OBSERVATION METHOD: A NEW TOOL FOR THE BRIDGE SCOUR ENGINEER

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SCOUR DEPTHS

$Z_{(abut)}$ Applies

$Z_{(cont)}$ Applies

Probable Flood Level

$Z_{(pier)}$

Normal Water Level
PROBLEM

1. Comparison between measured and calculated scour depths by current method (HEC-18) exhibits a lot of scatter.

2. Comparison between measured and calculated scour depths by current method (HEC-18) shows excessive conservatism on the average.
**HEC-18 RESULTS**

![Graph showing HEC-18 results with data points and a ratio of predicted to measured values.]

- **Measured Landers-Mueller Pier Scour, $z_{max}$ (m)**
- **Deterministic HEC-18 Sand, $z_{max}$ (m)**

- **LANDERS-MUELLER DATABASE PIER SCOUR**

- **Equation:** $Z_{predicted}/Z_{measured} = 3.26$
HEC 18 Results–Bridge Case Histories

\[ y = 1.7699x \]

\[ R^2 = 0.3074 \]
OMS Results-Bridge Case Histories

\[ y = 1.0669x \]

\[ R^2 = 0.8612 \]
EFA - EROSION FUNCTION APPARATUS
Scour Rate vs Shear Stress

Scour Rate vs Velocity

EROSION FUNCTION FOR A FINE SAND

Shear Stress (N/m²)

Scour Rate (mm/hr)

Velocity (m/s)

Scour Rate (mm/hr)

Sand

D₅₀=0.3 mm
EROSION FUNCTION FOR A LOW PI CLAY

Scour Rate vs Shear Stress

Scour Rate vs Velocity

Porcelain Clay
PI=16%
Su=23.3 Kpa
POCKET ERODOMETER

PET test result = Depth of hole in mm after 20 squirts at 8 m/s

$0.49 at Walmart
BOREHOLE EROSION TEST - BET

Fluid circulation

Borehole caliper
BOREHOLE EROSION TEST - BET
EROSION CLASSIFICATION

- Very High Erodibility I
  - Fine Sand
  - Non-plastic Silt
  - Increase in Compaction (well graded soils)
  - Increase in Density
  - Increase in Water Salinity (clay)

- High Erodibility II
  - Medium Sand
  - Low Plasticity Silt

- Medium Erodibility III
  - Jointed Rock (Spacing < 30 mm)
  - Fine Gravel
  - High Plasticity Silt
  - Low Plasticity Clay
  - All fissured Clays

- Low Erodibility IV
  - Jointed Rock (30-150 mm Spacing)
  - Cobbles
  - Coarse Gravel
  - High Plasticity Clay

- Very Low Erodibility V
  - Jointed Rock (150-1500 mm Spacing)
  - Riprap
  - Intact Rock (Spacing > 1500 mm)

- Non-Erosive VI

EROSION RATE (mm/hr)

SHEAR STRESS (Pa)
\[ V_c = 0.07 \left(D_{50}\right)^{-1.45} \]
\[ V_c = 0.1 \left(D_{50}\right)^{-0.12} \]
\[ V_c = 0.315 \left(D_{50}\right)^{0.5} \]

Legend:
- TAMU Erosion EFA Data - Coarse
- TAMU Erosion EFA Data - Fine
- Data from Shields, Casey, US.WES, Gilbert, White as reported by Vanoni, V.A., ed. (1975).

"Sedimentation Engineering." ASCE manuals and reports on engineering practice, ASCE, New York.
Legend:
- TAMU Erosion EFA Data - Coarse
- TAMU Erosion EFA Data - Fine
**Observation Method for Bridge Scour**

1. **Step 1**: Observe maximum scour depth = $Z_{mo}$
2. **Step 2**: Find out the maximum flood the bridge has been subjected to: Collect gage data, RI from TAMU-OMS, $Q_{mo}/Q_{100}$, $V_{mo}/V_{100}$
3. **Step 3**: Extrapolate field measurements to predict future scour depth
   \[
   \frac{Z_{fut}}{Z_{mo}} = F \left( \frac{V_{fut}}{V_{mo}} \right)
   \]
4. **Step 4**: Compare future scour depth to foundation depth (pier) $Z_{fut} < Z_{found}/2$
Step 1: Observe maximum scour depth = $Z_{mo}$

$Z_c = $ Contraction Scour

$Z_p = $ Pier Scour

$Z_a = $ Abutment Scour
Step 2: Find out the maximum flood the bridge has been subjected to = $V_{mo}$

930 Flow Gages in Texas and neighbor States
Step 2: Find out the maximum flood the bridge has been subjected to = $V_{mo}$

Maximum RI map between 1970 and 2005

Automated with TAMU-OMS software
Step 2: Find out the maximum flood the bridge has been subjected to = $V_{mo}$

Maximum RI map between 1920 and 2005

Automated with TAMU-OMS software
Step 3: Extrapolates field measurements to predict future depth $Z_{fut}$

$$\frac{Z_{fut}}{Z_{mo}} = F\left(\frac{V_{fut}}{V_{mo}}\right)$$

• Known = $Z_{mo}$ and $V_{mo}$
• Choose $V_{fut}$
• Obtain $Z_{fut}$ from charts
• The Z-Future Charts were developed by performing a large number (~350,000) of HEC-18 Clay simulations using varying pier, contraction & abutment scour geometries, varying soil conditions, varying velocities, and varying age of the bridge.
Step 3: Extrapolates field measurements to predict future scour depth $Z_{fut}/Z_{mo} = V_{fut}/V_{mo}$

**Category III Materials**
- Upstream Water Depth ($H_1$): 5 m to 20 m
- Contraction Ratio ($R_c$): 0.5 to 0.9
- Critical Velocity ($V_c$): 0.5 m/s
- Pier Diameter ($D$): 0.1 m to 1.0 m
- $t_{hyd} = 25$ years
Step 4: Compare future scour depth to foundation depth $Z_{fut} < \frac{Z_{found}}{2}$
APPLICATION TO SCOUR CRITICAL BRIDGES
Texas

- 15 bridges selected (12 scour critical, 3 stable)
- 6 scour critical bridges out of the 12 found stable by the observation method
- 3 stable bridges found stable by the observation method
- 6 of 12 bridges originally classified scour critical were found stable by the observation method
PROB. OF FAILURE: HIGH

TAMU-OMS Results
Soil Category = I&II
Rlmo = 68
Rlfut = 100
Vfut/Vmo = 1.035
Zfut/Zmo = 1.055

Zfut(OMS) = 3.38 m
Zfut(HEC-18) = 6.08 m
Zmo = 3.20 m
Zfound/2 = 2.99 m
Zfound = 5.98 m
PROB. OF FAILURE: LOW

TAMU-OMS Results

Soil Category = III
Rlmo = 34
Rlfut = 100
Vfut/Vmo = 1.105
Zfut/Zmo = 1.110

Zfut(OMS) = 0.18 m
Zfut(HEC-18) = 2.85 m
Zfound = 1.06 m
Zfound/2 = 0.53 m
Zmo = 0.16 m
0072-04-020

PROB. OF FAILURE: MED

TAMU-OMS Results
- Soil Category = I&II
- $R_{lmo} = 68$
- $R_{lfut} = 100$
- $V_{fut}/V_{mo} = 1.07$
- $Z_{fut}/Z_{mo} = 1.105$

Zfut(OMS) — — —
Zfut(HEC-18) — — —

$Z_{mo} = 1.92$ m

$Z_{fut}(OMS) = 2.12$ m

$Z_{fut}(HEC-18) = 7.28$ m

$Z_{found}/2 = 2.59$ m

$Z_{found} = 5.18$ m
TAMU-OMS Results
- Soil Category = I&II
- Rlmo = 74
- Rifut = 100
- Vfut/Vmo = 1.030
- Zfut/Zmo = 1.080

PROB. OF FAILURE: LOW

Zfut(OMS)
Zfut(HEC-18)

Zfound/2 = 2.69 m
Zfound = 5.37 m
Zmo = 0.60 m
Zfut(OMS) = 0.65 m
Zfut(HEC-18) = 1.55 m
TAMU-OMS Results

- Soil Category = I&II
- RLmo = 22
- Rlfut = 100
- Vfut/Vmo = 1.415
- Zfut/Zmo = 1.855
Drawbacks

• Requires a good network of flow gages
• Cannot be used directly for new bridges
• Estimate in filling (USGS and a TxDOT survey have found that it was rare (10% of the time) and ranged from 2 to 4 ft)
• Not yet developed for layered soil (be careful with thin hard layer over soft layer)
Advantages

- Valuable tool to prioritize bridge repairs, countermeasure decisions, asset management
- Can serve as an input to FHWA risk approach
- Part of the practical design concept
- No need for erosion testing
- Actual soil
- Actual flow history
- Actual geometry
- Based on observed measurements
DIFFERENCES BETWEEN HEC 18 AND OBSERVATION METHOD

<table>
<thead>
<tr>
<th><strong>HEC 18</strong></th>
<th><strong>OMS</strong></th>
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</thead>
<tbody>
<tr>
<td>• Flume tests (scale pb?)</td>
<td>• Full scale</td>
</tr>
<tr>
<td>• Wrong worst soil (Fine sand)</td>
<td>• Right soil</td>
</tr>
<tr>
<td>• Simplified geometry</td>
<td>• Exact geometry</td>
</tr>
<tr>
<td>• Simplified single velocity</td>
<td>• Exact velocity hydrograph</td>
</tr>
</tbody>
</table>
COMPARISON

HEC 18

\[ y = 1.7699x \]
\[ R^2 = 0.3074 \]

OMS

\[ y = 1.0669x \]
\[ R^2 = 0.8612 \]
The Million Dollar Stick with TAMU-OMS
Free
courtesy of TxDOT, MassDOT and TAMU