Office of Geotechnical Engineering

Design of Drilled Shafts for Landslide Stabilization

April 19, 2011

Alexander B.C. Dettloff, P.E.
Trapped Barges in Belleville Dam Flood Gates
Belleville Lock and Dam Upper Pool, January through February, 2005

Normal Pool
Old Lock No. 20
Example Exploratory Borings in Profile View

Head Scarp / Roadway Crack

Edge of Water

B-001-0
B-001-1
B-001-2
B-001-3

Toe
Example Soil and Bedrock Subsurface Profile
Estimated Shear Failure Surface

- Head Scarp / Roadway Crack
- Colluvium
- Clayey Alluvium
- Silty Alluvium
- Residuum
- Competent Rock
- Weak Rock
- Edge of Water
- Toe
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<th>Soil Desc.</th>
<th>Soil Type</th>
<th>Total Unit Wt.</th>
<th>Saturated Unit Wt.</th>
<th>Cohesion Interceptor</th>
<th>Friction Angle</th>
<th>Pore Pressure</th>
<th>Constant Pressure</th>
<th>Piez. Param.</th>
<th>Load Value</th>
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GSTABL7 v.2 FSmin=1.001
Safety Factors Are Calculated By The Modified Bishop Method
Dr. Robert Y. Liang
University of Akron

- Numerical Study of Soil Arching Mechanism in Drilled Shafts for Slope Stabilization (April 2002)
- Stability Analysis of Drilled Shafts Reinforced Slope (April 2002)
- Drilled Shaft Foundations for Noise Barrier Walls and Slope Stabilization (December 2002)
- Design Methodology for Drilled Shafts to Stabilize a Slope (June 2007)
- Field Instrumentation, Monitoring of Drilled Shafts for Landslide Stabilization and Development of Pertinent Design Method (November 2010)
Soil Arching Between Spaced Drilled Shafts
“Liang Method”
Calculated Results
- Factor of Safety: 1.000
- Force per Shaft: N/A lb
- Acting Point X: N/A ft, Y: N/A ft

Analysis Unit System
- English

Number of Vertical Sections and Soil Layers
- Vertical Section Num: 12
- Soil Layer Num: 8

Analysis Method
- Total Stress
- Effective Stress

Soil Properties
- Layer 1: Cohesion 100.0 (psf), Friction Angle 24.0, Total Unit Weight 120.0 (pcf)
- Layer 2: Cohesion 50.0 (psf), Friction Angle 20.0, Total Unit Weight 120.0 (pcf)
- Layer 3: Cohesion 100.0 (psf), Friction Angle 20.0, Total Unit Weight 125.0 (pcf)

Slope Profile Vertical Sections
- X (ft): Section 1: 0.00, Section 2: 8.20, Section 3: 24.60, Section 4: 41.20, Section 5: 47.90, Section 6: 58.10, Section 7: 86.00, Section 8: 95.60, Section 9: 139.10
- Y1 (ft): Section 1: 15.30, Section 2: 15.30, Section 3: 15.40, Section 4: 25.20, Section 5: 26.70, Section 6: 26.90, Section 7: 37.90, Section 8: 38.70, Section 9: 56.10
- Y2 (ft): Section 1: 17.80, Section 2: 19.10, Section 3: 21.60, Section 4: 25.20, Section 5: 26.70, Section 6: 26.90, Section 7: 27.70, Section 8: 28.70, Section 9: 56.10

Coordinates of Crest
- X: 24.60 ft, Y: 15.40 ft

Coordinates of Toe
- X: 145.90 ft, Y: 57.80 ft

Pore Water Pressure
- Pore Pressure Options: No Pore, Constant Ratio, Specified phreatic
- X (ft): Point 1: 0.00, Point 2: 24.60, Point 3: 47.90, Point 4: 58.10, Point 5: 86.00, Point 6: 88.50, Point 7: 150.00
- Y (ft): Point 1: 19.80, Point 2: 24.00, Point 3: 32.60, Point 4: 35.20, Point 5: 37.90, Point 6: 38.00, Point 7: 38.00

Slip Surface
- X (ft): Point 1: 8.20, Point 2: 24.60, Point 3: 41.20, Point 4: 47.90, Point 5: 58.10, Point 6: 70.00, Point 7: 86.00, Point 8: 89.50, Point 9: 120.00, Point 10: 144.00, Point 11: 144.00
- Y (ft): Point 1: 15.30, Point 2: 34.10, Point 3: 46.60, Point 4: 50.50, Point 5: 55.50, Point 6: 59.80, Point 7: 63.40, Point 8: 64.60, Point 9: 64.00, Point 10: 60.00, Point 11: 58.40

Drilled Shaft Information
- Calculate without Drilled Shaft
- Automatically Determine Contribution via Soil Arching Stabilization Mechanism
- Manually Defined Load Transfer Factor
- Diameter: 1.00 ft
- Clear Spacing: 0.00 ft
Plot of Factor of Safety versus Drilled Shaft Location

ABC-121-23.45 CrossSection 37+00
Factor of Safety vs. Offset

Offset (ft.) vs. Factor of Safety for different shaft sizes and S/D ratios.
Plot of Drilled Shaft Load versus Drilled Shaft Location

ABC-121-23.45 CrossSection 37+00
Shaft Load vs. Offset

- 36-in, S/D=2
- 36-in, S/D=3
- 42-in, S/D=2
- 42-in, S/D=3
- 48-in, S/D=2
- 48-in, S/D=3

Offset (ft.)

Shaft Load (kips)
LPile Plus
Version 4.0
© 1985-2003 by Ensoft Inc.

A program for analyzing stress and deformation of a pile or drilled shaft under lateral loading.

Licensed to:
ABCD
ODOT

ENSOFT, Incorporated
Phone: (512) 244-6464    Fax: (512) 244-6067
e-mail: ensoft@ensoftinc.com
www.ensoftinc.com

OK
Pile Properties

Total Pile Length (in) 480
Number of Increments 120
Distance from Pile Top to Ground Surface (in)
(negative if pile top is below ground) 0
Combined Ground Slope and Baiter Angles (degrees) 0

Edit Pile Sectional Properties

Pile Sections

<table>
<thead>
<tr>
<th>Section</th>
<th>Depth (in)</th>
<th>Diameter (in)</th>
<th>Mom. of Inertia (in^4)</th>
<th>Area (in^2)</th>
<th>Mod. of Elasticity (lbs/in^2)</th>
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Add Row | Insert Row | Delete Row
Traffic Live Load Surcharge

If horizontal distance to traffic loading, $a \leq \frac{1}{2}d_t$
also apply a traffic live load surcharge (LS) to the drilled shafts equal to
2 feet of soil
With minimum total unit weight
$\gamma_s = 125$ pcf

(see AASHTO Section 3.11.6.4)
<table>
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<th>Depth (in)</th>
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<td>2</td>
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<tr>
<td>3</td>
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</table>
**p-multiplier**

Reduction in soil resistance ($p$) for closely-spaced shafts in soil due to stress field overlap. For

$D = \text{Drilled Shaft Diameter} \\
S = \text{Drilled Shaft Spacing}$,

$$p\text{-multiplier } (\beta_a) = 0.64(S/D)^{0.34}$$


The $p$-multiplier does not apply in bedrock, where limited stress fields for bedrock resistance do not overlap.
Artificial Lowered Ground Surface

Where:

\[ \beta_{dh} = \text{angle of downhill slope from horizontal} \]

\[ d_\tau = \text{depth to the shear surface at drilled shaft location} \]

for \( \beta_{dh} < 45^\circ \) lower ground surface by

\[ d_\tau \tan \beta_{dh} \]

for \( \beta_{dh} \geq 45^\circ \) lower ground surface by

\[ d_\tau \]
Regraded Ground Surface

For the case in which a retaining wall will be used, and the ground surface downhill of the wall is to be regraded to a stable slope (according to stability analysis of the slope below the wall); for LPILE analysis, set the ground surface equal to the location of the proposed regraded ground surface at the base of the wall.

The soil mass downhill of the wall must have a minimum Factor of Safety (FS) = 1.30 against global stability failure.
Load Transfer Reduction

UA Slope 2.1 provides Factor of Safety (FS) for existing shear surface, accounting for load transfer to drilled shafts. This assumes the downhill soil mass stays in place.

For LPILE analysis, assume reduced passive resistance above shear surface, by modifying p-multiplier.

Reduced p-multiplier = \((1-1/FS) \times \beta_a\)

\[= \beta_a - (\beta_a / FS)\]
Compact Section

Non-Compact Section

Slender Section

\[ b_f \]

\[ t_f \]
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Equivalent Pipe Section

S = Steel Beam Section
S = Steel Beam Section
The analysis was completed without errors
LPILE Plus for Windows, Version 4.0 (4.0.8)
Analysis of Individual Piles and Drilled Shafts
Subjected to Lateral Loading Using the p-y Method
(c) Copyright ENSOFT, Inc., 1985-2003
All Rights Reserved

This program is licensed to:
ABCD
ODOT

Path to file locations: W:\GB7_Drilled_Shfts\LPILE\Liang_Shfts\ 
Name of input data file: 37p00 36in Spaced at 9 ft W27x129 FACTORED.ipo 
Name of output file: 37p00 36in Spaced at 9 ft W27x129 FACTORED.ipo 
Name of plot output file: 37p00 36in Spaced at 9 ft W27x129 FACTORED.ipp 
Name of runtime file: 37p00 36in Spaced at 9 ft W27x129 FACTORED.ipr

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Time and Date of Analysis
----------------------------------------------------------------------
Date: February 18, 2011   Time: 13: 9: 8

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Problem Title
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Geotechnical Bulletin 7, 37+00, 36" shafts, 9-foot spaced S/D=3

----------------------------------------------------------------------
Program Options
----------------------------------------------------------------------
Units Used in Computations - US Customary Units, inches, pounds
Basic Program Options:
Analysis Type 4:
- Computation of Nonlinear Bending Stiffness and Ultimate Bending Moment
  Capacity with Pile Response Using User-specified Constant EI
Computation Options:
- only internally-generated p-y curves used in analysis
- Analysis uses p-y multipliers for group action
20603077.072 9.32266E+10 .00021000 .00214179 10.791
2124723.855 8.45208E+10 .00025100 .00243253 10.791
2161983.296 7.69389E+10 .00028100 .00272327 10.791
2190668.939 7.04395E+10 .00031100 .00301401 10.791
2211144.047 6.48429E+10 .00034100 .00330475 10.791
2226818.312 6.00221E+10 .00037100 .00359549 10.791
2238951.419 5.58342E+10 .00040100 .00388623 10.791
2244577.988 5.21712E+10 .00041000 .00417697 10.791
2256530.219 4.89486E+10 .00046100 .00446771 10.791
2262686.159 4.60832E+10 .00049100 .00475845 10.791
2267906.077 4.32909E+10 .00052100 .00504919 10.791
2272356.276 4.12406E+10 .00055100 .00533993 10.791
2276034.632 3.92745E+10 .00058100 .00562067 10.791
2279138.071 3.73018E+10 .000592141 .00591214 10.791
2282173.367 3.56033E+10 .00064100 .00621215 10.791
2284235.824 3.40423E+10 .00067100 .00650289 10.791
2286297.580 3.26148E+10 .00070100 .00679363 10.791
2288359.336 3.13045E+10 .00073100 .00708437 10.791
2289813.384 3.00895E+10 .00076100 .00737511 10.791
2291102.283 2.89646E+10 .00079100 .00766585 10.791
2292390.832 2.79219E+10 .00082100 .00795659 10.791
2293676.181 2.69528E+10 .00085100 .00824733 10.791
2294794.312 2.60476E+10 .00088100 .00853807 10.791
2295338.153 2.51980E+10 .00091100 .00882881 10.791
2296273.294 2.44025E+10 .00094100 .00911955 10.791
2297016.636 2.36562E+10 .00097100 .00941029 10.791
2297752.877 2.29546E+10 .00100100 .00970103 10.791

Ultimate Moment Capacity = 21892.861 In-Kip

---

Computed Values of Load distribution and Deflection for Lateral Loading For Load Case Number 1

Pile-head boundary conditions are Shear and Moment (BC Type 1)
Specified shear force at pile head = .000 lbs
Specified bending moment at pile head = .000 in-lbs
Specified axial load at pile head = .000 lbs

(Zero moment for this load indicates free-head conditions)

| Depth (ft) | X | Y | M | V | S | Total Stiffness | Flx. Rig. | Soil Res | Stress | E | P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.000 | 3.264 | 3.9E-05 | 4.79E-07 | -.011225 | 8.69E-08 | 1.38E+11 | -117.566 |
| 4.000 | 3.219 | -940.5 | -438.3 | -.011225 | 3.56E-06 | 1.38E+11 | -120.950 |
| 8.000 | 3.174 | -3506.7 | -812.8 | -.011225 | 13.26E08 | 1.38E+11 | -124.303 |
| 12.000 | 3.129 | -7442.8 | -1123.2 | -.011226 | 28.14E05 | 1.38E+11 | -127.624 |
| 16.000 | 3.084 | -1.25E+04 | -1369.5 | -.011226 | 47.23E09 | 1.38E+11 | -130.914 |
Please note that because this analysis makes computations of ultimate moment capacity and pile response using nonlinear bending stiffness that the above values of total stress due to combined axial stress and bending may not be representative of actual conditions.

Output Verification:

Computed forces and moments are within specified convergence limits.

Output Summary for Load Case No. 1:

Pile-head deflection = 3.26352139 in
Computed slope at pile head = -0.0122532
Maximum bending moment = 12390250.079 lbs-in
Maximum shear force = -252909.945 lbs
Depth of maximum bending moment = 312.000 in
Depth of maximum shear force = 372.000 in
Number of iterations = 25
Number of zero deflection points = 4

------------------------
Summary of Pile-head Response
------------------------

Definition of symbols for pile-head boundary conditions:

\( y \) = pile-head displacement, in
\( M \) = pile-head moment, lbs-in
\( V \) = pile-head shear force, lbs
\( S \) = pile-head slope, radians
\( R \) = rotational stiffness of pile-head, in-lbs/ rad

<table>
<thead>
<tr>
<th>BC Type</th>
<th>Boundary Condition</th>
<th>Axial Load</th>
<th>Pile Head Deflection</th>
<th>Maximum Moment</th>
<th>Maximum Shear</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>V= 0.000 M= 0.000</td>
<td>0.0000</td>
<td>3.2635</td>
<td>1.239E+07</td>
<td>252909.945</td>
</tr>
</tbody>
</table>

The analysis ended normally.
Please note that because this analysis makes computations of ultimate moment capacity and pile response using nonlinear bending stiffness that the above values of total stress due to combined axial stress and bending may not be representative of actual conditions.

Output Verification:
Computed forces and moments are within specified convergence limits.

Output Summary for Load Case No. 1:

<table>
<thead>
<tr>
<th>Pile-head deflection</th>
<th>= 1.39075700 in</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computed slope at pile head</td>
<td>= -0.00453843</td>
</tr>
<tr>
<td>Maximum bending moment</td>
<td>= 584031.804 lbs-in</td>
</tr>
<tr>
<td>Maximum shear force</td>
<td>= -147388.077 lbs</td>
</tr>
<tr>
<td>Depth of maximum bending moment</td>
<td>= 316.000 in</td>
</tr>
<tr>
<td>Depth of maximum shear force</td>
<td>= 268.000 in</td>
</tr>
<tr>
<td>Number of iterations</td>
<td>= 22</td>
</tr>
<tr>
<td>Number of zero deflection points</td>
<td>= 4</td>
</tr>
</tbody>
</table>

---

**Summary of Pile-head Response**

Definition of symbols for pile-head boundary conditions:

- **y** = pile-head displacement, in
- **M** = pile-head moment, lbs-in
- **V** = pile-head shear force, lbs
- **S** = pile-head slope, radians
- **R** = rotational stiffness of pile-head, in-lbs/rad

<table>
<thead>
<tr>
<th>BC Type</th>
<th>Boundary Condition</th>
<th>Boundary Condition</th>
<th>Axial Load</th>
<th>Pile Head Deflection</th>
<th>Maximum Moment</th>
<th>Maximum Shear</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>V= 0.000 M= 0.000</td>
<td>2</td>
<td>0.0000</td>
<td>1.3908</td>
<td>5.840E+06</td>
<td>147388.0767</td>
</tr>
</tbody>
</table>

The analysis ended normally.
Geotechnical Resistance

A check of the resistance of the Geo-materials to overturning of the pile, per FHWA Geotechnical Engineering Circular No. 10, Publication FHWA-NHI-10-016, Drilled Shafts: Construction Procedures and LRFD Design Methods (GEC 10).

Resistance factor $\varphi=0.67$ is applied to Strength Limit Factored Load in inverse. In other words, multiply the Strength Limit Factored Load by 1.5 times.
Geotechnical Resistance

At increased loading of $1.5 \times$ Strength Limit Factored Load, the drilled shaft may fail structurally. However, Geotechnical Resistance is not a check of the structural capacity of the drilled shaft, but of the Geo-materials to resist movement of the pile. Therefore, for Geotechnical Resistance, analyze a stiffer, stronger pile.

For a re-bar reinforced concrete drilled shaft, follow the procedure for Geotechnical Strength Limit State analysis as described in FHWA GEC 10, Chapter 12, Section 12.3.3.3.1.

For a steel beam section reinforced drilled shaft, maintain Modulus of Elasticity ($E$) = 29,000 ksi, but increase Moment of Inertia of the steel section ($I_x$) by ratio between Strength Limit State Factored Load and Service Limit State Unfactored Load, divided by the resistance factor $\varphi=0.67$ (multiply $I_x$ by from approximately 2.2 to 2.6 times).
Geotechnical Resistance

Therefore, for a steel beam section reinforced drilled shaft:

\[ l'_x = l_x \times \frac{\text{Strength Limit State Factored Load}}{\text{Service Limit State Unfactored Load}} \times \frac{1}{0.67} \]

This should keep the stiffness / bending behavior of the drilled shaft under Geotechnical Strength Limit State factored loading proportional to the behavior of the drilled shaft under Service Limit State unfactored loading, discounting the effect of the soil reaction or passive resistance.
### Pile Properties

- **Total Pile Length (in):** 480
- **Number of Increments:** 120
- **Distance from Pile Top to Ground Surface (in):** 0
- **Combined Ground Slope and Battered Angles (degrees):** 0

### Loading Type

- **Type of Loading:**
  - Cyclic Loading
  - Static Loading
- **Number of Cycles of Cyclic Loading (2 to 5000):** 2

### Distributed Loads

<table>
<thead>
<tr>
<th>Section</th>
<th>Depth (in)</th>
<th>Lateral Load (lbs/in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>300</td>
<td>2176.19</td>
</tr>
</tbody>
</table>

### Pile Sections

<table>
<thead>
<tr>
<th>Section</th>
<th>Depth (in)</th>
<th>Diameter (in)</th>
<th>Moment of Inertia (in^4)</th>
<th>Area (in^2)</th>
<th>Mod. of Elasticity (lbs/in^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>36</td>
<td><strong>10710</strong></td>
<td>30</td>
<td>29000000</td>
</tr>
<tr>
<td>2</td>
<td>480</td>
<td>36</td>
<td><strong>10710</strong></td>
<td>30</td>
<td>29000000</td>
</tr>
</tbody>
</table>
Geotechnical Resistance

Check the deflection of the drilled shaft under Geotechnical Strength Limit State factored loading.

If the drilled shaft deflects more than 10% of the nominal drilled shaft diameter (D/10) this is considered failure of Geotechnical Resistance against overturning.

In this case, deeper embedment of the drilled shaft, a larger diameter drilled shaft, or stiffer reinforcement of the drilled shaft may be required.
Please note that because this analysis makes computations of ultimate moment capacity and pile response using nonlinear bending stiffness that the above values of total stress due to combined axial stress and bending may not be representative of actual conditions.

Output Verification:
Computed forces and moments are within specified convergence limits.

Output Summary for Load Case No. 1:

**Pile-head deflection** = 3.47931729 in
Computed slope at pile head = -0.0161480
Maximum bending moment = 25106009.936 lbs-in
Maximum shear force = -459942.482 lbs
Depth of maximum bending moment = 324.000 in
Depth of maximum shear force = 288.000 in
Number of iterations = 25
Number of zero deflection points = 3

---------------------------------------------------------------------
Summary of Pile-head Response
---------------------------------------------------------------------

**Definition of symbols for pile-head boundary conditions:**

- \( y \) = pile-head displacement, in
- \( M \) = pile-head moment, lbs-in
- \( V \) = pile-head shear force, lbs
- \( S \) = pile-head slope, radians
- \( R \) = rotational stiffness of pile-head, in-lbs/rad

<table>
<thead>
<tr>
<th>BC Type</th>
<th>Boundary Condition</th>
<th>Axial Load lbs</th>
<th>Pile Head Deflection in</th>
<th>Maximum Moment in-lbs</th>
<th>Maximum Shear lbs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>V= 0.000 M= 0.000</td>
<td>0.0000</td>
<td>3.4793</td>
<td>2.511E+07</td>
<td>459942.4823</td>
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</tbody>
</table>

The analysis ended normally.
Shear and Moment Design of Drilled Shaft

Per FHWA Policy Memorandum Related to Structures, dated June 28, 2000, Load and Resistance Factor Design (LRFD) Specifications are required for all new culverts, retaining walls, and other standard structures on which States initiate preliminary engineering after October 1, 2010.

If designing a conventional re-bar reinforced concrete shaft, utilize the FHWA LRFD design procedures for laterally loaded drilled shafts, per FHWA GEC 10, Chapter 12 and Chapter 16.

If designing drilled shafts reinforced with steel beam sections, Check the flexure resistance and shear resistance of the steel beam section according to AASHTO LRFD Bridge Design Specifications, Section 6.10.8 and Section 6.10.9.
A Retaining Wall may be necessary if any of the following is true:

- Insufficient Overall (Global) Stability
- Insufficient Downhill Stability
- Over-steepened Lower Slope
- Potential Erosion of Toe
- Limited Right of Way
Calculated Results

- Factor of Safety: 2.142
- Force per Shaft: 318580.876 lb
- Acting Point X: 50.000 ft, Y: 43.349 ft

Analysis Unit System

- English
- Metric

Number of Vertical Sections and Soil Layers

- Vertical Section Num: 12
- Soil Layer Num: 8

Analysis Method

- Total Stress
- Effective Stress

Soil Properties

<table>
<thead>
<tr>
<th>Layer</th>
<th>Cohesion (psf)</th>
<th>Friction Angle</th>
<th>Total Unit Weight (pcf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Layer1</td>
<td>100.0</td>
<td>24.0</td>
<td>120.0</td>
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<tr>
<td>Layer2</td>
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</tr>
<tr>
<td>Layer3</td>
<td>100.0</td>
<td>20.0</td>
<td>125.0</td>
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</table>

Slope Profile Vertical Sections

<table>
<thead>
<tr>
<th>Section</th>
<th>X (ft)</th>
<th>Y1 (ft)</th>
<th>Y2 (ft)</th>
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<tbody>
<tr>
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<tr>
<td>Section 2</td>
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<td>24.60</td>
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<tr>
<td>Section 3</td>
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<tr>
<td>Section 4</td>
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<td>58.10</td>
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<td>38.70</td>
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<td>56.10</td>
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<td>Section 8</td>
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<td>38.70</td>
<td>56.10</td>
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<tr>
<td>Section 9</td>
<td>139.10</td>
<td>56.10</td>
<td></td>
</tr>
</tbody>
</table>

Coordinates of Crest: X: 24.60 ft, Y: 15.40 ft
Coordinates of Toe: X: 145.90 ft, Y: 57.80 ft

Drilled Shaft Information

- Calculate without Drilled Shaft
- Automatically Determine Contribution via Soil Arching Stabilization Mechanism
- Manually Defined Load Transfer Factor: 0.00000

Clear Spacing: 6.00 ft
X Coordinate: 50.00 ft

Pore Water Pressure

Pore Pressure Options:
- No Pore
- Constant Ratio
- Specified phreatic

<table>
<thead>
<tr>
<th>Point</th>
<th>X (ft)</th>
<th>Y (ft)</th>
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<td>47.90</td>
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<table>
<thead>
<tr>
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<th>Y (ft)</th>
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Slip Surface

<table>
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<td>58.40</td>
</tr>
<tr>
<td>P</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Typical Types of Drilled Shaft Retaining Walls Include:

- Soldier Pile and Lagging Wall (most common)
- Tangent Pile Wall
- Plug Pile Wall
- Secant Pile Wall
Soldier Pile and Lagging Wall

- Backfill with structural concrete to bottom of lagging
- Corrosion protection of steel in lagged zone
- Excavate to Install Lagging Panels
- Reinforced Precast Concrete or Timber Panels
- Backfill behind wall with free-draining aggregate
- Regrade slope in front of wall
Soldier Pile and Lagging Wall; Soldier Piles
Soldier Pile and Lagging Wall; Precast Lagging Panels
Soldier Pile and Lagging Wall; Granular Backfill
Tangent Pile Wall

- Drilled shafts with a center-to-center spacing of one shaft diameter
- With every shaft reinforced, this is the strongest type of drilled shaft retaining wall
- Very expensive to construct
Plug Pile Wall

• Similar to Tangent Pile Wall with a center-to-center spacing of one shaft diameter
• However, every other shaft is reinforced
• Unreinforced shafts are generally shorter (they do not penetrate into bedrock) and serve the purpose of lagging
• Quick and easy wall
Secant Pile Wall

• Drilled shafts with a center-to-center spacing of less than one shaft diameter (the drilled shafts overlap)
• Every other shaft is reinforced, and unreinforced shafts serve the purpose of lagging
• Primary “King” and Secondary shafts
• Water-tight wall
• Very expensive and difficult to construct
• Not usually used for landslide stabilization
Secant Pile Wall
Photographic Credits

- U.S. Army Corps of Engineers, Huntington District
- C.R. Neale, W.Va. Towboat Photos (wvtowboats.com)
- Chris Merklin, P.E., Design Section Head, ODOT Office of Geotechnical Engineering
- Dave Nicklaus, Geologist, ODOT Office of Geotechnical Engineering
- Joe Smithson, P.E., ODOT District 8 Geotechnical Engineer
- Jason Wise, P.E., ODOT District 12 Geotechnical Engineer
References

Questions?