Averting bridge disasters: New technology could save hundreds of lives

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"If this kind of technology had been available in Minnesota four years ago, there's a good chance the fatal bridge collapse could have been avoided," the UMD researcher says. Credit: MDOT

Millions of U.S. drivers cross faulty or obsolete bridges every day, highway statistics show, but it's too costly to fix all these spans or adequately monitor their safety, says a University of Maryland researcher who's developed a new, affordable early warning system

This wireless technology could avert the kind of bridge collapse that killed 13 and injured 145 along Minneapolis' I-35W on Aug. 1, 2007, he says - and do so at one-one-hundredth the cost of current wired systems.

"Potentially hundreds of lives could be saved," says University of Maryland electrical engineering researcher Mehdi Kalantari. "One of every four U.S. highway bridges has known structural problems or exceeded its intended life-span. Most only get inspected once every one or two years. That's a bad mix."

Kalantari has created tiny wireless sensors that monitor and transmit minute-by-minute data on a bridge's structural integrity. A central computer analyzes the data and instantly warns officials of possible trouble. He plans to scale-up manufacture in the fall.

"If this kind of technology had been available in Minnesota four years ago, there's a good chance the fatal bridge collapse could have been avoided," Kalantari adds. "This new approach makes preventive maintenance affordable - even at a time when budgets are tight. Officials will be able to catch problems early and will have weeks or month to fix a problem."

More than one-in-four U.S. bridges are either structurally deficient or functionally obsolete, according to a 2009 estimate by the U.S. Society of Civil Engineers.

- 72,000-plus U.S. bridges are listed by the U.S. Department of Transportation as "structurally deficient" and require extra surveillance.
- 79,000 others are functionally obsolete, exceeding their life-span and carrying loads greater than they were designed to handle.

Kalantari's sensors measure indicators of a bridge's structural health, such as strain, vibration, flexibility, and development of metal cracks. The sensors are small, wireless, rugged, and require practically no maintenance, he says. They are expected to last more than a decade, with each costing about $20. An average-sized highway bridge would need about 500 sensors for a total cost of about $10,000.

"The immediacy, low cost, low energy and compact size add up to a revolution in bridge safety monitoring, providing a heightened level of early-warning capability," Kalantari concludes.

Newer "smart" bridges, including the I-35W replacement in Minneapolis, have embedded wired networks of sensors. But Kalantari says the cost is too high for use on older spans.

"A wired network approach will cost at least 100 times more than a wireless alternative, and that's simply unaffordable given the strain on local, state, and federal budgets," Kalantari estimates.

Current federal requirements call for an on-site, visual inspection of highway bridges once every two to five years, depending the span's condition. Bridges deemed structurally deficient must be inspected once each year.

In its report on the fatal Minneapolis bridge collapse, the National Transportation Safety Board identified a faulty "gusset plate" - a connector essential to the bridge's structural integrity - as a likely cause of the disaster.

The report notes an "inadequate use of technologies for accurately assessing the condition of gusset plates on deck truss bridges." Kalantari expects his technology to fill that need.

TESTING ON MARYLAND BRIDGES

For almost a year, Kalantari has been testing his device in conjunction with the Maryland Department of Transportation, measuring the structural parameters of highway bridges in a real setting. This has enabled him to optimize the device's performance and energy consumption. His updated model is smaller and ten times more energy efficient than its predecessor.

"Immediacy, low cost, low energy ... add up to a revolution in bridge safety monitoring," Kalantari says. Credit: UMD

The testing allows him to track the bridge's response to changes in weather conditions and traffic. For example, he's measuring how the metal expands and contracts as the temperature rises and falls. Also, he can compare the metal's response during periods of peak and light loads. He hopes to expand the field testing more broadly in Maryland and to deploy sensors fully across the spans.

Capital Beltway (I-495), Northwest Branch Bridge: Since August 2010, Kalantari has had eight sensors on the Northwest Branch Bridge, a truss span like the one that collapsed in Minneapolis, though smaller. The bridge has proven "safe" in all his tests, so far. "Everything is working the way it's supposed to - both the bridge and my instruments," he reports.

Frederick, Maryland (I-70), Conococheague Creek Bridge: This span is the second provided by Maryland highway officials for Kalantari's test.

HOW THE SYSTEM WORKS

As with conventional technology, the sensors measure variables reflecting the structural integrity of a bridge, such as strain, vibration, tilt, acceleration, deformation and cracking.

Serious problems are more obvious and easier to interpret, and so trip an alarm very quickly. Early-stage problems are more subtle, and it may take up to a few days until the system is confident enough to report a structural integrity issue.

The sensors are less than five millimeters thick and have four thin, flexible layers. The first senses and measures structural parameters; the second stores energy; the third communicates data; and the outer layer harvests energy from ambient light and ambient radio waves.

Kalantari says the sensors offer a significant improvement on existing technology:

- No wires, batteries, or dedicated external power source;
- Almost no maintenance;
- Low cost;
- Easy and quick to install;
- Suitable for new and existing bridges.

TIMETABLE

Kalantari says he's working in an "emerging market with no widely accepted commercial solution now available." To commercialize his technology, he founded Resensys LLC, a start-up in the University of Maryland's Technology Advancement Program incubator. He expects to scale-up production in September.

Provided by University of Maryland