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Joint Workshop on Abutment Scour: Present Knowledge and Future Needs - June 2008

DETAILS

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JOINT WORKSHOP ON ABUTMENT SCOUR: PRESENT KNOWLEDGE AND FUTURE NEEDS—JUNE 2008

This digest summarizes key findings from a workshop sponsored by NCHRP Project Panels 24-15, 24-20, and 24-27 on the state of knowledge of bridge abutment scour. The workshop was held 23–24 June 2008 at the National Academies' Keck Center, Washington, DC. The workshop notes on which this digest is based were prepared by Larry Arneson, Federal Highway Administration, and Peter Lagasse, Ayres Associates, Inc.

INTRODUCTION

The United States Geological Survey (USGS) defines scour as the hole left behind when sediment (sand and rock) is washed away from the bottom of a river.[1] Although scour may occur at any time, scour action is especially strong during floods. Swiftly flowing water has more energy than calm water to lift and carry sediment down river.

Scour affecting bridges may be classified as follows:

1. *Local* scour is the removal of sediment from around bridge piers or abutments.
2. *Contraction* scour is the removal of sediment from the bottom and sides of a river channel at the bridge opening; it is caused by the increase in the speed of water as it moves through a bridge opening that is narrower than the river channel.
3. *Degradational* scour is the general, more global removal of sediment from the river bottom by the flow of the river that, while a natural process, may cause removal of large amounts of sediment over time at the bridge site.

The obvious danger of scour at or near a bridge is that the scour will undermine the piers and abutments that support the bridge and cause its catastrophic failure. In 1987, the 35-year-old bridge carrying Interstate 90 over Schoharie Creek in New York State failed with loss of life during a spring flood. This flood was classified as a 50-year event; the bridge had experienced a 100-year event soon after its construction. The failure was initiated by extensive scour under one of the bridge piers; the absence of adequate countermeasures to scour at the pier as well as unnoted damage from the 100-year and later events contributed to the pier's failure.

In the aftermath of this failure and the comprehensive investigations into its causes, the Federal Highway Administration (FHWA) instituted requirements for the states to identify overwater bridges vulnerable to scour and determine those where scour was severe. These inventories

[1]Warren, Linda P. "Scour at Bridges—What's It All About?, Stream Stability and Scour Assessment at Bridges in Massachusetts," U.S. Geological Survey Open-File Report 93-480, Online Only, http://ma.water.usgs.gov/publications/ofr/scour.htm.

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of bridge-site examinations, often undertaken with the assistance of the USGS, have allowed the states to plan and conduct maintenance and rehabilitation to remedy present scour and slow or prevent its future development.

Besides these practical measures, the states—individually and collectively through the National Cooperative Highway Research Program (NCHRP)—FHWA, and USGS embarked in the early 1990s on coordinated research programs to quantify and model the mechanisms of bridge scour and develop effective, efficient countermeasures to its occurrence. Table 1, which presents active, completed, and planned NCHRP projects related to all aspects of bridge scour, illustrates the scale of these programs. Similar compilations are shown for FHWA at http://www.fhwa.dot.gov/engineering/hydraulics/index.cfm and for USGS at http://water.usgs.gov/nrp/currenttopics.html#sed.

Of particular interest in Table 1, the common objectives of NCHRP Projects 24-27(01), 24-27(02), and 24-27(03) are to (1) critically evaluate the bridge-scour research completed since the early 1990s and (2) recommend the adoption of specific research results to AASHTO in its development of new editions of two key highway hydraulic engineering guidance documents: *Policy for Design of Highway Drainage Facilities* and *Recommended Procedures for Design of Highway Drainage Facilities.* With these projects underway, the members of NCHRP Project Panels 24-15, 24-20, and 24-27 met with invited technical experts on 23–24 June 2008 in a facilitated workshop to:

1. Discuss possible changes to the FHWA document *Evaluating Scour at Bridges, Hydraulic Engineering Circular No. 18* (HEC-18) arising from the results of recently completed research on *abutment* scour, and
2. Forecast the next 5 years of research needs in bridge scour.

Table 2 lists the participants in the 2-day workshop and their affiliations. Participants were drawn from the project panels for NCHRP Projects 24-15, 24-20, and 24-27; the research teams involved in the three projects; and NCHRP staff. An experienced team from the Center for Leadership and Organizational Change at the University of Maryland–College Park facilitated the workshop.

Table 1 NCHRP bridge scour projects

Project Number	Project Title*	Period of Performance
24-06	Expert System for Stream Stability and Scour Evaluation	1993–1999
24-07	Countermeasures to Protect Bridge Piers from Scour	1995–1998
24-07(02)	Countermeasures to Protect Bridge Piers from Scour	2001–2006
24-14	Scour at Contracted Bridge Sites	1998–2004
24-15	Complex Pier Scour and Contraction Scour in Cohesive Soils	1999–2002
24-15(02)	Abutment Scour in Cohesive Soils	2004–2008
24-16	Methodology for Predicting Channel Migration	1999–2003
24-18	Countermeasures to Protect Bridge Abutments from Scour	2001–2003
24-18A	Countermeasures to Protect Bridge Abutments from Scour	2003–2006
24-20	Prediction of Scour at Bridge Abutments	2002–2007
24-24	Criteria for Selecting Numeric Hydraulic Modeling Software	2004–2006
24-25	Guidelines for Risk-Based Management of Bridges with Unknown Foundations	2004–2006
24-26	Effects of Debris on Bridge-Pier Scour	2004–2007
24-27(01)	Evaluation of Bridge Scour Research: Pier Scour Processes and Predictions	2008–
24-27(02)	Evaluation of Bridge Scour Research: Abutment and Contraction Scour Processes and Predictions	2008–
24-27(03)	Evaluation of Bridge Scour Research: Geomorphic Processes and Predictions	FY 2009
24-29	Scour at Bridge Foundations on Rock	FY 2009
24-32	Scour at Wide Piers and Long Skewed Piers	2007—
24-33	Development of Design Methods for In-Stream Flow Control Structures	FY 2009

*For detailed information, go to http://www.trb.org/CRP/NCHRP/NCHRPProjects.asp?AreaID=24.

Table 2 Workshop participants

Name	Title	Affiliation
Kenneth Akoh-Arrey	Bridge Hydraulics Engineer	Arizona DOT
Larry Arneson	Senior Hydraulic Engineer	Federal Highway Administration
Stephen Benedict	Hydrologist	U.S. Geological Survey
Bart Bergendahl	Senior Hydraulic Engineer	Federal Highway Administration
Jean-Louis Briaud	Professor of Civil Engineering	Texas A&M University
Kuang-An Chang	Professor of Civil Engineering	Texas A&M University
Hamn-Ching Chen		Texas A&M University
Stanley R. Davis	Hydraulic Engineer	Jacobs Civil, Inc.
Robert Ettema	Professor of Civil Engineer	University of Wyoming
Daryl J. Greer	Director, Division of Planning	Kentucky Transportation Cabinet
Larry Harrison	Consultant	
Robert W. Henthorne	Regional Geologist	Kansas DOT
J. Sterling Jones	Consultant	
Kornel Kerenyi	Hydraulics Laboratory Manager	Federal Highway Administration
Andrzej Kosicki	Assistant Division Chief, Bridge Design Division	Maryland State Highway Administration
Peter Lagasse	Senior Vice President	Ayres Associates, Inc.
William L. Moore III	Consultant	
Tatsuaki Nakato	Professor of Civil Engineering	Iowa State University
Steve Ng	Senior Bridge Engineer	CalTrans
Jorge Pagan-Ortiz	Principal Bridge Engineer-Hydraulics	Federal Highway Administration
Richard A. Phillips	Bridge Hydraulics Engineer	South Dakota DOT
Rick Renna	State Hydraulics Engineer	Florida DOT
Bradford M. Rognlie	Senior Bridge and Hydraulics Engineer	Kansas DOT
Amy Ronnfeldt	Assistant Hydraulics Engineer	Texas DOT
Terry Sturm	Professor of Civil Engineering	Georgia Tech
Larry J. Tolfa	Engineer	New York State DOT
Mehmet T. Tumay	Associate Dean for Research	Louisiana State University
Facilitators and NCHRP Staff		
Judy Tso	Organizational Development Specialist	Center for Leadership and Organizational Change, University of Maryland–College Park
Amy Ginther	Organizational Development Specialist	Center for Leadership and Organizational Change, University of Maryland–College Park
Edward Harrigan	Senior Program Officer	NCHRP
David Reynaud	Senior Program Officer	NCHRP

The following section of this digest summarizes the changes recommended for HEC-18 and the 5-year research needs identified by the workshop participants.

FINDINGS

The fourth and latest edition of HEC-18 was published in 2001 and is available online from the FHWA at http://isddc.dot.gov/OLPFiles/FHWA/010590.pdf. HEC-18 provides guidelines for (1) designing new and replacement bridges to resist scour, (2) evaluating existing bridges for vulnerability to scour, (3) inspecting bridges for scour, and (4) improving the state of practice of estimating scour at bridges. HEC-18 represents the current state of knowledge and practice on bridge scour, and the document is subject to a continuous, cooperative program of review and revision by the state DOTs, the FHWA, and their consultants.

The potential changes to HEC-18 considered by the workshop participants are presented in Table 3. These are based, to a large extent, on the workshop

Table 3 Potential changes to *Evaluating Scour at Bridges, Hydraulic Engineering Circular No. 18* (HEC-18)

Technical and Editorial Improvements

1. Include section on measurement and classification of soil properties.
2. Include section on field data sets available to verify and validate scour prediction models. Note strengths and weaknesses of the data sets. Organize and categorize data with graphs and tables to assist the engineer in developing an understanding of field performance trends.
3. Add a discussion of the geomorphology and scour processes found in gravel bed rivers. Incorporate in both HEC-18 and HEC-20.
4. Separate abutment design into two steps: (1) embankment stability design and (2) abutment foundation design, to account for hydraulic relief due to potential embankment failure.
5. Include a section addressing incorporation of scour prevention in bridge construction practice.
6. Include practical recommendations on abutment scour geotechnical failures.
7. Consider addressing relief bridge scour.
8. Discuss the physics of scour and how it influences the methodologies for scour reduction and prevention.
9. Actively edit the document to achieve uniformity throughout of voice, language, and format, as well as smooth flow from section to section.
10. Critique all design methodologies to improve their clarity and ease of use.

Changes to Policies and Procedures

1. Include a policy on channel degradation.
2. Include a policy on riprap protection of abutments.
3. Provide a list of forecasted changes in future editions.
4. Develop a procedure to validate abutment scour equations with field data.
5. Provide more quantitative abutment scour guidance derived from the physics of the underlying processes.
6. Include a discussion of how the use of estimated or default versus measured values in design calculations affects the precision of calculated scour depths.
7. Improve the procedure for calculating contraction scour to take account of soil type.
8. Provide a procedure for calculating lateral channel movement.
9. Provide a venue for discussing the impact and implementation of results from non-federal, non-NCHRP research.

participants' discussion of the findings and conclusions of several active and completed NCHRP and USGS research projects.

Results of NCHRP Projects 24-15(02) and 24-20, were presented by the two principal investigators, Professors Jean-Louis Briaud of Texas A&M University and Robert Ettema of the University of Wyoming, respectively. Professor Briaud stressed the need for HEC-18 to provide engineers with a better understanding of how the behavior of both cohesive and cohesionless materials affects development of scour in streambeds and embankments. Professor Ettema discussed his research team's work on incorporating embankment failure into the abutment scour process, including laboratory testing to support modeling of different abutment failure mechanisms.

In his presentation, Professor Terry Sturm of the Georgia Institute of Technology discussed possible changes to HEC-18 and the two AASHTO documents based on his team's analysis of past research on abutment scour in NCHRP Project 24-27(02). Professor Sturm pointed out the difficulty of estimating abutment scour compared to pier scour as well as the practical inseparability of abutment scour from contraction scour, even though each depends on different physical processes.

Dr. Stephen Benedict of the USGS and Mr. Stanley Davis of Jacobs Civil, Inc. discussed their work on the validation of scour mechanisms and predictive models with measured field data. Obviously difficult, such validation studies are nonetheless invaluable in reconciling different scour models and refining and calibrating them to achieve reliable predictions.

Finally, the workshop participants developed seven recommended research problem statements for conduct in the next 5 years as NCHRP or state pooled-funds projects; these are summarized in Table 4.

Table 4 Recommended near-term (5-year) NCHRP or state pooled-fund research problem statements

#	Title	Objective(s)	Recommended Funding
1.	Statistical Prediction of Unknown Foundations	Develop practical tools to determine the type and penetration of unknown foundations.	$750,000
2.	Risk Approach to Bridge Scour Predictions	Develop a methodology for calculating the probability that scour will not exceed a given depth under the impact of a 50-, 100-, or 500-year flood event.	$500,000
3.	Probabilistic Approach to Prediction of Scour at Bridges	(1) Develop a methodology to accurately estimate the variation present in physical and design factors that most significantly affect scour at bridge piers and abutments and approach embankments. (2) Develop stochastic prediction models that can account for the variation in significant factors and yield probabilistic estimates of scour depth. (3) Integrate the probabilistic models into a single comprehensive model for conducting a complete assessment of overall bridge reliability.	$350,000
4.	Influence of Soil Properties on Scour Processes	(1) Characterize the effects of erodibility and related properties of natural and manufactured soils on scour processes. (2) Develop guidance for selection of proper scour methodology based on soil properties.	$500,000
5.	Interaction of Abutment and Contraction Scour	Identify location, magnitude, and mechanisms of simultaneous abutment and contraction scour in laboratory and field.	$600,000
6.	Validation of Abutment Scour Equations	Verify and validate abutment-scour equations developed in NCHRP Projects 24-15 and 24-20 using USGS field data sets.	$600,000
7.	Abutment Scour in Cohesive and Non-Cohesive Soils	Develop a unified design approach for abutment scour in cohesive and non-cohesive soils based on the results of NCHRP Projects 24-15(02) and 24-20.	$500,000

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These digests are issued in order to increase awareness of research results emanating from projects in the Cooperative Research Programs (CRP). Persons wanting to pursue the project subject matter in greater depth should contact the CRP Staff, Transportation Research Board of the National Academies, 500 Fifth Street, NW, Washington, DC 20001.