Evaluating Bridges with Unknown Foundations for Vulnerability to Scour

North Carolina Applies Risk-Based Guidelines

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For approximately 10 percent of the estimated 600,000 bridges that span waterways in the United States, the "as built" information—that is, the details of the final structure—is not available or is missing. The National Bridge Inventory (NBI) of the Federal Highway Administration (FHWA) classifies these as bridges with unknown foundations.

Problem

Scour is the removal of material such as sand and rock around a bridge foundation—the abutment and piers—by flowing water. Scour affects the stability of the foundations of bridges over water and contributes to an estimated 60 percent of all U.S. bridge failures. Bridge failures cause loss of property—sometimes loss of lives—and disrupt traffic. Determining the vulnerability of a bridge's foundation to scour, therefore, is important.

Ideally, a bridge should have a construction plan and an as-built plan containing information on the type, depth, geometry, and materials incorporated in the foundation. This information is necessary to determine a bridge's vulnerability to scour. Bridges with unknown foundations, however, lack this information. Approximately 6,000 bridges in North Carolina have unknown foundations.

In 2001, FHWA encouraged each state and all bridge owners to develop a plan of action to evaluate bridges with unknown foundations for vulnerability to scour, to ensure the safety of the traveling public and to prevent traffic disruptions.

Solution

In 2004, the North Carolina Department of Transportation (DOT) established a plan of action for bridges with unknown foundations. The Scour Committee, which consists of the Geotechnical Engineering, Hydraulic, Structure, and Bridge Management Units and the local FHWA bridge engineer, would oversee the evaluations of the bridges; $1 million was allocated every two years for evaluations by

PHOTO: NORTH CAROLINA DOT

(a)

PHOTO: NORTH CAROLINA DOT

(b)

Pile integrity testing on (*a*) HP12x53 steel and (*b*) 12-in. timber.

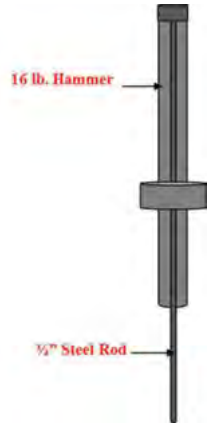

FIGURE 1 Schematic sketch of a half-inch sounding rod.

private firms in conjunction with the North Carolina DOT Geotechnical Engineering Unit.

The type of foundation and the lengths of the pile embedments would be determined through an in-house record search or through nondestructive testing (NDT). North Carolina DOT used NDT and half-inch steel rod soundings for field verification in evaluating bridges with unknown foundations for vulnerability to scour. The Scour Committee made the final evaluation of the 6,000 bridges.

Pile Integrity Testing

North Carolina DOT performed pile integrity testing (PIT) according to the ASTM D-5882 procedure, Low-Strain Integrity Testing of Piles (see photos, page 43). PIT length predictions for concrete, steel, and timber piles can only be considered approximations that must be verified, when possible, by other means, such as half-inch rod soundings.

The half-inch rod soundings procedure requires dropping a 16-lb weight from a vertical height of 24 inches to strike a rod 5 feet long and one-half inch in diameter (see photo below and Figure 1, above left). The rod is driven into the ground until penetration ceases, indicating the minimum tip elevation for the piles.

The verification method works well for PIT but is labor intensive and time consuming. From 2004 to 2011, North Carolina DOT evaluated 1,398 bridges at a total cost of $2.7 million, but 4,602 bridges with unknown foundations still required evaluation. North Carolina DOT realized that completing the evaluation of all the bridges with unknown foundations would be difficult within the allotted time and the allocated budget.

Risk-Based Method

A quicker, less expensive, but reliable method was needed to accomplish the task, and North Carolina DOT found the answer in the *Risk-Based Management Guidelines for Scour at Bridges with Unknown Foundations* (*1*), produced under National Cooperative Highway Research Program (NCHRP) Project 24-25. The method involves quantifying the probability of failure. The project studied both the occurrence of hazardous events and a bridge's susceptibility to these occurrences (*2*).

In 2009, FHWA issued a memorandum, "Additional Guidance for Assessment of Bridges over Waterways with Unknown Foundations," recommending the process developed under NCHRP Project 24-25. In 2010, North Carolina DOT applied the technical guidance in the FHWA memorandum and tested the risk-based management guidelines, evaluating 100 bridges with an average daily traffic of 500 or fewer vehicles. The results were acceptable.

PHOTO: NORTH CAROLINA DOT

Using a half-inch sounding rod.

Selection Criteria

The pilot effort yielded selection criteria for the bridges to be evaluated under the NCHRP procedure—the bridges should

- Be small, low impact, and low risk;
- Have a low average daily traffic of 500 or fewer vehicles;
- Be located on a secondary road; and
- Have a detour available if a failure occurs.

To evaluate these bridges, the Scour Committee used the bridge survey reports generated by the Bridge Management Unit, with reference to the North Carolina DOT bridge tier categories: statewide, regional, and subregional.

Application

In 2010, the Geotechnical Engineering Unit selected 3,752 bridges from the 4,602 still to be evaluated, using the bridge inventory reports. The NCHRP risk-based management guidelines were used to evaluate the bridges with unknown foundations for vulnerability to scour.

Most of the data required for the NCHRP procedure were available in electronic format; as a result, the data for a few hundred bridges could be processed at the same time. Evaluation of these bridges was completed in approximately three months.

The remaining 850 bridges were in mountainous areas; most had timber piles encased in concrete over rock and had to be field-inspected by North Carolina DOT staff; these bridges therefore were removed from the list. The evaluation of all the bridges with unknown foundations was completed in 2012. The total cost of evaluating the 3,752 bridges under the NCHRP risk-based approach was $21,000, or $5.60 per bridge.

Benefits

FHWA accepted the management plan that North Carolina DOT developed for evaluating the scour vulnerability of bridges with unknown foundations. The 3,752 bridges that the NBI shows as having unknown foundations now have plans of action for assessment.

The average cost to North Carolina DOT for evaluating a bridge with the conventional method was $1,900. Evaluating the 3,752 bridges under the conventional method would have cost more than $7 million total. As noted, the NCHRP risk-based approach to evaluate the 3,752 bridges cost North Carolina DOT $21,000—achieving nearly $7 million in savings or benefits.

Steps in Risk Management of Scour Failure

In the first phase of NCHRP Project 24-25, Guidelines for Risk-Based Management of Bridges with Unknown Foundations, researchers surveyed a variety of specialists, including engineers, economists, and state transportation officials, and analyzed their expert opinions. The analysis indicated that risk-based methods provide the most inexpensive and flexible approach to selecting a management plan.

The study proposed the following steps:

- Set the priority for a bridge according to its intended function. High-priority bridges should receive an aggressive management plan.
- Set minimum performance levels for each bridge category.
- Compare the estimated risk of bridge failure with the cost of automated monitoring and the installation of countermeasures, to determine if these actions are needed.

Researchers applied this basic approach to the assessment of scour failure, using the scour vulnerability assumptions described in the FHWA Report, *HYRISK Methodology and Users Guide* (*2*). The HYRISK estimate of scour vulnerability had a strong correlation with the known scour vulnerability of nearly 300,000 bridges with known foundations.

The maximum number of bridges that North Carolina DOT could evaluate with the conventional method was 200 in a year; processing the 3,752 bridges would have taken more than 12 years. In contrast, the risk-based approach completed the evaluations in three months, a considerable savings in project time. In addition, the scour vulnerability evaluations have ensured the safety of the traveling public, with no traffic disruptions.

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References

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