Improved Predictions of Pier Scour Save Bridge Resources

Florida Develops and Applies Findings

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Travelers in the United States rely on more than one-half million bridges to traverse valleys, bodies of water, roads, railroad tracks, and other physical obstacles. Bridge designs vary with function and with the nature of the terrain. In Florida, more than 8,600 bridges cross bodies of water.

Problem

Pier foundations placed in water disrupt the water's natural flow. The disrupted flow causes sediment erosion around the piers. This type of erosion, called local or pier scour, eventually lowers the channel bottom in the vicinity of the piers, reducing the stability of the bridge.

Standard practice requires that bridge foundations be designed to withstand the effects of scour for 100 years of flow. If the impacts of scour are underestimated, the bridge foundations will not be placed deeply enough in the stream bed, leading to bridge failure. In contrast, designs that overestimate scour depths produce bridge foundations that are deeper than required, significantly increasing the cost of construction. Accurate predictions of scour depths, therefore, are essential for a bridge to withstand conditions throughout its lifetime.

Local sediment scour at a bridge pier in a flood plain after a flow event.

Solution

The worldwide research community has identified the most important parameters related to structure, water flow, and sediment affecting pier scour depths. Applying dimensional analysis, researchers also have identified several dimensionless parameters that affect local scour depths. Determining the parameters that have the greatest impact and their interactions, however, has proved difficult.

Refining Predictive Equations

In the late 1980s, under a contract with the Florida Department of Transportation (DOT), Max Sheppard of the University of Florida tested the physical models of specific bridges. The test results showed that the predictive equations in the Federal Highway Administration's *FHWA Hydraulic Engineering Circular Number 18* (HEC-18) overpredicted scour depths for the cases examined. Applying the physical model results reduced the construction costs for the bridges significantly.

Florida DOT reinvested the savings from the shallower bridge substructure designs in additional research to develop equations for accurately predicting pier scour in noncohesive sediments, such as sand. As part of this research program, initiated in the early 1990s, Sheppard conducted local scour experiments in laboratories at the University of Florida, Colorado State University, the University of Auckland in New Zealand, and in a U.S. Geological Survey (USGS) Laboratory in Massachusetts. The experiments covered a range of structures and of sediment and flow conditions. The results from these tests served as the basis for developing the predictive equations.

The test results showed that local scour depths could be predicted accurately in terms of three parameters: V/V_c, y_1/a, and a/D_{50}, where V is the velocity of the flow approaching the pier, V_c is the flow velocity that initiates the movement of sediment away from the structure, y_1 is the unscoured water depth at the pier, a is the width of the pier, and D_{50} is the median grain diameter of the sediment at the site. Working independently, other researchers confirmed that these three are the most important parameters. The equations that were developed work well for piers of simple shape.

Adjusting for Complex Piers

Many bridge piers, however, are complex in shape, composed of pile groups, pile caps, and columns. In the late 1990s, Florida DOT and FHWA collaborated to develop predictive scour equations for complex piers. The equations build on the work with scour on simple structures and apply the predictive equations.

The complex pier was divided into its components, and an effective width was computed for each component. Effective width is defined as the width of a component if it were a single circular pile subjected to the same flow and sediment conditions as the complex pier component. The effective width of the complete complex pier is the sum of the effective widths of the components.

After the effective width of the complex pier is determined, the simple pier equations are used to compute the scour depth. Laboratory tests were conducted with pier components and complete piers to provide the information needed to develop equations for computing the effective widths of pier components. The fourth edition of HEC-18, issued in 2001, included a version of this procedure, and the methods and equations have been updated twice since then for the *Florida Scour Manual* as additional data became available.

Implementation

In 2005, Florida DOT adopted the newly developed pier scour equations as part of its design procedures. Florida DOT continues to update both the simple and complex pier scour design equations to reflect findings from ongoing research. Florida DOT applies the scour equations in the design of new bridges and in the scour analysis of existing bridges. Other states also are applying the equations.

Benefits

The findings from this research have improved the accuracy of local scour prediction. By using the new, more accurate equations, Florida DOT has avoided overpredicting scour at piers, especially for designs with fine sediment and large substructure widths. Florida DOT engineers have been able to design bridge foundations with lesser penetration depth and—in some cases—with fewer or smaller pilings.

In the past five years, Florida taxpayers have saved millions of dollars through the application of the new pier scour equations to bridge designs. In addition, Florida DOT has reclassified some bridges that previously had been considered high risk to low risk, because of the more accurate scour predictions.

Washington State applied the new equations in the construction of the new eastbound span of the Tacoma Narrows Bridge on State Route 16, reducing the predicted scour depth by 43 feet from that generated with the equations in HEC-18. This savings in construction cost for the two main piers amounted to approximately $8 million.

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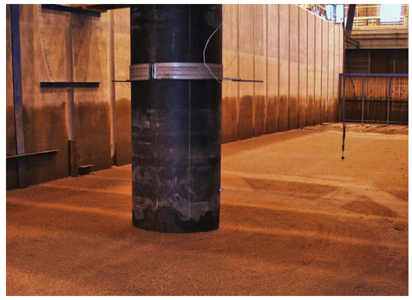

Local scour test in the S. O. Conte Anadromous Fish Research Center Hydraulics Laboratory, USGS, Turners Falls, Massachusetts: (*left*) setup in the 20-ft-wide by 126-ft-long flume with a 3-ft-diameter pier in 2.9-mm-diameter sand; (*right*) clear-water scour at the 3-ft-diameter pier after a testing with 6-ft water depth and flow velocity of 2.2 ft/s.

Resources

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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).