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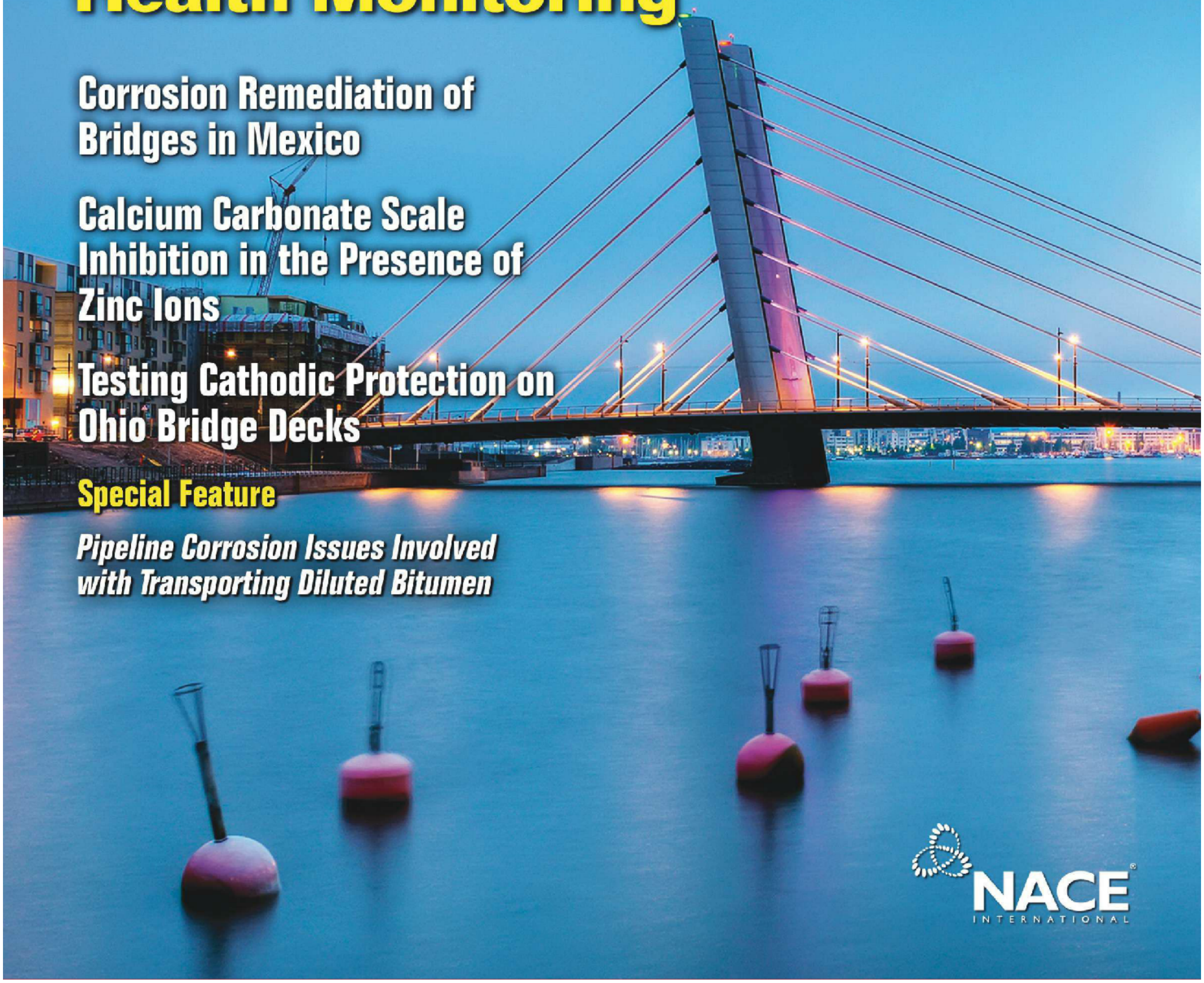


NACE INTERNATIONAL

Bridge corrosion risks assessed with structural health monitoring

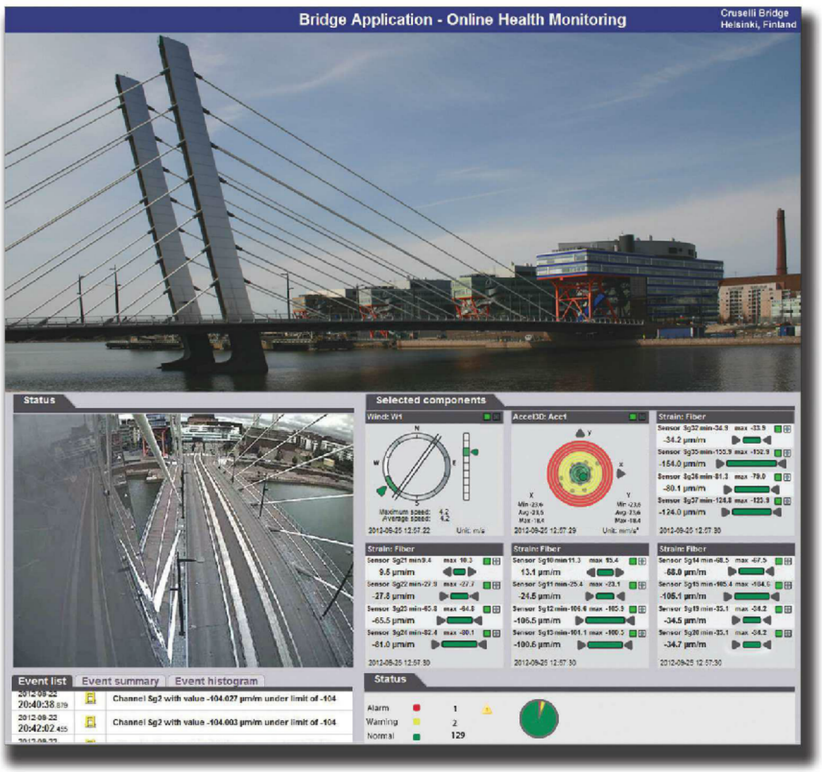
The intelligent SHM program installed on the Crusell Bridge during construction integrates a total of 92 different electrical, electrochemical, and fiber optic sensors, which are installed in various locations on the bridge's concrete deck, steel pylons, and expansion joint. Photo courtesy of Savcor Group, Ltd.

Advances in structural health monitoring (SHM) have enhanced the ability to continuously collect a variety of information about a structure. Incorporating SHM devices such as accelerometers, displacement transducers, inclinometers, temperature gauges, and corrosion sensors when designing and building a structure provides a management tool that helps those responsible for sustaining the structure to anticipate maintenance requirements and recognize safety issues by identifying and assessing operating incidents, damage, corrosion, degradation, and other anomalies.

Corrosion is a major factor that can affect the service life and safety of a structure. Steel components, a mainstay in structures constructed of reinforced and prestressed concrete (i.e., bridges, dams, buildings, etc.), are subject to corrosion stemming from several factors, which include water, chlorides from deicing salts and coastal environments, and variations in pH levels. All of these factors can be observed and tracked by incorporating corrosion monitoring into a SHM program.

The success of SHM is based on the ability to select the areas of a structure where information collection and assessment is critical, explains Atef Cheaitani, general manager-global operations with Savcor Group, Ltd. (North Sydney, New South Wales, Australia), an engineering firm that focuses on preserving infrastructure assets. For example, he says, on a bridge that crosses seawater in a harsh marine environment, critical areas of concern would be the splash zones on the reinforced concrete substructure that are continually exposed to wet and dry conditions.

An initial durability assessment of the structure should be conducted to establish the corrosion risks that can impact a structure as well as identify the specific areas on a structure where corrosion risks are high, says Cheaitani. "During this stage, we determine what type of corrosion prevention measures are needed—be it cathodic protection for the steel or use of stainless steel reinforcement in the concrete—and we also determine which aspects of a corrosion monitoring system should be incorporated in the structure based on the corrosion assessment risk," he explains. Cheaitani notes that it is important to understand the type of information needed to monitor corrosion and the type of sensor that will provide the information, and to create an optimum balance of the sensor quantity and type, as well as the number of readings taken, so that relevant data can be efficiently collected and interpreted. He emphasizes that effective monitoring is a matter of knowledge, not quantity, and cautions that thousands of readings from too many sensors can generate so much information that managing the data and drawing meaningful conclusions is not feasible.



The Web-based user interface displays data collected from the Crusell Bridge's intelligent SHM system in real time. Image courtesy of Savcor Group, Ltd.

Basically, corrosion sensors are installed in locations where the durability assessment indicates there is a high risk for corrosion, which can differ depending on the individual structure and its environment. If corrosion prevention measures are incorporated into the structure during the construction phase, then applicable sensors are selected to monitor the performance of these measures as well as detect any corrosion activity. Corrosion prevention measures for a concrete bridge can include cathodic protection (CP) of the reinforcing steel, galvanized or stainless steel reinforcement, corrosion inhibitors added into the concrete, and protective coatings applied to the concrete's surface.

Corrosion sensors using various electrochemical techniques, such as linear polarization resistance (LPR) or the galvanostatic pulse method, are normally utilized to measure resistivity of the concrete and the corrosion rates of embedded reinforcing steel in a concrete bridge exposed to water and chlorides. Information collected from the sensors is used to make an assessment on the level of chloride ingress into the concrete and the corrosion status of the reinforcing steel, and support decisions regarding the need to incorporate additional corrosion control measures.

Since corrosion monitoring is typically just one component of a comprehensive SHM program, a structure can contain a multitude of sensors to measure a variety of other factors that affect its overall health. Cheaitani indicates it is common for one structure to have several individual monitoring systems as part of an overall SHM program, and each use their own unique hardware and software systems. This can create a challenge when trying to combine all the collected data for assessing a structure's health. An intelligent structure concept recently developed by Savcor for marine structures

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integrates all aspects of SHM, including structural integrity monitoring, corrosion rate monitoring, and corrosion protection and prevention monitoring (e.g., CP monitoring), into one system. All hardware components (sensors, corrosion probes, anodes, reference electrodes, and traffic control equipment) are incorporated into one centralized system; and monitoring and performance data are merged into one comprehensive report, accessible via the Internet through a Web-based user interface, that provides all essential information regarding the health of the structure. The intelligent structure concept is unique, Cheaitani says, because it presents synchronized information about a structure—weather conditions, traffic loading, corrosion activity, corrosion protection functionality—that provides a complete picture for analyzing and understanding structural health.

This concept was used to develop a SHM program for the Crusell Bridge, a landmark bridge in Helsinki, Finland that crosses the bay separating the western residential area of Jätkäsaari and the Ruoholahti district. The 25-m wide bridge, designed by WSP Finland and constructed by Skanska, officially opened in June 2011. It features two independent steel pylons that rise 49 m above sea level and two asymmetrical cable-stayed spans that total 143 m in length, with the longest span measuring 92 m. The bridge's superstructure is constructed from longitudinally post-tensioned prestressed concrete beams and perpendicular beams that are a composite of steel and concrete.

Cheaitani comments that the critical corrosion risk identified for the Crusell Bridge is corrosion of the superstructure's reinforcing steel stemming from chlorides in road deicing salts. Although the structure spans the bay, the water is brackish with a low salt content and the durability assessment indicated a low risk of corrosion of the bridge piers. The complete substructure is coated to protect the steel against corrosion. A CP system was not installed.

The bridge's SHM program integrates a total of 92 different electrical, electrochemical, and fiber optic sensors, which are installed in various locations on the bridge's deck, pylons, and expansion joint. "Structural intelligence was used in this exercise because placing sensors in the wrong location or putting the wrong sensor on the structure will give you information that you don't need. It's not cost effective," Cheaitani says. The corrosion monitoring portion of the SHM program includes two corrosion measurement assemblies located at each end of the bridge deck that are comprised of a multi-depth, ladder-type corrosion rate sensor and seven corrosion potential sensors (reference electrodes) strategically placed in regards to the structure's geometry and exposure to factors that promote corrosion.

The potential value of the steel reinforcement bar in the concrete is measured by the electrochemical corrosion potential sensors vs. manganese dioxide (MnO_2) reference electrodes, and the corrosion rate is periodically measured using the galvanostatic pulse method. Data from the corrosion sensors are collected at selected intervals by a data management system, stored in a database, and synchronized with the other SHM data during analysis so that everything happening on the bridge can be viewed in real time on the Web-based user interface. Because the data are automatically coordinated and presented regularly, signs of corrosion activity and structural deterioration can be detected promptly and provide early warnings of potential structural failure.

Contact Atef Cheaitani, Savcor Group, Ltd. e-mail: Atef.Cheaitani@savcor.com.au.

Bibliography

Cheaitani, A., and T. Laurila. "Latest Trends in Corrosion Control for New Reinforced Concrete Structures and a New Concept for Intelligent Structures." CORROSION 2012, paper no. C2012-0001531. Houston, TX: NACE International, 2012. MP