ARIZONA STATE GOVERNMENT BRIDGE SCOUR PROGRAM – A PRACTITIONER'S PERSPECTIVE

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The waterway bridges in the state of Arizona, an arid region, experience infrequent flash floods. Not considering culverts, there are approximately two thousand waterway bridges, half of them owned by State and the other half by local and Federal agencies. Following the guidelines from the Federal Highway Administration, Arizona and the other states have evaluated the waterway bridges for possible scour vulnerability. The results of these scour assessments are already reported. In Arizona, more than forty percent of the bridges were vulnerable to scour based on the calculated scour. Since then, the Arizona Department of Transportation has been installing various scour countermeasures under these bridges as a part of the States' Plan of Action. The current scour status of the bridges within the state is presented.

This paper will feature the scour countermeasures installed at three typical sites around the State. One such site encounters severe long term degradation. For this site, the countermeasure, comprising a concrete floor and an energy dissipater, under super critical flow conditions is discussed.

Keywords: Arizona; Scour; Countermeasure

1. INTRODUCTION

1.1. *Background*

A scour evaluation program for the Arizona Department of Transportation (ADOT) was triggered by the floods that prevailed during the period of 1977 through 1983. These events caused considerable damage to highways, with bridges lost during the flood of 1978, 1980 and 1983. ADOT and the Federal Highway Administration (FHWA) jointly implemented a scour evaluation program for the State bridges as early as 1979, acknowledging the multidisciplinary nature of scour and embraced the team concept for the different phases of the program.

Following the failure of the New York Thruway bridge over Schoharie Creek in 1987, Federal Highway Administration instituted the National Scour Program in 1988 through the Technical Advisory (TA) 5140.20. Later in 1991, a more comprehensive TA 5140.23 was issued detailing the guidelines and policies for assessing the scour vulnerability of existing and new bridges. Further, the FHWA technical publications entitled "Evaluating Scour at Bridges", Hydraulic Engineering Circular Number 18 (HEC - 18); "Stream Stability at Highway Structures" (HEC - 20) and "Bridge Scour and Stream Instability Countermeasures (HEC - 23) assisted the bridge owners in the implementation of the program [Richardson and Davis (2001), Lagasse et al (2001)]

The evaluation of the scour susceptibility of all public bridges has been mandated by the FHWA and was to be completed by January 1997. The states complied and the results are compiled and presented in the FHWA publication HEC-18. However, to conform with the FHWA directives, the bridge owners, had to develop further guidelines deem appropriate to each state. These criteria were necessary in developing abbreviated procedures and governing criteria to efficiently handle the scour assessment of large numbers of bridges. For example, in the state of Minnesota, erosion resistant rock included: granite, basalt, gabbro, quartzite and gneiss. If drainage area is less than 400 sq. mi. and piles are 40 ft. below the thalweg, the bridge is considered stable without analysis. If the average flood velocities are less than 3 fps for noncohesive material and 5 fps for clay, the bridge is considered stable without analysis. Nevada Department of Transportation (DOT) revisited the evaluation based on the most recent HEC-18 publication (fourth edition) and found that the number of scour critical bridges reduced by almost fifteen percent. Oregon DOT used the criterion that Spread footings with less than six foot embedment below the thalweg are assumed scour critical. In the state of Washington, if a pile foundation is embedded less than 10 feet below the calculated scour elevation, the bridge is declared scour critical. Most scour assessments utilize a single section normal flow analysis using the Manning's Equation. The effect of pressure flow is not considered.

ADOT bridges were evaluated based on similar criteria and assumptions. A minimum of 15 degrees skew is considered. Because most of the waterway bridges are ephemeral and most watersheds are vegetated four feet of debris width is added to the effective width of obstruction to the flow by the pier in estimating the scour depths. Also, similar to other states, a minimum of 50% of original embedment depth is considered necessary to remain for the bridge to be stable below the scour elevation after a superflood event. The superflood event was either the 500-year event or overtopping flood. It may also be noted that there were subtle differences between the scour assessment of state and local government bridges.

1.2. *Status of the Scour Program*

The initial evaluations have currently been translated to FHWA recommended National Bridge Inventory (NBI) ratings for the item No.113 [see Ref. Federal Highway Administration, (1995)]. The codes used and number of bridges in the assessed categories for combined local and state owned public bridges are listed in Table 1. Bergendahl and Jordan (1996) reported the details of the local government bridge scour evaluation. Table 1 is prepared pursuant to FHWA guidelines [also see Ref. Richardson and Davis, (2001)] for local government and state bridges. The analysis typifies that the state was conservative in its evaluation compared to other states' assessment of scour, if the culverts can be excluded from the list.

Table 1. Status of the Bridge Scour Evaluation Program as per FHWA's Requirements

State Bridges, Reporting Categories	NBI Item No 113	Federal Aid System	Federal Aid Off System	Total Number
I. Over Waterways		4240	1281	5521
II. Evaluation Total		4240	1281	5521
A) Low Risk	4-9	3758	944	4702
(1) Calculated or Assessed	4,5,7,8,9	3605	794	4399
(2) Screened	6	0	0	0
(3) Culverts	8	2917	729	3646
B) Scour Susceptible	6	44	67	111
C) Unknown Foundations	U	21	68	89
D) Tidal	T	0	0	0
E) Scour Critical	3	311	118	429
III. Analyzed for Scour		1323	552	1875
IV Countermeasures Planned		244	18	262
5. Monitoring Planned		0	0	0

2. TYPICAL CASE HISTORIES

A streambed usually comprises of silt, sand, gravel, cobbles and boulders over a rock formation that can be sedimentary or metamorphic. Usually driven piling is assumed to have encountered refusal at rock and embedment in rock and is often ignored in calculating the bearing capacity of the piles.

Scour countermeasures; a concrete floor, a concrete armor and a combination of bank protection, concrete floor and energy dissipater, installed at three different geographical locations of the state are outlined below.

2.1. Concrete Floor

This is the most common scour countermeasure the State uses because of reduced maintenance, reduced life cycle cost and dependability. It consists of constructing a reinforced concrete floor on top of the spread footings with cut-off walls both upstream and downstream. The floor is buried to avoid floodplain impacts and to promote vegetation growth.

2.2 Concrete Armor

This site is located towards the northeast part of the state. The spread footing foundation was initially thought to be on bedrock. However, Figure 1 illustrates that recent flash floods have caused the material under the footings to erode. There is a ten percent drop of the streambed across the bridge. A follow up geotechnical investigation indicated that the underlying Lukachukai Sandstone formation is composed of sub-rounded, light brown clear quartz, very fine grained and well sorted. The formation can readily deteriorate under the following conditions:

1. Leaching of Calcium significantly reduces the inter-particle bonding strength of sandstone
2. Permeable sandstone is susceptible to degradation from volume changes of freezing water.

The trough type deposit is calcareous cemented, with an unconfined compressive strength ranging from 2800 to 4600 psi and the unit weight ranged from 118 to 121 pcf.

Based on these considerations, a reinforced concrete apron with cut off walls was proposed around each spread footing as the countermeasure. The installation of the reinforced concrete armor around the pier is depicted in Figure 2. It may be noted that the raised armor is anchored to the existing sandstone formation with cut off walls embedded into the sandstone sufficiently away from the footings of the pier.

Figure 1 The scoured spread footing foundation prior to installing the countermeasure

Figure 2 The spread footing foundation after during the installation of the countermeasure

2.3 Combination of bank protection, concrete floor and energy dissipator

This site is located towards the northwest part of the state. Downstream channel degradation due to a gravel mining operation, had caused channel head cutting to propagate upstream to the bridge location. The head cutting and scour downstream of the bridge had resulted in a 15 feet drop located 65 feet downstream of the bridge. A geomorphic analysis, based on Simons, Li & Associates (1982 and 19886), predicted the ultimate channel thalweg elevation just downstream of the bridge to be between 27 and 30 feet below the pier caps, and the predicted scour hole for the 500 yr flood to add an additional 17 feet of depth. Also, the channel has a 70 degree bend located 150 feet upstream of the bridge and a 90 degree bend located 700 feet upstream of the bridge.

At this location the countermeasure chosen was a reinforced concrete floor under the bridge, and a baffle chute spillway downstream of the bridge. Bank protection upstream of the bridge was also constructed at the channel bends. The concrete floor extends to the brink of the baffle chute spillway, which is located 36 feet downstream of the bridge. The methodology in U.S. Department of the Interior, Bureau of Reclamation (1987) was used to design the spillway. This methodology assumes subcritical flow at the spillway brink, and the normal flow through the bridge is supercritical. To avoid having to force a hydraulic jump upstream of the spillway, which could potentially reduce the flow capacity of the bridge, the methodology was modified to allow for supercritical flow at the spillway brink, using the methodology in Heggen (1995). The supercritical flow design reduces splash at the top of the spillway by eliminating the vertical sill at the spillway brink and reducing the height of the top four rows of baffles. To protect from scour downstream of the end of the spillway a 25 foot long Articulated Block Mat (ABM) was attached to the downstream end of the spillway. Fourteen foot high training walls along the spillway with riprap along the outside of the walls, will prevent erosion from any splashing that occurs.

3. CONCLUSIONS

The paper details a practitioner's perspective of the scour program, envisioned by the FHWA. Culverts quoted with the NBI rating N113=8, because of the existing concrete floor, can be excluded from the list, so that the results are not skewed. An engineering team approach will always develop the best results. The paper demonstrates the need for research to link calculated scour depth to observed condition. Also, it may further be concluded that the bridge owners should have the flexibility to use engineering judgments as deemed appropriate to each site so that the safety of the traveling public is not compromised.

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