Ferrando, Guillermo; Santa Fe, Carlos Cian

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PREDICTION PAPERS
PIER SCOUR PREDICTION FOR MISSISSIPPI RIVER BRIDGE
PIER 11 for the 08-03-93 flood event
Bridge Case 7

Authors: Civil Engineer Guillermo Ferrando and Hydroresources Engineer Carlos Cian
Santa Fe – ARGENTINA.

A - Prediction Methodology used.
To determine pier scour we used the CSU (Colorado State University) equation. The equation is:

(1) \[ Y_s = Y_1 \cdot 2.0 \cdot K_1 \cdot K_2 \cdot K_3 \cdot K_4 \cdot (a/Y_1)^{0.65} \cdot \text{Fr}_1^{0.43} \]

Where:

- \( Y_s \) = Scour depth; m
- \( Y_1 \) = Flow depth directly upstream of the pier; m
- \( K_1 \) = Correction factor for pier nose shape.
- \( K_2 \) = Correction factor for angle of attack of flow.
- \( K_3 \) = Correction factor for bed condition.
- \( K_4 \) = Correction factor for armoring by bed material size.
- \( L \) = Length of pier; m.
- \( a \) = Pier width; m.
- \( \text{Fr}_1 \) = Froude Number directly upstream of the pier; \( V_1/(g \cdot Y_1)^{1/2} \).
- \( V_1 \) = Mean velocity of flow directly upstream of the pier; m/s.
- \( g \) = Acceleration of gravity; 9.81 m/s².

There are many situations about this case.

At the first time, we have the basic formula (1) with the data of the footing, to know:
- WS elevation: 118.38 m
- Bed elevation: 95.86 m
- Skew angle (\( \theta \)): 11°
- Pier scour in condition "Live - bed"
- Bed form: Dune
- \( Y_1 \) = 22.52 m

We calculated the values of "a" and "L", using the following averages pondered for the depth:

(2) \[ a_{\text{average}} = \frac{3.20 \text{m} \times 7.32 \text{m} + 10.67 \text{m} \times 5.49 \text{m} + 8.65 \text{m} \times (2.74 \text{m} + 2.42 \text{m})/2}{3.20 \text{m} + 10.67 \text{m} + 8.65 \text{m}} = 4.63 \text{m} \]

(3) \[ L_{\text{average}} = \frac{3.20 \text{m} \times 16.00 \text{m} + 10.67 \text{m} \times 14.78 \text{m} + 11.57 \text{m} \times 6.86 \text{m} + 7.63 \text{m} \times 1.79 \text{m}}{22.52 \text{m}} = 13.41 \text{m} \]

\( V_1 = 2.429 \text{ m/s} \)

Froude number:
\( \text{Fr}_1 = \frac{2.429}{(9.81 \times 22.52)^{1/2}} = 0.163 \)

\( K_1 \) - The correction factor \( K_1 \) for pier nose shape should be determined for angles of attack up to 5 degrees. For greater angles, \( K_2 \) dominates and \( K_1 \) is considered as 1. Then \( K_1 = 1 \).

\( K_2 \) can be calculated using the following equation:

\[ K_2 = (\cos\theta + L/a \cdot \sin\theta)^{0.65} \]

\[ K_2 = (\cos 11° + 13.41/4.63 \times \sin 11°)^{0.65} = 1.32 \]
K₃ = 1.1, because the data is dune.

K₄.- The correction factor result from recent research for FHWA by Molinas at CSU. This factor decreases scour depths for armoring of the scour hole for bed material that have a D₅₀ equal to or larger than 0.06m (D₅₀ ≥ 0.06m).- For this case D₅₀ = 0.0006m, then K₄ = 1.0

Other data used are:
WS elevation: 118.38 m
Bed elevation: 95.86 m
Skew angle (θ): 11°
Pier scour in condition “Live - bed”
Bed form: Dune

Equation 21:
\[ Y_{s1} = 22.52 \times 2.0 \times 1.0 \times 1.32 \times 1.1 \times 1.0 \times \left( \frac{4.63}{22.52} \right)^{0.05} \times \left( \frac{0.163}{0.43} \right) \]

Then: \[ Y_{s1} = 10.72 \text{ m} \]

We calculated the one second value of scour depth based in recommendations of the publication Nº FHWA-IP-90-017 – November 1995, Hydraulic Engineering Circular Nº 18, pages 39 and 40, we used for prediction pier scour the followings sketch:

The formula is:
(4) \[ V_f = V_1 \times \frac{\ln (10.93 \times Y_f / D_{84} + 1)}{\ln (10.93 \times Y_1 / D_{84} + 1)} \]
Where:
\[ V_1 = 2.249 \text{ m/s} \]
\[ Y_1 = 22.52 \text{ m} \]
\[ D_{84} = 0.0013 \text{ m} \]
\[ Y_f = 3.20 \text{ m} \]

Then \[ V_f = 2.04 \text{ m/s} \]

The Froude number is:
\[ Fr_f = \frac{2.04}{(9.81 \times 3.20)^{1/2}} = 0.364 \]

And \[ K_2 = (\cos 11^\circ + 13.41 \text{ m/4.63 m} \times \sin 11^\circ)^{0.66} = 1.321 \]

K₃ = 1.1, adopted of table for small dunes.
K₄ = 1.0

Applied the CSU equation with this data we obtain:
$$Y_{s1} = 3.20m \times 2.0 \times 1 \times 1.321 \times 1.1 \times 1 \times (4.63m/3.20m)^{0.65} \times (0.364)^{0.43}$$

Then: $$Y_{s2} = 7.66 \text{m}$$

Note: during the data investigation, we knowed (internet) that in 1993 the measured scour at the pile 11 in this bridge was 7.10m (23.3 ft) – BSDMS Summary Report – Site 57 Mississippi River at S.R.51/150 at Chester, which very similar to $Y_{s2}$ calculated in this paper.

The HEC-18 has recommended to adopt the bigger within both results (page 39).

According with HEC-18, for PREDICTION EVENT we adopt the value $$Y_{s1} = 10.72 \text{m}.$$  

**B - Additional data.**
We had considered that the data was enough for this case.

**C – Best estimate of the cost for obtaining the additional data.**
Is not necessary additional cost.

IC Guillermo Ferrando
IRH Carlos Cian