Development of a Durable Bridge Scour Monitoring System based on Time Domain Reflectometry

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Outline

• Introduction
• TDR basics/ review
• Development of TDR scour sensing waveguide
• Data reduction: calibration and measurement
• Pilot field installation and evaluation
• Future study
Introduction

2000 KaoPing bridge

2008 HoFung bridge

2012 ChungZen bridge
Introduction

Dropping weight

Sonar, Acoustic

Float out device

Magnetic sliding collar

Piezoelectric film

Optical, FBG

Feasibility for Taiwan

1. Durability
2. Economy

Possible Solution:

→ Time Domain Reflectometry (TDR)
TDR basics

TDR System

- Step Generator
- Sampler

Coaxial Cable

Sensing waveguide

Oscilloscope

Cable deformation type

Landslide

Interface type

Dielectric type

Extensometer

Rain gauge

Water level

Water content

Suspended sediment concentration
TDR scour review

Dowding and Pierce (1994)

Max scour & Hard installation

Attenuation & Hard installation

Yankielun and Zabilansky (1999)

Practical probe design

Yu & Yu (2011)
Development of TDR scour sensing waveguide

Main steel strand + insulated wire

1. Reduce signal attenuation
2. Increase durability
3. Easy installation
Development of TDR scour sensing waveguide

1. Spacing effect

2. Insulated wire size effect

3. Main steel strand size effect
Data Reduction: Calibration and Measurement

Modified total travel time analysis

Improve measurement accuracy & stability

Step 1: $V_a$ calibration

$$ (t_{a/w,m} - t_0) - (t_{a/w,r} - t_0) = \frac{2\Delta L_a}{V_a} $$

Step 2: $V_w$ & $V_s$ calibration

$$ \begin{cases} 
(t_{e,r} - t_{a/w,r}) = \frac{2L_{w,r}}{V_w} + \frac{2L_{s,r}}{V_s} \\
(t_{e,m} - t_{a/w,m}) = \frac{2L_{w,m}}{V_w} + \frac{2L_{s,m}}{V_s} 
\end{cases} $$

Step 3: Real measurement

$$ (t_{e,m} - t_{a/w,m}) = \frac{2(L_{a/w,m} - L_{s,m})}{V_w} + \frac{2L_{s,m}}{V_s} $$
Data Reduction: Calibration and Measurement

\[
\begin{align*}
L_a, m & \quad t_{a/w} - t_0, ns \\
L_w, m & \quad t_e - t_{a/w}, ns \\
L_s, m & \quad t_e - t_{a/w}, ns \\
\end{align*}
\]

\[
\begin{align*}
V_a &= 2.12 \times 10^8 \text{ m/s} \\
V_w &= 1.12 \times 10^8 \text{ m/s} \\
V_s &= 1.18 \times 10^8 \text{ m/s}
\end{align*}
\]

Estimated sediment level, m vs. Real sediment level, m

\[
\begin{align*}
\text{Data} & \quad \text{Linear Regression} \\
1:1 & \\
\end{align*}
\]
Pilot Field Installation and Evaluation

Riverbed Elevation (m)

- Datalogger
- Fixer
- TDR Scour Waveguide
- Flow Direction
- River Bed
- Backfill Sand (10m)
- Centralizer
- Anchor
- Grout (3m)

Graph showing riverbed elevation over time: 2010/08/02 to 2010/08/30

Graph y-axis labels: 315, 316, 317, 318, 319, 320

Time labels: 08/02, 08/05, 08/10, 08/15, 08/20, 08/25, 2010/08/30

Riverbed Elevation (m)

320
319
318
317
316
315

320
319
318
317
316
315

2010/08/02 08/05 08/10 08/15 08/20 08/25 2010/08/30
Future Study

Bottom-up measurement

- Reduce the rainfall influence at air section

Bottom-up type wire
1. Single wire
2. Coaxial embedded
Thank you for your attention

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