New Ways to Predict Bridge Performance

Advances in Structural Health Monitoring

Exploratory Advanced Research . . . Next Generation Transportation Solutions

Fiscally responsible, safe, life-cycle management of the Nation's bridges depends on reliably predicting their health over time. The goal of the Exploratory Advanced Research (EAR) Program project, "Development and Demonstration of Systems-Based Monitoring Approaches for Improved Infrastructure Management Under Uncertainty," is a next-generation, integrated framework to advance the reliability of bridge assessment. The Federal Highway Administration (FHWA) awarded this project to researchers from the University of Central Florida and Lehigh University.

Developing a New Infrastructure Management Framework

The deterioration of the Nation's infrastructure brings new urgency to improving the safety and performance of bridges and other highway structures. Effectively managing their maintenance, repair, and replacement requires a deeper understanding of how these complex structures and their components respond to environmental conditions and increasing traffic loads and to unusual hazards such as earthquakes, floods, fires, and collisions.

"Our knowledge of how structures behave over time under a wide range of environmental and load conditions is broad but incomplete," says Hamid Ghasemi, of FHWA's Office of Infrastructure Research and Development. "This research is pursuing a structural monitoring framework that can accommodate the collection, integration, and analysis of monitoring data to better predict bridge performance. The goal is to provide the best information possible to inform decisions about further testing, repairs, and reconstructions."

The framework under development is unique in several ways: in the variety, location, and number of sensors it utilizes; in its global approach to monitoring structural, mechanical, and electrical components; in the sheer amount of data that can be collected, integrated, and effectively analyzed; and finally, in new methods of quantifying uncertainties in making decisions about a structure's reliability and load-carrying capacity and in predicting its future performance. Advances are under way in the following general areas:

- Data—Integrating data from a broad array of sources for analysis and future research, including historical data.
- Reliability models—Defining safety and serviceability performance expectations for individual structural components and structural systems.
- Analysis and prediction—Developing reliable 3D finite element models that can be constantly updated with new data.

Gathering and Integrating Data

Using state-of-the-art data mining and analysis techniques, information generated during the design, construction, and maintenance of structures can be integrated with continuously updated data from a network of monitoring sensors. Common monitoring technologies (e.g., sensors for strain, temperature, displacement, tilt, vibration) are being used, as well as technologies that are newer or not traditionally used in bridge monitoring (e.g., video imaging, infrared sensing, pressure gages, microphones). The way in which the sensors are used along with signal processing techniques the researchers have developed make this entire application a novel method. The study also includes the collection of uncertainty information for sensors by means of analyzing data over the long term.

Using Advanced, Systems-Based Analysis Methods

The proposed framework is expected to support decisionmaking through automated analysis and

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data management—providing information that will allow infrastructure owners to schedule maintenance and other interventions at the most cost-effective intervals. The researchers have developed time-dependent deterioration models that are calibrated with monitoring data collected within the framework, and a software program to compute these models. The Bayesian updating technique is used to incorporate data from the monitoring system, permitting a higher degree of accuracy in the prediction of future outcomes. As part of the high-risk nature of this project, the researchers have explored and demonstrated novel methods such as the use of synchronized video imaging and sensor data in structural health monitoring, which shows great promise in the laboratory and in real-life implementation for predicting the load-carrying capacity of bridges.

Future Efforts

The project's technologies, algorithms, and methods have been tested in physical test beds in laboratories and are now being implemented on a mid-size steel bridge near Ft. Lauderdale with support from the Florida Department of Transportation, District 4. This 1-year demonstration under real-world conditions will allow investigators to evaluate and refine the framework under a full annual cycle of weather and traffic conditions. While the researchers have been reporting their findings at conferences and in scientific journals, the project's final products will be shared with transportation engineers at the conclusion of the study.

This research could lead to significant cost efficiencies in managing transportation structures, while also reducing the cost of information processing and analysis through automated data collection and evaluation processes. Perhaps most important, the structural health monitoring framework is expected to accelerate advances in performance-based condition assessment of transportation infrastructure.

EXPLORATORY ADVANCED **RESEARCH**

What Is the Exploratory Advanced Research Program?

FHWA's Exploratory Advanced Research (EAR) Program focuses on long-term, high-risk research with a high payoff potential. The program addresses underlying gaps faced by applied highway research programs, anticipates emerging issues with national implications, and reflects broad transportation industry goals and objectives.

To learn more about the EAR Program, visit the Exploratory Advanced Research Web site at www.fhwa.dot.gov/advancedresearch. The site features information on research solicitations, updates on ongoing research, links to published materials, summaries of past EAR Program events, and details on upcoming events. For additional information, contact David Kuehn at FHWA, 202-493-3414 (email: david.kuehn@dot.gov), or Terry Halkyard at FHWA, 202-493-3467 (email: terry.halkyard@dot.gov).

Learn More

For more information on this EAR Program project, contact Hamid Ghasemi, FHWA Office of Infrastructure Research and Development, at 202-493-3042 (email: hamid.ghasemi@dot.gov).

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