Ground Support PLLC

15704 NE 157th Street
Woodinville, WA 98072
Phone 425.985.9338

Design Memorandum

PROJECT: Cheshire (Project No. 23-30)

ADDRESS: 7615 E Mercer Way
Mercer Island, WA 98040

CLIENT: Long View Bella, LLC
7615 East Mercer Way
Mercer Island, WA 98040
Attention: Mr. Derek Cheshire

DATE: November 20, 2023

REFERENCES:

1. "Geotechnical Report, Cheshire Short Plat, 7615 East Mercer Way, Mercer Island, Washington", prepared by Terra Associates, Inc., dated November 22, 2023.
2. 2018 International Building Code.
3. "Geotechnical Engineering Circular No. 4, Ground Anchors and Anchored Systems", FHWA, dated June 1999.

11-20-2023

BACKGROUND:

The planned residential project is located at 7615 E Mercer Way on Mercer Island, Washington. The site is bounded by SE76th Street to the north, E Mercer Way to the southeast and an adjacent property to the northwest. The site slopes to the east and southeast from elevation 126 feet along the northwest property line to 100-114 feet along the southeast property line. A new residence is planned for the central area of the site. Excavations for the installation of building foundations will extend to elevation 107 feet. Temporary shoring is required along the south, west and north sides of the planned residence. The overall length of the required shoring wall is 130 feet, with depths of excavation ranging up to 18 feet and an overall shored surface area of 1750 square feet.

The south and west shoring walls will be set back on the order of 5 feet from the residence and the space between the residence and the wall will be backfilled to elevation 118.5 feet along the west side. The upper portions of the south and west walls will also serve as a permanent retaining wall supporting the final grade changes between the backfilled areas and the existing topography. The permanent retaining wall will have a maximum height of 7 feet.

SUBSURFACE CONDITIONS:

The geotechnical report indicates that the subsurface soils consist of several feet of dense fill overlying 7 to 13 feet of medium dense to dense silty sand over medium dense to dense silt. Groundwater seepage was noted within the sandier soils.

SHORING/RETAINING WALL SYSTEM:

For this application, a soldier pile system with wood lagging offers the technically preferred shoring approach. For the planned depths of excavation, both cantilevered soldier piles and soldier piles supported by a single row of tieback anchors will be used. The upper portions of the soldier piles installed for temporary shoring will also be used to provide permanent support as a cantilevered soldier pile retaining wall. A permanent shotcrete facing will be attached to the cantilevered soldier piles.

DESIGN PARAMETERS:

Design earth pressures corresponding to the soil self-weight are recommended in the geotechnical report. For both cantilevered soldier piles and soldier piles that are supported by a single row of anchors, a soil self-weight design earth loading of 35 pcf was used.

Live load lateral surcharge pressures are as presented on the Plans to account for general surface surcharge loading and are taken as 75 psf. For the permanent retaining wall condition, an additional seismic earth pressure of 10H psf (H=height of the wall in feet) was applied.

The following design values were used to evaluate the depth of embedment of the soldier piles below the base of the excavation:

Passive Equivalent Fluid Density	250 pcf over 2 pile diameters
Allowable Pile End Bearing	15 ksf
Allowable Pile Skin Friction	1.5 ksf

DESIGN:

Anchors:

Individual anchor loads are developed from the design earth pressure diagrams presented on the Plans, using a tributary area method to assign loads to the individual anchors and to the toe shear in the piles. Anchor lengths are then determined from the no-load zone (see Plans) and the required bond zone. The length of the bond zone is determined from the anchor design load and the allowable pullout value. An allowable pullout resistance of 2 kips per linear foot (klf) has been used for all anchors. Anchor designs are presented in Appendix A.

Soldier Piles:

Soldier pile loadings are determined from the design earth pressure diagrams and the locations and inclinations of the anchors. The spreadsheet output presented in Appendix B summarizes the following design aspects for both the shoring piles and the toe piles that support the rakers:

- Calculation of soldier pile loads and bending moments, consistent with the design apparent earth pressure diagrams provided on the Plans. For each soldier pile, the calculated shear force, axial load and bending moment are provided. Representative earth pressure diagrams, together with calculated shear force and bending moment diagrams, are shown for a number of piles, in Appendix B.
- Calculation of pile toe embedment requirements using the criteria indicated on the Plans.
- Pile structural steel sizing in accordance with the AISC 360-18 Specification for Structural Steel Buildings. Combined flexure and axial load, shear, and compact section steel design checks are performed for the critically loaded section of each pile along the length of the wall. The spreadsheet output summarizes the minimum steel section required for each pile.

Both the temporary shoring and the permanent retaining wall conditions are addressed in Appendix B.

Anchor/Pile Connections:

The designs of the connections of the anchors to the soldier piles are summarized in Table 1. Required weld lengths and connection plate sizes were determined in accordance with AISC 360-18 and for Grade 50 steel plates and E70XX weld electrodes.

Lagging:

Timber lagging will be used to support the soil between adjacent soldier piles. The average design earth pressures for the lagging are indicated in Appendix A, and these design earth pressures are derived directly from the design earth pressure diagrams. Hem-Fir No. 2 lagging (4-inch) or equivalent will provide adequate support for the soil between the soldier piles, per the recommendations of the FHWA Engineering Circular No. 4.

Permanent Facing:

A permanent shotcrete facing will be used to retain the soil between the piles for the upper part of the system that will be used as a permanent retaining wall. The shotcrete facing will be attached to the soldier piles by headed studs welded to the piles and embedded within the shotcrete facing. Design calculations for the facing and connection are presented in Appendix C.

TABLES

ANCHOR POCKET DESIGN SPREADSHEET **VERSION 2.0 (7/24/01)**

DESIGN ASSUMPTIONS

E70XX Electrodes For All Welding
Cover Plates Welded to Flange at Each End, Along Narrow End & Returned Down Edge Along Pile Web
Web Stiffener Plates Are Full Depth, Are Flush At Bearing End, & Welded Full Length & Along Bearing End On One Side Only

CONNECTION INPUT DATA

Case	Pile Section	Pile Grade (ksi)	Plate Steel Grade (ksi)	Design Anchor Load (k)	Actual Design Pile Moment (ft-k)	Max Design Pile Moment (ft-k)	Flange Width b_f (in)	Flange Thick t_f (in)	Beam Depth d (in)	Web Thick t_w (in)	Max Cutout Width (in)	Max Cutout Area (in^2)
1	W14x34	50.0	50.0	40.0	133.7	133.7	6.750	0.455	14.000	0.285	3.23	1.47

DESIGN CALCULATIONS FOR COVER PLATE

Case	Max Cutout Force (k)	Design Cutout Force (k)	Cover Plate E70XX Weld Size (in)	Req'd Weld Length L (in)	Design Weld Length L (in)	Design Weld Width (in)	Req'd Weld Return Length (in)	Design Cover Plate Thick (in)	Req'd Cover Plate Width (in)	Design Cover Plate Width (in)	Req'd Cover Plate Length (in)	Design Cover Plate Length (in)
1	48.5	48.5	0.2500	13.1	13.0	2.5	10.5	0.500	2.94	3.00	27.0	27.0

DESIGN CALCULATIONS FOR WEB STIFFENER

Case	Single Stiffener Force (k)	Total Stiffener E70XX Weld Size (in)	Stiffener Thickness (in)	Req'd Weld Length (in)	Design Weld & Stiffener Length (in)	Req'd Stiffener Compress Area (in^2)	Req'd Stiffener Width (in)	Design Stiffener Width (in)	Stiffener "b/t" Ratio	Allowable Stiffener "b/t" Ratio
1	20.0	0.2500	0.500	5.4	12.0	0.667	1.3	4.0	8.0	10.7

TABLE 1
ANCHOR POCKET DESIGN

APPENDIX A

ANCHOR DESIGN

							Anchor 1						Design	Pile Top	Pile Toe	Pile Toe	Pile	Lagging
					L=NH^2	Unif. Press.	Elevation	Angle	Anchor Load	No. of	Total Length	Bond Length	Beam	Elevation	Embed	Elevation	Length	Pressure
Pile ID	Station (ft)	Height (ft)	Spacing (ft)	No. Anchors	N (psf/ft)	P (psf)	(feet)	(degrees)	(kips)	Strands	(feet)	(feet)		(feet)	(feet)	(feet)	(feet)	(psf)
S1	56	3.8	7	0	17.5	75	0.00	0	0	0	0.0	0.0	W14x34	111.0	8.0	99.0	12.0	209
S2	64.5	6.1	8.5	0	17.5	75	0.00	0	0	0	0.0	0.0	W14x34	113.3	11.0	96.0	17.3	288
S3	73	9.0	8.5	0	17.5	75	0.00	0	0	0	0.0	0.0	W14x43	116.0	14.9	92.0	24.0	390
S4	81.5	12.0	8.25	1	17.5	75	115.00	25	23	1	30.0	15.0	W14x34	119.0	8.0	99.0	20.0	493
S5	89.5	14.2	8	1	17.5	75	116.50	25	29	1	30.0	15.0	W14x34	121.3	8.0	99.0	22.3	573
S6	97.5	16.3	6.5	1	17.5	75	118.00	25	30	1	30.0	15.0	W14x34	123.5	8.0	99.0	24.5	647
W1	202.3	17.7	6	1	17.5	75	119.00	25	31	1	30.8	15.8	W14x34	124.8	8.0	99.0	25.8	693
W2	209.3	17.8	7	1	17.5	75	119.00	25	37	2	33.8	18.8	W14x34	125.0	8.0	99.0	26.0	698
W3	216.3	18.0	7	1	17.5	75	119.00	25	38	2	34.0	19.0	W14x34	125.0	8.0	99.0	26.0	704
W4	223.3	18.1	7	1	17.5	75	119.00	25	38	2	34.2	19.2	W14x34	125.3	8.0	99.0	26.3	707
W5	230.3	17.9	7.5	1	17.5	75	119.00	25	40	2	35.3	20.3	W14x34	125.0	8.0	99.0	26.0	702
W6	238.3	17.7	8	1	17.5	75	119.00	25	42	2	36.2	21.2	W14x34	124.8	8.0	99.0	25.8	694
W7	246.3	17.4	8	1	17.5	75	118.50	25	41	2	35.6	20.6	W14x34	124.5	8.0	99.0	25.5	683
W8	254.3	16.7	7	1	17.5	75	118.00	25	33	1	31.8	16.8	W14x34	123.8	8.0	99.0	24.8	659
N1	303	14.2	6.5	1	17.5	75	116.50	25	24	1	30.0	15.0	W14x34	121.3	8.0	99.0	22.3	572
N2	310	10.5	7	0	17.5	75	0.00	0	0	0	0.0	0.0	W14x48	117.5	15.7	91.3	26.3	443
N3	317	9.3	7	0	17.5	75	0.00	0	0	0	0.0	0.0	W14x34	116.3	14.1	92.8	23.5	399
N4	324	3.4	7	0	17.5	75	0.00	0	0	0	0.0	0.0	W14x34	110.5	8.0	99.0	11.5	195

TABLE A1
TEMPORARY ANCHOR DESIGN

APPENDIX B

SOLDIER PILE DESIGN

		Soldier Beam Loads-Below Anchor 1					Pile Vertical Load Analysis								Toe Dist. Depth (ft) 2	Pile Vertical Punching Analysis									
Pile ID	Design Beam	Axial Load (kips)	Moment (ft-kips)	Free Length (feet)	Steel Section	Flex/Ax Ratio	Pile Diameter (ft)	Pile End Area (ft^2)	Pile Skin Area (ft^2/ft)	Pile End Bear (ksf)	Pile Skin Frict (ksf)	End Bearing (kips)	Skin Friction (klf)	Axial Load (kips)	Embed Length (ft)	Pile Depth (in)	Pile Flange (in)	Pile End Area (ft^2)	Pile Skin Area (ft^2/ft)	Pile End Bear (ksf)	Pile Skin Frict (ksf)	End Bearing (kips)	Skin Friction (klf)	Axial Load (kips)	Embed Length (ft)
S1	W14x34	0	19	3.83	W14x34	0.14	2.00	3.14	6.28	15.00	1.50	47.1	9.4	0	0.0	14	6.75	0.66	3.46	15	0.5	0.0	1.8	0	0.0
S2	W14x34	0	64	6.08	W14x34	0.47	2.00	3.14	6.28	15.00	1.50	47.1	9.4	0	0.0	14	6.75	0.66	3.46	15	0.7	0.0	2.6	0	0.0
S3	W14x43	0	160	8.99	W14x43	0.92	2.00	3.14	6.28	15.00	1.50	47.1	9.4	0	0.0	13.7	8	0.76	3.62	15	1.0	0.0	3.8	0	0.0
S4	W14x34	10	44	7.99	W14x34	0.34	2.00	3.14	6.28	15.00	1.50	47.1	9.4	10	-2.0	14	6.75	0.66	3.46	15	0.9	9.8	3.0	10	-0.1
S5	W14x34	12	69	9.50	W14x34	0.53	2.00	3.14	6.28	15.00	1.50	47.1	9.4	12	-1.7	14	6.75	0.66	3.46	15	1.0	9.8	3.4	12	0.7
S6	W14x34	13	81	10.91	W14x34	0.62	2.00	3.14	6.28	15.00	1.50	47.1	9.4	13	-1.7	14	6.75	0.66	3.46	15	1.1	9.8	3.7	13	0.8
W1	W14x34	13	92	11.79	W14x34	0.70	2.00	3.14	6.28	15.00	1.50	47.1	9.4	13	-1.6	14	6.75	0.66	3.46	15	1.1	9.8	3.9	13	0.9
W2	W14x34	16	111	11.90	W14x34	0.85	2.00	3.14	6.28	15.00	1.50	47.1	9.4	16	-1.3	14	6.75	0.66	3.46	15	1.1	9.8	3.9	16	1.5
W3	W14x34	16	114	12.00	W14x34	0.87	2.00	3.14	6.28	15.00	1.50	47.1	9.4	16	-1.3	14	6.75	0.66	3.46	15	1.1	9.8	4.0	16	1.6
W4	W14x34	16	116	12.07	W14x34	0.89	2.00	3.14	6.28	15.00	1.50	47.1	9.4	16	-1.3	14	6.75	0.66	3.46	15	1.1	9.8	4.0	16	1.6
W5	W14x34	17	122	11.96	W14x34	0.93	2.00	3.14	6.28	15.00	1.50	47.1	9.4	17	-1.2	14	6.75	0.66	3.46	15	1.1	9.8	3.9	17	1.8
W6	W14x34	18	126	11.81	W14x34	0.96	2.00	3.14	6.28	15.00	1.50	47.1	9.4	18	-1.1	14	6.75	0.66	3.46	15	1.1	9.8	3.9	18	2.1
W7	W14x34	17	120	11.60	W14x34	0.91	2.00	3.14	6.28	15.00	1.50	47.1	9.4	17	-1.2	14	6.75	0.66	3.46	15	1.1	9.8	3.9	17	1.9
W8	W14x34	14	93	11.15	W14x34	0.71	2.00	3.14	6.28	15.00	1.50	47.1	9.4	14	-1.5	14	6.75	0.66	3.46	15	1.1	9.8	3.8	14	1.1
N1	W14x34	10	55	9.49	W14x34	0.42	2.00	3.14	6.28	15.00	1.50	47.1	9.4	10	-1.9	14	6.75	0.66	3.46	15	1.0	9.8	3.4	10	0.0
N2	W14x48	0	186	10.50	W14x48	0.95	2.00	3.14	6.28	15.00	1.50	47.1	9.4	0	0.0	13.8	8.03	0.77	3.64	15	1.2	0.0	4.2	0	0.0
N3	W14x34	0	136	9.25	W14x34	1.00	2.00	3.14	6.28	15.00	1.50	47.1	9.4	0	0.0	14	6.75	0.66	3.46	15	1.0	0.0	3.6	0	0.0
N4	W14x34	0	15	3.42	W14x34	0.11	2.00	3.14	6.28	15.00	1.50	47.1	9.4	0	0.0	14	6.75	0.66	3.46	15	0.5	0.0	1.7	0	0.0

TABLE B1
SOLDIER PILE DESIGN - TEMPORARY SHORING CONDITION

Wall Height (ft)	8.99
Depth of Embed (ft)	14.86
Depth to Top of Passive (ft)	10.99

	Force	p (psf)	K_γ (psf)	h (ft)	w (ft)	phw (lbf)	$K_\gamma h^2 w/2$ (lbf)	depth (ft)	moment arm (ft)	moment (ft-lbf)
Driving	A1	75.0		8.99	8.50	5729		4.49	19.35	110880
	A2		35.0	8.99	8.50		12015	5.99	17.85	214522
	A3	314.6		14.86	2.00	9348		16.42	7.43	69452
	A4		35.0	14.86	2.00		7728	18.89	4.95	38277
Resisting	P1	500.0		12.86	4.00	25718		17.42	6.43	165359
	P2		250.0	12.86	4.00		82680	19.56	4.29	354398
	P3	0.0		0.00	4.00	0		23.85	0.00	0
	P4		0.0	0.00	4.00		0	23.85	0.00	0

Moments about pile toe

Sum of resisting moments (ft-lbf)	519757
Sum of driving moments (ft-lbf)	433131
FS	1.20

Depth to Zero Shear (ft) at "M"	16.21

	Force	p (psf)	K_γ (psf)	h (ft)	w (ft)	phw (lbf)	$K_\gamma h^2 w/2$ (lbf)	depth (ft)	moment arm (ft)	moment (ft-lbf)
Driving	a1	75.0		8.99	8.50	5729		4.49	11.72	67156
	a2		35.0	8.99	8.50		12015	5.99	10.22	122831
	a3	314.6		7.23	2.00	4547		12.60	3.61	16432
	a4		35.0	7.23	2.00		1828	13.81	2.41	4405
Resisting	p1	500.0		5.23	4.00	10455		13.60	2.61	27328
	p2		250.0	5.23	4.00		13664	14.47	1.74	23810
	p3	0.0		0.00	4.00	0		0.00	16.21	0
	p4		0.0	0.00	4.00		0	0.00	16.21	0

Moments at Zero Shear Point

Sum of shear forces (lbf) at "M"	0
Sum of moments (ft-lbf) at "M"	159685

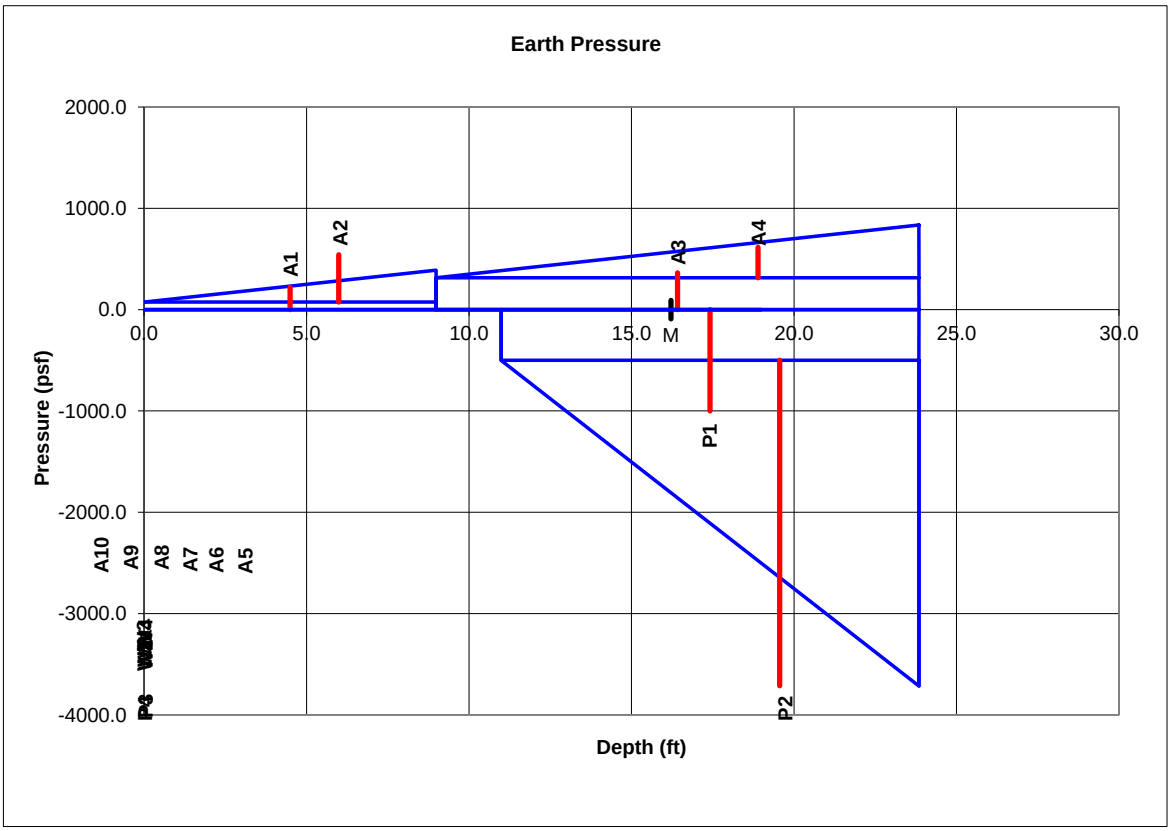
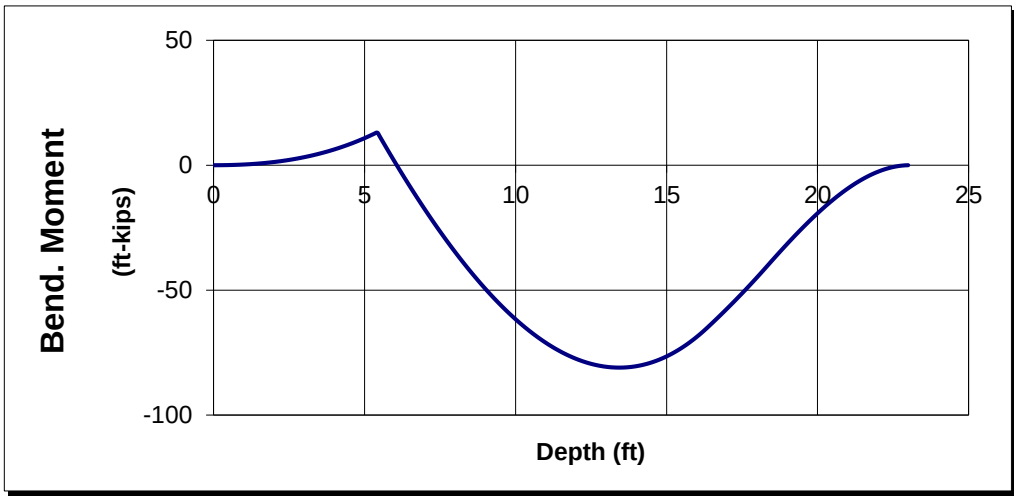
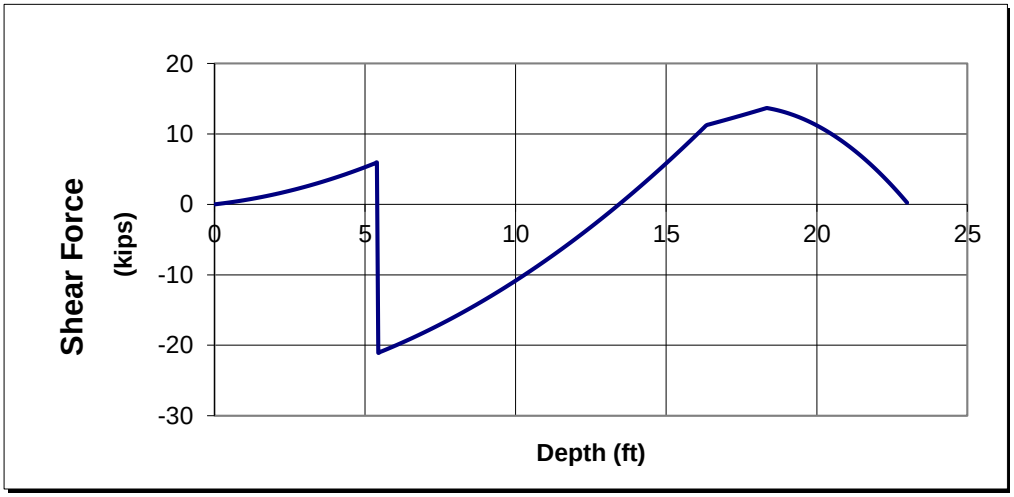
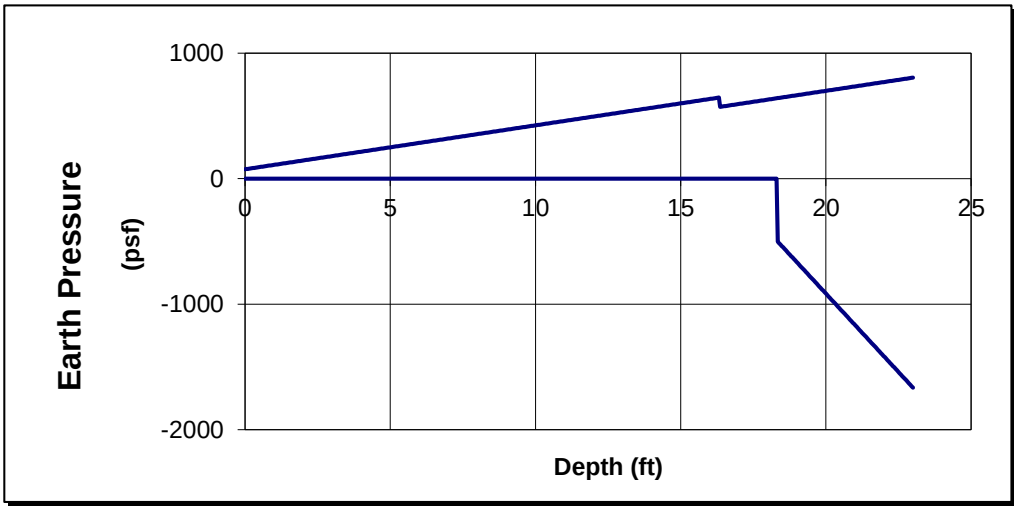


FIGURE B1 SOLDIER BEAM - S3







Wall Height (ft)	**16.3**
Pile Spacing (ft)	**6.50**

FIGURE B2 SOLDIER BEAM - S6

Point	Depth	Pressure	Width		Force	Depth(CG)	Moment
A	0.00	0.0	6.50	F_{AB}	30362	10.89	368997
B	16.34	571.8	6.50	F_{BC}	0	0.00	0
C	16.34	571.8	6.50	F_{CD}	0	0.00	0
D	16.34	0.0	6.50	F_{AD}	30362	10.89	
	16.34	0.0					
E	16.34	571.8	2.00	F_{EF}	9245	19.88	29244
F	23.04	806.6	2.00				
	23.04	0.0					
G	18.34	0.0	4.00	F_{GH}	0	0.00	0
H	18.34	-500.0	4.00	F_{HI}	-20493	21.12	-39541
I	23.04	-1676.8	4.00	F_{IJ}	0	0.00	0
J	23.04	-1676.8	4.00	F_{JK}	0	0.00	0
K	23.04	-1676.8	4.00	F_{GK}	-20493	21.12	
	23.04	0.0					
	0.00	0.0					
L	0.00	75.0	6.50	F_{LM}	7965	8.17	118483
M	16.34	75.0	6.50				
	16.34	0.0					
	0.00	0.0					
N	0.00	0.0	6.50	F_{NO}	0	0.00	0
O	0.00	0.0	6.50				
	0.00	0.0					
	0.00	0.0					
P	0.00	0.0	6.50	F_{PQ}	0	0.00	0
Q	0.00	0.0	6.50				
	0.00	0.0					
	0.00	0.0					
R	0.00	0.0	6.50	F_{RS}	0	0.00	0
S	0.00	0.0	6.50				
	0.00	0.0					
T	16.34	0.0	6.50	F_{TU}	0	0.00	0
U	16.34	0.0	6.50	F_{UV}	0	0.00	0
V	16.34	0.0	6.50	F_{VW}	0	0.00	0
W	23.04	0.0	6.50	F_{TW}	0	0.00	
	23.04	0					
				Anchor 1	27079	5.42	477183
				Amchor 2	0	0.00	0
				Anchor 3	0	0.00	0
				Anchor 4	0	0.00	0
				Load 1	0	0.00	0
				Σ Forces	0	Σ Moments	0

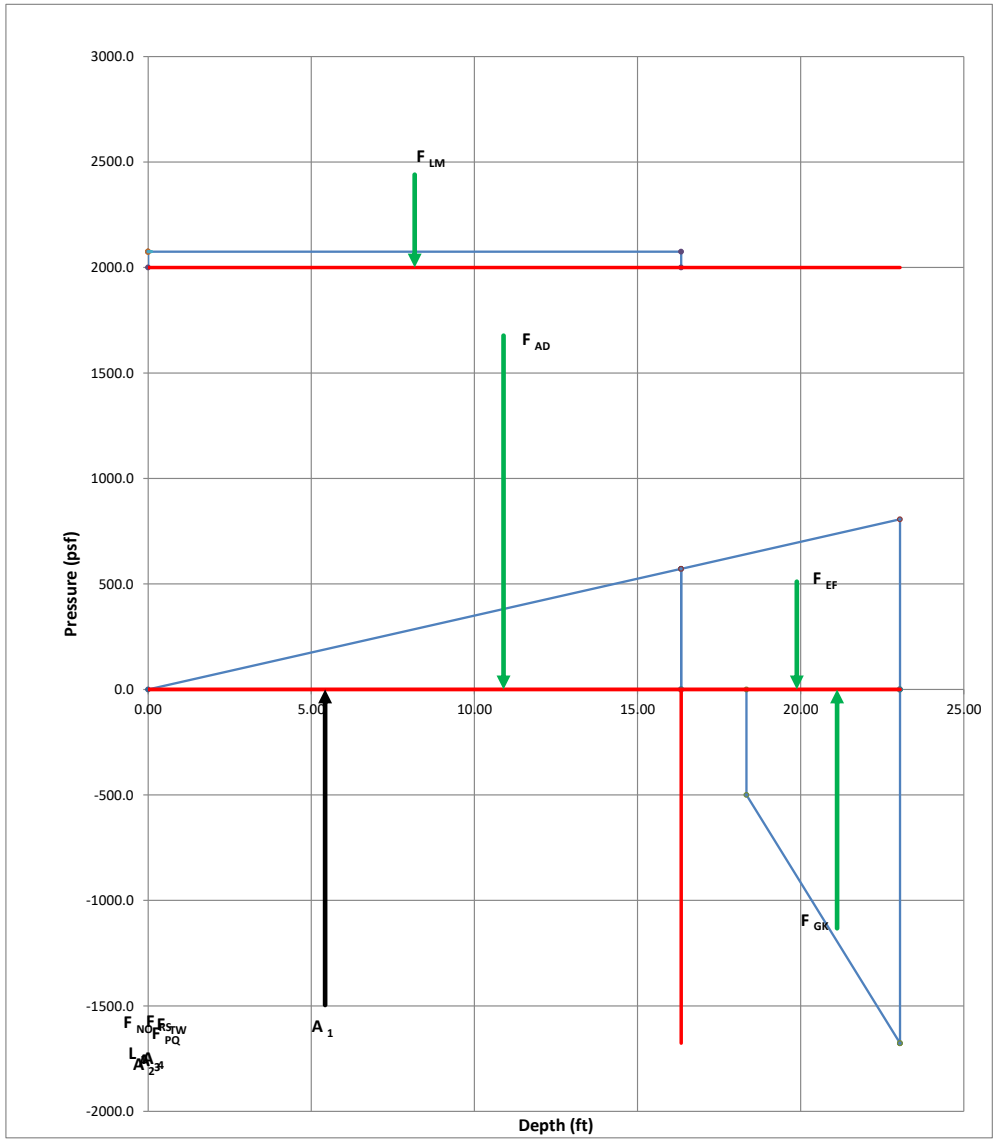
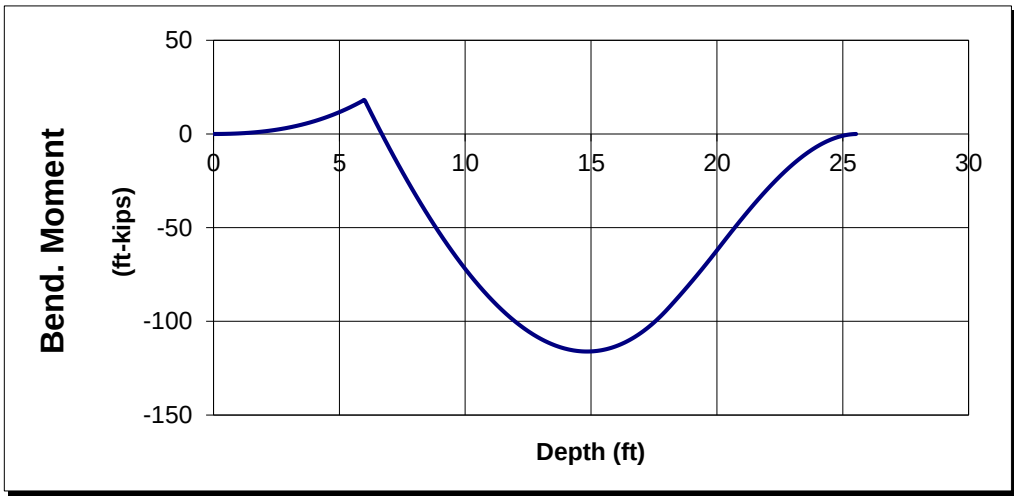
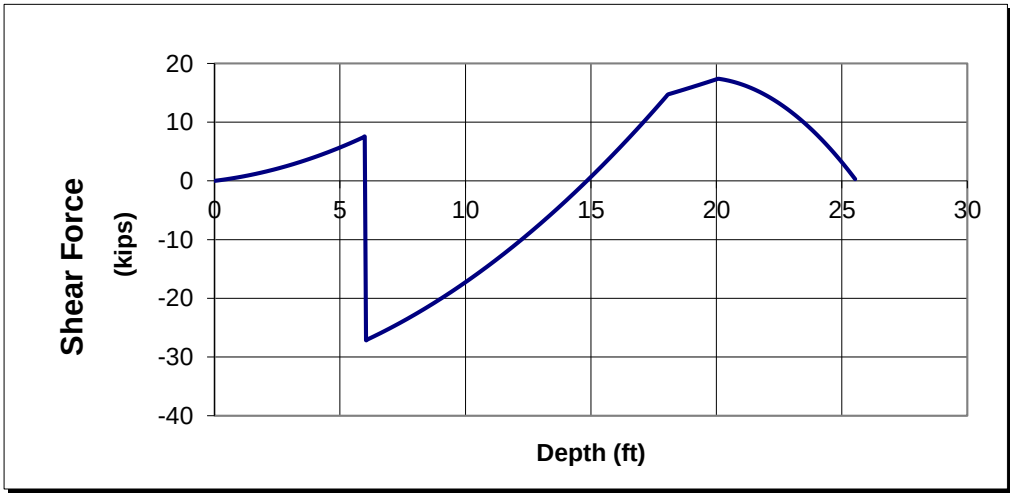
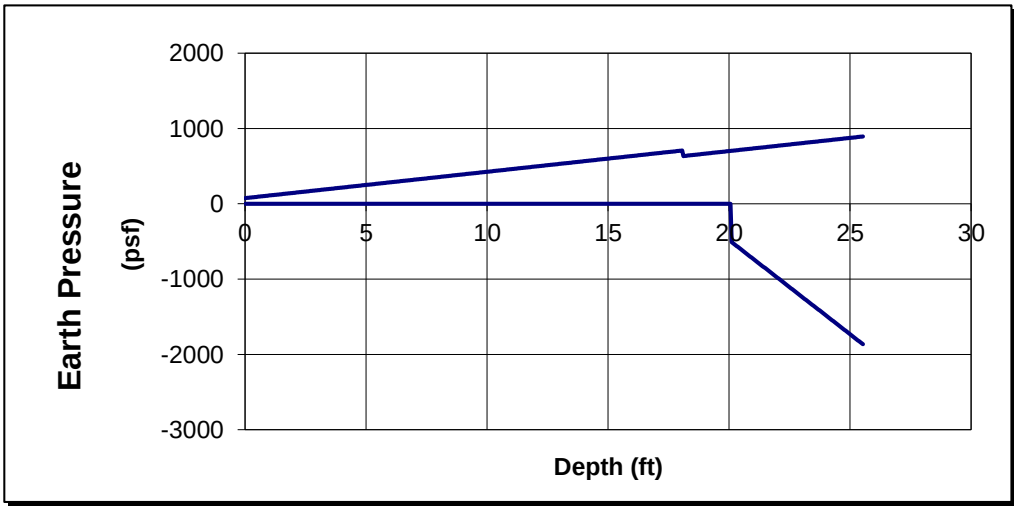


FIGURE B2 (cont'd) SOLDIER BEAM - S6

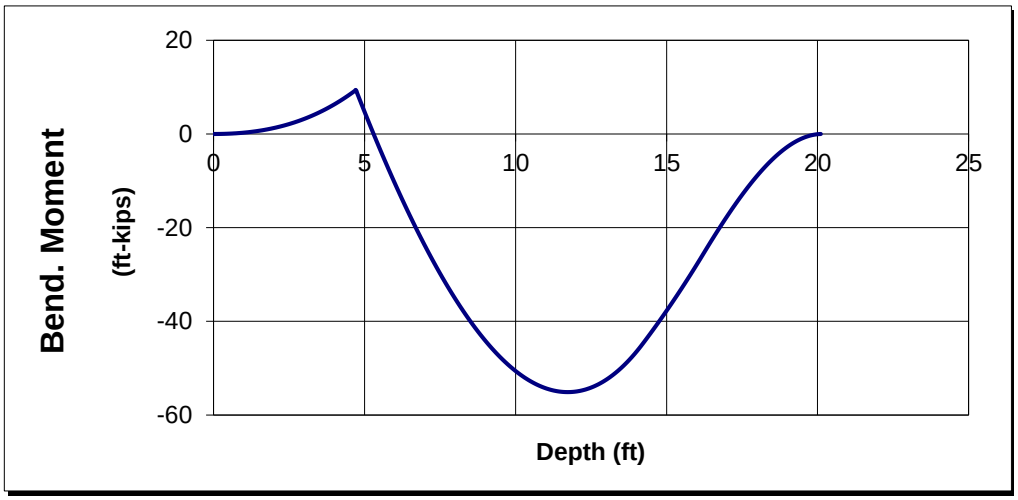


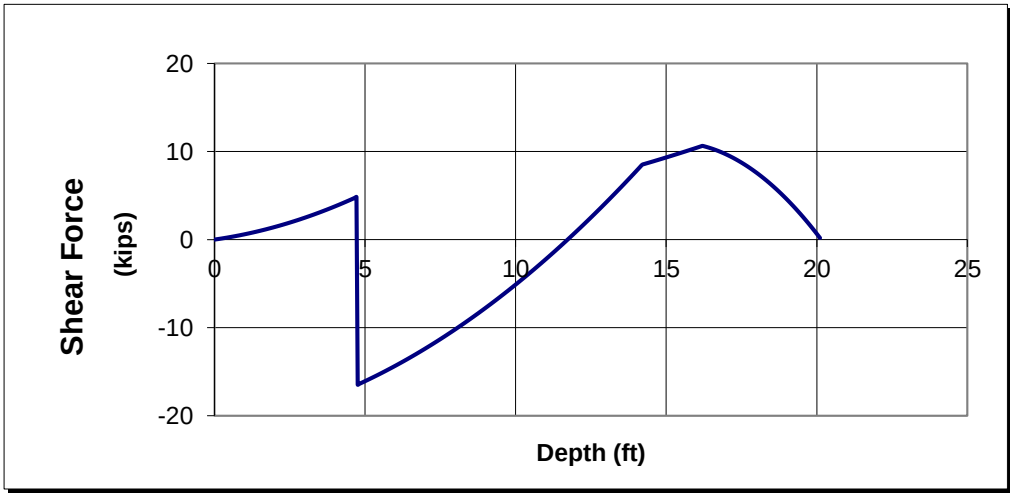


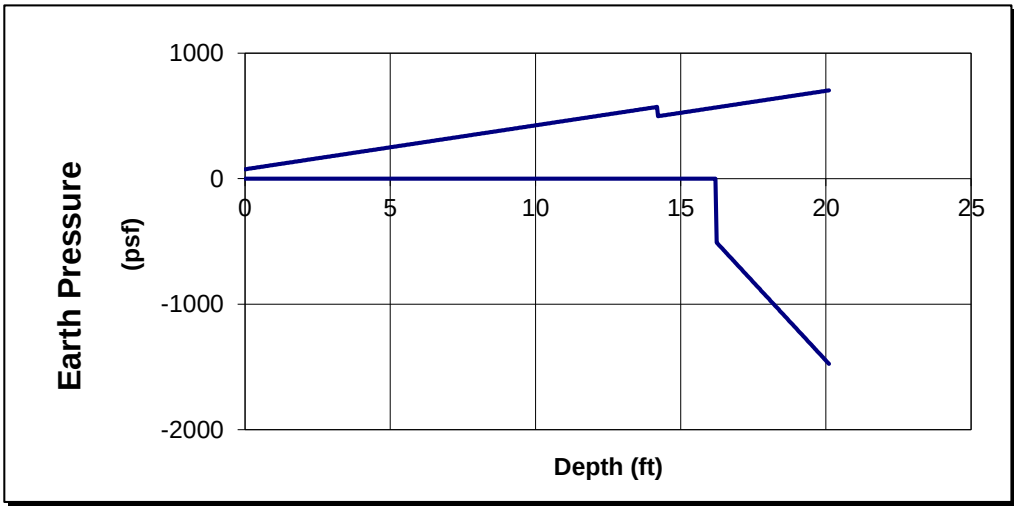


Wall Height (ft)	**18.1**
Pile Spacing (ft)	**7.00**

FIGURE B3 SOLDIER BEAM - W4







Wall Height (ft)	**14.2**
Pile Spacing (ft)	**6.50**

FIGURE B4 SOLDIER BEAM - N1

Wall Height (ft)	10.50
Depth of Embed (ft)	15.65
Depth to Top of Passive (ft)	12.50

	Force	p (psf)	K_γ (psf)	h (ft)	w (ft)	phw (lbf)	$K_\gamma h^2 w/2$ (lbf)	depth (ft)	moment arm (ft)	moment (ft-lbf)
Driving	A1	75.0		10.50	7.00	5513		5.25	20.90	115217
	A2		35.0	10.50	7.00		13506	7.00	19.15	258647
	A3	367.5		15.65	2.00	11504		18.33	7.83	90022
	A4		35.0	15.65	2.00		8573	20.93	5.22	44728
Resisting	P1	500.0		13.65	4.00	27302		19.33	6.83	186352
	P2		250.0	13.65	4.00		93176	21.60	4.55	423985
	P3	0.0		0.00	4.00	0		26.15	0.00	0
	P4		0.0	0.00	4.00		0	26.15	0.00	0

Moments about pile toe

Sum of resisting moments (ft-lbf)	610337
Sum of driving moments (ft-lbf)	508614
FS	1.20

Depth to Zero Shear (ft) at "M"	18.06

	Force	p (psf)	K_γ (psf)	h (ft)	w (ft)	phw (lbf)	$K_\gamma h^2 w/2$ (lbf)	depth (ft)	moment arm (ft)	moment (ft-lbf)
Driving	a1	75.0		10.50	7.00	5513		5.25	12.81	70614
	a2		35.0	10.50	7.00		13506	7.00	11.06	149369
	a3	367.5		7.56	2.00	5556		14.28	3.78	21002
	a4		35.0	7.56	2.00		2000	15.54	2.52	5040
Resisting	p1	500.0		5.56	4.00	11119		15.28	2.78	30911
	p2		250.0	5.56	4.00		15455	16.21	1.85	28642
	p3	0.0		0.00	4.00	0		0.00	18.06	0
	p4		0.0	0.00	4.00		0	0.00	18.06	0

Moments at Zero Shear Point

Sum of shear forces (lbf) at "M"	0
Sum of moments (ft-lbf) at "M"	186472

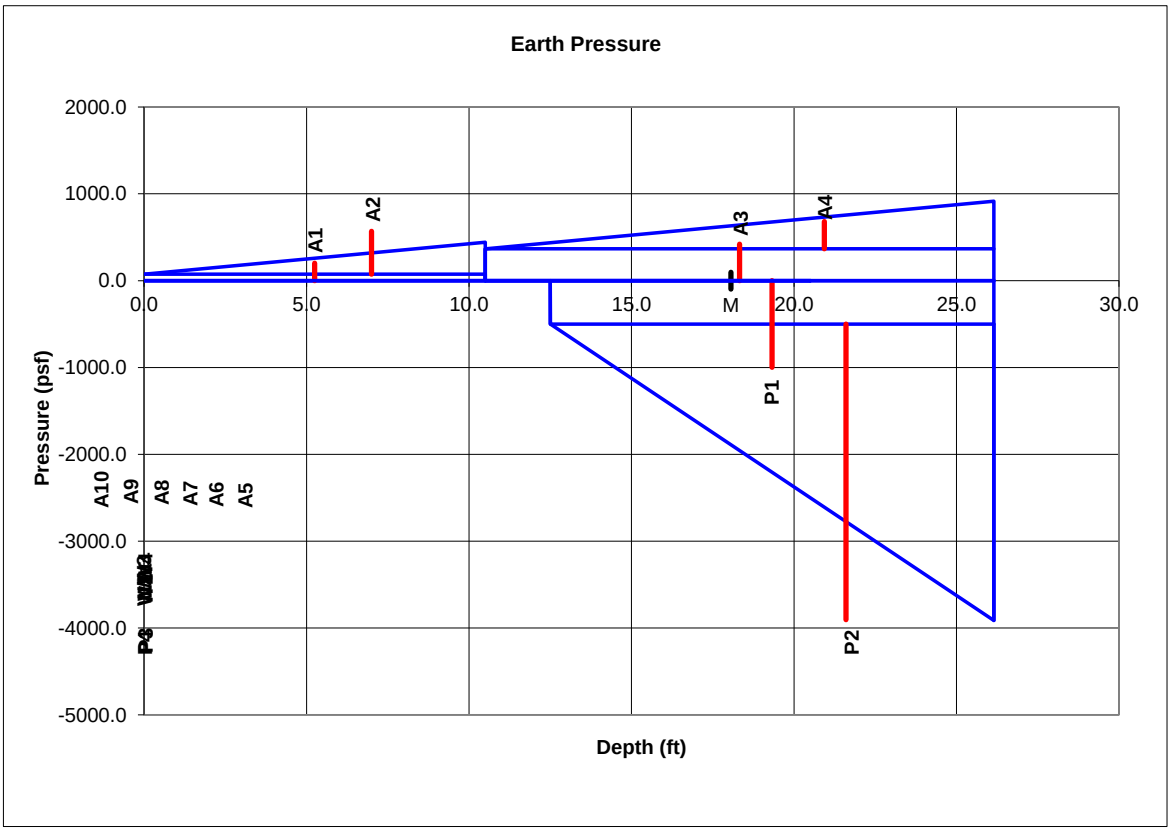


FIGURE B5 SOLDIER BEAM - N2

													Soldier Beam - Flexure/Compression				
					$L=NH^2$	Unif. Press.	Design	Pile Top	Pile Toe	Pile Toe	Pile	Lagging	Axial		Free		
Pile ID	Station (ft)	Height (ft)	Spacing (ft)	No. Anchors	N (psf/ft)	P (psf)	Beam	Elevation (feet)	Embed (feet)	Elevation (feet)	Length (feet)	Pressure (psf)	Load (kips)	Moment (ft-kips)	Length (feet)	Steel Section	Flex/Ax Ratio
S1	56	1.8	7	0	17.5	75	W14x34	111.0	8.0	101.0	10.0	139	0	5	1.83	W14x34	0.04
S2	64.5	4.1	8.5	0	17.5	78	W14x34	113.3	8.3	100.5	12.8	221	0	27	4.08	W14x34	0.20
S3	73	4.5	8.5	0	17.5	80	W14x34	116.0	8.9	102.5	13.5	237	0	34	4.49	W14x34	0.25
S4	81.5	7.5	8.25	0	17.5	95	W14x34	119.0	13.1	98.3	20.8	356	0	111	7.45	W14x34	0.81
S5	89.5	5.7	8	0	17.5	86	W14x34	121.3	10.5	105.0	16.3	286	0	56	5.72	W14x34	0.41
S6	97.5	5.3	6.5	0	17.5	84	W14x34	123.5	9.2	108.8	14.8	271	0	37	5.34	W14x34	0.27
W1	202.3	6.7	6	0	17.5	91	W14x34	124.8	10.6	107.3	17.5	324	0	58	6.65	W14x34	0.42
W2	209.3	6.8	7	0	17.5	92	W14x34	125.0	11.5	106.5	18.5	330	0	73	6.81	W14x34	0.53
W3	216.3	7.0	7	0	17.5	93	W14x34	125.0	11.7	106.3	18.8	337	0	77	6.97	W14x34	0.57
W4	223.3	7.1	7	0	17.5	93	W14x34	125.3	11.8	106.0	19.3	341	0	80	7.07	W14x34	0.59
W5	230.3	6.9	7.5	0	17.5	92	W14x34	125.0	11.9	106.0	19.0	334	0	82	6.90	W14x34	0.60
W6	238.3	6.7	8	0	17.5	91	W14x34	124.8	11.9	106.0	18.8	325	0	81	6.68	W14x34	0.59
W7	246.3	6.4	8	0	17.5	90	W14x34	124.5	11.4	106.5	18.0	312	0	72	6.37	W14x34	0.53
W8	254.3	5.7	7	0	17.5	86	W14x34	123.8	9.9	108.0	15.8	285	0	47	5.69	W14x34	0.35

TABLE B2
PERMANENT SOLDIER PILE DESIGN

Wall Height (ft)	7.45
Depth of Embed (ft)	13.15
Depth to Top of Passive (ft)	9.45

	Force	p (psf)	K_γ (psf)	h (ft)	w (ft)	phw (lbf)	$K_\gamma h^2 w/2$ (lbf)	depth (ft)	moment arm (ft)	moment (ft-lbf)
Driving	A1	95.4		7.45	8.25	5865		3.73	16.88	98980
	A2		35.0	7.45	8.25		8021	4.97	15.63	125397
	A3	260.9		13.15	2.00	6860		14.03	6.57	45100
	A4		35.0	13.15	2.00		6051	16.22	4.38	26518
Resisting	P1	500.0		11.15	4.00	22296		15.03	5.57	124280
	P2		250.0	11.15	4.00		62140	16.89	3.72	230913
	P3	0.0		0.00	4.00	0		20.60	0.00	0
	P4		0.0	0.00	4.00		0	20.60	0.00	0

Moments about pile toe

Sum of resisting moments (ft-lbf)	355193
Sum of driving moments (ft-lbf)	295994
FS	1.20

Depth to Zero Shear (ft) at "M"	13.89

	Force	p (psf)	K_γ (psf)	h (ft)	w (ft)	phw (lbf)	$K_\gamma h^2 w/2$ (lbf)	depth (ft)	moment arm (ft)	moment (ft-lbf)
Driving	a1	95.4		7.45	8.25	5865		3.73	10.16	59593
	a2		35.0	7.45	8.25		8021	4.97	8.92	71532
	a3	260.9		6.43	2.00	3357		10.67	3.22	10796
	a4		35.0	6.43	2.00		1448	11.74	2.14	3106
Resisting	p1	500.0		4.43	4.00	8866		11.67	2.22	19652
	p2		250.0	4.43	4.00		9826	12.41	1.48	14519
	p3	0.0		0.00	4.00	0		0.00	13.89	0
	p4		0.0	0.00	4.00		0	0.00	13.89	0

Moments at Zero Shear Point

Sum of shear forces (lbf) at "M"	0
Sum of moments (ft-lbf) at "M"	110857

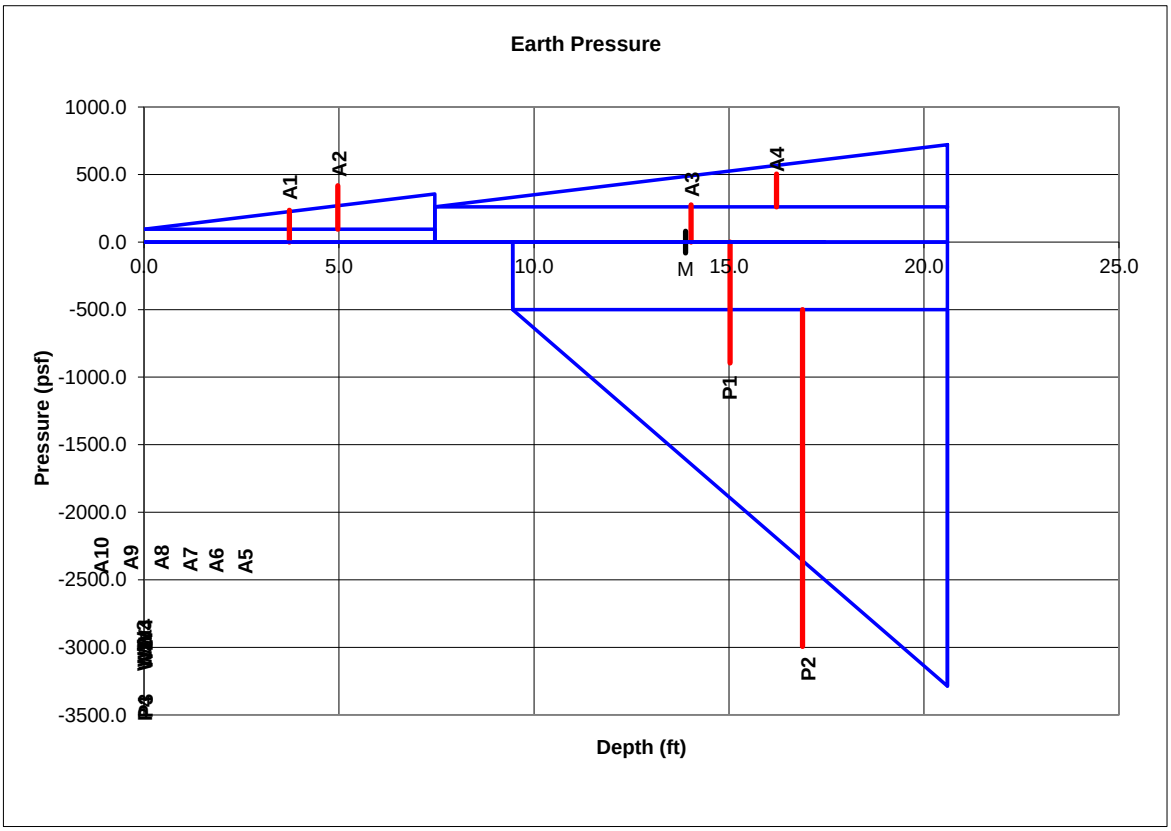


FIGURE B6 SOLDIER BEAM - S4

Wall Height (ft)	7.07
Depth of Embed (ft)	11.81
Depth to Top of Passive (ft)	9.07

	Force	p (psf)	K_γ (psf)	h (ft)	w (ft)	phw (lbf)	$K_\gamma h^2 w/2$ (lbf)	depth (ft)	moment arm (ft)	moment (ft-lbf)
Driving	A1	93.4		7.07	7.00	4621		3.54	15.35	70930
	A2		35.0	7.07	7.00		6124	4.71	14.17	86781
	A3	247.5		11.81	2.00	5847		12.98	5.91	34533
	A4		35.0	11.81	2.00		4884	14.95	3.94	19231
Resisting	P1	500.0		9.81	4.00	19626		13.98	4.91	96291
	P2		250.0	9.81	4.00		48145	15.61	3.27	157480
	P3	0.0		0.00	4.00	0		18.88	0.00	0
	P4		0.0	0.00	4.00		0	18.88	0.00	0

Moments about pile toe

Sum of resisting moments (ft-lbf)	253771
Sum of driving moments (ft-lbf)	211476
FS	1.20

Depth to Zero Shear (ft) at "M"	12.87

	Force	p (psf)	K_γ (psf)	h (ft)	w (ft)	phw (lbf)	$K_\gamma h^2 w/2$ (lbf)	depth (ft)	moment arm (ft)	moment (ft-lbf)
Driving	a1	93.4		7.07	7.00	4621		3.54	9.33	43118
	a2		35.0	7.07	7.00		6124	4.71	8.15	49924
	a3	247.5		5.79	2.00	2868		9.97	2.90	8310
	a4		35.0	5.79	2.00		1175	10.93	1.93	2270
Resisting	p1	500.0		3.79	4.00	7589		10.97	1.90	14400
	p2		250.0	3.79	4.00		7200	11.60	1.26	9107
	p3	0.0		0.00	4.00	0		0.00	12.87	0
	p4		0.0	0.00	4.00		0	0.00	12.87	0

Moments at Zero Shear Point

Sum of shear forces (lbf) at "M"	0
Sum of moments (ft-lbf) at "M"	80115

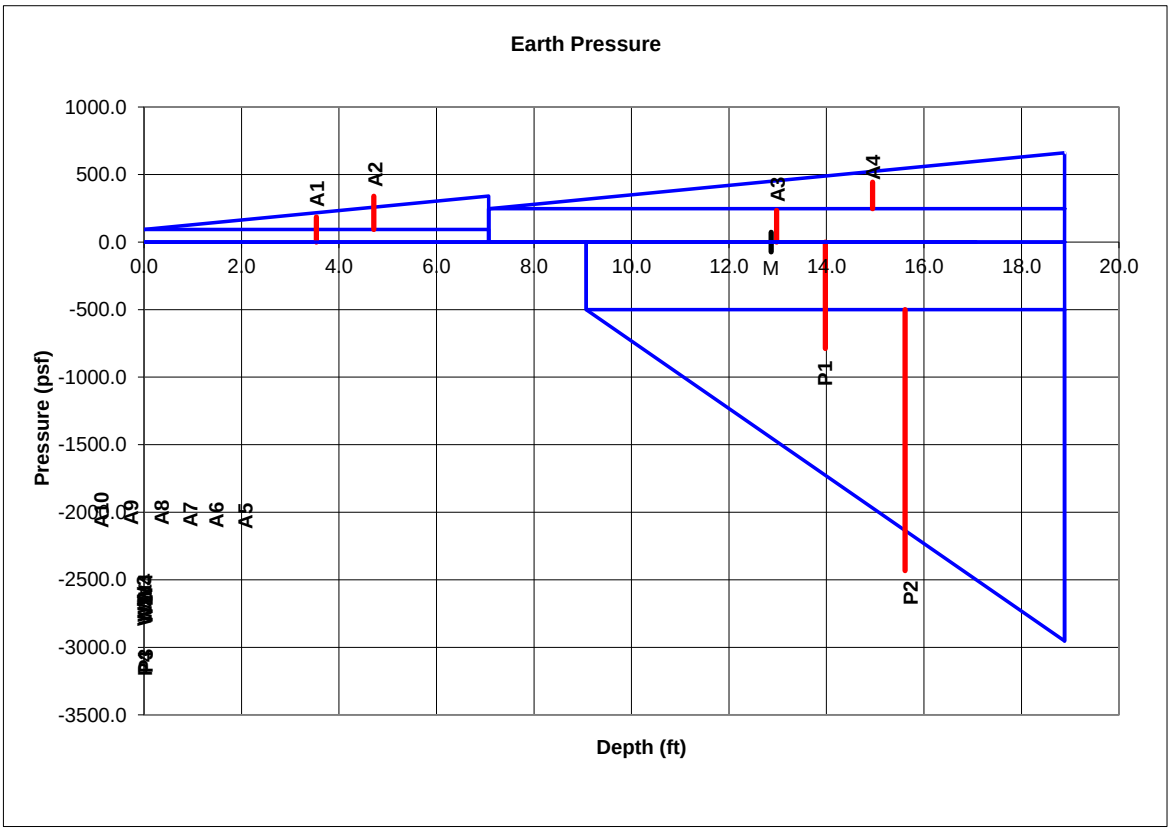
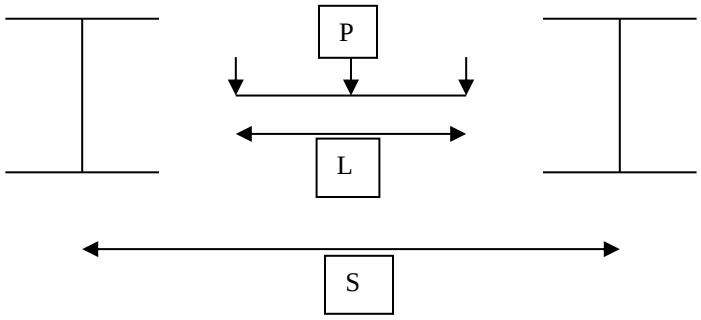


FIGURE B7 SOLDIER BEAM - W4

APPENDIX C

PERMANENT FACING DESIGN

SHOTCRETE FACING DESIGN



General

Facing consists of reinforced shotcrete with a single layer of reinforcement at mid thickness, and attached to soldier piles with headed studs.

Soldier Pile Spacing (S) 8.5 ft
Effective Load Width (L) 6.5 ft

Service Static Load (P_{ST}) = 350 psf
Ultimate Load (P_{ULT}) = $1.6P_{ST}$
= 560 psf

Flexure

Ultimate Moment = $P_{ULT}.L.(S-L/2)/6$
= (560) (6.5) (8.5-6.5/2)/6
= 3,185 ft-lbf/ft

Design Flexural Strength ϕM_n = 0.9 (4,170)
= 3,753 ft-lbf/ft (OK in flexure)
(Note: Nominal flexural strength of facing is for a 6-inch-thick shotcrete facing reinforced with No. 4 bars on 8-inch vertical centers)

One-Way Shear

Ultimate Shear Force = $P_{ULT}.L/2$
= (560) (6.5)/2
= 1,820 lbf/ft

Design Shear Strength ϕV_n = 0.75 (2) $(f^1_c)^{0.5}$ (3) (12)
= 0.75 (2) $(4{,}000)^{0.5}$ (3) (12)

= 3,415 lbf/ft (OK in shear)

Headed Studs and Punching Shear

Ultimate Stud Load = P_{ULT}.L
= (560) (6.5)
= 3,640 lbf/ft

Design Shear Strength ϕV_n = $0.7N_b$
= $(0.7)k(f'_c)^{0.5}h^{1.5}$ per D-7 of ACI 318
= $(0.7)(24)(4000)^{0.5}(3.688)^{1.5}$ for 4-inch stud
= 7,525 lbf/stud

Design Stud Tensile Strength = $0.75\ A_{STUD}\ f_{UT}$
= 0.75 (0.2) (61,000) (for 1/2-inch diam. studs conforming to ASTM A29 with minimum ultimate tensile strength of 61 ksi)
= 9,150 lbf/stud

Design OK for 4-inch long 1/2-inch diameter headed studs on 24-inch vertical centers.