitoring and artificial intelligence for data analysis.

Implementation and Benefits

The research findings lay the groundwork for WisDOT to thoroughly evaluate smart SHM systems. A searchable database of the technologies identified is being developed that will allow state bridge engineers to rapidly locate candidate technologies for specific applications and assess their capabilities. The final report bibliography cites more than 30 technical reports, product Web sites and other resources that provide further information about SHM research, development and implementation.

Project Manager

"This study helps point the way for WisDOT to further investigate SHM systems."

–Stan Woods
WisDOT Bureau of Structures
stan.woods@dot.state.wi.us

This brief summarizes Project 0092-04-14, "Health Monitoring of Bridge Structures and Components Using Smart-Structure Technology," produced through the Wisconsin Highway Research Program for the Wisconsin Department of Transportation Research, Development & Technology Transfer Program, 4802 Sheboygan Ave., Madison, WI 53707.

Nina McLawhorn, Research Administrator