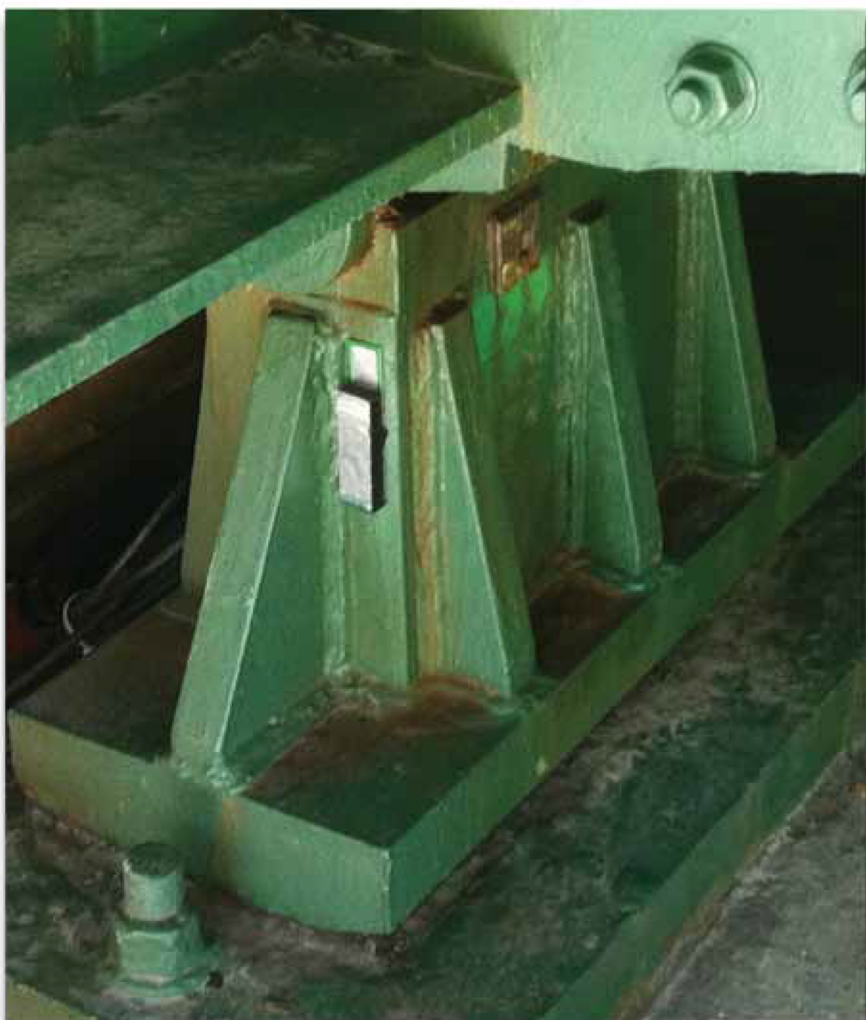
New sensor technology enables self-powered, wireless structural monitoring

For many people in the United States, driving over one or more of the nation's ~602,000 highway bridges is part of their daily commute, and recent statistics from the Federal Highway Administration indicate that more than 145,500 of these bridges are either structurally deficient or functionally obsolete.[1] To help assess the structural stability of these and other highway bridges so that structural issues are pinpointed and necessary maintenance and repairs can be planned to ensure bridge safety and longevity, University of Maryland (College Park, Maryland) electrical and computer engineering research scientist Mehdi Kalantari has developed and is commercializing a self-powered, wireless structural health-monitoring system for existing bridges and bridges under construction that features small, low-cost, easy-to-install wireless sensors that measure a variety of variables affecting the performance of a bridge. Data collected from the sensors can provide bridge owners with diverse information on bridge structural health such as overstrain, changes in load conditions, deformation, excessive vibration, crack development and growth, and conditions that are conducive to corrosion. In addition to bridges, the system also can be used to monitor the structural health of buildings and pipelines.



A wireless sensor is applied to a support structure on the Northwest Branch Bridge on the Capital Beltway (I-495) in Silver Spring, Maryland. Photo courtesy of Resensys.

"This new approach makes preventive maintenance affordable—even at a time when budgets are tight. Officials will be able to catch problems early and have weeks or months to fix a problem," says Kalantari.

Typically, one of the limiting factors of wireless technology is the absence of a connection to a permanent source of electrical power, he comments, which requires the equipment to draw power from a battery or an ambient energy source such as ambient light. Consequently, a wireless sensor needs to be as energy efficient as possible, Kalantari explains, so that it can take readings continuously over a long period of time without requiring a large supply of power. This monitoring system is unique, he says, because of the extremely low amount of power (4 µW) needed to operate an individual sensor.

Each sensor is 1-in (25-mm) wide, 3-in (76-mm) tall, and 0.6-in (15-mm) thick and is attached to the surface of a bridge structure with adhesive. The sensor's design consists of a module that contains the applicable sensing technology for the particular variable to be measured, such as strain, vibration, tilt and inclination, temperature, and cracking; a module that contains a small solar cell, similar to the type used in a solar calculator, that collects and stores energy from ambient light from the environment or, alternatively, a small lithium-ion battery; and another module that contains the telecommunications device that wirelessly transmits the raw data. The sensors are capable of taking measurements at a typical rate of every 60 seconds and sending the raw data a distance of ~1.3 km. The numbers of sensors used to monitor a typical bridge can range from 40 to 100, Kalantari notes.

The system also includes solar-powered communications coordination equipment at the bridge site that collects raw data from the sensors and transmits it to an offsite computer via a cellular modem, and the computer software program that analyzes and processes the raw data into visualizations and reports.

Kalantari is in the process of developing additional versions of the wireless sensor to monitor specific variables that indicate favorable conditions for corrosion of reinforcing steel in concrete—moisture, electrochemical activity, and chloride concentration. These sensors possess a small probe that is inserted into the concrete at a depth that enables close proximity to the reinforcing steel. The type of probe used on the sensor corresponds with the conditions being monitored in the concrete (i.e., the amount of moisture, the concentration of chloride ions, or the presence of an electrochemical current between the steel and the concrete).

For more than a year, with cooperation from the Maryland Department of Transportation, Kalantari has been testing the wireless monitoring system on two of the state's highway bridges and optimizing its performance and energy consumption, and plans to install a monitoring system on several additional bridges. A monitoring system is now in place on the Northwest Branch Bridge in Silver Spring, a truss span bridge that has signs of deck deterioration and is currently being rehabilitated. Another test site for the monitoring system is the bridge on I-70 that crosses Conococheague Creek in Frederick, which the Maryland State Highway Administration plans to rehabilitate in 2012.

Resensys, LLC, a start-up company founded by Kalantari and formed with the help of the University of Maryland's Technology Advancement Program, which serves as a technology business incubator, is now commercializing the wireless monitoring system. Resensys has received grants through the University's Maryland Technology Enterprise Institute and the Maryland Technology Development Corp., as well as a Small Business Innovation Research (SBIR) grant from the National Science Foundation.

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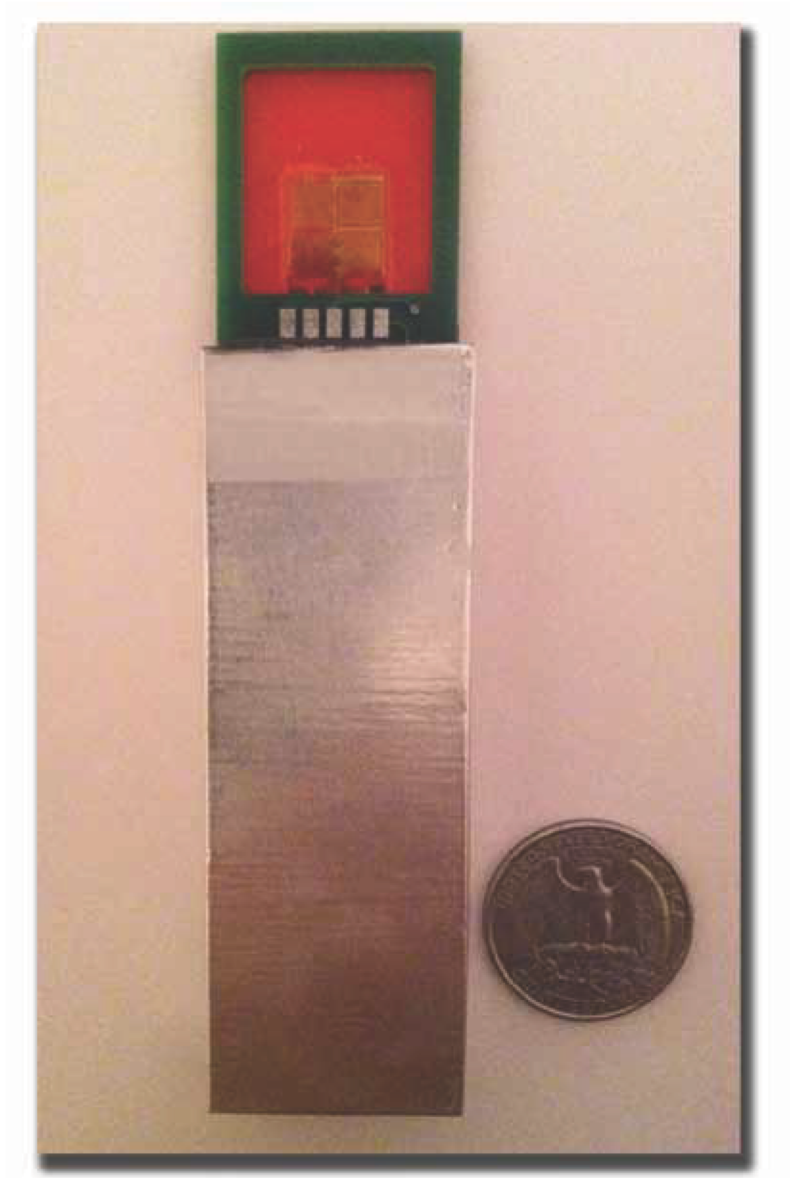

Each sensor is 1-in wide, 3-in tall, and 0.6-in thick, and comprises a sensing module, an energy module with either a solar cell or a small lithium-ion battery, and a wireless transmission module. Photo courtesy of Resensys.

Reference

1 "National Bridge Inventory," U.S. Department of Transportation Federal Highway Administration, December 2010, http://www.fhwa.dot.gov/bridge/nbi.htm (Sept. 21, 2011). MP

—K.R. Larsen