Bridge-Saving Sensors

With America's bridge infrastructure rapidly deteriorating, wireless sensor solutions provide low cost remote damage detection and on-going health monitoring.

» *By Meaghan Ziemba, Editor*

According to the American Society of Civil Engineers (ASCE), "One in nine of the nation's bridges are rated as structurally deficient."[1] In order to eliminate bridge infrastructure deficiency, the Federal Highway Administration (FWHA) claims that $20.5 billion needs to be invested on an annual basis.[2] However, "preserving aging bridges while replacing deficient bridges is a significant challenge for cash-strapped state and local governments to manage."[3]

Wireless sensor solutions, such as remote damage detection and on-going health monitoring systems, help to provide long-term resolutions for America's rapidly deteriorating bridge infrastructure by decreasing certain costs associated with installation and maintenance.

TRACKING BRIDGE DECAY

Currently, most bridges are being inspected by people on a periodic basis. In certain environments, human inspection can be a challenge, especially if a bridge is located 100 feet above water. It can also be costly, depending on traffic control and equipment needed to fulfill the inspection requirements.

"In situations involving floods, the base of the pier is undercut, which is very difficult to detect above water," says Rick Carlson, COO of Metrom Rail. "You would have to have a diver in the water to inspect, which can be challenging depending on the environmental conditions."

University of Pittsburg engineers developed this sensor for PennDOT that detects the erosion of concrete aggregate surrounding bridge abutments. The device is powered by a Tadiran TLM-1550HP battery. Photo Credit: Nicholas Franconi, University of Pittsburgh

The various elements of a bridge that can be measured and monitored to track structural decay include: temperature, humidity, inclination, strain, displacement, pressure deformation, and tilt. Slight changes in these elements can cause the structure of a bridge to move, crack, or buckle, which can lead to tragic events, such as the 2007, I-35W bridge collapse in Minneapolis, MN.[4] Thirteen people were killed, and 145 were injured.[5] Monitoring systems help track any structural integrity problems well before they develop, decreasing the likelihood for such tragedies.

BENEFITS OF SENSOR SOLUTIONS

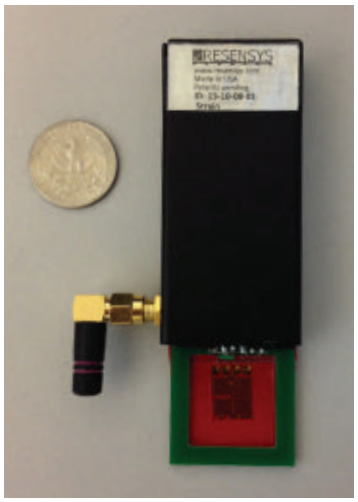
The actual installation of certain monitoring systems can be expensive, especially if specialized equipment is needed to place them in the right areas of the bridge, and if traffic around the bridge needs to be delayed

Above: A Resensys wireless SenSpot sensor monitoring tilt and strain on rocker bearing of a 76-year old steel bridge. Photo Credit: Resensys LLC. Right: Alliance Sensors Group's LV-45s installed with Metrom Rail's safe structure system on bridge. Photo Credit: Alliance Sensors Group

or rerouted. However, the expense of a sensor system is small when compared to the expense of replacing an entire bridge.

"The intent of Metrom Rail's systems is to determine how stable a structure actually is, so that somebody can determine which structures should be a priority and worked on first," explains Carlson.

One of the challenges for designing monitoring systems for bridge infrastructure is that no two bridges are alike. Mehdi Khandani, founder of Resensys, says "Bridges are complex. There are various types of bridges, from very old to very complicated designs." Carlson agrees, "No two bridges are the same, because no two locations are the same. Every bridge is essentially a new application for the monitoring system, so a little customization is going to be required."



Left: A Resensys wireless high precision tilt SenSpot sensor used to monitor bridge piers. Photo Credit: Resensys LLC. Below: A Resensys wireless tilt/strain SenSpot sensor. Photo Credit Resensys LLC. Right: Alliance Sensors Group's LV-45 linear sensor. Photo Credit: Alliance Sensors Group

The sensors that can be incorporated into a monitoring system include: linear sensors, tilt sensors, accelerometers, and water level sensors for bridges above water. Some examples include the LV-45 and LV-48 linear position sensors from Alliance Sensors Group, which are attached to a bridge and its supporting pier with rod-eye swivel ends. The sensors measure movement of the bridge over all three axes relative to the pier over time and ambient temperature.

"One of the biggest challenges for Alliance Sensors Group was creating a solution that could withstand the extreme weather conditions, such as snow, rain, ice, and extreme temperatures," says John Matlack, vice president of sales at Alliance Sensors Group. "Another challenge was making the sensors low power so they wouldn't drain the power of the overall monitoring system."

Data collected from the sensors is used for trends analysis. "As time goes on, we learn more about what is happening with certain bridge infrastructure," says Khandani. "By adding more data to the whole, we can track what is normal versus what isn't normal, and produce early alerts that help to fix structural malfunctions before they cause bigger problems."

Carlson adds, "By collecting incremental data on the bridge itself, we can determine things, like if a pier has been tilting a certain way over a certain timeframe. Once we figure out what the issues are with the bridge, we can determine which methods to use to fix them."

POWER MANAGEMENT

For monitoring systems to be successful, the appropriate power solution needs to be incorporated. From a power management perspective, some of the major structural components on a bridge are often highly inaccessible. The cost of labor to service or replace a sensor installed on a bridge can be more expensive than the sensor itself, so long-term reliability is a paramount concern.

"We don't have the luxury to access an unlimited power supply, or to charge it on a regular basis," explains Khandani. "It is important for power supplies to be reliable, and for them to work over long periods of time with little or no maintenance."

"The main concerns for power supply manufacturers are the life of the sensor, operating temperature range, the ability to replace or recharge the batteries, and, if at all, battery self-discharge," says Sol Jacobs, vice president and general manager of Tadiran Batteries. "It is also important to know how often the battery is going to be used; if there is a standby phase; and if high pulses are required."

Carlson explains how Metrom Rail uses available power at the sites to communicate to the bridge through a cell modem. "We have individual nodes that we apply to several piers on the bridge. These nodes are tied together with an RS485 system, so there are wires involved. Power goes through a central processing unit, which has a battery back-up." He continues to explain that in situations not involving power, systems are able to operate using solar cells.

The power supply depends on the application it is powering. Jacobs asserts, "If the sensors can be located where there is sunlight, then they can be solar powered with a rechargeable battery used for energy storage. If not, then a long-life primary lithium battery is required, with bobbin-type LiSOCL2 batteries offering a long operating life due to their low rate design."

Power decisions depend on the expected lifetime of the sensors and how often they communicate. One example is the SenSpot integrity sensor from Resensys, which takes readings on a variety of elements once a minute, drawing only microwatts of energy. "We also developed a proprietary low power communications protocol for our wireless network to further minimize energy consumption," says Khandani.

Wireless sensing and monitoring systems are a step in the right direction to maintain current and old bridge infrastructure. However, the ASCE claims that federal, state, and local bridge investments are not keeping pace with the growing costs of aging bridges. "The FHWA estimates that the current cost to repair or replace only the deficient bridges eligible under the Federal Highway Bridge Program is almost $76 billion. […] If bridge maintenance continues to be deferred over the next 25 years, these backlog costs will rise."[6]

To put these numbers in perspective, over the last 30 years Congress has provided approximately $77 billion to the states through the federal-aid bridge program.[7] **WDD**

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