Slope Stabilization with Steel H-Piles

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Overview

• Project site – landslide features and subsurface conditions
• Slope stability – existing and stabilized
• Lateral pile design – distribution of lateral load
• Pile layout
• Construction
Site Location

Source: ESRI, Digital Globe, GeoEye, i-Cubed
Site Location

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Scarp
Damage along Old SR 15
Plan View

- SCARP
- CRACK
- RESERVOIR
- MASW B
- MASW A
- BULGE
- PVMT
- WATER

- 6 PIEZOMETERS
- 10 INCLINOMETERS

Scale:
- 0 50 100 FEET
Subsurface Profile – Station 1303+00

φ = 16.4° (RESIDUAL)
φ = 25° (PEAK)
φ = 36°

LEGEND:
- VIBRATING WIRE PIEZOMETER
- DEFORMATION IN INCLINOMETER
- WATER LEVEL
- WEAK/SOFT LAKE DEPOSITS
- EST. FAILURE SURFACE

OLD SR 15

1.75H:1H

EDGE OF LAKE
RESERVOIR

NB EMBANKMENT
PRE 1973 GRADE
CURRENT GRADE
CONSTRUCTION
Geophysics Profile along Old SR 15

Deformation in Inclinometers

Station Along S.R. 15 Southbound

Cracks Crossing Old S.R. 15

Approximate Ground Surface

Limits of MASW Survey

Legend
- Vibrating Wire Piezometer
- Deformation in Inclinometer
- SPT N-Value (bpf)

Rock
3 Rows of Piles
4 Rows of Piles

Note: Exaggerated Vertical Scale
Slope Stability

- GSTABL7 – Wedge
- Existing slope without piles: $FS = 1.0$
- Remediated slope with piles: $FS = 1.3$
  - Pile resistance input as lateral load
  - Lateral load input per foot of embankment
Pile Design

- Computer software LPILE
- Lateral load triangularly distributed
- p-multiplier
- Pile tip fixity
- Moment criteria for $M_{\text{MAX}} \leq M_{\text{RESISTING}}$
- Pile layout
Lateral Load Distribution

Ground Surface

Failure Surface

Pile

\[ Ph = 2 \times \frac{Fh}{\text{Length}} \]

Pile Layout – Plan View

Triangular distribution per ODOT (2011) Geotechnical Bulletin 7
Lateral Load Distribution - Example

Ground Surface

Failure Surface

Pile

\[ P_h = 2 \times \frac{75 \text{ k/ft}}{35 \text{ ft}} \times \frac{6 \text{ ft}}{4 \text{ rows}} \]

\[ = 6.43 \text{ kips/ft per pile} \]

\[ = 536 \text{ lbs/in} \]
Lateral Load Distribution - Example

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Subsurface Profile for Lateral Pile Analysis

- Reduction to soil resistance (p-y curves)
  - Active landslide
  - Pile spacing:diameter
  - FS in front of pile
  - p-multiplier = 0.231

Ref: ODOT (2011) GB 7
Lateral Pile Analysis Results (HP 12x53)

- **Bending Moment, kips-in.**
  - $M_{\text{MAX}} = 1,744$ kip-in
  - $M_{\text{RES}} = 1,983$ kip-in

- **Shear Force, kips**
  - $V_{\text{MAX}} = 41$ kips
  - $V_{\text{RES}} = 98$ kips

- **Deflection, in.**
  - $\delta = 2.2$ in.

Just for interest
Design: 462 PILES

3 ROWS

4 ROWS

SCARP
Test Piles
Test Piles
Test Piles

20+ BPF

PDA > 150 KIPS

DESIGN PILE LENGTH

L=35'
L=40'
L=45'
L=50'
L=55'
L=55'
L=55'
L=50'
Production Driving

Photo courtesy of Glenn O. Hawbaker, Inc.
Production Driving

Photo courtesy of Glenn O. Hawbaker, Inc.

TOP OF SCARP
Production Driving
Pile Quantities

Design:  8 test piles with total length = 465 LF
454 production piles with total length = 22,325 LF

Construction:  29 piles lengthened by 5’
10 piles added with L = 60’  \[ \Delta \text{Total Length} = 3\% \]
Summary

• Slope failure and subsurface conditions
• Existing slope model calibrated to FS = 1.0
• Slope stability
  – FS=1.3 Strength limit state of lateral pile load
• Lateral pile design
  – Lateral load triangularly distributed
  – p-multiplier
• Pile layout based on geophysics profile
• Quantity of installed piles only 3% > design
Acknowledgements

Thank you!

Photo courtesy of PennDOT