A Decade of High Priority Bridge Scour Research in the U.S.

By
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Abstract: The highway industry in the United States has sponsored scour research for more than 50 years, but it was always at a very modest level until a series of catastrophic bridge failures occurred in the late 1980's and early 1990's. These bridge failures lead to a tremendous increase in R&D, training and professional attention to a long standing problem for highway engineers involved in foundation design. The Federal Highway Administration was identified as the lead agency to address bridge scour issues in the U.S. This paper is a brief overview of the strategies and major activities undertaken in the U.S. to focus worldwide attention on this problem. The authors have been in the midst of most of these activities and are in a unique position to reflect on the most intense decade of bridge scour research that has ever been undertaken.

Background

The Federal Highway Administration (FHWA), or U.S. Bureau of Public Roads (BPR) prior to 1970, has sponsored bridge scour research for many years. Dr. E.M. Laursen conducted a series of bridge scour studies sponsored by the Iowa Highway Department under the BPR Highway Planning and Research Program (HP&R) at the University of Iowa in the 1950's. Laursen (1956) published the Iowa Highway Research Board Bulletin No. 4 (often referred to as the "redbook" on scour) and a series of journal papers that were the primary guidelines for bridge scour for a number of years to follow. In the 1960's the BPR funded a follow-up study at CSU using administrative contract funds. Dr Laursen spent a portion of his sabbatical leave from the University serving as an advisor to BPR while this study was being conducted. Dr. Verne Schneider's Ph D., dissertation was based in part on results from this study. Several research reports and journal articles were published by the researchers, but BPR did not implement the results in an engineering circular or a manual that would have been used as official guidelines for evaluating bridge scour.

In 1970, the National Cooperative Highway Research Program (NCHRP) Synthesis of Highway Practice No. 5 "Scour at Bridge Waterways" was published. The synthesis report identified at least 12 pier scour prediction equations, but was critical that there were not more answers after "80 years of research" dating back to at least to 1894 when H. Engels published results of model experiments. Authors of the synthesis report attributed the failure to produce more answers to a lack of sustained research effort. There were too many starts and restarts with researchers repeating what others had done without getting into the real difficult problems. The first priority in research on scour problems recommended in the synthesis report was field measurements.

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In 1971, the (by then) FHWA had negotiated a research contract with West Virginia University to make field measurements using automated instrumentation to operate during flood conditions whether or not researchers could reach the site during an event. That study, see Hopkins et al (1975), had limited success because of limited number of sites and instrumentation malfunctions at critical times. Following that study, FHWA determined that the best agency to make field measurements was the U.S. Geological Survey with a network of engineers in every State who were experienced in stream gaging activities. In 1987, an interagency agreement was set up between FHWA and USGS to begin the most successful real time bridge scour field measurement program that has ever been conducted.

Three Catastrophic Events that Provided Impetus for the National Scour Evaluation Program in the U.S.

The USGS field study and the bridge scour research program in general got major boosts in 1987, 1989 and 1995 when three catastrophic bridge collapses got national attention. When we reflected on our history of bridge failures we realized that more bridges collapses in the U.S. are caused by flooding and bridge scour than all other causes combined. Putting more of our national resources into a sustained bridge scour research program was not only justified; it was essential.

The first of the catastrophic failures occurred in April 1987 when the NY Throughway (I-90) over the Schoharie Creek collapsed in broad daylight and caused 10 fatalities. The collapse was captured on a video camera and made national news for several days. That failure demonstrated the erodibility of cohesive soils (a consolidated glacial till in this case) and the vulnerability of riprap protection if it is not inspected and maintained on a regular basis. For the first time in our memory, the national transportation safety board (NTSB), which routinely investigates airplane crashes, became involved in a bridge collapse investigation. One of the primary recommendations from NTSB was that FHWA was the responsible agency to take the lead in evaluating the nation’s bridges to determine how many others were vulnerable to this type of failure. That was the beginning of the national bridge scour evaluation program that involved every State Highway Agency in the U.S.

In April 1989, the second of the failures occurred at the U.S. 51 crossing of the Hatchie River near Covington, TN and caused 8 fatalities. That failure demonstrated the importance of considering channel migration in scour evaluations and of visualizing the foundation profiles against bathemetric surveys taken during bridge inspections.

In March 1995, the third failure occurred at the I5 crossing of the Los Gatos creek near Coalinga, CA and caused 7 fatalities. That failure featured a classic case of contraction scour and skewed pier scour for a long narrow obstruction. It also demonstrated the importance of having an interdisplinary team involved in bridge scour evaluations because a construction practice of using plain concrete below a certain elevation was part of the reason this bridge failed.

These three failures all involved fatalities, which is part of the reason they are considered catastrophic. There were scores of other bridges that failed during the same time period but were relatively unnoticed because they did not cause fatalities. Two of the three were also on Interstate highways, which are the highest level of the U.S. highways. The Interstate system is not expected to fail, but no one explained that expectation to the streams they cross.

A number of actions were taken during this time period that lead to where we are today. On Sept 16, 1988, FHWA issued Technical Advisory T5140.20 initiating the national bridge scour evaluation program and transmitting "Interim Procedures for Estimating Scour at Bridges" which was the predecessor to FHWA's Hydraulic Engineering Circular No. 18 (HEC-18). In October 1989, the Interagency Advisory Committee on Water Data Subcommittee on Sedimentation co-sponsored, with FHWA and the U.S. Geological Survey, the first Bridge Scour Symposium held at the FHWA Turner Fairbank Highway Research Center. Proceedings from that symposium contained 21 papers on six topics—scour prediction, monitoring, modeling, protection, special problems and research needs. On Oct 28, 1991, FHWA issued Technical Advisory T5140.23, which superceded the earlier Technical Advisory and referred to the first edition of HEC-18 "Evaluating Scour at Bridges" as guidance for conducting scour evaluations. This Technical Advisory also named scour at bridges as a High Priority National Program Area (HPNPA) for research to improve the state-of-practice for designing new bridges and evaluating existing bridges for scour.

Ramping the Research Program

Initiating the National Scour Evaluation program and elevating bridge scour research to a HPNPA status gave priority to funding for FHWA scour studies and cleared the way for extending the USGS field study and for initiating a number of new studies. State Highway agencies saw the need for better procedures and initiated cooperative field studies, with individual USGS district offices, which were coordinated by and fed into the national field study sponsored by FHWA. The program also prompted more and more requests by State Highway Agencies for scour studies through the National Cooperative Highway Research Program (NCHRP), which is funded by pooling a percentage of the State Planning and Research (SP&R) allocation from the federal aid construction budget.

FHWA dedicated its hydraulics laboratory to scour related studies for several years to investigate riprap protection at piers by Parola (1991), riprap protection at abutments by Pagan (1991), scour protection alternatives to riprap by Bertoldi et al (1996) and scour around complex pier geometries by Salim and Jones (1999). Additionally, FHWA initiated a series of important studies by contract to industry and other laboratories to investigate effects of bed material cohesion and gradation on scour by Molinas et al (2004), abutment scour in compound channels by Sturm (2004), geophysical techniques for measuring in-filled scour holes by Placzek and Haeni(1995), erodibility index method for determining scour limits through rock strata by Annandale (1995), large scale clear water experiments by Sheppard (2002), and remote methods for underwater bridge inspections by Bath (1999).

Prior to 1987, there was scarcely one NCHRP project on hydraulics or bridge scour in any given year. After the national scour evaluation program was underway, there were so many requests for scour studies that the NCHRP staff set up one project to lay out a strategic plan for bridge scour research. NCHRP has been funding projects from that strategic plan for the last decade. One NCHRP project (Lagasse et al 1997) developed scour monitoring and measurement instrumentation that has been installed at over 70 scour susceptible bridges. Currently there are more than a dozen NCHRP scour related projects ranging from scour in cohesive soils to risk based guidelines for managing bridges with unknown foundations. A description of all NCHRP projects- ongoing as well as completed - can be viewed on www4.nas.edu/trb/crp. A recent survey by Lagasse (2004) looked at how well the objectives in the NCHRP strategic plan have been addressed by research from all sources.

The Role of Professional Societies

Professional societies especially TRB and ASCE played a key role in binging researchers and practitioners together. TRB has sponsored at least one bridge scour technical session at the annual meetings every year since 1989 on Bridge Scour. TRB has sponsored several international bridge conferences with several bridge scour sessions that have been well received by bridge engineers in the U.S. ASCE formed a Task Committee, chaired by Dr. E.V. Richardson, on scour at bridges in 1990. The task committee organized bridge scour technical sessions at Hydraulics conferences every year from 1991 to 1998. In 12993, the task force was awarded the ASCE Hydraulic Division's Task Committee Excellence Award. The major deliverable from the Task Committee was the Compendium of Stream Stability and Scour Papers Presented at Conferences Sponsored by the Water Resources Engineering (Hydraulics) Division from 1991 to 1998 edited by Richardson and Lagasse (1999).

Guidelines and Training

FHWA published three engineering circulars to provide guidelines for evaluating scour at bridges and for selecting and designing scour countermeasures. Hydraulic Engineering Circular 18 (HEC-18) "Evaluating Scour at Bridges" was first published in 1991, but the fourth edition was published in 2001 (Richardson and Davis 2001). HEC-20 "Stream Stability at Highway Structures," is currently in the third edition (Lagasse, Schall and Richardson 2001). HEC-23 "Bridge Scour and Stream In stability Countermeasures," is currently in the second edition (Lagasse, Zevenbergen, Schall and Clopper 2001). Although these circulars are often thought of as FHWA policy, they were always intended as guidelines that assemble the best available research results in a format that facilitate the scour evaluation and countermeasure selection process.

The FHWA National Highway Institute developed three training course based on these three circulars. NHI course 135046, "Stream Stability and Scour at Highway Bridges" is the basic bridge course that has been taught in every state in the U.S. and a number of times abroad; it has been taught well over 100 times all together. NHI course 135047, "Stream Stability and Scour at Highway Bridges for Bridge Inspectors" is a shortened version that omits the equations and problem solving lessons. NHI course 135048 is the countermeasures course that focuses on HEC-23

The Next Step

Most of the major studies initiated during the last decade are nearing completion. Almost all of the objectives in the NCHRP strategic plan have apparently been addressed at least in part by some research. NCHRP is currently assembling a team of experts to look at the credibility of the research results to determine which ones are ready for implementation and which ones require additional work. Engineering circulars and training materials will continue to be updated periodically as research results are ready for implementation.

There are still numerous unanswered questions about bridge scour, but the lack of answers should not be attributed to a lack of sustained research.

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