LOUISIANA TRANSPORTATION RESEARCH CENTER
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Evaluation of Design Methods to Determine Scour Depths for Bridge Structures

INTRODUCTION

Scour of bridge foundations is the most common cause of bridge failures. The Federal Highway Administration (FHWA) has developed a design method, HEC-18, for the state Departments of Transportation (DOTs) to evaluate the scour potential of existing bridges and predict the scour depths for new bridges. The scour models in the HEC-18 were based on a number of empirical equations that were developed primarily from laboratory flume studies with limited field data verification. Because of the complex nature of scour process, these scour-prediction equations recommended in HEC-18 may tend to provide conservative scour depth estimates to ensure that an adequate factor of safety is considered for bridge scour design. Underestimation of scour depths may result in costly bridge repairs or even catastrophic bridge failures, while overestimation may cause costly, unnecessarily deep foundations. The scour potential evaluation for existing bridges is also important. Overestimation of scour depths causes more bridges to be misclassified as "scour critical," thus resulting in unnecessary installation of scour countermeasures or bridge replacements. Currently, the Louisiana Department of Transportation and Development (DOTD) uses the HEC-18 method for bridge scour design. Costs associated with the current design methods that usually lead to conservative estimation of scour depths can be very high. On the other hand, DOTD has developed and maintained a large database for a large number of bridge structures that are prone to scour. Those bridges were monitored and hydrologic and hydraulic data collected. In addition, different bed materials scour at different rates and, because of this fact, HEC-18 does not always accurately predict the scour depth at a certain time. A more reliable scour prediction method is needed, especially for the clay and silty clay soils common in Louisiana, with distinct local climatic characteristics (e.g., heavy downpours, severe storms, and hurricanes).

OBJECTIVE

The overall goal of the project was to evaluate the applicability of the existing HEC-18 method to Louisiana bridges that are mostly situated on cohesive soils and develop a more reliable design method for scour depth prediction in the state of Louisiana, with the consideration of the state's special meteorological and climatic characteristics and soil/sediment properties. In addition, the project also aimed to develop an innovative method to derive the real-time, accurate hydrologic and hydraulic properties required for scour analysis using the archived satellite remotely sensed data, so that the uncertainty in scour prediction associated with assumed virtual flood events can be minimized.

SCOPE

The scope of the project was limited to the evaluation of "pile-bent" supported bridges, but not including those bridges with footings. In addition to the total scour depth, it also considered the rate of scour and time to scour. The total scour depth included the long-term degradation or aggradation, general scour (particularly contraction scour), and local scour (pier or abutment scour). In terms of the soil types for bridge pile/pier foundations, both cohesionless and cohesive soils were considered, based on the types of soil recorded in the DOTD Bridge Scour Database. In particular, this project selected appropriate bridges from the DOTD Bridge Scour Database by considering the availability of scour survey data, stream/rain gage and weather data, and variable

LTRC Report 491

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PRINCIPAL INVESTIGATOR:
Guoping (Gregg) Zhang, Ph.D., P.E.
LSU

LTRC CONTACT:
Walid R. Alaywan, P.E., Ph.D.
225.767.9106

FUNDING:
State: TT-Reg

Louisiana Transportation Research Center

4101 Gourrier Ave
Baton Rouge, LA 70808-4443

www.ltrc.lsu.edu

soil types. The target case studies were 8-10 bridges, preferably with 2-3 bridges from each of the three major soil types considered: sand, clay, and silty-clay.

METHODOLOGY

A multidisciplinary approach was adopted to conduct the research, and it consisted of a series of analyses to derive the hydrologic and hydraulic parameters, followed by the scour analysis using the existing HEC-18 method.

The DOTD Bridge Scour Database was analyzed to select seven bridges situated on clayey and sandy soils as detailed case studies (Table 1 and Figure 1). For the selected bridges, the surveyed scour data were analyzed to develop scour depth development curves, which were then used to compare the calculated scour depths using the HEC-18 method.

Table 1
Summary of the seven selected bridges

Bridge	Bridge No.	Latitude	Longitude	Route	Crossing	Year built	Major soil type
Bogue Chitto Bridge	275-01-0801-1	30.9904	-90.1959	LA 438	Bogue Chitto	1967	sand
Bayou Lacassine Bridge	196-03-0258-1	30.0702	-92.8786	LA 14	Bayou Lacassine	1959	Silty clay
Bayou Nezpique at Jennings	450-04-0000-1	30.2401	-92.6225	I10	Bayou Nezpique	1961	Silty clay
Mermentau River @ Mermentau	003-09-0000-1	30.1910	-92.5941	US 90	Mermentau River	1980	Gray silty clay
Saline Bayou @ St. Maurice	009-05-0000-1	31.7682	-92.9692	US 71	Saline Bayou	1956	stiff clay
Tickfaw River Bridge	454-02-1883-1	30.4748	-90.6754	I12	Tickfaw River	1969	Silty sand
West Fork Calcasieu River Bridge	810-12-0422-1	30.2904	-93.2497	LA 378	West Fork Calcasieu River	1968	Silty clay

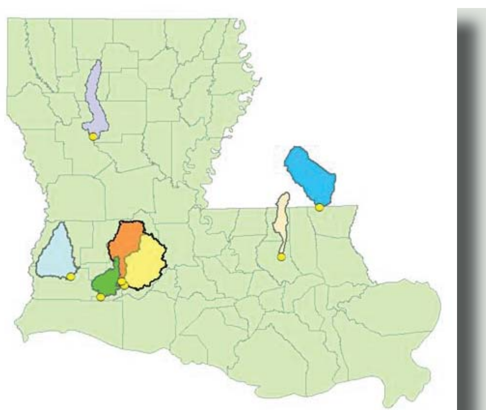

Figure 1
Location and watershed of seven selected bridges

For each selected bridge, the corresponding watershed model was developed using Geographic Information Systems (GIS) and HCE-GeoHMS. Such a GIS model considered the geophysical properties of the watershed, such as land coverage, elevation, topography, and soil types. Based on the location of the watershed, the satellite remotely sensed cloud top temperature images were then downloaded from data archives in the LSU Earth Scan Lab. After digitalization of these images, precipitation for the watershed was then obtained by a conversion of the cloud top temperature. Based on the record of U.S. Geological Survey (USGS) river gage data, two to five largest flood events were founded, and the storm events corresponding to these flood events were then determined as the initial input for the above analysis.

The hydrologic analysis of each flood event was conducted to determine the maximum discharge at the bridge site for the entire watershed, using the HEC-HMS software, followed by the hydraulic analysis and scour analysis using an integrated USGS program, WSPRO. The calculated scour depth was then compared and evaluated against the surveyed scour depth for each bridge and each flood events.

RECOMMENDATIONS

This study developed a new method to derive the real-time hydrologic and hydraulic data for scour analysis, hence significantly reducing the uncertainty associated with a virtual, assumed flood event. In addition, the flood and hydraulic data derived from satellite archived imagery are valuable and accurate dataset that can be used for future studies. The existing HEC-18 method tends to overestimate scour depth for the same flood event, as indicated by the significant discrepancy between the surveyed scour depth and the calculated one. Their ratio ranges from 0.07 to 0.60.

According to this study, it is recommended that scour surveys should collect more accurate data immediately or only after a large flood to avoid misleading long-term aggradation from small floods/flows, and it is not necessary to conduct scour depth measurements one to two times every year. Reduced scour frequency can reduce the expenditures for scour survey. Real-time (during a flood) scour monitoring and flood measurements for selected bridges are more useful for accurate calibration of the HEC-18 method. Finally, for new or replacement bridges, the geotechnical site investigation and testing program can be slightly expanded to collect more meaningful and useful data to be used for scour analysis. A unique combination of Louisiana's soil and climate conditions warrants special cautions in choosing a rational/reliable method to be used by DOTD engineers for scour analysis.