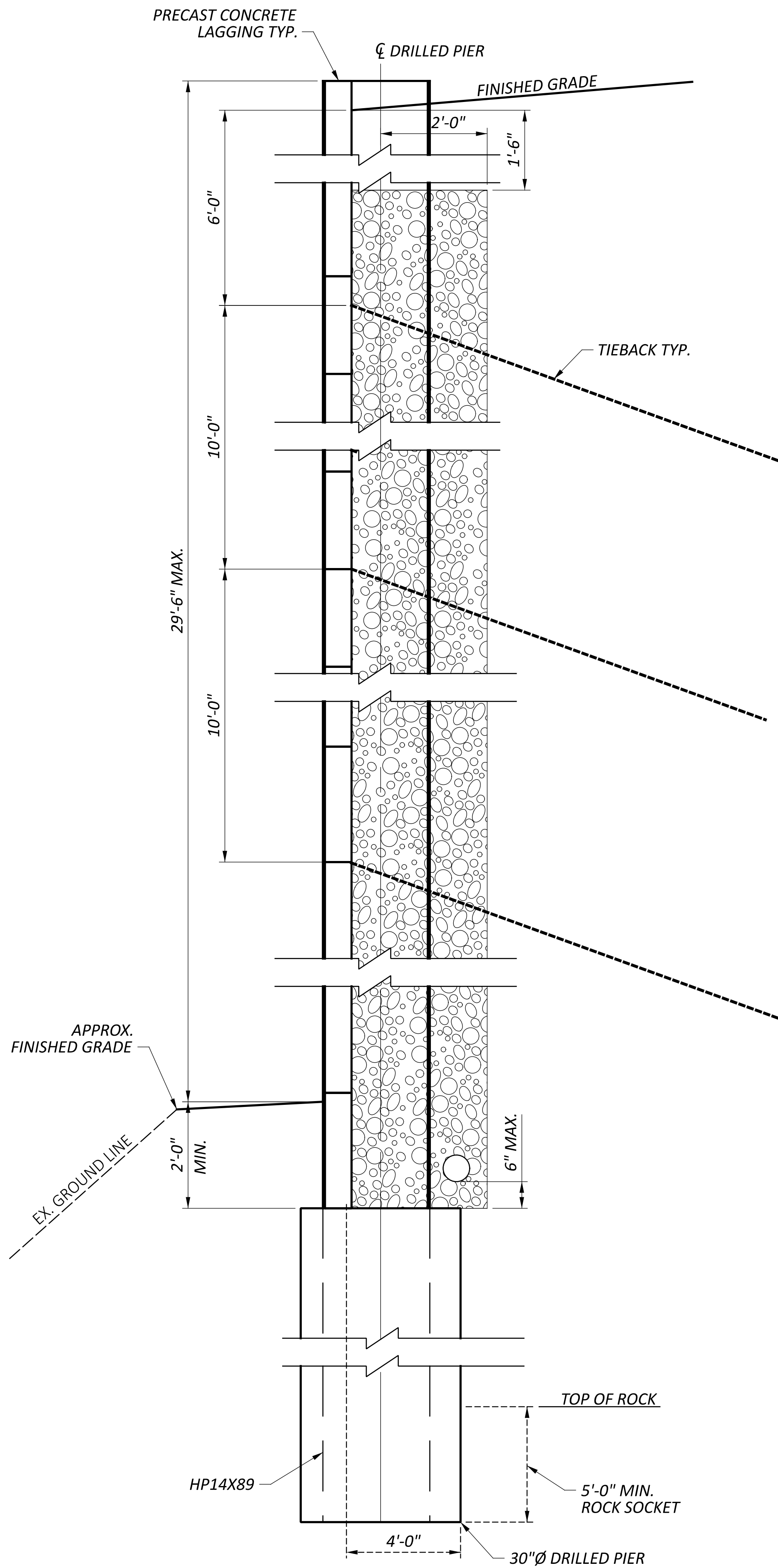


Client: ODOT District 10
Project: WAS-77-9.58

TIEBACK SCHEDULE

PILE NO.	Wall Height to Top of Shaft (ft)	Reinforcing Section	INCLINE BELOW HORIZONTAL (DEG)	TIEBACK NO. 1				TIEBACK NO. 2				TIEBACK NO. 3			
				DEPTH BELOW TOP OF WALL (ft)	UNBONDED LENGTH (ft)	TOTAL LENGTH (ft)	No. of 0.6-inch Steel Strands ¹	DEPTH BELOW TOP OF WALL (ft)	UNBONDED LENGTH (ft)	TOTAL LENGTH (ft)	No. of 0.6-inch Steel Strands ¹	DEPTH BELOW TOP OF WALL (ft)	UNBONDED LENGTH (ft)	TOTAL LENGTH (ft)	No. of 0.6-inch Steel Strands ¹
1	13	HP 14 x 89	20	6	15	48	5	--	--	--	--	--	--	--	--
2	13	HP 14 x 89	20	6	15	48	5	--	--	--	--	--	--	--	--
3	13	HP 14 x 89	20	6	15	48	5	--	--	--	--	--	--	--	--
4	18	HP 14 x 89	20	6	15	48	5	16	15	46	5	--	--	--	--
5	18	HP 14 x 89	20	6	15	48	5	16	15	46	5	--	--	--	--
6	18	HP 14 x 89	20	6	15	48	5	16	15	46	5	--	--	--	--
7	23	HP 14 x 89	20	6	18	68	7	16	15	55	6	--	--	--	--
8	23	HP 14 x 89	20	6	18	68	7	16	15	55	6	--	--	--	--
9	29.5	HP 14 x 89	20	6	23	63	6	16	18	58	6	26	15	41	4
10	29.5	HP 14 x 89	20	6	23	63	6	16	18	58	6	26	15	41	4
11	29.5	HP 14 x 89	20	6	23	63	6	16	18	58	6	26	15	41	4
12	29.5	HP 14 x 89	20	6	23	63	6	16	18	58	6	26	15	41	4
13	29.5	HP 14 x 89	20	6	23	63	6	16	18	58	6	26	15	41	4
14	29.5	HP 14 x 89	20	6	23	63	6	16	18	58	6	26	15	41	4
15	23	HP 14 x 89	20	6	23	63	6	16	15	46	5	--	--	--	--
16	23	HP 14 x 89	20	6	23	63	6	16	15	46	5	--	--	--	--
17	23	HP 14 x 89	20	6	23	63	6	16	15	46	5	--	--	--	--
18	18	HP 14 x 89	20	6	15	48	5	16	15	46	5	--	--	--	--
19	18	HP 14 x 89	20	6	15	48	5	16	15	46	5	--	--	--	--
20	18	HP 14 x 89	20	6	15	48	5	16	15	46	5	--	--	--	--
21	13	HP 14 x 89	20	6	15	48	5	--	--	--	--	--	--	--	--
22	13	HP 14 x 89	20	6	15	48	5	--	--	--	--	--	--	--	--
23	13	HP 14 x 89	20	6	15	48	5	--	--	--	--	--	--	--	--

1) ASTM A416, Grade 270



TYPICAL SECTION
NOT TO SCALE

TIEBACKS (AT PILE Nos. 1-3, 21-23)

SHOULD BE INCLINED 20 DEGREES BELOW HORIZONTAL, SPACED AT 6' BELOW THE TOP OF THE WALL.

UNBONDED LENGTH OF 15', TOTAL LENGTH OF 48', MADE OF 5-0.6" DIAMETER PRESTRESSING STEEL STRANDS

TIEBACKS (AT PILE Nos. 4-6, 15-20):

SHOULD BE INCLINED 20 DEGREES BELOW HORIZONTAL, SPACED AT 6' AND 16' BELOW THE TOP OF THE WALL.

AT 6', UNBONDED LENGTH OF 15', TOTAL LENGTH OF 48', MADE OF 5-0.6" DIAMETER PRESTRESSING STEEL STRANDS

AT 16', UNBONDED LENGTH OF 15', TOTAL LENGTH OF 46', MADE OF 5-0.6" DIAMETER PRESTRESSING STEEL STRANDS

TIEBACKS (AT PILE Nos. 7 AND 8):
(CULVERT SPAN)

SHOULD BE INCLINED 20 DEGREES BELOW HORIZONTAL, SPACED AT 6' AND 16' BELOW THE TOP OF THE WALL.

AT 6', UNBONDED LENGTH OF 18', TOTAL LENGTH OF 68', MADE OF 7-0.6" DIAMETER PRESTRESSING STEEL STRANDS

AT 16', UNBONDED LENGTH OF 15', TOTAL LENGTH OF 55', MADE OF 6-0.6" DIAMETER PRESTRESSING STEEL STRANDS

TIEBACKS (AT PILE Nos. 9-14):

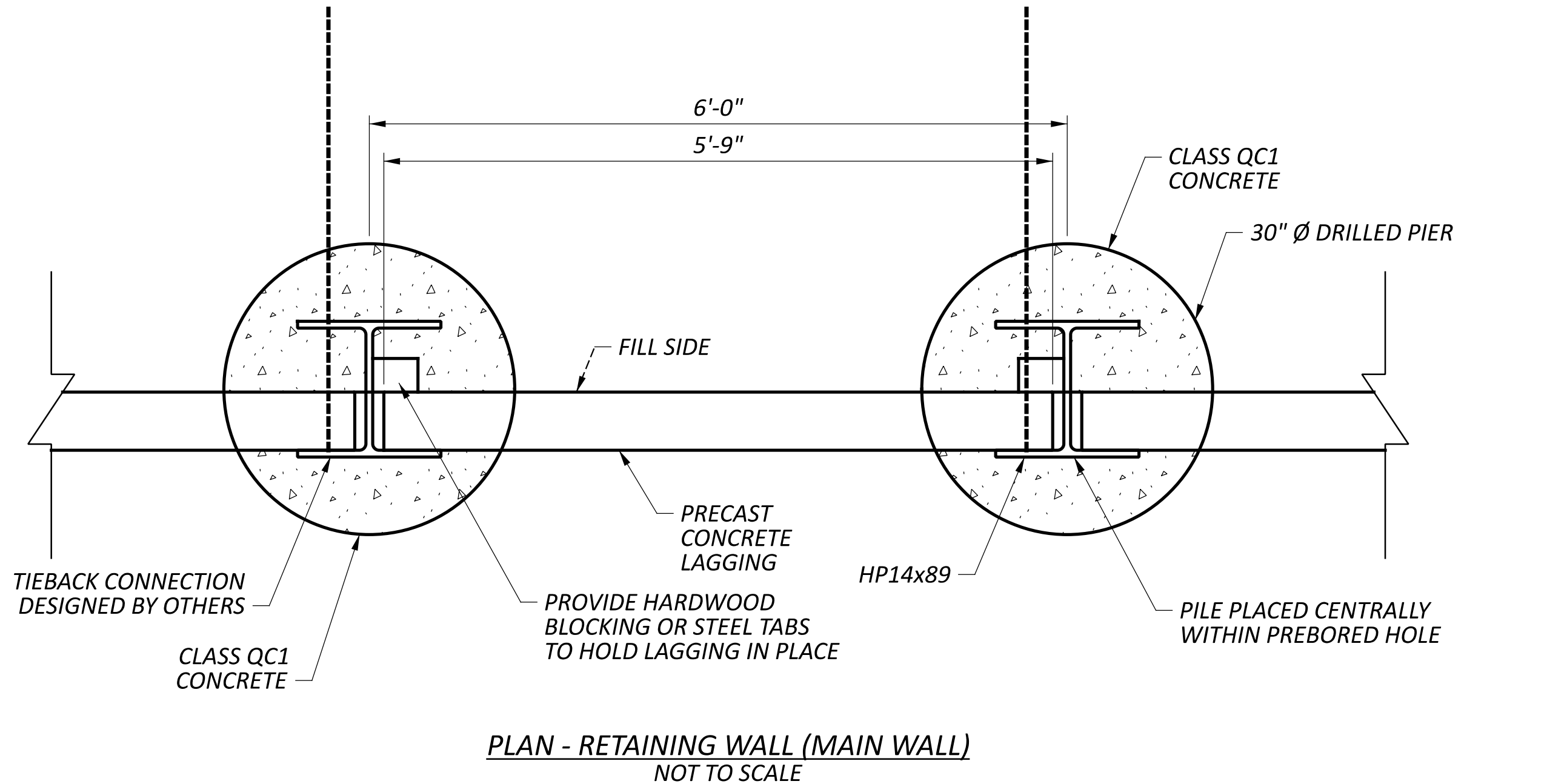
SHOULD BE INCLINED 20 DEGREES BELOW HORIZONTAL, SPACED AT 6', 16', AND 26' BELOW THE TOP OF THE WALL.

AT 6', UNBONDED LENGTH OF 23', TOTAL LENGTH OF 63', MADE OF 6-0.6" DIAMETER PRESTRESSING STEEL STRANDS

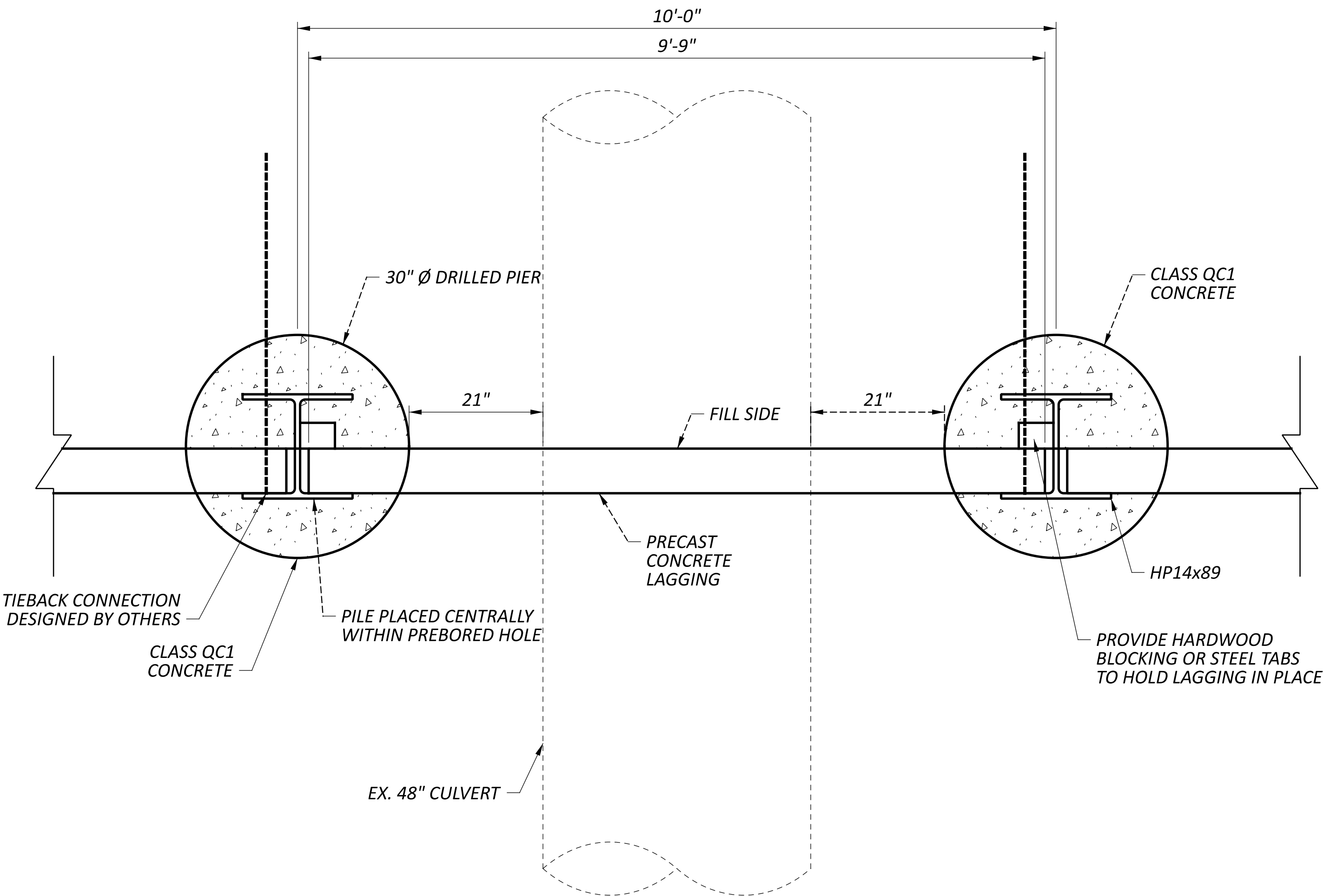
AT 16', UNBONDED LENGTH OF 18', TOTAL LENGTH OF 58', MADE OF 6-0.6" DIAMETER PRESTRESSING STEEL STRANDS

AT 26', UNBONDED LENGTH OF 15', TOTAL LENGTH OF 41', MADE OF 4-0.6" DIAMETER PRESTRESSING STEEL STRANDS

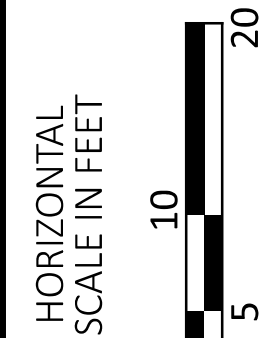
BORING	STATION	OFFSET	APPROX. SURFACE ELEVATION	APPROX. ROCK SURFACE ELEVATION
B-005-0-23	504+48	243' LT	858.7	810.2
B-006-0-23	504+40	322' LT	839.8	804.8
B-007-0-23	505+17	280' LT	849.7	814.7



PLAN - RETAINING WALL (MAIN WALL)
NOT TO SCALE



PLAN - RETAINING WALL (CULVERT SPAN)
NOT TO SCALE



TIEBACK WALL DETAILS
CRITICAL SECTION STA. 504+50

DESIGN AGENCY



DESIGNER

AKB

REVIEWER

DMV 09/08/23

PROJECT ID

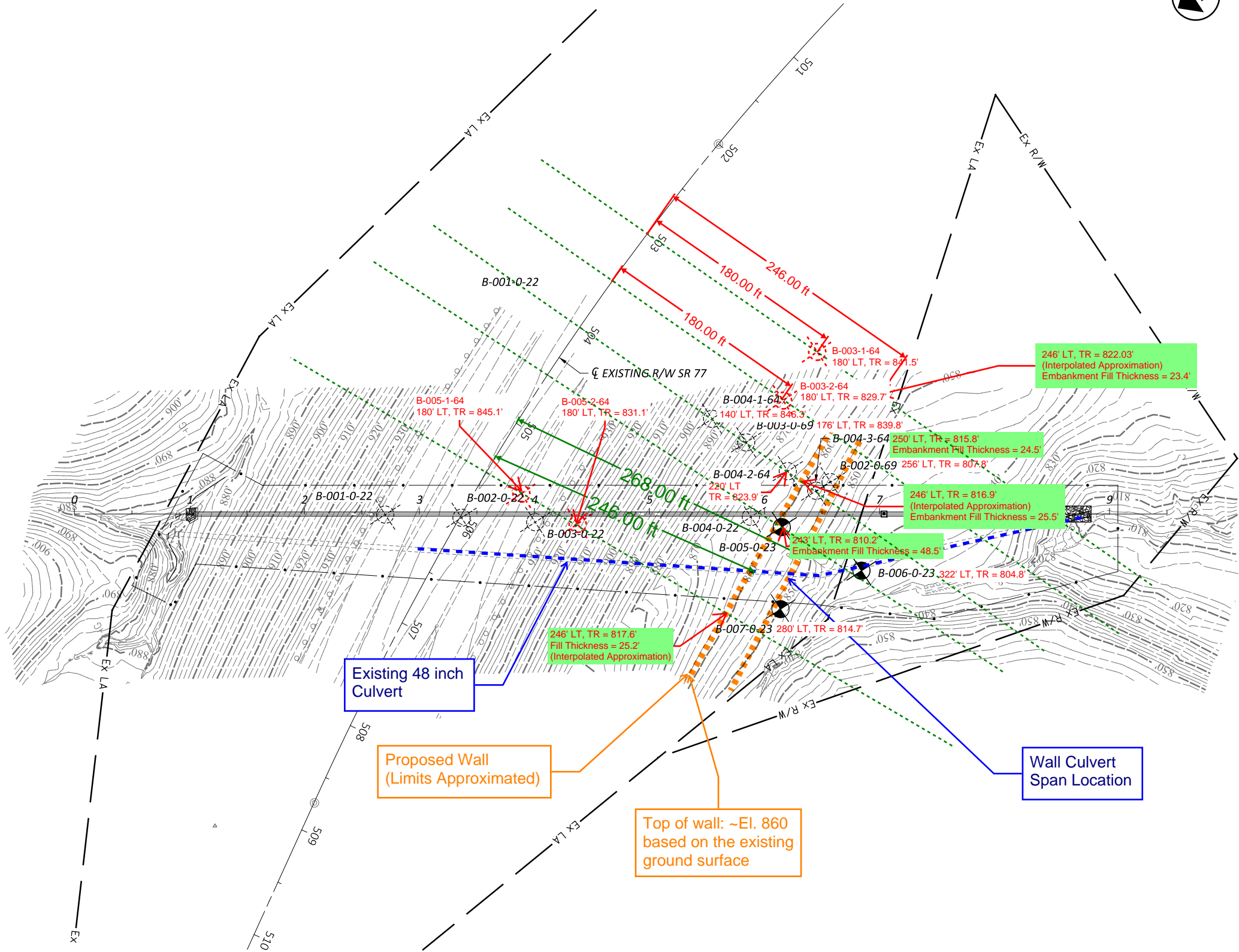
115420

SHEET

TOTAL

1

1



TR = Top of Rock

BORING LOCATION PLAN

DESIGN AGENCY



DESIGNER

AKB

REVIEWER

DMV 08/23/23

PROJECT ID

115420

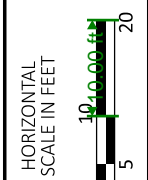
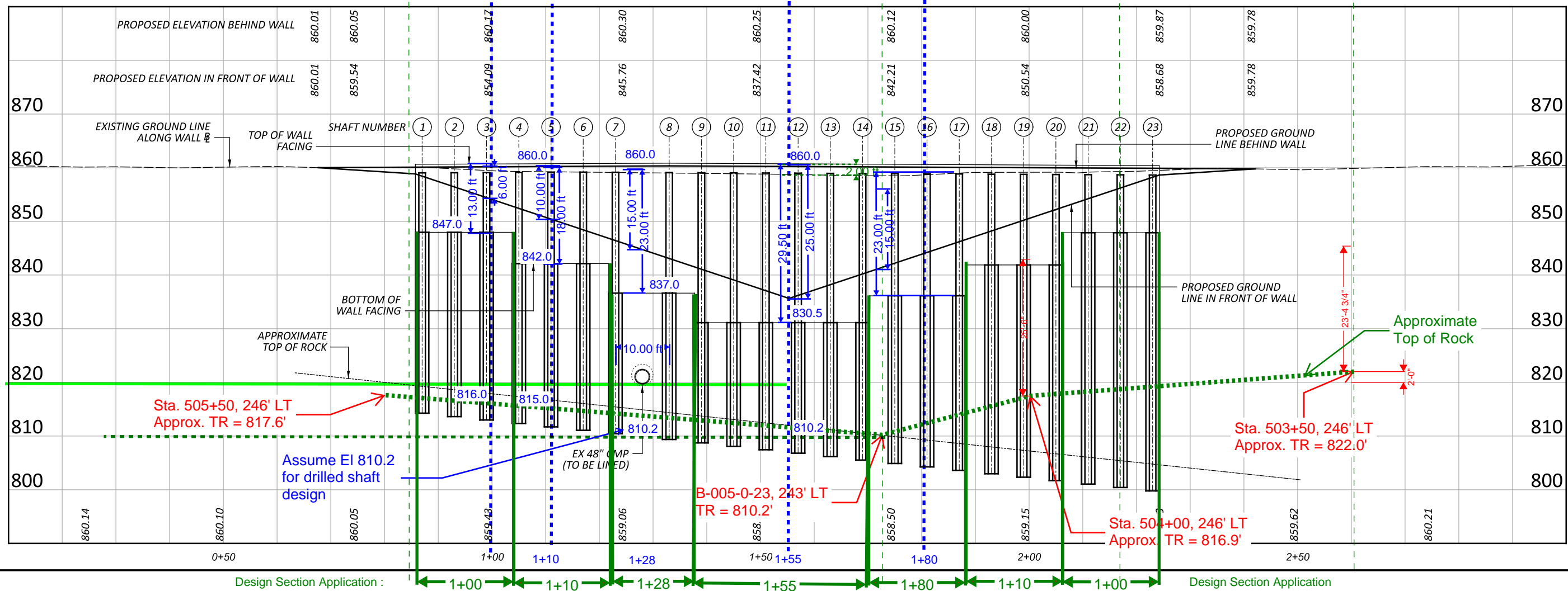
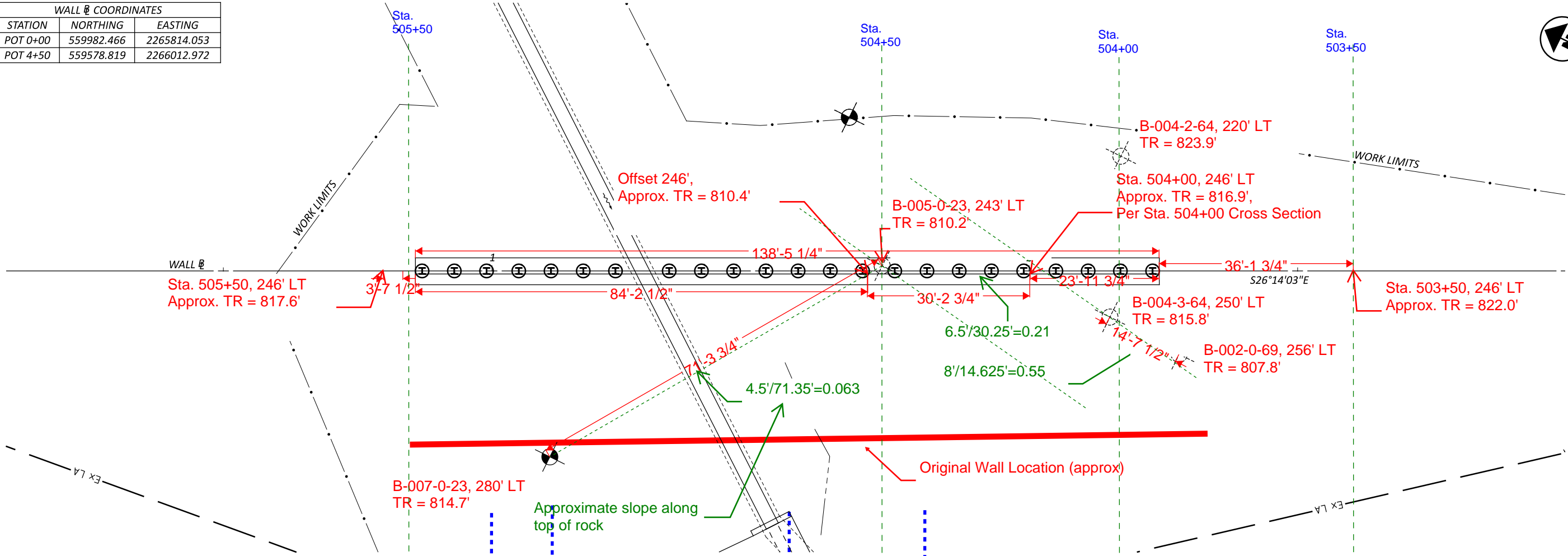
SHEET

1

TOTAL

0

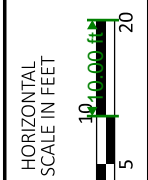
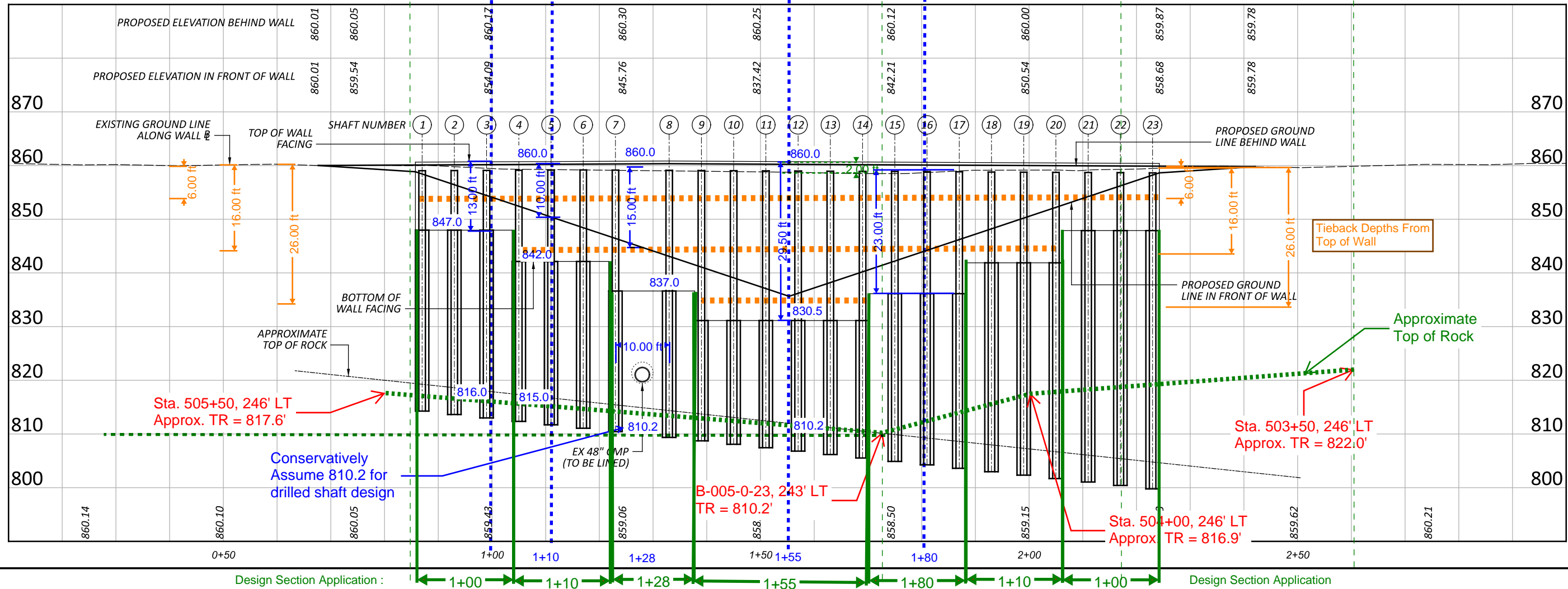
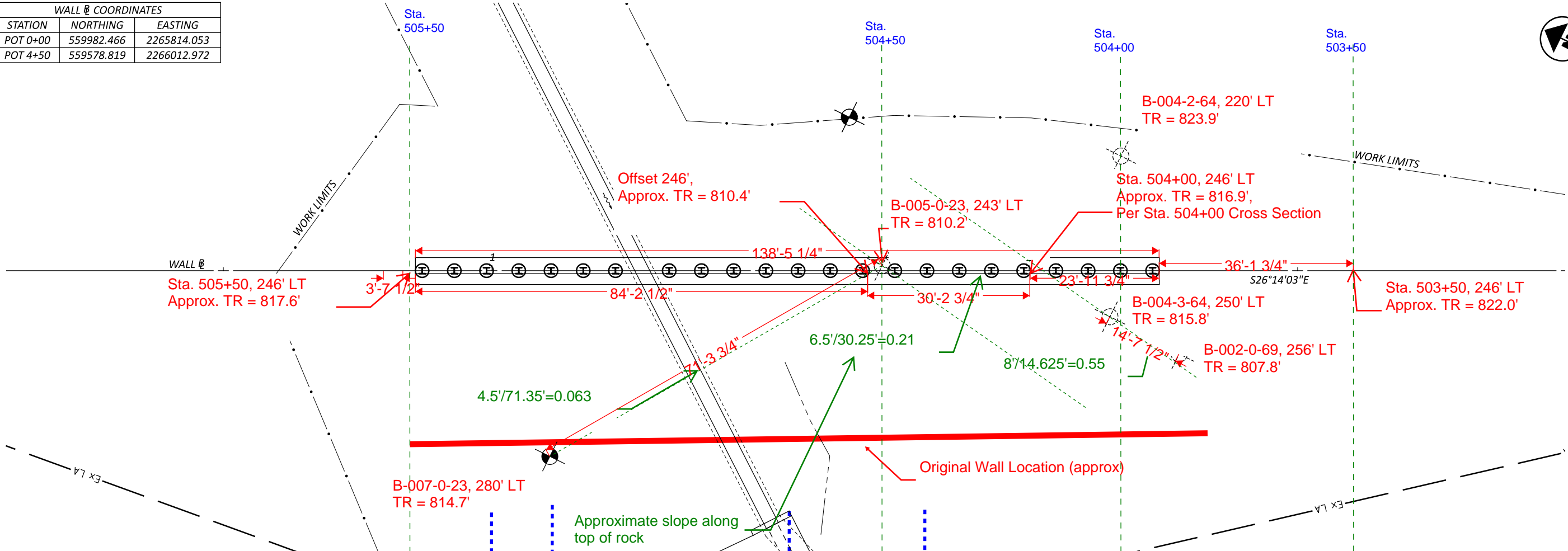
WALL B COORDINATES		
STATION	NORTHING	EASTING
POT 0+00	559982.466	2265814.053
POT 4+50	559578.819	2266012.972



RETAINING WALL PLAN AND PROFILE

DESIGN AGENCY	
DESIGNER	JPH
REVIEWER	XXX MM-DD-YY
PROJECT ID	115420
SHEET	P.0
TOTAL	0

WALL B COORDINATES		
STATION	NORTHING	EASTING
POT 0+00	559982.466	2265814.053
POT 4+50	559578.819	2266012.972



RETAINING WALL PLAN AND PROFILE

DESIGN AGENCY	
DESIGNER	JPH
REVIEWER	XXX MM-DD-YY
PROJECT ID	115420
SHEET	P.O
TOTAL	0

Client: ODOT District 10
Project: WAS-77-9.58

Calculated DCM 1/18/2025
Checked DMV 1/24/2025

Tieback Wall Analysis Summary

Load Limit State for Determining Values:				Service Limit		Strength Limit		Service Limit		Strength Limit		Service Limit		Strength Limit		Service Limit		Strength Limit		Service Limit		Strength Limit		Service Limit		Strength Limit		Service Limit		Strength Limit	
Station	Wall Height to Top of shaft Height (ft)	Reinforcing Section	Recommended Total Shaft Length** (ft)	Tiebacks (Location measured from top of pile)										Top Deflection (in)	Shear kips	Moment in-kips															
				Location (ft)	No. 1 Load (kips)	Load (kips)	Location (ft)	No. 2 Load (kips)	Load (kips)	Location (ft)	No. 3 Load (kips)	Load (kips)																			
1+00	13*	HP 14 x 89	55	--	--	--	--	--	--	--	--	--	8.6	96.2	9388.3																
1+00	13	HP 14 x 89	55	6	71.3	114	--	--	--	--	--	--	0.03	60.2	1356.2																
1+10	18	HP 14 x 89	55	6	103.3	158.4	16	42	69.4	--	--	--	0.01	76.73	1419.0																
(Culvert)																															
1+28	23	HP 14 x 89	55	6	155.9	238.5	16	122.2	194.6	--	--	--	0.01	121.96	2201.4																
1+55	29.5	HP 14 x 89	55	6	126.2	192.8	16	125.2	189.7	26	75.9	125.1	0.02	105.14	2195.5																
1+80	23	HP 14 x 89	55	6	116.9	178.9	16	92.5	148.9	--	--	--	0.01	91.36	1804.1																

* Cantilevered Retaining Wall. No Tiebacks
** Shaft Length based on top of wall El. 860 and a 5 ft embedment into bedrock (El. 810.2) rounded up to the nearest 5 feet.

Tieback Summary

	Wall Height to Top of Shaft (ft)	Tieback No.	Height Above Bottom of Facing ft	Total Unbonded Length ft	Tieback Drill Hole Diameter in	Required Anchor Load kips	Recommended Bond Length ft	Total Tieback Length ft	No. of 0.6-inch Steel Strands ¹
1+00	13	1	7	15	9	114	25	40	4
1+10	18	1	12	15	9	159	35	50	5
		2	2	15	9	70	15	30	2
(Culvert)	23	1	17	18	9	239	50	68	7
1+28		2	7	15	9	195	40	55	6
1+55	29.5	1	23.5	23	9	193	40	63	6
		2	13.5	18	9	190	40	58	6
		3	3.5	15	9	126	26	41	4
1+80	23	1	17	18	9	179	37	55	6
		2	7	15	9	149	31	46	5

1) ASTM A416, Grade 270

L-Pile Analysis

Wall Sta. 1+00

13.0 ft Height (Max during Construction)

(with Traffic Surcharge Loading)

Geometry

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Wall Loading Profile

	Top Elev.	Thickness (ft)	Cohesion (psf)	Phi (deg)	Unit Wt (pcf)
Layer 2 Medium Stiff to Stiff Cohesive	860.0	9.8	115	23	140
Layer 1 Soft to Medium Stiff Cohesive	850.2	3.2	65	21	115
Bottom of Facing	847.0				
Weighted Value		13.0	105	23	135

Earth Pressure Coefficients

	Deg	
Shear Resistance, Φ =	25	
Wall Friction, δ^A =	0.0	
Wall Slope, θ =	90	
Backfill Slope, β =	21.80	
Revised Backfill Slope, β =	21.80	
Backfill Condition	INFINITE	
Horz. Backslope Dist.	50.0	feet (C/L of Wall - Bottom of Embankment)
Wall Height (H)	13.0	feet (Top of Wall - Bottom of Wall Facing)
Slope Height (h)	20.0	feet (Bottom of Embankment - Top of Wall)
I =	37.57	degrees

Active Earth Coefficient

$$K_a = \frac{\sin^2(\theta + \Phi)}{(\sin^2(\theta) \cdot \sin(\theta - \delta) \cdot [1 + \nu(\sin(\Phi + \delta) \cdot \sin(\Phi - \beta)) / (\sin(\theta - \delta) \cdot \sin(\theta + \beta))]^2)}$$

$K_a = 0.631$

At-Rest Earth Coefficient

$$K_o = (1 - \sin(\phi)) \cdot (1 + \sin(\beta))$$

$K_o = 0.803$

Notes:

- Wall friction neglected
- Figure and Equation for Active Earth Pressure from AASHTO 3.11.5.3 (LRFD Design Manual).
- The wall backfill will consist of proposed fill and cohesive overburden. Using the soil layer thicknesses and respective soil parameters as determined by backcalculation in SlopeW, a weighted average was determined and assumed for the entire backfill ($c' = 105$ psf and $\phi' = 23^\circ$, per backcalculated UA Slope Values). The parameters were converted to equivalent soil strength parameters $c' = 0$ psf and $\phi' = 25^\circ$ for computing earth pressures based on a 1 degree increase in friction angle for every 50 psf decrease in cohesion up to 150 psf (Ref: Hall's Thesis).

Soil Lateral Design Profile

	Top Elev	Depth (ft)	Cohesion (psf)	Phi (deg)	Unit Wt (pcf)	ϵ_{50}	k
Layer 2 Medium Stiff to Stiff Cohesive	847.0	13.0	1500	0	77.6	0.007	N/A
Layer 3 Stiff to Very Stiff Cohesive	835.2	24.8	3000	0	72.6	0.005	N/A
Layer 4 Hard Cohesive	815.2	44.8	4000	0	82.6	0.005	N/A
Bedrock	810.2	49.8	N/A	N/A	N/A	N/A	N/A

Bedrock Lateral Design Profile

	Top Elev	Depth (ft)	qu (psi)	Em (psi)	Unit Wt (pcf)	RQD (%)	krm
Claystone	810.2	49.8	330	37400	150	64	0.0005
Claystone	807.3	52.7	1150	179800	160	100	0.0005
Sandstone/Claystone	800.8	59.2	1150	179800	160	91	0.0005
Claystone	798.1	61.9	330	37400	150	17	0.0005
Claystone	795.7	64.3	330	37400	150	86	0.0005

Depths referenced below the top of wall, starting at the lowered ground surface. ϵ_{50} and k values per LPile Technical Manual.

Wall Loading Computations

Earth Pressure Model = **CONVENTIONAL** (Conventional or UA SLOPE)

1) Soil Unit Weight = **135** pcf Weighted Average Along Cantilevered Wall Height

2) Determine Coefficient of Earth Pressure (K)

Restraint Condition = **ACTIVE** (Active or At-Rest)

$K_a =$ **0.631**

3) Determine Equivalent Fluid Weight (G_H)

$G_H = (\gamma_m) * (K_a)$

$G_H =$ **85** For application to CONVENTIONAL Earth Pressure Model

4) Artificially Lowered Ground Surface (ODOT GDM Section 903.3.2, pg. 9-14) for $FS_{dh} < 1.30$

Consider Lowered G. S.? **NO**

5) Modification of p-y curves (ODOT GDM Section 903.2, pg. 9-13)

$P_m = 0.64 * (S/D)^{0.34}$ (Ref: Reese, Isenhower, & Wang - 2006)

$D =$ **2.5** feet (shaft diameter or pile flange width)

Assumed Shaft Spacing = **6** feet (center-to-center pile spacing)

$P_m =$ **0.86** For retaining wall, applies from top of wall to top of rock/bottom of drilled shafts

For a row of drilled shafts, applies below shear plane to top of rock/bottom of drilled shafts

Reduce p-multiplier? **NO** For application above shear plane if using a row of spaced drilled shafts instead of a retaining wall

6) Determine Lateral Thrust

Conventional Earth Pressure Theory

Exposed Wall Height (H) = **13** feet

Wall Height (H) + G_{AL} = **13.0**

$P = 1/2 * G_H * H^2$

$P =$ **7201** lbs/foot

$P_{SH} = P * (\text{Shaft Spacing})$ (earth loading)

$P_{SH} =$ **43206** lbs/shaft

7) Resolve horizontal earth force to distributed triangular load (for LPILE)

$w = 2 * P_{SH} / H$

$w =$ **6647** lbs/foot per shaft (Earth - Service Limit)

$w =$ **554** lbs/inch per shaft (Earth - Service Limit)

$\gamma_E =$ **1.5** Earth Load Factor

$w = (2 * P_{SH} / H) * \gamma_E$

$w =$ **831** lbs/inch per shaft (Earth - Strength Limit)

8) Determine live-load traffic surcharge force (P_s)

Include traffic surcharge? **NO**

Surcharge Pressure (q_s) = **NA** psf

$P_s = K_a * q_s * H$

$P_s =$ **NA** lbs/foot (surcharge resolved to distributed load)

$P_s =$ **NA** lbs/shaft

9) Resolve surcharge to distributed rectangular load (for LPILE)

$w = P_s / H$

$w =$ **0** lbs/foot per shaft (surcharge - unfactored)

$w =$ **0** lbs/inch per shaft (surcharge - unfactored)

$\gamma_s =$ **1.75** Surcharge Load Factor - Strength I

$w = (P_s / L) * \gamma_s$

$w =$ **0** lbs/inch per shaft (Surcharge - Strength I)

Distributed Lateral Loads for LPILE

CONVENTIONAL		
Depth (ft.)	Service (lb/in)	Strength-I (lb/in)
0	0	0
13.0	554	831

Steel Beam and Cross-Section Properties

Assumed Pile Shape **HP 14x89**

Pile Availability

AISC Member Producers	3
Non-Member Producers	0

Shaft Geometry

Shaft Diameter	30	in
Longest Beam Dimension	20.162589	in
Clear Distance	4.9187054	in

Steel Beam Geometry

Beam Depth (D)	13.8	in
Web Thickness (t _w)	0.615	in
Flange Width (B _f)	14.7	in
Flange Thickness (t _f)	0.615	in
Area of Steel (A _s)	26.1	in ²

Steel Properties

Yield Strength of Steel	50	ksi
Moment of Inertia (I _{xx}) of Steel	904	in ⁴
Modulus of Elasticity of Steel (E)	29000	ksi
Modulus of Elasticity of Steel (E)	29000000	psi
EI (Steel Only)	2.622E+10	lb*in ²
Section Modulus (S _x)	131	in ³
Section Modulus (Z _x)	146	in ³
Shear-Buckling Coefficient (k)	5	
Ratio of Shear-Buckling Resistance (C)	1	
D/t _w	22.439024	
1.12VEk/F _{yw}	60.313846	
1.40VEk/F _{yw}	75.392307	

Determined by AASHTO LRFD Bridge Specifications
Eqn's 6.10.9.3.2-4, 6.10.9.3.2-5, and 6.10.9.3.2-6

Shear Capacity Calculation

$$V_u \leq \phi V_{cr}$$
$$\phi_b = \boxed{1} \text{ AASHTO LRFD Bridge Design Spec's 6.5.4.2}$$
$$V_u = \text{shear in web due to factored permanent and construction loads applied to noncompact section (kips)}$$
$$V_{cr} = \text{shear buckling resistance determined from Equation 6.10.9.3.3-1 (AASHTO LRFD Bridge Design Spec's)}$$
$$V_n = V_{cr} = C V_p$$
$$V_p = 0.58 F_{yw} D t_w$$
$$V_p = \text{plastic shear force (kips)}$$
$$C = \text{ratio of shear-buckling resistance to shear yield strength determined by AASHTO Eqn's 6.10.9.3.2-4, 6.10.9.3.2-5, 6.10.9.3.2-5, or 6.10.9.3.2-6}$$
$$V_p = 0.58 * 50 * 13.8 * 0.615$$
$$V_p = \boxed{246.1} \text{ kips}$$
$$\phi V_{cr} = \phi * C * V_p$$
$$\phi V_{cr} = 1 * 1 * 246.1$$
$$\phi V_{cr} = \boxed{246.1} \text{ kips}$$
$$V_u = \boxed{96.236} \text{ kips (from LPILE)}$$
$$\boxed{} \text{ kips (from PYWALL)}$$
$$V_u < \phi V_{cr} \quad \text{OK}$$

Flexure Capacity Calculation

$$M_u \leq \phi M_n$$
$$\phi_b = \boxed{1} \text{ AASHTO LRFD Bridge Design Spec's 6.5.4.2}$$
$$M_u = \text{Moment due to the factored loads}$$
$$M_n = \text{Nominal flexural resistance of a section}$$
$$S_x = \text{Elastic section modulus about the x-axis}$$
$$\phi M_n = \phi * F_y * S_x$$
$$\phi M_n = 1 * 50 * 131$$
$$\phi M_n = \boxed{6550} \text{ in*kips}$$
$$M_u = \boxed{9388.3} \text{ in*kips (from LPILE)}$$
$$M_u = \boxed{} \text{ in*kips (from PYWALL)}$$
$$M_u < \phi M_n$$

Deflection Criteria

Pile Length Above Rock = 49.8	ft	Exposed Wall Height = 13	ft
Pile Length Above Rock = 	in	Exposed Wall Height = 156	in

1.)

Per the ODOT GDM, pile-head deflection in the service limit state limited to 1% or less of the shaft length above bedrock, or 1% of total drilled shaft length if not embedded in bedrock.

2.)

Following industry acceptance criteria, limit wall deflection to 1% of exposed wall height where ODOT landslide criteria does not govern. Alternatively, limit wall deflection to 1.5% of the exposed wall height in accordance with NCDOT guidelines. Use 1.5% wall deflection for PYWALL software.

ODOT Landslide Criteria Governs **NO**

1% Wall Height OR 2 inches- LPILE **2** in $\delta = \boxed{8.58}$ in (from LPILE)

1.5% Wall Height - PYWALL **2.34** in $\delta = \boxed{}$ in (from PYWALL)

Drilled Shafts Located Within 10 feet of Edge of Pavement **NO**

Service Limit

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LFile for Windows, Version 2022-12.009

Analysis of Individual Piles and Drilled Shafts
Subjected to Lateral Loading Using the p-y Method
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Files Used for Analysis

Path to file locations:
\ODOT-District 10 GES\Task 10-13 WAS-77-9.58\20250116_Redesign Calculations\20250116_Updated Analyses\

Name of input data file:
WAS-77-9.58 13' Wall Service Case_20250116.lp12d

Name of output report file:
WAS-77-9.58 13' Wall Service Case_20250116.lp12o

Name of plot output file:
WAS-77-9.58 13' Wall Service Case_20250116.lp12p

Name of runtime message file:
WAS-77-9.58 13' Wall Service Case_20250116.lp12r

Date and Time of Analysis

Date: January 24, 2025

Time: 9:37:57

Problem Title

Project Name: WAS-77-9.58

Job Number:

Client: ODOT D10

Engineer: HDR

Description: Service Case

Program Options and Settings

Computational Options:

- Conventional Analysis

Engineering Units Used for Data Input and Computations:

- US Customary System Units (pounds, feet, inches)

Analysis Control Options:

- | | | |
|--|---|---------------|
| - Maximum number of iterations allowed | = | 500 |
| - Deflection tolerance for convergence | = | 1.0000E-05 in |
| - Maximum allowable deflection | = | 100.0000 in |
| - Number of pile increments | = | 100 |

Loading Type and Number of Cycles of Loading:

- Static loading specified
- Analysis uses p-y modification factors for p-y curves
- Analysis uses layering correction (Method of Georgiadis)
- Analysis includes loading by one distributed lateral load acting on pile
- Loading by lateral soil movements acting on pile not selected
- Input of shear resistance at the pile tip not selected
- Input of moment resistance at the pile tip not selected
- Computation of pile-head foundation stiffness matrix not selected
- Push-over analysis of pile not selected
- Buckling analysis of pile not selected

Output Options:

- Output files use decimal points to denote decimal symbols.
- Values of pile-head deflection, bending moment, shear force, and soil reaction are printed for full length of pile.
- Printing Increment (nodal spacing of output points) = 1

- No p-y curves to be computed and reported for user-specified depths
- Print using wide report formats

Pile Structural Properties and Geometry

Number of pile sections defined = 1
 Total length of pile = 55.000 ft
 Depth of ground surface below top of pile = 13.0000 ft

Pile diameters used for p-y curve computations are defined using 2 points.

p-y curves are computed using pile diameter values interpolated with depth over the length of the pile. A summary of values of pile diameter vs. depth follows.

Point No.	Depth Below Pile Head feet	Pile Diameter inches
1	0.000	30.0000
2	55.000	30.0000

Input Structural Properties for Pile Sections:

Pile Section No. 1:

Section 1 is an elastic pile
 Cross-sectional Shape = Circular Pile
 Length of section = 55.000000 ft
 Width of top of section = 30.000000 in
 Width of bottom of section = 30.000000 in
 Top Area = 26.100000 sq. in
 Bottom Area = 26.100000 sq. in
 Moment of Inertia at Top = 904.000000 in^4
 Moment of Inertia at Bottom = 904.000000 in^4
 Elastic Modulus = 29000000. psi

Soil and Rock Layering Information

The soil profile is modelled using 8 layers

Layer 1 is stiff clay without free water

Distance from top of pile to top of layer	=	13.000000 ft
Distance from top of pile to bottom of layer	=	24.800000 ft
Effective unit weight at top of layer	=	77.600000 pcf
Effective unit weight at bottom of layer	=	77.600000 pcf
Undrained cohesion at top of layer	=	1500. psf
Undrained cohesion at bottom of layer	=	1500. psf
Epsilon-50 at top of layer	=	0.007000
Epsilon-50 at bottom of layer	=	0.007000

Layer 2 is stiff clay without free water

Distance from top of pile to top of layer	=	24.800000 ft
Distance from top of pile to bottom of layer	=	44.800000 ft
Effective unit weight at top of layer	=	72.600000 pcf
Effective unit weight at bottom of layer	=	72.600000 pcf
Undrained cohesion at top of layer	=	3000. psf
Undrained cohesion at bottom of layer	=	3000. psf
Epsilon-50 at top of layer	=	0.005000
Epsilon-50 at bottom of layer	=	0.005000

Layer 3 is stiff clay without free water

Distance from top of pile to top of layer	=	44.800000 ft
Distance from top of pile to bottom of layer	=	49.800000 ft
Effective unit weight at top of layer	=	82.600000 pcf
Effective unit weight at bottom of layer	=	82.600000 pcf
Undrained cohesion at top of layer	=	4000. psf
Undrained cohesion at bottom of layer	=	4000. psf
Epsilon-50 at top of layer	=	0.005000
Epsilon-50 at bottom of layer	=	0.005000

Layer 4 is weak rock, p-y criteria by Reese, 1997

Distance from top of pile to top of layer	=	49.800000 ft
Distance from top of pile to bottom of layer	=	52.700000 ft
Effective unit weight at top of layer	=	150.000000 pcf
Effective unit weight at bottom of layer	=	150.000000 pcf
Uniaxial compressive strength at top of layer	=	330.000000 psi
Uniaxial compressive strength at bottom of layer	=	330.000000 psi
Initial modulus of rock at top of layer	=	37400. psi
Initial modulus of rock at bottom of layer	=	37400. psi
RQD of rock at top of layer	=	64.000000 %
RQD of rock at bottom of layer	=	64.000000 %
k _{rm} of rock at top of layer	=	0.0005000
k _{rm} of rock at bottom of layer	=	0.0005000

Layer 5 is weak rock, p-y criteria by Reese, 1997

Distance from top of pile to top of layer	=	52.700000 ft
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Distance from top of pile to bottom of layer	=	59.200000	ft
Effective unit weight at top of layer	=	160.000000	pcf
Effective unit weight at bottom of layer	=	160.000000	pcf
Uniaxial compressive strength at top of layer	=	1150.	psi
Uniaxial compressive strength at bottom of layer	=	1150.	psi
Initial modulus of rock at top of layer	=	179800.	psi
Initial modulus of rock at bottom of layer	=	179800.	psi
RQD of rock at top of layer	=	100.000000	%
RQD of rock at bottom of layer	=	100.000000	%
k _{rm} of rock at top of layer	=	0.0005000	
k _{rm} of rock at bottom of layer	=	0.0005000	

Layer 6 is weak rock, p-y criteria by Reese, 1997

Distance from top of pile to top of layer	=	59.200000	ft
Distance from top of pile to bottom of layer	=	61.900000	ft
Effective unit weight at top of layer	=	160.000000	pcf
Effective unit weight at bottom of layer	=	160.000000	pcf
Uniaxial compressive strength at top of layer	=	1150.	psi
Uniaxial compressive strength at bottom of layer	=	1150.	psi
Initial modulus of rock at top of layer	=	179800.	psi
Initial modulus of rock at bottom of layer	=	179800.	psi
RQD of rock at top of layer	=	91.000000	%
RQD of rock at bottom of layer	=	91.000000	%
k _{rm} of rock at top of layer	=	0.0005000	
k _{rm} of rock at bottom of layer	=	0.0005000	

Layer 7 is weak rock, p-y criteria by Reese, 1997

Distance from top of pile to top of layer	=	61.900000	ft
Distance from top of pile to bottom of layer	=	64.300000	ft
Effective unit weight at top of layer	=	150.000000	pcf
Effective unit weight at bottom of layer	=	150.000000	pcf
Uniaxial compressive strength at top of layer	=	330.000000	psi
Uniaxial compressive strength at bottom of layer	=	330.000000	psi
Initial modulus of rock at top of layer	=	37400.	psi
Initial modulus of rock at bottom of layer	=	37400.	psi
RQD of rock at top of layer	=	17.000000	%
RQD of rock at bottom of layer	=	17.000000	%
k _{rm} of rock at top of layer	=	0.0005000	
k _{rm} of rock at bottom of layer	=	0.0005000	

Layer 8 is weak rock, p-y criteria by Reese, 1997

Distance from top of pile to top of layer	=	64.300000	ft
Distance from top of pile to bottom of layer	=	95.000000	ft
Effective unit weight at top of layer	=	150.000000	pcf
Effective unit weight at bottom of layer	=	150.000000	pcf
Uniaxial compressive strength at top of layer	=	330.000000	psi
Uniaxial compressive strength at bottom of layer	=	330.000000	psi

Initial modulus of rock at top of layer = 37400. psi
 Initial modulus of rock at bottom of layer = 37400. psi
 RQD of rock at top of layer = 86.000000 %
 RQD of rock at bottom of layer = 86.000000 %
 k_{rm} of rock at top of layer = 0.0005000
 k_{rm} of rock at bottom of layer = 0.0005000

(Depth of the lowest soil layer extends 40.000 ft below the pile tip)

**** Warning - Possible Input Data Error ****

Values entered for effective unit weight of rock were outside the limits of 50 pcf to 150 pcf.

The maximum input value, in layer 8, for effective unit weight = 160.00 pcf

This data may be erroneous. Please check your data.

Summary of Input Soil Properties

Layer Num.	Soil Type Name (p-y Curve Type)	Layer Depth ft	Effective Unit Wt. pcf	Cohesion psf	Uniaxial qu psi	RQD %	E50 or k _{rm}	Rock Mass Modulus psi
1	Stiff Clay	13.0000	77.6000	1500.	--	--	0.00700	--
	w/o Free Water	24.8000	77.6000	1500.	--	--	0.00700	--
2	Stiff Clay	24.8000	72.6000	3000.	--	--	0.00500	--
	w/o Free Water	44.8000	72.6000	3000.	--	--	0.00500	--
3	Stiff Clay	44.8000	82.6000	4000.	--	--	0.00500	--
	w/o Free Water	49.8000	82.6000	4000.	--	--	0.00500	--
4	Weak	49.8000	150.0000	--	330.0000	64.0000	5.00E-04	37400.
	Rock	52.7000	150.0000	--	330.0000	64.0000	5.00E-04	37400.
5	Weak	52.7000	160.0000	--	1150.	100.0000	5.00E-04	179800.
	Rock	59.2000	160.0000	--	1150.	100.0000	5.00E-04	179800.
6	Weak	59.2000	160.0000	--	1150.	91.0000	5.00E-04	179800.
	Rock	61.9000	160.0000	--	1150.	91.0000	5.00E-04	179800.
7	Weak	61.9000	150.0000	--	330.0000	17.0000	5.00E-04	37400.
	Rock	64.3000	150.0000	--	330.0000	17.0000	5.00E-04	37400.
8	Weak	64.3000	150.0000	--	330.0000	86.0000	5.00E-04	37400.
	Rock	95.0000	150.0000	--	330.0000	86.0000	5.00E-04	37400.

Modification Factors for p-y Curves

Distribution of p-y modifiers with depth defined using 2 points

Point No.	Depth X ft	p-mult	y-mult
1	13.000	0.8600	1.0000
2	49.800	0.8600	1.0000

 Static Loading Type

Static loading criteria were used when computing p-y curves for all analyses.

 Distributed Lateral Loading Used For All Load Cases

Distributed lateral load intensity defined using 2 points

Point No.	Depth X ft	Dist. Load lb/in
1	0.000	79.000
2	13.000	633.000

 Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 1

Load No.	Load Type	Condition 1	Condition 2	Axial Thrust Force, lbs	Compute Top y vs. Pile Length	Run Analysis
1	1	V = 0.0000 lbs	M = 0.0000 in-lbs	0.000000	Yes	Yes

V = shear force applied normal to pile axis

M = bending moment applied to pile head

y = lateral deflection normal to pile axis

S = pile slope relative to original pile batter angle

R = rotational stiffness applied to pile head

Values of top y vs. pile lengths can be computed only for load types with specified shear loading (Load Types 1, 2, and 3).

Thrust force is assumed to be acting axially for all pile batter angles.

 Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness

Axial thrust force values were determined from pile-head loading conditions

Number of Pile Sections Analyzed = 1

Pile Section No. 1:

Moment-curvature properties were derived from elastic section properties

 Layering Correction Equivalent Depths of Soil & Rock Layers

Layer No.	Top of Layer Below Pile Head ft	Equivalent Top Depth Below Grnd Surf ft	Same Layer Type As Layer Above	Layer is Rock or is Below Rock Layer	F0 Integral for Layer lbs	F1 Integral for Layer lbs
1	13.0000	0.00	N.A.	No	0.00	198867.
2	24.8000	6.9960	Yes	No	198867.	1023925.
3	44.8000	22.4295	Yes	No	1222792.	430929.
4	49.8000	36.8000	No	Yes	N.A.	N.A.
5	52.7000	39.7000	No	Yes	N.A.	N.A.
6	59.2000	46.2000	No	Yes	N.A.	N.A.
7	61.9000	48.9000	No	Yes	N.A.	N.A.
8	64.3000	51.3000	No	Yes	N.A.	N.A.

Notes: The F0 integral of Layer n+1 equals the sum of the F0 and F1 integrals for Layer n. Layering correction equivalent depths are computed only for soil types with both shallow-depth and deep-depth expressions for peak lateral load transfer. These soil types are soft and stiff clays, non-liquefied sands, and cemented c-phi soil.

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

Pile-head conditions are Shear and Moment (Loading Type 1)

Shear force at pile head = 0.0 lbs
 Applied moment at pile head = 0.0 in-lbs

Axial thrust load on pile head

= 0.0 lbs

Depth X feet	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness lb-in^2	Soil Res. p lb/inch	Soil Spr. Es*H lb/inch	Distrib. Lat. Load lb/inch
0.00	8.5831	-3.21E-06	0.00	-0.03755	5.32E-08	2.62E+10	0.00	0.00	84.8596
0.5500	8.3352	1848.	618.0837	-0.03755	30.6677	2.62E+10	0.00	0.00	102.4385
1.1000	8.0874	8159.	1372.	-0.03755	135.3767	2.62E+10	0.00	0.00	125.8769
1.6500	7.8396	19952.	2280.	-0.03754	331.0680	2.62E+10	0.00	0.00	149.3154
2.2000	7.5918	38250.	3342.	-0.03754	634.6826	2.62E+10	0.00	0.00	172.7538
2.7500	7.3441	64073.	4560.	-0.03752	1063.	2.62E+10	0.00	0.00	196.1923
3.3000	7.0965	98442.	5932.	-0.03750	1633.	2.62E+10	0.00	0.00	219.6308
3.8500	6.8490	142379.	7459.	-0.03747	2362.	2.62E+10	0.00	0.00	243.0692
4.4000	6.6018	196903.	9141.	-0.03743	3267.	2.62E+10	0.00	0.00	266.5077
4.9500	6.3549	263036.	10977.	-0.03737	4365.	2.62E+10	0.00	0.00	289.9462
5.5000	6.1085	341800.	12968.	-0.03730	5671.	2.62E+10	0.00	0.00	313.3846
6.0500	5.8626	434214.	15114.	-0.03720	7205.	2.62E+10	0.00	0.00	336.8231
6.6000	5.6175	541301.	17414.	-0.03708	8982.	2.62E+10	0.00	0.00	360.2615
7.1500	5.3732	664080.	19869.	-0.03693	11019.	2.62E+10	0.00	0.00	383.7000
7.7000	5.1301	803574.	22479.	-0.03674	13334.	2.62E+10	0.00	0.00	407.1385
8.2500	4.8882	960802.	25243.	-0.03652	15943.	2.62E+10	0.00	0.00	430.5769
8.8000	4.6480	1136787.	28163.	-0.03625	18863.	2.62E+10	0.00	0.00	454.0154
9.3500	4.4097	1332548.	31236.	-0.03594	22111.	2.62E+10	0.00	0.00	477.4538
9.9000	4.1736	1549107.	34465.	-0.03558	25704.	2.62E+10	0.00	0.00	500.8923
10.4500	3.9400	1787485.	37848.	-0.03516	29660.	2.62E+10	0.00	0.00	524.3308
11.0000	3.7094	2048703.	41386.	-0.03468	33994.	2.62E+10	0.00	0.00	547.7692
11.5500	3.4823	2333782.	45079.	-0.03413	38724.	2.62E+10	0.00	0.00	571.2077
12.1000	3.2590	2643742.	48926.	-0.03350	43867.	2.62E+10	0.00	0.00	594.6462
12.6500	3.0401	2979606.	52928.	-0.03279	49440.	2.62E+10	0.00	0.00	618.0846
13.2000	2.8261	3342393.	53192.	-0.03200	55460.	2.62E+10	-624.347	1458.	86.1003
13.7500	2.6177	3681734.	49302.	-0.03111	61091.	2.62E+10	-640.306	1614.	0.00
14.3000	2.4155	3993183.	45028.	-0.03015	66259.	2.62E+10	-654.809	1789.	0.00
14.8500	2.2198	4276109.	40664.	-0.02910	70953.	2.62E+10	-667.805	1986.	0.00
15.4000	2.0313	4529945.	36219.	-0.02800	75165.	2.62E+10	-679.243	2207.	0.00
15.9500	1.8503	4754193.	31703.	-0.02683	78886.	2.62E+10	-689.069	2458.	0.00
16.5000	1.6771	4948426.	27128.	-0.02561	82109.	2.62E+10	-697.226	2744.	0.00
17.0500	1.5123	5112287.	22505.	-0.02434	84828.	2.62E+10	-703.655	3071.	0.00
17.6000	1.3559	5245497.	17846.	-0.02304	87038.	2.62E+10	-708.296	3448.	0.00
18.1500	1.2082	5347854.	13162.	-0.02170	88737.	2.62E+10	-711.083	3884.	0.00
18.7000	1.0694	5419236.	8466.	-0.02035	89921.	2.62E+10	-711.943	4394.	0.00
19.2500	0.9396	5459606.	3771.	-0.01898	90591.	2.62E+10	-710.801	4993.	0.00
19.8000	0.8189	5469013.	-909.648	-0.01760	90747.	2.62E+10	-707.572	5703.	0.00
20.3500	0.7073	5447599.	-5562.	-0.01623	90392.	2.62E+10	-702.161	6552.	0.00
20.9000	0.6047	5395598.	-10171.	-0.01486	89529.	2.62E+10	-694.460	7580.	0.00
21.4500	0.5111	5313346.	-14721.	-0.01351	88164.	2.62E+10	-684.343	8838.	0.00
22.0000	0.4263	5201285.	-19195.	-0.01219	86305.	2.62E+10	-671.662	10399.	0.00
22.5500	0.3501	5059966.	-23578.	-0.01090	83960.	2.62E+10	-656.234	12370.	0.00
23.1000	0.2824	4890062.	-27848.	-0.00965	81140.	2.62E+10	-637.827	14907.	0.00
23.6500	0.2228	4692373.	-31986.	-0.00844	77860.	2.62E+10	-616.136	18252.	0.00
24.2000	0.1710	4467846.	-35969.	-0.00729	74135.	2.62E+10	-590.738	22803.	0.00
24.7500	0.1266	4217586.	-39769.	-0.00619	69982.	2.62E+10	-561.010	29249.	0.00
25.3000	0.08921	3942889.	-44527.	-0.00517	65424.	2.62E+10	-880.758	65162.	0.00

25.8500	0.05838	3629826.	-50117.	-0.00421	60229.	2.62E+10	-813.042	91919.	0.00
26.4000	0.03358	3281347.	-55196.	-0.00334	54447.	2.62E+10	-726.233	142739.	0.00
26.9500	0.01423	2901233.	-59575.	-0.00257	48140.	2.62E+10	-600.643	278517.	0.00
27.5000	-2.92E-04	2494955.	-61109.	-0.00189	41399.	2.62E+10	135.8523	3066813.	0.00
28.0500	-0.01067	2094595.	-58726.	-0.00131	34755.	2.62E+10	586.2023	362513.	0.00
28.6000	-0.01757	1719769.	-54549.	-8.29E-04	28536.	2.62E+10	679.4787	255205.	0.00
29.1500	-0.02161	1374542.	-49892.	-4.39E-04	22808.	2.62E+10	731.8413	223467.	0.00
29.7000	-0.02337	1061194.	-44960.	-1.33E-04	17608.	2.62E+10	762.8768	215419.	0.00
30.2500	-0.02337	781077.	-39870.	9.91E-05	12960.	2.62E+10	779.4196	220136.	0.00
30.8000	-0.02207	534911.	-34708.	2.65E-04	8876.	2.62E+10	784.6675	234702.	0.00
31.3500	-0.01987	322925.	-29544.	3.73E-04	5358.	2.62E+10	780.3359	259144.	0.00
31.9000	-0.01715	144931.	-24436.	4.32E-04	2405.	2.62E+10	767.4008	295397.	0.00
32.4500	-0.01418	365.0152	-19441.	4.50E-04	6.0567	2.62E+10	746.4075	347485.	0.00
33.0000	-0.01121	-111688.	-14610.	4.36E-04	1853.	2.62E+10	717.6086	422593.	0.00
33.5500	-0.00842	-192481.	-9994.	3.98E-04	3194.	2.62E+10	681.0117	533581.	0.00
34.1000	-0.00596	-243610.	-5647.	3.43E-04	4042.	2.62E+10	636.3530	704743.	0.00
34.6500	-0.00390	-267019.	-1623.	2.78E-04	4431.	2.62E+10	582.9538	986483.	0.00
35.2000	-0.00228	-265035.	2014.	2.11E-04	4398.	2.62E+10	519.2637	1500118.	0.00
35.7500	-0.00111	-240432.	5184.	1.48E-04	3989.	2.62E+10	441.2048	2624978.	0.00
36.3000	-3.34E-04	-196610.	7346.	9.28E-05	3262.	2.62E+10	214.0261	4234781.	0.00
36.8500	1.16E-04	-143464.	7804.	5.00E-05	2380.	2.62E+10	-75.394	4307743.	0.00
37.4000	3.26E-04	-93603.	6840.	2.01E-05	1553.	2.62E+10	-216.521	4380703.	0.00
37.9500	3.81E-04	-53174.	5276.	1.67E-06	882.3105	2.62E+10	-257.355	4453661.	0.00
38.5000	3.48E-04	-23955.	3639.	-8.04E-06	397.4817	2.62E+10	-238.812	4526616.	0.00
39.0500	2.75E-04	-5139.	2218.	-1.17E-05	85.2637	2.62E+10	-191.797	4599569.	0.00
39.6000	1.94E-04	5323.	1133.	-1.17E-05	88.3257	2.62E+10	-137.124	4672521.	0.00
40.1500	1.21E-04	9812.	392.9598	-9.78E-06	162.8039	2.62E+10	-87.007	4745470.	0.00
40.7000	6.46E-05	10510.	-49.879	-7.22E-06	174.3943	2.62E+10	-47.186	4818418.	0.00
41.2500	2.57E-05	9153.	-268.498	-4.74E-06	151.8790	2.62E+10	-19.062	4891365.	0.00
41.8000	2.02E-06	6966.	-336.407	-2.71E-06	115.5861	2.62E+10	-1.517	4964309.	0.00
42.3500	-1.01E-05	4713.	-315.940	-1.24E-06	78.1970	2.62E+10	7.7186	5037253.	0.00
42.9000	-1.44E-05	2796.	-253.644	-2.99E-07	46.3869	2.62E+10	11.1590	5110195.	0.00
43.4500	-1.41E-05	1365.	-180.366	2.24E-07	22.6423	2.62E+10	11.0465	5183136.	0.00
44.0000	-1.15E-05	414.7558	-113.814	4.48E-07	6.8820	2.62E+10	9.1207	5256075.	0.00
44.5500	-8.15E-06	-137.766	-62.031	4.83E-07	2.2859	2.62E+10	6.5711	5321250.	0.00
45.1000	-5.08E-06	-404.051	-24.399	4.15E-07	6.7044	2.62E+10	4.8324	6282562.	0.00
45.6500	-2.67E-06	-459.836	0.07594	3.06E-07	7.6300	2.62E+10	2.5843	6377981.	0.00
46.2000	-1.04E-06	-403.048	11.9575	1.97E-07	6.6877	2.62E+10	1.0162	6473408.	0.00
46.7500	-6.75E-08	-301.996	15.5326	1.09E-07	5.0110	2.62E+10	0.06718	6568844.	0.00
47.3000	3.99E-07	-198.018	14.4239	4.58E-08	3.2857	2.62E+10	-0.403	6664287.	0.00
47.8500	5.37E-07	-111.601	11.2787	6.82E-09	1.8518	2.62E+10	-0.550	6759737.	0.00
48.4000	4.89E-07	-49.139	7.7868	-1.34E-08	0.8154	2.62E+10	-0.508	6855194.	0.00
48.9500	3.60E-07	-8.815	4.8590	-2.07E-08	0.1463	2.62E+10	-0.379	6950657.	0.00
49.5000	2.16E-07	15.0000	2.8476	-1.99E-08	0.2489	2.62E+10	-0.230	7046127.	0.00
50.0500	9.68E-08	28.7743	0.7328	-1.44E-08	0.4774	2.62E+10	-0.410	2.80E+07	0.00
50.6000	2.55E-08	24.6726	-1.071	-7.69E-09	0.4094	2.62E+10	-0.136	3.52E+07	0.00
51.1500	-4.73E-09	14.6330	-1.421	-2.75E-09	0.2428	2.62E+10	0.03041	4.25E+07	0.00
51.7000	-1.07E-08	5.9181	-1.055	-1.58E-10	0.09820	2.62E+10	0.08048	4.97E+07	0.00
52.2500	-6.81E-09	0.7086	-0.595	6.76E-10	0.01176	2.62E+10	0.05879	5.69E+07	0.00
52.8000	-1.76E-09	-1.940	-0.129	5.21E-10	0.03219	2.62E+10	0.08249	3.09E+08	0.00
53.3500	6.23E-11	-0.995	0.1324	1.51E-10	0.01652	2.62E+10	-0.00324	3.43E+08	0.00
53.9000	2.35E-10	-0.192	0.07729	1.99E-12	0.00319	2.62E+10	-0.01347	3.78E+08	0.00
54.4500	8.86E-11	0.02472	0.01455	-1.91E-11	4.10E-04	2.62E+10	-0.00554	4.13E+08	0.00

55.0000 -1.67E-11 0.00 0.00 -1.60E-11 0.00 2.62E+10 0.00113 2.24E+08 0.00

* The above values of total stress are combined axial and bending stresses.

Output Summary for Load Case No. 1:

Pile-head deflection = 8.58305883 inches
 Computed slope at pile head = -0.0375500 radians
 Maximum bending moment = 5469013. inch-lbs
 Maximum shear force = -61109. lbs
 Depth of maximum bending moment = 19.80000000 feet below pile head
 Depth of maximum shear force = 27.50000000 feet below pile head
 Number of iterations = 30
 Number of zero deflection points = 7
 Pile deflection at ground = 2.90392620 inches

Pile-head Deflection vs. Pile Length for Load Case 1

Boundary Condition Type 1, Shear and Moment

Shear = 0. lbs
 Moment = 0. in-lbs
 Axial Load = 0. lbs

Pile Length feet	Pile Head Deflection inches	Maximum Moment ln-lbs	Maximum Shear lbs
55.00000	8.58305883	5469013.	-61109.
52.25000	8.42933931	5406541.	-60838.
49.50000	8.79573247	5564315.	-62284.
46.75000	8.50220454	5433830.	-60919.
44.00000	8.63158452	5497720.	-61961.
41.25000	8.65385837	5503245.	-61922.
38.50000	8.53702587	5455405.	-61762.
35.75000	8.71941418	5528917.	-61661.
33.00000	8.92985285	5493842.	-64810.
30.25000	11.84889838	5163219.	-70790.
27.50000	35.05753062	4925974.	-75415.

Summary of Pile-head Responses for Conventional Analyses

Definitions of Pile-head Loading Conditions:

Load Type 1: Load 1 = Shear, V, lbs, and Load 2 = Moment, M, in-lbs

Load Type 2: Load 1 = Shear, V, lbs, and Load 2 = Slope, S, radians
 Load Type 3: Load 1 = Shear, V, lbs, and Load 2 = Rot. Stiffness, R, in-lbs/rad.
 Load Type 4: Load 1 = Top Deflection, y, inches, and Load 2 = Moment, M, in-lbs
 Load Type 5: Load 1 = Top Deflection, y, inches, and Load 2 = Slope, S, radians

Load Case No.	Load Type 1	Pile-head Load 1	Load Type 2	Pile-head Load 2	Axial Loading lbs	Pile-head Deflection inches	Pile-head Rotation radians	Max Shear in Pile lbs	Max Moment in Pile in-lbs
1	V, lb	0.00	M, in-lb	0.00	0.00	8.5831	-0.03755	-61109.	5469013.

Maximum pile-head deflection = 8.5830588307 inches
 Maximum pile-head rotation = -0.0375499932 radians = -2.151456 deg.

Summary of Warning Messages

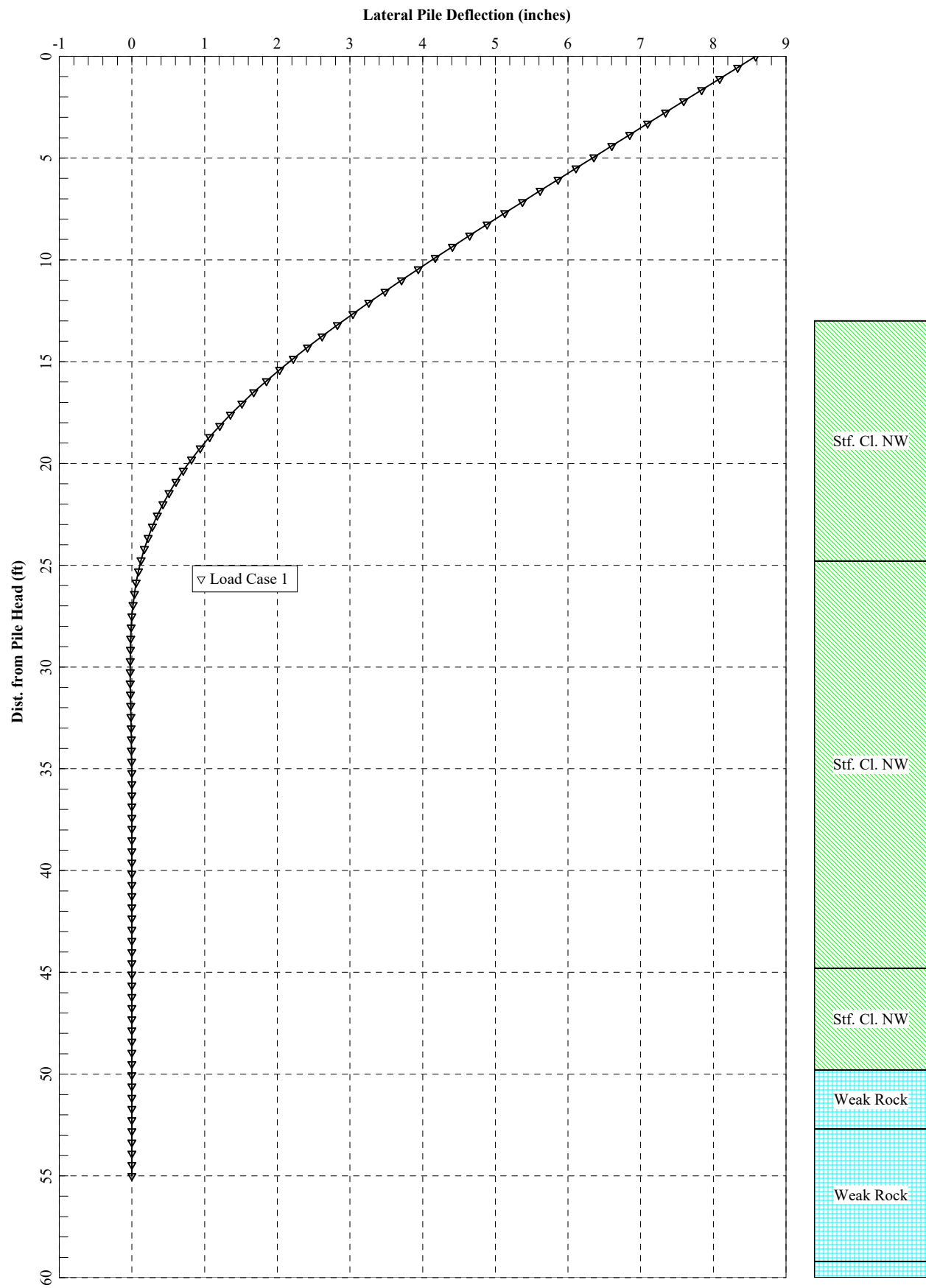
The following warning was reported 305 times

**** Warning ****

An unreasonable input value for unconfined compressive strength has been specified for a soil defined using the weak rock criteria. The input value is greater than 500 psi. Please check your input data for correctness.

The analysis ended normally.

Excessive deflection
with HP 14x89
cantilever wall (no
tiebacks)



Strength Limit

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LPILE for Windows, Version 2022-12.009

Analysis of Individual Piles and Drilled Shafts
Subjected to Lateral Loading Using the p-y Method
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Files Used for Analysis

Path to file locations:
\\ODOT-District 10 GES\\Task 10-13 WAS-77-9.58\\20250116_Redesign Calculations\\20250116_Updated Analyses\\

Name of input data file:
WAS-77-9.58 13' Wall Strength Case_20250116.lp12d

Name of output report file:
WAS-77-9.58 13' Wall Strength Case_20250116.lp12o

Name of plot output file:
WAS-77-9.58 13' Wall Strength Case_20250116.lp12p

Name of runtime message file:
WAS-77-9.58 13' Wall Strength Case_20250116.lp12r

Date and Time of Analysis

Date: January 24, 2025

Time: 9:45:48

Problem Title

Project Name: WAS-77-9.58

Job Number:

Client: ODOT D10

Engineer: HDR

Description: Strength Case

Program Options and Settings

Computational Options:

- Conventional Analysis

Engineering Units Used for Data Input and Computations:

- US Customary System Units (pounds, feet, inches)

Analysis Control Options:

- | | | |
|--|---|---------------|
| - Maximum number of iterations allowed | = | 500 |
| - Deflection tolerance for convergence | = | 1.0000E-05 in |
| - Maximum allowable deflection | = | 100.0000 in |
| - Number of pile increments | = | 100 |

Loading Type and Number of Cycles of Loading:

- Static loading specified
- Analysis uses p-y modification factors for p-y curves
- Analysis uses layering correction (Method of Georgiadis)
- Analysis includes loading by one distributed lateral load acting on pile
- Loading by lateral soil movements acting on pile not selected
- Input of shear resistance at the pile tip not selected
- Input of moment resistance at the pile tip not selected
- Computation of pile-head foundation stiffness matrix not selected
- Push-over analysis of pile not selected
- Buckling analysis of pile not selected

Output Options:

- Output files use decimal points to denote decimal symbols.
- Values of pile-head deflection, bending moment, shear force, and soil reaction are printed for full length of pile.
- Printing Increment (nodal spacing of output points) = 1
- No p-y curves to be computed and reported for user-specified depths
- Print using wide report formats

Pile Structural Properties and Geometry

Number of pile sections defined = 1
Total length of pile = 55.000 ft
Depth of ground surface below top of pile = 13.0000 ft

Pile diameters used for p-y curve computations are defined using 2 points.

p-y curves are computed using pile diameter values interpolated with depth over the length of the pile. A summary of values of pile diameter vs. depth follows.

Point No.	Depth Below Pile Head feet	Pile Diameter inches
1	0.000	30.0000
2	55.000	30.0000

Input Structural Properties for Pile Sections:

Pile Section No. 1:

Section 1 is an elastic pile
Cross-sectional Shape = Circular Pile
Length of section = 55.000000 ft
Width of top of section = 30.000000 in
Width of bottom of section = 30.000000 in
Top Area = 26.100000 sq. in
Bottom Area = 26.100000 sq. in
Moment of Inertia at Top = 904.000000 in^4
Moment of Inertia at Bottom = 904.000000 in^4
Elastic Modulus = 29000000. psi

Soil and Rock Layering Information

The soil profile is modelled using 8 layers

Layer 1 is stiff clay without free water

Distance from top of pile to top of layer	=	13.000000 ft
Distance from top of pile to bottom of layer	=	24.800000 ft
Effective unit weight at top of layer	=	77.600000 pcf
Effective unit weight at bottom of layer	=	77.600000 pcf
Undrained cohesion at top of layer	=	1500. psf
Undrained cohesion at bottom of layer	=	1500. psf
Epsilon-50 at top of layer	=	0.007000
Epsilon-50 at bottom of layer	=	0.007000

Layer 2 is stiff clay without free water

Distance from top of pile to top of layer	=	24.800000 ft
Distance from top of pile to bottom of layer	=	44.800000 ft
Effective unit weight at top of layer	=	72.600000 pcf
Effective unit weight at bottom of layer	=	72.600000 pcf
Undrained cohesion at top of layer	=	3000. psf
Undrained cohesion at bottom of layer	=	3000. psf
Epsilon-50 at top of layer	=	0.005000
Epsilon-50 at bottom of layer	=	0.005000

Layer 3 is stiff clay without free water

Distance from top of pile to top of layer	=	44.800000 ft
Distance from top of pile to bottom of layer	=	49.800000 ft
Effective unit weight at top of layer	=	82.600000 pcf
Effective unit weight at bottom of layer	=	82.600000 pcf
Undrained cohesion at top of layer	=	4000. psf
Undrained cohesion at bottom of layer	=	4000. psf
Epsilon-50 at top of layer	=	0.005000
Epsilon-50 at bottom of layer	=	0.005000

Layer 4 is weak rock, p-y criteria by Reese, 1997

Distance from top of pile to top of layer	=	49.800000 ft
Distance from top of pile to bottom of layer	=	52.700000 ft
Effective unit weight at top of layer	=	150.000000 pcf
Effective unit weight at bottom of layer	=	150.000000 pcf
Uniaxial compressive strength at top of layer	=	330.000000 psi

Uniaxial compressive strength at bottom of layer	=	330.000000 psi
Initial modulus of rock at top of layer	=	37400. psi
Initial modulus of rock at bottom of layer	=	37400. psi
RQD of rock at top of layer	=	64.000000 %
RQD of rock at bottom of layer	=	64.000000 %
k _{rm} of rock at top of layer	=	0.0005000
k _{rm} of rock at bottom of layer	=	0.0005000

Layer 5 is weak rock, p-y criteria by Reese, 1997

Distance from top of pile to top of layer	=	52.700000 ft
Distance from top of pile to bottom of layer	=	59.200000 ft
Effective unit weight at top of layer	=	160.000000 pcf
Effective unit weight at bottom of layer	=	160.000000 pcf
Uniaxial compressive strength at top of layer	=	1150. psi
Uniaxial compressive strength at bottom of layer	=	1150. psi
Initial modulus of rock at top of layer	=	179800. psi
Initial modulus of rock at bottom of layer	=	179800. psi
RQD of rock at top of layer	=	100.000000 %
RQD of rock at bottom of layer	=	100.000000 %
k _{rm} of rock at top of layer	=	0.0005000
k _{rm} of rock at bottom of layer	=	0.0005000

Layer 6 is weak rock, p-y criteria by Reese, 1997

Distance from top of pile to top of layer	=	59.200000 ft
Distance from top of pile to bottom of layer	=	61.900000 ft
Effective unit weight at top of layer	=	160.000000 pcf
Effective unit weight at bottom of layer	=	160.000000 pcf
Uniaxial compressive strength at top of layer	=	1150. psi
Uniaxial compressive strength at bottom of layer	=	1150. psi
Initial modulus of rock at top of layer	=	179800. psi
Initial modulus of rock at bottom of layer	=	179800. psi
RQD of rock at top of layer	=	91.000000 %
RQD of rock at bottom of layer	=	91.000000 %
k _{rm} of rock at top of layer	=	0.0005000
k _{rm} of rock at bottom of layer	=	0.0005000

Layer 7 is weak rock, p-y criteria by Reese, 1997

Distance from top of pile to top of layer	=	61.900000 ft
Distance from top of pile to bottom of layer	=	64.300000 ft
Effective unit weight at top of layer	=	150.000000 pcf
Effective unit weight at bottom of layer	=	150.000000 pcf
Uniaxial compressive strength at top of layer	=	330.000000 psi
Uniaxial compressive strength at bottom of layer	=	330.000000 psi
Initial modulus of rock at top of layer	=	37400. psi

Initial modulus of rock at bottom of layer	=	37400. psi
RQD of rock at top of layer	=	17.000000 %
RQD of rock at bottom of layer	=	17.000000 %
k _{rm} of rock at top of layer	=	0.0005000
k _{rm} of rock at bottom of layer	=	0.0005000

Layer 8 is weak rock, p-y criteria by Reese, 1997

Distance from top of pile to top of layer	=	64.300000 ft
Distance from top of pile to bottom of layer	=	95.000000 ft
Effective unit weight at top of layer	=	150.000000 pcf
Effective unit weight at bottom of layer	=	150.000000 pcf
Uniaxial compressive strength at top of layer	=	330.000000 psi
Uniaxial compressive strength at bottom of layer	=	330.000000 psi
Initial modulus of rock at top of layer	=	37400. psi
Initial modulus of rock at bottom of layer	=	37400. psi
RQD of rock at top of layer	=	86.000000 %
RQD of rock at bottom of layer	=	86.000000 %
k _{rm} of rock at top of layer	=	0.0005000
k _{rm} of rock at bottom of layer	=	0.0005000

(Depth of the lowest soil layer extends 40.000 ft below the pile tip)

**** Warning - Possible Input Data Error ****

Values entered for effective unit weight of rock were outside the limits of 50 pcf to 150 pcf.

The maximum input value, in layer 8, for effective unit weight = 160.00 pcf

This data may be erroneous. Please check your data.

Summary of Input Soil Properties								
Layer Num.	Soil Type Name (p-y Curve Type)	Layer Depth ft	Effective Unit Wt. pcf	Cohesion psf	Uniaxial qu psi	RQD %	E50 or k _{rm}	Rock Mass Modulus psi
1	Stiff Clay	13.0000	77.6000	1500.	--	--	0.00700	--
	w/o Free Water	24.8000	77.6000	1500.	--	--	0.00700	--
2	Stiff Clay	24.8000	72.6000	3000.	--	--	0.00500	--
	w/o Free Water	44.8000	72.6000	3000.	--	--	0.00500	--
3	Stiff Clay	44.8000	82.6000	4000.	--	--	0.00500	--

	w/o Free Water	49.8000	82.6000	4000.	--	--	0.00500	--
4	Weak	49.8000	150.0000	--	330.0000	64.0000	5.00E-04	37400.
	Rock	52.7000	150.0000	--	330.0000	64.0000	5.00E-04	37400.
5	Weak	52.7000	160.0000	--	1150.	100.0000	5.00E-04	179800.
	Rock	59.2000	160.0000	--	1150.	100.0000	5.00E-04	179800.
6	Weak	59.2000	160.0000	--	1150.	91.0000	5.00E-04	179800.
	Rock	61.9000	160.0000	--	1150.	91.0000	5.00E-04	179800.
7	Weak	61.9000	150.0000	--	330.0000	17.0000	5.00E-04	37400.
	Rock	64.3000	150.0000	--	330.0000	17.0000	5.00E-04	37400.
8	Weak	64.3000	150.0000	--	330.0000	86.0000	5.00E-04	37400.
	Rock	95.0000	150.0000	--	330.0000	86.0000	5.00E-04	37400.

Modification Factors for p-y Curves

Distribution of p-y modifiers with depth defined using 2 points

Point No.	Depth X ft	p-mult	y-mult
1	13.000	0.8600	1.0000
2	49.800	0.8600	1.0000

Static Loading Type

Static loading criteria were used when computing p-y curves for all analyses.

Distributed Lateral Loading Used For All Load Cases

Distributed lateral load intensity defined using 2 points

Point No.	Depth X ft	Dist. Load lb/in
1	0.000	138.000
2	13.000	969.000

Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 1

Load No.	Load Type	Condition 1	Condition 2	Axial Thrust Force, lbs	Compute Top y vs. Pile Length	Run Analysis
1	1	V = 0.0000 lbs	M = 0.0000 in-lbs	0.0000000	Yes	Yes

V = shear force applied normal to pile axis

M = bending moment applied to pile head

y = lateral deflection normal to pile axis

S = pile slope relative to original pile batter angle

R = rotational stiffness applied to pile head

Values of top y vs. pile lengths can be computed only for load types with specified shear loading (Load Types 1, 2, and 3).

Thrust force is assumed to be acting axially for all pile batter angles.

Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness

Axial thrust force values were determined from pile-head loading conditions

Number of Pile Sections Analyzed = 1

Pile Section No. 1:

Moment-curvature properties were derived from elastic section properties

Layering Correction Equivalent Depths of Soil & Rock Layers

Layer No.	Top of Layer Below Pile Head ft	Equivalent Top Depth Below Grnd Surf ft	Same Layer Type As Layer Above	Layer is Rock or is Below Rock Layer	F0 Integral for Layer lbs	F1 Integral for Layer lbs
1	13.0000	0.00	N.A.	No	0.00	198867.
2	24.8000	6.9960	Yes	No	198867.	1023925.
3	44.8000	22.4295	Yes	No	1222792.	430929.

4	49.8000	36.8000	No	Yes	N.A.	N.A.
5	52.7000	39.7000	No	Yes	N.A.	N.A.
6	59.2000	46.2000	No	Yes	N.A.	N.A.
7	61.9000	48.9000	No	Yes	N.A.	N.A.
8	64.3000	51.3000	No	Yes	N.A.	N.A.

Notes: The F0 integral of Layer n+1 equals the sum of the F0 and F1 integrals for Layer n. Layering correction equivalent depths are computed only for soil types with both shallow-depth and deep-depth expressions for peak lateral load transfer. These soil types are soft and stiff clays, non-liquefied sands, and cemented c-phi soil.

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

Pile-head conditions are Shear and Moment (Loading Type 1)

Shear force at pile head = 0.0 lbs
Applied moment at pile head = 0.0 in-lbs
Axial thrust load on pile head = 0.0 lbs

Depth X feet	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness lb-in^2	Soil Res. p lb/inch	Soil Spr. Es*H lb/inch	Distrib. Lat. Load lb/inch
0.00	17.5340	-2.14E-06	-1.62E-07	-0.07175	3.55E-08	2.62E+10	0.00	0.00	146.7894
0.5500	17.0604	3197.	1056.	-0.07175	53.0488	2.62E+10	0.00	0.00	173.1577
1.1000	16.5869	13937.	2315.	-0.07175	231.2538	2.62E+10	0.00	0.00	208.3154
1.6500	16.1133	33751.	3806.	-0.07174	560.0266	2.62E+10	0.00	0.00	243.4731
2.2000	15.6398	64171.	5529.	-0.07173	1065.	2.62E+10	0.00	0.00	278.6308
2.7500	15.1665	106728.	7484.	-0.07171	1771.	2.62E+10	0.00	0.00	313.7885
3.3000	14.6933	162953.	9671.	-0.07168	2704.	2.62E+10	0.00	0.00	348.9462
3.8500	14.2203	234379.	12090.	-0.07163	3889.	2.62E+10	0.00	0.00	384.1038
4.4000	13.7478	322536.	14741.	-0.07156	5352.	2.62E+10	0.00	0.00	419.2615
4.9500	13.2758	428956.	17624.	-0.07146	7118.	2.62E+10	0.00	0.00	454.4192
5.5000	12.8045	555171.	20739.	-0.07134	9212.	2.62E+10	0.00	0.00	489.5769
6.0500	12.3341	702711.	24086.	-0.07118	11660.	2.62E+10	0.00	0.00	524.7346
6.6000	11.8649	873110.	27666.	-0.07098	14487.	2.62E+10	0.00	0.00	559.8923
7.1500	11.3971	1067897.	31477.	-0.07074	17720.	2.62E+10	0.00	0.00	595.0500
7.7000	10.9312	1288604.	35520.	-0.07044	21382.	2.62E+10	0.00	0.00	630.2077
8.2500	10.4673	1536763.	39796.	-0.07009	25499.	2.62E+10	0.00	0.00	665.3654
8.8000	10.0060	1813906.	44303.	-0.06966	30098.	2.62E+10	0.00	0.00	700.5231
9.3500	9.5478	2121563.	49042.	-0.06917	35203.	2.62E+10	0.00	0.00	735.6808
9.9000	9.0930	2461267.	54014.	-0.06859	40840.	2.62E+10	0.00	0.00	770.8385
10.4500	8.6424	2834548.	59218.	-0.06792	47033.	2.62E+10	0.00	0.00	805.9962

11.0000	8.1964	3242939.	64653.	-0.06716	53810.	2.62E+10	0.00	0.00	841.1538
11.5500	7.7559	3687970.	70321.	-0.06629	61194.	2.62E+10	0.00	0.00	876.3115
12.1000	7.3214	4171173.	76220.	-0.06530	69212.	2.62E+10	0.00	0.00	911.4692
12.6500	6.8939	4694080.	82352.	-0.06418	77888.	2.62E+10	0.00	0.00	946.6269
13.2000	6.4742	5258222.	83376.	-0.06293	87249.	2.62E+10	-768.113	783.0345	131.8095
13.7500	6.0633	5794647.	78670.	-0.06154	96150.	2.62E+10	-789.920	859.8448	0.00
14.3000	5.6619	6296662.	73389.	-0.06002	104480.	2.62E+10	-810.226	944.4636	0.00
14.8500	5.2711	6763384.	67980.	-0.05837	112224.	2.62E+10	-828.982	1038.	0.00
15.4000	4.8914	7193996.	62452.	-0.05661	119369.	2.62E+10	-846.139	1142.	0.00
15.9500	4.5237	7587750.	56816.	-0.05475	125903.	2.62E+10	-861.645	1257.	0.00
16.5000	4.1687	7943971.	51084.	-0.05280	131814.	2.62E+10	-875.446	1386.	0.00
17.0500	3.8268	8262057.	45266.	-0.05076	137092.	2.62E+10	-887.487	1531.	0.00
17.6000	3.4987	8541484.	39375.	-0.04864	141728.	2.62E+10	-897.710	1693.	0.00
18.1500	3.1847	8781807.	33423.	-0.04646	145716.	2.62E+10	-906.053	1878.	0.00
18.7000	2.8853	8982663.	27422.	-0.04423	149049.	2.62E+10	-912.452	2087.	0.00
19.2500	2.6009	9143772.	21385.	-0.04195	151722.	2.62E+10	-916.839	2327.	0.00
19.8000	2.3317	9264943.	15326.	-0.03963	153732.	2.62E+10	-919.138	2602.	0.00
20.3500	2.0778	9346077.	9259.	-0.03729	155079.	2.62E+10	-919.271	2920.	0.00
20.9000	1.8395	9387168.	3199.	-0.03493	155761.	2.62E+10	-917.150	3291.	0.00
21.4500	1.6168	9388307.	-2839.	-0.03256	155779.	2.62E+10	-912.676	3726.	0.00
22.0000	1.4096	9349690.	-8840.	-0.03021	155139.	2.62E+10	-905.742	4241.	0.00
22.5500	1.2181	9271619.	-14786.	-0.02786	153843.	2.62E+10	-896.222	4856.	0.00
23.1000	1.0419	9154509.	-20661.	-0.02554	151900.	2.62E+10	-883.974	5600.	0.00
23.6500	0.8809	8998893.	-26445.	-0.02326	149318.	2.62E+10	-868.827	6510.	0.00
24.2000	0.7349	8805430.	-32119.	-0.02102	146108.	2.62E+10	-850.576	7639.	0.00
24.7500	0.6035	8574917.	-37662.	-0.01883	142283.	2.62E+10	-828.970	9066.	0.00
25.3000	0.4864	8308293.	-44839.	-0.01670	137859.	2.62E+10	-1346.	18264.	0.00
25.8500	0.3830	7983045.	-53574.	-0.01465	132462.	2.62E+10	-1301.	22422.	0.00
26.4000	0.2929	7601115.	-61987.	-0.01269	126125.	2.62E+10	-1248.	28120.	0.00
26.9500	0.2155	7164818.	-70016.	-0.01083	118885.	2.62E+10	-1185.	36286.	0.00
27.5000	0.1500	6676909.	-77584.	-0.00909	110789.	2.62E+10	-1109.	48787.	0.00
28.0500	0.09553	6140711.	-84588.	-0.00748	101892.	2.62E+10	-1014.	70054.	0.00
28.6000	0.05129	5560345.	-90865.	-0.00600	92262.	2.62E+10	-888.155	114287.	0.00
29.1500	0.01629	4941291.	-96047.	-0.00468	81990.	2.62E+10	-681.953	276276.	0.00
29.7000	-0.01050	4292531.	-96236.	-0.00352	71226.	2.62E+10	624.4394	392593.	0.00
30.2500	-0.03015	3670971.	-91434.	-0.00252	60912.	2.62E+10	830.6747	181814.	0.00
30.8000	-0.04371	3085596.	-85621.	-0.00167	51199.	2.62E+10	930.8726	140554.	0.00
31.3500	-0.05214	2540769.	-79272.	-9.57E-04	42159.	2.62E+10	993.0987	125706.	0.00
31.9000	-0.05635	2039202.	-72585.	-3.81E-04	33836.	2.62E+10	1033.	121017.	0.00
32.4500	-0.05717	1582642.	-65685.	7.50E-05	26261.	2.62E+10	1058.	122107.	0.00
33.0000	-0.05536	1172155.	-58665.	4.22E-04	19449.	2.62E+10	1070.	127540.	0.00
33.5500	-0.05160	808268.	-51599.	6.71E-04	13412.	2.62E+10	1071.	137028.	0.00
34.1000	-0.04650	491048.	-44554.	8.35E-04	8148.	2.62E+10	1064.	150946.	0.00
34.6500	-0.04059	220156.	-37589.	9.24E-04	3653.	2.62E+10	1047.	170259.	0.00
35.2000	-0.03430	-5130.	-30761.	9.51E-04	85.1156	2.62E+10	1022.	196655.	0.00
35.7500	-0.02803	-185892.	-24124.	9.27E-04	3084.	2.62E+10	989.1258	232902.	0.00
36.3000	-0.02207	-323568.	-17732.	8.63E-04	5369.	2.62E+10	948.0274	283568.	0.00
36.8500	-0.01664	-419949.	-11638.	7.69E-04	6968.	2.62E+10	898.6458	356473.	0.00
37.4000	-0.01191	-477184.	-5898.	6.56E-04	7918.	2.62E+10	840.5688	465850.	0.00
37.9500	-0.00797	-497804.	-573.362	5.34E-04	8260.	2.62E+10	772.9941	639920.	0.00

38.5000	-0.00486	-484752.	4269.	4.10E-04	8043.	2.62E+10	694.3268	942282.	0.00
39.0500	-0.00256	-441456.	8543.	2.93E-04	7325.	2.62E+10	600.9099	1549550.	0.00
39.6000	-9.89E-04	-371984.	12114.	1.91E-04	6172.	2.62E+10	481.3003	3211343.	0.00
40.1500	-3.70E-05	-281546.	13790.	1.09E-04	4672.	2.62E+10	26.5855	4745470.	0.00
40.7000	4.47E-04	-189950.	12800.	4.95E-05	3152.	2.62E+10	-326.641	4818418.	0.00
41.2500	6.16E-04	-112583.	10245.	1.14E-05	1868.	2.62E+10	-447.639	4794692.	0.00
41.8000	5.98E-04	-54715.	7284.	-9.66E-06	907.8847	2.62E+10	-449.714	4964309.	0.00
42.3500	4.89E-04	-16437.	4569.	-1.86E-05	272.7327	2.62E+10	-372.971	5037253.	0.00
42.9000	3.52E-04	5595.	2438.	-2.00E-05	92.8402	2.62E+10	-272.669	5110195.	0.00
43.4500	2.25E-04	15750.	955.6006	-1.73E-05	261.3313	2.62E+10	-176.650	5183136.	0.00
44.0000	1.24E-04	18209.	47.0804	-1.30E-05	302.1421	2.62E+10	-98.659	5256075.	0.00
44.5500	5.31E-05	16371.	-419.742	-8.67E-06	271.6432	2.62E+10	-42.802	5321250.	0.00
45.1000	9.49E-06	12669.	-590.805	-5.01E-06	210.2075	2.62E+10	-9.035	6282562.	0.00
45.6500	-1.31E-05	8572.	-578.992	-2.34E-06	142.2412	2.62E+10	12.6152	6377981.	0.00
46.2000	-2.14E-05	5026.	-468.236	-6.25E-07	83.3930	2.62E+10	20.9471	6473408.	0.00
46.7500	-2.13E-05	2392.	-329.125	3.08E-07	39.6850	2.62E+10	21.2077	6568844.	0.00
47.3000	-1.73E-05	681.3601	-201.541	6.95E-07	11.3058	2.62E+10	17.4543	6664287.	0.00
47.8500	-1.21E-05	-268.652	-102.939	7.47E-07	4.4577	2.62E+10	12.4251	6759737.	0.00
48.4000	-7.42E-06	-677.428	-36.491	6.28E-07	11.2405	2.62E+10	7.7104	6855194.	0.00
48.9500	-3.84E-06	-750.340	2.3011	4.48E-07	12.4503	2.62E+10	4.0449	6950657.	0.00
49.5000	-1.51E-06	-647.054	20.9519	2.72E-07	10.7365	2.62E+10	1.6068	7046127.	0.00
50.0500	-2.44E-07	-473.775	29.6741	1.31E-07	7.8613	2.62E+10	1.0363	2.80E+07	0.00
50.6000	2.29E-07	-255.356	29.0629	3.96E-08	4.2371	2.62E+10	-1.221	3.52E+07	0.00
51.1500	2.78E-07	-90.144	19.1298	-3.91E-09	1.4958	2.62E+10	-1.789	4.25E+07	0.00
51.7000	1.77E-07	-2.843	8.8202	-1.56E-08	0.04717	2.62E+10	-1.336	4.97E+07	0.00
52.2500	7.20E-08	26.2824	2.3639	-1.27E-08	0.4361	2.62E+10	-0.621	5.69E+07	0.00
52.8000	1.03E-08	28.3603	-1.267	-5.78E-09	0.4706	2.62E+10	-0.479	3.09E+08	0.00
53.3500	-4.35E-09	9.5640	-2.101	-1.01E-09	0.1587	2.62E+10	0.2263	3.43E+08	0.00
53.9000	-3.06E-09	0.6240	-0.776	2.74E-10	0.01035	2.62E+10	0.1752	3.78E+08	0.00
54.4500	-7.30E-10	-0.683	-0.04727	2.67E-10	0.01134	2.62E+10	0.04569	4.13E+08	0.00
55.0000	4.62E-10	0.00	0.00	1.81E-10	0.00	2.62E+10	-0.03137	2.24E+08	0.00

* The above values of total stress are combined axial and bending stresses.

Output Summary for Load Case No. 1:

Pile-head deflection	=	17.53401975 inches
Computed slope at pile head	=	-0.0717534 radians
Maximum bending moment	=	9388307. inch-lbs
Maximum shear force	=	-96236. lbs
Depth of maximum bending moment	=	21.45000000 feet below pile head
Depth of maximum shear force	=	29.70000000 feet below pile head
Number of iterations	=	39
Number of zero deflection points	=	6
Pile deflection at ground	=	6.62685032 inches

Pile-head Deflection vs. Pile Length for Load Case 1

Boundary Condition Type 1, Shear and Moment

Shear = 0. lbs
 Moment = 0. in-lbs
 Axial Load = 0. lbs

Pile Length feet	Pile Head Deflection inches	Maximum Moment ln-lbs	Maximum Shear lbs
55.00000	17.53401975	9388307.	-96236.
52.25000	17.25006684	9300662.	-96073.
49.50000	17.89936774	9534335.	-97871.
46.75000	17.39679306	9338263.	-96248.
44.00000	17.60978199	9435152.	-97380.
41.25000	17.66207161	9441114.	-97204.
38.50000	17.46446399	9371627.	-95579.
35.75000	18.31455097	9424518.	-102267.
33.00000	25.37315674	9011671.	-113908.

Summary of Pile-head Responses for Conventional Analyses

Definitions of Pile-head Loading Conditions:

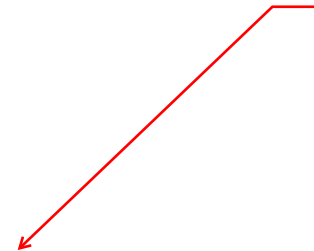
Load Type 1: Load 1 = Shear, V, lbs, and Load 2 = Moment, M, in-lbs
 Load Type 2: Load 1 = Shear, V, lbs, and Load 2 = Slope, S, radians
 Load Type 3: Load 1 = Shear, V, lbs, and Load 2 = Rot. Stiffness, R, in-lbs/rad.
 Load Type 4: Load 1 = Top Deflection, y, inches, and Load 2 = Moment, M, in-lbs
 Load Type 5: Load 1 = Top Deflection, y, inches, and Load 2 = Slope, S, radians

Load Case No.	Load Type 1	Pile-head Load 1	Load Type 2	Pile-head Load 2	Axial Loading lbs	Pile-head Deflection inches	Pile-head Rotation radians	Max Shear in Pile lbs	Max Moment in Pile in-lbs
1	V, lb	0.00	M, in-lb	0.00	0.00	17.5340	-0.07175	-96236.	9388307.

Maximum pile-head deflection = 17.5340197451 inches
 Maximum pile-head rotation = -0.0717534380 radians = -4.111169 deg.

Summary of Warning Messages

Exceeds factored
 resistance for HP
 14x89 section

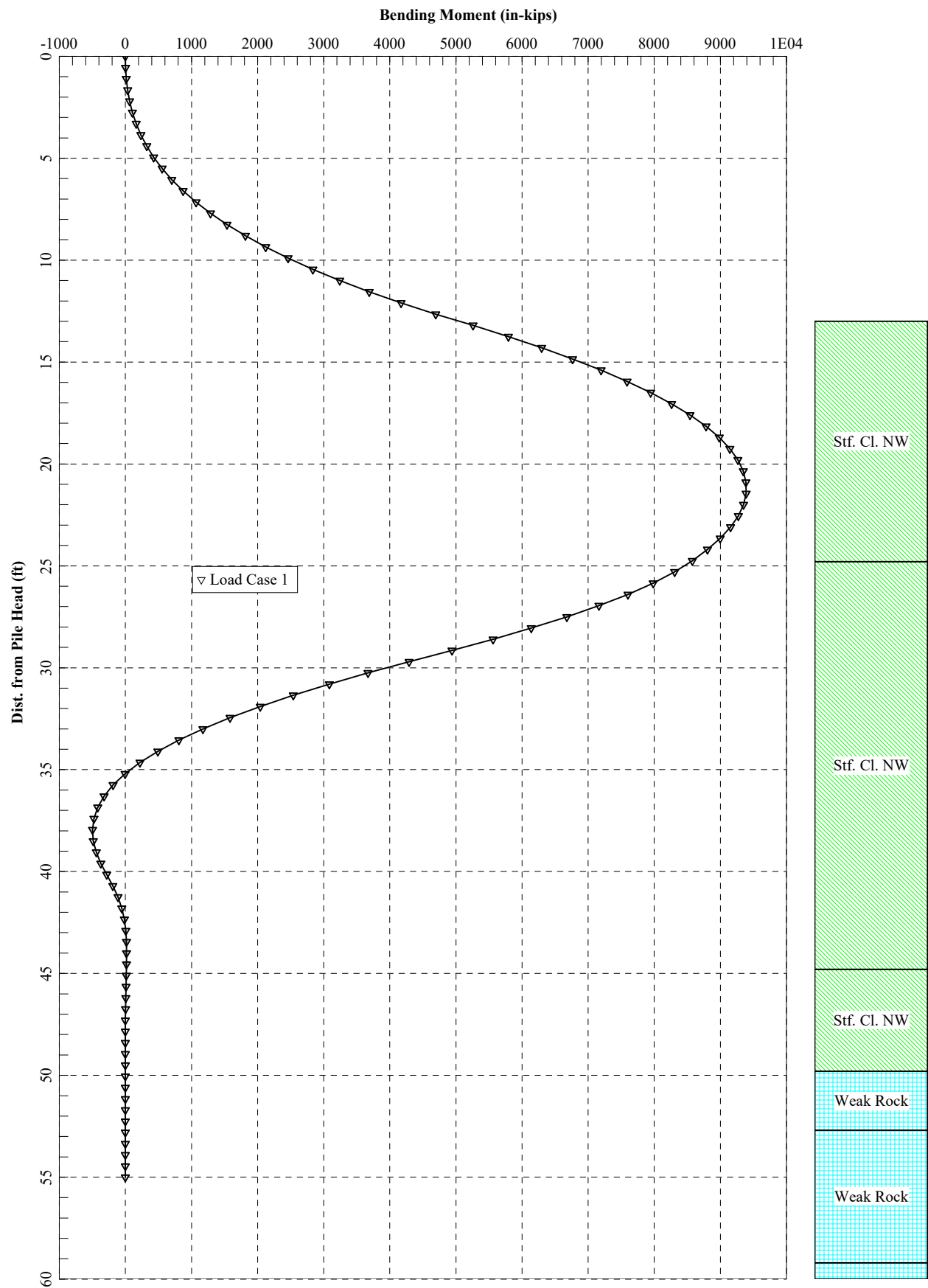


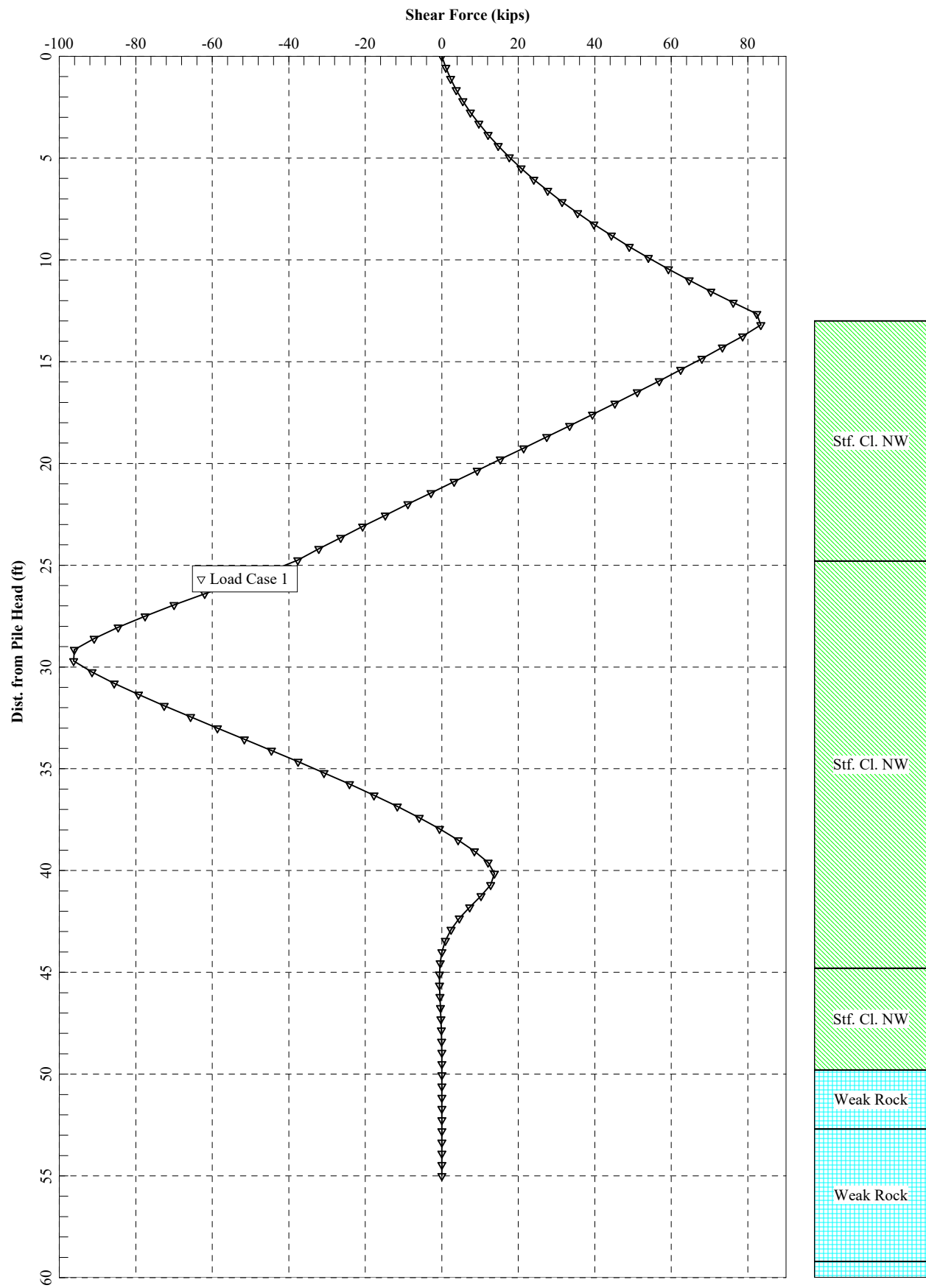
The following warning was reported 395 times

**** Warning ****

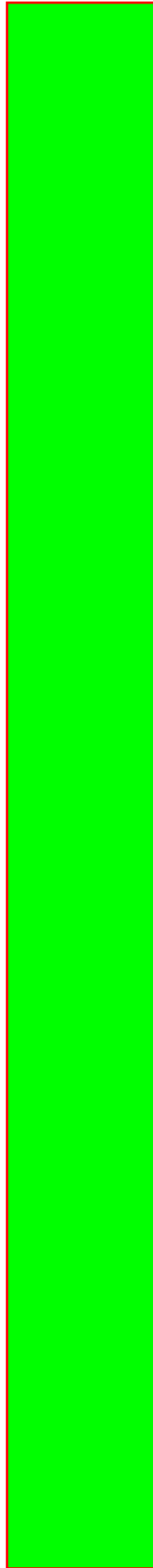
An unreasonable input value for unconfined compressive strength has been specified for a soil defined using the weak rock criteria. The input value is greater than 500 psi. Please check your input data for correctness.

The analysis ended normally.





13 ft



Shoring Suite Analysis

Wall Sta. 1+00

13.0 ft Height (Max during Construction)

Geometry

Elevation (ft)			Minimum Horiz. Distance from C/L (ft)		
Top of Backfill =	880.0	at Bottom of Embankment	Start of Wall Backfill =	50.0	at Bottom of Embankment
Top of Wall =	860.0	at C/L of Wall	Wall =	0.0	at C/L of Wall
Existing Ground Surface =	858.0	at C/L of Wall			
Bottom of Facing =	847.0	at C/L of Wall (Top of Shaft)	Backfill Slope Angle =	2.5	H:1V
Groundwater =	848.5	at C/L of Wall		21.8	degrees

Wall Loading Profile (B-005-0-23)

	Top Elev.	Thickness (ft)	Cohesion (psf)	Phi (deg)	Unit Wt (pcf)
Layer 2 Medium Stiff to Stiff Cohesive	860.0	9.8	115	23	140
Layer 1 Soft to Medium Stiff Cohesive	850.2	3.2	65	21	115
Bottom of Facing	847.0				
Weighted Value		13.0	105	23	135

Earth Pressure Coefficients

	Deg	
Shear Resistance, Φ =	25	
Wall Friction, δ^A =	0.0	
Wall Slope, θ =	90	
Backfill Slope, β =	21.80	
Revised Backfill Slope, β =	21.80	
Backfill Condition	INFINITE	
Horz. Backslope Dist.	50.0	feet (C/L of Wall - Bottom of Embankment)
Wall Height (H)	13.0	feet (Top of Wall - Bottom of Facing)
Slope Height (h)	20.0	feet (Top of Backfill - Top of Wall)
I =	37.57	degrees

Notes:

- Wall friction neglected
- Figure and Equation for Active Earth Pressure from AASHTO 3.11.5.3 (LRFD Design Manual).
- The wall retained soil will consist of existing cohesive overburden. Using the soil layer thicknesses and respective soil parameters, a weighted average was determined and assumed for the entire profile ($c' = 105$ psf and $\phi' = 23^\circ$). The parameters were converted to equivalent soil strength parameters $c' = 0$ psf and $\phi' = 25^\circ$ for checking tieback lengths based on a 1 degree increase in friction angle for every 50 psf decrease in cohesion up to 150 psf (Ref: Hall's Thesis).

Shoring Suite Design Profile

	Top Elev	Depth (ft)	Cohesion (psf)	Phi (deg)	Unit Wt (pcf)
Layer 2 Medium Stiff to Stiff Cohesive	860.0	0.0	0	25	140
Layer 1 Soft to Medium Stiff Cohesive	850.2	9.8	0	22	115
Layer 2 Medium Stiff to Stiff Cohesive	845.2	14.8	0	25	140
Layer 3 Stiff to Very Stiff Cohesive	835.2	24.8	0	28	135
Layer 4 Hard Cohesive	815.2	44.8	0	31	145
Bedrock	810.2	49.8	0	45	150

Depths referenced below the top of wall. Friction angles reflect adjustments made per Hall's Thesis. Bedrock modeled as very dense gravel.

Steel Beam and Cross-Section Properties

Assumed Pile Shape **HP 14x89**

Pile Availability

AISC Member Producers	3
Non-Member Producers	0

Shaft Geometry

Shaft Diameter	30	in
Longest Beam Dimension	20.162589	in
Clear Distance	4.9187054	in

Steel Beam Geometry

Beam Depth (D)	13.8	in
Web Thickness (t _w)	0.615	in
Flange Width (B _f)	14.7	in
Flange Thickness (t _f)	0.615	in
Area of Steel (A _s)	26.1	in ²

Steel Properties

Yield Strength of Steel	50	ksi
Moment of Inertia (I _{xx}) of Steel	904	in ⁴
Modulus of Elasticity of Steel (E)	29000	ksi
Modulus of Elasticity of Steel (E)	29000000	psi
EI (Steel Only)	2.622E+10	lb*in ²
Section Modulus (S _x)	131	in ³
Section Modulus (Z _x)	146	in ³
Shear-Buckling Coefficient (k)	5	
Ratio of Shear-Buckling Resistance (C)	1	
D/t _w	22.439024	
1.12VEk/F _{yw}	60.313846	
1.40VEk/F _{yw}	75.392307	

Determined by AASHTO LRFD Bridge Specifications
Eqn's 6.10.9.3.2-4, 6.10.9.3.2-5, and 6.10.9.3.2-6

Shear Capacity Calculation

$$V_u \leq \phi V_{cr}$$
$$\phi_b = \boxed{1} \text{ AASHTO LRFD Bridge Design Spec's 6.5.4.2}$$
$$V_u = \text{shear in web due to factored permanent and construction loads applied to noncompact section (kips)}$$
$$V_{cr} = \text{shear buckling resistance determined from Equation 6.10.9.3.3-1 (AASHTO LRFD Bridge Design Spec's)}$$
$$V_n = V_{cr} = C V_p$$
$$V_p = 0.58 F_{yw} D t_w$$
$$V_p = \text{plastic shear force (kips)}$$
$$C = \text{ratio of shear-buckling resistance to shear yield strength determined by AASHTO Eqn's 6.10.9.3.2-4, 6.10.9.3.2-5, 6.10.9.3.2-5, or 6.10.9.3.2-6}$$
$$V_p = 0.58 * 50 * 13.8 * 0.615$$
$$V_p = \boxed{246.1} \text{ kips}$$
$$\phi V_{cr} = \phi * C * V_p$$
$$\phi V_{cr} = 1 * 1 * 246.1$$
$$\phi V_{cr} = \boxed{246.1} \text{ kips}$$
$$V_u = \boxed{60.23} \text{ kips (from Shoring Suite)}$$
$$\boxed{} \text{ kips (from PYWALL)}$$
$$V_u < \phi V_{cr} \quad \text{OK}$$

Flexure Capacity Calculation

$$M_u \leq \phi M_n$$
$$\phi_b = \boxed{1} \text{ AASHTO LRFD Bridge Design Spec's 6.5.4.2}$$
$$M_u = \text{Moment due to the factored loads}$$
$$M_n = \text{Nominal flexural resistance of a section}$$
$$S_x = \text{Elastic section modulus about the x-axis}$$
$$\phi M_n = \phi * F_y * S_x$$
$$\phi M_n = 1 * 50 * 131$$
$$\phi M_n = \boxed{6550} \text{ in*kips}$$
$$M_u = \boxed{1356.2} \text{ in*kips (from Shoring Suite)}$$
$$M_u = \boxed{} \text{ in*kips (from PYWALL)}$$
$$M_u < \phi M_n \quad \text{OK}$$

Deflection Criteria

Pile Length Above Rock = 28	ft	Exposed Wall Height = 13	ft
Pile Length Above Rock = 	in	Exposed Wall Height = 156	in

1.)

Per the ODOT GDM, pile-head deflection in the service limit state limited to 1% or less of the shaft length above bedrock, or 1% of total drilled shaft length if not embedded in bedrock.

2.)

Following industry acceptance criteria, limit wall deflection to 1% of exposed wall height where ODOT landslide criteria does not govern. Alternatively, limit wall deflection to 1.5% of the exposed wall height in accordance with NCDOT guidelines. Use 1.5% wall deflection for PYWALL software.

ODOT Landslide Criteria Governs

NO

OK

1% Wall Height OR 2 inches- LPILE

1.56

in

$\delta = \boxed{0.03}$ in (from Shoring Suite)

1.5% Wall Height - PYWALL

2.34

in

$\delta = \boxed{}$ in (from PYWALL)

Drilled Shafts Located Within 10 feet of Edge of Pavement

NO

Tieback Loading Computations

Design Tieback Load, $TF1 = 107.1$ kips / shaft

Horizontal values determined from Shoring Suite calculations.

1) Determine Tiebacks

Strands

0.6 GUTS per strand = 35.2 kips per strand (FHWA-NHI-07-071: Table 8-16)
(GUTS = guaranteed ultimate tensile strength)

Tieback	Inclin.	Required Anchor Load**	Strands	
No.	deg	kips	Required	Selected
1	20	114.0	3.2	4.0

**Required Anchor Load = $(TF) / [\cos(\text{Inclin. Angle})]$

Table 8-16. Properties of 0.6 in. Diameter Prestressing Steel Strands (ASTM A416, Grade 270).

Number of 0.6 in. diameter strands	Cross section area (in. ²)	Ultimate strength (=GUTS) (kips)	Prestressing force		
			0.8 $f_{pu}A_{ps}$ (kips)	0.7 $f_{pu}A_{ps}$ (kips)	0.6 $f_{pu}A_{ps}$ (kips)
1	0.217	58.6	46.9	41.0	35.2

2) Check Pull-Out Capacity and Bond Length

Pullout Resistance Factor $\phi_{pr} = 0.7$ Per AASHTO LRFD Table 11.5.7-1 for "Pullout resistance of anchors, cohesive soils"

Soil Friction Angle $\phi = 25$

Tieback	Height Above Bottom of Facing	Tieback Length to Active Wedge	Total Unbonded Length	Ultimate Bond Strength	Tieback Drill Hole Diameter	Surface Area per Foot of Tieback	Allowable Bond Strength per Foot of Tieback	Required Anchor Load	Required Bond Length	Total Tieback Length
No.	ft	ft	ft	ksf	in	in ² /ft	kips/ft	kips	ft	ft
1	7	3.9	15	3	9	339.3	4.95	114.0	24 (25)	39 (40)

Total unbonded length = Tieback length to active wedge + greater of 5 feet or $H/3$, with a 15 foot minimum, per AASHTO LRFD Figure 11.9.1-1
Ultimate bond strength per AASHTO LRFD Table C11.9.4.2-1. Tieback lengths assume entire bond length is in clay.

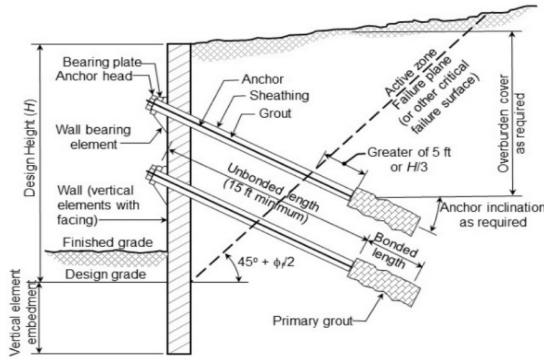


Figure 11.9.1-1—Anchored Wall Nomenclature and Anchor Embedment Guidelines

Table C11.9.4.2-1—Presumptive Ultimate Unit Bond Stress for Anchors in Cohesive Soils

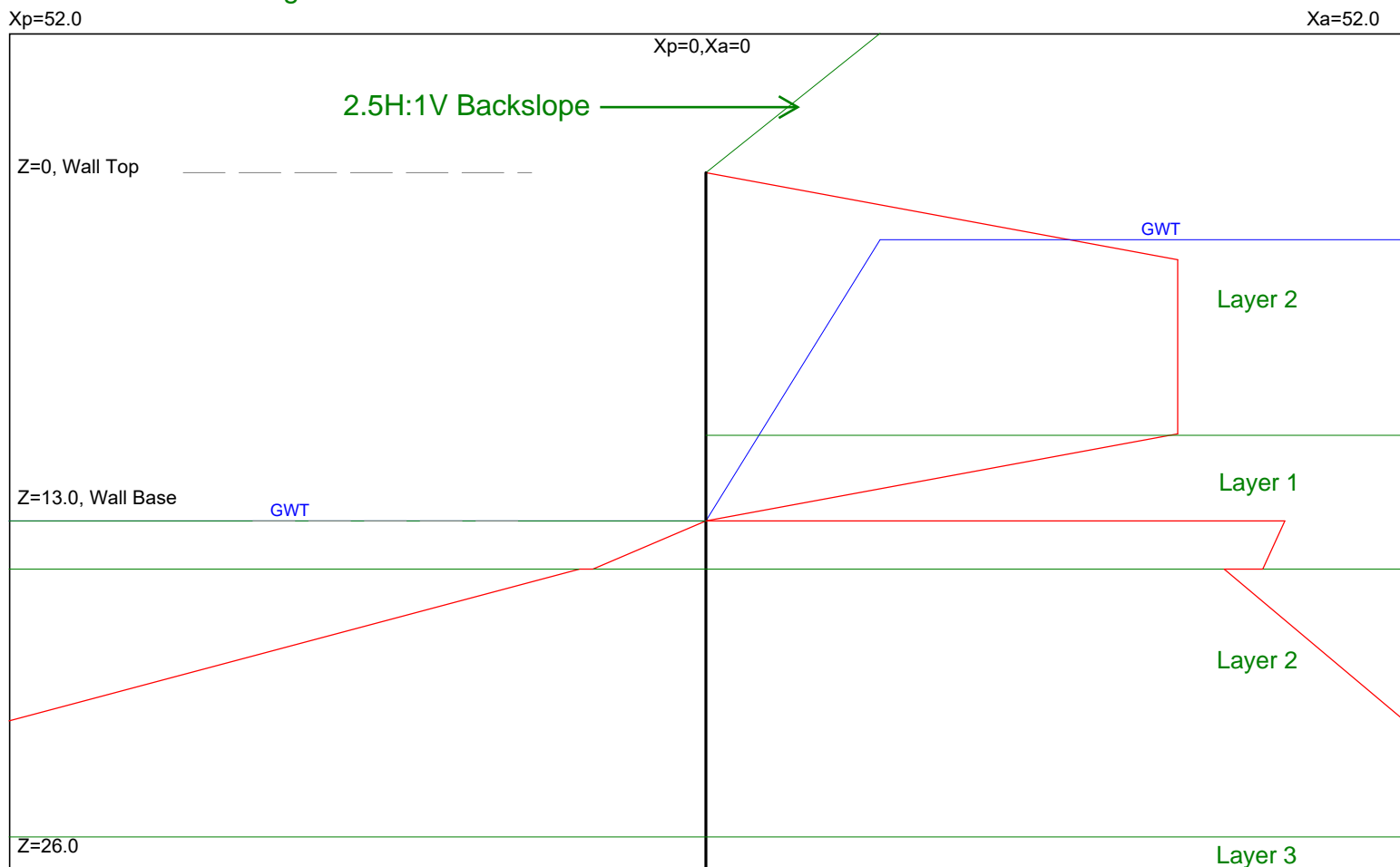
Anchor/Soil Type (Grout Pressure)	Soil Stiffness or Unconfined Compressive Strength (tsf)	Presumptive Ultimate Unit Bond Stress, τ_u (ksf)
Gravity Grouted Anchors (<50 psi)		
Silt-Clay Mixtures	Stiff to Very Stiff 1.0-4.0	0.6 to 1.5
Pressure Grouted Anchors (50 psi-400 psi)		
High Plasticity Clay	Stiff 1.0-2.5 V. Stiff 2.5-4.0	0.6 to 2.0 1.5 to 3.6
Medium Plasticity Clay	Stiff 1.0-2.5 V. Stiff 2.5-4.0	2.0 to 5.2 2.9 to 7.3
Medium Plasticity Sandy Silt	V. Stiff 2.5-4.0	5.8 to 7.9

Recommended Lengths

Earth Pressure Loading

Earth pressures generated using
Service loading.

WAS-77-9.58



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UNITS: DEPTH/DISTANCE: ft, UNIT WEIGHT: pcf, FORCE: kip/ft, PRESSURE: ksf, SLOPE: kcf

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* INPUT DATA *

Wall Height=13.0 Total Soil Types= 5

Soil No.	Weight	Saturate	Phi	Cohesion	Nspt	Type	Description
1	115.0	120.0	22	0	5	1	1. Soft to M
2	140.0	145.0	25	0.0	11	1	2. Medium St
3	135.0	140.0	28	0.0	24	1	3. Stiff to
4	145.0	150.0	31	0.0	65	1	4. Hard Cohe
5	150.0	155.0	45	0.0	100	5	Bedrock

Ground Surface at Active Side:

Line	Z1	Xa1	Z2	Xa2	Soil No.	Description
1	0.0	0.0	-20.0	50.0	2	2. Medium St
2	-20.0	50.0	-50.0	800.0	2	2. Medium St
3	9.8	0.0	9.8	800.0	1	1. Soft to M
4	14.8	0.0	14.8	800.0	2	2. Medium St
5	24.8	0.0	24.8	800.0	3	3. Stiff to
6	44.8	0.0	44.8	800.0	4	4. Hard Cohe
7	49.8	0.0	49.8	800.0	5	Bedrock

Water Table at Active Side:

Point	Z-water	X-water
1	13.0	0.0
2	2.5	13.0
3	2.5	800.0

Bedrock modeled
as dense gravel to
generate active
pressures

Ground Surface at Passive Side:

Line	Z1	Xp1	Z2	Xp2	Soil No.	Description
1	13.0	0.0	13.0	800.0	1	1. Soft to M
2	14.8	0.0	14.8	800.0	2	2. Medium St
3	24.8	0.0	24.8	800.0	3	3. Stiff to
4	44.8	0.0	44.8	800.0	4	4. Hard Cohe
5	49.8	0.0	49.8	800.0	5	Bedrock

Water Table at Passive Side:

Point	Z-water	X-water
1	13.0	0.0
2	13.0	800.0

Wall Friction Options: 1.* No wall friction

Wall Batter Angle = 0

Apparent Pressure Conversion: 1.* Default (Terzaghi and Peck)*

Water Density = 62.4

Water Pressure: 1.* No seepage at wall tip

* OUTPUT RESULTS *

Total Force above Base= 7.75 per one linear foot (or meter) width along wall height

Total Static Force above Base= 7.75. Distributed in Apparent Envelope along wall height. Ignore soil layers and water line

Driving Pressure above Base - Output to Shoring - Multiplier of Pressure = 1

Z1	Pa1	Z2	Pa2	Slope	Coef.
0.00	0.00	3.25	0.95	0.2933	2.0953
3.25	0.95	9.75	0.95	0.0000	0.0000
9.75	0.95	13.00	0.00	-0.2933	-2.0953

Driving Pressure below Base - Output to Shoring - Multiplier of Pressure = 1

Z1	Pa1	Z2	Pa2	Slope	Ka or Ko
13.00	1.17	14.80	1.12	-0.0250	-0.4342
14.80	1.05	24.80	1.69	0.0645	0.7808
24.80	1.47	26.00	1.54	0.0621	0.8005

Passive Pressure below Base - Output to Shoring - Multiplier of Pressure = 1

Z1	Pp1	Z2	Pp2	Slope	Kp
13.00	0.00	14.80	0.23	0.127	2.1980
14.80	0.25	24.80	2.29	0.204	2.4652
24.80	2.55	26.00	2.82	0.219	2.8211

UNITS: DEPTH/DISTANCE: ft, UNIT WEIGHT: pcf, FORCE: kip/ft, PRESSURE: ksf, SLOPE: kcf

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EARTH PRESSURE ANALYSIS SUMMARY
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Title 1: WAS-77-9.58
Title 2:

Input data: *****

Wall Height = 13.00
Depth of Ground at Active Side = 0.00
Depth of Ground at Passive Side = 13.00
Apparent Pressure Envelope: 4. 2-Trapezoid Envelope (Braced, Stiff Clay)
Pressure Type: 1.* Active, Ka
Earthquake Loading Apply to: 1. No Earthq. Loads
Earthquake Horizontal Acceleration, Kh = 0
Earthquake Vertical Acceleration, Kv = 0
Calculation Methods: 1.* Numerical Solution (Wedge Analysis)
Wall Friction Options: 1.* No wall friction
Wall Batter Angle = 0
Apparent Pressure Conversion: 1.* Default (Terzaghi and Peck)*
Water Density = 62.4
Water Pressure: 1.* No seepage at wall tip
User's Settings
Ignore Passive from Depth = 0
Multiplier of Active Pressure = 1
Multiplier of Passive Pressure = 1
Multiplier of Water Pressure = 1
Multiplier of Earthq. Pressure = 1
Estimated Embedment: Very Shallow: 2H
Program's Settings
Max. Height, Hmax = 130.00
Analysis Segment, dz = 0.33
No. of Active Segment at H, nz0 = 2
No. of Active Segment at Hmax, nz = 7
No. of Passive Segment, nzp = 5
Active Depth at H, Zh = 13.00
Active Depth at Hmax, Z = 130.00
Passive Depth at Hmax, Zp = 130.00
Max. Pressure = 60.61

Total Soil Types= 5

Soil	Weight	W(S)	Phi	Cohesion	Nspt	Type	Description
1	115.0	120.0	22	0	5	1	1. Soft to M
>	115.0	120.0	22.0	0.0	5	1	Converted
2	140.0	145.0	25	0.0	11	1	2. Medium St
>	140.0	145.0	25.0	0.0	11	1	Converted
3	135.0	140.0	28	0.0	24	1	3. Stiff to
>	135.0	140.0	28.0	0.0	24	1	Converted
4	145.0	150.0	31	0.0	65	1	4. Hard Cohe
>	145.0	150.0	31.0	0.0	65	1	Converted
5	150.0	155.0	45	0.0	100	5	Bedrock

Soil Type: 1 Equivalent Clay; 2 Clay; 3 Silt; 4 Sand; 5 Gravel

Ground Surface at Active Side:

Line	Z1	Xa1	Z2	Xa2	Soil No.
1	0.0	0.0	-20.0	50.0	2
2	-20.0	50.0	-50.0	800.0	2
3	9.8	0.0	9.8	800.0	1
4	14.8	0.0	14.8	800.0	2
5	24.8	0.0	24.8	800.0	3

6	44.8	0.0	44.8	800.0	4
7	49.8	0.0	49.8	800.0	5

Water Table at Active Side:

Point	Z-water	X-water
1	13.0	0.0
2	2.5	13.0
3	2.5	800.0

Ground Surface at Passive Side:

Line	Z1	Xp1	Z2	Xp2	Soil No.
1	13.0	0.0	13.0	800.0	1
2	14.8	0.0	14.8	800.0	2
3	24.8	0.0	24.8	800.0	3
4	44.8	0.0	44.8	800.0	4
5	49.8	0.0	49.8	800.0	5

Water Table at Passive Side:

Point	Z-water	X-water
1	13.0	0.0
2	13.0	800.0

Output data: *****

Total Force above Base= 7.75 per one linear foot (or meter) width along wall height

Static Force above Base= 7.75. Distributed in Apparent Envelope along wall height. Ignore soil layers and water line

Apparent Pressure above Base - Output to Shoring

Active/At-Rest Force above Base, Ea = 7.75

No	Z1	P1	Z2	P2	Slope	Coef.
0	0.0	0.00	3.3	0.95	0.2933	2.0953
1	3.3	0.95	9.8	0.95	0.0000	0.0000
2	9.8	0.95	13.0	0.00	-0.2933	-2.0953

Driving Pressure below Base - Output to Shoring

No	Z1	P1	Z2	P2	Slope	Ka or Ko
0	13.0	1.17	14.8	1.12	-0.0250	-0.4342
1	14.8	1.05	24.8	1.69	0.0645	0.7808
2	24.8	1.51	44.8	2.29	0.0393	0.5063
3	44.8	2.03	49.8	2.21	0.0368	0.4200
4	49.8	1.23	130.0	2.62	0.0173	0.1866

Passive Pressure below Base - Output to Shoring

No	Z1	P1	Z2	P2	Slope	Kp
0	13.0	0.00	14.8	0.23	0.1266	2.1980
1	14.8	0.25	24.8	2.29	0.2036	2.4652
2	24.8	2.56	44.8	6.87	0.2156	2.7779
3	44.8	7.67	49.8	9.07	0.2805	3.2019
4	49.8	15.12	130.0	60.61	0.5671	6.1246

Passive pressures below 49.8 feet manually adjusted in shoring module to reflect claystone strength.

DEPTH/DISTANCE: ft, UNIT WEIGHT: pcf, FORCE: kip/ft, PRESSURE: ksf, SLOPE: kcf

Z, Xa, Xp - Coordinates of ground lines

Z- Depth measured from wall top

Xa - Distance measure from wall to active side.

Xp - Distance measure from wall to passive side

Z1, P1, Z2, P2 - Four values to define a pressure diagram

Z1- Top depth of the diagram

P1- Top pressure of the diagram

Z2- Bottom depth of the diagram

P2- Bottom pressure of the diagram

Slope - (P2-P1)/(Z2-Z1), Slope of the diagram. It also called Equivalent fluid density.

Coef. - Pressure Coefficient = Slope/Unit Weight

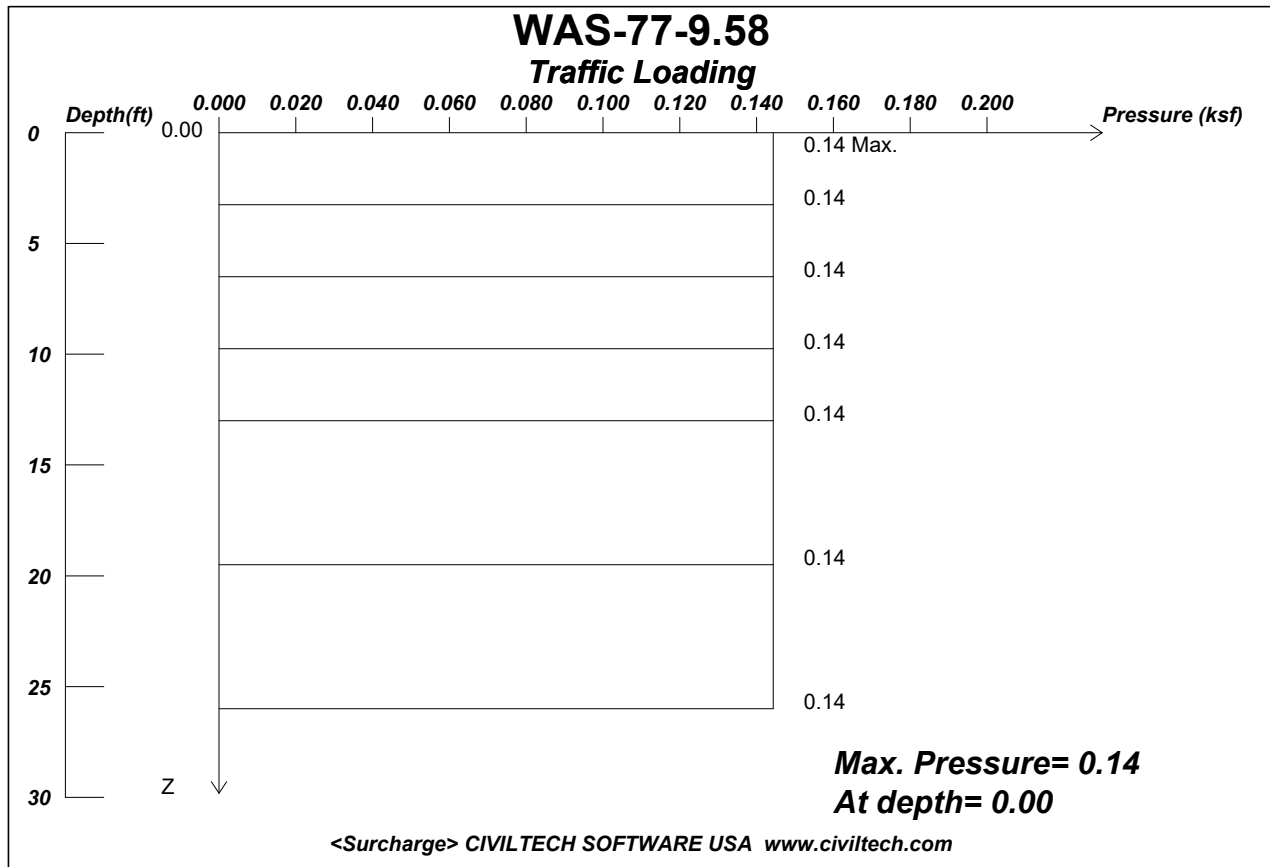
Ka - Active Earth Pressure Coefficient

Ko - At-Rest Earth Pressure Coefficient

Kp - Passive Earth Pressure Coefficient

Traffic Load Surcharge (Service Limit)

Construction Traffic



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Wall Height, H= 13

Load Depth, D= 0

Load Factor of Surcharge Loading = 1

Rigid Wall Condition -- No movement or deflection of the wall are allowed.

Max. Pressure = 0.144 at depth = 0.00

Infinite Surcharge, Q=.250

Active Wedge Approach * (recommend)

UNITS: LENGTH/DEPTH: ft, Qpoint: kip, Qline: kip/ft, Qstrip/Qarea/PRESSURE: ksf

SURCHARGE LOADS CALCULATION SUMMARY
<Surcharge>
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Reference: Foundation Design, Wayne C. Teng, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1962

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Calculations\20250116_Updated Analyses\WAS-77-9.58 13' Wall Surcharge Service.lp8

WAS-77-9.58
Traffic Loading

Height of Wall = 13
Depth of Load = 0
Load Factor of Surcharge Loading = 1

Wall Condition:
Rigid Wall Condition -- No movement or deflection of the wall are allowed.

*****Loading*****

INFINITE SURCHARGE LOADING: Q=.250
Active Wedge Approach * (recommend)

*****Total Pressure Distribution*****

Max. Pressure =0.144 at depth =0.00

Depth	Pressure
0.00	0.144
0.65	0.144
1.30	0.144
1.95	0.144
2.60	0.144
3.25	0.144
3.90	0.144
4.55	0.144
5.20	0.144
5.85	0.144
6.50	0.144
7.15	0.144
7.80	0.144
8.45	0.144
9.10	0.144
9.75	0.144
10.40	0.144
11.05	0.144
11.70	0.144
12.35	0.144
13.00	0.144
14.30	0.144
15.60	0.144
16.90	0.144
18.20	0.144
19.50	0.144
20.80	0.144
22.10	0.144
23.40	0.144
24.70	0.144
26.00	0.144
28.60	0.144
31.20	0.144
33.80	0.144
36.40	0.144

39.00	0.144
41.60	0.144
44.20	0.144
46.80	0.144
49.40	0.144
52.00	0.000

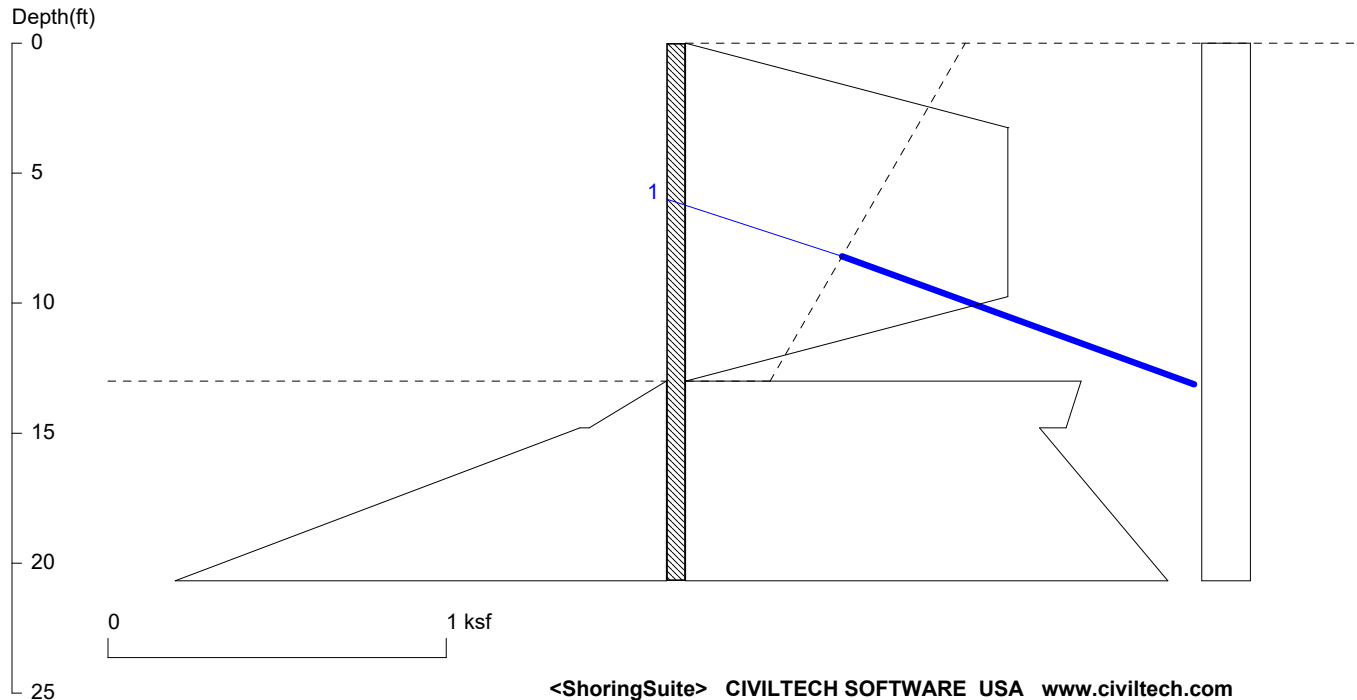
Surcharge loading cut off at top of rock (49.8 feet) in shoring module.

Depth Is Measured From Top of the Wall

LENGTH/DEPTH: ft, Qpoint: kip, Qline: kip/ft, Qstrip/Qarea/PRESSURE: ksf

Service Limit

WAS-77-9.58



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Wall Height=13.0 Pile Diameter=2.5 Pile Spacing=6.0 Wall Type: 2. Soldier Pile, Drilled

PILE LENGTH: Min. Embedment=7.68 Min. Pile Length=20.68

MOMENT IN PILE: Max. Moment=72.60 per Pile Spacing=6.0 at Depth=6.01

PILE SELECTION:

Request Min. Section Modulus = 17.4 in³/pile=285.54 cm³/pile, Fy= 50 ksi = 345 MPa, Fb/Fy=1

HP14X89 has Section Modulus = 131.0 in³/pile=2146.70 cm³/pile. It is greater than Min. Requirements!

Top Deflection = 0.03(in) based on E (ksi)=29000.00 and I (in⁴)/pile=904.0

BRACE FORCE: Strut, Tieback, Plate Anchor, Deadman, Sheet Pile as Anchor

No. & Type	Depth	Angle	Space	Total F.	Horiz. F.	Vert. F.	L_free	Fixed Length
1. Tieback	6.0	20.0	6.0	71.3	67.0	24.4	6.4	14.4

UNITS: Width,Diameter,Spacing,Length,Depth,and Height - ft; Force - kip; Bond Strength and Pressure - ksf

DRIVING PRESSURES (ACTIVE, WATER, & SURCHARGE):

Z1	P1	Z2	P2	Slope
*	Above	Base		
0.000	0.000	3.250	0.953	0.293342
3.250	0.953	9.750	0.953	0.000000
9.750	0.953	13.000	0.000	-0.293342
*	Below	Base		
13.000	1.170	14.800	1.125	-0.025012
14.800	1.047	24.800	1.692	0.064494
*	Sur-	charge		
0.000	0.144	0.650	0.144	0.000000
0.650	0.144	1.300	0.144	0.000000
1.300	0.144	1.950	0.144	0.000000
1.950	0.144	2.600	0.144	0.000000
2.600	0.144	3.250	0.144	0.000000

3.250	0.144	3.900	0.144	0.000000
3.900	0.144	4.550	0.144	0.000000
4.550	0.144	5.200	0.144	0.000000
5.200	0.144	5.850	0.144	0.000000
5.850	0.144	6.500	0.144	0.000000
6.500	0.144	7.150	0.144	0.000000
7.150	0.144	7.800	0.144	0.000000
7.800	0.144	8.450	0.144	0.000000
8.450	0.144	9.100	0.144	0.000000
9.100	0.144	9.750	0.144	0.000000
9.750	0.144	10.400	0.144	0.000000
10.400	0.144	11.050	0.144	0.000000
11.050	0.144	11.700	0.144	0.000000
11.700	0.144	12.350	0.144	0.000000
12.350	0.144	13.000	0.144	0.000000
13.000	0.144	14.300	0.144	0.000000
14.300	0.144	15.600	0.144	0.000000
15.600	0.144	16.900	0.144	0.000000
16.900	0.144	18.200	0.144	0.000000
18.200	0.144	19.500	0.144	0.000000
19.500	0.144	20.800	0.144	0.000000

PASSIVE PRESSURES:

Z1	P1	Z2	P2	Slope
*	Below	Base		
13.000	0.000	14.800	0.228	0.126604
14.800	0.255	24.800	2.291	0.203628

ACTIVE SPACING:

No.	Z depth	Spacing
1	0.00	6.00
2	13.00	2.50

PASSIVE SPACING:

No.	Z depth	Spacing
1	13.00	5.00

UNITS: Width,Spacing,Diameter,Length,and Depth - ft; Force - kip; Moment - kip-ft
Friction,Bearing,and Pressure - ksf; Pres. Slope - kip/ft³; Deflection - in

SHORING WALL CALCULATION SUMMARY
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The calculation method is based on the following references:

1. FHWA 98-011, FHWA-RD-97-130, FHWA SA 96-069, FHWA-IF-99-015
2. STEEL SHEET PILING DESIGN MANUAL by Pile Buck Inc., 1987
3. DESIGN MANUAL DM-7 (NAVFAC), Department of the Navy, May 1982
4. TRENCHING AND SHORING MANUAL Revision 12, California Department of Transportation, January 2000
6. EARTH SUPPORT SYSTEM & RETAINING STRUCTURES, Pile Buck Inc. 2002
5. DESIGN OF SHEET PILE WALLS, EM 1110-2-2504, U.S. Army Corps of Engineers, 31 March 1994
7. EARTH RETENTION SYSTEMS HANDBOOK, Alan Macnab, McGraw-Hill. 2002
8. Temporary Structures in Construction, Robert T. Ratay (Co-author of Chapter 7: John J. Peirce), McGraw-Hill. 2012
9. AASHTO HB-17, American Association of State and Highway Transportation Officials, 2 September 2002

UNITS: Width/Spacing/Diameter/Length/Depth - ft, Force - kip, Moment - kip-ft, Friction/Bearing/Pressure - ksf, Pres. Slope - kip/ft³, Deflection - in

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Date: 1/25/2025 File: J:\ODOT-District 10 GES\Task 10-13 WAS-77-9.58\20250116_Redesign
Calculations\20250116_Updated Analyses\WAS-77-9.58 13' Main Wall Tieback Service.sh8

Title: WAS-77-9.58

Subtitle:

*****INPUT DATA*****

Wall Type: 2. Soldier Pile, Drilled

Wall Height: 13.00

Pile Diameter: 2.50

Pile Spacing: 6.00

Factor of Safety (F.S.): 1.00

Lateral Support Type (Braces): 3. Tieback

Top Brace Increase (Multi-Bracing): Add 15%*

Brace Position (One Brace Case): Normal Brace*

No-Load Zone:

Vertical Depth for No-Load Zone: 13.00

H-Distance (Input H/V ratio) for No-Load Zone: 0.25

Angle from H. Line for No-Load Zone: 60.00

Embedment Option: 1. Yes

Friction at Pile Tip: No

Pile Properties:

Steel Strength, Fy: 50 ksi = 345 MPa

Allowable Fb/Fy: 1

Elastic Module, E: 29000.00

Moment of Inertia, I: 904.00

User Input Pile: HP14x89

* DRIVING PRESSURE (ACTIVE, WATER, & SURCHARGE) *

No.	Z1 top	Top Pres.	Z2 bottom	Bottom Pres.	Slope
1	*	Above	Base		
2	0.000	0.000	3.250	0.953	0.293342
3	3.250	0.953	9.750	0.953	0.000000
4	9.750	0.953	13.000	0.000	-0.293342
5	*	Below	Base		
6	13.000	1.170	14.800	1.125	-0.025012
7	14.800	1.047	24.800	1.692	0.064494
8	24.800	1.508	44.800	2.293	0.039290
9	44.800	2.029	49.800	2.213	0.036796
10	49.800	1.203	117.000	2.435	0.018342
11	*	Sur-	charge		
12	0.000	0.144	0.650	0.144	0.000000

13	0.650	0.144	1.300	0.144	0.000000
14	1.300	0.144	1.950	0.144	0.000000
15	1.950	0.144	2.600	0.144	0.000000
16	2.600	0.144	3.250	0.144	0.000000
17	3.250	0.144	3.900	0.144	0.000000
18	3.900	0.144	4.550	0.144	0.000000
19	4.550	0.144	5.200	0.144	0.000000
20	5.200	0.144	5.850	0.144	0.000000
21	5.850	0.144	6.500	0.144	0.000000
22	6.500	0.144	7.150	0.144	0.000000
23	7.150	0.144	7.800	0.144	0.000000
24	7.800	0.144	8.450	0.144	0.000000
25	8.450	0.144	9.100	0.144	0.000000
26	9.100	0.144	9.750	0.144	0.000000
27	9.750	0.144	10.400	0.144	0.000000
28	10.400	0.144	11.050	0.144	0.000000
29	11.050	0.144	11.700	0.144	0.000000
30	11.700	0.144	12.350	0.144	0.000000
31	12.350	0.144	13.000	0.144	0.000000
32	13.000	0.144	14.300	0.144	0.000000
33	14.300	0.144	15.600	0.144	0.000000
34	15.600	0.144	16.900	0.144	0.000000
35	16.900	0.144	18.200	0.144	0.000000
36	18.200	0.144	19.500	0.144	0.000000
37	19.500	0.144	20.800	0.144	0.000000
38	20.800	0.144	22.100	0.144	0.000000
39	22.100	0.144	23.400	0.144	0.000000
40	23.400	0.144	24.700	0.144	0.000000
41	24.700	0.144	26.000	0.144	0.000000
42	26.000	0.144	28.600	0.144	0.000000
43	28.600	0.144	31.200	0.144	0.000000
44	31.200	0.144	33.800	0.144	0.000000
45	33.800	0.144	36.400	0.144	0.000000
46	36.400	0.144	39.000	0.144	0.000000
47	39.000	0.144	41.600	0.144	0.000000
48	41.600	0.144	44.200	0.144	0.000000
49	44.200	0.144	46.800	0.144	0.000000
50	46.800	0.144	49.400	0.144	0.000000
51	49.400	0.144	52.000	0.000	-0.055518

Surcharge loading terminated at top of rock (approx 49.8 feet).

* PASSIVE PRESSURE *

No.	Z1 top	Top Pres.	Z2 bottom	Bottom Pres.	Slope
1	*	Below	Base		
2	13.000	0.000	14.800	0.228	0.126604
3	14.800	0.255	24.800	2.291	0.203628
4	24.800	2.563	44.800	6.875	0.215565
5	44.800	7.668	49.800	9.070	0.280490
6	49.800	47	117.000	47	0.0000

Passive pressure for bedrock adjusted to 47 ksf based on an unconfined strength of 330 psi.

* ACTIVE SPACE *

No.	Z depth	Spacing
1	0.00	6.00
2	13.00	2.50

Hole diameter in feet (9 inches)

* PASSIVE SPACE *

No.	Z depth	Spacing
1	13.00	5.00

Allowable bond strength = resistance factor * ultimate bond strength = 0.7*3 ksf

* BRACE: STRUT, TIEBACK, ANCHOR PLATE, DEADMAN, OR SHEET PILE AS ANCHOR*

No.	Z brace	Angle	Spacing	Input1*	Input2*	Type
1	6.00	20.0	6.00	0.75	2.10	Tieback

*For Tieback: Input1 = Diameter; Input2 = Bond Strength
 *For Plate: Input1 = Diameter; Input2 = Allowable Pressure
 *For Deadman: Input1 = Horz. Width; Input2 = Passive Pressure;
 *For Sheet Pile Anchor: Input1 = Horz. Width; Input2 = Passive Slope;

*****CALCULATION*****

The calculated moment and shear are per pile spacing. Sheet piles are per one foot or meter; Soldier piles are per pile.

Top Pressures start at depth = 0.00

NUMBER OF BRACE LEVEL = 1

```

      |      D1=0.00
      |
      |<-- D2=6.00      R1=66.96
      |
      |
==|== D3=13.00
      |
      |      D4=20.68
  
```

D1 - TOP DEPTH
 D2 - BRACE DEPTH R1 - REACTION
 D3 - EXCAVATION BASE
 D4 - PILE TIP

TOTAL REACTION: R1 = 66.96
 TOTAL PRESSURES ACTING ON WALL = 66.96
 Total Reactions = Total Pressures, OK!

BRACE NO.1 AT DEPTH = 6.00
 R1 = Brace Load = 66.96

*****RESULTS*****

* EMBEDMENT *
 MINIMUM EMBEDMENT = 7.68, TOTAL MINIMUM PILE LENGTH = 20.68

* MOMENT IN PILE (per pile spacing)*
 Pile Spacing: sheet piles are one foot or one meter; soldier piles are one pile.

No.	Depth	M @ Brace	Mmax in Span	Depth of Mmax
1	6.00	72.28	33.33	12.98

Overall Maximum Moment = 72.60 at 6.01
 Maximum Shear = 36.72
 Moment and Shear are per pile spacing: 6.0 foot or meter

* BRACE: STRUT, TIEBACK, ANCHOR PLATE, DEADMAN, OR SHEET PILE AS ANCHOR*
 The calculated brace force are per brace spacing.

No.	DEPTH	Tangle	SPACING	HORIZONTAL	VERTICAL	TOTAL LOAD
1	6.00	20.0	6.00	66.96	24.37	71.26

No.	DEPTH	Free length	Brace Type
1	6.00	6.41	Tieback, Bond length = 14.40

* VERTICAL LOADING *

Vertical Loading from Braces = 24.37

Vertical Loading from External Load = 0.00

Total Vertical Loading = 24.37

*****SPECIFIED PILE *****

Overall Maximum Moment = 72.60 at 6.01

The pile selection is based on the magnitude of the moment only. Axial force is neglected.

Request Min. Section Modulus = 17.43 in³/pile = 285.54 cm³/pile, Fy= 50 ksi = 345 MPa, Fb/Fy=1

HP14X89 has been found in Soldier Pile list!

(English Units):

Area= 26.1 in. Depth= 13.8 in. Width= 14.7 in. Height= 14 in.

Flange thickness= 0.615 in. Web thickness= 0.615 in.

Ix= 904 in⁴/pile Sx= 131 in³/pile Iy= 326 in⁴/pile Sy= 44.3 in³/pile

(Metric Units):

Ix= 376.24 x10⁰cm⁴/pile Sx= 2146.70 cm³/pile Iy= 135.68 x10⁰cm⁴/pile Sy= 725.94 cm³/pile

The pile selection is based on the magnitude of the moment only. Axial force is neglected.

HP14X89 is capable to support the shoring!

Top deflection = 0.028(in)

Max. deflection = 0.034(in)

***** LAGGING SIZE ESTIMATION *****

Max. Pressure above base = 1.10

Piles are more rigid than timber lagging, due to arching, only portion of pressures are acting to lagging, 30-50% loading is suggested.

If 50% loading is used for lagging design, Design Pressure = 0.55

Pile Spacing =6.0, Max. Moment in lagging = 2.47

For 4"x12" Timber, Section Modules S=23.47 in³. The request allowable bending strength, fb=M/S=1.26

For 6"x12" Timber, Section Modules S=57.98 in³. The request allowable bending strength, fb=M/S=0.51

If 30% loading is used for lagging design, Design Pressure = 0.33

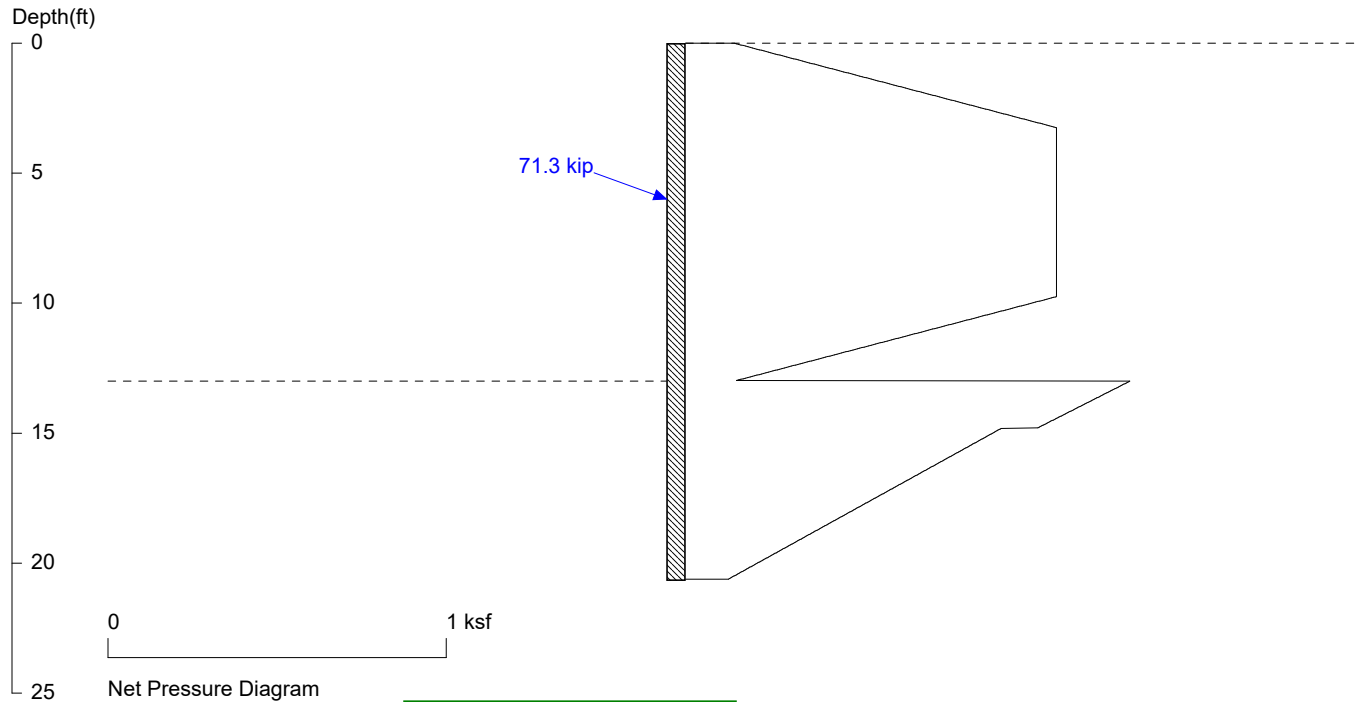
Pile Spacing =6.0, Max. Moment in lagging = 1.48

For 4"x12" Timber, Section Modules S=23.47 in³. The request allowable bending strength, fb=M/S=0.76

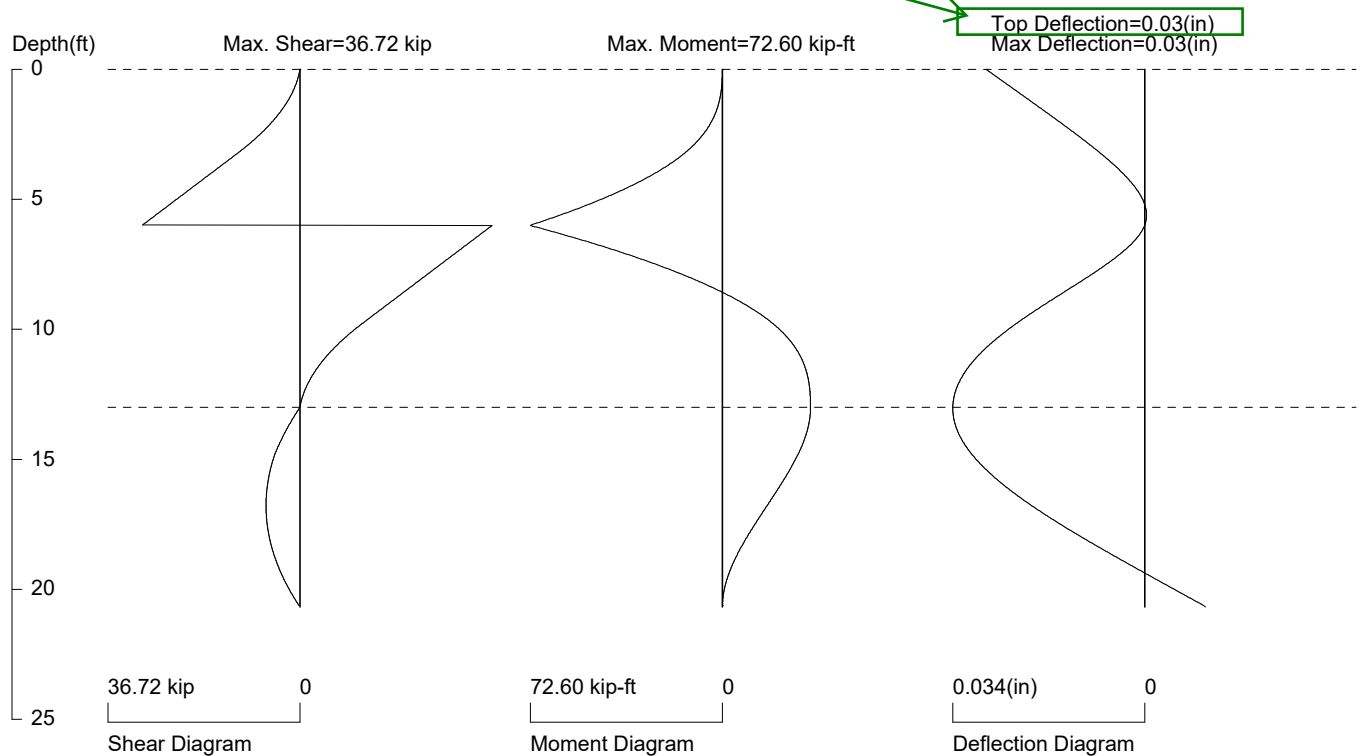
For 6"x12" Timber, Section Modules S=57.98 in³. The request allowable bending strength, fb=M/S=0.31

Unit: Pressure: ksf, Spacing: ft, Moment: kip-ft, Bending Strength, fb: ksi

WAS-77-9.58



Pile head deflection =



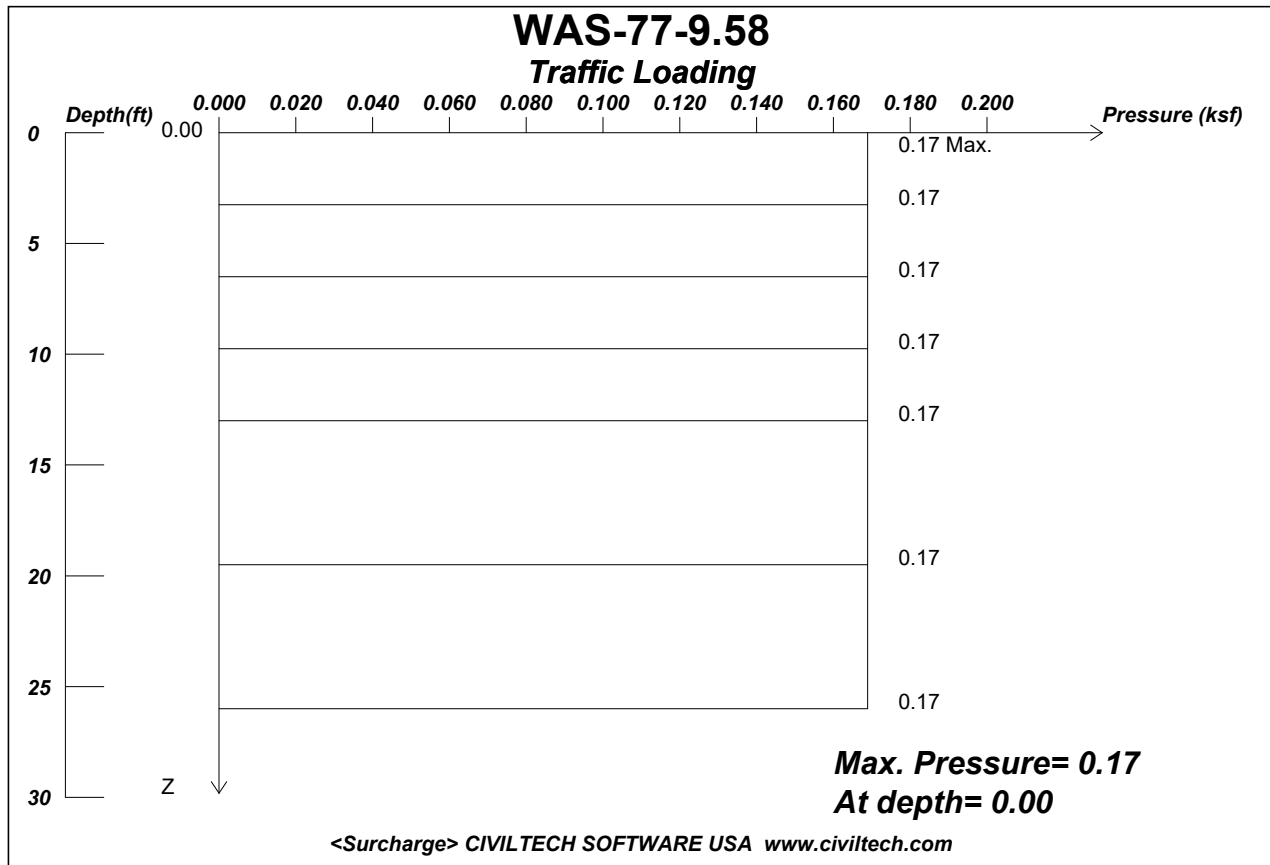
PRESSURE, SHEAR, MOMENT, AND DEFLECTION DIAGRAMS

Based on pile spacing: 6.0 foot or meter

User Input Pile, HP14x89: E (ksi)=29000.0, I (in4)/pile=904.0

Path: J:\ODOT-District 10 GES\Task 10-13 WAS-77-9.58\20250116_Redesign Calculations\20250116_Updated Analyses\WAS-77-9.58 13' Main Wall Tieback Service.sh

Traffic Load Surcharge (Strength Limit)



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Wall Height, H= 13

Load Depth, D= 0

Load Factor of Surcharge Loading = 1.17

Rigid Wall Condition -- No movement or deflection of the wall are allowed.

Max. Pressure = 0.169 at depth = 0.00

Infinite Surcharge, Q=.250

Active Wedge Approach * (recommend)

A load factor of 1.5 is applied to all active loading in the wall analysis. As traffic loading uses 1.75, an extra factor has been applied here ($1.75/1.5 = 1.17$).

UNITS: LENGTH/DEPTH: ft, Qpoint: kip, Qline: kip/ft, Qstrip/Qarea/PRESSURE: ksf

SURCHARGE LOADS CALCULATION SUMMARY
<Surcharge>
Software Copyright by CivilTech Software
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Reference: Foundation Design, Wayne C. Teng, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1962

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Calculations\20250116_Updated Analyses\WAS-77-9.58 13' Wall Surcharge Strength.lp8

WAS-77-9.58
Traffic Loading

Height of Wall = 13
Depth of Load = 0
Load Factor of Surcharge Loading = 1.17

Wall Condition:
Rigid Wall Condition -- No movement or deflection of the wall are allowed.

*****Loading*****

INFINITE SURCHARGE LOADING: Q=.250
Active Wedge Approach * (recommend)

*****Total Pressure Distribution*****

Max. Pressure =0.169 at depth =0.00

Depth	Pressure
0.00	0.169
0.65	0.169
1.30	0.169
1.95	0.169
2.60	0.169
3.25	0.169
3.90	0.169
4.55	0.169
5.20	0.169
5.85	0.169
6.50	0.169
7.15	0.169
7.80	0.169
8.45	0.169
9.10	0.169
9.75	0.169
10.40	0.169
11.05	0.169
11.70	0.169
12.35	0.169
13.00	0.169
14.30	0.169
15.60	0.169
16.90	0.169
18.20	0.169
19.50	0.169
20.80	0.169
22.10	0.169
23.40	0.169
24.70	0.169
26.00	0.169
28.60	0.169
31.20	0.169
33.80	0.169
36.40	0.169

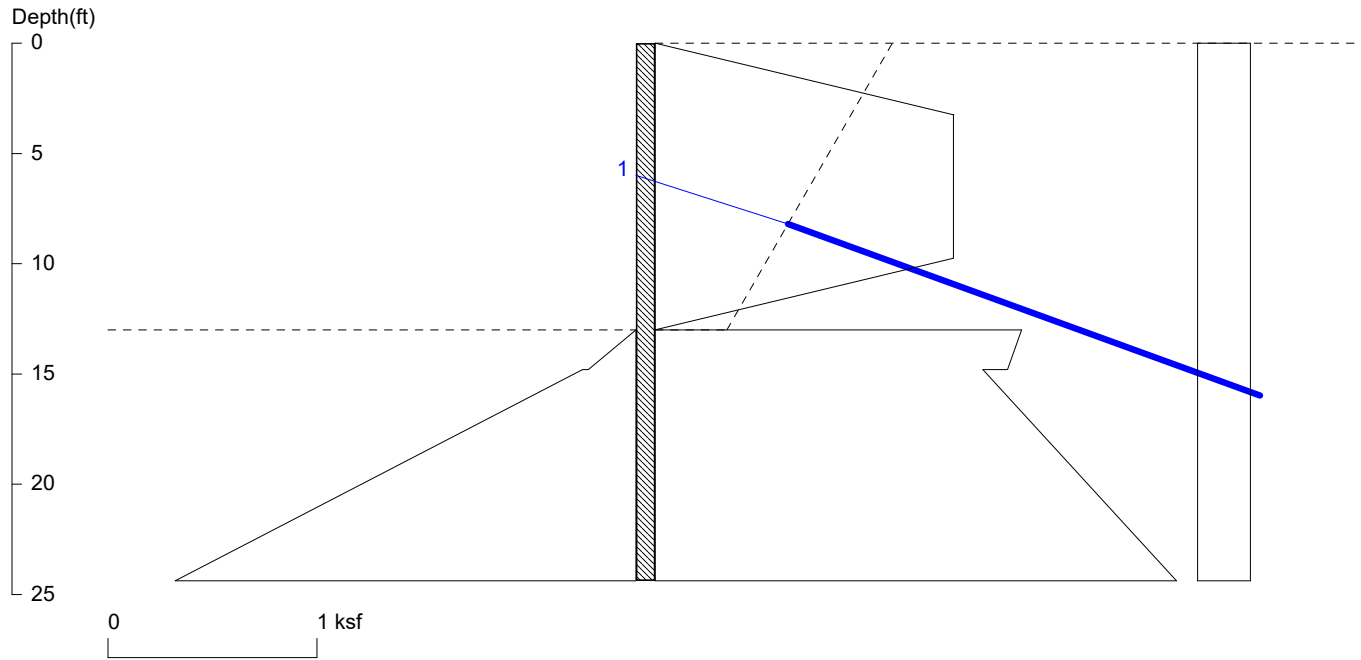
39.00	0.169
41.60	0.169
44.20	0.169
46.80	0.169
49.40	0.169
52.00	0.000

Depth Is Measured From Top of the Wall

LENGTH/DEPTH: ft, Qpoint: kip, Qline: kip/ft, Qstrip/Qarea/PRESSURE: ksf

Strength Limit

WAS-77-9.58



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Wall Height=13.0

Pile Diameter=2.5

Pile Spacing=6.0

Wall Type: 2. Soldier Pile, Drilled

PILE LENGTH: Min. Embedment=11.38 Min. Pile Length=24.38

MOMENT IN PILE: Max. Moment=113.02 per Pile Spacing=6.0 at Depth=5.99

PILE SELECTION:

Request Min. Section Modulus = 27.1 in³/pile=444.48 cm³/pile, Fy= 50 ksi = 345 MPa, Fb/Fy=1

HP14X89 has Section Modulus = 131.0 in³/pile=2146.70 cm³/pile. It is greater than Min. Requirements!

Top Deflection = -0.03(in) based on E (ksi)=29000.00 and I (in⁴)/pile=904.0

BRACE FORCE: Strut, Tieback, Plate Anchor, Deadman, Sheet Pile as Anchor

No. & Type	Depth	Angle	Space	Total F.	Horiz. F.	Vert. F.	L_free	Fixed Length
1. Tieback	6.0	20.0	6.0	114.0	107.1	39.0	6.4	23.0

UNITS: Width,Diameter,Spacing,Length,Depth,and Height - ft; Force - kip; Bond Strength and Pressure - ksf

DRIVING PRESSURES (ACTIVE, WATER, & SURCHARGE): Pressures below will be multiplied by a Factor =1.5

Z1	P1	Z2	P2	Slope
*	Above	Base		
0.000	0.000	3.250	0.953	0.293342
3.250	0.953	9.750	0.953	0.000000
9.750	0.953	13.000	0.000	-0.293342
*	Below	Base		
13.000	1.170	14.800	1.125	-0.025012
14.800	1.047	24.800	1.692	0.064494
*	Sur-	charge		
0.000	0.169	0.650	0.169	0.000000
0.650	0.169	1.300	0.169	0.000000
1.300	0.169	1.950	0.169	0.000000
1.950	0.169	2.600	0.169	0.000000
2.600	0.169	3.250	0.169	0.000000

Anchor loads and lengths

Unbonded Length Bonded Length

Applied 1.5 load factor for active earth pressures.

3.250	0.169	3.900	0.169	0.000000
3.900	0.169	4.550	0.169	0.000000
4.550	0.169	5.200	0.169	0.000000
5.200	0.169	5.850	0.169	0.000000
5.850	0.169	6.500	0.169	0.000000
6.500	0.169	7.150	0.169	0.000000
7.150	0.169	7.800	0.169	0.000000
7.800	0.169	8.450	0.169	0.000000
8.450	0.169	9.100	0.169	0.000000
9.100	0.169	9.750	0.169	0.000000
9.750	0.169	10.400	0.169	0.000000
10.400	0.169	11.050	0.169	0.000000
11.050	0.169	11.700	0.169	0.000000
11.700	0.169	12.350	0.169	0.000000
12.350	0.169	13.000	0.169	0.000000
13.000	0.169	14.300	0.169	0.000000
14.300	0.169	15.600	0.169	0.000000
15.600	0.169	16.900	0.169	0.000000
16.900	0.169	18.200	0.169	0.000000
18.200	0.169	19.500	0.169	0.000000
19.500	0.169	20.800	0.169	0.000000
20.800	0.169	22.100	0.169	0.000000
22.100	0.169	23.400	0.169	0.000000
23.400	0.169	24.700	0.169	0.000000

PASSIVE PRESSURES:

Z1	P1	Z2	P2	Slope
*	Below	Base		
13.000	0.000	14.800	0.228	0.126604
14.800	0.255	24.800	2.291	0.203628

ACTIVE SPACING:

No.	Z depth	Spacing
1	0.00	6.00
2	13.00	2.50

PASSIVE SPACING:

No.	Z depth	Spacing
1	13.00	5.00

UNITS: Width,Spacing,Diameter,Length,and Depth - ft; Force - kip; Moment - kip-ft
Friction,Bearing,and Pressure - ksf; Pres. Slope - kip/ft³; Deflection - in

SHORING WALL CALCULATION SUMMARY
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3. DESIGN MANUAL DM-7 (NAVFAC), Department of the Navy, May 1982
4. TRENCHING AND SHORING MANUAL Revision 12, California Department of Transportation, January 2000
6. EARTH SUPPORT SYSTEM & RETAINING STRUCTURES, Pile Buck Inc. 2002
5. DESIGN OF SHEET PILE WALLS, EM 1110-2-2504, U.S. Army Corps of Engineers, 31 March 1994
7. EARTH RETENTION SYSTEMS HANDBOOK, Alan Macnab, McGraw-Hill. 2002
8. Temporary Structures in Construction, Robert T. Ratay (Co-author of Chapter 7: John J. Peirce), McGraw-Hill. 2012
9. AASHTO HB-17, American Association of State and Highway Transportation Officials, 2 September 2002

UNITS: Width/Spacing/Diameter/Length/Depth - ft, Force - kip, Moment - kip-ft, Friction/Bearing/Pressure - ksf, Pres. Slope - kip/ft³, Deflection - in

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Calculations\20250116_Updated Analyses\WAS-77-9.58 13' Main Wall Tieback Strength.sh8

Title: WAS-77-9.58

Subtitle:

*****INPUT DATA*****

Wall Type: 2. Soldier Pile, Drilled

Wall Height: 13.00
Pile Diameter: 2.50
Pile Spacing: 6.00
Factor of Safety (F.S.): 1.00

Lateral Support Type (Braces): 3. Tieback

Top Brace Increase (Multi-Bracing): Add 15%
Brace Position (One Brace Case): Normal Brace*

No-Load Zone:

Vertical Depth for No-Load Zone: 13.00
H-Distance (Input H/V ratio) for No-Load Zone: 0.25
Angle from H. Line for No-Load Zone: 60.00

Embedment Option: 1. Yes

Friction at Pile Tip: No

Pile Properties:

Steel Strength, Fy: 50 ksi = 345 MPa
Allowable Fb/Fy: 1
Elastic Module, E: 29000.00
Moment of Inertia, I: 904.00
User Input Pile: HP14X89

* DRIVING PRESSURE (ACTIVE, WATER, & SURCHARGE) *

The pressures below will be multiplied by a Factor =1.5

No.	Z1 top	Top Pres.	Z2 bottom	Bottom Pres.	Slope
1	*	Above	Base		
2	0.000	0.000	3.250	0.953	0.293342
3	3.250	0.953	9.750	0.953	0.000000
4	9.750	0.953	13.000	0.000	-0.293342
5	*	Below	Base		
6	13.000	1.170	14.800	1.125	-0.025012
7	14.800	1.047	24.800	1.692	0.064494
8	24.800	1.508	44.800	2.293	0.039290
9	44.800	2.029	49.800	2.213	0.036796
10	49.800	1.203	117.000	2.435	0.018342
11	*	Sur-	charge		

12	0.000	0.169	0.650	0.169	0.000000
13	0.650	0.169	1.300	0.169	0.000000
14	1.300	0.169	1.950	0.169	0.000000
15	1.950	0.169	2.600	0.169	0.000000
16	2.600	0.169	3.250	0.169	0.000000
17	3.250	0.169	3.900	0.169	0.000000
18	3.900	0.169	4.550	0.169	0.000000
19	4.550	0.169	5.200	0.169	0.000000
20	5.200	0.169	5.850	0.169	0.000000
21	5.850	0.169	6.500	0.169	0.000000
22	6.500	0.169	7.150	0.169	0.000000
23	7.150	0.169	7.800	0.169	0.000000
24	7.800	0.169	8.450	0.169	0.000000
25	8.450	0.169	9.100	0.169	0.000000
26	9.100	0.169	9.750	0.169	0.000000
27	9.750	0.169	10.400	0.169	0.000000
28	10.400	0.169	11.050	0.169	0.000000
29	11.050	0.169	11.700	0.169	0.000000
30	11.700	0.169	12.350	0.169	0.000000
31	12.350	0.169	13.000	0.169	0.000000
32	13.000	0.169	14.300	0.169	0.000000
33	14.300	0.169	15.600	0.169	0.000000
34	15.600	0.169	16.900	0.169	0.000000
35	16.900	0.169	18.200	0.169	0.000000
36	18.200	0.169	19.500	0.169	0.000000
37	19.500	0.169	20.800	0.169	0.000000
38	20.800	0.169	22.100	0.169	0.000000
39	22.100	0.169	23.400	0.169	0.000000
40	23.400	0.169	24.700	0.169	0.000000
41	24.700	0.169	26.000	0.169	0.000000
42	26.000	0.169	28.600	0.169	0.000000
43	28.600	0.169	31.200	0.169	0.000000
44	31.200	0.169	33.800	0.169	0.000000
45	33.800	0.169	36.400	0.169	0.000000
46	36.400	0.169	39.000	0.169	0.000000
47	39.000	0.169	41.600	0.169	0.000000
48	41.600	0.169	44.200	0.169	0.000000
49	44.200	0.169	46.800	0.169	0.000000
50	46.800	0.169	49.400	0.169	0.000000
51	49.400	0.169	52.000	0.000	-0.064955

Surcharge loading terminated at top of rock (approx 49.8 feet).

* PASSIVE PRESSURE *

No.	Z1 top	Top Pres.	Z2 bottom	Bottom Pres.	Slope
1	*	Below	Base		
2	13.000	0.000	14.800	0.228	0.126604
3	14.800	0.255	24.800	2.291	0.203628
4	24.800	2.563	44.800	6.875	0.215565
5	44.800	7.668	49.800	9.070	0.280490
6	49.800	47	117.000	47	0.0000

Passive pressure for bedrock adjusted to 47 ksf based on an unconfined strength of 330 psi.

* ACTIVE SPACE *

No.	Z depth	Spacing
1	0.00	6.00
2	13.00	2.50

* PASSIVE SPACE *

No.	Z depth	Spacing
1	13.00	5.00

Hole diameter in feet (9 inches)

Allowable bond strength = resistance factor * ultimate bond strength = 0.7*3 ksf

* BRACE: STRUT, TIEBACK, ANCHOR PLATE, DEADMAN, OR SHEET PILE AS ANCHOR*

No.	Z brace	Angle	Spacing	Input1*	Input2*	Type
-----	---------	-------	---------	---------	---------	------

1	6.00	20.0	6.00	0.75	2.10	Tieback
---	------	------	------	------	------	---------

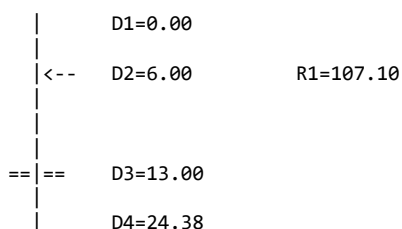
*For Tieback: Input1 = Diameter; Input2 = Bond Strength
 *For Plate: Input1 = Diameter; Input2 = Allowable Pressure
 *For Deadman: Input1 = Horz. Width; Input2 = Passive Pressure;
 *For Sheet Pile Anchor: Input1 = Horz. Width; Input2 = Passive Slope;

*****CALCULATION*****

The calculated moment and shear are per pile spacing. Sheet piles are per one foot or meter; Soldier piles are per pile.

Top Pressures start at depth = 0.00

NUMBER OF BRACE LEVEL = 1



D1 - TOP DEPTH
 D2 - BRACE DEPTH R1 - REACTION
 D3 - EXCAVATION BASE
 D4 - PILE TIP

TOTAL REACTION: R1 = 107.10
 TOTAL PRESSURES ACTING ON WALL = 107.10
 Total Reactions = Total Pressures, OK!

BRACE NO.1 AT DEPTH = 6.00
 R1 = Brace Load = 107.10

*****RESULTS*****

* EMBEDMENT *
 MINIMUM EMBEDMENT = 11.38, TOTAL MINIMUM PILE LENGTH = 24.38

* MOMENT IN PILE (per pile spacing)*
 Pile Spacing: sheet piles are one foot or one meter; soldier piles are one pile.

No.	Depth	M @ Brace	Mmax in Span	Depth of Mmax
1	6.00	111.76	78.99	13.78

Overall Maximum Moment = 113.02 at 5.99
 Maximum Shear = 60.23
 Moment and Shear are per pile spacing: 6.0 foot or meter

* BRACE: STRUT, TIEBACK, ANCHOR PLATE, DEADMAN, OR SHEET PILE AS ANCHOR*
 The calculated brace force are per brace spacing.

No.	DEPTH	Tangle	SPACING	HORIZONTAL	VERTICAL	TOTAL LOAD
1	6.00	20.0	6.00	107.10	38.98	113.98

No.	DEPTH	Free length	Brace Type
1	6.00	6.41	Tieback, Bond length = 23.03

* VERTICAL LOADING *

Vertical Loading from Braces = 38.98

Vertical Loading from External Load = 0.00

Total Vertical Loading = 38.98

*****SPECIFIED PILE *****

Overall Maximum Moment = 113.02 at 5.99

The pile selection is based on the magnitude of the moment only. Axial force is neglected.

Request Min. Section Modulus = 27.12 in³/pile = 444.48 cm³/pile, Fy= 50 ksi = 345 MPa, Fb/Fy=1

HP14X89 has been found in Soldier Pile list!

(English Units):

Area= 26.1 in. Depth= 13.8 in. Width= 14.7 in. Height= 14 in.

Flange thickness= 0.615 in. Web thickness= 0.615 in.

Ix= 904 in⁴/pile Sx= 131 in³/pile Iy= 326 in⁴/pile Sy= 44.3 in³/pile

(Metric Units):

Ix= 376.24 x100cm⁴/pile Sx= 2146.70 cm³/pile Iy= 135.68 x100cm⁴/pile Sy= 725.94 cm³/pile

The pile selection is based on the magnitude of the moment only. Axial force is neglected.

HP14X89 is capable to support the shoring!

Top deflection = -0.030(in)

Max. deflection = 0.129(in)

***** LAGGING SIZE ESTIMATION *****

Max. Pressure above base = 1.68

Piles are more rigid than timber lagging, due to arching, only portion of pressures are acting to lagging, 30-50% loading is suggested.

If 50% loading is used for lagging design, Design Pressure = 0.84

Pile Spacing =6.0, Max. Moment in lagging = 3.79

For 4"x12" Timber, Section Modules S=23.47 in³. The request allowable bending strength, fb=M/S=1.94

For 6"x12" Timber, Section Modules S=57.98 in³. The request allowable bending strength, fb=M/S=0.78

If 30% loading is used for lagging design, Design Pressure = 0.50

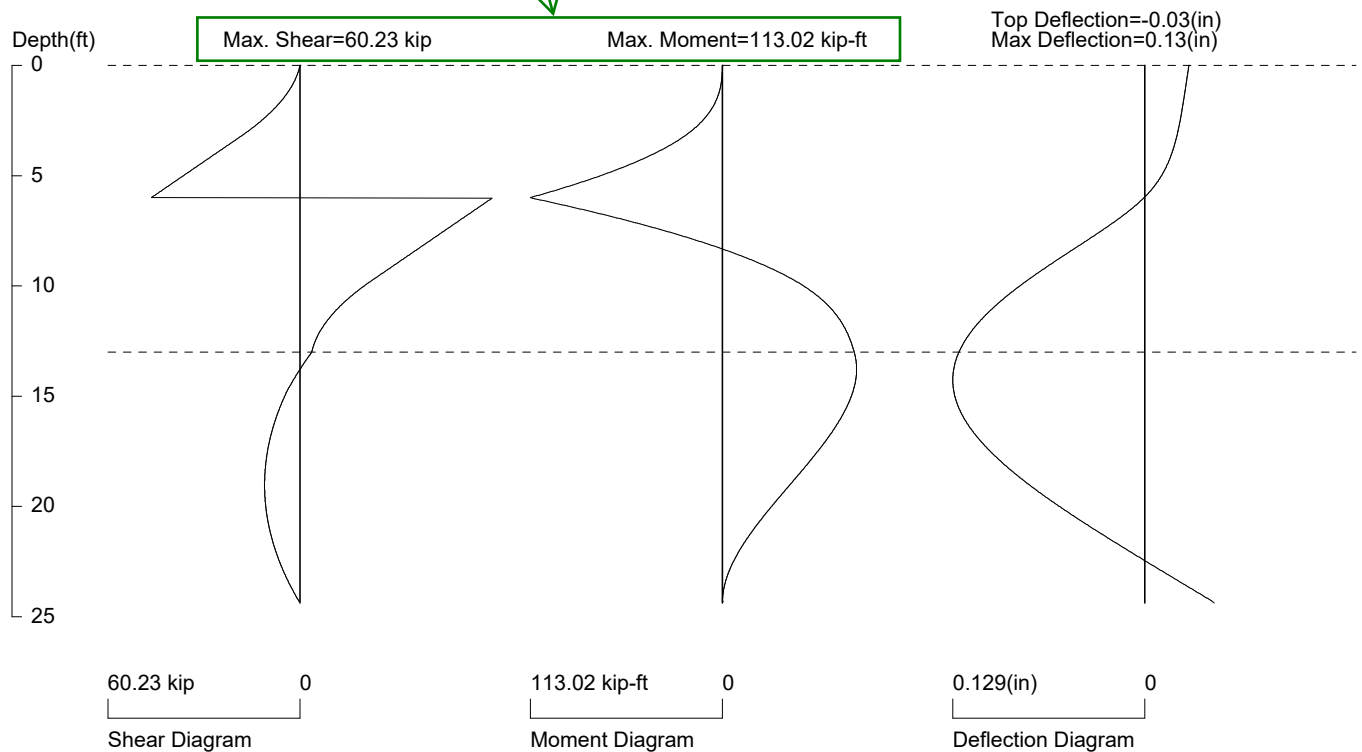
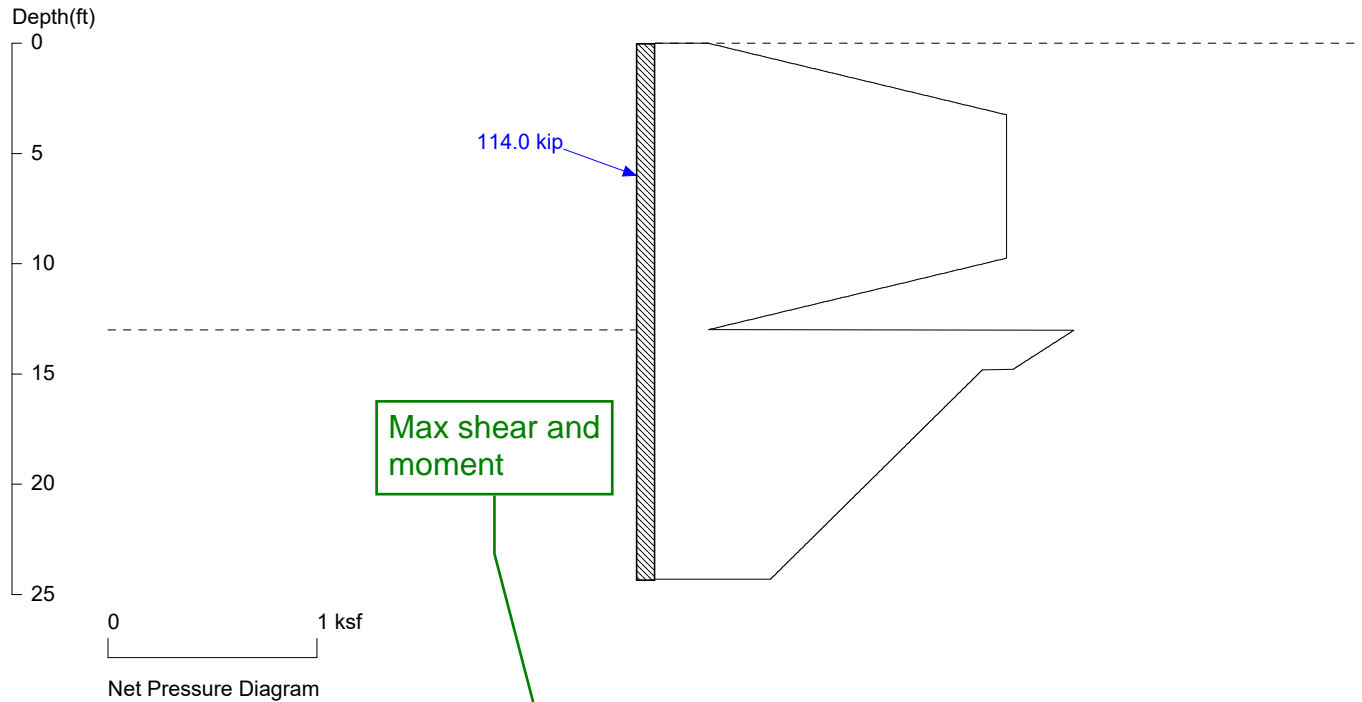
Pile Spacing =6.0, Max. Moment in lagging = 2.27

For 4"x12" Timber, Section Modules S=23.47 in³. The request allowable bending strength, fb=M/S=1.16

For 6"x12" Timber, Section Modules S=57.98 in³. The request allowable bending strength, fb=M/S=0.47

Unit: Pressure: ksf, Spacing: ft, Moment: kip-ft, Bending Strength, fb: ksi

WAS-77-9.58



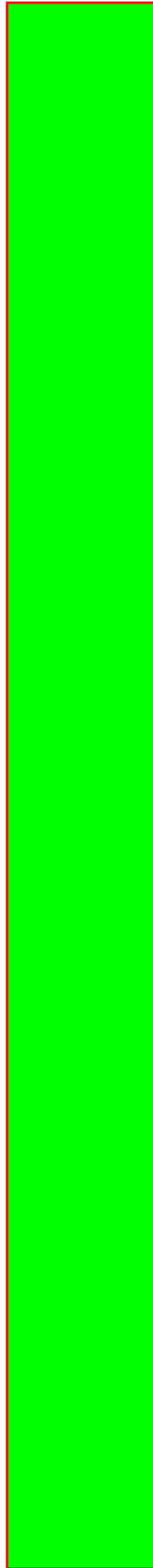
PRESSURE, SHEAR, MOMENT, AND DEFLECTION DIAGRAM

Based on pile spacing: 6.0 foot or meter

User Input Pile, HP14X89: E (ksi)=29000.0, I (in⁴)/pile=904.0

J:\ODOT-District 10 GES\Task 10-13 WAS-77-9.58\20250116_Redesign Calculations\20250116_Updated Analyses\WAS-77-9.58 13' Main Wall Tieback Strength.s

18 ft



Shoring Suite Analysis

Wall Sta. 1+10

18.0 ft Height (Max during Construction)

Geometry

Elevation (ft)			Minimum Horiz. Distance from C/L (ft)		
Top of Backfill =	880.0	at Bottom of Embankment	Start of Wall Backfill =	50.0	at Bottom of Embankment
Top of Wall =	860.0	at C/L of Wall	Wall =	0.0	at C/L of Wall
Existing Ground Surface =	858.0	at C/L of Wall			
Bottom of Facing =	842.0	at C/L of Wall (Top of Shaft)	Backfill Slope Angle =	2.5	H:1V
Groundwater =	848.5	at C/L of Wall		21.8	degrees

Wall Loading Profile (B-005-0-23)

	Top Elev.	Thickness (ft)	Cohesion (psf)	Phi (deg)	Unit Wt (pcf)
Layer 2 Medium Stiff to Stiff Cohesive	860.0	9.8	115	23	140
Layer 1 Soft to Medium Stiff Cohesive	850.2	5.0	65	21	115
Layer 2 Medium Stiff to Stiff Cohesive	845.2	3.2	115	23	140
Layer 3 Stiff to Very Stiff Cohesive	842.0	0.0			
Bottom of Facing	842.0				
Weighted Value		18.0	100	22	135

Earth Pressure Coefficients

	Deg	
Shear Resistance, Φ =	24	
Wall Friction, δ^A =	0.0	
Wall Slope, θ =	90	
Backfill Slope, β =	21.80	
Revised Backfill Slope, β =	21.80	
Backfill Condition	INFINITE	
Horz. Backslope Dist.	50.0	feet (C/L of Wall - Bottom of Embankment)
Wall Height (H)	18.0	feet (Top of Wall - Bottom of Wall Facing)
Slope Height (h)	20.0	feet (Bottom of Embankment - Top of Wall)
I =	29.05	degrees

Notes:

- Wall friction neglected
- Figure and Equation for Active Earth Pressure from AASHTO 3.11.5.3 (LRFD Design Manual).
- The wall retained soil will consist of existing cohesive overburden. Using the soil layer thicknesses and respective soil parameters, a weighted average was determined and assumed for the entire profile ($c' = 100$ psf and $\phi' = 22^\circ$). The parameters were converted to equivalent soil strength parameters $c' = 0$ psf and $\phi' = 24^\circ$ for checking tieback lengths based on a 1 degree increase in friction angle for every 50 psf decrease in cohesion up to 150 psf (Ref: Hall's Thesis).

Shoring Suite Design Profile

	Top Elev	Depth (ft)	Cohesion (psf)	Phi (deg)	Unit Wt (pcf)
Layer 2 Medium Stiff to Stiff Cohesive	860.0	0.0	0	25	140
Layer 1 Soft to Medium Stiff Cohesive	850.2	9.8	0	22	115
Layer 2 Medium Stiff to Stiff Cohesive	845.2	14.8	0	25	140
Layer 3 Stiff to Very Stiff Cohesive	842.0	18.0	0	28	135
Layer 4 Hard Cohesive	815.2	44.8	0	31	145
Bedrock	810.2	49.8	0	45	150

Depths referenced below the top of wall. Friction angles reflect adjustments made per Hall's Thesis. Bedrock modeled as very dense gravel.

Steel Beam and Cross-Section Properties

Assumed Pile Shape **HP 14x89**

Pile Availability

AISC Member Producers	3
Non-Member Producers	0

Shaft Geometry

Shaft Diameter	30	in
Longest Beam Dimension	20.162589	in
Clear Distance	4.9187054	in

Steel Beam Geometry

Beam Depth (D)	13.8	in
Web Thickness (t _w)	0.615	in
Flange Width (B _f)	14.7	in
Flange Thickness (t _f)	0.615	in
Area of Steel (A _s)	26.1	in ²

Steel Properties

Yield Strength of Steel	50	ksi
Moment of Inertia (I _{xx}) of Steel	904	in ⁴
Modulus of Elasticity of Steel (E)	29000	ksi
Modulus of Elasticity of Steel (E)	29000000	psi
EI (Steel Only)	2.622E+10	lb*in ²
Section Modulus (S _x)	131	in ³
Section Modulus (Z _x)	146	in ³
Shear-Buckling Coefficient (k)	5	
Ratio of Shear-Buckling Resistance (C)	1	
D/t _w	22.439024	
1.12VEk/F _{yw}	60.313846	
1.40VEk/F _{yw}	75.392307	

Determined by AASHTO LRFD Bridge Specifications
Eqn's 6.10.9.3.2-4, 6.10.9.3.2-5, and 6.10.9.3.2-6

Shear Capacity Calculation

$$V_u \leq \phi V_{cr}$$
$$\phi_b = \boxed{1} \text{ AASHTO LRFD Bridge Design Spec's 6.5.4.2}$$
$$V_u = \text{shear in web due to factored permanent and construction loads applied to noncompact section (kips)}$$
$$V_{cr} = \text{shear buckling resistance determined from Equation 6.10.9.3.3-1 (AASHTO LRFD Bridge Design Spec's)}$$
$$V_n = V_{cr} = C V_p$$
$$V_p = 0.58 F_{yw} D t_w$$
$$V_p = \text{plastic shear force (kips)}$$
$$C = \text{ratio of shear-buckling resistance to shear yield strength determined by AASHTO Eqn's 6.10.9.3.2-4, 6.10.9.3.2-5, 6.10.9.3.2-5, or 6.10.9.3.2-6}$$
$$V_p = 0.58 * 50 * 13.8 * 0.615$$
$$V_p = \boxed{246.1} \text{ kips}$$
$$\phi V_{cr} = \phi * C * V_p$$
$$\phi V_{cr} = 1 * 1 * 246.1$$
$$\phi V_{cr} = \boxed{246.1} \text{ kips}$$
$$V_u = \boxed{76.73} \text{ kips (from Shoring Suite)}$$
$$\boxed{} \text{ kips (from PYWALL)}$$
$$V_u < \phi V_{cr} \quad \text{OK}$$

Flexure Capacity Calculation

$$M_u \leq \phi M_n$$
$$\phi_b = \boxed{1} \text{ AASHTO LRFD Bridge Design Spec's 6.5.4.2}$$
$$M_u = \text{Moment due to the factored loads}$$
$$M_n = \text{Nominal flexural resistance of a section}$$
$$S_x = \text{Elastic section modulus about the x-axis}$$
$$\phi M_n = \phi * F_y * S_x$$
$$\phi M_n = 1 * 50 * 131$$
$$\phi M_n = \boxed{6550} \text{ in*kips}$$
$$M_u = \boxed{1419} \text{ in*kips (from Shoring Suite)}$$
$$M_u = \boxed{} \text{ in*kips (from PYWALL)}$$
$$M_u < \phi M_n \quad \text{OK}$$

Deflection Criteria

Pile Length Above Rock = 49.8	ft	Exposed Wall Height = 18	ft
Pile Length Above Rock = 	in	Exposed Wall Height = 216	in

1.)

Per the ODOT GDM, pile-head deflection in the service limit state limited to 1% or less of the shaft length above bedrock, or 1% of total drilled shaft length if not embedded in bedrock.

2.)

Following industry acceptance criteria, limit wall deflection to 1% of exposed wall height where ODOT landslide criteria does not govern. Alternatively, limit wall deflection to 1.5% of the exposed wall height in accordance with NCDOT guidelines. Use 1.5% wall deflection for PYWALL software.

ODOT Landslide Criteria Governs

NO

OK

1% Wall Height OR 2 inches- LPILE

2.16

in

$\delta = \boxed{0.01}$ in (from Shoring Suite)

1.5% Wall Height - PYWALL

3.24

in

$\delta = \boxed{}$ in (from PYWALL)

Drilled Shafts Located Within 10 feet of Edge of Pavement

NO

Tieback Loading Computations

Design Tieback Load, TF1 = 148.9 kips / shaft
Design Tieback Load, TF2 = 65.2 kips / shaft

Horizontal values determined from Shoring Suite calculations.
Horizontal values determined from Shoring Suite calculations.

1) Determine Tiebacks

Strands

0.6 GUTS per strand = 35.2 kips per strand (FHWA-NHI-07-071: Table 8-16)

(GUTS = guaranteed ultimate tensile strength)

Tieback	Inclin.	Required Anchor Load**	Strands	
No.	deg	kips	Required	Selected
1	20	158.5	4.5	5.0
1	20	69.4	2.0	2.0

**Required Anchor Load = (TF) / [Cos (Inclin. Angle)]

Table 8-16. Properties of 0.6 in. Diameter Prestressing Steel Strands (ASTM A416, Grade 270).

Number of 0.6 in. diameter strands	Cross section area	Ultimate strength (=GUTS)	Prestressing force		
			0.8 $f_{pu}A_{ps}$	0.7 $f_{pu}A_{ps}$	0.6 $f_{pu}A_{ps}$
	(in. ²)	(kips)	(kips)	(kips)	(kips)
1	0.217	58.6	46.9	41.0	35.2

2) Check Pull-Out Capacity and Bond Length

Pullout Resistance Factor ϕ_{pr} = 0.7 Per AASHTO LRFD Table 11.5.7-1 for "Pullout resistance of anchors, cohesive soils"

Soil Friction Angle ϕ = 24

Tieback	Height Above Bottom of Facing	Tieback Length to Active Wedge	Total Unbonded Length	Ultimate Bond Strength	Tieback Drill Hole Diameter	Surface Area per Foot of Tieback	Allowable Bond Strength per Foot of Tieback	Required Anchor Load	Required Bond Length	Total Tieback Length
No.	ft	ft	ft	ksf	in	in ² /ft	kips/ft	kips	ft	ft
1	12	6.7	15	3	9	339.3	4.95	158.5	33 (35)	48 (50)
2	2	1.1	15	3	9	339.3	4.95	69.4	15	30

Total unbonded length = Tieback length to active wedge + greater of 5 feet or H/3, with a 15 foot minimum, per AASHTO LRFD Figure 11.9.1-1

Ultimate bond strength per AASHTO LRFD Table C11.9.4.2-1. Tieback lengths assume entire bond length is in clay.

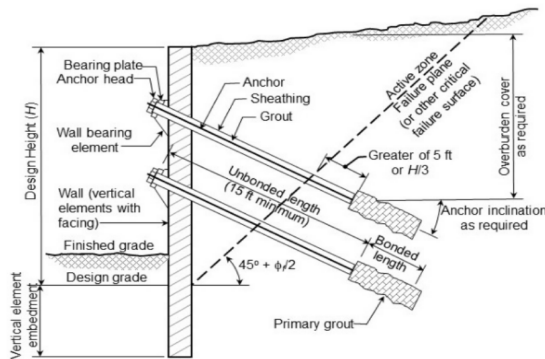


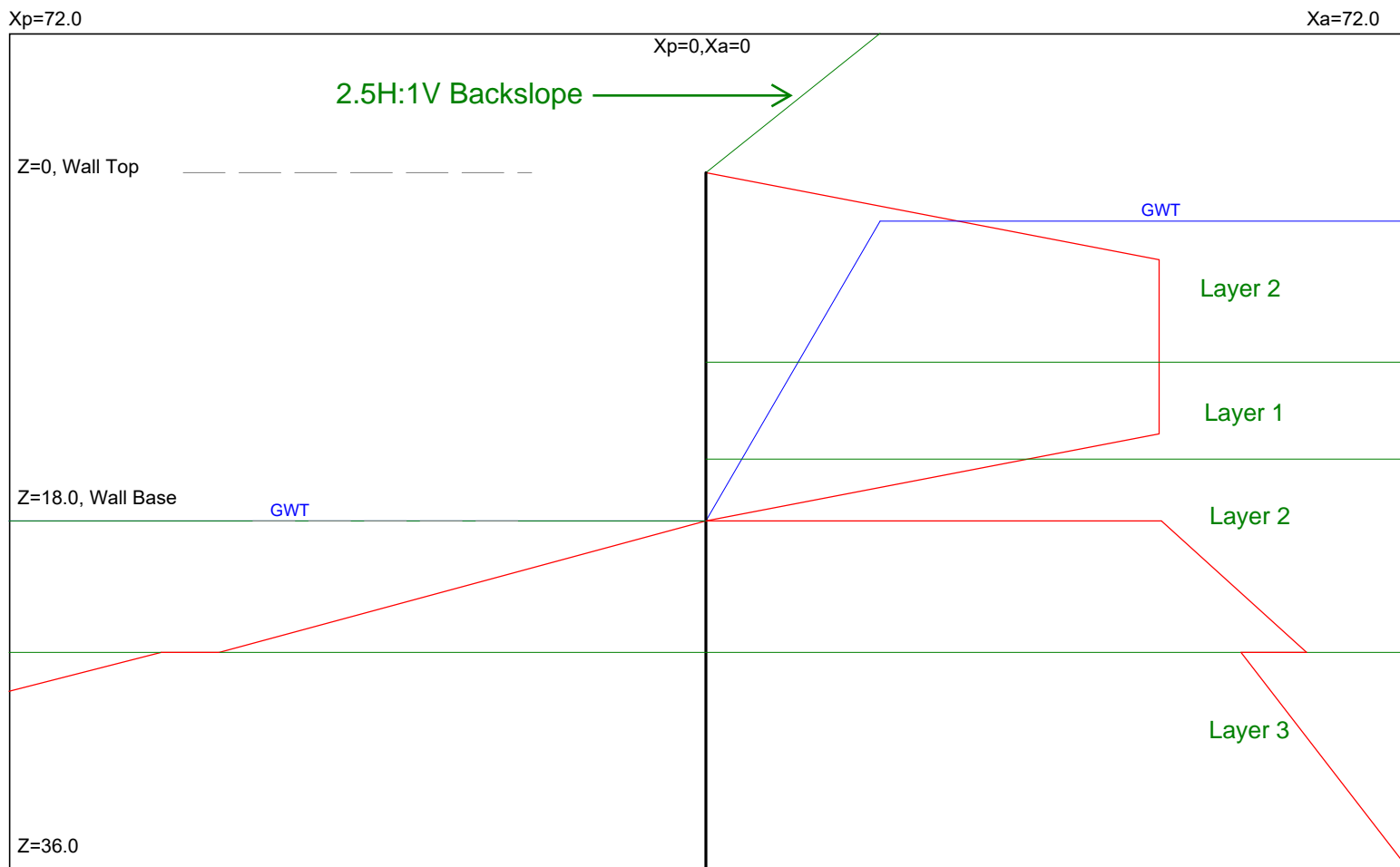
Figure 11.9.1-1—Anchored Wall Nomenclature and Anchor Embedment Guidelines

Table C11.9.4.2-1—Presumptive Ultimate Unit Bond Stress for Anchors in Cohesive Soils

Anchor/Soil Type (Grout Pressure)	Soil Stiffness or Unconfined Compressive Strength (tsf)	Presumptive Ultimate Unit Bond Stress, τ_u (ksf)
Gravity Grouted Anchors (<50 psi)		
Silt-Clay Mixtures	Stiff to Very Stiff 1.0–4.0	0.6 to 1.5
Pressure Grouted Anchors (50 psi–400 psi)		
High Plasticity Clay	Stiff 1.0–2.5 V. Stiff 2.5–4.0	0.6 to 2 1.5 to 3.6
Medium Plasticity Clay	Stiff 1.0–2.5 V. Stiff 2.5–4.0	2.0 to 5.2 2.9 to 7.3
Medium Plasticity Sandy Silt	V. Stiff 2.5–4.0	5.8 to 7.9

Recommended Lengths

Earth Pressure Loading



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UNITS: DEPTH/DISTANCE: ft, UNIT WEIGHT: pcf, FORCE: kip/ft, PRESSURE: ksf, SLOPE: kcf

1/17/2025

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* INPUT DATA *

Wall Height=18.0 Total Soil Types= 5

Soil No.	Weight	Saturate	Phi	Cohesion	Nspt	Type	Description
1	115.0	120.0	22	0	5	1	1. Soft to M
2	140.0	145.0	25	0.0	11	1	2. Medium St
3	135.0	140.0	28	0.0	24	1	3. Stiff to
4	145.0	150.0	31	0.0	65	1	4. Hard Cohe
5	150.0	155.0	45	0.0	100	5	Bedrock

Ground Surface at Active Side:

Line	Z1	Xa1	Z2	Xa2	Soil No.	Description
1	0.0	0.0	-20.0	50.0	2	2. Medium St
2	-20.0	50.0	-50.0	800.0	2	2. Medium St
3	9.8	0.0	9.8	800.0	1	1. Soft to M
4	14.8	0.0	14.8	800.0	2	2. Medium St
5	24.8	0.0	24.8	800.0	3	3. Stiff to
6	44.8	0.0	44.8	800.0	4	4. Hard Cohe
7	49.8	0.0	49.8	800.0	5	Bedrock

Water Table at Active Side:

Point	Z-water	X-water
1	18.0	0.0
2	2.5	18.0
3	2.5	800.0

Bedrock modeled
as dense gravel to
generate active
pressures

Soil Layers in Front of Wall

Ground Surface at Passive Side:

Line	Z1	Xp1	Z2	Xp2	Soil No.	Description
1	18.0	0.0	18.0	800.0	2	2. Medium St
2	24.8	0.0	24.8	800.0	3	3. Stiff to
3	44.8	0.0	44.8	800.0	4	4. Hard Cohe
4	49.8	0.0	49.8	800.0	5	Bedrock

Water Depth in Front of Wall

Water Table at Passive Side:

Point	Z-water	X-water
1	18.0	0.0
2	18.0	800.0

Wall Friction Options: 1.* No wall friction

Wall Batter Angle = 0

Apparent Pressure Conversion: 1.* Default (Terzaghi and Peck)*

Water Density = 62.4

Water Pressure: 1.* No seepage at wall tip

* OUTPUT RESULTS *

Total Force above Base= 14.50 per one linear foot (or meter) width along wall height

Total Static Force above Base= 14.50. Distributed in Apparent Envelope along wall height. Ignore soil layers and water line

Driving Pressure above Base - Output to Shoring - Multiplier of Pressure = 1

Z1	Pa1	Z2	Pa2	Slope	Coef.
0.00	0.00	4.50	1.29	0.2864	2.0460
4.50	1.29	13.50	1.29	0.0000	0.0000
13.50	1.29	18.00	0.00	-0.2864	-2.4908

Driving Pressure below Base - Output to Shoring - Multiplier of Pressure = 1

Z1	Pa1	Z2	Pa2	Slope	Ka or Ko
18.00	1.30	24.80	1.71	0.0607	0.7350
24.80	1.52	36.00	2.00	0.0425	0.5480

Passive Pressure below Base - Output to Shoring - Multiplier of Pressure = 1

Z1	Pp1	Z2	Pp2	Slope	Kp
18.00	0.00	24.80	1.38	0.204	2.4643
24.80	1.55	36.00	3.96	0.216	2.7783

UNITS: DEPTH/DISTANCE: ft, UNIT WEIGHT: pcf, FORCE: kip/ft, PRESSURE: ksf, SLOPE: kcf

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Calculations\20250116_Updated Analyses\WAS-77-9.58 10' Main Wall Tieback.ep8

Title 1: WAS-77-9.58

Title 2:

Input data: *****

Wall Height = 18.00
Depth of Ground at Active Side = 0.00
Depth of Ground at Passive Side = 18.00
Apparent Pressure Envelope: 4. 2-Trapezoid Envelope (Braced, Stiff Clay)
Pressure Type: 1.* Active, Ka
Earthquake Loading Apply to: 1. No Earthq. Loads
Earthquake Horizontal Acceleration, Kh = 0
Earthquake Vertical Acceleration, Kv = 0
Calculation Methods: 1.* Numerical Solution (Wedge Analysis)
Wall Friction Options: 1.* No wall friction
Wall Batter Angle = 0
Apparent Pressure Conversion: 1.* Default (Terzaghi and Peck)*
Water Density = 62.4
Water Pressure: 1.* No seepage at wall tip
User's Settings
Ignore Passive from Depth = 0
Multiplier of Active Pressure = 1
Multiplier of Passive Pressure = 1
Multiplier of Water Pressure = 1
Multiplier of Earthq. Pressure = 1
Estimated Embedment: Very Shallow: 2H
Program's Settings
Max. Height, Hmax = 180.00
Analysis Segment, dz = 0.45
No. of Active Segment at H, nz0 = 3
No. of Active Segment at Hmax, nz = 7
No. of Passive Segment, nzp = 4
Active Depth at H, Zh = 18.00
Active Depth at Hmax, Z = 180.00
Passive Depth at Hmax, Zp = 180.00
Max. Pressure = 85.41

Total Soil Types= 5

Soil	Weight	W(S)	Phi	Cohesion	Nspt	Type	Description
1	115.0	120.0	22	0	5	1	1. Soft to M
>	115.0	120.0	22.0	0.0	5	1	Converted
2	140.0	145.0	25	0.0	11	1	2. Medium St
>	140.0	145.0	25.0	0.0	11	1	Converted
3	135.0	140.0	28	0.0	24	1	3. Stiff to
>	135.0	140.0	28.0	0.0	24	1	Converted
4	145.0	150.0	31	0.0	65	1	4. Hard Cohe
>	145.0	150.0	31.0	0.0	65	1	Converted
5	150.0	155.0	45	0.0	100	5	Bedrock

Soil Type: 1 Equivalent Clay; 2 Clay; 3 Silt; 4 Sand; 5 Gravel

Ground Surface at Active Side:

Line	Z1	Xa1	Z2	Xa2	Soil No.
1	0.0	0.0	-20.0	50.0	2
2	-20.0	50.0	-50.0	800.0	2
3	9.8	0.0	9.8	800.0	1
4	14.8	0.0	14.8	800.0	2
5	24.8	0.0	24.8	800.0	3
6	44.8	0.0	44.8	800.0	4
7	49.8	0.0	49.8	800.0	5

Water Table at Active Side:

Point	Z-water	X-water
1	18.0	0.0
2	2.5	18.0
3	2.5	800.0

Ground Surface at Passive Side:

Line	Z1	Xp1	Z2	Xp2	Soil No.
1	18.0	0.0	18.0	800.0	2
2	24.8	0.0	24.8	800.0	3
3	44.8	0.0	44.8	800.0	4
4	49.8	0.0	49.8	800.0	5

Water Table at Passive Side:

Point	Z-water	X-water
1	18.0	0.0
2	18.0	800.0

Output data: *****

Total Force above Base= 14.50 per one linear foot (or meter) width along wall height

Static Force above Base= 14.50. Distributed in Apparent Envelope along wall height. Ignore soil layers and water line

Apparent Pressure above Base - Output to Shoring

Active/At-Rest Force above Base, Ea = 14.50

No	Z1	P1	Z2	P2	Slope	Coef.
0	0.0	0.00	4.5	1.29	0.2864	2.0460
1	4.5	1.29	13.5	1.29	0.0000	0.0000
2	13.5	1.29	18.0	0.00	-0.2864	-2.4908

Driving Pressure below Base - Output to Shoring

No	Z1	P1	Z2	P2	Slope	Ka or Ko
0	18.0	1.30	24.8	1.71	0.0607	0.7350
1	24.8	1.53	44.8	2.33	0.0399	0.5138
2	44.8	2.08	49.8	2.23	0.0301	0.3439
3	49.8	1.29	180.0	3.38	0.0161	0.1734

Passive Pressure below Base - Output to Shoring

No	Z1	P1	Z2	P2	Slope	Kp
0	18.0	0.00	24.8	1.38	0.2036	2.4643
1	24.8	1.55	44.8	5.86	0.2153	2.7738
2	44.8	6.54	49.8	7.94	0.2796	3.1919
3	49.8	13.83	180.0	85.41	0.5498	5.9371

Passive pressures below 49.8 feet manually adjusted in shoring module to reflect claystone strength.

DEPTH/DISTANCE: ft, UNIT WEIGHT: pcf, FORCE: kip/ft, PRESSURE: ksf, SLOPE: kcf

Z, Xa, Xp - Coordinates of ground lines

Z- Depth measured from wall top

Xa - Distance measure from wall to active side.

Xp - Distance measure from wall to passive side

Z1, P1, Z2, P2 - Four values to define a pressure diagram

Z1- Top depth of the diagram

P1- Top pressure of the diagram

Z2- Bottom depth of the diagram

P2- Bottom pressure of the diagram

Slope - (P2-P1)/(Z2-Z1), Slope of the diagram. It also called Equivalent fluid density.

Coef. - Pressure Coefficient = Slope/Unit Weight

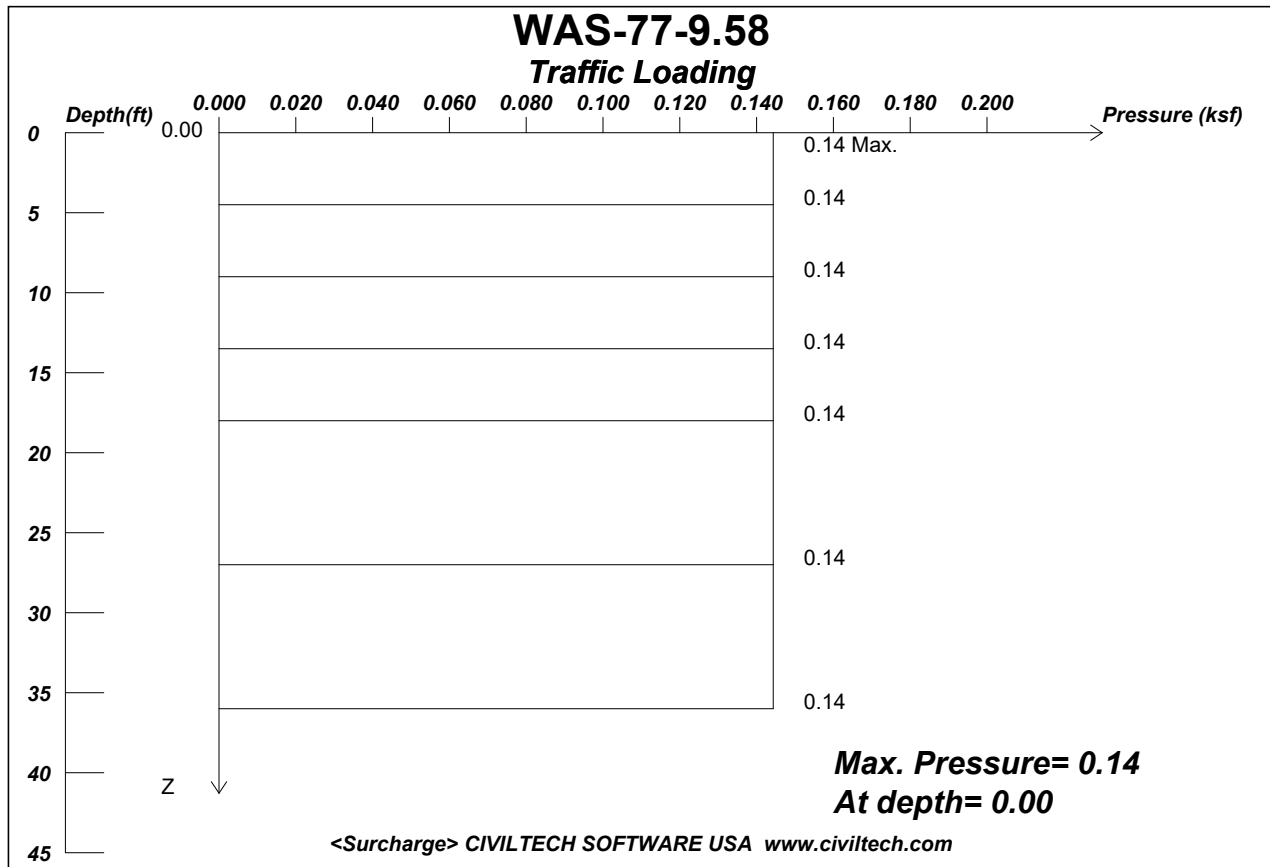
Ka - Active Earth Pressure Coefficient

Ko - At-Rest Earth Pressure Coefficient

Kp - Passive Earth Pressure Coefficient

Traffic Surcharge Load (Service Limit)

Construction Traffic



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Wall Height, H= 18

Load Depth, D= 0

Load Factor of Surcharge Loading = 1

Rigid Wall Condition -- No movement or deflection of the wall are allowed.

Max. Pressure = 0.144 at depth = 0.00

Infinite Surcharge, Q=.250

Active Wedge Approach * (recommend)

UNITS: LENGTH/DEPTH: ft, Qpoint: kip, Qline: kip/ft, Qstrip/Qarea/PRESSURE: ksf

SURCHARGE LOADS CALCULATION SUMMARY
<Surcharge>
Software Copyright by CivilTech Software
www.civiltech.com

Reference: Foundation Design, Wayne C. Teng, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1962

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Date: 1/17/2025 File: J:\ODOT-District 10 GES\Task 10-13 WAS-77-9.58\20250116_Redesign
Calculations\20250116_Updated Analyses\WAS-77-9.58 18' Wall Surcharge Service.lp8

WAS-77-9.58
Traffic Loading

Height of Wall = 18
Depth of Load = 0
Load Factor of Surcharge Loading = 1

Wall Condition:
Rigid Wall Condition -- No movement or deflection of the wall are allowed.

*****Loading*****

INFINITE SURCHARGE LOADING: Q=.250
Active Wedge Approach * (recommend)

*****Total Pressure Distribution*****

Max. Pressure =0.144 at depth =0.00

Depth	Pressure
0.00	0.144
0.90	0.144
1.80	0.144
2.70	0.144
3.60	0.144
4.50	0.144
5.40	0.144
6.30	0.144
7.20	0.144
8.10	0.144
9.00	0.144
9.90	0.144
10.80	0.144
11.70	0.144
12.60	0.144
13.50	0.144
14.40	0.144
15.30	0.144
16.20	0.144
17.10	0.144
18.00	0.144
19.80	0.144
21.60	0.144
23.40	0.144
25.20	0.144
27.00	0.144
28.80	0.144
30.60	0.144
32.40	0.144
34.20	0.144
36.00	0.144
39.60	0.144
43.20	0.144
46.80	0.144
50.40	0.144

Surcharge loading cut off at top of
rock (49.8 feet) in shoring module.

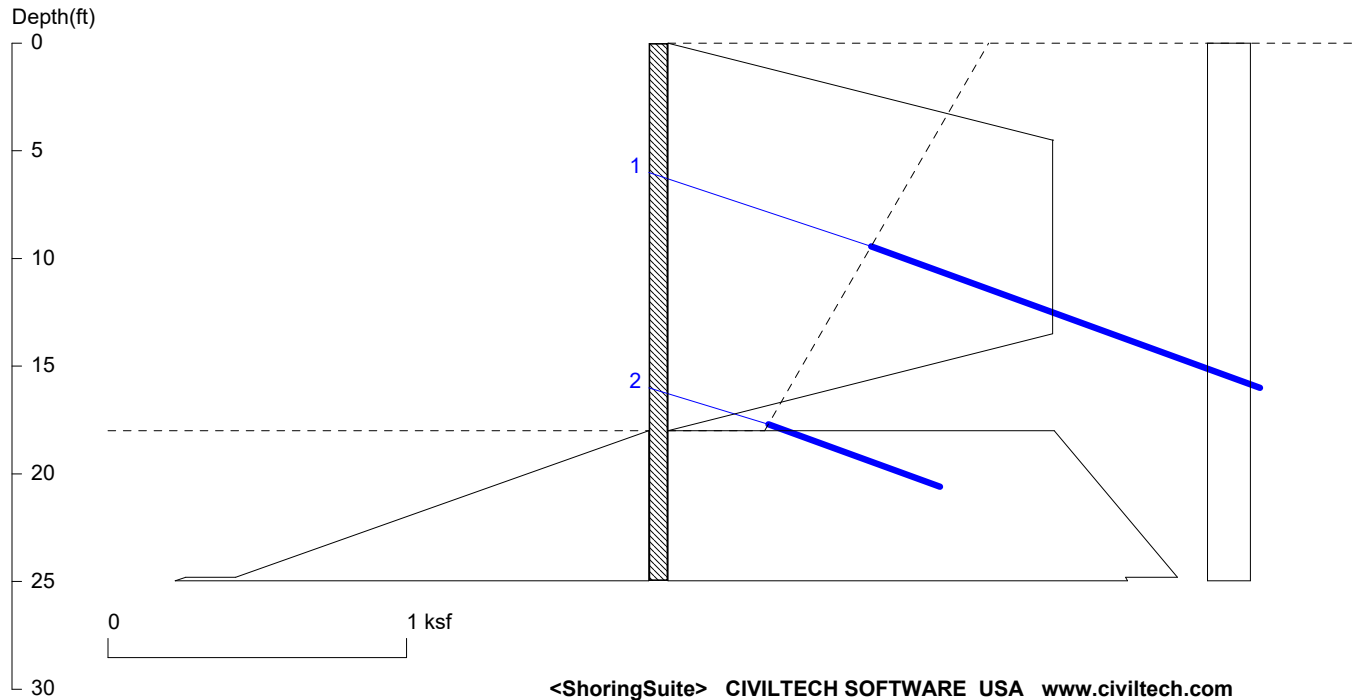
54.00	0.144
57.60	0.144
61.20	0.144
64.80	0.144
68.40	0.144
72.00	0.000

Depth Is Measured From Top of the Wall

LENGTH/DEPTH: ft, Qpoint: kip, Qline: kip/ft, Qstrip/Qarea/PRESSURE: ksf

Service Limit

WAS-77-9.58



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Date: 1/24/2025

File: J:\ODOT-District 10 GES\Task 10-13 WAS-77-9.58\20250116_Redesign Calculations\20250116_Updated Analyses\WA

Wall Height=18.0 Pile Diameter=2.5 Pile Spacing=6.0 Wall Type: 2. Soldier Pile, Drilled

PILE LENGTH: Min. Embedment=6.96 Min. Pile Length=24.96

MOMENT IN PILE: Max. Moment=76.43 per Pile Spacing=6.0 at Depth=6.00

PILE SELECTION:

Request Min. Section Modulus = 18.3 in³/pile=300.60 cm³/pile, Fy= 50 ksi = 345 MPa, Fb/Fy=1

HP14X89 has Section Modulus = 131.0 in³/pile=2146.70 cm³/pile. It is greater than Min. Requirements!

Top Deflection = 0.01(in) based on E (ksi)=29000.00 and I (in⁴)/pile=904.0

BRACE FORCE: Strut, Tieback, Plate Anchor, Deadman, Sheet Pile as Anchor

No. & Type	Depth	Angle	Space	Total F.	Horiz. F.	Vert. F.	L_free	Fixed Length
1. Tieback	6.0	20.0	6.0	103.3*	97.0	35.3	10.0	20.9
2. Tieback	16.0	20.0	6.0	42.0	39.4	14.4	5.0	8.5

* Top Brace increased by 15% (DM7.2-103)

UNITS: Width,Diameter,Spacing,Length,Depth,and Height - ft; Force - kip; Bond Strength and Pressure - ksf

DRIVING PRESSURES (ACTIVE, WATER, & SURCHARGE):

Z1	P1	Z2	P2	Slope
*	Above	Base		
0.000	0.000	4.500	1.289	0.286439
4.500	1.289	13.50	1.289	0.000000
13.50	1.289	18.00	0.000	-0.28643
*	Below	Base		
18.00	1.295	24.80	1.708	0.060712
24.80	1.534	44.80	2.332	0.039872
*	Sur-	charg		
0.000	0.144	0.900	0.144	0.000000
0.900	0.144	1.800	0.144	0.000000
1.800	0.144	2.700	0.144	0.000000

2.700	0.144	3.600	0.144	0.000000
3.600	0.144	4.500	0.144	0.000000
4.500	0.144	5.400	0.144	0.000000
5.400	0.144	6.300	0.144	0.000000
6.300	0.144	7.200	0.144	0.000000
7.200	0.144	8.100	0.144	0.000000
8.100	0.144	9.000	0.144	0.000000
9.000	0.144	9.900	0.144	0.000000
9.900	0.144	10.80	0.144	0.000000
10.80	0.144	11.70	0.144	0.000000
11.70	0.144	12.60	0.144	0.000000
12.60	0.144	13.50	0.144	0.000000
13.50	0.144	14.40	0.144	0.000000
14.40	0.144	15.30	0.144	0.000000
15.30	0.144	16.20	0.144	0.000000
16.20	0.144	17.10	0.144	0.000000
17.10	0.144	18.00	0.144	0.000000
18.00	0.144	19.80	0.144	0.000000
19.80	0.144	21.60	0.144	0.000000
21.60	0.144	23.40	0.144	0.000000
23.40	0.144	25.20	0.144	0.000000

PASSIVE PRESSURES:

Z1	P1	Z2	P2	Slope
*	Below	Base		
18.00	0.000	24.80	1.384	0.203551
24.80	1.551	44.80	5.856	0.215251

ACTIVE SPACING:

No.	Z depth	Spacing
1	0.00	6.00
2	18.00	2.50

PASSIVE SPACING:

No.	Z depth	Spacing
1	18.00	5.00

UNITS: Width,Spacing,Diameter,Length,and Depth - ft; Force - kip; Moment - kip-ft
Friction,Bearing,and Pressure - ksf; Pres. Slope - kip/ft³; Deflection - in

SHORING WALL CALCULATION SUMMARY
The leading shoring design and calculation software
Software Copyright by CivilTech Software
www.civiltech.com

ShoringSuite Software is developed by CivilTech Software, Bellevue, WA, USA.

The calculation method is based on the following references:

1. FHWA 98-011, FHWA-RD-97-130, FHWA SA 96-069, FHWA-IF-99-015
2. STEEL SHEET PILING DESIGN MANUAL by Pile Buck Inc., 1987
3. DESIGN MANUAL DM-7 (NAVFAC), Department of the Navy, May 1982
4. TRENCHING AND SHORING MANUAL Revision 12, California Department of Transportation, January 2000
6. EARTH SUPPORT SYSTEM & RETAINING STRUCTURES, Pile Buck Inc. 2002
5. DESIGN OF SHEET PILE WALLS, EM 1110-2-2504, U.S. Army Corps of Engineers, 31 March 1994
7. EARTH RETENTION SYSTEMS HANDBOOK, Alan Macnab, McGraw-Hill. 2002
8. Temporary Structures in Construction, Robert T. Ratay (Co-author of Chapter 7: John J. Peirce), McGraw-Hill. 2012
9. AASHTO HB-17, American Association of State and Highway Transportation Officials, 2 September 2002

UNITS: Width/Spacing/Diameter/Length/Depth - ft, Force - kip, Moment - kip-ft, Friction/Bearing/Pressure - ksf, Pres. Slope - kip/ft³, Deflection - in

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Date: 1/24/2025 File: J:\ODOT-District 10 GES\Task 10-13 WAS-77-9.58\20250116_Redesign
Calculations\20250116_Updated Analyses\WAS-77-9.58 18' Main Wall Tieback Service.sh8

Title: WAS-77-9.58
Subtitle:

*****INPUT DATA*****

Wall Type: 2. Soldier Pile, Drilled

Wall Height: 18.00
Pile Diameter: 2.50
Pile Spacing: 6.00
Factor of Safety (F.S.): 1.00
As Continuous Span Beam

Lateral Support Type (Braces): 3. Tieback
Top Brace Increase (Multi-Bracing): Add 15%*

No-Load Zone:
Vertical Depth for No-Load Zone: 18.00
H-Distance (Input H/V ratio) for No-Load Zone: 0.25
Angle from H. Line for No-Load Zone: 60.00

Embedment Option: 1. Yes
Friction at Pile Tip: No

Pile Properties:
Steel Strength, Fy: 50 ksi = 345 MPa
Allowable Fb/Fy: 1
Elastic Module, E: 29000.00
Moment of Inertia, I: 904.00
User Input Pile: HP14x89

* DRIVING PRESSURE (ACTIVE, WATER, & SURCHARGE) *

No.	Z1 top	Top Pres.	Z2 bottom	Bottom Pres.	Slope
1	*	Above	Base		
2	0.000	0.000	4.500	1.289	0.286439
3	4.500	1.289	13.50	1.289	0.000000
4	13.50	1.289	18.00	0.000	-0.28643
5	*	Below	Base		
6	18.00	1.295	24.80	1.708	0.060712
7	24.80	1.534	44.80	2.332	0.039872
8	44.80	2.079	49.80	2.230	0.030127
9	49.80	1.243	144.0	2.865	0.017216
10	*	Sur-	charg		
11	0.000	0.144	0.900	0.144	0.000000
12	0.900	0.144	1.800	0.144	0.000000

13	1.800	0.144	2.700	0.144	0.000000
14	2.700	0.144	3.600	0.144	0.000000
15	3.600	0.144	4.500	0.144	0.000000
16	4.500	0.144	5.400	0.144	0.000000
17	5.400	0.144	6.300	0.144	0.000000
18	6.300	0.144	7.200	0.144	0.000000
19	7.200	0.144	8.100	0.144	0.000000
20	8.100	0.144	9.000	0.144	0.000000
21	9.000	0.144	9.900	0.144	0.000000
22	9.900	0.144	10.80	0.144	0.000000
23	10.80	0.144	11.70	0.144	0.000000
24	11.70	0.144	12.60	0.144	0.000000
25	12.60	0.144	13.50	0.144	0.000000
26	13.50	0.144	14.40	0.144	0.000000
27	14.40	0.144	15.30	0.144	0.000000
28	15.30	0.144	16.20	0.144	0.000000
29	16.20	0.144	17.10	0.144	0.000000
30	17.10	0.144	18.00	0.144	0.000000
31	18.00	0.144	19.80	0.144	0.000000
32	19.80	0.144	21.60	0.144	0.000000
33	21.60	0.144	23.40	0.144	0.000000
34	23.40	0.144	25.20	0.144	0.000000
35	25.20	0.144	27.00	0.144	0.000000
36	27.00	0.144	28.80	0.144	0.000000
37	28.80	0.144	30.60	0.144	0.000000
38	30.60	0.144	32.40	0.144	0.000000
39	32.40	0.144	34.20	0.144	0.000000
40	34.20	0.144	36.00	0.144	0.000000
41	36.00	0.144	39.60	0.144	0.000000
42	39.60	0.144	43.20	0.144	0.000000
43	43.20	0.144	46.80	0.144	0.000000
44	46.80	0.144	50.4	0.144	0.000000

Surcharge loading terminated at top of rock (approx 49.8 feet).

* PASSIVE PRESSURE *

No.	Z1 top	Top Pres.	Z2 bottom	Bottom Pres.	Slope
1	*	Below	Base		
2	18.00	0.000	24.80	1.384	0.203551
3	24.80	1.551	44.80	5.856	0.215251
4	44.80	6.540	49.80	7.938	0.279614
5	49.80	47	144.0	47	0.0000

* ACTIVE SPACE *

No.	Z depth	Spacing
1	0.00	6.00
2	18.00	2.50

Passive pressure for bedrock adjusted to 47 ksf based on an unconfined strength of 330 psi.

* PASSIVE SPACE *

No.	Z depth	Spacing
1	18.00	5.00

Hole diameter in feet (9 inches)

Allowable bond strength = resistance factor * ultimate bond strength = 0.7*3 ksf

* BRACE: STRUT, TIEBACK, ANCHOR PLATE, DEADMAN, OR SHEET PILE AS ANCHOR*

No.	Z brace	Angle	Spacing	Input1*	Input2*	Type
1	6.00	20.0	6.00	0.75	2.10	Tieback
2	16.00	20.0	6.00	0.75	2.10	Tieback

*For Tieback: Input1 = Diameter; Input2 = Bond Strength

*For Plate: Input1 = Diameter; Input2 = Allowable Pressure

*For Deadman: Input1 = Horz. Width; Input2 = Passive Pressure;

*For Sheet Pile Anchor: Input1 = Horz. Width; Input2 = Passive Slope;

*****CALCULATION*****

The calculated moment and shear are per pile spacing. Sheet piles are per one foot or meter; Soldier piles are per pile.

Top Pressures start at depth = 0.00

* CALCULATE REQUEST EMBEDMENT *

```

|<-- D1=16.00
|
|== D2=18.00
|
| D3=24.96

```

D1 - TOP DEPTH R1 - TOP REACTION
D2 - EXCAVATION BASE
D3 - PILE TIP

TOTAL REACTION: R1 = 9.01
TOTAL PRESSURES ACTING ON WALL = 9.01
Total Reactions = Total Pressures, OK!
The Calculated Embedment, Yend = 6.96

-----MULTIPLE BRACE / TIEBACK CASE-----

** Use the calculated embedment, Yend = 6.96 for graphics and analysis.

NUMBER OF BRACE LEVEL= 2

* CANTILEVER SPAN, N0.0 *

```

| D1=0.00
|
|<-- D2=6.00                      R2=34.19, with Cantilever Moment=76.46

```

D1 - TOP DEPTH
D2 - BOTTOM DEPTH R2 - BOTTOM REACTION

TOTAL REACTION: R2 = 34.19
TOTAL PRESSURES ACTING ON WALL = 34.19
Total Reactions = Total Pressures, OK!

BRACE NO.1 AT DEPTH = 6.00
R2 of Span No.0 } Sum of Reaction = Brace Load = 84.37
R1 of Last Span

* LAST SPAN *

```

|<-- D1=6.00                      R1=50.19
|
|
|<-- D2=16.00                      R2=39.43
|
| D3=24.96

```

D1 - TOP DEPTH R1 - TOP REACTION
D2 - LAST BRACE DEPTH R2 - LAST BRACE REACTION
D3 - BOTTOM DEPTH

TOTAL REACTION: R1+R2 = 89.62
TOTAL PRESSURES ACTING ON WALL = 89.62

Total Reactions >= Total Pressures, OK!

BRACE NO.2 AT DEPTH = 16.00
R2 of Last Span = Brace Load = 39.43

*****RESULTS*****

* EMBEDMENT *

MINIMUM EMBEDMENT = 6.96, TOTAL MINIMUM PILE LENGTH = 24.96

* MOMENT IN PILE (per pile spacing)*

Pile Spacing: sheet piles are one foot or one meter; soldier piles are one pile.

No.	Depth	M @ Brace	Mmax in Span	Depth of Mmax
1	6.00	76.43	56.34	11.55
2	16.00	8.35	11.24	19.47

Overall Maximum Moment = 76.43 at 6.00

Maximum Shear = 49.96

Moment and Shear are per pile spacing: 6.0 foot or meter

-> Top Brace Increase 15%. (Horizontal) From 84.37 to 97.03

* BRACE: STRUT, TIEBACK, ANCHOR PLATE, DEADMAN, OR SHEET PILE AS ANCHOR*

The calculated brace force are per brace spacing.

No.	DEPTH	Tangle	SPACING	HORIZONTAL	VERTICAL	TOTAL LOAD
1	6.00	20.0	6.00	97.03	35.32	103.26
2	16.00	20.0	6.00	39.43	14.35	41.96

No.	DEPTH	Free length	Brace Type
1	6.00	10.05	Tieback, Bond length = 20.87
2	16.00	4.97	Tieback, Bond length = 8.48

* VERTICAL LOADING *

Vertical Loading from Braces = 49.67

Vertical Loading from External Load = 0.00

Total Vertical Loading = 49.67

*****SPECIFIED PILE *****

Overall Maximum Moment = 76.43 at 6.00

The pile selection is based on the magnitude of the moment only. Axial force is neglected.

Request Min. Section Modulus = 18.34 in³/pile = 300.60 cm³/pile, Fy= 50 ksi = 345 MPa, Fb/Fy=1

HP14X89 has been found in Soldier Pile list!

(English Units):

Area= 26.1 in. Depth= 13.8 in. Width= 14.7 in. Height= 14 in.

Flange thickness= 0.615 in. Web thickness= 0.615 in.

Ix= 904 in⁴/pile Sx= 131 in³/pile Iy= 326 in⁴/pile Sy= 44.3 in³/pile

(Metric Units):

Ix= 376.24 x100cm⁴/pile Sx= 2146.70 cm³/pile Iy= 135.68 x100cm⁴/pile Sy= 725.94 cm³/pile

The pile selection is based on the magnitude of the moment only. Axial force is neglected.

HP14X89 is capable to support the shoring!

Top deflection = 0.011(in)

Max. deflection = 0.023(in)

***** LAGGING SIZE ESTIMATION *****

Max. Pressure above base = 1.43

Piles are more rigid than timber lagging, due to arching, only portion of pressures are acting to lagging, 30-50% loading is suggested.

If 50% loading is used for lagging design, Design Pressure = 0.72

Pile Spacing = 6.0, Max. Moment in lagging = 3.22

For 4"x12" Timber, Section Modules $S=23.47 \text{ in}^3$. The request allowable bending strength, $fb=M/S=1.65$

For 6"x12" Timber, Section Modules $S=57.98 \text{ in}^3$. The request allowable bending strength, $fb=M/S=0.67$

If 30% loading is used for lagging design, Design Pressure = 0.43

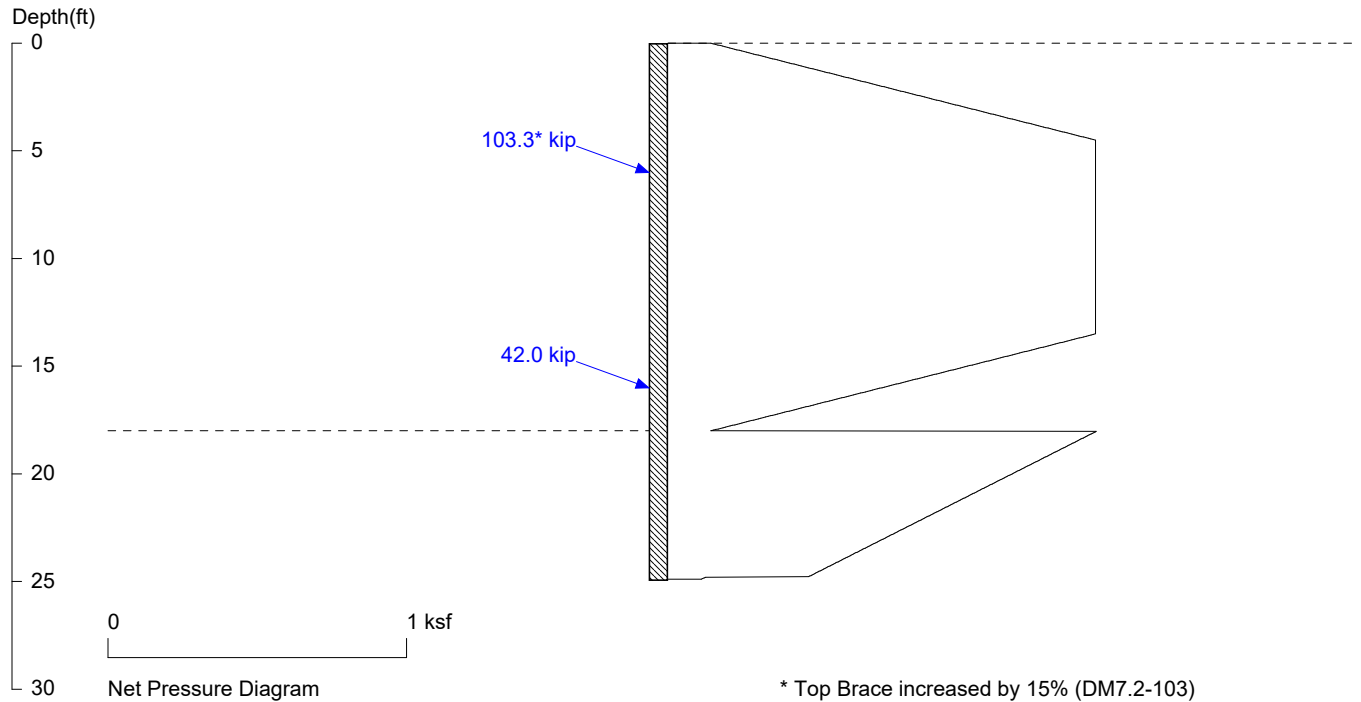
Pile Spacing = 6.0, Max. Moment in lagging = 1.93

For 4"x12" Timber, Section Modules $S=23.47 \text{ in}^3$. The request allowable bending strength, $fb=M/S=0.99$

For 6"x12" Timber, Section Modules $S=57.98 \text{ in}^3$. The request allowable bending strength, $fb=M/S=0.40$

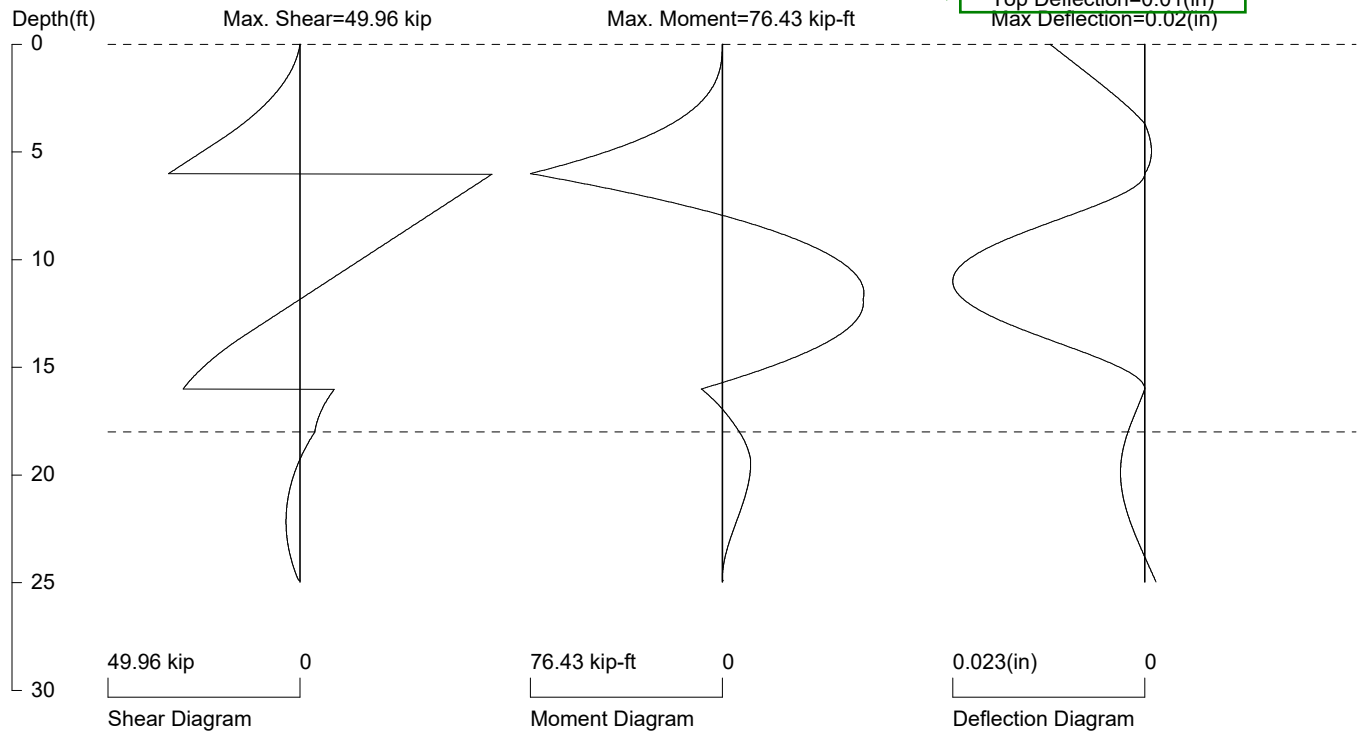
Unit: Pressure: ksf, Spacing: ft, Moment: kip-ft, Bending Strength, fb: ksi

WAS-77-9.58



Pile head deflection =

Top Deflection=0.01(in)
Max Deflection=0.02(in)



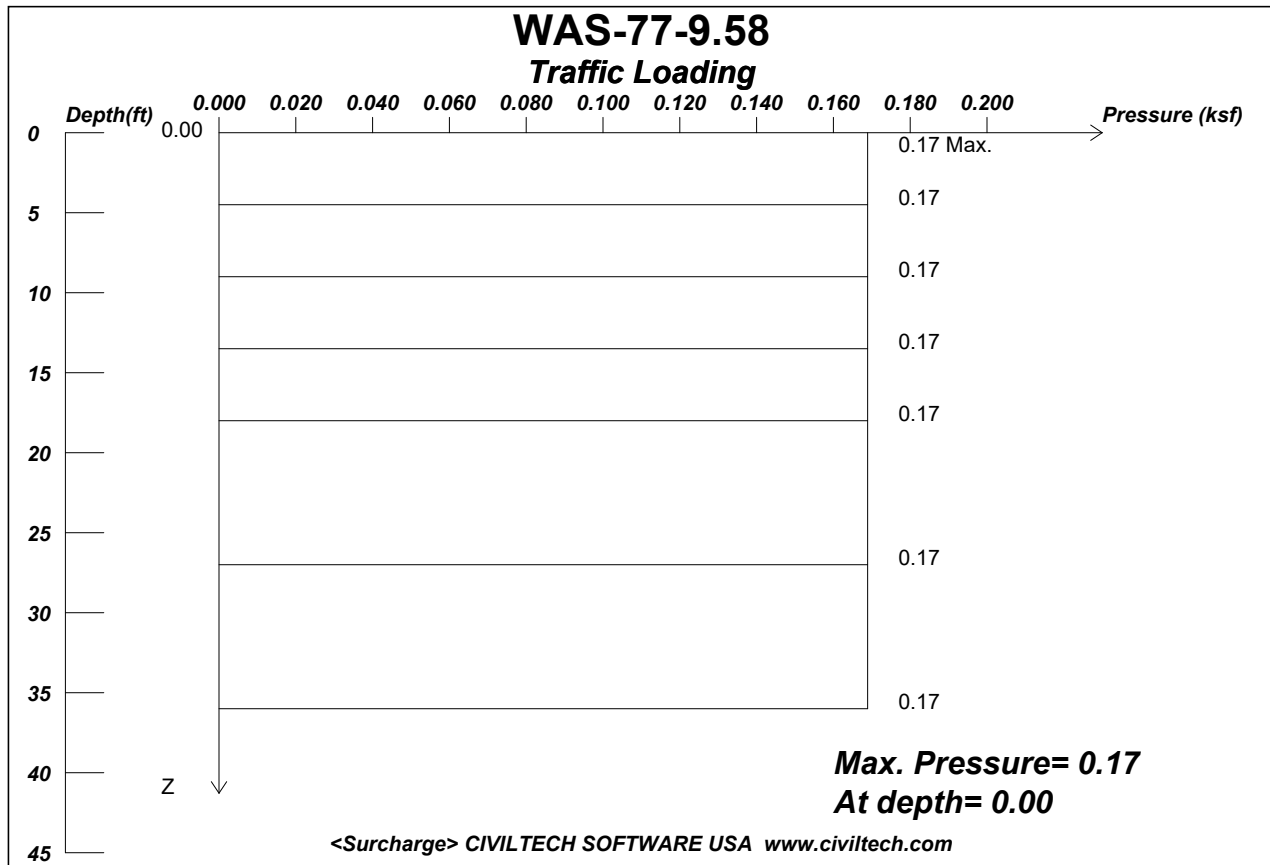
PRESSURE, SHEAR, MOMENT, AND DEFLECTION DIAGRAMS

Based on pile spacing: 6.0 foot or meter

User Input Pile, HP14x89: E (ksi)=29000.0, I (in4)/pile=904.0

Path: J:\ODOT-District 10 GES\Task 10-13 WAS-77-9.58\20250116_Redesign Calculations\20250116_Updated Analyses\WAS-77-9.58 18' Main Wall Tieback Service.sh

Traffic Surcharge Load (Strength Limit)



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Date: 1/17/2025 File: J:\ODOT-District 10 GES\Task 10-13 WAS-77-9.58\20250116_Redesign Calculations\20250116_U

Wall Height, H= 18

Load Depth, D= 0

Load Factor of Surcharge Loading = 1.17

Rigid Wall Condition -- No movement or deflection of the wall are allowed.

Max. Pressure = 0.169 at depth = 0.00

Infinite Surcharge, Q=.250

Active Wedge Approach * (recommend)

A load factor of 1.5 is applied to all active loading in the wall analysis. As traffic loading uses 1.75, an extra factor has been applied here ($1.75/1.5 = 1.17$).

UNITS: LENGTH/DEPTH: ft, Qpoint: kip, Qline: kip/ft, Qstrip/Qarea/PRESSURE: ksf

SURCHARGE LOADS CALCULATION SUMMARY
<Surcharge>
Software Copyright by CivilTech Software
www.civiltech.com

Reference: Foundation Design, Wayne C. Teng, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1962

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Calculations\20250116_Updated Analyses\WAS-77-9.58 18' Wall Surcharge Strength.lp8

WAS-77-9.58
Traffic Loading

Height of Wall = 18
Depth of Load = 0
Load Factor of Surcharge Loading = 1.17

Wall Condition:
Rigid Wall Condition -- No movement or deflection of the wall are allowed.

*****Loading*****

INFINITE SURCHARGE LOADING: Q=.250
Active Wedge Approach * (recommend)

*****Total Pressure Distribution*****

Max. Pressure =0.169 at depth =0.00

Depth	Pressure
0.00	0.169
0.90	0.169
1.80	0.169
2.70	0.169
3.60	0.169
4.50	0.169
5.40	0.169
6.30	0.169
7.20	0.169
8.10	0.169
9.00	0.169
9.90	0.169
10.80	0.169
11.70	0.169
12.60	0.169
13.50	0.169
14.40	0.169
15.30	0.169
16.20	0.169
17.10	0.169
18.00	0.169
19.80	0.169
21.60	0.169
23.40	0.169
25.20	0.169
27.00	0.169
28.80	0.169
30.60	0.169
32.40	0.169
34.20	0.169
36.00	0.169
39.60	0.169
43.20	0.169
46.80	0.169
50.40	0.169

Surcharge loading cut off at top of
rock (49.8 feet) in shoring module.

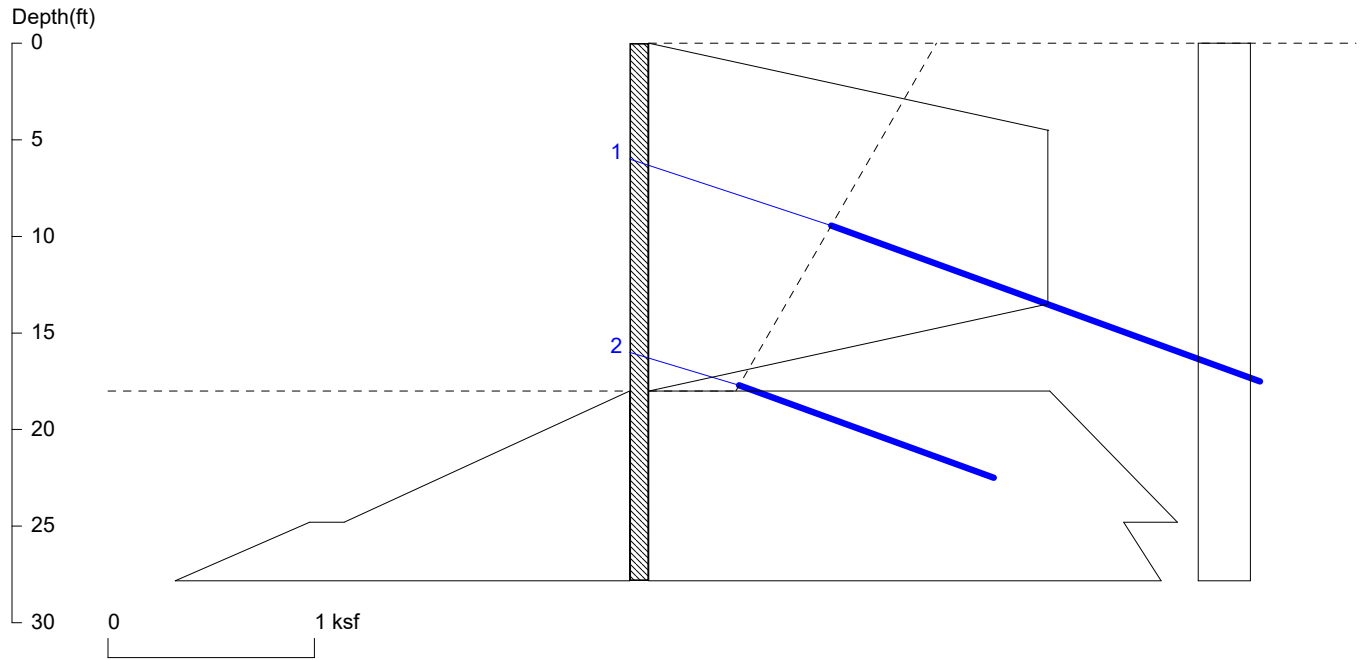
54.00	0.169
57.60	0.169
61.20	0.169
64.80	0.169
68.40	0.169
72.00	0.000

Depth Is Measured From Top of the Wall

LENGTH/DEPTH: ft, Qpoint: kip, Qline: kip/ft, Qstrip/Qarea/PRESSURE: ksf

Strength Limit

WAS-77-9.58



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Date: 1/24/2025

File: J:\ODOT-District 10 GES\Task 10-13 WAS-77-9.58\20250116_Redesign Calculations\20250116_Updated Analyses\WA

Wall Height=18.0

Pile Diameter=2.5

Pile Spacing=6.0

Wall Type: 2. Soldier Pile, Drilled

PILE LENGTH: Min. Embedment=9.83 Min. Pile Length=27.83

MOMENT IN PILE: Max. Moment=118.25 per Pile Spacing=6.0 at Depth=6.01

Anchor loads and lengths

PILE SELECTION:

Request Min. Section Modulus = 28.4 in³/pile=465.07 cm³/pile, Fy= 50 ksi = 345 MPa, Fb/Fy=1

HP14X89 has Section Modulus = 131.0 in³/pile=2146.70 cm³/pile. It is greater than Min. Requirements!

Top Deflection = 0.02(in) based on E (ksi)=29000.00 and I (in⁴)/pile=904.0

BRACE FORCE: Strut, Tieback, Plate Anchor, Deadman, Sheet Pile as Anchor

No. & Type	Depth	Angle	Space	Total F.	Horiz. F.	Vert. F.	L_free	Fixed Length
1. Tieback	6.0	20.0	6.0	158.4*	148.9	54.2	10.0	32.0
2. Tieback	16.0	20.0	6.0	69.4	65.2	23.7	5.0	14.0

Unbonded Length Bonded Length

* Top Brace increased by 15% (DM7.2-103)

UNITS: Width,Diameter,Spacing,Length,Depth,and Height - ft; Force - kip; Bond Strength and Pressure - ksf

DRIVING PRESSURES (ACTIVE, WATER, & SURCHARGE): Pressures below will be multiplied by a Factor =1.5

Z1	P1	Z2	P2	Slope
*	Above	Base		
0.000	0.000	4.500	1.289	0.286439
4.500	1.289	13.50	1.289	0.000000
13.50	1.289	18.00	0.000	-0.28643
*	Below	Base		
18.00	1.295	24.80	1.708	0.060712
24.80	1.534	44.80	2.332	0.039872
*	Sur-	charg		
0.000	0.169	0.900	0.169	0.000000
0.900	0.169	1.800	0.169	0.000000
1.800	0.169	2.700	0.169	0.000000

Applied 1.5 load factor for active earth pressures.

2.700	0.169	3.600	0.169	0.000000
3.600	0.169	4.500	0.169	0.000000
4.500	0.169	5.400	0.169	0.000000
5.400	0.169	6.300	0.169	0.000000
6.300	0.169	7.200	0.169	0.000000
7.200	0.169	8.100	0.169	0.000000
8.100	0.169	9.000	0.169	0.000000
9.000	0.169	9.900	0.169	0.000000
9.900	0.169	10.80	0.169	0.000000
10.80	0.169	11.70	0.169	0.000000
11.70	0.169	12.60	0.169	0.000000
12.60	0.169	13.50	0.169	0.000000
13.50	0.169	14.40	0.169	0.000000
14.40	0.169	15.30	0.169	0.000000
15.30	0.169	16.20	0.169	0.000000
16.20	0.169	17.10	0.169	0.000000
17.10	0.169	18.00	0.169	0.000000
18.00	0.169	19.80	0.169	0.000000
19.80	0.169	21.60	0.169	0.000000
21.60	0.169	23.40	0.169	0.000000
23.40	0.169	25.20	0.169	0.000000
25.20	0.169	27.00	0.169	0.000000
27.00	0.169	28.80	0.169	0.000000

PASSIVE PRESSURES:

Z1	P1	Z2	P2	Slope
*	Below	Base		
18.00	0.000	24.80	1.384	0.203551
24.80	1.551	44.80	5.856	0.215251

ACTIVE SPACING:

No.	Z depth	Spacing
1	0.00	6.00
2	18.00	2.50

PASSIVE SPACING:

No.	Z depth	Spacing
1	18.00	5.00

UNITS: Width,Spacing,Diameter,Length,and Depth - ft; Force - kip; Moment - kip-ft
Friction,Bearing,and Pressure - ksf; Pres. Slope - kip/ft³; Deflection - in

SHORING WALL CALCULATION SUMMARY
The leading shoring design and calculation software
Software Copyright by CivilTech Software
www.civiltech.com

ShoringSuite Software is developed by CivilTech Software, Bellevue, WA, USA.

The calculation method is based on the following references:

1. FHWA 98-011, FHWA-RD-97-130, FHWA SA 96-069, FHWA-IF-99-015
2. STEEL SHEET PILING DESIGN MANUAL by Pile Buck Inc., 1987
3. DESIGN MANUAL DM-7 (NAVFAC), Department of the Navy, May 1982
4. TRENCHING AND SHORING MANUAL Revision 12, California Department of Transportation, January 2000
6. EARTH SUPPORT SYSTEM & RETAINING STRUCTURES, Pile Buck Inc. 2002
5. DESIGN OF SHEET PILE WALLS, EM 1110-2-2504, U.S. Army Corps of Engineers, 31 March 1994
7. EARTH RETENTION SYSTEMS HANDBOOK, Alan Macnab, McGraw-Hill. 2002
8. Temporary Structures in Construction, Robert T. Ratay (Co-author of Chapter 7: John J. Peirce), McGraw-Hill. 2012
9. AASHTO HB-17, American Association of State and Highway Transportation Officials, 2 September 2002

UNITS: Width/Spacing/Diameter/Length/Depth - ft, Force - kip, Moment - kip-ft, Friction/Bearing/Pressure - ksf, Pres. Slope - kip/ft³, Deflection - in

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Calculations\20250116_Updated Analyses\WAS-77-9.58 18' Main Wall Tieback Strength.sh8

Title: WAS-77-9.58

Subtitle:

*****INPUT DATA*****

Wall Type: 2. Soldier Pile, Drilled

Wall Height: 18.00
Pile Diameter: 2.50
Pile Spacing: 6.00
Factor of Safety (F.S.): 1.00
As Continuous Span Beam

Lateral Support Type (Braces): 3. Tieback

Top Brace Increase (Multi-Bracing): Add 15%*

No-Load Zone:

Vertical Depth for No-Load Zone: 18.00
H-Distance (Input H/V ratio) for No-Load Zone: 0.25
Angle from H. Line for No-Load Zone: 60.00

Embedment Option: 1. Yes

Friction at Pile Tip: No

Pile Properties:

Steel Strength, Fy: 50 ksi = 345 MPa
Allowable Fb/Fy: 1
Elastic Module, E: 29000.00
Moment of Inertia, I: 904.00
User Input Pile: HP14X89

* DRIVING PRESSURE (ACTIVE, WATER, & SURCHARGE) *

The pressures below will be multiplied by a Factor =1.5

No.	Z1 top	Top Pres.	Z2 bottom	Bottom Pres.	Slope

1	*	Above	Base		
2	0.000	0.000	4.500	1.289	0.286439
3	4.500	1.289	13.50	1.289	0.000000
4	13.50	1.289	18.00	0.000	-0.28643
5	*	Below	Base		
6	18.00	1.295	24.80	1.708	0.060712
7	24.80	1.534	44.80	2.332	0.039872
8	44.80	2.079	49.80	2.230	0.030127
9	49.80	1.243	144.0	2.865	0.017216
10	*	Sur-	charg		
11	0.000	0.169	0.900	0.169	0.000000

12	0.900	0.169	1.800	0.169	0.000000
13	1.800	0.169	2.700	0.169	0.000000
14	2.700	0.169	3.600	0.169	0.000000
15	3.600	0.169	4.500	0.169	0.000000
16	4.500	0.169	5.400	0.169	0.000000
17	5.400	0.169	6.300	0.169	0.000000
18	6.300	0.169	7.200	0.169	0.000000
19	7.200	0.169	8.100	0.169	0.000000
20	8.100	0.169	9.000	0.169	0.000000
21	9.000	0.169	9.900	0.169	0.000000
22	9.900	0.169	10.80	0.169	0.000000
23	10.80	0.169	11.70	0.169	0.000000
24	11.70	0.169	12.60	0.169	0.000000
25	12.60	0.169	13.50	0.169	0.000000
26	13.50	0.169	14.40	0.169	0.000000
27	14.40	0.169	15.30	0.169	0.000000
28	15.30	0.169	16.20	0.169	0.000000
29	16.20	0.169	17.10	0.169	0.000000
30	17.10	0.169	18.00	0.169	0.000000
31	18.00	0.169	19.80	0.169	0.000000
32	19.80	0.169	21.60	0.169	0.000000
33	21.60	0.169	23.40	0.169	0.000000
34	23.40	0.169	25.20	0.169	0.000000
35	25.20	0.169	27.00	0.169	0.000000
36	27.00	0.169	28.80	0.169	0.000000
37	28.80	0.169	30.60	0.169	0.000000
38	30.60	0.169	32.40	0.169	0.000000
39	32.40	0.169	34.20	0.169	0.000000
40	34.20	0.169	36.00	0.169	0.000000
41	36.00	0.169	39.60	0.169	0.000000
42	39.60	0.169	43.20	0.169	0.000000
43	43.20	0.169	46.80	0.169	0.000000
44	46.80	0.169	50.40	0.169	0.000000

Surcharge loading terminated at top of rock (approx 49.8 feet).

* PASSIVE PRESSURE *

No.	Z1 top	Top Pres.	Z2 bottom	Bottom Pres.	Slope
1	*	Below	Base		
2	18.00	0.000	24.80	1.384	0.203551
3	24.80	1.551	44.80	5.856	0.215251
4	44.80	6.540	49.80	7.938	0.279614
5	49.80	47	144.0	47	0.0000

* ACTIVE SPACE *

No.	Z depth	Spacing
1	0.00	6.00
2	18.00	2.50

Passive pressure for bedrock adjusted to 47 ksf based on an unconfined strength of 330 psi.

* PASSIVE SPACE *

No.	Z depth	Spacing
1	18.00	5.00

Hole diameter in feet (9 inches)

Allowable bond strength = resistance factor * ultimate bond strength = 0.7*3 ksf

* BRACE: STRUT, TIEBACK, ANCHOR PLATE, DEADMAN, OR SHEET PILE AS ANCHOR*

No.	Z brace	Angle	Spacing	Input1*	Input2*	Type
1	6.00	20.0	6.00	0.75	2.10	Tieback
2	16.00	20.0	6.00	0.75	2.10	Tieback

*For Tieback: Input1 = Diameter; Input2 = Bond Strength

*For Plate: Input1 = Diameter; Input2 = Allowable Pressure

*For Deadman: Input1 = Horz. Width; Input2 = Passive Pressure;

*For Sheet Pile Anchor: Input1 = Horz. Width; Input2 = Passive Slope;

*****CALCULATION*****

The calculated moment and shear are per pile spacing. Sheet piles are per one foot or meter; Soldier piles are per pile.

Top Pressures start at depth = 0.00

* CALCULATE REQUEST EMBEDMENT *

```

| <-- D1=16.00
|
| == D2=18.00
|
| D3=27.83

```

D1 - TOP DEPTH R1 - TOP REACTION
D2 - EXCAVATION BASE
D3 - PILE TIP

TOTAL REACTION: R1 = 18.87
TOTAL PRESSURES ACTING ON WALL = 18.87
Total Reactions = Total Pressures, OK!
The Calculated Embedment, Yend = 9.83

-----MULTIPLE BRACE / TIEBACK CASE-----
** Use the calculated embedment, Yend = 9.83 for graphics and analysis.

NUMBER OF BRACE LEVEL= 2

* CANTILEVER SPAN, N0.0 *

```

| D1=0.00
|
|
| <-- D2=6.00                      R2=52.63, with Cantilever Moment=118.73

```

D1 - TOP DEPTH
D2 - BOTTOM DEPTH R2 - BOTTOM REACTION

TOTAL REACTION: R2 = 52.63
TOTAL PRESSURES ACTING ON WALL = 52.63
Total Reactions = Total Pressures, OK!

BRACE NO.1 AT DEPTH = 6.00
R2 of Span No.0 } Sum of Reaction = Brace Load = 129.44
R1 of Last Span

* LAST SPAN *

```

| <-- D1=6.00                      R1=76.81
|
|
| <-- D2=16.00                      R2=65.22
|
|
| D3=27.83

```

D1 - TOP DEPTH R1 - TOP REACTION
D2 - LAST BRACE DEPTH R2 - LAST BRACE REACTION
D3 - BOTTOM DEPTH

TOTAL REACTION: R1+R2 = 142.03

TOTAL PRESSURES ACTING ON WALL = 142.03
Total Reactions >= Total Pressures, OK!

BRACE NO.2 AT DEPTH = 16.00
R2 of Last Span = Brace Load = 65.22

*****RESULTS*****

* EMBEDMENT *

MINIMUM EMBEDMENT = 9.83, TOTAL MINIMUM PILE LENGTH = 27.83

* MOMENT IN PILE (per pile spacing)*

Pile Spacing: sheet piles are one foot or one meter; soldier piles are one pile.

No.	Depth	M @ Brace	Mmax in Span	Depth of Mmax
1	6.00	118.25	85.38	11.58
2	16.00	14.44	31.71	20.62

Overall Maximum Moment = 118.25 at 6.01

Maximum Shear = 76.73

Moment and Shear are per pile spacing: 6.0 foot or meter

-> Top Brace Increase 15%. (Horizontal) From 129.44 to 148.86

* BRACE: STRUT, TIEBACK, ANCHOR PLATE, DEADMAN, OR SHEET PILE AS ANCHOR*

The calculated brace force are per brace spacing.

No.	DEPTH	Tangle	SPACING	HORIZONTAL	VERTICAL	TOTAL LOAD
1	6.00	20.0	6.00	148.86	54.18	158.41
2	16.00	20.0	6.00	65.22	23.74	69.41

No.	DEPTH	Free length	Brace Type
1	6.00	10.05	Tieback, Bond length = 32.01
2	16.00	4.97	Tieback, Bond length = 14.03

* VERTICAL LOADING *

Vertical Loading from Braces = 77.92

Vertical Loading from External Load = 0.00

Total Vertical Loading = 77.92

*****SPECIFIED PILE *****

Overall Maximum Moment = 118.25 at 6.01

The pile selection is based on the magnitude of the moment only. Axial force is neglected.

Request Min. Section Modulus = 28.38 in³/pile = 465.07 cm³/pile, Fy= 50 ksi = 345 MPa, Fb/Fy=1

HP14X89 has been found in Soldier Pile list!

(English Units):

Area= 26.1 in. Depth= 13.8 in. Width= 14.7 in. Height= 14 in.

Flange thickness= 0.615 in. Web thickness= 0.615 in.

Ix= 904 in⁴/pile Sx= 131 in³/pile Iy= 326 in⁴/pile Sy= 44.3 in³/pile

(Metric Units):

Ix= 376.24 x100cm⁴/pile Sx= 2146.70 cm³/pile Iy= 135.68 x100cm⁴/pile Sy= 725.94 cm³/pile

The pile selection is based on the magnitude of the moment only. Axial force is neglected.

HP14X89 is capable to support the shoring!

Top deflection = 0.020(in)

Max. deflection = 0.034(in)

***** LAGGING SIZE ESTIMATION *****

Max. Pressure above base = 2.19

Piles are more rigid than timber lagging, due to arching, only portion of pressures are acting to lagging, 30-50% loading is suggested.

If 50% loading is used for lagging design, Design Pressure = 1.09

Pile Spacing = 6.0, Max. Moment in lagging = 4.92

For 4"x12" Timber, Section Modules $S=23.47 \text{ in}^3$. The request allowable bending strength, $fb=M/S=2.52$

For 6"x12" Timber, Section Modules $S=57.98 \text{ in}^3$. The request allowable bending strength, $fb=M/S=1.02$

If 30% loading is used for lagging design, Design Pressure = 0.66

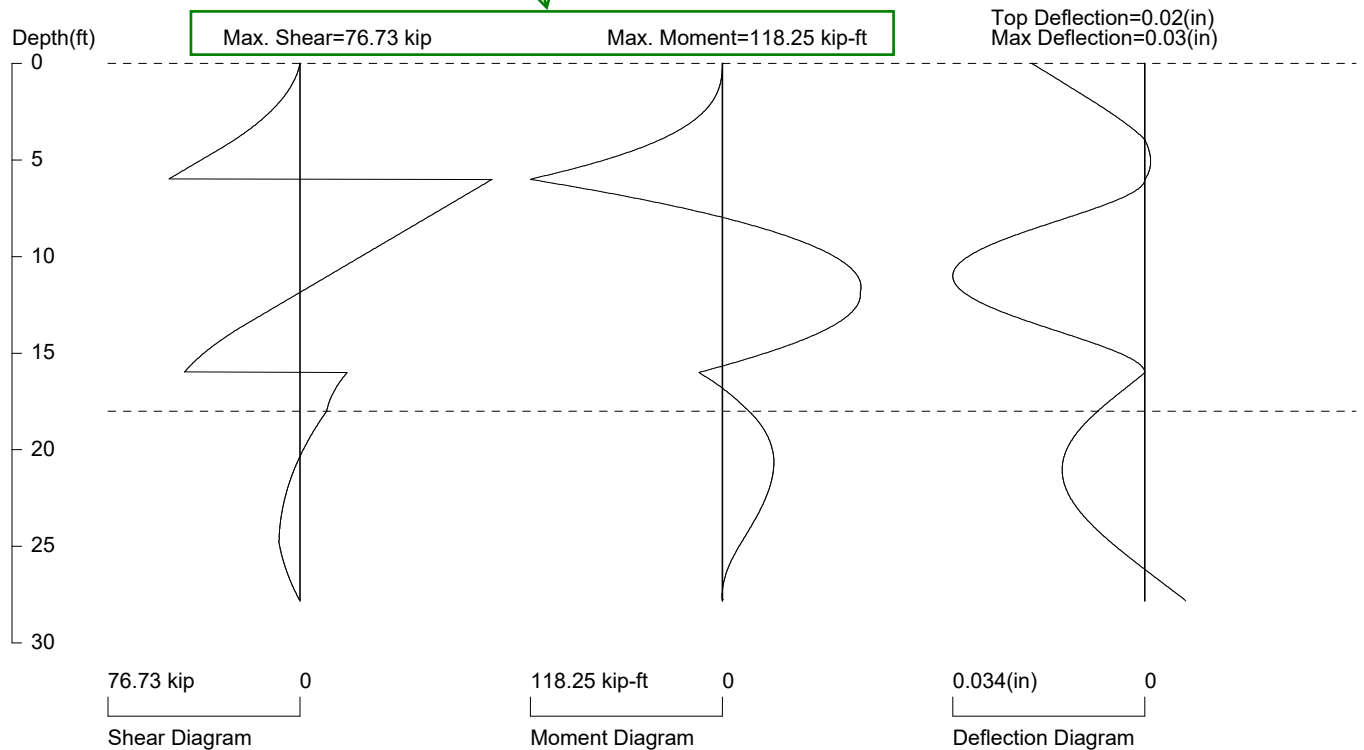
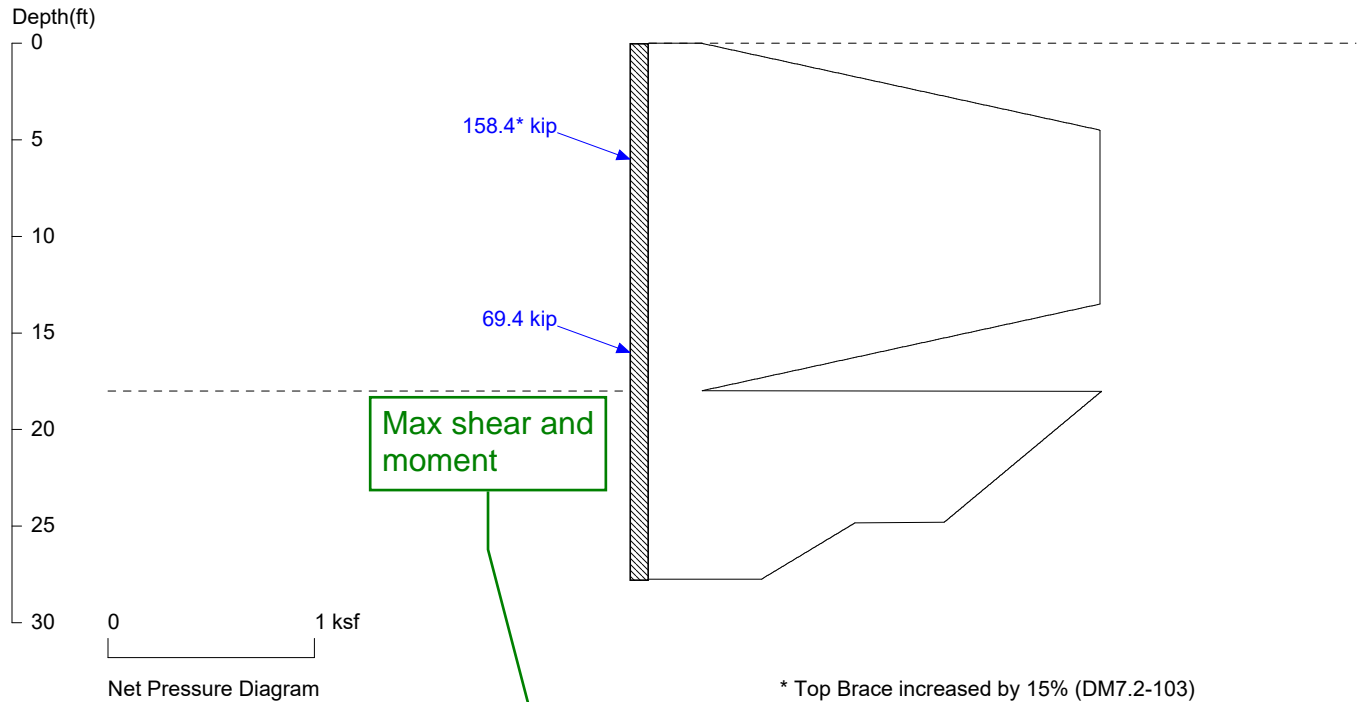
Pile Spacing = 6.0, Max. Moment in lagging = 2.95

For 4"x12" Timber, Section Modules $S=23.47 \text{ in}^3$. The request allowable bending strength, $fb=M/S=1.51$

For 6"x12" Timber, Section Modules $S=57.98 \text{ in}^3$. The request allowable bending strength, $fb=M/S=0.61$

Unit: Pressure: ksf, Spacing: ft, Moment: kip-ft, Bending Strength, fb: ksi

WAS-77-9.58



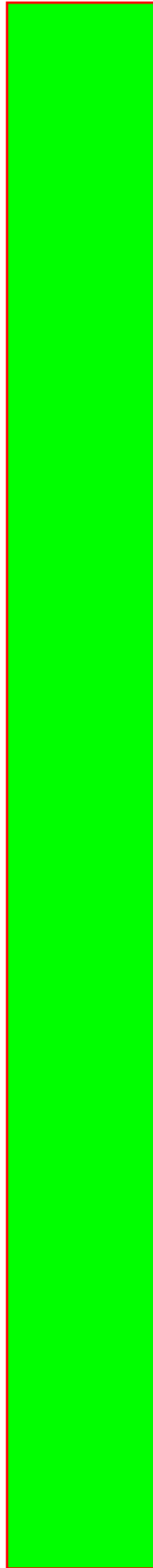
PRESSURE, SHEAR, MOMENT, AND DEFLECTION DIAGRAMS

Based on pile spacing: 6.0 foot or meter

User Input Pile, HP14X89: E (ksi)=29000.0, I (in4)/pile=904.0

J:\ODOT-District 10 GES\Task 10-13 WAS-77-9.58\20250116_Redesign Calculations\20250116_Updated Analyses\WAS-77-9.58 18' Main Wall Tieback Strength.sh

23.0 ft
(Culvert)



Shoring Suite Analysis

Wall Sta. 1+28 (Culvert Analysis)
23.0 ft Height (Max during Construction)

Geometry

Elevation (ft)			Minimum Horiz. Distance from C/L (ft)		
Top of Backfill =	880.0	at Bottom of Embankment	Start of Wall Backfill =	50.0	at Bottom of Embankment
Top of Wall =	860.0	at C/L of Wall	Wall =	0.0	at C/L of Wall
Existing Ground Surface =	858.0	at C/L of Wall			
Bottom of Facing =	837.0	at C/L of Wall (Top of Shaft)	Backfill Slope Angle =	2.5	H:1V
Groundwater =	848.5	at C/L of Wall		21.8	degrees

Wall Loading Profile (B-005-0-23)

	Top Elev.	Thickness (ft)	Cohesion (psf)	Phi (deg)	Unit Wt (pcf)
Layer 2 Medium Stiff to Stiff Cohesive	860.0	9.8	115	23	140
Layer 1 Soft to Medium Stiff Cohesive	850.2	5.0	65	21	115
Layer 2 Medium Stiff to Stiff Cohesive	845.2	10.0	115	23	140
Bottom of Facing	837.0				
Weighted Value		24.8	105	23	135

Earth Pressure Coefficients

	Deg	
Shear Resistance, Φ =	25	
Wall Friction, δ^A =	0.0	
Wall Slope, θ =	90	
Backfill Slope, β =	21.80	
Revised Backfill Slope, β =	21.80	
Backfill Condition	INFINITE	
Horz. Backslope Dist.	50.0	feet (C/L of Wall - Bottom of Embankment)
Wall Height (H)	23.0	feet (Top of Wall - Bottom of Wall Facing)
Slope Height (h)	20.0	feet (Bottom of Embankment - Top of Wall)
I =	23.50	degrees

Notes:

- Wall friction neglected
- Figure and Equation for Active Earth Pressure from AASHTO 3.11.5.3 (LRFD Design Manual).
- The wall retained soil will consist of existing cohesive overburden. Using the soil layer thicknesses and respective soil parameters, a weighted average was determined and assumed for the entire profile ($c' = 105$ psf and $\phi' = 23^\circ$). The parameters were converted to equivalent soil strength parameters $c' = 0$ psf and $\phi' = 25^\circ$ for checking tieback lengths based on a 1 degree increase in friction angle for every 50 psf decrease in cohesion up to 150 psf (Ref: Hall's Thesis).

Shoring Suite Design Profile

	Top Elev	Depth (ft)	Cohesion (psf)	Phi (deg)	Unit Wt (pcf)
Layer 2 Medium Stiff to Stiff Cohesive	860.0	0.0	0	25	140
Layer 1 Soft to Medium Stiff Cohesive	850.2	9.8	0	22	115
Layer 2 Medium Stiff to Stiff Cohesive	845.2	14.8	0	25	140
Layer 3 Stiff to Very Stiff Cohesive	835.2	24.8	0	28	135
Layer 4 Hard Cohesive	815.2	44.8	0	31	145
Bedrock	810.2	49.8	0	45	150

Depths referenced below the top of wall. Friction angles reflect adjustments made per Hall's Thesis. Bedrock modeled as very dense gravel.

Steel Beam and Cross-Section Properties

Assumed Pile Shape **HP 14x89**

Pile Availability

AISC Member Producers	3
Non-Member Producers	0

Shaft Geometry

Shaft Diameter	30	in
Longest Beam Dimension	20.162589	in
Clear Distance	4.9187054	in

Steel Beam Geometry

Beam Depth (D)	13.8	in
Web Thickness (t _w)	0.615	in
Flange Width (B _f)	14.7	in
Flange Thickness (t _f)	0.615	in
Area of Steel (A _s)	26.1	in ²

Steel Properties

Yield Strength of Steel	50	ksi
Moment of Inertia (I _{xx}) of Steel	904	in ⁴
Modulus of Elasticity of Steel (E)	29000	ksi
Modulus of Elasticity of Steel (E)	29000000	psi
EI (Steel Only)	2.622E+10	lb*in ²
Section Modulus (S _x)	131	in ³
Section Modulus (Z _x)	146	in ³
Shear-Buckling Coefficient (k)	5	
Ratio of Shear-Buckling Resistance (C)	1	
D/t _w	22.439024	
1.12VEk/F _{yw}	60.313846	
1.40VEk/F _{yw}	75.392307	

Determined by AASHTO LRFD Bridge Specifications
Eqn's 6.10.9.3.2-4, 6.10.9.3.2-5, and 6.10.9.3.2-6

Shear Capacity Calculation

$$V_u \leq \phi V_{cr}$$
$$\phi_b = \boxed{1} \text{ AASHTO LRFD Bridge Design Spec's 6.5.4.2}$$
$$V_u = \text{shear in web due to factored permanent and construction loads applied to noncompact section (kips)}$$
$$V_{cr} = \text{shear buckling resistance determined from Equation 6.10.9.3.3-1 (AASHTO LRFD Bridge Design Spec's)}$$
$$V_n = V_{cr} = C V_p$$
$$V_p = 0.58 F_{yw} D t_w$$
$$V_p = \text{plastic shear force (kips)}$$
$$C = \text{ratio of shear-buckling resistance to shear yield strength determined by AASHTO Eqn's 6.10.9.3.2-4, 6.10.9.3.2-5, 6.10.9.3.2-5, or 6.10.9.3.2-6}$$
$$V_p = 0.58 * 50 * 13.8 * 0.615$$
$$V_p = \boxed{246.1} \text{ kips}$$
$$\phi V_{cr} = \phi * C * V_p$$
$$\phi V_{cr} = 1 * 1 * 246.1$$
$$\phi V_{cr} = \boxed{246.1} \text{ kips}$$
$$V_u = \boxed{121.96} \text{ kips (from Shoring Suite)}$$
$$\boxed{} \text{ kips (from PYWALL)}$$
$$V_u < \phi V_{cr} \quad \text{OK}$$

Flexure Capacity Calculation

$$M_u \leq \phi M_n$$
$$\phi_b = \boxed{1} \text{ AASHTO LRFD Bridge Design Spec's 6.5.4.2}$$
$$M_u = \text{Moment due to the factored loads}$$
$$M_n = \text{Nominal flexural resistance of a section}$$
$$S_x = \text{Elastic section modulus about the x-axis}$$
$$\phi M_n = \phi * F_y * S_x$$
$$\phi M_n = 1 * 50 * 131$$
$$\phi M_n = \boxed{6550} \text{ in*kips}$$
$$M_u = \boxed{2201.4} \text{ in*kips (from Shoring Suite)}$$
$$M_u = \boxed{} \text{ in*kips (from PYWALL)}$$
$$M_u < \phi M_n \quad \text{OK}$$

Deflection Criteria

Pile Length Above Rock = 49.8	ft	Exposed Wall Height = 23	ft
Pile Length Above Rock = 	in	Exposed Wall Height = 276	in

1.)

Per the ODOT GDM, pile-head deflection in the service limit state limited to 1% or less of the shaft length above bedrock, or 1% of total drilled shaft length if not embedded in bedrock.

2.)

Following industry acceptance criteria, limit wall deflection to 1% of exposed wall height where ODOT landslide criteria does not govern. Alternatively, limit wall deflection to 1.5% of the exposed wall height in accordance with NCDOT guidelines. Use 1.5% wall deflection for PYWALL software.

ODOT Landslide Criteria Governs

NO

OK

1% Wall Height OR 2 inches- LPILE

2.76

in

0.01

in

(from Shoring Suite)

1.5% Wall Height - PYWALL

4.14

in

in

(from PYWALL)

Drilled Shafts Located Within 10 feet of Edge of Pavement

NO

Tieback Loading Computations

Design Tieback Load, TF1 = 224.2 kips / shaft
Design Tieback Load, TF2 = 182.8 kips / shaft

Horizontal values determined from Shoring Suite calculations.
Horizontal values determined from Shoring Suite calculations.

1) Determine Tiebacks

Strands

0.6 GUTS per strand = 35.2 kips per strand (FHWA-NHI-07-071: Table 8-16)

(GUTS = guaranteed ultimate tensile strength)

Tieback	Inclin.	Required Anchor Load**	Strands	
No.	deg	kips	Required	Selected
1	20	238.6	6.8	7.0
1	20	194.5	5.5	6.0

**Required Anchor Load = (TF) / [Cos (Inclin. Angle)]

Table 8-16. Properties of 0.6 in. Diameter Prestressing Steel Strands (ASTM A416, Grade 270).

Number of 0.6 in. diameter strands	Cross section area	Ultimate strength (=GUTS)	Prestressing force		
			0.8 $f_{pu}A_{ps}$	0.7 $f_{pu}A_{ps}$	0.6 $f_{pu}A_{ps}$
	(in. ²)	(kips)	(kips)	(kips)	(kips)
1	0.217	58.6	46.9	41.0	35.2

2) Check Pull-Out Capacity and Bond Length

Pullout Resistance Factor ϕ_{pr} = 0.7 Per AASHTO LRFD Table 11.5.7-1 for "Pullout resistance of anchors, cohesive soils"

Soil Friction Angle ϕ = 25

Tieback	Height Above Bottom of Facing	Tieback Length to Active Wedge	Total Unbonded Length	Ultimate Bond Strength	Tieback Drill Hole Diameter	Surface Area per Foot of Tieback	Allowable Bond Strength per Foot of Tieback	Required Anchor Load	Required Bond Length	Total Tieback Length
No.	ft	ft	ft	ksf	in	in ² /ft	kips/ft	kips	ft	ft
1	17	9.4	18	3	9	339.3	4.95	238.6	49 (50)	67 (68)
2	7	3.9	15	3	9	339.3	4.95	194.5	40	55

Total unbonded length = Tieback length to active wedge + greater of 5 feet or H/3, with a 15 foot minimum, per AASHTO LRFD Figure 11.9.1-1

Ultimate bond strength per AASHTO LRFD Table C11.9.4.2-1. Tieback lengths assume entire bond length is in clay.

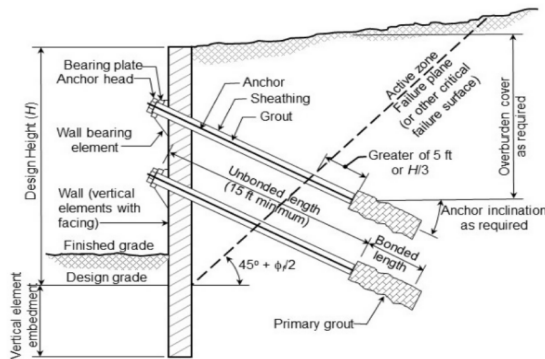


Figure 11.9.1-1—Anchored Wall Nomenclature and Anchor Embedment Guidelines

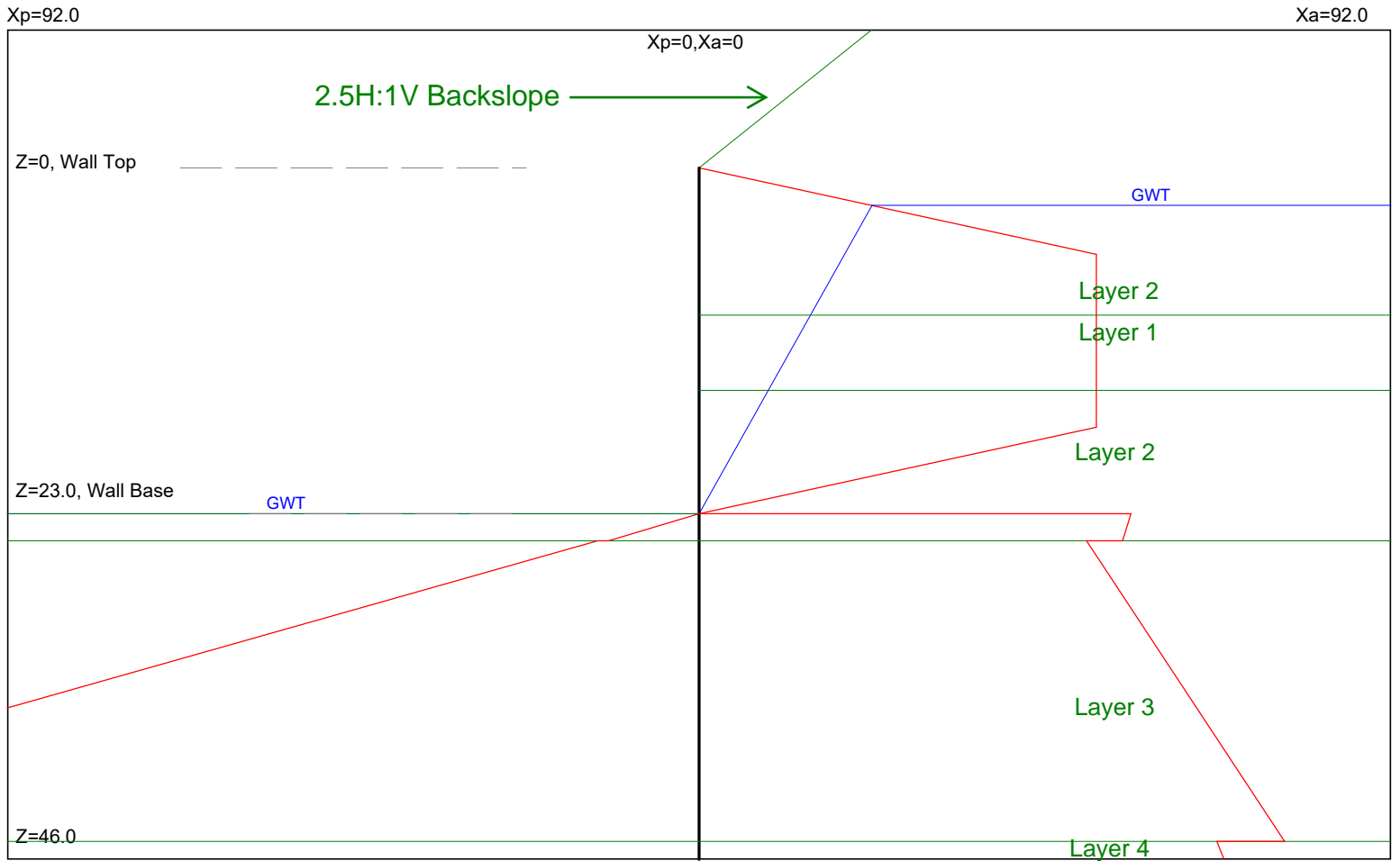
Table C11.9.4.2-1—Presumptive Ultimate Unit Bond Stress for Anchors in Cohesive Soils

Anchor/Soil Type (Grout Pressure)	Soil Stiffness or Unconfined Compressive Strength (tsf)	Presumptive Ultimate Unit Bond Stress, τ_u (ksf)
Gravity Grouted Anchors (<50 psi)		
Silt-Clay Mixtures	Stiff to Very Stiff 1.0–4.0	0.6 to 1.5
Pressure Grouted Anchors (50 psi–400 psi)		
High Plasticity Clay	Stiff 1.0–2.5 V. Stiff 2.5–4.0	0.6 to 2 1.5 to 3.6
Medium Plasticity Clay	Stiff 1.0–2.5 V. Stiff 2.5–4.0	2.0 to 5.2 2.9 to 7.3
Medium Plasticity Sandy Silt	V. Stiff 2.5–4.0	5.8 to 7.9

Recommended Lengths

Earth Pressure Loading

Earth pressures generated using WAS-77-9.58 Service loading.



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UNITS: DEPTH/DISTANCE: ft, UNIT WEIGHT: pcf, FORCE: kip/ft, PRESSURE: ksf, SLOPE: kcf

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* INPUT DATA *

Wall Height=23.0 Total Soil Types= 5

Soil No.	Weight	Saturate	Phi	Cohesion	Nspt	Type	Description
1	115.0	120.0	22	0	5	1	1. Soft to M
2	140.0	145.0	25	0.0	11	1	2. Medium St
3	135.0	140.0	28	0.0	24	1	3. Stiff to
4	145.0	150.0	31	0.0	65	1	4. Hard Cohe
5	150.0	155.0	45	0.0	100	5	Bedrock

Ground Surface at Active Side:

Line	Z1	Xa1	Z2	Xa2	Soil No.	Description
1	0.0	0.0	-20.0	50.0	2	2. Medium St
2	-20.0	50.0	-50.0	800.0	2	2. Medium St
3	9.8	0.0	9.8	800.0	1	1. Soft to M
4	14.8	0.0	14.8	800.0	2	2. Medium St
5	24.8	0.0	24.8	800.0	3	3. Stiff to
6	44.8	0.0	44.8	800.0	4	4. Hard Cohe
7	49.8	0.0	49.8	800.0	5	Bedrock

Water Table at Active Side:

Point	Z-water	X-water
1	23.0	0.0
2	2.5	23.0
3	2.5	800.0

Soil Layers in Front of Wall

Ground Surface at Passive Side:

Line	Z1	Xp1	Z2	Xp2	Soil No.	Description
1	23.0	0.0	23.0	800.0	2	2. Medium St
2	24.8	0.0	24.8	800.0	3	3. Stiff to
3	44.8	0.0	44.8	800.0	4	4. Hard Cohe
4	49.8	0.0	49.8	800.0	5	Bedrock

Water Depth in Front of Wall

Water Table at Passive Side:

Point	Z-water	X-water
1	23.0	0.0
2	23.0	800.0

Wall Friction Options: 1.* No wall friction

Wall Batter Angle = 0

Apparent Pressure Conversion: 1.* Default (Terzaghi and Peck)*

Water Density = 62.4

Water Pressure: 1.* No seepage at wall tip

* OUTPUT RESULTS *

Total Force above Base= 23.13 per one linear foot (or meter) width along wall height

Total Static Force above Base= 23.13. Distributed in Apparent Envelope along wall height. Ignore soil layers and water line

Driving Pressure above Base - Output to Shoring - Multiplier of Pressure = 1

Z1	Pa1	Z2	Pa2	Slope	Coef.
0.00	0.00	5.75	1.61	0.2798	1.9987
5.75	1.61	17.25	1.61	0.0000	0.0000
17.25	1.61	23.00	0.00	-0.2798	-1.9987

Driving Pressure below Base - Output to Shoring - Multiplier of Pressure = 1

Z1	Pa1	Z2	Pa2	Slope	Ka or Ko
23.00	1.75	24.80	1.72	-0.0187	-0.2264
24.80	1.57	44.80	2.37	0.0401	0.5170
44.80	2.10	46.00	2.13	0.0239	0.2728

Passive Pressure below Base - Output to Shoring - Multiplier of Pressure = 1

Z1	Pp1	Z2	Pp2	Slope	Kp
23.00	0.00	24.80	0.37	0.204	2.4643
24.80	0.41	44.80	4.71	0.215	2.7702
44.80	5.27	46.00	5.60	0.280	3.1972

UNITS: DEPTH/DISTANCE: ft, UNIT WEIGHT: pcf, FORCE: kip/ft, PRESSURE: ksf, SLOPE: kcf

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EARTH PRESSURE ANALYSIS SUMMARY
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Calculations\20250116_Updated Analyses\WAS-77-9.58 23' Main Wall Tieback.ep8

Title 1: WAS-77-9.58

Title 2:

Input data: *****

Wall Height = 23.00
Depth of Ground at Active Side = 0.00
Depth of Ground at Passive Side = 23.00
Apparent Pressure Envelope: 4. 2-Trapezoid Envelope (Braced, Stiff Clay)
Pressure Type: 1.* Active, Ka
Earthquake Loading Apply to: 1. No Earthq. Loads
Earthquake Horizontal Acceleration, Kh = 0
Earthquake Vertical Acceleration, Kv = 0
Calculation Methods: 1.* Numerical Solution (Wedge Analysis)
Wall Friction Options: 1.* No wall friction
Wall Batter Angle = 0
Apparent Pressure Conversion: 1.* Default (Terzaghi and Peck)*
Water Density = 62.4
Water Pressure: 1.* No seepage at wall tip
User's Settings
Ignore Passive from Depth = 0
Multiplier of Active Pressure = 1
Multiplier of Passive Pressure = 1
Multiplier of Water Pressure = 1
Multiplier of Earthq. Pressure = 1
Estimated Embedment: Very Shallow: 2H
Program's Settings
Max. Height, Hmax = 230.00
Analysis Segment, dz = 0.57
No. of Active Segment at H, nz0 = 3
No. of Active Segment at Hmax, nz = 7
No. of Passive Segment, nzp = 4
Active Depth at H, Zh = 23.00
Active Depth at Hmax, Z = 230.00
Passive Depth at Hmax, Zp = 230.00
Max. Pressure = 109.93

Total Soil Types= 5

Soil	Weight	W(S)	Phi	Cohesion	Nspt	Type	Description
1	115.0	120.0	22	0	5	1	1. Soft to M
>	115.0	120.0	22.0	0.0	5	1	Converted
2	140.0	145.0	25	0.0	11	1	2. Medium St
>	140.0	145.0	25.0	0.0	11	1	Converted
3	135.0	140.0	28	0.0	24	1	3. Stiff to
>	135.0	140.0	28.0	0.0	24	1	Converted
4	145.0	150.0	31	0.0	65	1	4. Hard Cohe
>	145.0	150.0	31.0	0.0	65	1	Converted
5	150.0	155.0	45	0.0	100	5	Bedrock

Soil Type: 1 Equivalent Clay; 2 Clay; 3 Silt; 4 Sand; 5 Gravel

Ground Surface at Active Side:

Line	Z1	Xa1	Z2	Xa2	Soil No.
1	0.0	0.0	-20.0	50.0	2
2	-20.0	50.0	-50.0	800.0	2
3	9.8	0.0	9.8	800.0	1
4	14.8	0.0	14.8	800.0	2
5	24.8	0.0	24.8	800.0	3
6	44.8	0.0	44.8	800.0	4
7	49.8	0.0	49.8	800.0	5

Water Table at Active Side:

Point	Z-water	X-water
1	23.0	0.0
2	2.5	23.0
3	2.5	800.0

Ground Surface at Passive Side:

Line	Z1	Xp1	Z2	Xp2	Soil No.
1	23.0	0.0	23.0	800.0	2
2	24.8	0.0	24.8	800.0	3
3	44.8	0.0	44.8	800.0	4
4	49.8	0.0	49.8	800.0	5

Water Table at Passive Side:

Point	Z-water	X-water
1	23.0	0.0
2	23.0	800.0

Output data: *****

Total Force above Base= 23.13 per one linear foot (or meter) width along wall height
 Static Force above Base= 23.13. Distributed in Apparent Envelope along wall height. Ignore soil layers and water line

Apparent Pressure above Base - Output to Shoring

Active/At-Rest Force above Base, Ea = 23.13

No	Z1	P1	Z2	P2	Slope	Coef.
0	0.0	0.00	5.8	1.61	0.2798	1.9987
1	5.8	1.61	17.3	1.61	0.0000	0.0000
2	17.3	1.61	23.0	0.00	-0.2798	-1.9987

Driving Pressure below Base - Output to Shoring

No	Z1	P1	Z2	P2	Slope	Ka or Ko
0	23.0	1.75	24.8	1.72	-0.0187	-0.2264
1	24.8	1.57	44.8	2.37	0.0401	0.5170
2	44.8	2.09	49.8	2.28	0.0384	0.4380
3	49.8	1.31	230.0	4.22	0.0161	0.1743

Passive Pressure below Base - Output to Shoring

No	Z1	P1	Z2	P2	Slope	Kp
0	23.0	0.00	24.8	0.37	0.2036	2.4643
1	24.8	0.41	44.8	4.71	0.2150	2.7702
2	44.8	5.27	49.8	6.66	0.2788	3.1825
3	49.8	11.89	230.0	109.93	0.5441	5.8755

Passive pressures below 49.8 feet manually adjusted in shoring module to reflect claystone strength.

DEPTH/DISTANCE: ft, UNIT WEIGHT: pcf, FORCE: kip/ft, PRESSURE: ksf, SLOPE: kcf

Z, Xa, Xp - Coordinates of ground lines

Z- Depth measured from wall top

Xa - Distance measure from wall to active side.

Xp - Distance measure from wall to passive side

Z1, P1, Z2, P2 - Four values to define a pressure diagram

Z1- Top depth of the diagram

P1- Top pressure of the diagram

Z2- Bottom depth of the diagram

P2- Bottom pressure of the diagram

Slope - (P2-P1)/(Z2-Z1), Slope of the diagram. It also called Equivalent fluid density.

Coef. - Pressure Coefficient = Slope/Unit Weight

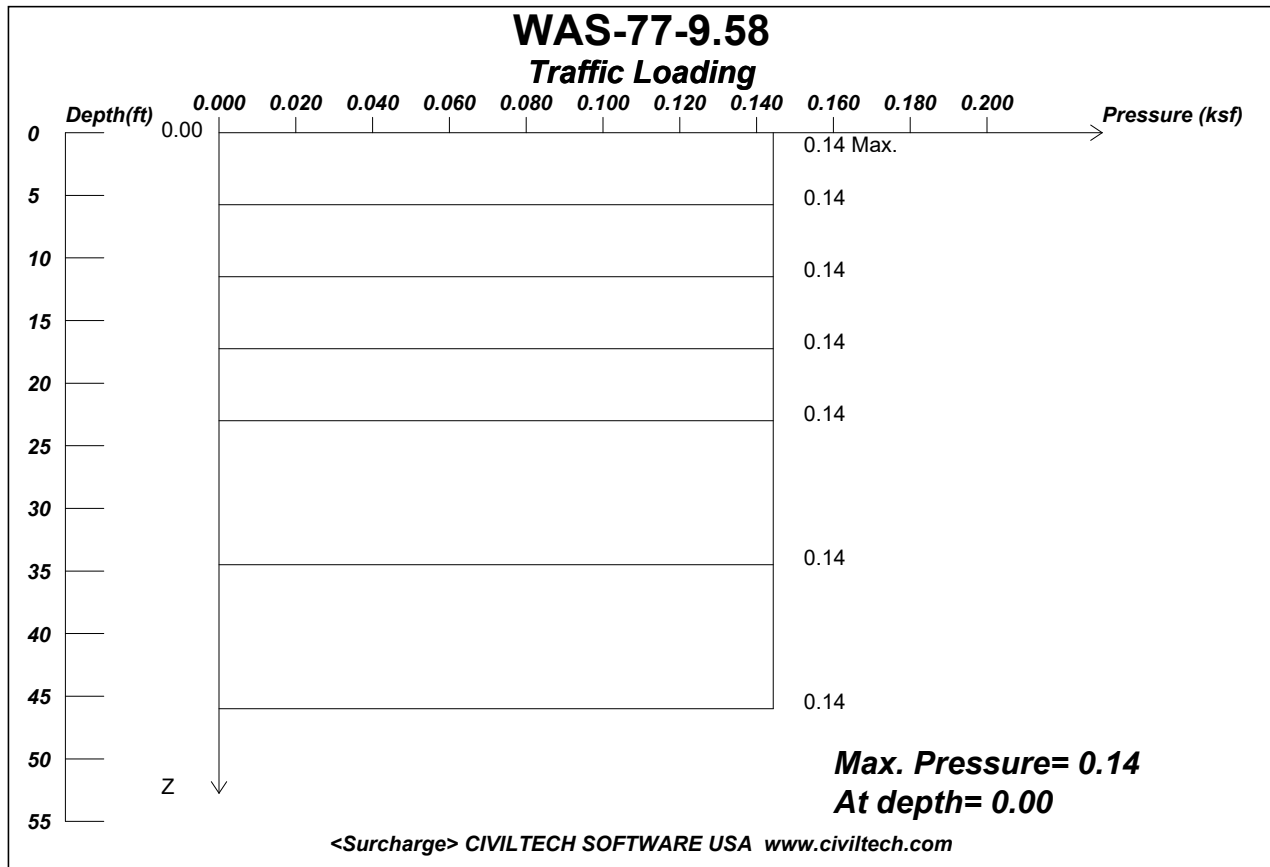
Ka - Active Earth Pressure Coefficient

Ko - At-Rest Earth Pressure Coefficient

Kp - Passive Earth Pressure Coefficient

Traffic Surcharge Loading (Service Limit)

Construction Traffic



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Wall Height, H= 23

Load Depth, D= 0

Load Factor of Surcharge Loading = 1

Rigid Wall Condition -- No movement or deflection of the wall are allowed.

Max. Pressure = 0.144 at depth = 0.00

Infinite Surcharge, Q=.250

Active Wedge Approach * (recommend)

UNITS: LENGTH/DEPTH: ft, Qpoint: kip, Qline: kip/ft, Qstrip/Qarea/PRESSURE: ksf

SURCHARGE LOADS CALCULATION SUMMARY
<Surcharge>
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Reference: Foundation Design, Wayne C. Teng, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1962

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Calculations\20250116_Updated Analyses\WAS-77-9.58 23' Wall Surcharge Service.lp8

WAS-77-9.58
Traffic Loading

Height of Wall = 23
Depth of Load = 0
Load Factor of Surcharge Loading = 1

Wall Condition:
Rigid Wall Condition -- No movement or deflection of the wall are allowed.

*****Loading*****

INFINITE SURCHARGE LOADING: Q=.250
Active Wedge Approach * (recommend)

*****Total Pressure Distribution*****

Max. Pressure =0.144 at depth =0.00

Depth	Pressure
0.00	0.144
1.15	0.144
2.30	0.144
3.45	0.144
4.60	0.144
5.75	0.144
6.90	0.144
8.05	0.144
9.20	0.144
10.35	0.144
11.50	0.144
12.65	0.144
13.80	0.144
14.95	0.144
16.10	0.144
17.25	0.144
18.40	0.144
19.55	0.144
20.70	0.144
21.85	0.144
23.00	0.144
25.30	0.144
27.60	0.144
29.90	0.144
32.20	0.144
34.50	0.144
36.80	0.144
39.10	0.144
41.40	0.144
43.70	0.144
46.00	0.144
50.60	0.144
55.20	0.144
59.80	0.144
64.40	0.144

Surcharge loading cut off at top of
rock (49.8 feet) in shoring module.

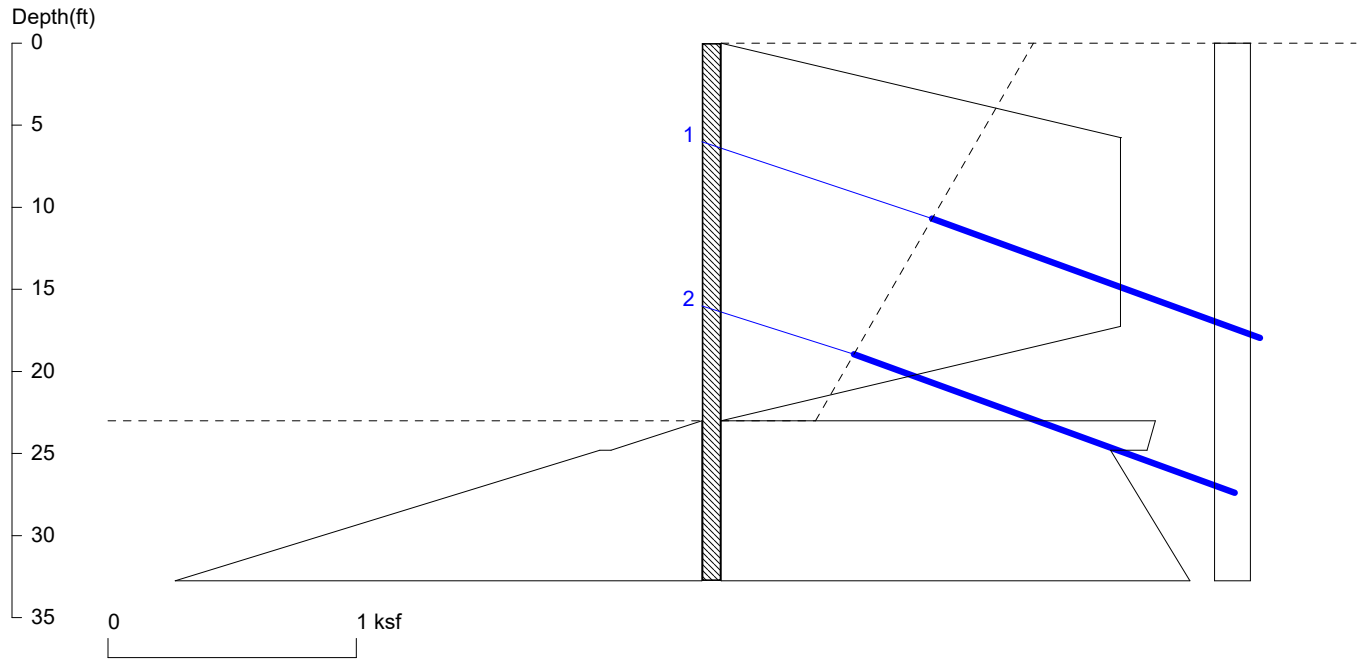
69.00	0.144
73.60	0.144
78.20	0.144
82.80	0.144
87.40	0.144
92.00	0.000

Depth Is Measured From Top of the Wall

LENGTH/DEPTH: ft, Qpoint: kip, Qline: kip/ft, Qstrip/Qarea/PRESSURE: ksf

Service Limit

WAS-77-9.58



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Wall Height=23.0

Pile Diameter=2.5

Pile Spacing=8.0

Wall Type: 2. Soldier Pile, Drilled

PILE LENGTH: Min. Embedment=9.76 Min. Pile Length=32.76

MOMENT IN PILE: Max. Moment=103.41 per Pile Spacing=8.0 at Depth=11.41

PILE SELECTION:

Request Min. Section Modulus = 24.8 in³/pile=406.68 cm³/pile, F_y= 50 ksi = 345 MPa, F_b/F_y=1

HP14X89 has Section Modulus = 131.0 in³/pile=2146.70 cm³/pile. It is greater than Min. Requirements!

Top Deflection = 0.00(in) based on E (ksi)=29000.00 and I (in⁴)/pile=904.0

Average of 10-foot and 6-foot pile spacing

BRACE FORCE: Strut, Tieback, Plate Anchor, Deadman, Sheet Pile as Anchor

No. & Type	Depth	Angle	Space	Total F.	Horiz. F.	Vert. F.	L _{free}	Fixed Length
1. Tieback	6.0	20.0	8.0	155.9*	146.5	53.3	13.7	31.5
2. Tieback	16.0	20.0	8.0	122.2	114.8	41.8	8.6	24.7

* Top Brace increased by 15% (DM7.2-103)

UNITS: Width,Diameter,Spacing,Length,Depth,and Height - ft; Force - kip; Bond Strength and Pressure - ksf

DRIVING PRESSURES (ACTIVE, WATER, & SURCHARGE):

Z1	P1	Z2	P2	Slope
*	Above	Base		
0.000	0.000	5.750	1.609	0.279817
5.750	1.609	17.25	1.609	0.000000
17.25	1.609	23.00	0.000	-0.27981
*	Below	Base		
23.00	1.749	24.80	1.715	-0.01870
24.80	1.569	44.80	2.371	0.040119
*	Sur-	charg		
0.000	0.144	1.150	0.144	0.000000
1.150	0.144	2.300	0.144	0.000000
2.300	0.144	3.450	0.144	0.000000

3.450	0.144	4.600	0.144	0.000000
4.600	0.144	5.750	0.144	0.000000
5.750	0.144	6.900	0.144	0.000000
6.900	0.144	8.050	0.144	0.000000
8.050	0.144	9.200	0.144	0.000000
9.200	0.144	10.35	0.144	0.000000
10.35	0.144	11.50	0.144	0.000000
11.50	0.144	12.65	0.144	0.000000
12.65	0.144	13.80	0.144	0.000000
13.80	0.144	14.95	0.144	0.000000
14.95	0.144	16.10	0.144	0.000000
16.10	0.144	17.25	0.144	0.000000
17.25	0.144	18.40	0.144	0.000000
18.40	0.144	19.55	0.144	0.000000
19.55	0.144	20.70	0.144	0.000000
20.70	0.144	21.85	0.144	0.000000
21.85	0.144	23.00	0.144	0.000000
23.00	0.144	25.30	0.144	0.000000
25.30	0.144	27.60	0.144	0.000000
27.60	0.144	29.90	0.144	0.000000
29.90	0.144	32.20	0.144	0.000000
32.20	0.144	34.50	0.144	0.000000

PASSIVE PRESSURES:

Z1	P1	Z2	P2	Slope
*	Below	Base		
23.00	0.000	24.80	0.366	0.203551
24.80	0.411	44.80	4.711	0.214969

ACTIVE SPACING:

No.	Z depth	Spacing
1	0.00	8.00
2	23.00	2.50

PASSIVE SPACING:

No.	Z depth	Spacing
1	23.00	5.00

UNITS: Width,Spacing,Diameter,Length,and Depth - ft; Force - kip; Moment - kip-ft
Friction,Bearing,and Pressure - ksf; Pres. Slope - kip/ft³; Deflection - in

SHORING WALL CALCULATION SUMMARY
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The calculation method is based on the following references:

1. FHWA 98-011, FHWA-RD-97-130, FHWA SA 96-069, FHWA-IF-99-015
2. STEEL SHEET PILING DESIGN MANUAL by Pile Buck Inc., 1987
3. DESIGN MANUAL DM-7 (NAVFAC), Department of the Navy, May 1982
4. TRENCHING AND SHORING MANUAL Revision 12, California Department of Transportation, January 2000
6. EARTH SUPPORT SYSTEM & RETAINING STRUCTURES, Pile Buck Inc. 2002
5. DESIGN OF SHEET PILE WALLS, EM 1110-2-2504, U.S. Army Corps of Engineers, 31 March 1994
7. EARTH RETENTION SYSTEMS HANDBOOK, Alan Macnab, McGraw-Hill. 2002
8. Temporary Structures in Construction, Robert T. Ratay (Co-author of Chapter 7: John J. Peirce), McGraw-Hill. 2012
9. AASHTO HB-17, American Association of State and Highway Transportation Officials, 2 September 2002

UNITS: Width/Spacing/Diameter/Length/Depth - ft, Force - kip, Moment - kip-ft, Friction/Bearing/Pressure - ksf,
Pres. Slope - kip/ft³, Deflection - in

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Date: 1/27/2025 File: J:\ODOT-District 10 GES\Task 10-13 WAS-77-9.58\20250116_Redesign
Calculations\20250116_Updated Analyses\WAS-77-9.58 23' Culvert Wall Tieback Service.sh8

Title: WAS-77-9.58

Subtitle:

*****INPUT DATA*****

Wall Type: 2. Soldier Pile, Drilled

Wall Height: 23.00
Pile Diameter: 2.50
Pile Spacing: 8.00
Factor of Safety (F.S.): 1.00
As Continuous Span Beam

Lateral Support Type (Braces): 3. Tieback
Top Brace Increase (Multi-Bracing): Add 15%*

No-Load Zone:
Vertical Depth for No-Load Zone: 23.00
H-Distance (Input H/V ratio) for No-Load Zone: 0.25
Angle from H. Line for No-Load Zone: 60.00

Embedment Option: 1. Yes
Friction at Pile Tip: No

Pile Properties:
Steel Strength, Fy: 50 ksi = 345 MPa
Allowable Fb/Fy: 1
Elastic Module, E: 29000.00
Moment of Inertia, I: 904.00
User Input Pile: HP14x89

* DRIVING PRESSURE (ACTIVE, WATER, & SURCHARGE) *

No.	Z1 top	Top Pres.	Z2 bottom	Bottom Pres.	Slope
1	*	Above	Base		
2	0.000	0.000	5.750	1.609	0.279817
3	5.750	1.609	17.25	1.609	0.000000
4	17.25	1.609	23.00	0.000	-0.27981
5	*	Below	Base		
6	23.00	1.749	24.80	1.715	-0.01870
7	24.80	1.569	44.80	2.371	0.040119
8	44.80	2.085	49.80	2.277	0.038365
9	49.80	1.292	184.0	3.488	0.016366
10	*	Sur-	charg		
11	0.000	0.144	1.150	0.144	0.000000
12	1.150	0.144	2.300	0.144	0.000000

13	2.300	0.144	3.450	0.144	0.000000
14	3.450	0.144	4.600	0.144	0.000000
15	4.600	0.144	5.750	0.144	0.000000
16	5.750	0.144	6.900	0.144	0.000000
17	6.900	0.144	8.050	0.144	0.000000
18	8.050	0.144	9.200	0.144	0.000000
19	9.200	0.144	10.35	0.144	0.000000
20	10.35	0.144	11.50	0.144	0.000000
21	11.50	0.144	12.65	0.144	0.000000
22	12.65	0.144	13.80	0.144	0.000000
23	13.80	0.144	14.95	0.144	0.000000
24	14.95	0.144	16.10	0.144	0.000000
25	16.10	0.144	17.25	0.144	0.000000
26	17.25	0.144	18.40	0.144	0.000000
27	18.40	0.144	19.55	0.144	0.000000
28	19.55	0.144	20.70	0.144	0.000000
29	20.70	0.144	21.85	0.144	0.000000
30	21.85	0.144	23.00	0.144	0.000000
31	23.00	0.144	25.30	0.144	0.000000
32	25.30	0.144	27.60	0.144	0.000000
33	27.60	0.144	29.90	0.144	0.000000
34	29.90	0.144	32.20	0.144	0.000000
35	32.20	0.144	34.50	0.144	0.000000
36	34.50	0.144	36.80	0.144	0.000000
37	36.80	0.144	39.10	0.144	0.000000
38	39.10	0.144	41.40	0.144	0.000000
39	41.40	0.144	43.70	0.144	0.000000
40	43.70	0.144	46.00	0.144	0.000000
41	46.00	0.144	50.60	0.144	0.000000

Surcharge loading terminated at top of rock (approx 49.8 feet).

* PASSIVE PRESSURE *

No.	Z1 top	Top Pres.	Z2 bottom	Bottom Pres.	Slope
1	*	Below	Base		
2	23.00	0.000	24.80	0.366	0.203551
3	24.80	0.411	44.80	4.711	0.214969
4	44.80	5.269	49.80	6.663	0.278791
5	49.80	47	184.0	47	0.0000

* ACTIVE SPACE *

No.	Z depth	Spacing
1	0.00	8.00
2	23.00	2.50

Passive pressure for bedrock adjusted to 47 ksf based on an unconfined strength of 330 psi.

* PASSIVE SPACE *

No.	Z depth	Spacing
1	23.00	5.00

Hole diameter in feet (9 inches)

Allowable bond strength = resistance factor * ultimate bond strength = 0.7*3 ksf

* BRACE: STRUT, TIEBACK, ANCHOR PLATE, DEADMAN, OR SHEET PILE AS ANCHOR*

No.	Z brace	Angle	Spacing	Input1*	Input2*	Type
1	6.00	20.0	8.00	0.75	2.10	Tieback
2	16.00	20.0	8.00	0.75	2.10	Tieback

*For Tieback: Input1 = Diameter; Input2 = Bond Strength

*For Plate: Input1 = Diameter; Input2 = Allowable Pressure

*For Deadman: Input1 = Horz. Width; Input2 = Passive Pressure;

*For Sheet Pile Anchor: Input1 = Horz. Width; Input2 = Passive Slope;

*****CALCULATION*****

The calculated moment and shear are per pile spacing. Sheet piles are per one foot or meter; Soldier piles are

per pile.

Top Pressures start at depth = 0.00

* CALCULATE REQUEST EMBEDMENT *

```
|<-- D1=16.00
|
==|== D2=23.00
|
|      D3=32.76
```

D1 - TOP DEPTH R1 - TOP REACTION
D2 - EXCAVATION BASE
D3 - PILE TIP

TOTAL REACTION: R1 = 54.83
TOTAL PRESSURES ACTING ON WALL = 54.83
Total Reactions = Total Pressures, OK!
The Calculated Embedment, Yend = 9.76

-----MULTIPLE BRACE / TIEBACK CASE-----
** Use the calculated embedment, Yend = 9.76 for graphics and analysis.

NUMBER OF BRACE LEVEL= 2

* CANTILEVER SPAN, N0.0 *

```
|      D1=0.00
|
|<-- D2=6.00                      R2=47.14, with Cantilever Moment=101.32
```

D1 - TOP DEPTH
D2 - BOTTOM DEPTH R2 - BOTTOM REACTION

TOTAL REACTION: R2 = 47.14
TOTAL PRESSURES ACTING ON WALL = 47.14
Total Reactions = Total Pressures, OK!

BRACE NO.1 AT DEPTH = 6.00
R2 of Span No.0 } Sum of Reaction = Brace Load = 127.39
R1 of Last Span

* LAST SPAN *

```
|<-- D1=6.00                      R1=80.25
|
|<-- D2=16.00                      R2=114.82
|
|      D3=32.76
```

D1 - TOP DEPTH R1 - TOP REACTION
D2 - LAST BRACE DEPTH R2 - LAST BRACE REACTION
D3 - BOTTOM DEPTH

TOTAL REACTION: R1+R2 = 195.07
TOTAL PRESSURES ACTING ON WALL = 195.07
Total Reactions >= Total Pressures, OK!

BRACE NO.2 AT DEPTH = 16.00
R2 of Last Span = Brace Load = 114.82

*****RESULTS*****

* EMBEDMENT *

MINIMUM EMBEDMENT = 9.76, TOTAL MINIMUM PILE LENGTH = 32.76

* MOMENT IN PILE (per pile spacing)*

Pile Spacing: sheet piles are one foot or one meter; soldier piles are one pile.

No.	Depth	M @ Brace	Mmax in Span	Depth of Mmax
1	6.00	100.28	103.41	11.41
2	16.00	24.59	95.20	21.50

Overall Maximum Moment = 103.41 at 11.41

Maximum Shear = 80.07

Moment and Shear are per pile spacing: 8.0 foot or meter

-> Top Brace Increase 15%. (Horizontal) From 127.39 to 146.49

* BRACE: STRUT, TIEBACK, ANCHOR PLATE, DEADMAN, OR SHEET PILE AS ANCHOR*

The calculated brace force are per brace spacing.

No.	DEPTH	Tangle	SPACING	HORIZONTAL	VERTICAL	TOTAL LOAD
1	6.00	20.0	8.00	146.49	53.32	155.90
2	16.00	20.0	8.00	114.82	41.79	122.19

No.	DEPTH	Free length	Brace Type
1	6.00	13.69	Tieback, Bond length = 31.51
2	16.00	8.61	Tieback, Bond length = 24.69

* VERTICAL LOADING *

Vertical Loading from Braces = 95.11

Vertical Loading from External Load = 0.00

Total Vertical Loading = 95.11

*****SPECIFIED PILE *****

Overall Maximum Moment = 103.41 at 11.41

The pile selection is based on the magnitude of the moment only. Axial force is neglected.

Request Min. Section Modulus = 24.82 in³/pile = 406.68 cm³/pile, Fy= 50 ksi = 345 MPa, Fb/Fy=1

HP14X89 has been found in Soldier Pile list!

(English Units):

Area= 26.1 in. Depth= 13.8 in. Width= 14.7 in. Height= 14 in.

Flange thickness= 0.615 in. Web thickness= 0.615 in.

Ix= 904 in⁴/pile Sx= 131 in³/pile Iy= 326 in⁴/pile Sy= 44.3 in³/pile

(Metric Units):

Ix= 376.24 x100cm⁴/pile Sx= 2146.70 cm³/pile Iy= 135.68 x100cm⁴/pile Sy= 725.94 cm³/pile

The pile selection is based on the magnitude of the moment only. Axial force is neglected.

HP14X89 is capable to support the shoring!

Top deflection = 0.000(in)

Max. deflection = 0.385(in)

***** LAGGING SIZE ESTIMATION *****

Max. Pressure above base = 1.75

Piles are more rigid than timber lagging, due to arching, only portion of pressures are acting to lagging, 30-50% loading is suggested.

If 50% loading is used for lagging design, Design Pressure = 0.88

Pile Spacing = 8.0, Max. Moment in lagging = 7.01

For 4"x12" Timber, Section Modules $S=23.47 \text{ in}^3$. The request allowable bending strength, $fb=M/S=3.59$

For 6"x12" Timber, Section Modules $S=57.98 \text{ in}^3$. The request allowable bending strength, $fb=M/S=1.45$

If 30% loading is used for lagging design, Design Pressure = 0.53

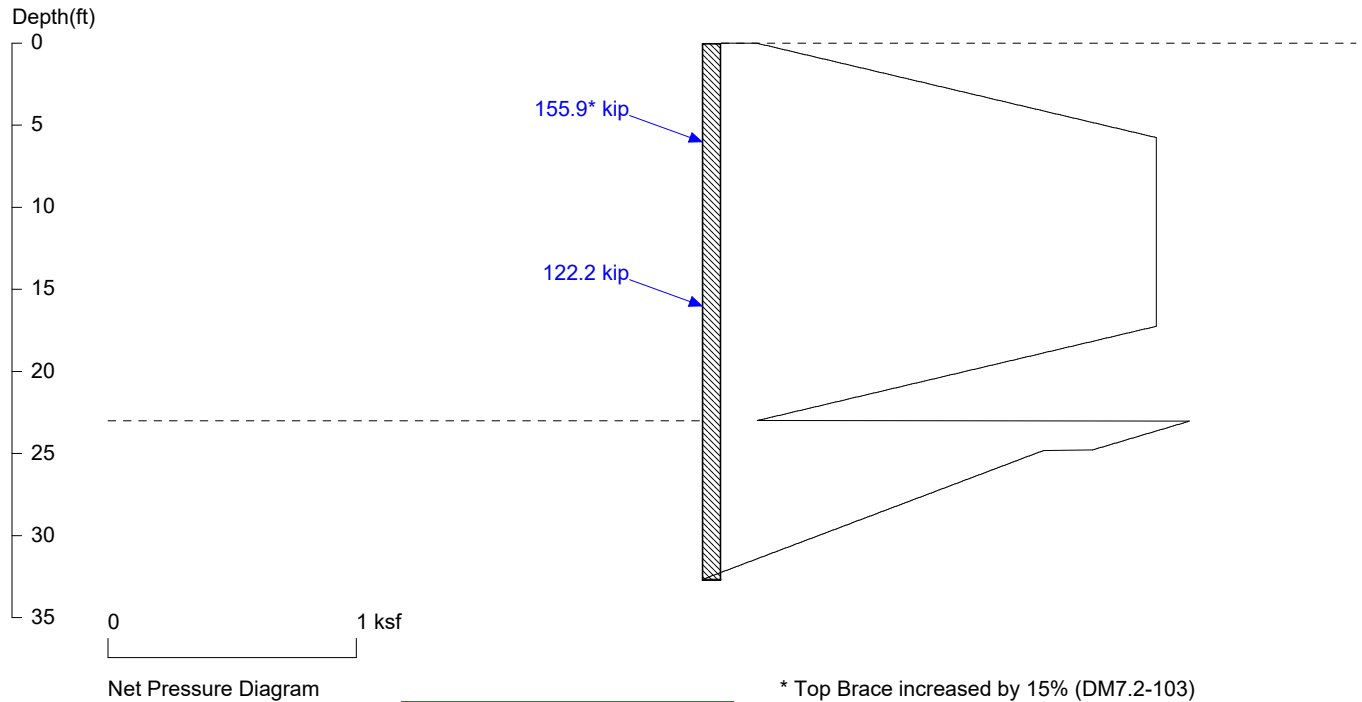
Pile Spacing = 8.0, Max. Moment in lagging = 4.21

For 4"x12" Timber, Section Modules $S=23.47 \text{ in}^3$. The request allowable bending strength, $fb=M/S=2.15$

For 6"x12" Timber, Section Modules $S=57.98 \text{ in}^3$. The request allowable bending strength, $fb=M/S=0.87$

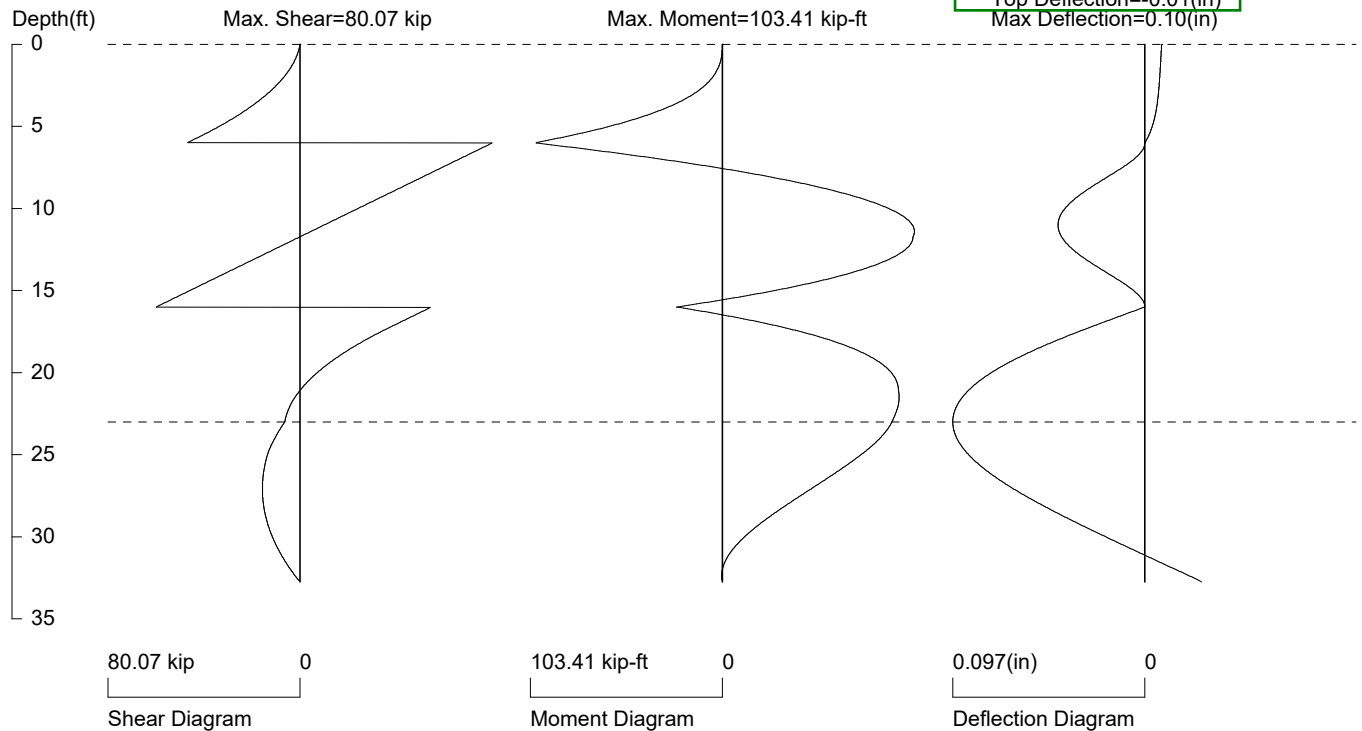
Unit: Pressure: ksf, Spacing: ft, Moment: kip-ft, Bending Strength, fb: ksi

WAS-77-9.58



Pile head deflection =

Top Deflection=-0.01(in)
Max Deflection=0.10(in)



PRESSURE, SHEAR, MOMENT, AND DEFLECTION DIAGRAMS

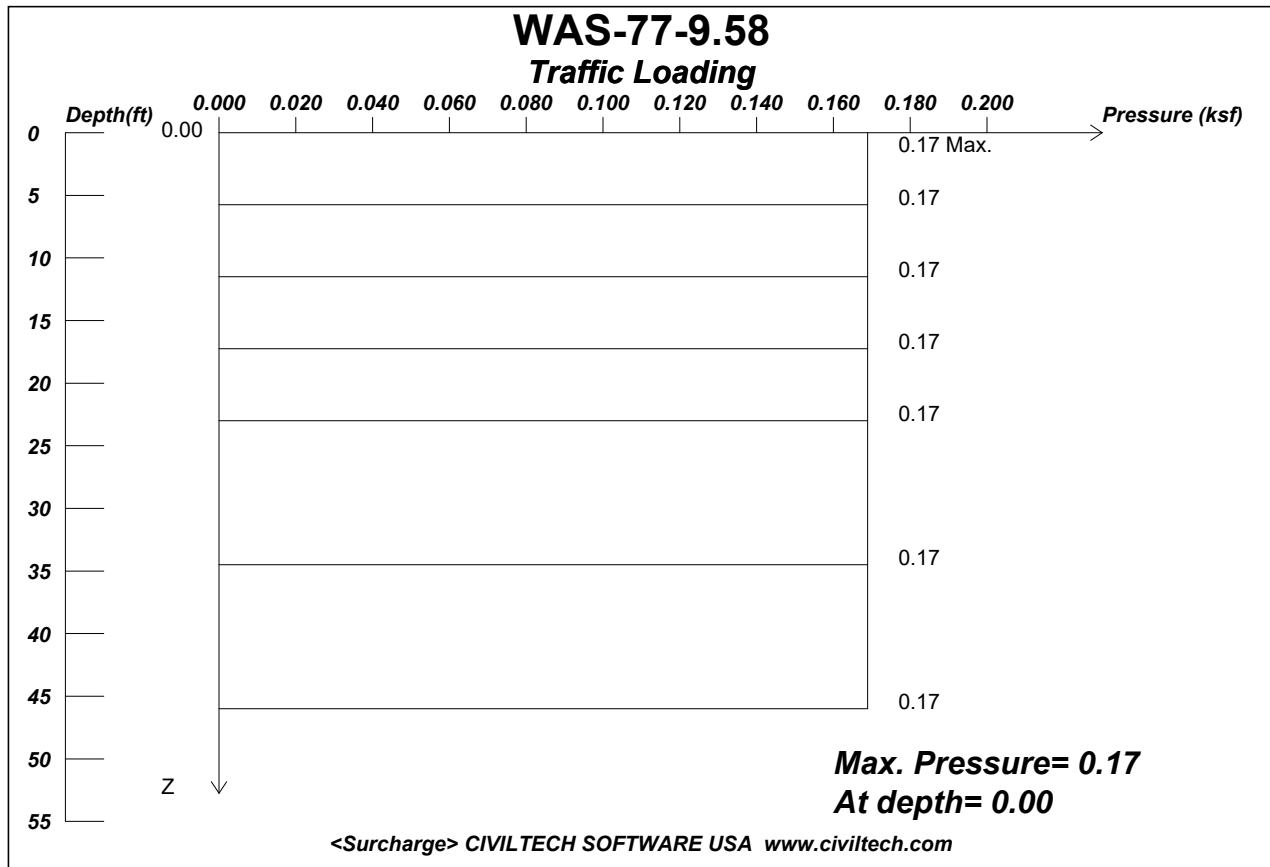
Based on pile spacing: 8.0 foot or meter

User Input Pile, HP14x89: E (ksi)=29000.0, I (in⁴)/pile=904.0

J:\ODOT-District 10 GES\Task 10-13 WAS-77-9.58\20250116_Redesign Calculations\20250116_Updated Analyses\WAS-77-9.58 23' Culvert Wall Tieback Service.s

Traffic Surcharge Loading (Strength Limit)

Construction Traffic



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Wall Height, H= 23

Load Depth, D= 0

Load Factor of Surcharge Loading = 1.17

Rigid Wall Condition -- No movement or deflection of the wall are allowed.

Max. Pressure = 0.169 at depth = 0.00

Infinite Surcharge, Q=.250

Active Wedge Approach * (recommend)

A load factor of 1.5 is applied to all active loading in the wall analysis. As traffic loading uses 1.75, an extra factor has been applied here ($1.75/1.5 = 1.17$).

UNITS: LENGTH/DEPTH: ft, Qpoint: kip, Qline: kip/ft, Qstrip/Qarea/PRESSURE: ksf

SURCHARGE LOADS CALCULATION SUMMARY
<Surcharge>
Software Copyright by CivilTech Software
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Reference: Foundation Design, Wayne C. Teng, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1962

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Calculations\20250116_Updated Analyses\WAS-77-9.58 23' Wall Surcharge Strength.lp8

WAS-77-9.58
Traffic Loading

Height of Wall = 23
Depth of Load = 0
Load Factor of Surcharge Loading = 1.17

Wall Condition:
Rigid Wall Condition -- No movement or deflection of the wall are allowed.

*****Loading*****

INFINITE SURCHARGE LOADING: Q=.250
Active Wedge Approach * (recommend)

*****Total Pressure Distribution*****

Max. Pressure =0.169 at depth =0.00

Depth	Pressure
0.00	0.169
1.15	0.169
2.30	0.169
3.45	0.169
4.60	0.169
5.75	0.169
6.90	0.169
8.05	0.169
9.20	0.169
10.35	0.169
11.50	0.169
12.65	0.169
13.80	0.169
14.95	0.169
16.10	0.169
17.25	0.169
18.40	0.169
19.55	0.169
20.70	0.169
21.85	0.169
23.00	0.169
25.30	0.169
27.60	0.169
29.90	0.169
32.20	0.169
34.50	0.169
36.80	0.169
39.10	0.169
41.40	0.169
43.70	0.169
46.00	0.169
50.60	0.169
55.20	0.169
59.80	0.169
64.40	0.169

Surcharge loading cut off at top of
rock (49.8 feet) in shoring module.

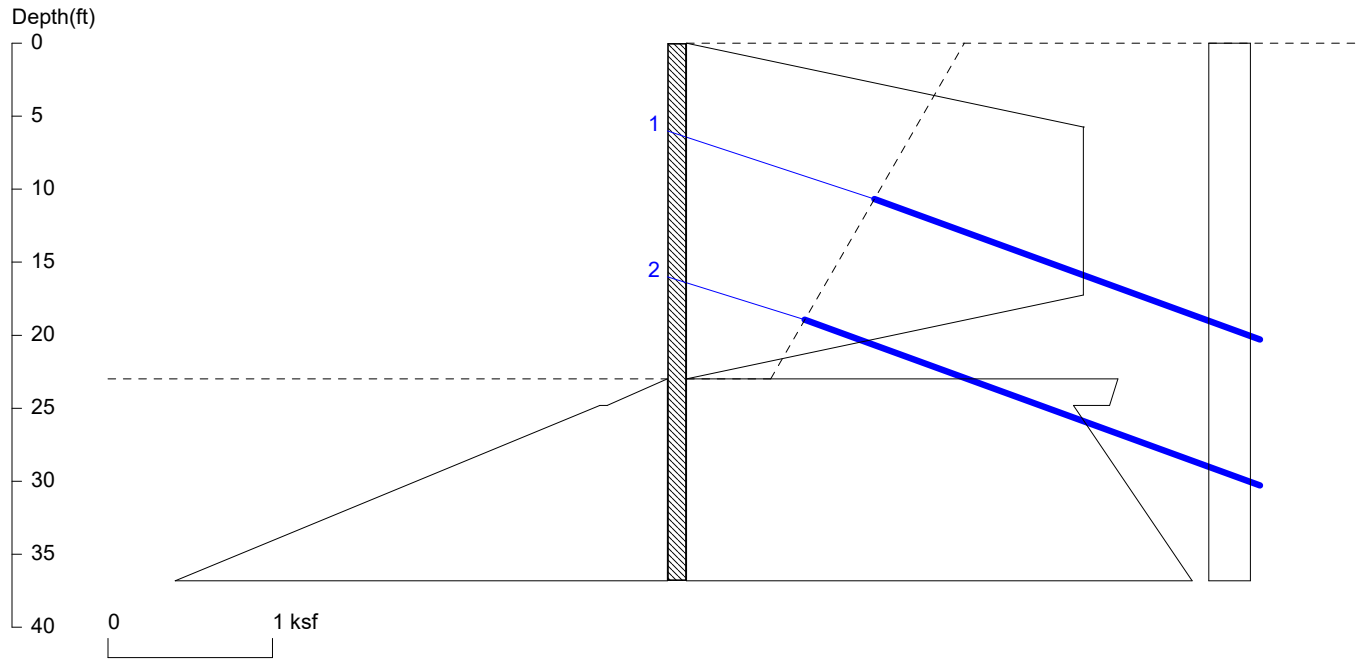
69.00	0.169
73.60	0.169
78.20	0.169
82.80	0.169
87.40	0.169
92.00	0.000

Depth Is Measured From Top of the Wall

LENGTH/DEPTH: ft, Qpoint: kip, Qline: kip/ft, Qstrip/Qarea/PRESSURE: ksf

Strength Limit

WAS-77-9.58



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Wall Height=23.0

Pile Diameter=2.5

Pile Spacing=8.0

Wall Type: 2. Soldier Pile, Drilled

PILE LENGTH: Min. Embedment=13.82 Min. Pile Length=36.82

MOMENT IN PILE: Max. Moment=183.45 per Pile Spacing=8.0 at Depth=23.18

PILE SELECTION:

Request Min. Section Modulus = 44.0 in³/pile=721.48 cm³/pile, F_y= 50 ksi = 345 MPa, F_b/F_y=1

HP14X89 has Section Modulus = 131.0 in³/pile=2146.70 cm³/pile. It is greater than Min. Requirements!

Top Deflection = -0.01(in) based on E (ksi)=29000.00 and I (in⁴)/pile=904.0

Anchor loads and lengths

BRACE FORCE: Strut, Tieback, Plate Anchor, Deadman, Sheet Pile as Anchor

No. & Type	Depth	Angle	Space	Total F.	Horiz. F.	Vert. F.	L_free	Fixed Length
1. Tieback	6.0	20.0	8.0	238.5*	224.2	81.6	13.7	48.2
2. Tieback	16.0	20.0	8.0	194.6	182.8	66.5	8.6	39.3

Unbonded Length

Bonded Length

* Top Brace increased by 15% (DM7.2-103)

UNITS: Width,Diameter,Spacing,Length,Depth,and Height - ft; Force - kip; Bond Strength and Pressure - ksf

DRIVING PRESSURES (ACTIVE, WATER, & SURCHARGE): Pressures below will be multiplied by a Factor =1.5

Z1	P1	Z2	P2	Slope
*	Above	Base		
0.000	0.000	5.750	1.609	0.279817
5.750	1.609	17.25	1.609	0.000000
17.25	1.609	23.00	0.000	-0.27981
*	Below	Base		
23.00	1.749	24.80	1.715	-0.01870
24.80	1.569	44.80	2.371	0.040119
*	Sur-	charg		
0.000	0.169	1.150	0.169	0.000000
1.150	0.169	2.300	0.169	0.000000
2.300	0.169	3.450	0.169	0.000000

Applied 1.5 load factor for active earth pressures.

3.450	0.169	4.600	0.169	0.000000
4.600	0.169	5.750	0.169	0.000000
5.750	0.169	6.900	0.169	0.000000
6.900	0.169	8.050	0.169	0.000000
8.050	0.169	9.200	0.169	0.000000
9.200	0.169	10.35	0.169	0.000000
10.35	0.169	11.50	0.169	0.000000
11.50	0.169	12.65	0.169	0.000000
12.65	0.169	13.80	0.169	0.000000
13.80	0.169	14.95	0.169	0.000000
14.95	0.169	16.10	0.169	0.000000
16.10	0.169	17.25	0.169	0.000000
17.25	0.169	18.40	0.169	0.000000
18.40	0.169	19.55	0.169	0.000000
19.55	0.169	20.70	0.169	0.000000
20.70	0.169	21.85	0.169	0.000000
21.85	0.169	23.00	0.169	0.000000
23.00	0.169	25.30	0.169	0.000000
25.30	0.169	27.60	0.169	0.000000
27.60	0.169	29.90	0.169	0.000000
29.90	0.169	32.20	0.169	0.000000
32.20	0.169	34.50	0.169	0.000000
34.50	0.169	36.80	0.169	0.000000
36.80	0.169	39.10	0.169	0.000000

PASSIVE PRESSURES:

Z1	P1	Z2	P2	Slope
*	Below	Base		
23.00	0.000	24.80	0.366	0.203551
24.80	0.411	44.80	4.711	0.214969

ACTIVE SPACING:

No.	Z depth	Spacing
1	0.00	8.00
2	23.00	2.50

PASSIVE SPACING:

No.	Z depth	Spacing
1	23.00	5.00

UNITS: Width,Spacing,Diameter,Length,and Depth - ft; Force - kip; Moment - kip-ft
Friction,Bearing,and Pressure - ksf; Pres. Slope - kip/ft³; Deflection - in

SHORING WALL CALCULATION SUMMARY
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3. DESIGN MANUAL DM-7 (NAVFAC), Department of the Navy, May 1982
4. TRENCHING AND SHORING MANUAL Revision 12, California Department of Transportation, January 2000
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8. Temporary Structures in Construction, Robert T. Ratay (Co-author of Chapter 7: John J. Peirce), McGraw-Hill. 2012
9. AASHTO HB-17, American Association of State and Highway Transportation Officials, 2 September 2002

UNITS: Width/Spacing/Diameter/Length/Depth - ft, Force - kip, Moment - kip-ft, Friction/Bearing/Pressure - ksf,
Pres. Slope - kip/ft³, Deflection - in

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Calculations\20250116_Updated Analyses\WAS-77-9.58 23' Culvert Wall Tieback Strength.sh8

Title: WAS-77-9.58

Subtitle:

*****INPUT DATA*****

Wall Type: 2. Soldier Pile, Drilled

Wall Height: 23.00

Pile Diameter: 2.50

Pile Spacing: 8.00

Factor of Safety (F.S.): 1.00

As Continuous Span Beam

Lateral Support Type (Braces): 3. Tieback

Top Brace Increase (Multi-Bracing): Add 15%*

No-Load Zone:

Vertical Depth for No-Load Zone: 23.00

H-Distance (Input H/V ratio) for No-Load Zone: 0.25

Angle from H. Line for No-Load Zone: 60.00

Embedment Option: 1. Yes

Friction at Pile Tip: No

Pile Properties:

Steel Strength, Fy: 50 ksi = 345 MPa

Allowable Fb/Fy: 1

Elastic Module, E: 29000.00

Moment of Inertia, I: 904.00

User Input Pile: HP14X89

* DRIVING PRESSURE (ACTIVE, WATER, & SURCHARGE) *

The pressures below will be multiplied by a Factor =1.5

No.	Z1 top	Top Pres.	Z2 bottom	Bottom Pres.	Slope
1	*	Above	Base		
2	0.000	0.000	5.750	1.609	0.279817
3	5.750	1.609	17.25	1.609	0.000000
4	17.25	1.609	23.00	0.000	-0.27981
5	*	Below	Base		
6	23.00	1.749	24.80	1.715	-0.01870
7	24.80	1.569	44.80	2.371	0.040119
8	44.80	2.085	49.80	2.277	0.038365
9	49.80	1.292	184.0	3.488	0.016366
10	*	Sur-	charg		
11	0.000	0.169	1.150	0.169	0.000000

12	1.150	0.169	2.300	0.169	0.000000
13	2.300	0.169	3.450	0.169	0.000000
14	3.450	0.169	4.600	0.169	0.000000
15	4.600	0.169	5.750	0.169	0.000000
16	5.750	0.169	6.900	0.169	0.000000
17	6.900	0.169	8.050	0.169	0.000000
18	8.050	0.169	9.200	0.169	0.000000
19	9.200	0.169	10.35	0.169	0.000000
20	10.35	0.169	11.50	0.169	0.000000
21	11.50	0.169	12.65	0.169	0.000000
22	12.65	0.169	13.80	0.169	0.000000
23	13.80	0.169	14.95	0.169	0.000000
24	14.95	0.169	16.10	0.169	0.000000
25	16.10	0.169	17.25	0.169	0.000000
26	17.25	0.169	18.40	0.169	0.000000
27	18.40	0.169	19.55	0.169	0.000000
28	19.55	0.169	20.70	0.169	0.000000
29	20.70	0.169	21.85	0.169	0.000000
30	21.85	0.169	23.00	0.169	0.000000
31	23.00	0.169	25.30	0.169	0.000000
32	25.30	0.169	27.60	0.169	0.000000
33	27.60	0.169	29.90	0.169	0.000000
34	29.90	0.169	32.20	0.169	0.000000
35	32.20	0.169	34.50	0.169	0.000000
36	34.50	0.169	36.80	0.169	0.000000
37	36.80	0.169	39.10	0.169	0.000000
38	39.10	0.169	41.40	0.169	0.000000
39	41.40	0.169	43.70	0.169	0.000000
40	43.70	0.169	46.00	0.169	0.000000
41	46.00	0.169	50.60	0.169	0.000000

Surcharge loading
terminated at top of
rock (approx 49.8 feet).

* PASSIVE PRESSURE *

No.	Z1 top	Top Pres.	Z2 bottom	Bottom Pres.	Slope
1	*	Below	Base		
2	23.00	0.000	24.80	0.366	0.203551
3	24.80	0.411	44.80	4.711	0.214969
4	44.80	5.269	49.80	6.663	0.278791
5	49.80	47	184.0	47	0.0000

* ACTIVE SPACE *

No.	Z depth	Spacing
1	0.00	8.00
2	23.00	2.50

Passive pressure for bedrock adjusted to 47 ksf
based on an unconfined strength of 330 psi.

* PASSIVE SPACE *

No.	Z depth	Spacing
1	23.00	5.00

Hole diameter in
feet (9 inches)

Allowable bond strength =
resistance factor * ultimate
bond strength = 0.7*3 ksf

* BRACE: STRUT, TIEBACK, ANCHOR PLATE, DEADMAN, OR SHEET PILE AS ANCHOR*

No.	Z brace	Angle	Spacing	Input1*	Input2*	Type
1	6.00	20.0	8.00	0.75	2.10	Tieback
2	16.00	20.0	8.00	0.75	2.10	Tieback

*For Tieback: Input1 = Diameter; Input2 = Bond Strength

*For Plate: Input1 = Diameter; Input2 = Allowable Pressure

*For Deadman: Input1 = Horz. Width; Input2 = Passive Pressure;

*For Sheet Pile Anchor: Input1 = Horz. Width; Input2 = Passive Slope;

*****CALCULATION*****

The calculated moment and shear are per pile spacing. Sheet piles are per one foot or meter; Soldier piles are per pile.

Top Pressures start at depth = 0.00

* CALCULATE REQUEST EMBEDMENT *

```
|<-- D1=16.00
|
==|== D2=23.00
|
| D3=36.82
```

D1 - TOP DEPTH R1 - TOP REACTION
D2 - EXCAVATION BASE
D3 - PILE TIP

TOTAL REACTION: R1 = 91.89
TOTAL PRESSURES ACTING ON WALL = 91.89
Total Reactions = Total Pressures, OK!
The Calculated Embedment, Yend = 13.82

-----MULTIPLE BRACE / TIEBACK CASE-----
** Use the calculated embedment, Yend = 13.82 for graphics and analysis.

NUMBER OF BRACE LEVEL= 2

* CANTILEVER SPAN, N0.0 *

```
| D1=0.00
|
|<-- D2=6.00                      R2=72.50, with Cantilever Moment=157.38
```

D1 - TOP DEPTH
D2 - BOTTOM DEPTH R2 - BOTTOM REACTION

TOTAL REACTION: R2 = 72.50
TOTAL PRESSURES ACTING ON WALL = 72.50
Total Reactions = Total Pressures, OK!

BRACE NO.1 AT DEPTH = 6.00
R2 of Span No.0 } Sum of Reaction = Brace Load = 194.92
R1 of Last Span

* LAST SPAN *

```
|<-- D1=6.00                      R1=122.42
|
|<-- D2=16.00                      R2=182.83
|
| D3=36.82
```

D1 - TOP DEPTH R1 - TOP REACTION
D2 - LAST BRACE DEPTH R2 - LAST BRACE REACTION
D3 - BOTTOM DEPTH

TOTAL REACTION: R1+R2 = 305.25
TOTAL PRESSURES ACTING ON WALL = 305.25
Total Reactions >= Total Pressures, OK!

BRACE NO.2 AT DEPTH = 16.00
R2 of Last Span = Brace Load = 182.83

*****RESULTS*****

* EMBEDMENT *

MINIMUM EMBEDMENT = 13.82, TOTAL MINIMUM PILE LENGTH = 36.82

* MOMENT IN PILE (per pile spacing)*

Pile Spacing: sheet piles are one foot or one meter; soldier piles are one pile.

No.	Depth	M @ Brace	Mmax in Span	Depth of Mmax
1	6.00	155.97	156.23	11.43
2	16.00	40.66	183.45	23.18

Overall Maximum Moment = 183.45 at 23.18

Maximum Shear = 121.96

Moment and Shear are per pile spacing: 8.0 foot or meter

-> Top Brace Increase 15%. (Horizontal) From 194.92 to 224.16

* BRACE: STRUT, TIEBACK, ANCHOR PLATE, DEADMAN, OR SHEET PILE AS ANCHOR*

The calculated brace force are per brace spacing.

No.	DEPTH	Tangle	SPACING	HORIZONTAL	VERTICAL	TOTAL LOAD
1	6.00	20.0	8.00	224.16	81.59	238.54
2	16.00	20.0	8.00	182.83	66.55	194.57

No.	DEPTH	Free length	Brace Type
1	6.00	13.69	Tieback, Bond length = 48.21
2	16.00	8.61	Tieback, Bond length = 39.32

* VERTICAL LOADING *

Vertical Loading from Braces = 148.13

Vertical Loading from External Load = 0.00

Total Vertical Loading = 148.13

*****SPECIFIED PILE *****

Overall Maximum Moment = 183.45 at 23.18

The pile selection is based on the magnitude of the moment only. Axial force is neglected.

Request Min. Section Modulus = 44.03 in³/pile = 721.48 cm³/pile, Fy= 50 ksi = 345 MPa, Fb/Fy=1

HP14X89 has been found in Soldier Pile list!

(English Units):

Area= 26.1 in. Depth= 13.8 in. Width= 14.7 in. Height= 14 in.

Flange thickness= 0.615 in. Web thickness= 0.615 in.

Ix= 904 in⁴/pile Sx= 131 in³/pile Iy= 326 in⁴/pile Sy= 44.3 in³/pile

(Metric Units):

Ix= 376.24 x100cm⁴/pile Sx= 2146.70 cm³/pile Iy= 135.68 x100cm⁴/pile Sy= 725.94 cm³/pile

The pile selection is based on the magnitude of the moment only. Axial force is neglected.

HP14X89 is capable to support the shoring!

Top deflection = -0.010(in)

Max. deflection = 0.282(in)

***** LAGGING SIZE ESTIMATION *****

Max. Pressure above base = 2.67

Piles are more rigid than timber lagging, due to arching, only portion of pressures are acting to lagging, 30-50%

loading is suggested.

If 50% loading is used for lagging design, Design Pressure = 1.33

Pile Spacing = 8.0, Max. Moment in lagging = 10.67

For 4"x12" Timber, Section Modules $S=23.47 \text{ in}^3$. The request allowable bending strength, $fb=M/S=5.45$

For 6"x12" Timber, Section Modules $S=57.98 \text{ in}^3$. The request allowable bending strength, $fb=M/S=2.21$

If 30% loading is used for lagging design, Design Pressure = 0.80

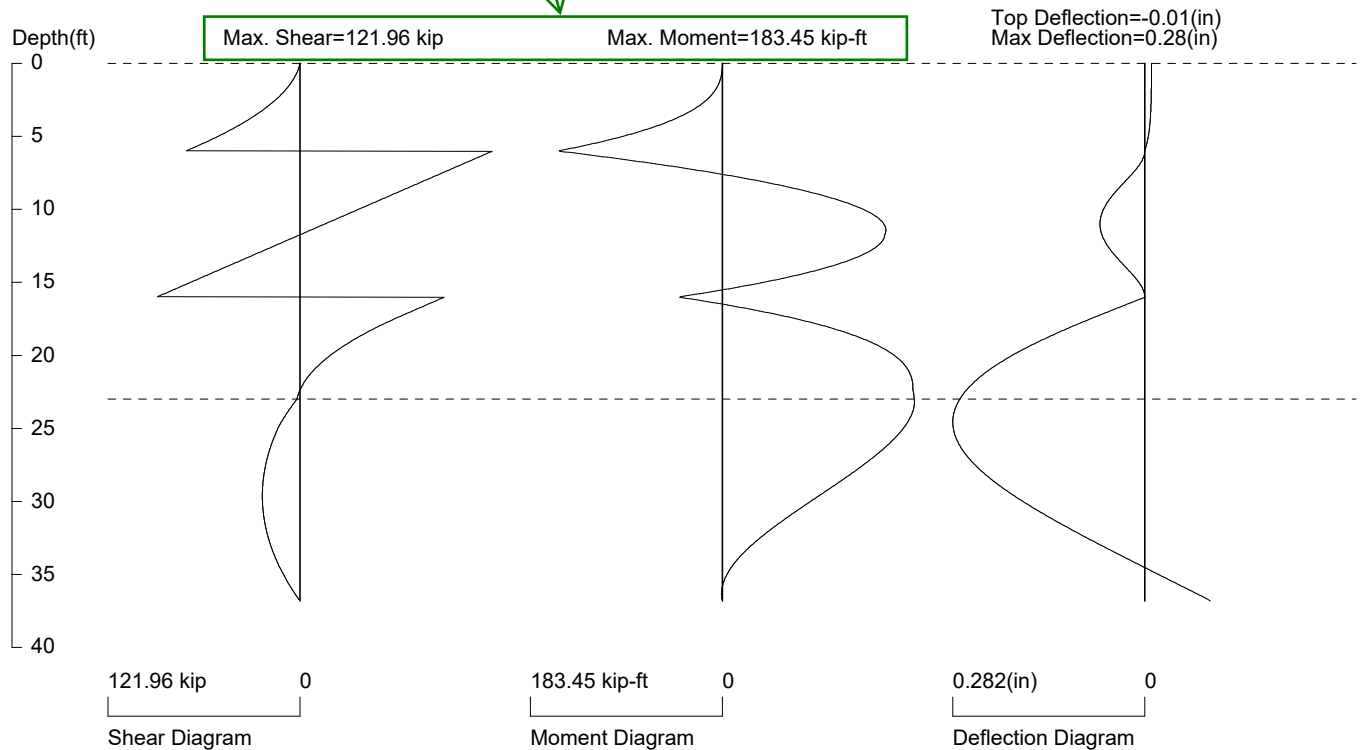
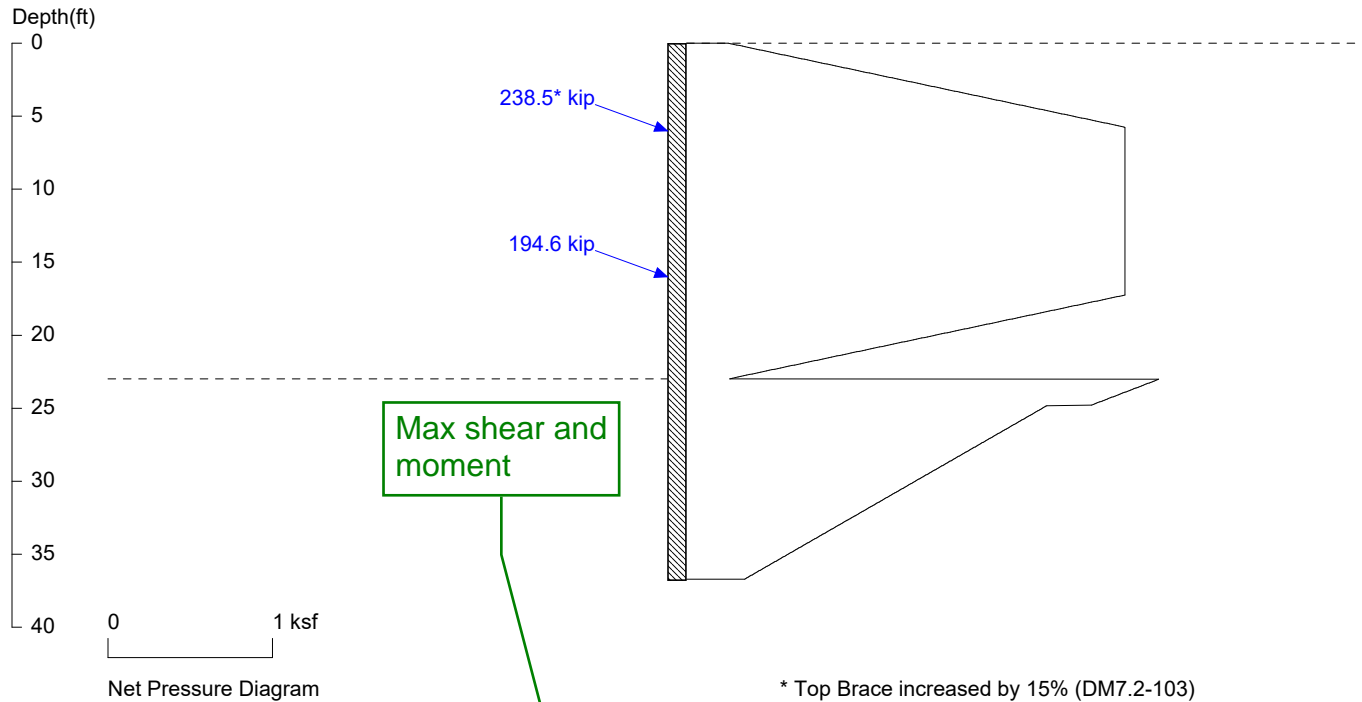
Pile Spacing = 8.0, Max. Moment in lagging = 6.40

For 4"x12" Timber, Section Modules $S=23.47 \text{ in}^3$. The request allowable bending strength, $fb=M/S=3.27$

For 6"x12" Timber, Section Modules $S=57.98 \text{ in}^3$. The request allowable bending strength, $fb=M/S=1.32$

Unit: Pressure: ksf, Spacing: ft, Moment: kip-ft, Bending Strength, fb: ksi

WAS-77-9.58



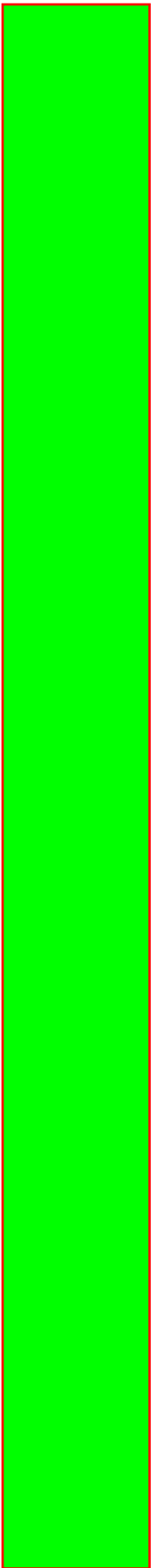
PRESSURE, SHEAR, MOMENT, AND DEFLECTION DIAGRAMS

Based on pile spacing: 8.0 foot or meter

User Input Pile, HP14X89: E (ksi)=29000.0, I (in4)/pile=904.0

J:\ODOT-District 10 GES\Task 10-13 WAS-77-9.58\20250116_Redesign Calculations\20250116_Updated Analyses\WAS-77-9.58 23' Culvert Wall Tieback Strength.

29.5 ft



Shoring Suite Analysis

Wall Sta. 1+55

29.5 ft Height (Max during Construction)

Geometry

Elevation (ft)			Minimum Horiz. Distance from C/L (ft)		
Top of Backfill =	880.0	at Bottom of Embankment	Start of Wall Backfill =	50.0	at Bottom of Embankment
Top of Wall =	860.0	at C/L of Wall	Wall =	0.0	at C/L of Wall
Existing Ground Surface =	858.0	at C/L of Wall			
Bottom of Facing =	830.5	at C/L of Wall (Top of Shaft)	Backfill Slope Angle =	2.5	H:1V
Groundwater =	848.5	at C/L of Wall		21.8	degrees

Wall Loading Profile (B-005-0-23)

	Top Elev.	Thickness (ft)	Cohesion (psf)	Phi (deg)	Unit Wt (pcf)
Layer 2 Medium Stiff to Stiff Cohesive	860.0	9.8	115	23	140
Layer 1 Soft to Medium Stiff Cohesive	850.2	5.0	65	21	115
Layer 2 Medium Stiff to Stiff Cohesive	845.2	10.0	115	23	140
Layer 3 Stiff to Very Stiff Cohesive	835.2	4.7	175	25	135
Bottom of Facing	830.5				
Weighted Value		29.5	115	23	135

Earth Pressure Coefficients

	Deg	
Shear Resistance, Φ =	25	
Wall Friction, δ^A =	0.0	
Wall Slope, θ =	90	
Backfill Slope, β =	21.80	
Revised Backfill Slope, β =	21.80	
Backfill Condition	INFINITE	
Horz. Backslope Dist.	50.0	feet (C/L of Wall - Bottom of Embankment)
Wall Height (H)	29.5	feet (Top of Wall - Bottom of Wall Facing)
Slope Height (h)	20.0	feet (Bottom of Embankment - Top of Wall)
I =	18.73	degrees

Notes:

- Wall friction neglected
- Figure and Equation for Active Earth Pressure from AASHTO 3.11.5.3 (LRFD Design Manual).
- The wall retained soil will consist of existing cohesive overburden. Using the soil layer thicknesses and respective soil parameters, a weighted average was determined and assumed for the entire profile ($c' = 115$ psf and $\phi' = 23^\circ$). The parameters were converted to equivalent soil strength parameters $c' = 0$ psf and $\phi' = 25^\circ$ for checking tieback lengths based on a 1 degree increase in friction angle for every 50 psf decrease in cohesion up to 150 psf (Ref: Hall's Thesis).

Shoring Suite Design Profile

	Top Elev	Depth (ft)	Cohesion (psf)	Phi (deg)	Unit Wt (pcf)
Layer 2 Medium Stiff to Stiff Cohesive	860.0	0.0	0	25	140
Layer 1 Soft to Medium Stiff Cohesive	850.2	9.8	0	22	115
Layer 2 Medium Stiff to Stiff Cohesive	845.2	14.8	0	25	140
Layer 3 Stiff to Very Stiff Cohesive	835.2	24.8	0	28	135
Layer 4 Hard Cohesive	815.2	44.8	0	31	145
Bedrock	810.2	49.8	0	45	150

Depths referenced below the top of wall. Friction angles reflect adjustments made per Hall's Thesis. Bedrock modeled as very dense gravel.

Steel Beam and Cross-Section Properties

Assumed Pile Shape **HP 14x89**

Pile Availability

AISC Member Producers	3
Non-Member Producers	0

Shaft Geometry

Shaft Diameter	30	in
Longest Beam Dimension	20.162589	in
Clear Distance	4.9187054	in

Steel Beam Geometry

Beam Depth (D)	13.8	in
Web Thickness (t _w)	0.615	in
Flange Width (B _f)	14.7	in
Flange Thickness (t _f)	0.615	in
Area of Steel (A _s)	26.1	in ²

Steel Properties

Yield Strength of Steel	50	ksi
Moment of Inertia (I _{xx}) of Steel	904	in ⁴
Modulus of Elasticity of Steel (E)	29000	ksi
Modulus of Elasticity of Steel (E)	29000000	psi
EI (Steel Only)	2.622E+10	lb*in ²
Section Modulus (S _x)	131	in ³
Section Modulus (Z _x)	146	in ³
Shear-Buckling Coefficient (k)	5	
Ratio of Shear-Buckling Resistance (C)	1	
D/t _w	22.439024	
1.12VEk/F _{yw}	60.313846	
1.40VEk/F _{yw}	75.392307	

Determined by AASHTO LRFD Bridge Specifications
Eqn's 6.10.9.3.2-4, 6.10.9.3.2-5, and 6.10.9.3.2-6

Shear Capacity Calculation

$$V_u \leq \phi V_{cr}$$
$$\phi_b = \boxed{1} \text{ AASHTO LRFD Bridge Design Spec's 6.5.4.2}$$
$$V_u = \text{shear in web due to factored permanent and construction loads applied to noncompact section (kips)}$$
$$V_{cr} = \text{shear buckling resistance determined from Equation 6.10.9.3.3-1 (AASHTO LRFD Bridge Design Spec's)}$$
$$V_n = V_{cr} = C V_p$$
$$V_p = 0.58 F_{yw} D t_w$$
$$V_p = \text{plastic shear force (kips)}$$
$$C = \text{ratio of shear-buckling resistance to shear yield strength determined by AASHTO Eqn's 6.10.9.3.2-4, 6.10.9.3.2-5, 6.10.9.3.2-5, or 6.10.9.3.2-6}$$
$$V_p = 0.58 * 50 * 13.8 * 0.615$$
$$V_p = \boxed{246.1} \text{ kips}$$
$$\phi V_{cr} = \phi * C * V_p$$
$$\phi V_{cr} = 1 * 1 * 246.1$$
$$\phi V_{cr} = \boxed{246.1} \text{ kips}$$
$$V_u = \boxed{105.14} \text{ kips (from Shoring Suite)}$$
$$\boxed{} \text{ kips (from PYWALL)}$$
$$V_u < \phi V_{cr} \quad \text{OK}$$

Flexure Capacity Calculation

$$M_u \leq \phi M_n$$
$$\phi_b = \boxed{1} \text{ AASHTO LRFD Bridge Design Spec's 6.5.4.2}$$
$$M_u = \text{Moment due to the factored loads}$$
$$M_n = \text{Nominal flexural resistance of a section}$$
$$S_x = \text{Elastic section modulus about the x-axis}$$
$$\phi M_n = \phi * F_y * S_x$$
$$\phi M_n = 1 * 50 * 131$$
$$\phi M_n = \boxed{6550} \text{ in*kips}$$
$$M_u = \boxed{2195.5} \text{ in*kips (from Shoring Suite)}$$
$$M_u = \boxed{} \text{ in*kips (from PYWALL)}$$
$$M_u < \phi M_n \quad \text{OK}$$

Deflection Criteria

Pile Length Above Rock = 49.8	ft	Exposed Wall Height = 29.5	ft
Pile Length Above Rock = 49.8	in	Exposed Wall Height = 354	in

1.)

Per the ODOT GDM, pile-head deflection in the service limit state limited to 1% or less of the shaft length above bedrock, or 1% of total drilled shaft length if not embedded in bedrock.

2.)

Following industry acceptance criteria, limit wall deflection to 1% of exposed wall height where ODOT landslide criteria does not govern. Alternatively, limit wall deflection to 1.5% of the exposed wall height in accordance with NCDOT guidelines. Use 1.5% wall deflection for PYWALL software.

ODOT Landslide Criteria Governs

NO

OK

1% Wall Height OR 2 inches- LPILE

3.54

in

$\delta = \boxed{0.02}$ in (from Shoring Suite)

1.5% Wall Height - PYWALL

5.31

in

$\delta = \boxed{}$ in (from PYWALL)

Drilled Shafts Located Within 10 feet of Edge of Pavement

NO

Tieback Loading Computations

Design Tieback Load, TF1 = 181.2 kips / shaft
 Design Tieback Load, TF2 = 178.2 kips / shaft
 Design Tieback Load, TF3 = 117.6 kips / shaft

Horizontal values determined from Shoring Suite calculations.
 Horizontal values determined from Shoring Suite calculations.
 Horizontal values determined from Shoring Suite calculations.

1) Determine Tiebacks

Strands

0.6 GUTS per strand = 35.2 kips per strand (FHWA-NHI-07-071: Table 8-16)

(GUTS = guaranteed ultimate tensile strength)

Tieback	Inclin.	Required Anchor Load**	Strands	
No.	deg	kips	Required	Selected
1	20	192.8	5.5	6.0
1	20	189.6	5.4	6.0
1	20	125.1	3.6	4.0

**Required Anchor Load = (TF) / [Cos (Inclin. Angle)]

Table 8-16. Properties of 0.6 in. Diameter Prestressing Steel Strands (ASTM A416, Grade 270).

Number of 0.6 in. diameter strands	Cross section area (in. ²)	Ultimate strength (=GUTS) (kips)	Prestressing force		
			0.8 $f_{pu}A_{ps}$ (kips)	0.7 $f_{pu}A_{ps}$ (kips)	0.6 $f_{pu}A_{ps}$ (kips)
1	0.217	58.6	46.9	41.0	35.2

2) Check Pull-Out Capacity and Bond Length

Pullout Resistance Factor ϕ_{pr} = 0.7 Per AASHTO LRFD Table 11.5.7-1 for "Pullout resistance of anchors, cohesive soils"

Soil Friction Angle ϕ = 25

Recommended Lengths

Tieback	Height Above Bottom of Facing	Tieback Length to Active Wedge	Total Unbonded Length	Ultimate Bond Strength	Tieback Drill Hole Diameter	Surface Area per Foot of Tieback	Allowable Bond Strength per Foot of Tieback	Required Anchor Load	Required Bond Length	Total Tieback Length
No.	ft	ft	ft	ksf	in	in ² /ft	kips/ft	kips	ft	ft
1	23.5	12.9	23	3	9	339.3	4.95	192.8	39 (40)	62 (63)
2	13.5	7.4	18	3	9	339.3	4.95	189.6	39 (40)	57 (58)
3	3.5	1.9	15	3	9	339.3	4.95	125.1	26	41

Total unbonded length = Tieback length to active wedge + greater of 5 feet or H/3, with a 15 foot minimum, per AASHTO LRFD Figure 11.9.1-1

Ultimate bond strength per AASHTO LRFD Table C11.9.4.2-1. Tieback lengths assume entire bond length is in clay.

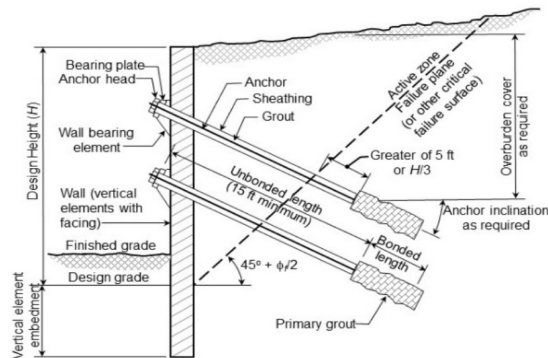
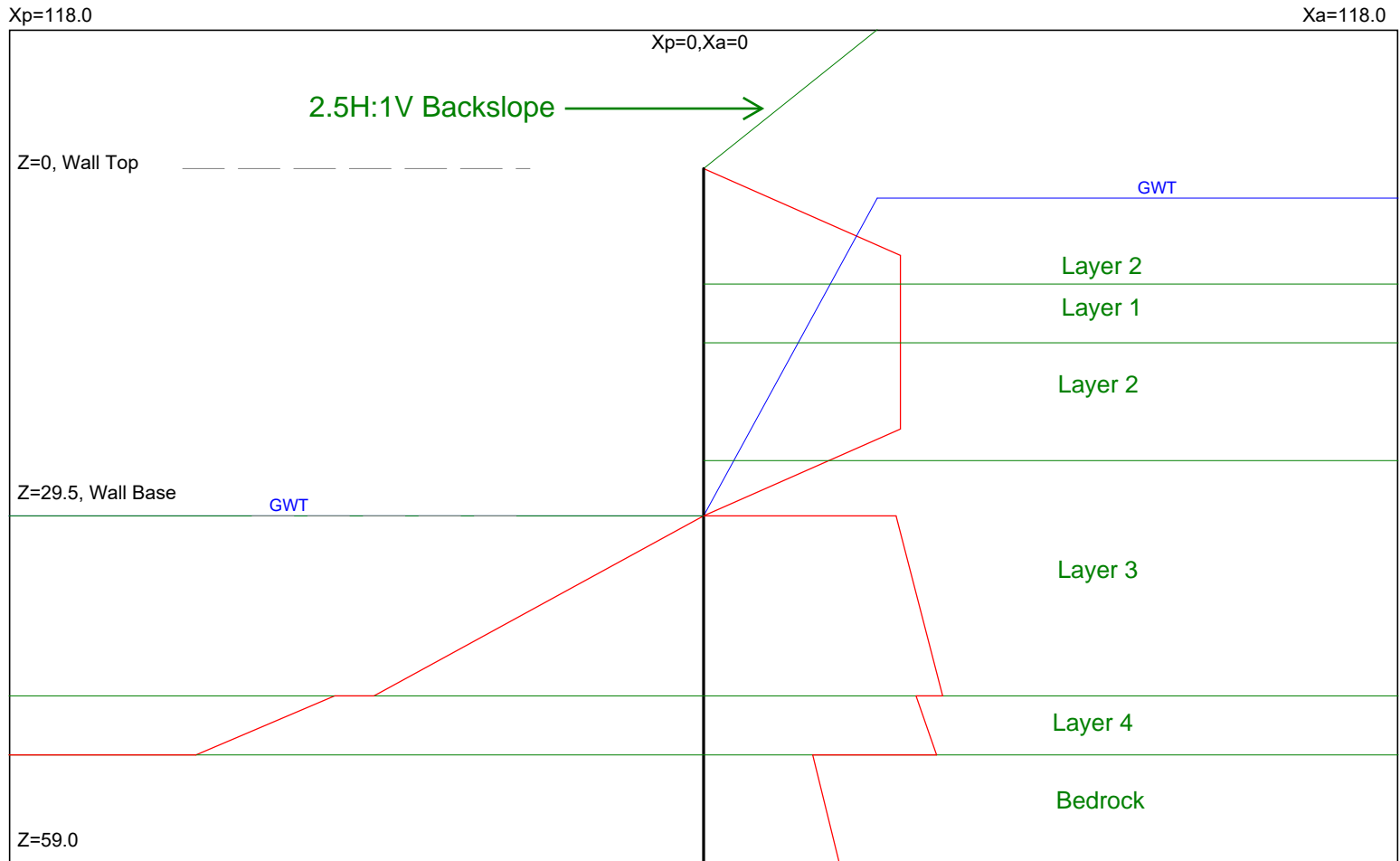


Figure 11.9.1-1—Anchored Wall Nomenclature and Anchor Embedment Guidelines

Table C11.9.4.2-1—Presumptive Ultimate Unit Bond Stress for Anchors in Cohesive Soils

Anchor/Soil Type (Grout Pressure)	Soil Stiffness or Unconfined Compressive Strength (tsf)	Presumptive Ultimate Unit Bond Stress, τ_u (ksf)
Gravity Grouted Anchors (<50 psi)		
Silt-Clay Mixtures	Stiff to Very Stiff 1.0-4.0	0.6 to 1.5
Pressure Grouted Anchors (50 psi-400 psi)		
High Plasticity Clay	Stiff 1.0-2.5 V. Stiff 2.5-4.0	0.6 to 2 1.5 to 3.6
Medium Plasticity Clay	Stiff 1.0-2.5 V. Stiff 2.5-4.0	2.0 to 5.2 2.9 to 7.3
Medium Plasticity Sandy Silt	V. Stiff 2.5-4.0	5.8 to 7.9

Earth Pressure Loading



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UNITS: DEPTH/DISTANCE: ft, UNIT WEIGHT: pcf, FORCE: kip/ft, PRESSURE: ksf, SLOPE: kcf

1/17/2025

File: J:\ODOT-District 10 GES\Task 10-13 WAS-77-9.58\20250116_Redesign Calculations\20250116_Updated Analyses\WAS-77-9.58 25' Main Wall Tieback

*** INPUT DATA ***

Wall Height=29.5 Total Soil Types= 5

Soil No.	Weight	Saturate	Phi	Cohesion	Nspt	Type	Description
1	115.0	120.0	22	0	5	1	1. Soft to M
2	140.0	145.0	25	0.0	11	1	2. Medium St
3	135.0	140.0	28	0.0	24	1	3. Stiff to
4	145.0	150.0	31	0.0	65	1	4. Hard Cohe
5	150.0	155.0	45	0.0	100	5	Bedrock

Ground Surface at Active Side:

Line	Z1	Xa1	Z2	Xa2	Soil No.	Description
1	0.0	0.0	-20.0	50.0	2	2. Medium St
2	-20.0	50.0	-50.0	800.0	2	2. Medium St
3	9.8	0.0	9.8	800.0	1	1. Soft to M
4	14.8	0.0	14.8	800.0	2	2. Medium St
5	24.8	0.0	24.8	800.0	3	3. Stiff to
6	44.8	0.0	44.8	800.0	4	4. Hard Cohe
7	49.8	0.0	49.8	800.0	5	Bedrock

Water Table at Active Side:

Point	Z-water	X-water
1	29.5	0.0
2	2.5	29.5
3	2.5	800.0

Soil Layers in Front of Wall

Ground Surface at Passive Side:

Line	Z1	Xp1	Z2	Xp2	Soil No.	Description
1	29.5	0.0	29.5	800.0	3	3. Stiff to
2	44.8	0.0	44.8	800.0	4	4. Hard Cohe
3	49.8	0.0	49.8	800.0	5	Bedrock

Water Table at Passive Side:

Water Depth in Front of Wall

Point	Z-water	X-water
1	29.5	0.0
2	29.5	800.0

Wall Friction Options: 1.* No wall friction

Wall Batter Angle = 0

Apparent Pressure Conversion: 1.* Default (Terzaghi and Peck)*

Water Density = 62.4

Water Pressure: 1.* No seepage at wall tip

* OUTPUT RESULTS *

Total Force above Base= 36.23 per one linear foot (or meter) width along wall height

Total Static Force above Base= 36.23. Distributed in Apparent Envelope along wall height. Ignore soil layers and water line

Driving Pressure above Base - Output to Shoring - Multiplier of Pressure = 1

Z1	Pa1	Z2	Pa2	Slope	Coef.
0.00	0.00	7.38	1.97	0.2665	1.9033
7.38	1.97	22.13	1.97	0.0000	0.0000
22.13	1.97	29.50	0.00	-0.2665	-1.9033

Driving Pressure below Base - Output to Shoring - Multiplier of Pressure = 1

Z1	Pa1	Z2	Pa2	Slope	Ka or Ko
29.50	1.92	44.80	2.39	0.0304	0.3911
44.80	2.12	49.80	2.32	0.0405	0.4628
49.80	1.09	59.00	1.36	0.0291	0.3139

Passive Pressure below Base - Output to Shoring - Multiplier of Pressure = 1

Z1	Pp1	Z2	Pp2	Slope	Kp
29.50	0.00	44.80	3.29	0.215	2.7698
44.80	3.68	49.80	5.06	0.277	3.1570
49.80	7.87	59.00	13.86	0.651	7.0308

Passive pressures below 45.8 feet manually adjusted in shoring module to reflect claystone strength.

UNITS: DEPTH/DISTANCE: ft, UNIT WEIGHT: pcf, FORCE: kip/ft, PRESSURE: ksf, SLOPE: kcf

Date: 1/17/2025 File Name: J:\ODOT-District 10 GES\Task 10-13 WAS-77-9.58\20250116_Redesign Calculations\20250116_Updated Analyses\WAS

EARTH PRESSURE ANALYSIS SUMMARY

<EarthPres>

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Date: 1/17/2025 File: J:\ODOT-District 10 GES\Task 10-13 WAS-77-9.58\20250116_Redesign
Calculations\20250116_Updated Analyses\WAS-77-9.58 25' Main Wall Tieback.ep8

Title 1: WAS-77-9.58

Title 2:

Input data: *****

Wall Height = 29.50

Depth of Ground at Active Side = 0.00

Depth of Ground at Passive Side = 29.50

Apparent Pressure Envelope: 4. 2-Trapezoid Envelope (Braced, Stiff Clay)

Pressure Type: 1.* Active, Ka

Earthquake Loading Apply to: 1. No Earthq. Loads

Earthquake Horizontal Acceleration, Kh = 0

Earthquake Vertical Acceleration, Kv = 0

Calculation Methods: 1.* Numerical Solution (Wedge Analysis)

Wall Friction Options: 1.* No wall friction

Wall Batter Angle = 0

Apparent Pressure Conversion: 1.* Default (Terzaghi and Peck)*

Water Density = 62.4

Water Pressure: 1.* No seepage at wall tip

User's Settings

Ignore Passive from Depth = 0

Multiplier of Active Pressure = 1

Multiplier of Passive Pressure = 1

Multiplier of Water Pressure = 1

Multiplier of Earthq. Pressure = 1

Estimated Embedment: Very Shallow: 2H

Program's Settings

Max. Height, Hmax = 295.00

Analysis Segment, dz = 0.74

No. of Active Segment at H, nz0 = 4

No. of Active Segment at Hmax, nz = 7

No. of Passive Segment, nzp = 3

Active Depth at H, Zh = 29.50

Active Depth at Hmax, Z = 295.00

Passive Depth at Hmax, Zp = 295.00

Max. Pressure = 141.95

Total Soil Types= 5

Soil	Weight	W(S)	Phi	Cohesion	Nspt	Type	Description
1	115.0	120.0	22	0	5	1	1. Soft to M
>	115.0	120.0	22.0	0.0	5	1	Converted
2	140.0	145.0	25	0.0	11	1	2. Medium St
>	140.0	145.0	25.0	0.0	11	1	Converted
3	135.0	140.0	28	0.0	24	1	3. Stiff to
>	135.0	140.0	28.0	0.0	24	1	Converted
4	145.0	150.0	31	0.0	65	1	4. Hard Cohe
>	145.0	150.0	31.0	0.0	65	1	Converted
5	150.0	155.0	45	0.0	100	5	Bedrock

Soil Type: 1 Equivalent Clay; 2 Clay; 3 Silt; 4 Sand; 5 Gravel

Ground Surface at Active Side:

Line	Z1	Xa1	Z2	Xa2	Soil No.
1	0.0	0.0	-20.0	50.0	2
2	-20.0	50.0	-50.0	800.0	2
3	9.8	0.0	9.8	800.0	1
4	14.8	0.0	14.8	800.0	2
5	24.8	0.0	24.8	800.0	3
6	44.8	0.0	44.8	800.0	4
7	49.8	0.0	49.8	800.0	5

Water Table at Active Side:

Point	Z-water	X-water
1	29.5	0.0
2	2.5	29.5
3	2.5	800.0

Ground Surface at Passive Side:

Line	Z1	Xp1	Z2	Xp2	Soil No.
1	29.5	0.0	29.5	800.0	3
2	44.8	0.0	44.8	800.0	4
3	49.8	0.0	49.8	800.0	5

Water Table at Passive Side:

Point	Z-water	X-water
1	29.5	0.0
2	29.5	800.0

Output data: *****

Total Force above Base= 36.23 per one linear foot (or meter) width along wall height

Static Force above Base= 36.23. Distributed in Apparent Envelope along wall height. Ignore soil layers and water line

Apparent Pressure above Base - Output to Shoring

Active/At-Rest Force above Base, Ea = 36.23

No	Z1	P1	Z2	P2	Slope	Coef.
0	0.0	0.00	7.4	1.97	0.2665	1.9033
1	7.4	1.97	22.1	1.97	0.0000	0.0000
2	22.1	1.97	29.5	0.00	-0.2665	-1.9033

Driving Pressure below Base - Output to Shoring

No	Z1	P1	Z2	P2	Slope	Ka or Ko
0	29.5	1.92	44.8	2.39	0.0304	0.3911
1	44.8	2.12	49.8	2.32	0.0405	0.4628
2	49.8	1.31	295.0	5.34	0.0164	0.1774

Passive Pressure below Base - Output to Shoring

No	Z1	P1	Z2	P2	Slope	Kp
0	29.5	0.00	44.8	3.29	0.2149	2.7698
1	44.8	3.68	49.8	5.06	0.2766	3.1570
2	49.8	9.23	295.0	141.95	0.5413	5.8455

Passive pressures below 45.8 feet manually adjusted in shoring module to reflect claystone strength.

DEPTH/DISTANCE: ft, UNIT WEIGHT: pcf, FORCE: kip/ft, PRESSURE: ksf, SLOPE: kcf

Z, Xa, Xp - Coordinates of ground lines

Z- Depth measured from wall top

Xa - Distance measure from wall to active side.

Xp - Distance measure from wall to passive side

Z1, P1, Z2, P2 - Four values to define a pressure diagram

Z1- Top depth of the diagram

P1- Top pressure of the diagram

Z2- Bottom depth of the diagram

P2- Bottom pressure of the diagram

Slope - (P2-P1)/(Z2-Z1), Slope of the diagram. It also called Equivalent fluid density.

Coef. - Pressure Coefficient = Slope/Unit Weight

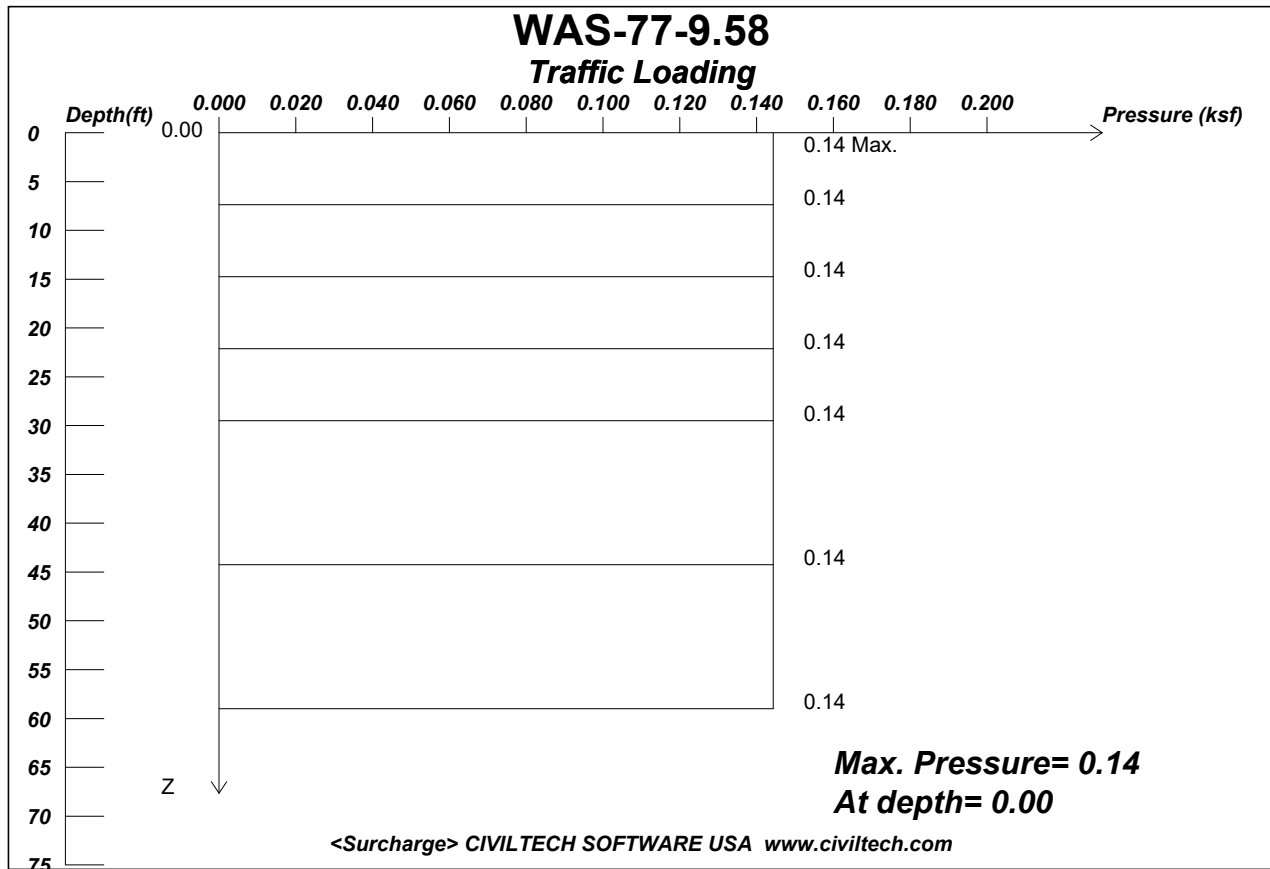
Ka - Active Earth Pressure Coefficient

Ko - At-Rest Earth Pressure Coefficient

Kp - Passive Earth Pressure Coefficient

Traffic Surcharge Loading (Service Limit)

Construction Traffic



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Wall Height, H= 29.5

Load Depth, D= 0

Load Factor of Surcharge Loading = 1

Rigid Wall Condition -- No movement or deflection of the wall are allowed.

Max. Pressure = 0.144 at depth = 0.00

Infinite Surcharge, Q=.250

Active Wedge Approach * (recommend)

UNITS: LENGTH/DEPTH: ft, Qpoint: kip, Qline: kip/ft, Qstrip/Qarea/PRESSURE: ksf

SURCHARGE LOADS CALCULATION SUMMARY
<Surcharge>
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www.civiltech.com

Reference: Foundation Design, Wayne C. Teng, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1962

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Date: 1/17/2025 File: J:\ODOT-District 10 GES\Task 10-13 WAS-77-9.58\20250116_Redesign
Calculations\20250116_Updated Analyses\WAS-77-9.58 29.5' Wall Surcharge Service.lp8

WAS-77-9.58
Traffic Loading

Height of Wall = 29.5
Depth of Load = 0
Load Factor of Surcharge Loading = 1

Wall Condition:
Rigid Wall Condition -- No movement or deflection of the wall are allowed.

*****Loading*****

INFINITE SURCHARGE LOADING: Q=.250
Active Wedge Approach * (recommend)

*****Total Pressure Distribution*****

Max. Pressure =0.144 at depth =0.00

Depth	Pressure
0.00	0.144
1.48	0.144
2.95	0.144
4.43	0.144
5.90	0.144
7.38	0.144
8.85	0.144
10.33	0.144
11.80	0.144
13.28	0.144
14.75	0.144
16.23	0.144
17.70	0.144
19.18	0.144
20.65	0.144
22.13	0.144
23.60	0.144
25.08	0.144
26.55	0.144
28.03	0.144
29.50	0.144
32.45	0.144
35.40	0.144
38.35	0.144
41.30	0.144
44.25	0.144
47.20	0.144
50.15	0.144
53.10	0.144
56.05	0.144
59.00	0.144
64.90	0.144
70.80	0.144
76.70	0.144
82.60	0.144

Surcharge loading cut off at top of
rock (49.8 feet) in shoring module.

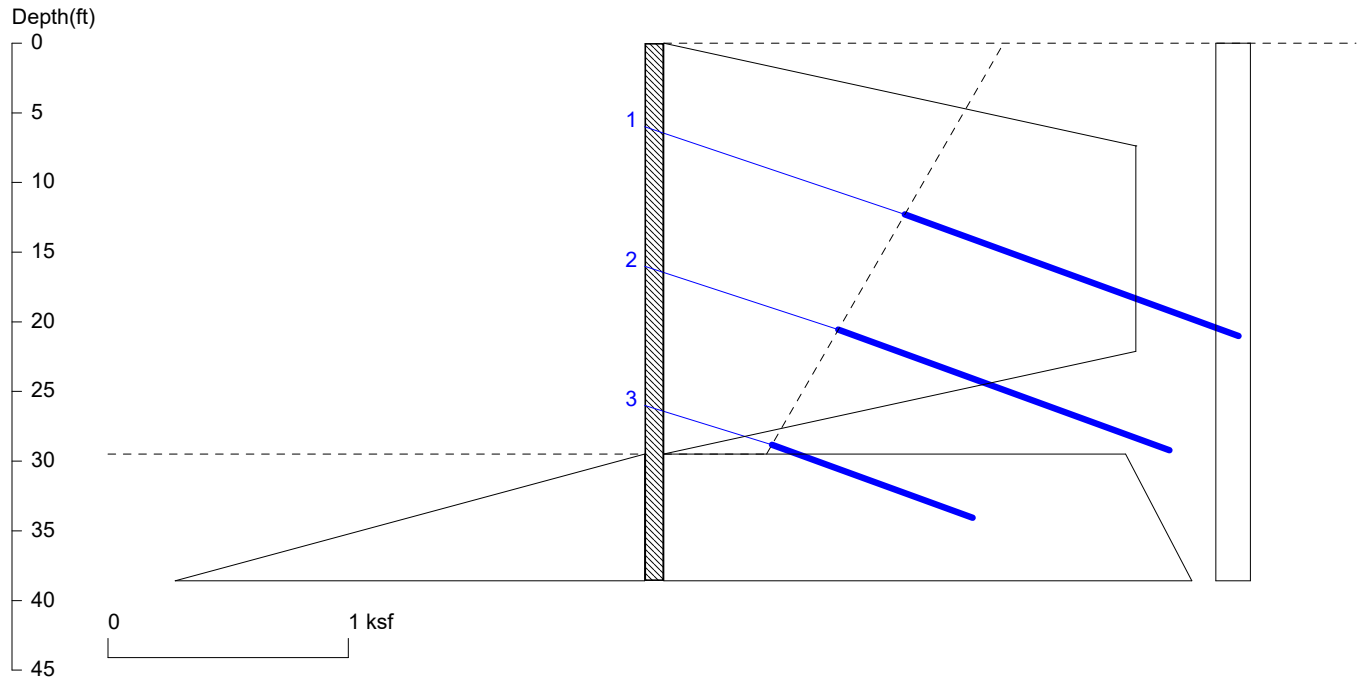
88.50	0.144
94.40	0.144
100.30	0.144
106.20	0.144
112.10	0.144
118.00	0.000

Depth Is Measured From Top of the Wall

LENGTH/DEPTH: ft, Qpoint: kip, Qline: kip/ft, Qstrip/Qarea/PRESSURE: ksf

Service Limit

WAS-77-9.58



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Date: 1/24/2025

File: J:\ODOT-District 10 GES\Task 10-13 WAS-77-9.58\20250116_Redesign Calculations\20250116_Updated Analyses\WA

Wall Height=29.5

Pile Diameter=2.5

Pile Spacing=6.0

Wall Type: 2. Soldier Pile, Drilled

PILE LENGTH: Min. Embedment=9.09 Min. Pile Length=38.59

MOMENT IN PILE: Max. Moment=120.59 per Pile Spacing=6.0 at Depth=21.03

PILE SELECTION:

Request Min. Section Modulus = 28.9 in³/pile=474.28 cm³/pile, Fy= 50 ksi = 345 MPa, Fb/Fy=1

HP14X89 has Section Modulus = 131.0 in³/pile=2146.70 cm³/pile. It is greater than Min. Requirements!

Top Deflection = -0.02(in) based on E (ksi)=29000.00 and I (in⁴)/pile=904.0

BRACE FORCE: Strut, Tieback, Plate Anchor, Deadman, Sheet Pile as Anchor

No. & Type	Depth	Angle	Space	Total F.	Horiz. F.	Vert. F.	L_free	Fixed Length
1. Tieback	6.0	20.0	6.0	126.2*	118.6	43.2	18.4	25.5
2. Tieback	16.0	20.0	6.0	125.1	117.6	42.8	13.3	25.3
3. Tieback	26.0	20.0	6.0	75.9	71.3	25.9	8.3	15.3

* Top Brace increased by 15% (DM7.2-103)

UNITS: Width,Diameter,Spacing,Length,Depth,and Height - ft; Force - kip; Bond Strength and Pressure - ksf

DRIVING PRESSURES (ACTIVE, WATER, & SURCHARGE):

Z1	P1	Z2	P2	Slope
*	Above	Base		
0.000	0.000	7.375	1.965	0.266456
7.375	1.965	22.12	1.965	0.000000
22.12	1.965	29.50	0.000	-0.26645
*	Below	Base		
29.50	1.922	44.80	2.386	0.030353
*	Sur-	charg		
0.000	0.144	1.475	0.144	0.000000
1.475	0.144	2.950	0.144	0.000000
2.950	0.144	4.425	0.144	0.000000

4.425	0.144	5.900	0.144	0.000000
5.900	0.144	7.375	0.144	0.000000
7.375	0.144	8.850	0.144	0.000000
8.850	0.144	10.32	0.144	0.000000
10.32	0.144	11.80	0.144	0.000000
11.80	0.144	13.27	0.144	0.000000
13.27	0.144	14.75	0.144	0.000000
14.75	0.144	16.22	0.144	0.000000
16.22	0.144	17.70	0.144	0.000000
17.70	0.144	19.17	0.144	0.000000
19.17	0.144	20.65	0.144	0.000000
20.65	0.144	22.12	0.144	0.000000
22.12	0.144	23.60	0.144	0.000000
23.60	0.144	25.07	0.144	0.000000
25.07	0.144	26.55	0.144	0.000000
26.55	0.144	28.02	0.144	0.000000
28.02	0.144	29.50	0.144	0.000000
29.50	0.144	32.45	0.144	0.000000
32.45	0.144	35.40	0.144	0.000000
35.40	0.144	38.35	0.144	0.000000
38.35	0.144	41.30	0.144	0.000000

PASSIVE PRESSURES:

Z1	P1	Z2	P2	Slope
*	Below	Base		
29.50	0.000	44.80	3.289	0.214939

ACTIVE SPACING:

No.	Z depth	Spacing
1	0.00	6.00
2	29.50	2.50

PASSIVE SPACING:

No.	Z depth	Spacing
1	29.50	5.00

UNITS: Width,Spacing,Diameter,Length,and Depth - ft; Force - kip; Moment - kip-ft
Friction,Bearing,and Pressure - ksf; Pres. Slope - kip/ft³; Deflection - in

SHORING WALL CALCULATION SUMMARY
The leading shoring design and calculation software
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ShoringSuite Software is developed by CivilTech Software, Bellevue, WA, USA.

The calculation method is based on the following references:

1. FHWA 98-011, FHWA-RD-97-130, FHWA SA 96-069, FHWA-IF-99-015
2. STEEL SHEET PILING DESIGN MANUAL by Pile Buck Inc., 1987
3. DESIGN MANUAL DM-7 (NAVFAC), Department of the Navy, May 1982
4. TRENCHING AND SHORING MANUAL Revision 12, California Department of Transportation, January 2000
6. EARTH SUPPORT SYSTEM & RETAINING STRUCTURES, Pile Buck Inc. 2002
5. DESIGN OF SHEET PILE WALLS, EM 1110-2-2504, U.S. Army Corps of Engineers, 31 March 1994
7. EARTH RETENTION SYSTEMS HANDBOOK, Alan Macnab, McGraw-Hill. 2002
8. Temporary Structures in Construction, Robert T. Ratay (Co-author of Chapter 7: John J. Peirce), McGraw-Hill. 2012
9. AASHTO HB-17, American Association of State and Highway Transportation Officials, 2 September 2002

UNITS: Width/Spacing/Diameter/Length/Depth - ft, Force - kip, Moment - kip-ft, Friction/Bearing/Pressure - ksf,
Pres. Slope - kip/ft³, Deflection - in

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Date: 1/24/2025 File: J:\ODOT-District 10 GES\Task 10-13 WAS-77-9.58\20250116_Redesign
Calculations\20250116_Updated Analyses\WAS-77-9.58 29.5' Main Wall Tieback Service.sh8

Title: WAS-77-9.58

Subtitle:

*****INPUT DATA*****

Wall Type: 2. Soldier Pile, Drilled

Wall Height: 29.50

Pile Diameter: 2.50

Pile Spacing: 6.00

Factor of Safety (F.S.): 1.00

As Continuous Span Beam

Lateral Support Type (Braces): 3. Tieback

Top Brace Increase (Multi-Bracing): Add 15%*

No-Load Zone:

Vertical Depth for No-Load Zone: 29.50

H-Distance (Input H/V ratio) for No-Load Zone: 0.25

Angle from H. Line for No-Load Zone: 60.00

Embedment Option: 1. Yes

Friction at Pile Tip: No

Pile Properties:

Steel Strength, Fy: 50 ksi = 345 MPa

Allowable Fb/Fy: 1

Elastic Module, E: 29000.00

Moment of Inertia, I: 904.00

User Input Pile: HP14x89

* DRIVING PRESSURE (ACTIVE, WATER, & SURCHARGE) *

No.	Z1 top	Top Pres.	Z2 bottom	Bottom Pres.	Slope
1	*	Above	Base		
2	0.000	0.000	7.375	1.965	0.266456
3	7.375	1.965	22.12	1.965	0.000000
4	22.12	1.965	29.50	0.000	-0.26645
5	*	Below	Base		
6	29.50	1.922	44.80	2.386	0.030353
7	44.80	2.121	49.80	2.324	0.040538
8	49.80	1.302	206.5	3.899	0.016570
9	*	Sur-	charg		
10	0.000	0.144	1.475	0.144	0.000000
11	1.475	0.144	2.950	0.144	0.000000
12	2.950	0.144	4.425	0.144	0.000000

13	4.425	0.144	5.900	0.144	0.000000
14	5.900	0.144	7.375	0.144	0.000000
15	7.375	0.144	8.850	0.144	0.000000
16	8.850	0.144	10.32	0.144	0.000000
17	10.32	0.144	11.80	0.144	0.000000
18	11.80	0.144	13.27	0.144	0.000000
19	13.27	0.144	14.75	0.144	0.000000
20	14.75	0.144	16.22	0.144	0.000000
21	16.22	0.144	17.70	0.144	0.000000
22	17.70	0.144	19.17	0.144	0.000000
23	19.17	0.144	20.65	0.144	0.000000
24	20.65	0.144	22.12	0.144	0.000000
25	22.12	0.144	23.60	0.144	0.000000
26	23.60	0.144	25.07	0.144	0.000000
27	25.07	0.144	26.55	0.144	0.000000
28	26.55	0.144	28.02	0.144	0.000000
29	28.02	0.144	29.50	0.144	0.000000
30	29.50	0.144	32.45	0.144	0.000000
31	32.45	0.144	35.40	0.144	0.000000
32	35.40	0.144	38.35	0.144	0.000000
33	38.35	0.144	41.30	0.144	0.000000
34	41.30	0.144	44.25	0.144	0.000000
35	44.25	0.144	47.20	0.144	0.000000
36	47.20	0.144	50.15	0.144	0.000000

Surcharge loading terminated at top of rock (approx 49.8 feet).

* PASSIVE PRESSURE *

No.	Z1 top	Top Pres.	Z2 bottom	Bottom Pres.	Slope
1	*	Below	Base		
2	29.50	0.000	44.80	3.289	0.214939
3	44.80	3.682	49.80	5.064	0.276553
4	49.80	47	206.5	47	0.0000

Passive pressure for bedrock adjusted to 47 ksf based on an unconfined strength of 330 psi.

* ACTIVE SPACE *

No.	Z depth	Spacing
1	0.00	6.00
2	29.50	2.50

* PASSIVE SPACE *

No.	Z depth	Spacing
1	29.50	5.00

Hole diameter in feet (9 inches)

Allowable bond strength = resistance factor * ultimate bond strength = 0.7*3 ksf

* BRACE: STRUT, TIEBACK, ANCHOR PLATE, DEADMAN, OR SHEET PILE AS ANCHOR*

No.	Z brace	Angle	Spacing	Input1*	Input2*	Type
1	6.00	20.0	6.00	0.75	2.10	Tieback
2	16.00	20.0	6.00	0.75	2.10	Tieback
3	26.00	20.0	6.00	0.75	2.10	Tieback

*For Tieback: Input1 = Diameter; Input2 = Bond Strength

*For Plate: Input1 = Diameter; Input2 = Allowable Pressure

*For Deadman: Input1 = Horz. Width; Input2 = Passive Pressure;

*For Sheet Pile Anchor: Input1 = Horz. Width; Input2 = Passive Slope;

*****CALCULATION*****

The calculated moment and shear are per pile spacing. Sheet piles are per one foot or meter; Soldier piles are per pile.

Top Pressures start at depth = 0.00

* CALCULATE REQUEST EMBEDMENT *

```

| <-- D1=26.00
|
==|== D2=29.50
|
| D3=38.59

```

D1 - TOP DEPTH R1 - TOP REACTION
 D2 - EXCAVATION BASE
 D3 - PILE TIP

TOTAL REACTION: R1 = 18.48
 TOTAL PRESSURES ACTING ON WALL = 18.48
 Total Reactions = Total Pressures, OK!
 The Calculated Embedment, Yend = 9.09

-----MULTIPLE BRACE / TIEBACK CASE-----
 ** Use the calculated embedment, Yend = 9.09 for graphics and analysis.

NUMBER OF BRACE LEVEL= 3

* CANTILEVER SPAN, N0.0 *

```

| D1=0.00
|
| <-- D2=6.00                      R2=33.96, with Cantilever Moment=73.11

```

D1 - TOP DEPTH
 D2 - BOTTOM DEPTH R2 - BOTTOM REACTION

TOTAL REACTION: R2 = 33.96
 TOTAL PRESSURES ACTING ON WALL = 33.96
 Total Reactions = Total Pressures, OK!

BRACE NO.1 AT DEPTH = 6.00
 R2 of Cantilever Span } Sum of Reaction = Brace Load = 103.10
 R1 of Span No.1

* MIDDLE SPAN NO.1 *

```

| <-- D1=6.00                      R1=69.14, with Cantilever Moment=73.11
|
| <-- D2=16.00                      R2=55.89

```

D1 - TOP DEPTH R1 - TOP REACTION
 D2 - BOTTOM DEPTH R2 - BOTTOM REACTION

TOTAL REACTION: R1+R2 = 125.03
 TOTAL PRESSURES ACTING ON WALL = 125.03
 Total Reactions = Total Pressures, OK!

BRACE NO.2 AT DEPTH = 16.00
 R2 of Span No.1 } Sum of Reaction = Brace Load = 117.60
 R1 of Last Span

* LAST SPAN *

```

| <-- D1=16.00                      R1=61.71
|
|

```

```

|<-- D2=26.00      R2=71.28
|
|
|      D3=38.59

```

D1 - TOP DEPTH R1 - TOP REACTION
 D2 - LAST BRACE DEPTH R2 - LAST BRACE REACTION
 D3 - BOTTOM DEPTH

TOTAL REACTION: R1+R2 = 132.99
 TOTAL PRESSURES ACTING ON WALL = 132.99
 Total Reactions >= Total Pressures, OK!

BRACE NO.3 AT DEPTH = 26.00
 R2 of Last Span = Brace Load = 71.28

*****RESULTS*****

* EMBEDMENT *
 MINIMUM EMBEDMENT = 9.09, TOTAL MINIMUM PILE LENGTH = 38.59

* MOMENT IN PILE (per pile spacing)*
 Pile Spacing: sheet piles are one foot or one meter; soldier piles are one pile.

No.	Depth	M @ Brace	Mmax in Span	Depth of Mmax
1	6.00	72.42	99.55	11.25
2	16.00	26.65	120.59	21.03
3	26.00	18.80	32.15	31.04

Overall Maximum Moment = 120.59 at 21.03
 Maximum Shear = 69.04
 Moment and Shear are per pile spacing: 6.0 foot or meter

-> Top Brace Increase 15%. (Horizontal) From 103.10 to 118.57

* BRACE: STRUT, TIEBACK, ANCHOR PLATE, DEADMAN, OR SHEET PILE AS ANCHOR*
 The calculated brace force are per brace spacing.

No.	DEPTH	Tangle	SPACING	HORIZONTAL	VERTICAL	TOTAL LOAD
1	6.00	20.0	6.00	118.57	43.15	126.18
2	16.00	20.0	6.00	117.60	42.80	125.15
3	26.00	20.0	6.00	71.28	25.94	75.85

No.	DEPTH	Free length	Brace Type
1	6.00	18.42	Tieback, Bond length = 25.50
2	16.00	13.34	Tieback, Bond length = 25.29
3	26.00	8.26	Tieback, Bond length = 15.33

* VERTICAL LOADING *
 Vertical Loading from Braces = 111.90
 Vertical Loading from External Load = 0.00
 Total Vertical Loading = 111.90

*****SPECIFIED PILE *****

Overall Maximum Moment = 120.59 at 21.03
 The pile selection is based on the magnitude of the moment only. Axial force is neglected.

Request Min. Section Modulus = 28.94 in³/pile = 474.28 cm³/pile, Fy= 50 ksi = 345 MPa, Fb/Fy=1

HP14X89 has been found in Soldier Pile list!
 (English Units):

Area= 26.1 in. Depth= 13.8 in. Width= 14.7 in. Height= 14 in.
Flange thickness= 0.615 in. Web thickness= 0.615 in.
Ix= 904 in⁴/pile Sx= 131 in³/pile Iy= 326 in⁴/pile Sy= 44.3 in³/pile
(Metric Units):
Ix= 376.24 x100cm⁴/pile Sx= 2146.70 cm³/pile Iy= 135.68 x100cm⁴/pile Sy= 725.94 cm³/pile

The pile selection is based on the magnitude of the moment only. Axial force is neglected.

HP14X89 is capable to support the shoring!
Top deflection = -0.020(in)
Max. deflection = 0.056(in)

***** LAGGING SIZE ESTIMATION *****

Max. Pressure above base = 2.11

Piles are more rigid than timber lagging, due to arching, only portion of pressures are acting to lagging, 30-50% loading is suggested.

If 50% loading is used for lagging design, Design Pressure = 1.05

Pile Spacing =6.0, Max. Moment in lagging = 4.75

For 4"x12" Timber, Section Modules S=23.47 in³. The request allowable bending strength, fb=M/S=2.43

For 6"x12" Timber, Section Modules S=57.98 in³. The request allowable bending strength, fb=M/S=0.98

If 30% loading is used for lagging design, Design Pressure = 0.63

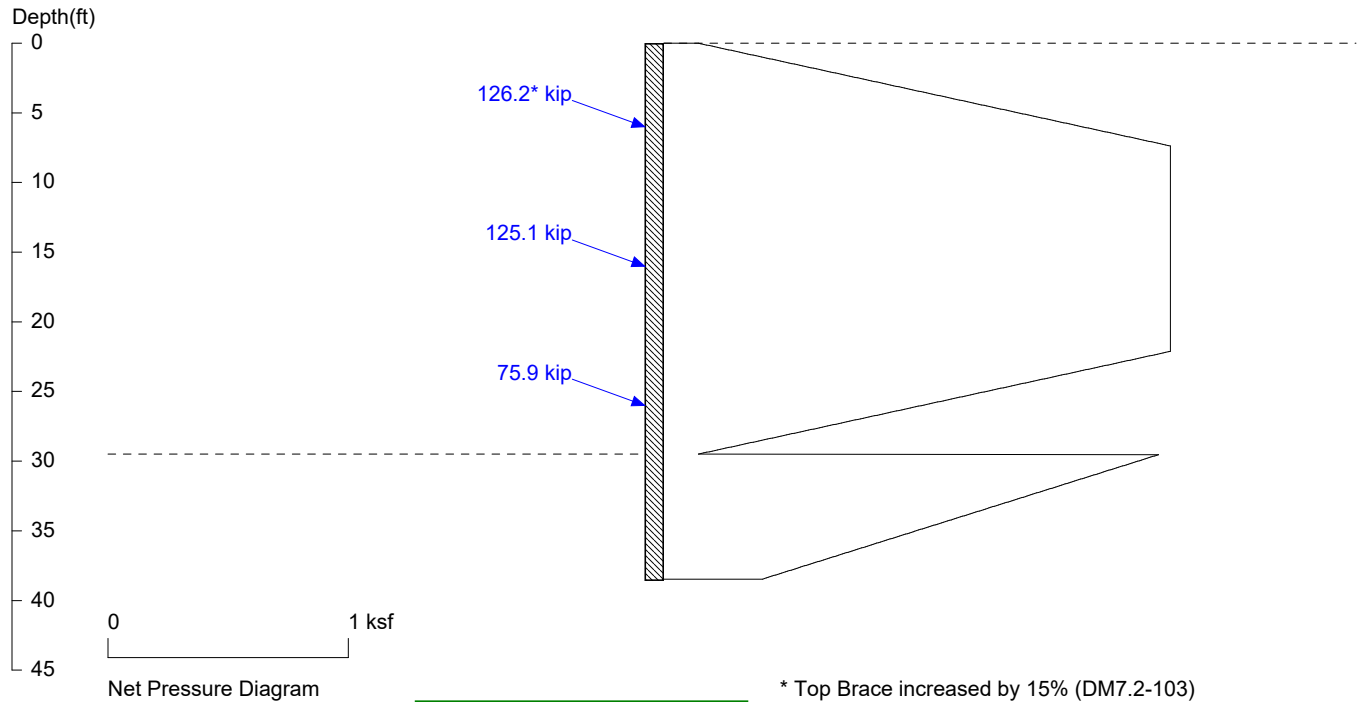
Pile Spacing =6.0, Max. Moment in lagging = 2.85

For 4"x12" Timber, Section Modules S=23.47 in³. The request allowable bending strength, fb=M/S=1.46

For 6"x12" Timber, Section Modules S=57.98 in³. The request allowable bending strength, fb=M/S=0.59

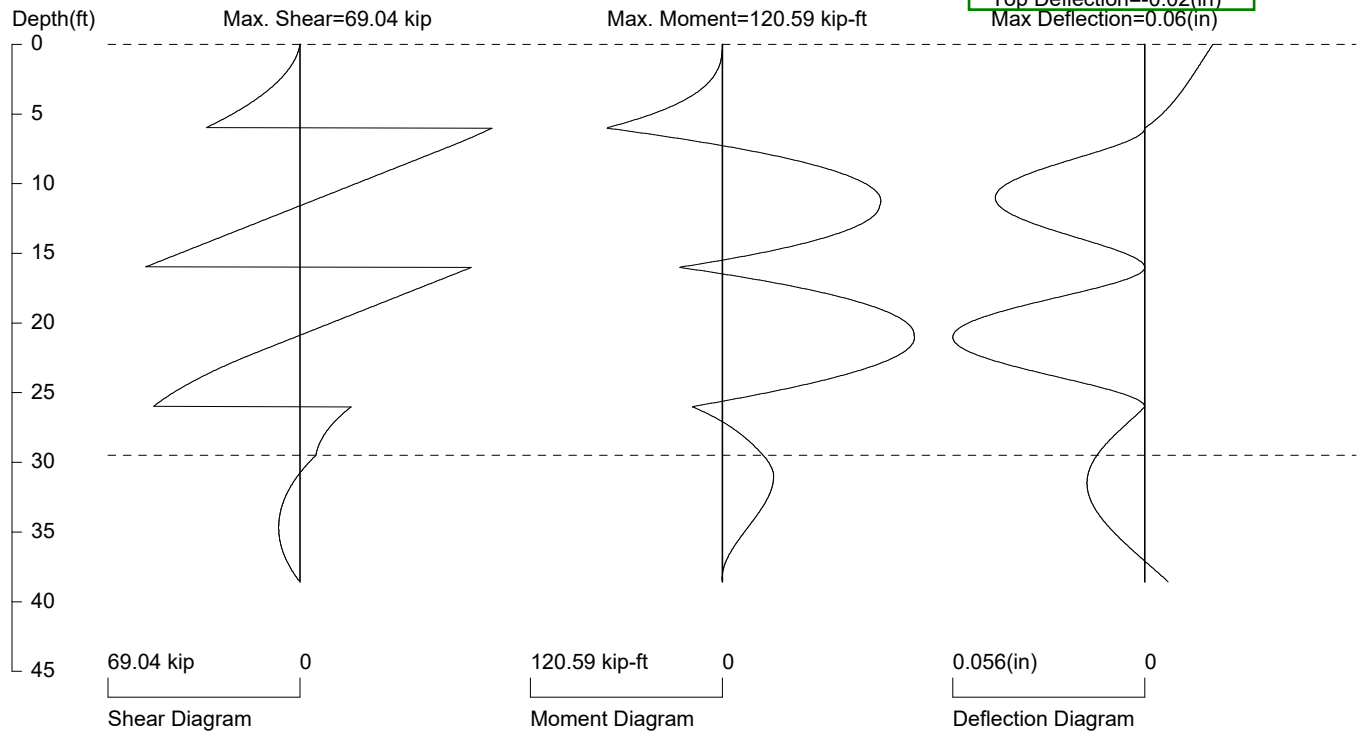
Unit: Pressure: ksf, Spacing: ft, Moment: kip-ft, Bending Strength, fb: ksi

WAS-77-9.58



Pile head deflection =

Top Deflection=-0.02(in)
Max Deflection=0.06(in)



PRESSURE, SHEAR, MOMENT, AND DEFLECTION DIAGRAMS

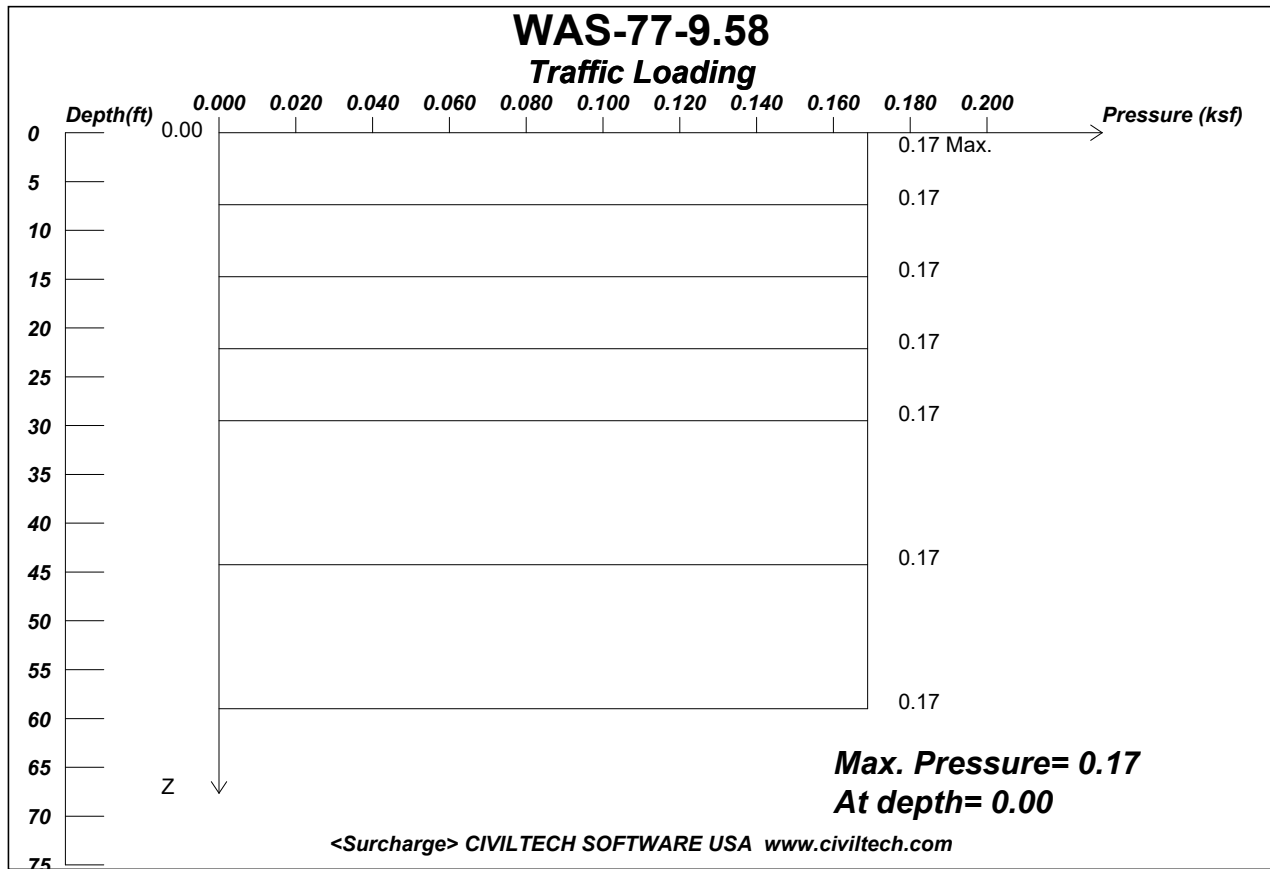
Based on pile spacing: 6.0 foot or meter

User Input Pile, HP14x89: E (ksi)=29000.0, I (in⁴)/pile=904.0

J:\ODOT-District 10 GES\Task 10-13 WAS-77-9.58\20250116_Redesign Calculations\20250116_Updated Analyses\WAS-77-9.58 29.5' Main Wall Tieback Service.s

Traffic Surcharge Loading (Strength Limit)

Construction Traffic



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Wall Height, H= 29.5

Load Depth, D= 0

Load Factor of Surcharge Loading = 1.17

Rigid Wall Condition -- No movement or deflection of the wall are allowed.

Max. Pressure = 0.169 at depth = 0.00

Infinite Surcharge, Q=.250

Active Wedge Approach * (recommend)

A load factor of 1.5 is applied to all active loading in the wall analysis. As traffic loading uses 1.75, an extra factor has been applied here ($1.75/1.5 = 1.17$).

UNITS: LENGTH/DEPTH: ft, Qpoint: kip, Qline: kip/ft, Qstrip/Qarea/PRESSURE: ksf

SURCHARGE LOADS CALCULATION SUMMARY
<Surcharge>
Software Copyright by CivilTech Software
www.civiltech.com

Reference: Foundation Design, Wayne C. Teng, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1962

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Date: 1/17/2025 File: J:\ODOT-District 10 GES\Task 10-13 WAS-77-9.58\20250116_Redesign
Calculations\20250116_Updated Analyses\WAS-77-9.58 29.5' Wall Surcharge Strength.lp8

WAS-77-9.58
Traffic Loading

Height of Wall = 29.5
Depth of Load = 0
Load Factor of Surcharge Loading = 1.17

Wall Condition:
Rigid Wall Condition -- No movement or deflection of the wall are allowed.

*****Loading*****

INFINITE SURCHARGE LOADING: Q=.250
Active Wedge Approach * (recommend)

*****Total Pressure Distribution*****

Max. Pressure =0.169 at depth =0.00

Depth	Pressure
0.00	0.169
1.48	0.169
2.95	0.169
4.43	0.169
5.90	0.169
7.38	0.169
8.85	0.169
10.33	0.169
11.80	0.169
13.28	0.169
14.75	0.169
16.23	0.169
17.70	0.169
19.18	0.169
20.65	0.169
22.13	0.169
23.60	0.169
25.08	0.169
26.55	0.169
28.03	0.169
29.50	0.169
32.45	0.169
35.40	0.169
38.35	0.169
41.30	0.169
44.25	0.169
47.20	0.169
50.15	0.169
53.10	0.169
56.05	0.169
59.00	0.169
64.90	0.169
70.80	0.169
76.70	0.169
82.60	0.169

Surcharge loading cut off at top of
rock (49.8 feet) in shoring module.

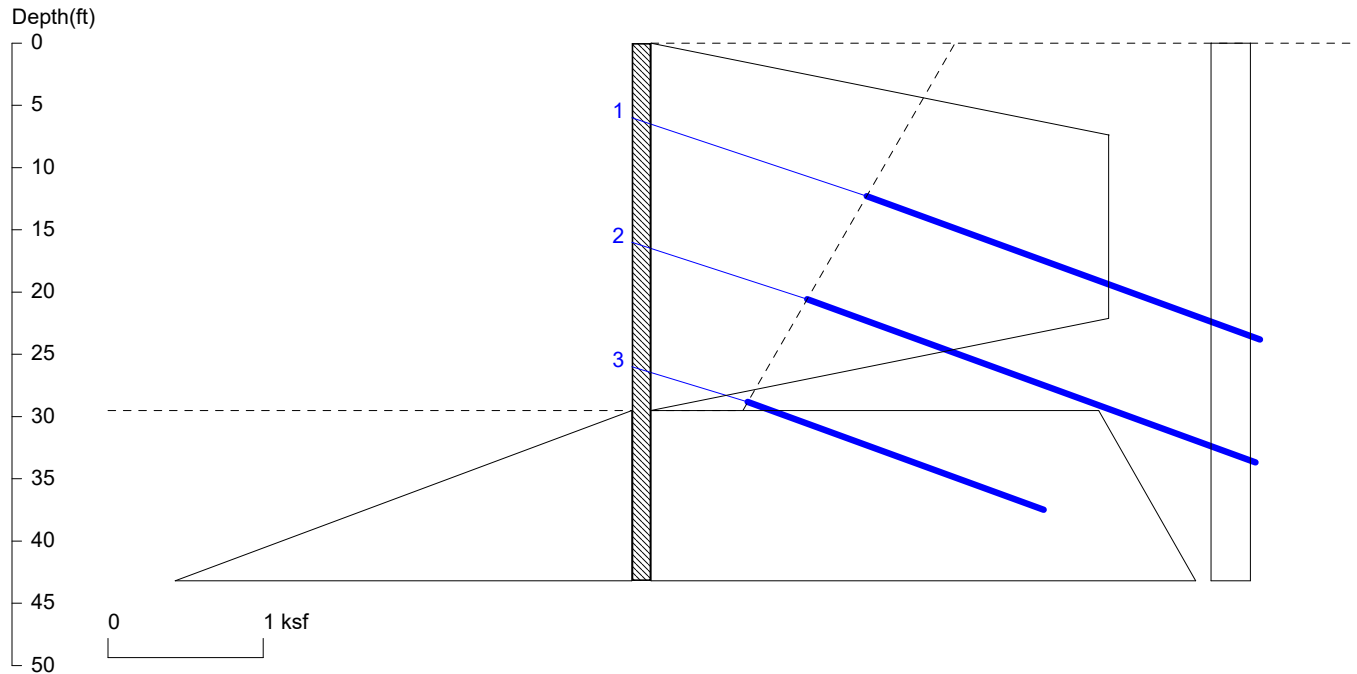
88.50	0.169
94.40	0.169
100.30	0.169
106.20	0.169
112.10	0.169
118.00	0.000

Depth Is Measured From Top of the Wall

LENGTH/DEPTH: ft, Qpoint: kip, Qline: kip/ft, Qstrip/Qarea/PRESSURE: ksf

Strength Limit

WAS-77-9.58



<ShoringSuite> CIVILTECH SOFTWARE USA www.civiltech.com

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Date: 1/24/2025

File: J:\ODOT-District 10 GES\Task 10-13 WAS-77-9.58\20250116_Redesign Calculations\20250116_Updated Analyses\WA

Wall Height=29.5

Pile Diameter=2.5

Pile Spacing=6.0

Wall Type: 2. Soldier Pile, Drilled

PILE LENGTH: Min. Embedment=13.69 Min. Pile Length=43.19

MOMENT IN PILE: Max. Moment=182.92 per Pile Spacing=6.0 at Depth=21.00

Anchor loads and lengths

PILE SELECTION:

Request Min. Section Modulus = 43.9 in³/pile=719.41 cm³/pile, Fy= 50 ksi = 345 MPa, Fb/Fy=1

HP14X89 has Section Modulus = 131.0 in³/pile=2146.70 cm³/pile. It is greater than Min. Requirements!

Top Deflection = -0.03(in) based on E (ksi)=29000.00 and I (in⁴)/pile=904.0

BRACE FORCE: Strut, Tieback, Plate Anchor, Deadman, Sheet Pile as Anchor

No. & Type	Depth	Angle	Space	Total F.	Horiz. F.	Vert. F.	L free	Fixed Length
1. Tieback	6.0	20.0	6.0	192.8*	181.2	65.9	18.4	39.0
2. Tieback	16.0	20.0	6.0	189.7	178.2	64.9	13.3	38.3
3. Tieback	26.0	20.0	6.0	125.1	117.6	42.8	8.3	25.3

Unbonded Length

Bonded Length

* Top Brace increased by 15% (DM7.2-103)

UNITS: Width,Diameter,Spacing,Length,Depth,and Height - ft; Force - kip; Bond Strength and Pressure - ksf

DRIVING PRESSURES (ACTIVE, WATER, & SURCHARGE): Pressures below will be multiplied by a Factor =1.5

Z1	P1	Z2	P2	Slope
*	Above	Base		
0.000	0.000	7.375	1.965	0.266456
7.375	1.965	22.12	1.965	0.000000
22.12	1.965	29.50	0.000	-0.26645
*	Below	Base		
29.50	1.922	44.80	2.386	0.030353
*	Sur-	charg		
0.000	0.169	1.475	0.169	0.000000
1.475	0.169	2.950	0.169	0.000000
2.950	0.169	4.425	0.169	0.000000

Applied 1.5 load factor for active earth pressures.

4.425	0.169	5.900	0.169	0.000000
5.900	0.169	7.375	0.169	0.000000
7.375	0.169	8.850	0.169	0.000000
8.850	0.169	10.32	0.169	0.000000
10.32	0.169	11.80	0.169	0.000000
11.80	0.169	13.27	0.169	0.000000
13.27	0.169	14.75	0.169	0.000000
14.75	0.169	16.22	0.169	0.000000
16.22	0.169	17.70	0.169	0.000000
17.70	0.169	19.17	0.169	0.000000
19.17	0.169	20.65	0.169	0.000000
20.65	0.169	22.12	0.169	0.000000
22.12	0.169	23.60	0.169	0.000000
23.60	0.169	25.07	0.169	0.000000
25.07	0.169	26.55	0.169	0.000000
26.55	0.169	28.02	0.169	0.000000
28.02	0.169	29.50	0.169	0.000000
29.50	0.169	32.45	0.169	0.000000
32.45	0.169	35.40	0.169	0.000000
35.40	0.169	38.35	0.169	0.000000
38.35	0.169	41.30	0.169	0.000000
41.30	0.169	44.25	0.169	0.000000

PASSIVE PRESSURES:

Z1	P1	Z2	P2	Slope
*	Below	Base		
29.50	0.000	44.80	3.289	0.214939

ACTIVE SPACING:

No.	Z depth	Spacing
1	0.00	6.00
2	29.50	2.50

PASSIVE SPACING:

No.	Z depth	Spacing
1	29.50	5.00

UNITS: Width,Spacing,Diameter,Length,and Depth - ft; Force - kip; Moment - kip-ft
Friction,Bearing,and Pressure - ksf; Pres. Slope - kip/ft³; Deflection - in

SHORING WALL CALCULATION SUMMARY
The leading shoring design and calculation software
Software Copyright by CivilTech Software
www.civiltech.com

ShoringSuite Software is developed by CivilTech Software, Bellevue, WA, USA.

The calculation method is based on the following references:

1. FHWA 98-011, FHWA-RD-97-130, FHWA SA 96-069, FHWA-IF-99-015
2. STEEL SHEET PILING DESIGN MANUAL by Pile Buck Inc., 1987
3. DESIGN MANUAL DM-7 (NAVFAC), Department of the Navy, May 1982
4. TRENCHING AND SHORING MANUAL Revision 12, California Department of Transportation, January 2000
6. EARTH SUPPORT SYSTEM & RETAINING STRUCTURES, Pile Buck Inc. 2002
5. DESIGN OF SHEET PILE WALLS, EM 1110-2-2504, U.S. Army Corps of Engineers, 31 March 1994
7. EARTH RETENTION SYSTEMS HANDBOOK, Alan Macnab, McGraw-Hill. 2002
8. Temporary Structures in Construction, Robert T. Ratay (Co-author of Chapter 7: John J. Peirce), McGraw-Hill. 2012
9. AASHTO HB-17, American Association of State and Highway Transportation Officials, 2 September 2002

UNITS: Width/Spacing/Diameter/Length/Depth - ft, Force - kip, Moment - kip-ft, Friction/Bearing/Pressure - ksf, Pres. Slope - kip/ft³, Deflection - in

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Date: 1/24/2025 File: J:\ODOT-District 10 GES\Task 10-13 WAS-77-9.58\20250116_Redesign
Calculations\20250116_Updated Analyses\WAS-77-9.58 29.5' Main Wall Tieback Strength.sh8

Title: WAS-77-9.58

Subtitle:

*****INPUT DATA*****

Wall Type: 2. Soldier Pile, Drilled

Wall Height: 29.50
Pile Diameter: 2.50
Pile Spacing: 6.00
Factor of Safety (F.S.): 1.00
As Continuous Span Beam

Lateral Support Type (Braces): 3. Tieback
Top Brace Increase (Multi-Bracing): Add 15%*

No-Load Zone:
Vertical Depth for No-Load Zone: 29.50
H-Distance (Input H/V ratio) for No-Load Zone: 0.25
Angle from H. Line for No-Load Zone: 60.00

Embedment Option: 1. Yes
Friction at Pile Tip: No

Pile Properties:
Steel Strength, Fy: 50 ksi = 345 MPa
Allowable Fb/Fy: 1
Elastic Module, E: 29000.00
Moment of Inertia, I: 904.00
User Input Pile: HP14X89

* DRIVING PRESSURE (ACTIVE, WATER, & SURCHARGE) *

The pressures below will be multiplied by a Factor =1.5

No.	Z1 top	Top Pres.	Z2 bottom	Bottom Pres.	Slope
1	*	Above	Base		
2	0.000	0.000	7.375	1.965	0.266456
3	7.375	1.965	22.12	1.965	0.000000
4	22.12	1.965	29.50	0.000	-0.26645
5	*	Below	Base		
6	29.50	1.922	44.80	2.386	0.030353
7	44.80	2.121	49.80	2.324	0.040538
8	49.80	1.302	206.5	3.899	0.016570
9	*	Sur-	charg		
10	0.000	0.169	1.475	0.169	0.000000
11	1.475	0.169	2.950	0.169	0.000000

12	2.950	0.169	4.425	0.169	0.000000
13	4.425	0.169	5.900	0.169	0.000000
14	5.900	0.169	7.375	0.169	0.000000
15	7.375	0.169	8.850	0.169	0.000000
16	8.850	0.169	10.32	0.169	0.000000
17	10.32	0.169	11.80	0.169	0.000000
18	11.80	0.169	13.27	0.169	0.000000
19	13.27	0.169	14.75	0.169	0.000000
20	14.75	0.169	16.22	0.169	0.000000
21	16.22	0.169	17.70	0.169	0.000000
22	17.70	0.169	19.17	0.169	0.000000
23	19.17	0.169	20.65	0.169	0.000000
24	20.65	0.169	22.12	0.169	0.000000
25	22.12	0.169	23.60	0.169	0.000000
26	23.60	0.169	25.07	0.169	0.000000
27	25.07	0.169	26.55	0.169	0.000000
28	26.55	0.169	28.02	0.169	0.000000
29	28.02	0.169	29.50	0.169	0.000000
30	29.50	0.169	32.45	0.169	0.000000
31	32.45	0.169	35.40	0.169	0.000000
32	35.40	0.169	38.35	0.169	0.000000
33	38.35	0.169	41.30	0.169	0.000000
34	41.30	0.169	44.25	0.169	0.000000
35	44.25	0.169	47.20	0.169	0.000000
36	47.20	0.169	50.15	0.169	0.000000

Surcharge loading terminated at top of rock (approx 49.8 feet).

* PASSIVE PRESSURE *

No.	Z1 top	Top Pres.	Z2 bottom	Bottom Pres.	Slope
1	*	Below	Base		
2	29.50	0.000	44.80	3.289	0.214939
3	44.80	3.682	49.80	5.064	0.276553
4	49.80	47	206.5	47	0.0000

* ACTIVE SPACE *

No.	Z depth	Spacing
1	0.00	6.00
2	29.50	2.50

Passive pressure for bedrock adjusted to 47 ksf based on an unconfined strength of 330 psi.

* PASSIVE SPACE *

No.	Z depth	Spacing
1	29.50	5.00

Hole diameter in feet (9 inches)

Allowable bond strength = resistance factor * ultimate bond strength = 0.7×3 ksf

* BRACE: STRUT, TIEBACK, ANCHOR PLATE, DEADMAN, OR SHEET PILE AS ANCHOR*

No.	Z brace	Angle	Spacing	Input1*	Input2*	Type
1	6.00	20.0	6.00	0.75	2.10	Tieback
2	16.00	20.0	6.00	0.75	2.10	Tieback
3	26.00	20.0	6.00	0.75	2.10	Tieback

*For Tieback: Input1 = Diameter; Input2 = Bond Strength

*For Plate: Input1 = Diameter; Input2 = Allowable Pressure

*For Deadman: Input1 = Horz. Width; Input2 = Passive Pressure;

*For Sheet Pile Anchor: Input1 = Horz. Width; Input2 = Passive Slope;

*****CALCULATION*****

The calculated moment and shear are per pile spacing. Sheet piles are per one foot or meter; Soldier piles are per pile.

Top Pressures start at depth = 0.00

* CALCULATE REQUEST EMBEDMENT *

```
|<-- D1=26.00
|
==|== D2=29.50
|
| D3=43.19
```

D1 - TOP DEPTH R1 - TOP REACTION
D2 - EXCAVATION BASE
D3 - PILE TIP

TOTAL REACTION: R1 = 37.28
TOTAL PRESSURES ACTING ON WALL = 37.28
Total Reactions = Total Pressures, OK!
The Calculated Embedment, Yend = 13.69

-----MULTIPLE BRACE / TIEBACK CASE-----
** Use the calculated embedment, Yend = 13.69 for graphics and analysis.

NUMBER OF BRACE LEVEL= 3

* CANTILEVER SPAN, N0.0 *

```
| D1=0.00
|
|<-- D2=6.00            R2=52.29, with Cantilever Moment=113.71
```

D1 - TOP DEPTH
D2 - BOTTOM DEPTH R2 - BOTTOM REACTION

TOTAL REACTION: R2 = 52.29
TOTAL PRESSURES ACTING ON WALL = 52.29
Total Reactions = Total Pressures, OK!

BRACE NO.1 AT DEPTH = 6.00
R2 of Cantilever Span } Sum of Reaction = Brace Load = 157.53
R1 of Span No.1

* MIDDLE SPAN NO.1 *

```
|<-- D1=6.00            R1=105.24, with Cantilever Moment=113.71
|
|<-- D2=16.00           R2=84.56
```

D1 - TOP DEPTH R1 - TOP REACTION
D2 - BOTTOM DEPTH R2 - BOTTOM REACTION

TOTAL REACTION: R1+R2 = 189.79
TOTAL PRESSURES ACTING ON WALL = 189.79
Total Reactions = Total Pressures, OK!

BRACE NO.2 AT DEPTH = 16.00
R2 of Span No.1 } Sum of Reaction = Brace Load = 178.25
R1 of Last Span

* LAST SPAN *

```
|<-- D1=16.00           R1=93.69
|
|
```

```

|
| <-- D2=26.00      R2=117.59
|
|
|      D3=43.19

```

D1 - TOP DEPTH R1 - TOP REACTION
 D2 - LAST BRACE DEPTH R2 - LAST BRACE REACTION
 D3 - BOTTOM DEPTH

TOTAL REACTION: R1+R2 = 211.29
 TOTAL PRESSURES ACTING ON WALL = 211.29
 Total Reactions >= Total Pressures, OK!

BRACE NO.3 AT DEPTH = 26.00
 R2 of Last Span = Brace Load = 117.59

*****RESULTS*****

* EMBEDMENT *
 MINIMUM EMBEDMENT = 13.69, TOTAL MINIMUM PILE LENGTH = 43.19

* MOMENT IN PILE (per pile spacing)*

Pile Spacing: sheet piles are one foot or one meter; soldier piles are one pile.

No.	Depth	M @ Brace	Mmax in Span	Depth of Mmax

1	6.00	113.09	149.94	11.24
2	16.00	41.44	182.92	21.00
3	26.00	33.16	86.95	32.53

Overall Maximum Moment = 182.92 at 21.00
 Maximum Shear = 105.15
 Moment and Shear are per pile spacing: 6.0 foot or meter

-> Top Brace Increase 15%. (Horizontal) From 157.53 to 181.16

* BRACE: STRUT, TIEBACK, ANCHOR PLATE, DEADMAN, OR SHEET PILE AS ANCHOR*
 The calculated brace force are per brace spacing.

No.	DEPTH	Tangle	SPACING	HORIZONTAL	VERTICAL	TOTAL LOAD
1	6.00	20.0	6.00	181.16	65.94	192.79
2	16.00	20.0	6.00	178.25	64.88	189.69
3	26.00	20.0	6.00	117.59	42.80	125.14
No.	DEPTH	Free length	Brace Type			
1	6.00	18.42	Tieback, Bond length = 38.96			
2	16.00	13.34	Tieback, Bond length = 38.34			
3	26.00	8.26	Tieback, Bond length = 25.29			

* VERTICAL LOADING *
 Vertical Loading from Braces = 173.61
 Vertical Loading from External Load = 0.00
 Total Vertical Loading = 173.61

*****SPECIFIED PILE *****

Overall Maximum Moment = 182.92 at 21.00
 The pile selection is based on the magnitude of the moment only. Axial force is neglected.

 Request Min. Section Modulus = 43.90 in3/pile = 719.41 cm3/pile, Fy= 50 ksi = 345 MPa, Fb/Fy=1

 HP14X89 has been found in Soldier Pile list!

(English Units):

Area= 26.1 in. Depth= 13.8 in. Width= 14.7 in. Height= 14 in.

Flange thickness= 0.615 in. Web thickness= 0.615 in.

Ix= 904 in⁴/pile Sx= 131 in³/pile Iy= 326 in⁴/pile Sy= 44.3 in³/pile

(Metric Units):

Ix= 376.24 x10⁰cm⁴/pile Sx= 2146.70 cm³/pile Iy= 135.68 x10⁰cm⁴/pile Sy= 725.94 cm³/pile

The pile selection is based on the magnitude of the moment only. Axial force is neglected.

HP14X89 is capable to support the shoring!

Top deflection = -0.028(in)

Max. deflection = 0.086(in)

***** LAGGING SIZE ESTIMATION *****

Max. Pressure above base = 3.20

Piles are more rigid than timber lagging, due to arching, only portion of pressures are acting to lagging, 30-50% loading is suggested.

If 50% loading is used for lagging design, Design Pressure = 1.60

Pile Spacing =6.0, Max. Moment in lagging = 7.20

For 4"x12" Timber, Section Modules S=23.47 in³. The request allowable bending strength, fb=M/S=3.68

For 6"x12" Timber, Section Modules S=57.98 in³. The request allowable bending strength, fb=M/S=1.49

If 30% loading is used for lagging design, Design Pressure = 0.96

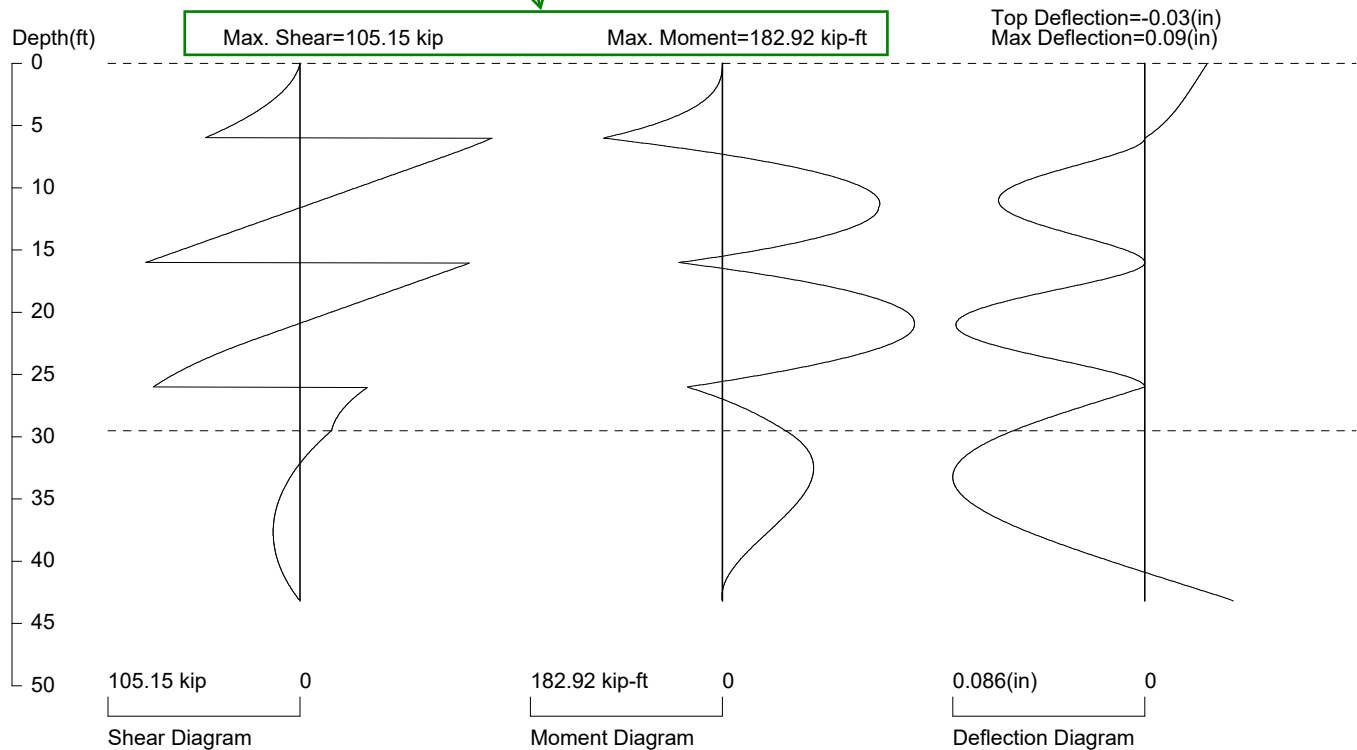
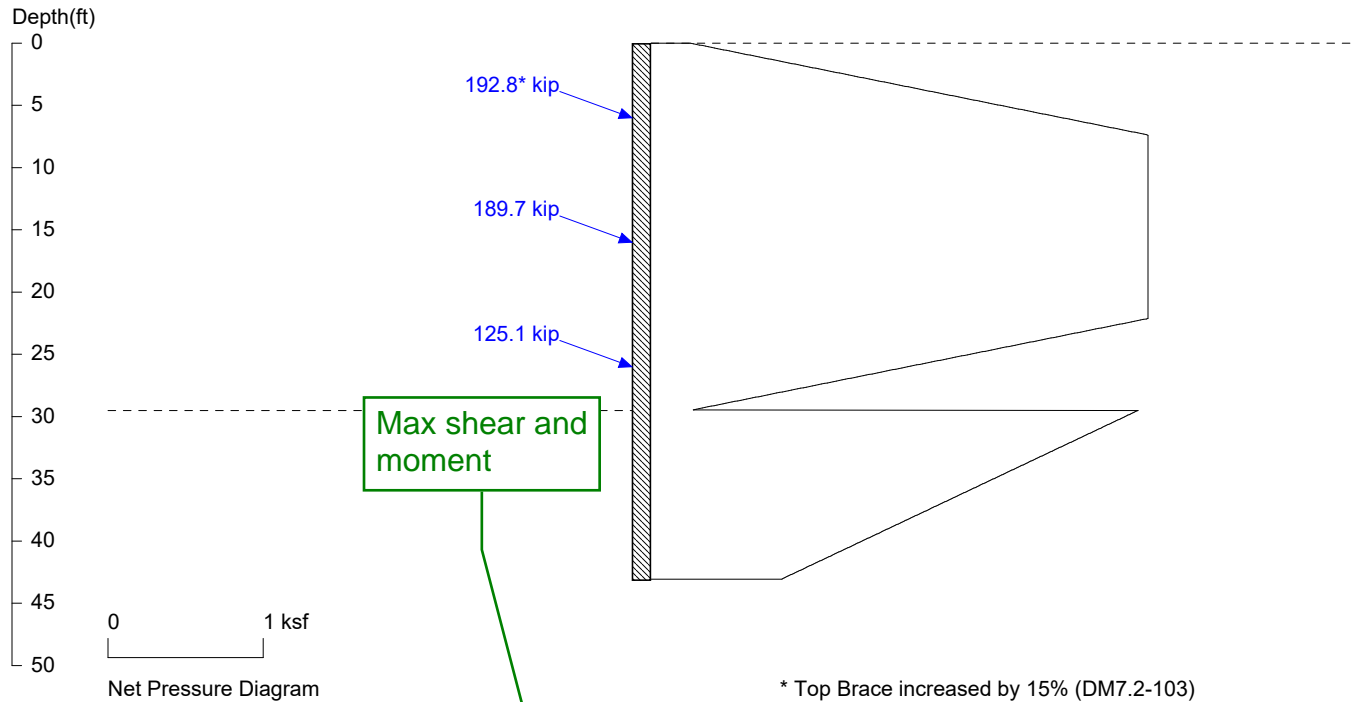
Pile Spacing =6.0, Max. Moment in lagging = 4.32

For 4"x12" Timber, Section Modules S=23.47 in³. The request allowable bending strength, fb=M/S=2.21

For 6"x12" Timber, Section Modules S=57.98 in³. The request allowable bending strength, fb=M/S=0.89

Unit: Pressure: ksf, Spacing: ft, Moment: kip-ft, Bending Strength, fb: ksi

WAS-77-9.58



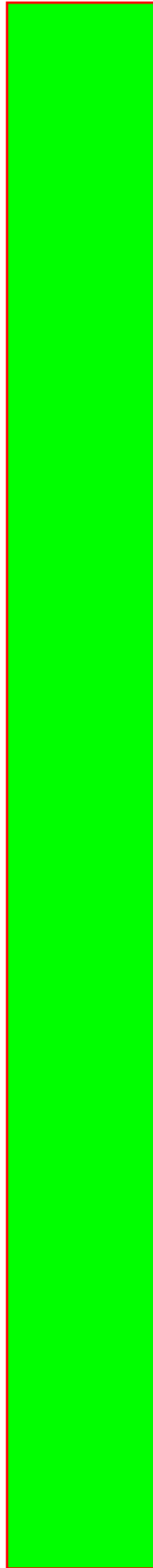
PRESSURE, SHEAR, MOMENT, AND DEFLECTION DIAGRAMS

Based on pile spacing: 6.0 foot or meter

User Input Pile, HP14X89: E (ksi)=29000.0, I (in⁴)/pile=904.0

J:\ODOT-District 10 GES\Task 10-13 WAS-77-9.58\20250116_Redesign Calculations\20250116_Updated Analyses\WAS-77-9.58 29.5' Main Wall Tieback Strength.s

23 ft



Shoring Suite Analysis

Wall Sta. 1+80

23.0 ft Height (Max during Construction)

Geometry

Elevation (ft)			Minimum Horiz. Distance from C/L (ft)		
Top of Backfill =	880.0	at Bottom of Embankment	Start of Wall Backfill =	50.0	at Bottom of Embankment
Top of Wall =	860.0	at C/L of Wall	Wall =	0.0	at C/L of Wall
Existing Ground Surface =	858.0	at C/L of Wall			
Bottom of Facing =	837.0	at C/L of Wall (Top of Shaft)	Backfill Slope Angle =	2.5	H:1V
Groundwater =	848.5	at C/L of Wall		21.8	degrees

Wall Loading Profile (B-005-0-23)

	Top Elev.	Thickness (ft)	Cohesion (psf)	Phi (deg)	Unit Wt (pcf)
Layer 2 Medium Stiff to Stiff Cohesive	860.0	9.8	115	23	140
Layer 1 Soft to Medium Stiff Cohesive	850.2	5.0	65	21	115
Layer 2 Medium Stiff to Stiff Cohesive	845.2	10.0	115	23	140
Bottom of Facing	837.0				
Weighted Value		24.8	105	23	135

Earth Pressure Coefficients

	Deg	
Shear Resistance, Φ =	25	
Wall Friction, δ^A =	0.0	
Wall Slope, θ =	90	
Backfill Slope, β =	21.80	
Revised Backfill Slope, β =	21.80	
Backfill Condition	INFINITE	
Horz. Backslope Dist.	50.0	feet (C/L of Wall - Bottom of Embankment)
Wall Height (H)	23.0	feet (Top of Wall - Bottom of Wall Facing)
Slope Height (h)	20.0	feet (Bottom of Embankment - Top of Wall)
I =	23.50	degrees

Notes:

- Wall friction neglected
- Figure and Equation for Active Earth Pressure from AASHTO 3.11.5.3 (LRFD Design Manual).
- The wall retained soil will consist of existing cohesive overburden. Using the soil layer thicknesses and respective soil parameters, a weighted average was determined and assumed for the entire profile ($c' = 105$ psf and $\phi' = 23^\circ$). The parameters were converted to equivalent soil strength parameters $c' = 0$ psf and $\phi' = 25^\circ$ for checking tieback lengths based on a 1 degree increase in friction angle for every 50 psf decrease in cohesion up to 150 psf (Ref: Hall's Thesis).

Shoring Suite Design Profile

	Top Elev	Depth (ft)	Cohesion (psf)	Phi (deg)	Unit Wt (pcf)
Layer 2 Medium Stiff to Stiff Cohesive	860.0	0.0	0	25	140
Layer 1 Soft to Medium Stiff Cohesive	850.2	9.8	0	22	115
Layer 2 Medium Stiff to Stiff Cohesive	845.2	14.8	0	25	140
Layer 3 Stiff to Very Stiff Cohesive	835.2	24.8	0	28	135
Layer 4 Hard Cohesive	815.2	44.8	0	31	145
Bedrock	810.2	49.8	0	45	150

Depths referenced below the top of wall. Friction angles reflect adjustments made per Hall's Thesis. Bedrock modeled as very dense gravel.

Steel Beam and Cross-Section Properties

Assumed Pile Shape **HP 14x89**

Pile Availability

AISC Member Producers	3
Non-Member Producers	0

Shaft Geometry

Shaft Diameter	30	in
Longest Beam Dimension	20.162589	in
Clear Distance	4.9187054	in

Steel Beam Geometry

Beam Depth (D)	13.8	in
Web Thickness (t _w)	0.615	in
Flange Width (B _f)	14.7	in
Flange Thickness (t _f)	0.615	in
Area of Steel (A _s)	26.1	in ²

Steel Properties

Yield Strength of Steel	50	ksi
Moment of Inertia (I _{xx}) of Steel	904	in ⁴
Modulus of Elasticity of Steel (E)	29000	ksi
Modulus of Elasticity of Steel (E)	29000000	psi
EI (Steel Only)	2.622E+10	lb*in ²
Section Modulus (S _x)	131	in ³
Section Modulus (Z _x)	146	in ³
Shear-Buckling Coefficient (k)	5	
Ratio of Shear-Buckling Resistance (C)	1	
D/t _w	22.439024	
1.12VEk/F _{yw}	60.313846	
1.40VEk/F _{yw}	75.392307	

Determined by AASHTO LRFD Bridge Specifications
Eqn's 6.10.9.3.2-4, 6.10.9.3.2-5, and 6.10.9.3.2-6

Shear Capacity Calculation

$$V_u \leq \phi V_{cr}$$
$$\phi_b = \boxed{1} \text{ AASHTO LRFD Bridge Design Spec's 6.5.4.2}$$
$$V_u = \text{shear in web due to factored permanent and construction loads applied to noncompact section (kips)}$$
$$V_{cr} = \text{shear buckling resistance determined from Equation 6.10.9.3.3-1 (AASHTO LRFD Bridge Design Spec's)}$$
$$V_n = V_{cr} = C V_p$$
$$V_p = 0.58 F_{yw} D t_w$$
$$V_p = \text{plastic shear force (kips)}$$
$$C = \text{ratio of shear-buckling resistance to shear yield strength determined by AASHTO Eqn's 6.10.9.3.2-4, 6.10.9.3.2-5, 6.10.9.3.2-5, or 6.10.9.3.2-6}$$
$$V_p = 0.58 * 50 * 13.8 * 0.615$$
$$V_p = \boxed{246.1} \text{ kips}$$
$$\phi V_{cr} = \phi * C * V_p$$
$$\phi V_{cr} = 1 * 1 * 246.1$$
$$\phi V_{cr} = \boxed{246.1} \text{ kips}$$
$$V_u = \boxed{91.36} \text{ kips (from Shoring Suite)}$$
$$\boxed{} \text{ kips (from PYWALL)}$$
$$V_u < \phi V_{cr} \quad \text{OK}$$

Flexure Capacity Calculation

$$M_u \leq \phi M_n$$
$$\phi_b = \boxed{1} \text{ AASHTO LRFD Bridge Design Spec's 6.5.4.2}$$
$$M_u = \text{Moment due to the factored loads}$$
$$M_n = \text{Nominal flexural resistance of a section}$$
$$S_x = \text{Elastic section modulus about the x-axis}$$
$$\phi M_n = \phi * F_y * S_x$$
$$\phi M_n = 1 * 50 * 131$$
$$\phi M_n = \boxed{6550} \text{ in*kips}$$
$$M_u = \boxed{1804.1} \text{ in*kips (from Shoring Suite)}$$
$$M_u = \boxed{} \text{ in*kips (from PYWALL)}$$
$$M_u < \phi M_n \quad \text{OK}$$

Deflection Criteria

Pile Length Above Rock = 49.8	ft	Exposed Wall Height = 23	ft
Pile Length Above Rock = 	in	Exposed Wall Height = 276	in

1.)

Per the ODOT GDM, pile-head deflection in the service limit state limited to 1% or less of the shaft length above bedrock, or 1% of total drilled shaft length if not embedded in bedrock.

2.)

Following industry acceptance criteria, limit wall deflection to 1% of exposed wall height where ODOT landslide criteria does not govern. Alternatively, limit wall deflection to 1.5% of the exposed wall height in accordance with NCDOT guidelines. Use 1.5% wall deflection for PYWALL software.

ODOT Landslide Criteria Governs

NO

OK

1% Wall Height OR 2 inches- LPILE

2.76

in

$\delta = \boxed{0.01}$ in (from Shoring Suite)

1.5% Wall Height - PYWALL

4.14

in

$\delta = \boxed{}$ in (from PYWALL)

Drilled Shafts Located Within 10 feet of Edge of Pavement

NO

Tieback Loading Computations

Design Tieback Load, TF1 = 168.0 kips / shaft
Design Tieback Load, TF2 = 139.6 kips / shaft

Horizontal values determined from Shoring Suite calculations.
Horizontal values determined from Shoring Suite calculations.

1) Determine Tiebacks

Strands

0.6 GUTS per strand = 35.2 kips per strand (FHWA-NHI-07-071: Table 8-16)

(GUTS = guaranteed ultimate tensile strength)

Tieback	Inclin.	Required Anchor Load**	Strands	
No.	deg	kips	Required	Selected
1	20	178.8	5.1	6.0
1	20	148.6	4.2	5.0

**Required Anchor Load = (TF) / [Cos (Inclin. Angle)]

Table 8-16. Properties of 0.6 in. Diameter Prestressing Steel Strands (ASTM A416, Grade 270).

Number of 0.6 in. diameter strands	Cross section area	Ultimate strength (=GUTS)	Prestressing force		
			0.8 $f_{pu}A_{ps}$	0.7 $f_{pu}A_{ps}$	0.6 $f_{pu}A_{ps}$
	(in. ²)	(kips)	(kips)	(kips)	(kips)
1	0.217	58.6	46.9	41.0	35.2

2) Check Pull-Out Capacity and Bond Length

Pullout Resistance Factor ϕ_{pr} = 0.7 Per AASHTO LRFD Table 11.5.7-1 for "Pullout resistance of anchors, cohesive soils"

Soil Friction Angle ϕ = 25

Tieback	Height Above Bottom of Facing	Tieback Length to Active Wedge	Total Unbonded Length	Ultimate Bond Strength	Tieback Drill Hole Diameter	Surface Area per Foot of Tieback	Allowable Bond Strength per Foot of Tieback	Required Anchor Load	Required Bond Length	Total Tieback Length
No.	ft	ft	ft	ksf	in	in ² /ft	kips/ft	kips	ft	ft
1	17	9.4	18	3	9	339.3	4.95	178.8	37	55
2	7	3.9	15	3	9	339.3	4.95	148.6	31	46

Total unbonded length = Tieback length to active wedge + greater of 5 feet or H/3, with a 15 foot minimum, per AASHTO LRFD Figure 11.9.1-1

Ultimate bond strength per AASHTO LRFD Table C11.9.4.2-1. Tieback lengths assume entire bond length is in clay.

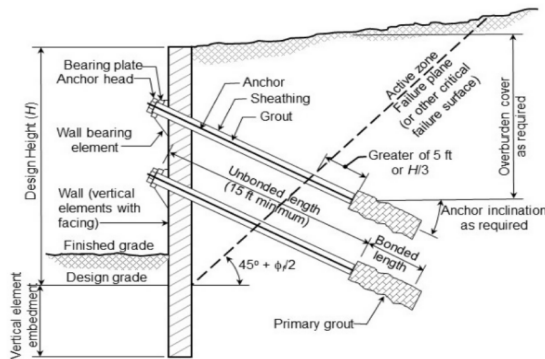
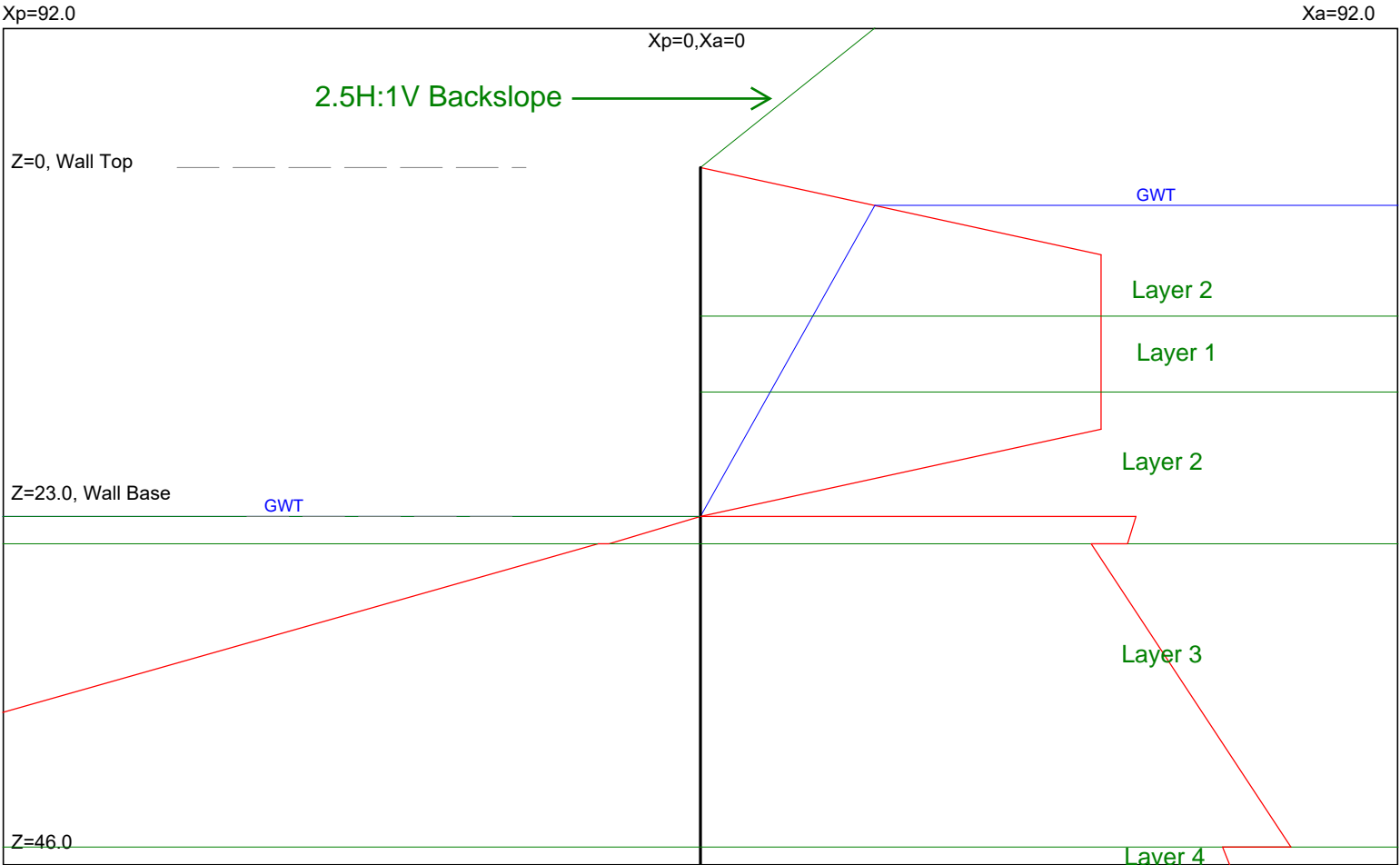


Figure 11.9.1-1—Anchored Wall Nomenclature and Anchor Embedment Guidelines

Table C11.9.4.2-1—Presumptive Ultimate Unit Bond Stress for Anchors in Cohesive Soils

Anchor/Soil Type (Grout Pressure)	Soil Stiffness or Unconfined Compressive Strength (tsf)	Presumptive Ultimate Unit Bond Stress, τ_u (ksf)
Gravity Grouted Anchors (<50 psi)		
Silt-Clay Mixtures	Stiff to Very Stiff 1.0-4.0	0.6 to 1.5
Pressure Grouted Anchors (50 psi-400 psi)		
High Plasticity Clay	Stiff 1.0-2.5 V. Stiff 2.5-4.0	0.6 to 2 1.5 to 3.6
Medium Plasticity Clay	Stiff 1.0-2.5 V. Stiff 2.5-4.0	2.0 to 5.2 2.9 to 7.3
Medium Plasticity Sandy Silt	V. Stiff 2.5-4.0	5.8 to 7.9

Earth Pressure Loading



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UNITS: DEPTH/DISTANCE: ft, UNIT WEIGHT: pcf, FORCE: kip/ft, PRESSURE: ksf, SLOPE: kcf

1/17/2025 File: J:\ODOT-District 10 GES\Task 10-13 WAS-77-9.58\20250116_Redesign Calculations\20250116_Updated Analyses\WAS-77-9.58 23' Main Wall Tieback

*** INPUT DATA ***

Wall Height=23.0		Total Soil Types= 5					
Soil No.	Weight	Saturate	Phi	Cohesion	Nspt	Type	Description
1	115.0	120.0	22	0	5	1	1. Soft to M
2	140.0	145.0	25	0.0	11	1	2. Medium St
3	135.0	140.0	28	0.0	24	1	3. Stiff to
4	145.0	150.0	31	0.0	65	1	4. Hard Cohe
5	150.0	155.0	45	0.0	100	5	Bedrock

Ground Surface at Active Side:

Line	Z1	Xa1	Z2	Xa2	Soil No.	Description
1	0.0	0.0	-20.0	50.0	2	2. Medium St
2	-20.0	50.0	-50.0	800.0	2	2. Medium St
3	9.8	0.0	9.8	800.0	1	1. Soft to M
4	14.8	0.0	14.8	800.0	2	2. Medium St
5	24.8	0.0	24.8	800.0	3	3. Stiff to
6	44.8	0.0	44.8	800.0	4	4. Hard Cohe
7	49.8	0.0	49.8	800.0	5	Bedrock

Water Table at Active Side:

Point	Z-water	X-water
1	23.0	0.0
2	2.5	23.0
3	2.5	800.0

Ground Surface at Passive Side:

Soil Layers in Front of Wall

Line	Z1	Xp1	Z2	Xp2	Soil No.	Description
1	23.0	0.0	23.0	800.0	2	2. Medium St
2	24.8	0.0	24.8	800.0	3	3. Stiff to
3	44.8	0.0	44.8	800.0	4	4. Hard Cohe
4	49.8	0.0	49.8	800.0	5	Bedrock

Water Table at Passive Side:

Water Depth in Front of Wall

Point	Z-water	X-water
1	23.0	0.0
2	23.0	800.0

Wall Friction Options: 1.* No wall friction

Wall Batter Angle = 0

Apparent Pressure Conversion: 1.* Default (Terzaghi and Peck)*

Water Density = 62.4

Water Pressure: 1.* No seepage at wall tip

* OUTPUT RESULTS *

Total Force above Base= 23.13 per one linear foot (or meter) width along wall height

Total Static Force above Base= 23.13. Distributed in Apparent Envelope along wall height. Ignore soil layers and water line

Driving Pressure above Base - Output to Shoring - Multiplier of Pressure = 1

Z1	Pa1	Z2	Pa2	Slope	Coef.
0.00	0.00	5.75	1.61	0.2798	1.9987
5.75	1.61	17.25	1.61	0.0000	0.0000
17.25	1.61	23.00	0.00	-0.2798	-1.9987

Driving Pressure below Base - Output to Shoring - Multiplier of Pressure = 1

Z1	Pa1	Z2	Pa2	Slope	Ka or Ko
23.00	1.75	24.80	1.72	-0.0187	-0.2264
24.80	1.57	44.80	2.37	0.0401	0.5170
44.80	2.10	46.00	2.13	0.0239	0.2728

Passive Pressure below Base - Output to Shoring - Multiplier of Pressure = 1

Z1	Pp1	Z2	Pp2	Slope	Kp
23.00	0.00	24.80	0.37	0.204	2.4643
24.80	0.41	44.80	4.71	0.215	2.7702
44.80	5.27	46.00	5.60	0.280	3.1972

UNITS: DEPTH/DISTANCE: ft, UNIT WEIGHT: pcf, FORCE: kip/ft, PRESSURE: ksf, SLOPE: kcf

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EARTH PRESSURE ANALYSIS SUMMARY
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Calculations\20250116_Updated Analyses\WAS-77-9.58 23' Main Wall Tieback.ep8

Title 1: WAS-77-9.58
Title 2:

Input data: *****

Wall Height = 23.00
Depth of Ground at Active Side = 0.00
Depth of Ground at Passive Side = 23.00
Apparent Pressure Envelope: 4. 2-Trapezoid Envelope (Braced, Stiff Clay)
Pressure Type: 1.* Active, Ka
Earthquake Loading Apply to: 1. No Earthq. Loads
Earthquake Horizontal Acceleration, Kh = 0
Earthquake Vertical Acceleration, Kv = 0
Calculation Methods: 1.* Numerical Solution (Wedge Analysis)
Wall Friction Options: 1.* No wall friction
Wall Batter Angle = 0
Apparent Pressure Conversion: 1.* Default (Terzaghi and Peck)*
Water Density = 62.4
Water Pressure: 1.* No seepage at wall tip
User's Settings
Ignore Passive from Depth = 0
Multiplier of Active Pressure = 1
Multiplier of Passive Pressure = 1
Multiplier of Water Pressure = 1
Multiplier of Earthq. Pressure = 1
Estimated Embedment: Very Shallow: 2H
Program's Settings
Max. Height, Hmax = 230.00
Analysis Segment, dz = 0.57
No. of Active Segment at H, nz0 = 3
No. of Active Segment at Hmax, nz = 7
No. of Passive Segment, nzp = 4
Active Depth at H, Zh = 23.00
Active Depth at Hmax, Z = 230.00
Passive Depth at Hmax, Zp = 230.00
Max. Pressure = 109.93

Total Soil Types= 5

Soil	Weight	W(S)	Phi	Cohesion	Nspt	Type	Description
1	115.0	120.0	22	0	5	1	1. Soft to M
>	115.0	120.0	22.0	0.0	5	1	Converted
2	140.0	145.0	25	0.0	11	1	2. Medium St
>	140.0	145.0	25.0	0.0	11	1	Converted
3	135.0	140.0	28	0.0	24	1	3. Stiff to
>	135.0	140.0	28.0	0.0	24	1	Converted
4	145.0	150.0	31	0.0	65	1	4. Hard Cohe
>	145.0	150.0	31.0	0.0	65	1	Converted
5	150.0	155.0	45	0.0	100	5	Bedrock

Soil Type: 1 Equivalent Clay; 2 Clay; 3 Silt; 4 Sand; 5 Gravel

Ground Surface at Active Side:

Line	Z1	Xa1	Z2	Xa2	Soil No.
1	0.0	0.0	-20.0	50.0	2
2	-20.0	50.0	-50.0	800.0	2
3	9.8	0.0	9.8	800.0	1
4	14.8	0.0	14.8	800.0	2
5	24.8	0.0	24.8	800.0	3
6	44.8	0.0	44.8	800.0	4
7	49.8	0.0	49.8	800.0	5

Water Table at Active Side:

Point	Z-water	X-water
1	23.0	0.0
2	2.5	23.0
3	2.5	800.0

Ground Surface at Passive Side:

Line	Z1	Xp1	Z2	Xp2	Soil No.
1	23.0	0.0	23.0	800.0	2
2	24.8	0.0	24.8	800.0	3
3	44.8	0.0	44.8	800.0	4
4	49.8	0.0	49.8	800.0	5

Water Table at Passive Side:

Point	Z-water	X-water
1	23.0	0.0
2	23.0	800.0

Output data: *****

Total Force above Base= 23.13 per one linear foot (or meter) width along wall height

Static Force above Base= 23.13. Distributed in Apparent Envelope along wall height. Ignore soil layers and water line

Apparent Pressure above Base - Output to Shoring

Active/At-Rest Force above Base, Ea = 23.13

No	Z1	P1	Z2	P2	Slope	Coef.
0	0.0	0.00	5.8	1.61	0.2798	1.9987
1	5.8	1.61	17.3	1.61	0.0000	0.0000
2	17.3	1.61	23.0	0.00	-0.2798	-1.9987

Driving Pressure below Base - Output to Shoring

No	Z1	P1	Z2	P2	Slope	Ka or Ko
0	23.0	1.75	24.8	1.72	-0.0187	-0.2264
1	24.8	1.57	44.8	2.37	0.0401	0.5170
2	44.8	2.09	49.8	2.28	0.0384	0.4380
3	49.8	1.31	230.0	4.22	0.0161	0.1743

Passive Pressure below Base - Output to Shoring

No	Z1	P1	Z2	P2	Slope	Kp
0	23.0	0.00	24.8	0.37	0.2036	2.4643
1	24.8	0.41	44.8	4.71	0.2150	2.7702
2	44.8	5.27	49.8	6.66	0.2788	3.1825
3	49.8	11.89	230.0	109.93	0.5441	5.8755

Passive pressures below 45.8 feet manually adjusted in shoring module to reflect claystone strength.

DEPTH/DISTANCE: ft, UNIT WEIGHT: pcf, FORCE: kip/ft, PRESSURE: ksf, SLOPE: kcf

Z, Xa, Xp - Coordinates of ground lines

Z- Depth measured from wall top

Xa - Distance measure from wall to active side.

Xp - Distance measure from wall to passive side

Z1, P1, Z2, P2 - Four values to define a pressure diagram

Z1- Top depth of the diagram

P1- Top pressure of the diagram

Z2- Bottom depth of the diagram

P2- Bottom pressure of the diagram

Slope - (P2-P1)/(Z2-Z1), Slope of the diagram. It also called Equivalent fluid density.

Coef. - Pressure Coefficient = Slope/Unit Weight

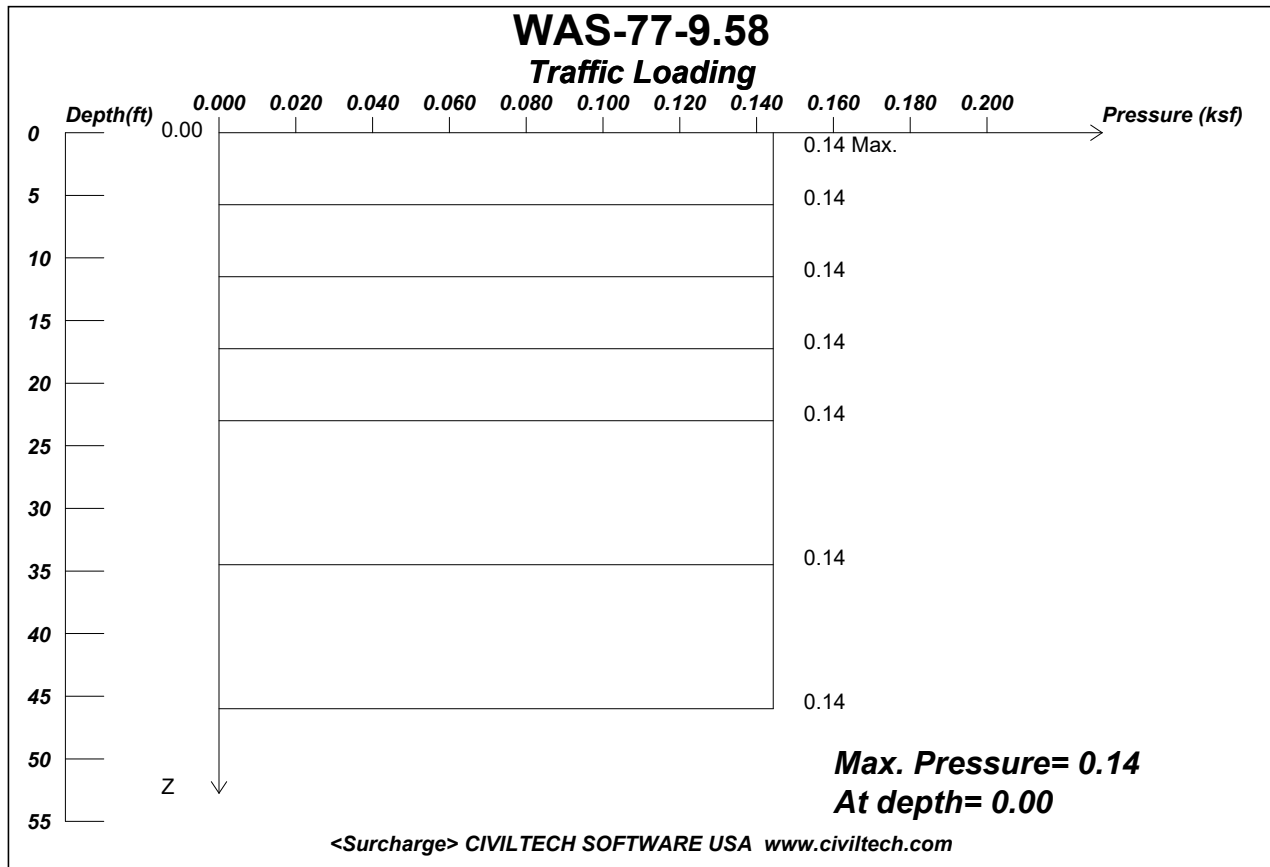
Ka - Active Earth Pressure Coefficient

Ko - At-Rest Earth Pressure Coefficient

Kp - Passive Earth Pressure Coefficient

Traffic Surcharge Loading (Service Limit)

Construction Traffic



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Wall Height, H= 23

Load Depth, D= 0

Load Factor of Surcharge Loading = 1

Rigid Wall Condition -- No movement or deflection of the wall are allowed.

Max. Pressure = 0.144 at depth = 0.00

Infinite Surcharge, Q=.250

Active Wedge Approach * (recommend)

UNITS: LENGTH/DEPTH: ft, Qpoint: kip, Qline: kip/ft, Qstrip/Qarea/PRESSURE: ksf

SURCHARGE LOADS CALCULATION SUMMARY
<Surcharge>
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Reference: Foundation Design, Wayne C. Teng, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1962

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Calculations\20250116_Updated Analyses\WAS-77-9.58 23' Wall Surcharge Service.lp8

WAS-77-9.58
Traffic Loading

Height of Wall = 23
Depth of Load = 0
Load Factor of Surcharge Loading = 1

Wall Condition:
Rigid Wall Condition -- No movement or deflection of the wall are allowed.

*****Loading*****

INFINITE SURCHARGE LOADING: Q=.250
Active Wedge Approach * (recommend)

*****Total Pressure Distribution*****

Max. Pressure =0.144 at depth =0.00

Depth	Pressure
0.00	0.144
1.15	0.144
2.30	0.144
3.45	0.144
4.60	0.144
5.75	0.144
6.90	0.144
8.05	0.144
9.20	0.144
10.35	0.144
11.50	0.144
12.65	0.144
13.80	0.144
14.95	0.144
16.10	0.144
17.25	0.144
18.40	0.144
19.55	0.144
20.70	0.144
21.85	0.144
23.00	0.144
25.30	0.144
27.60	0.144
29.90	0.144
32.20	0.144
34.50	0.144
36.80	0.144
39.10	0.144
41.40	0.144
43.70	0.144
46.00	0.144
50.60	0.144
55.20	0.144
59.80	0.144
64.40	0.144

Surcharge loading cut off at top of
rock (49.8 feet) in shoring module.

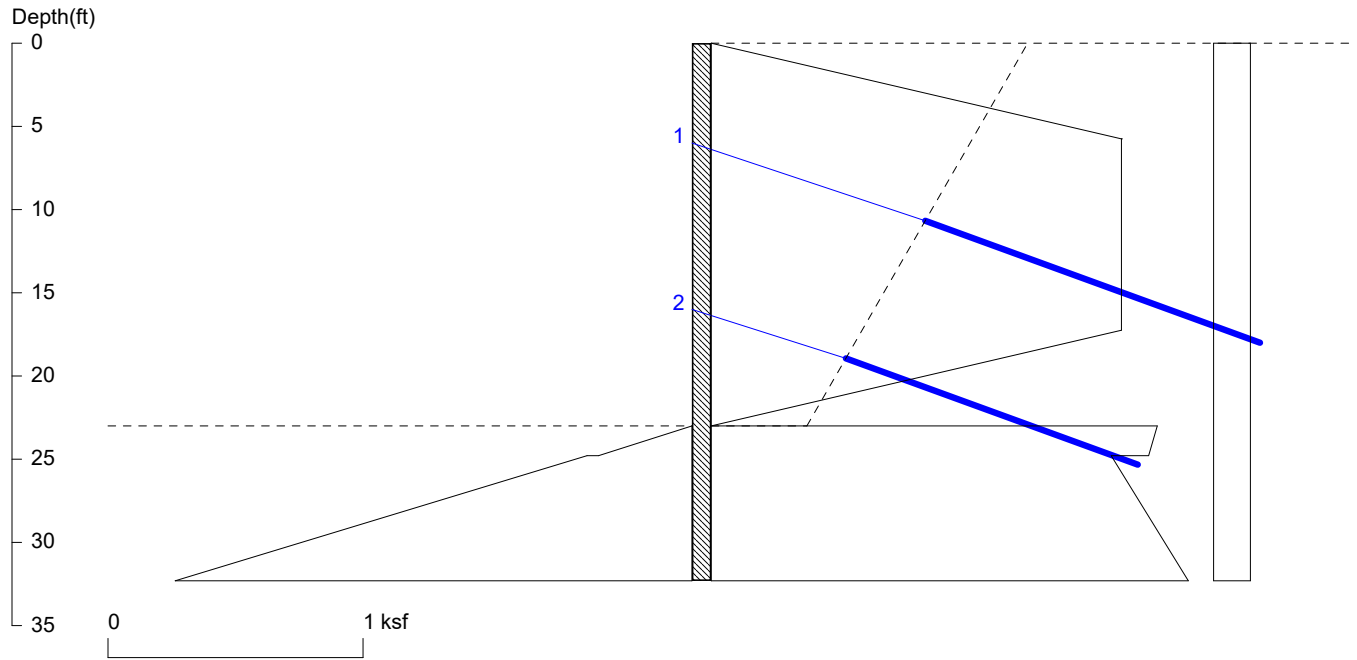
69.00	0.144
73.60	0.144
78.20	0.144
82.80	0.144
87.40	0.144
92.00	0.000

Depth Is Measured From Top of the Wall

LENGTH/DEPTH: ft, Qpoint: kip, Qline: kip/ft, Qstrip/Qarea/PRESSURE: ksf

Service Limit

WAS-77-9.58



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Date: 1/24/2025

File: J:\ODOT-District 10 GES\Task 10-13 WAS-77-9.58\20250116_Redesign Calculations\20250116_Updated Analyses\WA

Wall Height=23.0

Pile Diameter=2.5

Pile Spacing=6.0

Wall Type: 2. Soldier Pile, Drilled

PILE LENGTH: Min. Embedment=9.31 Min. Pile Length=32.31

MOMENT IN PILE: Max. Moment=77.50 per Pile Spacing=6.0 at Depth=11.40

PILE SELECTION:

Request Min. Section Modulus = 18.6 in³/pile=304.81 cm³/pile, Fy= 50 ksi = 345 MPa, Fb/Fy=1

HP14X89 has Section Modulus = 131.0 in³/pile=2146.70 cm³/pile. It is greater than Min. Requirements!

Top Deflection = -0.01(in) based on E (ksi)=29000.00 and I (in⁴)/pile=904.0

BRACE FORCE: Strut, Tieback, Plate Anchor, Deadman, Sheet Pile as Anchor

No. & Type	Depth	Angle	Space	Total F.	Horiz. F.	Vert. F.	L_free	Fixed Length
1. Tieback	6.0	20.0	6.0	116.9*	109.9	40.0	13.7	23.6
2. Tieback	16.0	20.0	6.0	92.5	86.9	31.6	8.6	18.7

* Top Brace increased by 15% (DM7.2-103)

UNITS: Width,Diameter,Spacing,Length,Depth,and Height - ft; Force - kip; Bond Strength and Pressure - ksf

DRIVING PRESSURES (ACTIVE, WATER, & SURCHARGE):

Z1	P1	Z2	P2	Slope
*	Above	Base		
0.000	0.000	5.750	1.609	0.279817
5.750	1.609	17.25	1.609	0.000000
17.25	1.609	23.00	0.000	-0.27981
*	Below	Base		
23.00	1.749	24.80	1.715	-0.01870
24.80	1.569	44.80	2.371	0.040119
*	Sur-	charg		
0.000	0.144	1.150	0.144	0.000000
1.150	0.144	2.300	0.144	0.000000
2.300	0.144	3.450	0.144	0.000000

3.450	0.144	4.600	0.144	0.000000
4.600	0.144	5.750	0.144	0.000000
5.750	0.144	6.900	0.144	0.000000
6.900	0.144	8.050	0.144	0.000000
8.050	0.144	9.200	0.144	0.000000
9.200	0.144	10.35	0.144	0.000000
10.35	0.144	11.50	0.144	0.000000
11.50	0.144	12.65	0.144	0.000000
12.65	0.144	13.80	0.144	0.000000
13.80	0.144	14.95	0.144	0.000000
14.95	0.144	16.10	0.144	0.000000
16.10	0.144	17.25	0.144	0.000000
17.25	0.144	18.40	0.144	0.000000
18.40	0.144	19.55	0.144	0.000000
19.55	0.144	20.70	0.144	0.000000
20.70	0.144	21.85	0.144	0.000000
21.85	0.144	23.00	0.144	0.000000
23.00	0.144	25.30	0.144	0.000000
25.30	0.144	27.60	0.144	0.000000
27.60	0.144	29.90	0.144	0.000000
29.90	0.144	32.20	0.144	0.000000
32.20	0.144	34.50	0.144	0.000000

PASSIVE PRESSURES:

Z1	P1	Z2	P2	Slope
*	Below	Base		
23.00	0.000	24.80	0.366	0.203551
24.80	0.411	44.80	4.711	0.214969

ACTIVE SPACING:

No.	Z depth	Spacing
1	0.00	6.00
2	23.00	2.50

PASSIVE SPACING:

No.	Z depth	Spacing
1	23.00	5.00

UNITS: Width,Spacing,Diameter,Length,and Depth - ft; Force - kip; Moment - kip-ft
Friction,Bearing,and Pressure - ksf; Pres. Slope - kip/ft³; Deflection - in

SHORING WALL CALCULATION SUMMARY
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The calculation method is based on the following references:

1. FHWA 98-011, FHWA-RD-97-130, FHWA SA 96-069, FHWA-IF-99-015
2. STEEL SHEET PILING DESIGN MANUAL by Pile Buck Inc., 1987
3. DESIGN MANUAL DM-7 (NAVFAC), Department of the Navy, May 1982
4. TRENCHING AND SHORING MANUAL Revision 12, California Department of Transportation, January 2000
6. EARTH SUPPORT SYSTEM & RETAINING STRUCTURES, Pile Buck Inc. 2002
5. DESIGN OF SHEET PILE WALLS, EM 1110-2-2504, U.S. Army Corps of Engineers, 31 March 1994
7. EARTH RETENTION SYSTEMS HANDBOOK, Alan Macnab, McGraw-Hill. 2002
8. Temporary Structures in Construction, Robert T. Ratay (Co-author of Chapter 7: John J. Peirce), McGraw-Hill. 2012
9. AASHTO HB-17, American Association of State and Highway Transportation Officials, 2 September 2002

UNITS: Width/Spacing/Diameter/Length/Depth - ft, Force - kip, Moment - kip-ft, Friction/Bearing/Pressure - ksf,
Pres. Slope - kip/ft³, Deflection - in

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Date: 1/24/2025 File: J:\ODOT-District 10 GES\Task 10-13 WAS-77-9.58\20250116_Redesign
Calculations\20250116_Updated Analyses\WAS-77-9.58 23' Main Wall Tieback Service.sh8

Title: WAS-77-9.58
Subtitle:

*****INPUT DATA*****

Wall Type: 2. Soldier Pile, Drilled

Wall Height: 23.00
Pile Diameter: 2.50
Pile Spacing: 6.00
Factor of Safety (F.S.): 1.00
As Continuous Span Beam

Lateral Support Type (Braces): 3. Tieback
Top Brace Increase (Multi-Bracing): Add 15%*

No-Load Zone:
Vertical Depth for No-Load Zone: 23.00
H-Distance (Input H/V ratio) for No-Load Zone: 0.25
Angle from H. Line for No-Load Zone: 60.00

Embedment Option: 1. Yes
Friction at Pile Tip: No

Pile Properties:
Steel Strength, Fy: 50 ksi = 345 MPa
Allowable Fb/Fy: 1
Elastic Module, E: 29000.00
Moment of Inertia, I: 904.00
User Input Pile: HP14x89

* DRIVING PRESSURE (ACTIVE, WATER, & SURCHARGE) *

No.	Z1 top	Top Pres.	Z2 bottom	Bottom Pres.	Slope
1	*	Above	Base		
2	0.000	0.000	5.750	1.609	0.279817
3	5.750	1.609	17.25	1.609	0.000000
4	17.25	1.609	23.00	0.000	-0.27981
5	*	Below	Base		
6	23.00	1.749	24.80	1.715	-0.01870
7	24.80	1.569	44.80	2.371	0.040119
8	44.80	2.085	49.80	2.277	0.038365
9	49.80	1.292	184.0	3.488	0.016366
10	*	Sur-	charg		
11	0.000	0.144	1.150	0.144	0.000000
12	1.150	0.144	2.300	0.144	0.000000

13	2.300	0.144	3.450	0.144	0.000000
14	3.450	0.144	4.600	0.144	0.000000
15	4.600	0.144	5.750	0.144	0.000000
16	5.750	0.144	6.900	0.144	0.000000
17	6.900	0.144	8.050	0.144	0.000000
18	8.050	0.144	9.200	0.144	0.000000
19	9.200	0.144	10.35	0.144	0.000000
20	10.35	0.144	11.50	0.144	0.000000
21	11.50	0.144	12.65	0.144	0.000000
22	12.65	0.144	13.80	0.144	0.000000
23	13.80	0.144	14.95	0.144	0.000000
24	14.95	0.144	16.10	0.144	0.000000
25	16.10	0.144	17.25	0.144	0.000000
26	17.25	0.144	18.40	0.144	0.000000
27	18.40	0.144	19.55	0.144	0.000000
28	19.55	0.144	20.70	0.144	0.000000
29	20.70	0.144	21.85	0.144	0.000000
30	21.85	0.144	23.00	0.144	0.000000
31	23.00	0.144	25.30	0.144	0.000000
32	25.30	0.144	27.60	0.144	0.000000
33	27.60	0.144	29.90	0.144	0.000000
34	29.90	0.144	32.20	0.144	0.000000
35	32.20	0.144	34.50	0.144	0.000000
36	34.50	0.144	36.80	0.144	0.000000
37	36.80	0.144	39.10	0.144	0.000000
38	39.10	0.144	41.40	0.144	0.000000
39	41.40	0.144	43.70	0.144	0.000000
40	43.70	0.144	46.00	0.144	0.000000
41	46.00	0.144	50.60	0.144	0.000000

Surcharge loading terminated at top of rock (approx 49.8 feet).

* PASSIVE PRESSURE *

No.	Z1 top	Top Pres.	Z2 bottom	Bottom Pres.	Slope
1	*	Below	Base		
2	23.00	0.000	24.80	0.366	0.203551
3	24.80	0.411	44.80	4.711	0.214969
4	44.80	5.269	49.80	6.663	0.278791
5	49.80	47	184.0	47	0.0000

* ACTIVE SPACE *

No.	Z depth	Spacing
1	0.00	6.00
2	23.00	2.50

Passive pressure for bedrock adjusted to 47 ksf based on an unconfined strength of 330 psi.

* PASSIVE SPACE *

No.	Z depth	Spacing
1	23.00	5.00

Hole diameter in feet (9 inches)

Allowable bond strength = resistance factor * ultimate bond strength = 0.7*3 ksf

* BRACE: STRUT, TIEBACK, ANCHOR PLATE, DEADMAN, OR SHEET PILE AS ANCHOR*

No.	Z brace	Angle	Spacing	Input1*	Input2*	Type
1	6.00	20.0	6.00	0.75	2.10	Tieback
2	16.00	20.0	6.00	0.75	2.10	Tieback

*For Tieback: Input1 = Diameter; Input2 = Bond Strength

*For Plate: Input1 = Diameter; Input2 = Allowable Pressure

*For Deadman: Input1 = Horz. Width; Input2 = Passive Pressure;

*For Sheet Pile Anchor: Input1 = Horz. Width; Input2 = Passive Slope;

*****CALCULATION*****

The calculated moment and shear are per pile spacing. Sheet piles are per one foot or meter; Soldier piles are

per pile.

Top Pressures start at depth = 0.00

* CALCULATE REQUEST EMBEDMENT *

```
|<-- D1=16.00
|
==|== D2=23.00
|
| D3=32.31
```

D1 - TOP DEPTH R1 - TOP REACTION
D2 - EXCAVATION BASE
D3 - PILE TIP

TOTAL REACTION: R1 = 41.89
TOTAL PRESSURES ACTING ON WALL = 41.89
Total Reactions = Total Pressures, OK!
The Calculated Embedment, Yend = 9.31

-----MULTIPLE BRACE / TIEBACK CASE-----
** Use the calculated embedment, Yend = 9.31 for graphics and analysis.

NUMBER OF BRACE LEVEL= 2

* CANTILEVER SPAN, N0.0 *

```
| D1=0.00
|
|<-- D2=6.00                      R2=35.35, with Cantilever Moment=75.99
```

D1 - TOP DEPTH
D2 - BOTTOM DEPTH R2 - BOTTOM REACTION

TOTAL REACTION: R2 = 35.35
TOTAL PRESSURES ACTING ON WALL = 35.35
Total Reactions = Total Pressures, OK!

BRACE NO.1 AT DEPTH = 6.00
R2 of Span No.0 } Sum of Reaction = Brace Load = 95.54
R1 of Last Span

* LAST SPAN *

```
|<-- D1=6.00                      R1=60.19
|
|<-- D2=16.00                      R2=86.88
|
| D3=32.31
```

D1 - TOP DEPTH R1 - TOP REACTION
D2 - LAST BRACE DEPTH R2 - LAST BRACE REACTION
D3 - BOTTOM DEPTH

TOTAL REACTION: R1+R2 = 147.07
TOTAL PRESSURES ACTING ON WALL = 147.07
Total Reactions >= Total Pressures, OK!

BRACE NO.2 AT DEPTH = 16.00
R2 of Last Span = Brace Load = 86.88

*****RESULTS*****

* EMBEDMENT *

MINIMUM EMBEDMENT = 9.31, TOTAL MINIMUM PILE LENGTH = 32.31

* MOMENT IN PILE (per pile spacing)*

Pile Spacing: sheet piles are one foot or one meter; soldier piles are one pile.

No.	Depth	M @ Brace	Mmax in Span	Depth of Mmax
1	6.00	75.77	77.50	11.40
2	16.00	18.82	74.70	21.79

Overall Maximum Moment = 77.50 at 11.40

Maximum Shear = 60.15

Moment and Shear are per pile spacing: 6.0 foot or meter

-> Top Brace Increase 15%. (Horizontal) From 95.54 to 109.87

* BRACE: STRUT, TIEBACK, ANCHOR PLATE, DEADMAN, OR SHEET PILE AS ANCHOR*

The calculated brace force are per brace spacing.

No.	DEPTH	Tangle	SPACING	HORIZONTAL	VERTICAL	TOTAL LOAD
1	6.00	20.0	6.00	109.87	39.99	116.92
2	16.00	20.0	6.00	86.88	31.62	92.46

No.	DEPTH	Free length	Brace Type
1	6.00	13.69	Tieback, Bond length = 23.63
2	16.00	8.61	Tieback, Bond length = 18.69

* VERTICAL LOADING *

Vertical Loading from Braces = 71.61

Vertical Loading from External Load = 0.00

Total Vertical Loading = 71.61

*****SPECIFIED PILE *****

Overall Maximum Moment = 77.50 at 11.40

The pile selection is based on the magnitude of the moment only. Axial force is neglected.

Request Min. Section Modulus = 18.60 in³/pile = 304.81 cm³/pile, Fy= 50 ksi = 345 MPa, Fb/Fy=1

HP14X89 has been found in Soldier Pile list!

(English Units):

Area= 26.1 in. Depth= 13.8 in. Width= 14.7 in. Height= 14 in.

Flange thickness= 0.615 in. Web thickness= 0.615 in.

Ix= 904 in⁴/pile Sx= 131 in³/pile Iy= 326 in⁴/pile Sy= 44.3 in³/pile

(Metric Units):

Ix= 376.24 x100cm⁴/pile Sx= 2146.70 cm³/pile Iy= 135.68 x100cm⁴/pile Sy= 725.94 cm³/pile

The pile selection is based on the magnitude of the moment only. Axial force is neglected.

HP14X89 is capable to support the shoring!

Top deflection = -0.006(in)

Max. deflection = 0.074(in)

***** LAGGING SIZE ESTIMATION *****

Max. Pressure above base = 1.75

Piles are more rigid than timber lagging, due to arching, only portion of pressures are acting to lagging, 30-50% loading is suggested.

If 50% loading is used for lagging design, Design Pressure = 0.88

Pile Spacing = 6.0, Max. Moment in lagging = 3.94

For 4"x12" Timber, Section Modules $S=23.47 \text{ in}^3$. The request allowable bending strength, $fb=M/S=2.02$

For 6"x12" Timber, Section Modules $S=57.98 \text{ in}^3$. The request allowable bending strength, $fb=M/S=0.82$

If 30% loading is used for lagging design, Design Pressure = 0.53

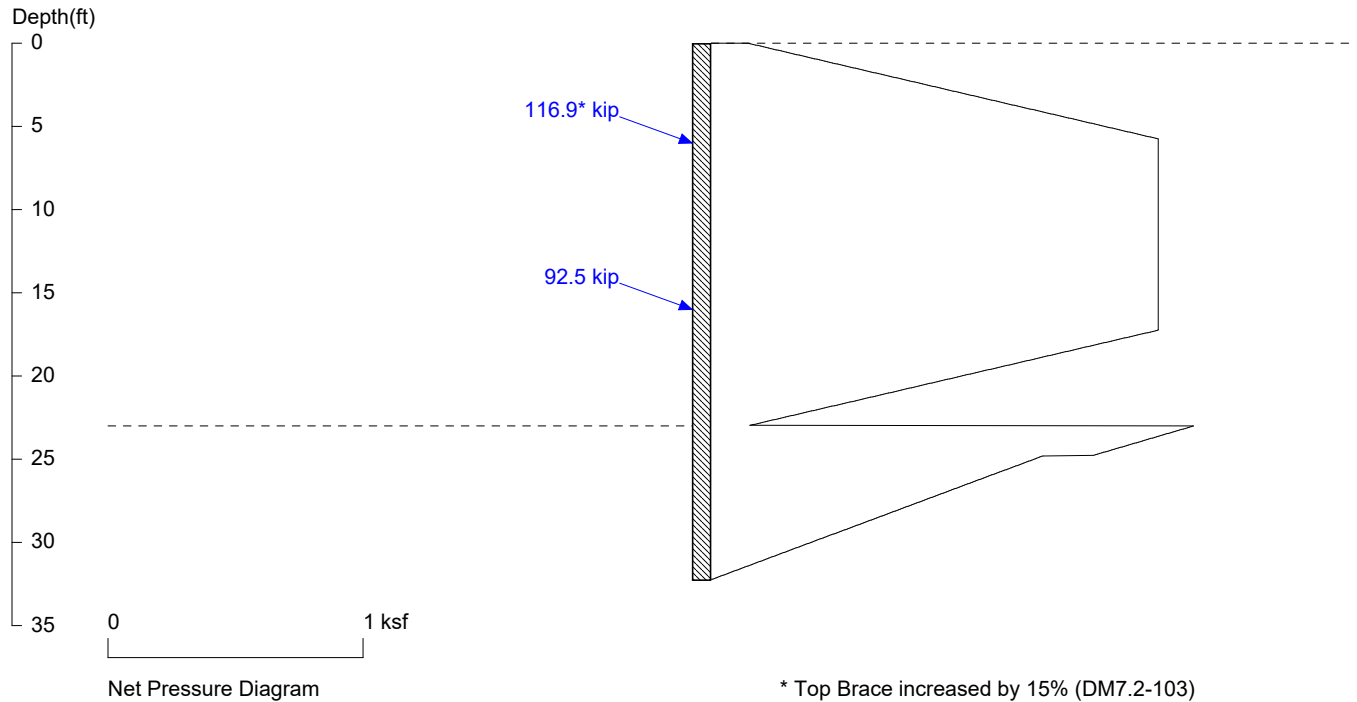
Pile Spacing = 6.0, Max. Moment in lagging = 2.37

For 4"x12" Timber, Section Modules $S=23.47 \text{ in}^3$. The request allowable bending strength, $fb=M/S=1.21$

For 6"x12" Timber, Section Modules $S=57.98 \text{ in}^3$. The request allowable bending strength, $fb=M/S=0.49$

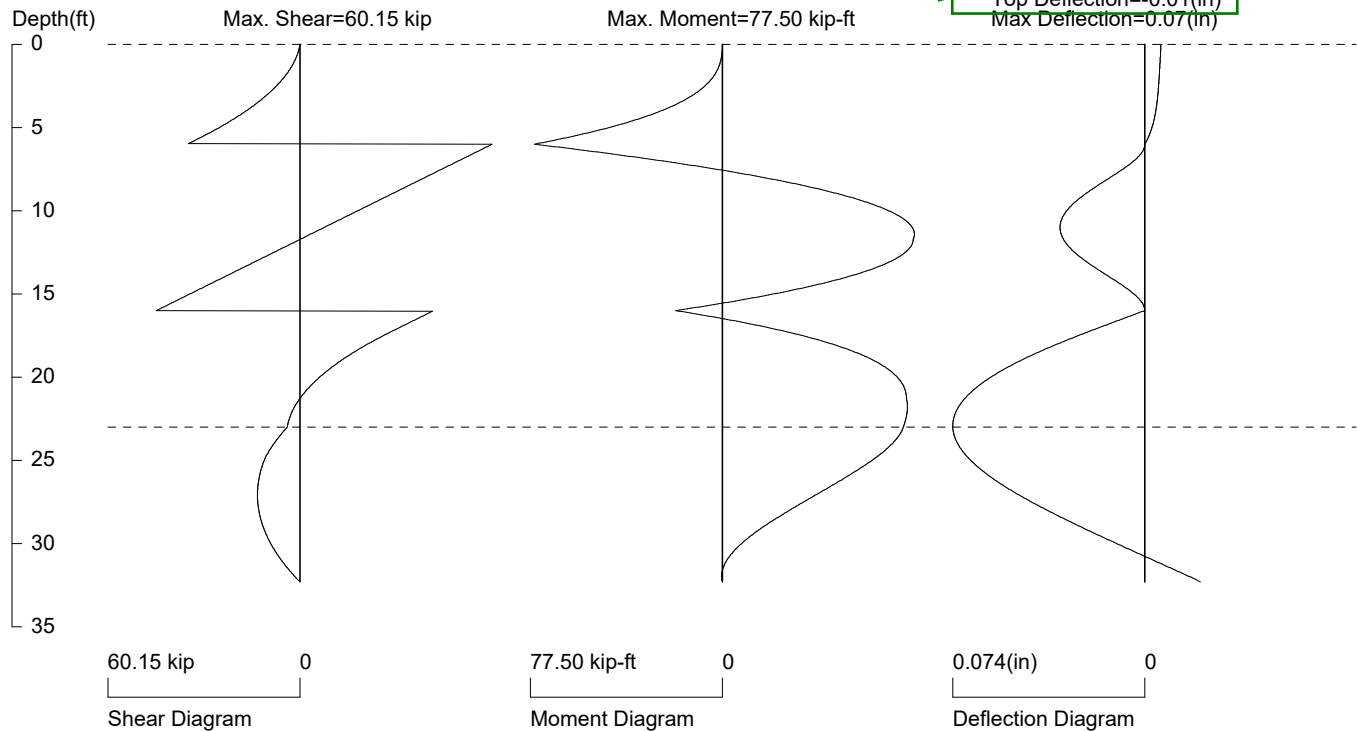
Unit: Pressure: ksf, Spacing: ft, Moment: kip-ft, Bending Strength, fb: ksi

WAS-77-9.58



Pile head deflection =

Top Deflection=-0.01(in)
Max Deflection=0.07(in)



PRESSURE, SHEAR, MOMENT, AND DEFLECTION DIAGRAMS

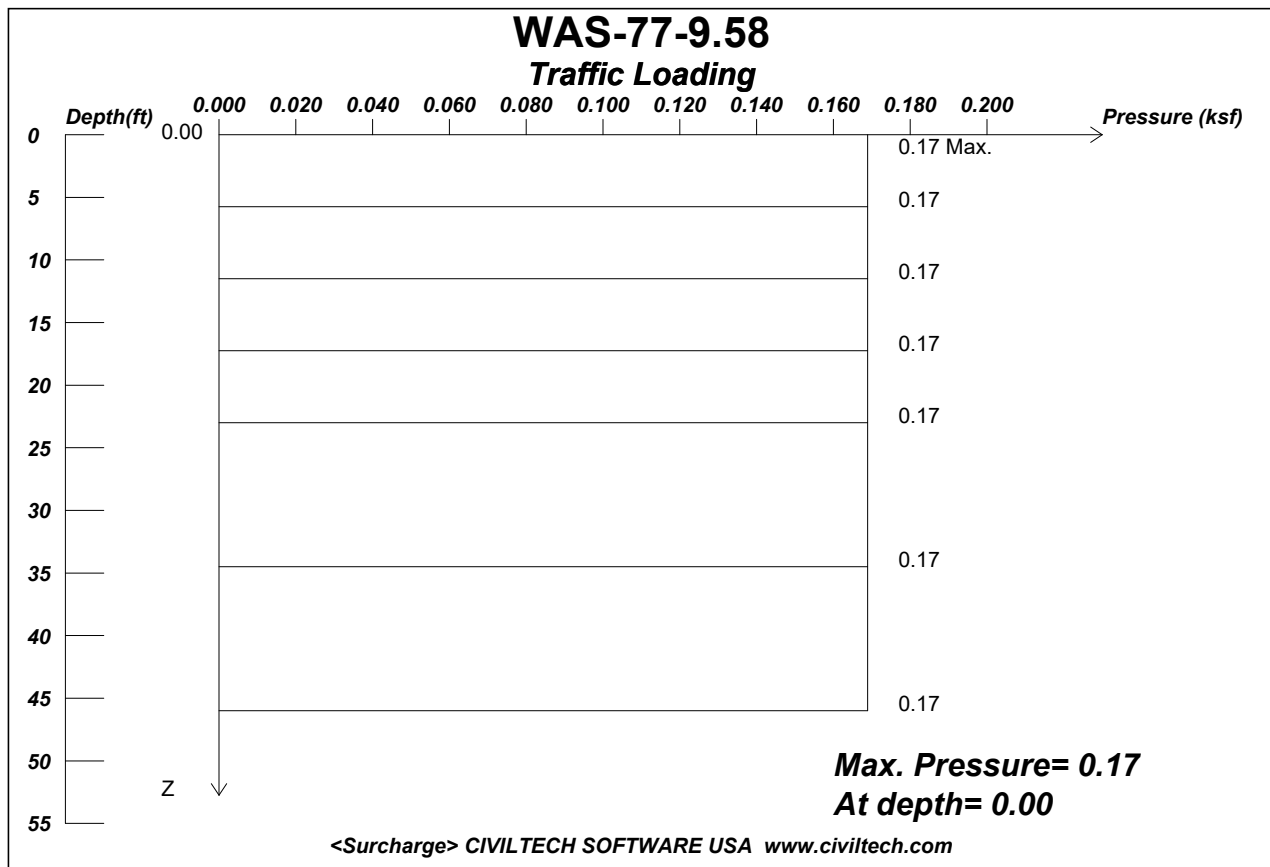
Based on pile spacing: 6.0 foot or meter

User Input Pile, HP14x89: E (ksi)=29000.0, I (in⁴)/pile=904.0

re: J:\ODOT-District 10 GES\Task 10-13 WAS-77-9.58\20250116_Redesign Calculations\20250116_Updated Analyses\WAS-77-9.58 23' Main Wall Tieback Service.sh

Traffic Surcharge Loading (Strength Limit)

Construction Traffic



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Wall Height, H= 23

Load Depth, D= 0

Load Factor of Surcharge Loading = 1.17

Rigid Wall Condition -- No movement or deflection of the wall are allowed.

Max. Pressure = 0.169 at depth = 0.00

Infinite Surcharge, Q=.250

Active Wedge Approach * (recommend)

A load factor of 1.5 is applied to all active loading in the wall analysis. As traffic loading uses 1.75, an extra factor has been applied here ($1.75/1.5 = 1.17$).

UNITS: LENGTH/DEPTH: ft, Qpoint: kip, Qline: kip/ft, Qstrip/Qarea/PRESSURE: ksf

SURCHARGE LOADS CALCULATION SUMMARY
<Surcharge>
Software Copyright by CivilTech Software
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Reference: Foundation Design, Wayne C. Teng, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1962

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WAS-77-9.58
Traffic Loading

Height of Wall = 23
Depth of Load = 0
Load Factor of Surcharge Loading = 1.17

Wall Condition:
Rigid Wall Condition -- No movement or deflection of the wall are allowed.

*****Loading*****

INFINITE SURCHARGE LOADING: Q=.250
Active Wedge Approach * (recommend)

*****Total Pressure Distribution*****

Max. Pressure =0.169 at depth =0.00

Depth	Pressure
0.00	0.169
1.15	0.169
2.30	0.169
3.45	0.169
4.60	0.169
5.75	0.169
6.90	0.169
8.05	0.169
9.20	0.169
10.35	0.169
11.50	0.169
12.65	0.169
13.80	0.169
14.95	0.169
16.10	0.169
17.25	0.169
18.40	0.169
19.55	0.169
20.70	0.169
21.85	0.169
23.00	0.169
25.30	0.169
27.60	0.169
29.90	0.169
32.20	0.169
34.50	0.169
36.80	0.169
39.10	0.169
41.40	0.169
43.70	0.169
46.00	0.169
50.60	0.169
55.20	0.169
59.80	0.169
64.40	0.169

Surcharge loading cut off at top of
rock (49.8 feet) in shoring module.

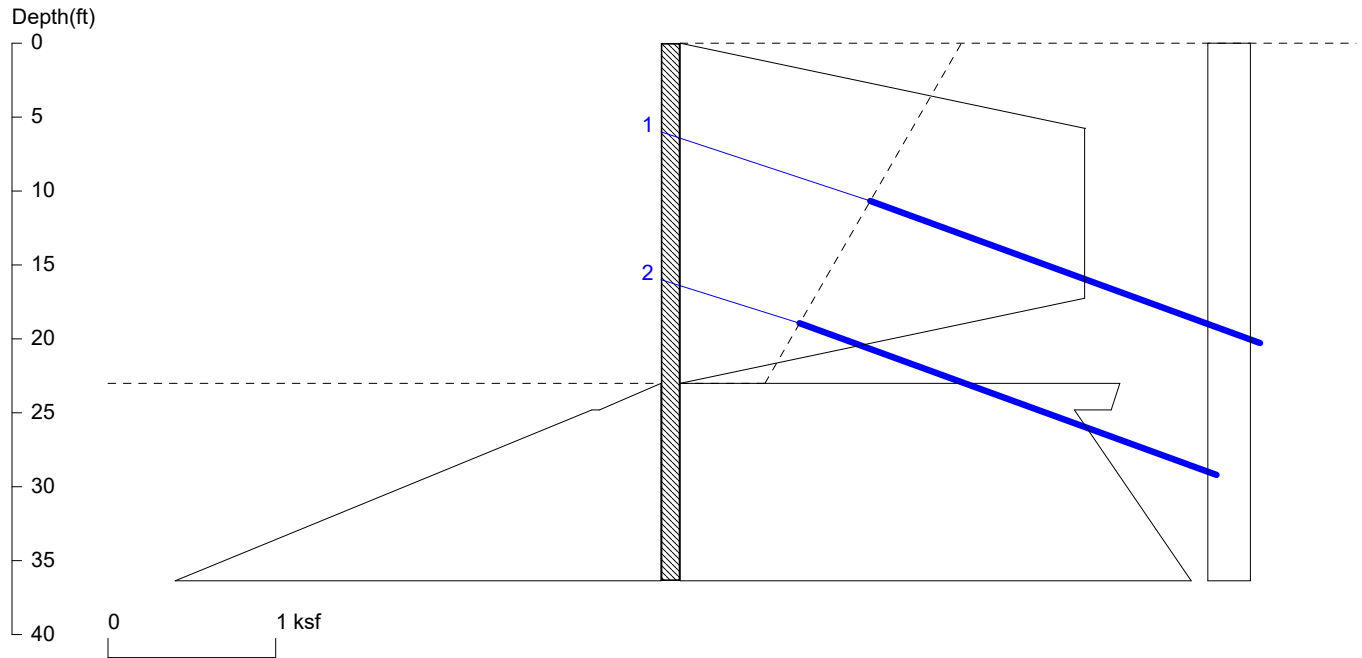
69.00	0.169
73.60	0.169
78.20	0.169
82.80	0.169
87.40	0.169
92.00	0.000

Depth Is Measured From Top of the Wall

LENGTH/DEPTH: ft, Qpoint: kip, Qline: kip/ft, Qstrip/Qarea/PRESSURE: ksf

Strength Limit

WAS-77-9.58



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Wall Height=23.0 Pile Diameter=2.5 Pile Spacing=6.0 Wall Type: 2. Soldier Pile, Drilled

PILE LENGTH: Min. Embedment=13.37 Min. Pile Length=36.37

MOMENT IN PILE: Max. Moment=150.35 per Pile Spacing=6.0 at Depth=23.55

Anchor loads and lengths

PILE SELECTION:

Request Min. Section Modulus = 36.1 in³/pile=591.29 cm³/pile, F_y= 50 ksi = 345 MPa, F_b/F_y=1

HP14X89 has Section Modulus = 131.0 in³/pile=2146.70 cm³/pile. It is greater than Min. Requirements!

Top Deflection = -0.01(in) based on E (ksi)=29000.00 and I (in⁴)/pile=904.0

BRACE FORCE: Strut, Tieback, Plate Anchor, Deadman, Sheet Pile as Anchor

No. & Type	Depth	Angle	Space	Total F.	Horiz. F.	Vert. F.	L _{free}	Fixed Length
1. Tieback	6.0	20.0	6.0	178.9*	168.1	61.2	13.7	36.2
2. Tieback	16.0	20.0	6.0	148.5	139.6	50.8	8.6	30.0

Unbonded Length Bonded Length

* Top Brace increased by 15% (DM7.2-103)

UNITS: Width,Diameter,Spacing,Length,Depth,and Height - ft; Force - kip; Bond Strength and Pressure - ksf

DRIVING PRESSURES (ACTIVE, WATER, & SURCHARGE): Pressures below will be multiplied by a Factor =1.5

Z1	P1	Z2	P2	Slope
*	Above	Base		
0.000	0.000	5.750	1.609	0.279817
5.750	1.609	17.25	1.609	0.000000
17.25	1.609	23.00	0.000	-0.27981
*	Below	Base		
23.00	1.749	24.80	1.715	-0.01870
24.80	1.569	44.80	2.371	0.040119
*	Sur-	charg		
0.000	0.169	1.150	0.169	0.000000
1.150	0.169	2.300	0.169	0.000000
2.300	0.169	3.450	0.169	0.000000

Applied 1.5 load factor for active earth pressures.

3.450	0.169	4.600	0.169	0.000000
4.600	0.169	5.750	0.169	0.000000
5.750	0.169	6.900	0.169	0.000000
6.900	0.169	8.050	0.169	0.000000
8.050	0.169	9.200	0.169	0.000000
9.200	0.169	10.35	0.169	0.000000
10.35	0.169	11.50	0.169	0.000000
11.50	0.169	12.65	0.169	0.000000
12.65	0.169	13.80	0.169	0.000000
13.80	0.169	14.95	0.169	0.000000
14.95	0.169	16.10	0.169	0.000000
16.10	0.169	17.25	0.169	0.000000
17.25	0.169	18.40	0.169	0.000000
18.40	0.169	19.55	0.169	0.000000
19.55	0.169	20.70	0.169	0.000000
20.70	0.169	21.85	0.169	0.000000
21.85	0.169	23.00	0.169	0.000000
23.00	0.169	25.30	0.169	0.000000
25.30	0.169	27.60	0.169	0.000000
27.60	0.169	29.90	0.169	0.000000
29.90	0.169	32.20	0.169	0.000000
32.20	0.169	34.50	0.169	0.000000
34.50	0.169	36.80	0.169	0.000000

PASSIVE PRESSURES:

Z1	P1	Z2	P2	Slope
*	Below	Base		
23.00	0.000	24.80	0.366	0.203551
24.80	0.411	44.80	4.711	0.214969

ACTIVE SPACING:

No.	Z depth	Spacing
1	0.00	6.00
2	23.00	2.50

PASSIVE SPACING:

No.	Z depth	Spacing
1	23.00	5.00

UNITS: Width,Spacing,Diameter,Length,and Depth - ft; Force - kip; Moment - kip-ft
Friction,Bearing,and Pressure - ksf; Pres. Slope - kip/ft³; Deflection - in

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UNITS: Width/Spacing/Diameter/Length/Depth - ft, Force - kip, Moment - kip-ft, Friction/Bearing/Pressure - ksf,
Pres. Slope - kip/ft³, Deflection - in

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Calculations\20250116_Updated Analyses\WAS-77-9.58 23' Main Wall Tieback Strength.sh8

Title: WAS-77-9.58

Subtitle:

*****INPUT DATA*****

Wall Type: 2. Soldier Pile, Drilled

Wall Height: 23.00
Pile Diameter: 2.50
Pile Spacing: 6.00
Factor of Safety (F.S.): 1.00
As Continuous Span Beam

Lateral Support Type (Braces): 3. Tieback

Top Brace Increase (Multi-Bracing): Add 15%*

No-Load Zone:

Vertical Depth for No-Load Zone: 23.00
H-Distance (Input H/V ratio) for No-Load Zone: 0.25
Angle from H. Line for No-Load Zone: 60.00

Embedment Option: 1. Yes

Friction at Pile Tip: No

Pile Properties:

Steel Strength, F_y : 50 ksi = 345 MPa
Allowable F_b/F_y : 1
Elastic Module, E : 29000.00
Moment of Inertia, I : 904.00
User Input Pile: HP14X89

* DRIVING PRESSURE (ACTIVE, WATER, & SURCHARGE) *

The pressures below will be multiplied by a Factor =1.5

No.	Z1 top	Top Pres.	Z2 bottom	Bottom Pres.	Slope
1	*	Above	Base		
2	0.000	0.000	5.750	1.609	0.279817
3	5.750	1.609	17.25	1.609	0.000000
4	17.25	1.609	23.00	0.000	-0.27981
5	*	Below	Base		
6	23.00	1.749	24.80	1.715	-0.01870
7	24.80	1.569	44.80	2.371	0.040119
8	44.80	2.085	49.80	2.277	0.038365
9	49.80	1.292	184.0	3.488	0.016366
10	*	Sur-	charg		
11	0.000	0.169	1.150	0.169	0.000000

12	1.150	0.169	2.300	0.169	0.000000
13	2.300	0.169	3.450	0.169	0.000000
14	3.450	0.169	4.600	0.169	0.000000
15	4.600	0.169	5.750	0.169	0.000000
16	5.750	0.169	6.900	0.169	0.000000
17	6.900	0.169	8.050	0.169	0.000000
18	8.050	0.169	9.200	0.169	0.000000
19	9.200	0.169	10.35	0.169	0.000000
20	10.35	0.169	11.50	0.169	0.000000
21	11.50	0.169	12.65	0.169	0.000000
22	12.65	0.169	13.80	0.169	0.000000
23	13.80	0.169	14.95	0.169	0.000000
24	14.95	0.169	16.10	0.169	0.000000
25	16.10	0.169	17.25	0.169	0.000000
26	17.25	0.169	18.40	0.169	0.000000
27	18.40	0.169	19.55	0.169	0.000000
28	19.55	0.169	20.70	0.169	0.000000
29	20.70	0.169	21.85	0.169	0.000000
30	21.85	0.169	23.00	0.169	0.000000
31	23.00	0.169	25.30	0.169	0.000000
32	25.30	0.169	27.60	0.169	0.000000
33	27.60	0.169	29.90	0.169	0.000000
34	29.90	0.169	32.20	0.169	0.000000
35	32.20	0.169	34.50	0.169	0.000000
36	34.50	0.169	36.80	0.169	0.000000
37	36.80	0.169	39.10	0.169	0.000000
38	39.10	0.169	41.40	0.169	0.000000
39	41.40	0.169	43.70	0.169	0.000000
40	43.70	0.169	46.00	0.169	0.000000
41	46.00	0.169	50.60	0.169	0.000000

Surcharge loading terminated at top of rock (approx 49.8 feet).

* PASSIVE PRESSURE *

No.	Z1 top	Top Pres.	Z2 bottom	Bottom Pres.	Slope
1	*	Below	Base		
2	23.00	0.000	24.80	0.366	0.203551
3	24.80	0.411	44.80	4.711	0.214969
4	44.80	5.269	49.80	6.663	0.278791
5	49.80	47	184.0	47	0.0000

* ACTIVE SPACE *

No.	Z depth	Spacing
1	0.00	6.00
2	23.00	2.50

Passive pressure for bedrock adjusted to 47 ksf based on an unconfined strength of 330 psi.

* PASSIVE SPACE *

No.	Z depth	Spacing
1	23.00	5.00

Hole diameter in feet (9 inches)

Allowable bond strength = resistance factor * ultimate bond strength = 0.7*3 ksf

* BRACE: STRUT, TIEBACK, ANCHOR PLATE, DEADMAN, OR SHEET PILE AS ANCHOR*

No.	Z brace	Angle	Spacing	Input1*	Input2*	Type
1	6.00	20.0	6.00	0.75	2.10	Tieback
2	16.00	20.0	6.00	0.75	2.10	Tieback

*For Tieback: Input1 = Diameter; Input2 = Bond Strength

*For Plate: Input1 = Diameter; Input2 = Allowable Pressure

*For Deadman: Input1 = Horz. Width; Input2 = Passive Pressure;

*For Sheet Pile Anchor: Input1 = Horz. Width; Input2 = Passive Slope;

*****CALCULATION*****

The calculated moment and shear are per pile spacing. Sheet piles are per one foot or meter; Soldier piles are per pile.

Top Pressures start at depth = 0.00

* CALCULATE REQUEST EMBEDMENT *

```
|<-- D1=16.00
|
==|== D2=23.00
|
|      D3=36.37
```

D1 - TOP DEPTH R1 - TOP REACTION
D2 - EXCAVATION BASE
D3 - PILE TIP

TOTAL REACTION: R1 = 71.35
TOTAL PRESSURES ACTING ON WALL = 71.35
Total Reactions = Total Pressures, OK!
The Calculated Embedment, Yend = 13.37

-----MULTIPLE BRACE / TIEBACK CASE-----
** Use the calculated embedment, Yend = 13.37 for graphics and analysis.

NUMBER OF BRACE LEVEL= 2

* CANTILEVER SPAN, N0.0 *

```
|      D1=0.00
|
|<-- D2=6.00                      R2=54.38, with Cantilever Moment=118.03
```

D1 - TOP DEPTH
D2 - BOTTOM DEPTH R2 - BOTTOM REACTION

TOTAL REACTION: R2 = 54.38
TOTAL PRESSURES ACTING ON WALL = 54.38
Total Reactions = Total Pressures, OK!

BRACE NO.1 AT DEPTH = 6.00
R2 of Span No.0 } Sum of Reaction = Brace Load = 146.19
R1 of Last Span

* LAST SPAN *

```
|<-- D1=6.00                      R1=91.81
|
|<-- D2=16.00                      R2=139.56
|
|      D3=36.37
```

D1 - TOP DEPTH R1 - TOP REACTION
D2 - LAST BRACE DEPTH R2 - LAST BRACE REACTION
D3 - BOTTOM DEPTH

TOTAL REACTION: R1+R2 = 231.37
TOTAL PRESSURES ACTING ON WALL = 231.37
Total Reactions >= Total Pressures, OK!

BRACE NO.2 AT DEPTH = 16.00
R2 of Last Span = Brace Load = 139.56

*****RESULTS*****

* EMBEDMENT *

MINIMUM EMBEDMENT = 13.37, TOTAL MINIMUM PILE LENGTH = 36.37

* MOMENT IN PILE (per pile spacing)*

Pile Spacing: sheet piles are one foot or one meter; soldier piles are one pile.

No.	Depth	M @ Brace	Mmax in Span	Depth of Mmax
1	6.00	117.37	117.06	11.41
2	16.00	31.97	150.35	23.55

Overall Maximum Moment = 150.35 at 23.55

Maximum Shear = 91.36

Moment and Shear are per pile spacing: 6.0 foot or meter

-> Top Brace Increase 15%. (Horizontal) From 146.19 to 168.12

* BRACE: STRUT, TIEBACK, ANCHOR PLATE, DEADMAN, OR SHEET PILE AS ANCHOR*

The calculated brace force are per brace spacing.

No.	DEPTH	Tangle	SPACING	HORIZONTAL	VERTICAL	TOTAL LOAD
1	6.00	20.0	6.00	168.12	61.19	178.91
2	16.00	20.0	6.00	139.56	50.79	148.51

No.	DEPTH	Free length	Brace Type
1	6.00	13.69	Tieback, Bond length = 36.16
2	16.00	8.61	Tieback, Bond length = 30.01

* VERTICAL LOADING *

Vertical Loading from Braces = 111.98

Vertical Loading from External Load = 0.00

Total Vertical Loading = 111.98

*****SPECIFIED PILE *****

Overall Maximum Moment = 150.35 at 23.55

The pile selection is based on the magnitude of the moment only. Axial force is neglected.

Request Min. Section Modulus = 36.08 in³/pile = 591.29 cm³/pile, Fy= 50 ksi = 345 MPa, Fb/Fy=1

HP14X89 has been found in Soldier Pile list!

(English Units):

Area= 26.1 in. Depth= 13.8 in. Width= 14.7 in. Height= 14 in.

Flange thickness= 0.615 in. Web thickness= 0.615 in.

Ix= 904 in⁴/pile Sx= 131 in³/pile Iy= 326 in⁴/pile Sy= 44.3 in³/pile

(Metric Units):

Ix= 376.24 x100cm⁴/pile Sx= 2146.70 cm³/pile Iy= 135.68 x100cm⁴/pile Sy= 725.94 cm³/pile

The pile selection is based on the magnitude of the moment only. Axial force is neglected.

HP14X89 is capable to support the shoring!

Top deflection = -0.007(in)

Max. deflection = 0.226(in)

***** LAGGING SIZE ESTIMATION *****

Max. Pressure above base = 2.67

Piles are more rigid than timber lagging, due to arching, only portion of pressures are acting to lagging, 30-50%

loading is suggested.

If 50% loading is used for lagging design, Design Pressure = 1.33

Pile Spacing = 6.0, Max. Moment in lagging = 6.00

For 4"x12" Timber, Section Modules $S=23.47 \text{ in}^3$. The request allowable bending strength, $fb=M/S=3.07$

For 6"x12" Timber, Section Modules $S=57.98 \text{ in}^3$. The request allowable bending strength, $fb=M/S=1.24$

If 30% loading is used for lagging design, Design Pressure = 0.80

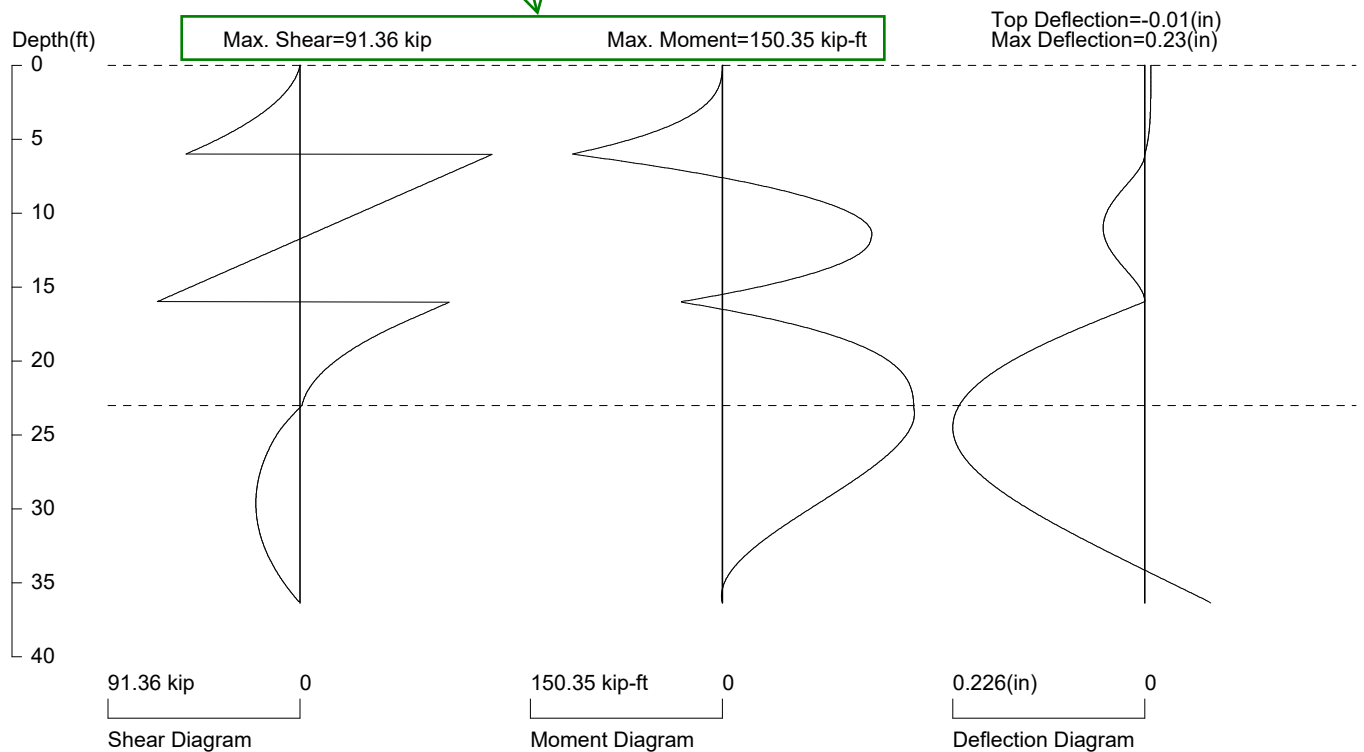
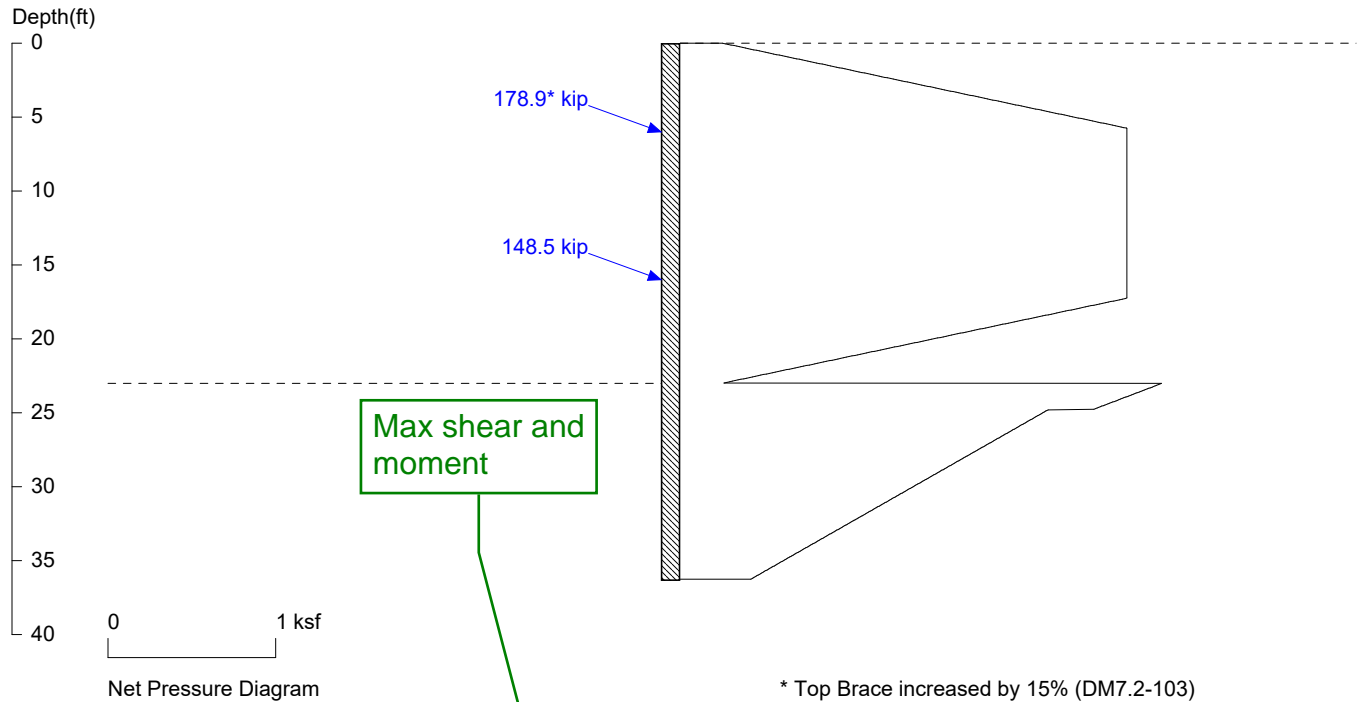
Pile Spacing = 6.0, Max. Moment in lagging = 3.60

For 4"x12" Timber, Section Modules $S=23.47 \text{ in}^3$. The request allowable bending strength, $fb=M/S=1.84$

For 6"x12" Timber, Section Modules $S=57.98 \text{ in}^3$. The request allowable bending strength, $fb=M/S=0.75$

Unit: Pressure: ksf, Spacing: ft, Moment: kip-ft, Bending Strength, fb: ksi

WAS-77-9.58



PRESSURE, SHEAR, MOMENT, AND DEFLECTION DIAGRAMS

Based on pile spacing: 6.0 foot or meter

User Input Pile, HP14X89: E (ksi)=29000.0, I (in4)/pile=904.0

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