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PREDICTION PAPERS

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

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A - Prediction Methodology used.

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

$$(1) \quad Y_s = Y_1 \cdot 2.0 \cdot K_1 \cdot K_2 \cdot K_3 \cdot K_4 \cdot (a/Y_1)^{0.65} \cdot Fr_1^{0.43}$$

equation number 21 - page 36 - Publication N° FHWA-IP-90-017. November 1995 - Circular HEC N°18.

Where:

Y_s = Scour depth; m
Y₁ = Flow depth directly upstream of the pier; m
K₁ = Correction factor for pier nose shape.
K₂ = Correction factor for angle of attack of flow.
K₃ = Correction factor for bed condition.
K₄ = Correction factor for armoring by bed material size.
L = Length of pier; m.
a = Pier width; m.
Fr₁ = Froude Number directly upstream of the pier; $V_1/(g Y_1)^{1/2}$.
V₁ = 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 (θ) : 11°

Pier scour in condition "Live - bed"

Bed form: Dune

Y₁ = 22.52 m

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

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

$$a_{\text{average}} = 4.63\text{m}$$

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

$$L_{\text{average}} = 13.41\text{m}$$

$$V_1 = 2.429\text{m/s}$$

Froude number:

$$Fr_1 = 2.429 / (9.81 \times 22.52)^{1/2} = 0.163$$

K₁.-The correction factor K₁ for pier nose shape should be determined for angles of attack up to 5 degrees.- For greater angles, K₂ dominates and K₁ is considered as 1. Then K₁= 1.

K₂ can be calculated using the following equation: $K_2 = (\cos \theta + L / a \sin \theta)^{0.65}$
 $K_2 = (\cos 11^\circ + 13.41/4.63 \times \sin 11^\circ)^{0.65} = 1.32$

$K_3 = 1.1$, because the data is dune.

K_4 .- 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 D_{50} equal to or larger than 0.06m ($D_{50} \geq 0.06\text{m}$).- For this case $D_{50} = 0.0006\text{m}$, then $K_4 = 1.0$

Other data used are:

WS elevation: 118.38 m

Bed elevation: 95.86 m

Skew angle (θ) : 11°

Pier scour in condition "Live - bed"

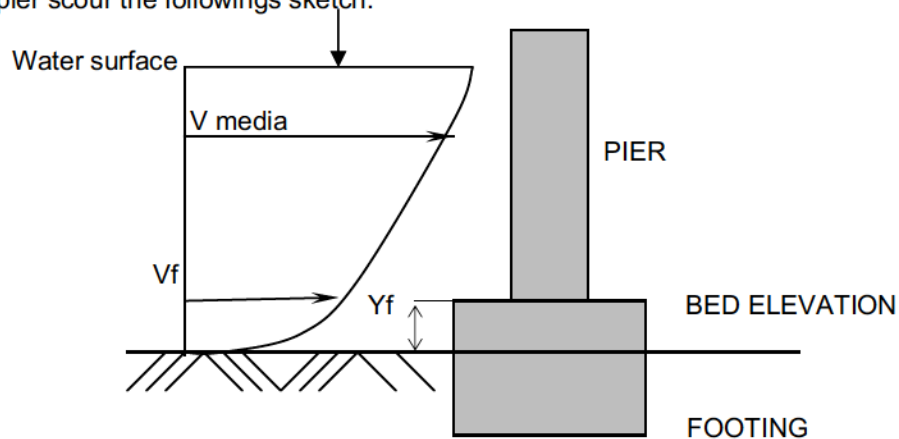
Bed form: Dune

Equation 21:

$$Y_{s1} = 22.52 \times 2.0 \times 1.0 \times 1.32 \times 1.1 \times 1.0 \times (4.63 / 22.52)^{0.65} \times (0.163)^{0.43}$$

Then : **$Y_{s1} = 10.72 \text{ m.}$**

We calculated the one second value of scour depth based in recommendations of the publication N° FHWA-IP-90-017 – November 1995, Hydraulic Engineering Circular N° 18, pages 39 and 40, we used for prediction pier scour the followings sketch:



The formula is:

$$(4) V_f = V_1 \times [\ln (10.93 \times Y_f / D_{84} + 1) / \ln (10.93 \times Y_1 / D_{84} + 1)]$$

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:

$$Fr_f = 2.04 / (9.81 \times 3.20)^{1/2} = 0.364$$

$$\text{And } K_2 = (\cos 11^\circ + 13.41\text{m}/4.63\text{m} \times \sin 11^\circ)^{0.65} = 1.321$$

$K_3 = 1.1$, adopted of table for small dunes.

$K_4 = 1.0$

Applied the CSU equation with this data we obtain:

$$Y_{s1} = 3.20\text{m} \times 2.0 \times 1 \times 1.321 \times 1.1 \times 1 \times (4.63\text{m}/3.20\text{m})^{0.65} \times (0.364)^{0.43}$$

Then : **Y_{s2} = 7.66 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*, wich very similar to Y_{s2} calculated in this paper.

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

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

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.-

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11/07/2002.