Real-Time Monitoring of Bridge Scour in Clayey Sediments

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Outline

- Introduction
- TDR Background and Previous Work
- Experiment Program
- Results
- Conclusions and Recommendations
Introduction

- Scour of pier or abutment poses a most severe threat to bridge service life. 503,000 bridges traverse waterways, over 20,000 are classified as scour critical (in U.S. alone).
- 1000 bridges have collapsed in 30 years in the USA and scour was responsible for 60% of those failures.
Introduction

Scour hole development – a dynamic process
TDR for Bridge Scour Monitoring

- Use guided “radar” to identify materials properties and interfaces.
- Involves fast rising EM pulse of picoseconds to identify high frequency responses

Schematic diagram of a TDR system for the application in Geotechnical Engineering
Information from TDR signal

- Dielectric constant and electrical conductivity

\[ K_a = \left( \frac{L_a}{L_p} \right)^2 \]

\[ L_p = \text{length of probe in soil} \]

\[ EC_b = \frac{1}{C} \left( \frac{V_s}{V_f} - 1 \right) \]

Apparent Length, \( L_a \)

\( V_s/2 \)

\( V_f \)
Measure simulated scour using TDR

Schematic of TDR monitoring of simulated scour
TDR Sensors

CS610 Sensor from Campbell Scientific

Strip Scour Sensor with U-Beam Support
Scour Measurement Equations

\[ \frac{\sqrt{K_{a,m}}}{\sqrt{K_{a,w}}} = \frac{x}{L} \left( \frac{\sqrt{K_{a,bs}}}{\sqrt{K_{a,w}}} - 1 \right) + 1 = -C x_r + 1 \]

Coated TDR Sensor (Ferré et al. 1996)

\[ K_c^n = w K_{coating}^n + (1-w) K_a^n \]
Previous Scour Measurement Equation

**Step 1:** Determining the bulk dielectric constant $K_{a,m}$ from TDR signal

**Step 2:** Determine the ratio of sand layer/probe length from design equation

**Step 3:** Calculate scour depth

$$\frac{\sqrt{K_{a,m}}}{\sqrt{K_{a,w}}} = ax_r + b$$

$$S_D = (1 - x_r)L$$

Procedure of using the measurement equation (data from fine sand)
Monitoring of Simulated Scour in Various Soil and Water Conditions

- Testing materials
Calibration coefficient for different soils

Normalized TDR measurements for coarse sand
Field Installation

Ohio State Route 122 Bridge over Great Miami River
Sample Results

Measured Waveforms at Different Time

Measured Scour Depth
Lab Experiment Program
Experiment setup

TDR CS610 Sensor

Strip-Scour Sensor
Sample Signals of Scour Measurement

Purdue TDR Method---Insitu MRP Test

Waveforms

Wave Analysis

Soil Parameters

Analysis Results

Save Test
Test Results – CS610 Sensor

- Reflections at probe head
- Water/clay interface

Graph showing Relative Voltage (V) versus Scaled Distance (m) for different sensor lengths in soil.
Test Results – Strip Scour Sensor

Reflections at air/water interface

- Sensor length in soil: 137mm
- Sensor length in soil: 198mm
- Sensor length in soil: 282mm
- Sensor length in soil: 352mm
- Sensor length in soil: 452mm
- Sensor length in soil: 590mm

Scaled Distance (m)

Relative Voltage (V)

water/clay interface

strip sensor end
Results Analysis

\[ \sqrt{\frac{K_{a\_all}}{K_{a\_water}}} \]

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\[ \sqrt{\frac{K_{a\_all}}{K_{a\_water}}} \]

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Linear fit of cs610
Linear fit of strip-sensor
Measured Dielectric constant by Strip Scour Sensor

\[ K_c^n = wK_{coating}^n + (1 - w)K_a^n \]
Measured Scour Depth

The graph shows the comparison between predicted and measured water depths. The data points are represented by black squares and red circles, respectively, indicating the performance of the strip-sensor. The dashed line represents a perfect 1:1 correlation, suggesting that the predicted depths closely match the measured ones.
Conclusions and Recommendations

- The strip scour sensor is sensitive to scour changes in porcelain clay. Both CS610 and strip TDR sensor can measure scour in the porcelain clay.
- The previous design equation works for porcelain clay with new calibration constants.
- More studies using in-situ clay samples are needed.
- More robust design to ease the installation and prevent the damage from flow debris.
Acknowledgements

- Bill Yu
- Anand Puppala
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Welcome Collaborations!