Service Life Modeling

Selecting Repair and Rehabilitation Options for Bridge Structures

ALI AKBAR SOHANGHPURWALA AND IVAN R. LASA

Sohanghpurwala is President, CONCORR, Inc., Sterling, Virginia; and Lasa is Corrosion Mitigation and Rehabilitation Technologist, Corrosion Research Laboratory, Florida Department of Transportation, Gainesville.

Evaluating the corrosion condition of a reinforced concrete structure is essential in developing a strategy for repair and rehabilitation after corrosion-induced damage. Several destructive and nondestructive test methods and techniques are available to ascertain the corrosion condition of the reinforcement in portions that do not yet show concrete damage. Most of these techniques, however, require significant resources to implement and then additional resources to interpret the data and make the decisions about repair and rehabilitation.

The National Cooperative Highway Research Program (NCHRP) therefore initiated a project to develop a protocol for evaluating the condition of bridge superstructure elements, for estimating the remaining service life, and for identifying the options for mitigating the corrosion. The project findings, published in 2006 in NCHRP Report 558, *Manual on Service Life of Corrosion-Damaged Reinforced Concrete Bridge Superstructure Elements,* produced a condition survey protocol, a model for remaining service life, and a susceptibility index to designate the likelihood of corrosion.

View of one of the examined bridges on I-95 near Bangor, Maine, showing cracking caused by reinforcement corrosion. Condition evaluation included a delamination survey, cover depth measurements, chloride ion content analysis, and petrographic analysis.

Problem

The National Bridge Inventory database, maintained by the Federal Highway Administration, contained a total of 587,964 bridges as of 2002. The average age of the bridge structures in the database is 40 years; 41 percent of the bridges are at least 40 years old.

The condition of the nation's aging highway bridge infrastructure has gained significant attention in the past two decades. Several independent evaluations of the condition of the nation's infrastructure have used the ratings in the database. These studies ascertained that 14 percent of the bridges were rated structurally deficient and that the primary cause of the deficiency was corrosion of the reinforcing steel. For the 20-year period from 1999 to 2019, the estimated cost of maintaining the nation's bridges is $5.8 billion per year, and the estimated cost of improving the same bridges and eliminating their deficiencies is $10.6 billion.

To address deterioration from corrosion, a bridge owner must decide whether to maintain, repair, or replace the structure, considering its present condition and its expected condition. The owner also must identify the materials and methods that are most appropriate to the task. Because of the lack of standard decision-making processes, most owners have made these complex decisions by relying on local experience and expertise. These decision-making processes often have resulted in inefficient, costly, nonstandard, and nonoptimal solutions.

A protocol capable of determining the optimal course of action—maintenance, repair, or replacement—and of assisting in the selection of the best materials and methodology was urgently needed.

Solution

Determining the optimal course of action requires information about the present condition of the structure and its expected deterioration. The present condition determines the quantity and the type of repairs necessary. The owner can use the expected future deterioration to determine the efficacy of alternative repairs and to assist in selecting a repair-andprevention strategy to minimize the cost of maintenance for the period of service life desired from the structure.

The future corrosion activity can be projected either from the estimated remaining service life of the structure or as a function of the concrete deterioration caused by the corrosion of the reinforcement. The remaining service life method requires the owner to formulate a criterion to define the end of the service life. The other approach, applying a function of concrete deterioration over time, provides the owner with scientific data on the progression of damage and facilitates identifying the types and timing of the most appropriate actions. The NCHRP project chose the second approach, which is more flexible. For simplicity and to conform to the naming convention in the literature, the project termed the process "service life modeling."

Although several mathematical methods have been proposed to model the corrosion process according to the extent of deterioration and the presence or absence of deleterious agents, none has been found to be comprehensive, verified scientifically, or standardized for the bridge community. The model developed in the NCHRP project, however, was statistically validated on three bridge structures in Kentucky, Ohio, and Maryland.

The model requires results from a delamination survey, a few cores for chloride profile analysis, and clear concrete cover data. A susceptibility index, based on the distribution of chloride ions in sound concrete, narrows the options available for corrosion control.

Applications

Florida has applied the model on several bridge structures. On the I-75 bridges over the Caloosahatchee River and the Tidal Marsh in Fort Meyers, Florida, a consultant used the results of service life modeling to recommend widening of the bridges with repairs instead of a complete replacement, producing a considerable savings for the state. The service life modeling provided confidence in the option of widening and repairs by providing a clear view of expected future damage.

The model also was used on the Courtney Campbell Bridge in Tampa to ascertain the magnitude of the corrosion problem and the options available for repair and rehabilitation. The model was applied recently for the historic North Torrey Pines Road Bridge, in Del Mar, California, to determine the best options for repair and rehabilitation of the substructure elements while maintaining the historical characteristics.

Other applications include the substructure elements of four bridges on I-95 near Bangor, Maine; piers of the Military Ocean Terminal, Sunny Point, North Carolina; piers of the Port of Moorehead City, North Carolina; and the terminal used by Alcoa in Charleston, South Carolina. In each instance, use of the model has resulted in the optimal design of repairs and of corrosion control systems.

Benefits

The model and the susceptibility index provide a streamlined mechanism for performing the corrosion condition survey and applying the survey results to determine the future progression of damage and to select the optimal repair and corrosion control system. The service life model allows the owner to perform life-cycle cost analyses of various options according to estimates of the progression of damage.

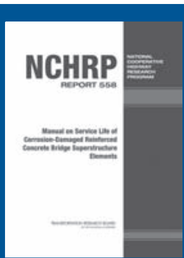
Service life modeling offers another advantage, by reducing the amount of field data collection and sampling. The model requires only the results of the delamination survey, chloride profile analyses, and a concrete clear cover survey.

The condition evaluation protocol of this model can be integrated easily into the routine bridge inspection. In addition, the model can be used to ascertain future susceptibility to corrosion-induced damage and the magnitude of the damage, so that the optimal corrosion control systems can be installed to reduce or stop corrosion and increase the remaining service life.

For more information, contact Ivan R. Lasa, Corrosion Research Laboratory, Florida Department of Transportation, 50057 NE 39th Avenue, Gainesville, FL 32609; 352-955-2902; ivan.lasa@dot.state.fl.us; or Ali Akbar Sohanghpurwala, CONCORR, Inc., 45710 Oakbrook Court, Sterling, VA 20166; 571-434-1852; ali@concorr.com.

EDITOR'S NOTE: Appreciation is expressed to Amir Hanna, Transportation Research Board, for his efforts in developing this article.

Suggestions for "Research Pays Off" topics are welcome. Contact G. P. Jayaprakash, Transportation Research Board, Keck 488, 500 Fifth Street, NW, Washington, DC 20001 (telephone 202-334-2952, e-mail gjayaprakash@nas.edu).



Manual Describes Protocols

NCHRP Report 558, *Manual on Service Life of Corrosion-Damaged Reinforced Concrete Bridge Superstructure Elements,* presents the findings of a research project conducted by CONCORR, Inc. The manual offers step-by-step procedures to assess the condition of corrosion-damaged bridge elements. Also included are procedures for estimating the expected remaining service life of reinforced concrete bridge superstructure elements and to determine the effects of maintenance and repair options on a structure's service life. The report is available online at http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_558.pdf.