New technology for monitoring 150,000 aging US highway bridges

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A photo of the ISHM remote bridge sensor. Credit: ISHM

On August 1, 2007, without warning, the roadway suddenly disappeared beneath drivers on Minneapolis' I-35W Bridge. The collapse sent more than 100 cars into the Mississippi River, killing 13 and injuring 145.

In the five years since, advances in wireless sensor technology are making warning systems to prevent such tragedies affordable and practical, say engineers at the University of Maryland. A new generation of these devices is needed to adequately monitor the nearly 150,000 U.S. highway bridges - about one in four - listed by the federal government as

either "structurally deficient" or "obsolete," the researchers add.

"We no longer need to roll the dice when it comes to the structural integrity of the nation's highway bridges," says University of Maryland research engineer Mehdi Kalantari. "Technical advances in wireless sensors make real-time monitoring both affordable and practical."

Kalantari leads one of two engineering teams at Maryland addressing the need. Working at the university's Mtech incubator, Kalantari has taken an entrepreneurial route, developing a system of tiny, long-lasting, energy-efficient, low-maintenance wireless sensors and software that analyzes real-time data collected. His startup, Rensensys, has manufactured systems for use in the private sector and for testing by Maryland State Highway officials.

Another University of Maryland engineering team - supported by federal and state funding and working with researchers from North Carolina State University and URS Corp. - is working on a total "smart bridge" package with multiple technology innovations. Their Integrated Structural Health Monitoring system is not yet available commercially. But, key elements of this system are being tested by Maryland State Highway officials, the Maryland Transportation Authority and the North Carolina Department of Transportation.

"Wireless technology definitely makes bridge structural health monitoring more efficient and more effective," says UMD civil and environmental engineering research professor Chung Fu, director of Maryland's Bridge Engineering Software & Technology Center and one of the leaders of this second research group.

"If the prices for system hardware and software are further reduced and standardized, we may see more widespread application in the next five to 10 years," Fu says, adding that he has seen great advancement in this

technology in the past decade.

Meanwhile, Kalantari is in the second year of testing his system on a Maryland Interstate bridge along the Capital Beltway in suburban Washington, D.C. Over the past 12 months, he has upgraded his system, making it fully operational, and expanded its use to the private sector. A few U.S. and international firms are using it on transportation projects, as well as for monitoring the safety of building facades and the safety of large construction cranes. Also, he's adapted the sensors for the purpose of monitoring cracks on bridge piers 120 feet underwater.

A few dozen tiny sensors, strategically placed on small to medium-sized bridges could measure prime factors such as strain, vibration, deformation, pressure, tilt, inclination, displacement, crack activity, humidity and temperature, Kalantari says - and for a much smaller price than current technology.

A photo of the Rensensys wireless bridge sensor. Credit: Rensensys

His team has equipped the system with a wide range of remote sensing functions and data analysis software capable of detecting structural anomalies. Also, the system delivers warnings to bridge maintenance engineers - by email or text messaging, in the case of severe warnings.

New "smart" bridges - including the replacement span in Minneapolis use wired networks of sensors to detect problems early, when repairs are often cheaper, providing a wide margin of safety. But these wired systems are generally too expensive to retrofit all the old bridges that need them, Kalantari says. Overall, he estimates that existing wired technologies cost at least 10 to 50 times more than his wireless system.

The latest statistics from the Federal Bureau of Transportation (2010) list nearly 70,000 U.S. bridges as "structurally deficient," requiring extra surveillance. In addition, more than 77,000 others are categorized as "obsolete" - exceeding their intended lifespan and carrying loads greater than they were designed to handle. Under federal requirements, structurally deficient bridges must be visually inspected once each year. Others must be inspected once every two to five years.

"Limited, in-person inspections are not sufficient to provide highway maintenance authorities with an adequate margin of safety when compared with real-time monitoring," Kalantari concludes. Ultimately, adds Fu, real-time remote sensing will serve as a valuable supplement, but not fully replace human inspections. "You can't put sensors everywhere," he says.

Highway officials have been paying attention to the advances in remote sensing applications. A UMD project using the Kalantari team's system to monitor a highway bridge and sponsored by the Maryland State Highway Administration (SHA) was selected as one of the "sweet 16"

most interesting developments. The results were presented this summer at the annual meeting of the American Association of State Highway and Transportation Officials (AASHTO) research advisory committee.

Kalantari hopes the system will receive the necessary approval and certifications over the next few years from AASHTO members and the U.S. Department of Transportation.

In its report on the fatal Minneapolis bridge collapse, the National Transportation Safety Board identified a faulty metal plate as a likely cause of the disaster. It notes an "inadequate use of technologies for accurately assessing the condition of gusset plates on deck truss bridges."

Both UMD engineering teams say the new wireless monitoring technology is poised to fill that need.

Provided by University of Maryland

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