NORTH AMERICAN STEEL SHEET PILING ASSOCIATION

Steel Sheet Piling

RETAINING WALL COMPARISON

TECHNICAL REPORT

Prepared by EIC Group, Inc., LLC

steel sheet piling . economical wall systems . steel sheet piling . permanent . retaining walls . cost effective . hot rolled steel sheet piling . permanent . steel sheet piling . proven stability . steel sheet piling . readily available . steel sheet piling . environmentally friendly . hot rolled steel sheet piling . fastest . steel sheet piling . permanent walls . sheet piling . readily available . steel sheet piling . environmental . steel sheet piling

NASSPA

NORTH AMERICAN STEEL SHEET PILING ASSOCIATION

May 2006
Revised October 2009

NARRATIVE

Comparison Retaining Wall Design and Cost Study
Steel Sheet Piling vs. Various Walls

Prepared By:

EIC Group LLC

420 Route 46 East, Suite 1
Fairfield, NJ 07004

NARRATIVE

We are pleased to present herein the results of our comparison study of steel sheet piling vs. various wall types for the North American Steel Sheet Piling Association (NASSPA). The purpose of this work was to determine the feasibility of utilizing permanent steel sheeting for retaining walls that traditionally used concrete, slurry, or other materials. The following walls were studied:

- Tied Back Steel Sheet Piling
- Reinforced Concrete Cantilever
- Concrete Modular Unit
- Mechanically Stabilized Earth
- Soldier Pile and Concrete Lagging
- Slurry Wall

A hypothetical retaining wall case study was developed based on conditions that often occur in practical situations. The proposed wall has an exposed face of 19 feet and retains dense fine sand with no water table present. Above the wall, the embankment slopes up at an 18-degree angle. The study assumed the walls were to be built in a cut situation with available space for open excavation. The cost of the cut in front of the wall is common to all cases and not included.

The above listed wall options were designed for the case study. Design criteria are based on AASHTO Standard Specifications for Highway Bridges, 17th Edition, 2002, ASD. No temporary retaining system during construction was assumed for any option. Drawings depicting the proposed configurations were developed along with engineering calculations. The excavation required in front of the walls to obtain the desired cut configuration was not included in the comparison since it was necessary for all options and not dependent on the wall type. A complete listing of quantities is given in the following summary tables.

Costs and construction durations were computed for each option. Reference data was taken from the current edition of "RS Means Heavy Construction Cost Data" and then compared to bid prices for recent NJDOT and NJTA projects for reasonableness. Cost estimates and construction durations are given in the following tables.

The results of the study reveal the following:

- The steel sheet pile option provides a minimum 35% cost savings over other wall type options. It provides a 65% savings over a traditional cast-in-place concrete wall.

- The steel sheet pile option has the shortest construction duration of all options.

It should also be noted that although the modular unit wall option was closest in cost to the sheet pile wall, it is often not feasible for situations where groundwater is present in the retained soil. Therefore, it may not be appropriate in many situations. In summary, the results of the study indicate that for the appropriate site conditions, a permanent steel sheet piling retaining wall is the least costly option over the other walls studied and has a significantly shorter construction duration.

North American Steel Sheet Piling Association

Retaining Wall Study
Calculations

Table of Contents

North American Steel Sheet Piling Association

Retaining Wall Study
Calculations

Table of Contents (Cont'd)

CHAPTER 1 Summary

Notes:

1. All design performed utilizing the Service Load Method.
2. Designs performed in accordance with the AASHTO Standard Specifications for Highway Bridges, 17th Edition 2002, ASD.

The designs presented herein are conceptual in nature to illustrate and compare construction methods and costs for the various walls studied. They should not be used for actual construction.

1.1 Conceptual Model

Wall Properties

$H := 19 \cdot ft$	Exposed Wall height
$L := 100 \cdot ft$	Wall Length

1.1.1 Soil and Site Parameters

Retained Soil - Existing above Excavation Level

$\gamma := 120 \cdot pcf$	Soil Density
$\phi f := 30 \cdot deg$	Angle of internal friction
$\delta := 0$	Angle of friction between soil and wall or per AASHTO table 5.5.2B
$\beta := 90 \cdot deg$	Batter of Wall, where 90 degrees is vertical except at Concrete Modular Units
$\alpha := 18 \cdot deg$	Slope of Retained Soil (approx 1:3 slope)
$c := 0$	Soil Cohesion

Foundation Soil - Below Excavation Level - same as Retained Soil above Excavation Level

Design Standard - AASHTO Standard Specifications for Highway Bridges - 17th Edition 2002 - Allowable Strength Design

Determine Coulomb's Passive Earth Pressure Coefficient, Kp

$$Kp := \frac{(\sin(\beta - \phi f))^2}{\sin(\beta)^2 \cdot \sin(\beta + \delta) \cdot \left[1 - \left(\sin(\phi f + \delta) \cdot \frac{\sin(\phi f + \alpha)}{\sin(\beta + \delta) \cdot \sin(\beta + \alpha)}\right)^{0.5}\right]^2}$$

$Kp = 5.33$ Coulomb's passive earth pressure coefficient

Determine Coulomb's Active Earth Pressure Coefficient, Ka

$$Ka := \frac{\sin(\beta + \phi f)^2}{\sin(\beta)^2 \cdot \sin(\beta - \delta) \cdot \left[1 + \sqrt{\left(\sin(\phi f + \delta) \cdot \frac{\sin(\phi f - \alpha)}{\sin(\beta - \delta) \cdot \sin(\alpha + \beta)}\right)}\right]^2}$$

$Ka = 0.424$ Coulomb's active earth pressure coefficient for fill material

Where:

$\beta = 90 \cdot deg$ $\delta = 0 \cdot deg$

$\phi f = 30 \cdot deg$ $\alpha = 18 \cdot deg$

NORTH AMERICAN STEEL SHEET PILING ASSOCIATION
RETAINING WALL STUDY
Section 1.2 Summary of Costs and Construction Time
All Walls

Retaining Wall Type	Construction Duration (Days)	Total Cost for 100 ft. Wall	Cost per Linear Ft.	Cost per Square Ft.
Grouted Anchor Steel Sheet Pile Wall	13	$ 90,607	$ 906.07	$ 47.69
Cast-In-Place Reinforced Concrete Wall	47	$ 258,572	$ 2,585.72	$ 136.09
Concrete Modular Unit Gravity Wall	31	$ 144,741	$ 1,447.41	$ 76.18
Mechanically Stabilized Earth Wall	35	$ 181,593	$ 1,815.93	$ 95.58
Soldier Pile and Lagging Wall	26	$ 171,856	$ 1,718.56	$ 90.45
Slurry Wall*	64	$ 400,145	$ 4,001.45	$ 210.60

*Concept model - not typical application for slurry wall but included in study to give comprehensive range of options

NORTH AMERICAN STEEL SHEET PILING ASSOCIATION
RETAINING WALL STUDY
Section 1.3 Summary of Costs and Construction Time, Each Wall

Grouted Anchor Steel Sheet Pile Wall

Pay Item No.	Item		Unit	Quantity	Daily Output (unit/day)	Time (day)	Unit Cost	Cost
5	Grouted Anchors - 1" Dia		LF	286.0	120	3	$ 20.20	$ 5,777.20
02	Sheet piling, 19 ft deep excavation	19.3 psf, left in place	TN	29.0	12.95	3	$ 1,950.00	$ 56,550.00
03	Wales, connections & struts	0	TN	1.5	NA	-	$ 300.00	$ 459.00
04	Anchors		TN	0.4	NA	-	$ 2,700.00	$ 958.50
07	Backfill structural	105 H.P. ,150 ft haul, sand & gravel	LCY	211.0	670	-	$ 2.02	$ 426.22
08	Borrow loading	Select granular fill	BCY	211.0	NA	-	$ 13.86	$ 2,924.46
09	Compaction, riding vibrating roller	12 in lift, 2 passes	ECY	-	5200	-	$ 0.23	$ -
10	Compaction, walk behind vibrating plate	12 in lift, 2 passes	ECY	211.0	560	1	$ 0.78	$ 164.58
12	Excavation, trench, common earth	14 ft to 20 ft deep, 1.5 cy hydraulic backhoe	BCY	211.0	480	1	$ 3.86	$ 814.46
15	Driven piles, complete pile driving setup	Mobilization, large	EA	1.0	0.27	4	$ 22,000.00	$ 22,000.00
16	Geotextile for subsurface drainage	Fabric, laid in trench, adverse conditions	SY	244.4	1600	1	$ 2.18	$ 532.79
	Totals					13		$ 90,607.21
							Cost per LF	$ 906.07
							Cost per SF	$ 47.69

NORTH AMERICAN STEEL SHEET PILING ASSOCIATION
RETAINING WALL STUDY
Section 1.3 Summary of Costs and Construction Time, Each Wall

Cast-In-Place Reinforced Concrete Wall

Pay Item No.	Item		Unit	Quantity	Daily Output (unit/day)	Time (day)	Unit Cost	Cost
07	Backfill structural	105 H.P., 150 ft. haul, sand &gravel	LCY	4,100.0	670	6	$ 2.02	$ 8,282.00
08	Borrow loading	Select granular fill	BCY	4,100.0	NA	-	$ 13.86	$ 56,826.00
09	Compaction, riding, vibrating roller	12 in. lift, 2 passes	ECY	4,100.0	5200	1	$ 0.23	$ 943.00
10	Compaction, walk behind vibrating plate	12 in. lift, 2 passes	ECY	144.0	560	1	$ 0.78	$ 112.32
12	Excavation, trench, common earth	14 ft to 20 ft deep, 1.5 cy hdraulic backhoe	BCY	4,100.0	480	9	$ 3.86	$ 15,826.00
18	Forms in place, footing	Continuous wall, plywood, 2x	SFCA	950.0	440	3	$ 2.80	$ 2,660.00
19	Forms in place, footing	Integral starter wall, to 4 in.	LF	100.0	400	1	$ 5.55	$ 555.00
20	Steel framed plywood	16 ft to 20 ft high	SFCA	4,300.0	400	11	$ 8.15	$ 35,045.00
21	Reinforcing steel, A615 Gr 60	10 - 50 ton job #3 to #7 bars	TN	21.3	2.1	10	$ 2,825.00	$ 60,172.50
23	Concrete, ready mix	Normal weight, 3500 psi	CY	540.0	NA	-	$ 114.00	$ 61,560.00
25	Placing concrete, footings	Continuous, shallow pumped	CY	330.0	150	3	$ 28.00	$ 9,240.00
26	Placing concrete, walls	15 in thk, pumped	CY	210.0	120	2	$ 35.00	$ 7,350.00
	Totals					47		$ 258,571.82
							Cost per LF	$ 2,585.72
							Cost per SF	$ 136.09

Concrete Modular Unit Gravity Wall

Pay Item No.	Item		Unit	Quantity	Daily Output (unit/day)	Time (day)	Unit Cost	Cost
07	Backfill structural	105 H.P., 150 ft. haul, sand &gravel	LCY	2,791.0	670	5	$ 2.02	$ 5,637.82
08	Borrow loading	Select granular fill	BCY	2,724.0	NA	-	$ 13.86	$ 37,754.64
09	Compaction, riding, vibrating roller	12 in. lift, 2 passes	ECY	2,724.0	5200	1	$ 0.23	$ 626.52
10	Compaction, walk behind, vibrating plate	12 in. lift, 2 passes	ECY	117.0	560	1	$ 0.78	$ 91.26
12	Excavation, trench, common earth	14 ft to 20 ft deep, 1.5 cy hdraulic backhoe	BCY	2,944.0	480	7	$ 3.86	$ 11,363.84
16	Geotextile for subsurface drainage	Fabric, laid in trench, adverse conditions	SY	300.0	1600	1	$ 2.18	$ 654.00
18	Forms in place, footing	Continuous wall, plywood, 2x	SFCA	400.0	440	1	$ 2.80	$ 1,120.00
21	Reinforcing steel, A615 Gr 60	10 - 50 ton job #3 to #7 bars	TN	21.5	2.1	10	$ 2,825.00	$ 60,737.50
23	Concrete, ready mix	Normal weight, 3500 psi	CY	146.5	NA	-	$ 114.00	$ 16,701.00
24	Placing concrete, footings	Continuous, shallow, direct chute	CY	128.0	120	2	$ 21.00	$ 2,688.00
25	Placing concrete, footings	Continuous, shallow pumped	CY	18.5	150	1	$ 28.00	$ 518.00
27	Placing concrete	with crane	CY	128.0	95	2	$ 53.50	$ 6,848.00
	Totals					31		$ 144,740.58
							Cost per LF	$ 1,447.41
							Cost per SF	$ 76.18

NORTH AMERICAN STEEL SHEET PILING ASSOCIATION
RETAINING WALL STUDY
Section 1.3 Summary of Costs and Construction Time, Each Wall

Mechanically Stabilized Earth Wall

Pay Item No.	Item		Unit	Quantity	Daily Output (unit/day)	Time (day)	Unit Cost	Cost
07	Backfill structural	105 H.P., 150 ft. haul, sand &gravel	LCY	3,593.0	670	6	$ 2.02	$ 7,257.86
08	Borrow loading	Select granular fill	BCY	3,593.0	NA	-	$ 13.86	$ 49,798.98
09	Compaction, riding, vibrating roller	12 in. lift, 2 passes	ECY	3,593.0	5200	1	$ 0.23	$ 826.39
10	Compaction, walk behind, vibrating plate	12 in. lift, 2 passes	ECY	117.0	560	1	$ 0.78	$ 91.26
12	Excavation, trench, common earth	14 ft to 20 ft deep, 1.5 cy hdraulic backhoe	BCY	3,593.0	480	8	$ 3.86	$ 13,868.98
16	Geotextile for subsurface drainage	Fabric, laid in trench, adverse conditions	SY	438.9	1600	1	$ 2.18	$ 956.80
21	Reinforcing steel, A615 Gr 60	10 - 50 ton job, # 3 to # 7 bars	TN	7.1	2.1	4	$ 2,825.00	$ 20,057.50
22	Welded wire fabric	6x6, W4xW4, 58psf/csf	CSF	193.0	27	8	$ 94.00	$ 18,142.00
23	Concrete, ready mix	Normal weight, 3500 psi	CY	11.1	NA	-	$ 114.00	$ 1,265.40
25	Placing concrete, footings	Continuous, shallow pumped	CY	600.0	150	4	$ 28.00	$ 16,800.00
29	Precast concrete wall panels	10 in. thick	SF	2,100.0	1550	2	$ 22.68	$ 47,628.00
30	Galvanizing steel in shop	1 ton to 20 tons	TN	5.6	NA	-	$ 875.00	$ 4,900.00
	Totals					35		$ 181,593.17
							Cost per LF	$ 1,815.93
							Cost per SF	$ 95.58

NORTH AMERICAN STEEL SHEET PILING ASSOCIATION
RETAINING WALL STUDY
Section 1.3 Summary of Costs and Construction Time, Each Wall

Soldier Pile and Lagging Wall

Pay Item No.	Item		Unit	Quantity	Daily Output (unit/day)	Time (day)	Unit Cost	Cost
05	Grouted Anchors 1" dia		LF	350.0	120	3	$ 20.20	$ 7,070.00
04	Anchors		TN	0.5	NA	-	$ 2,700.00	$ 1,269.00
07	Backfill structural	105 H.P., 150 ft. haul, sand &gravel	LCY	2,266.0	670	4	$ 2.02	$ 4,577.32
08	Borrow loading	Select granular fill	BCY	2,266.0	NA	-	$ 13.86	$ 31,406.76
09	Compaction, riding, vibrating roller	12 in. lift, 2 passes	ECY	2,266.0	5200	1	$ 0.23	$ 521.18
10	Compaction, walk behind vibrating plate	12 in. lift, 2 passes	ECY	106.0	560	1	$ 0.78	$ 82.68
11	Excavation, trench, common earth	6 ft to 10 ft deep, 1.5 cy hydraulic backhoe	BCY	968.0	600	2	$ 3.10	$ 3,000.80
12	Excavation, trench, common earth	14 ft to 20 ft deep, 1.5 cy hydraulic backhoe	BCY	1,298.0	480	3	$ 3.86	$ 5,010.28
14	Driven piles, H sections	HP14x89 to 50 ft length	VLF	420.0	510	1	$ 76.50	$ 32,130.00
15	Driven piles, complete pile driving setup	Mobilization, large	EA	1.0	0.27	4	$ 22,000.00	$ 22,000.00
16	Geotextile for subsurface drainage	Fabric, laid in trench, adverse conditions	SY	233.3	1600	1	$ 2.18	$ 508.59
21	Reinforcing steel, A615 Gr 60	10 - 50 ton job, # 3 to # 7 bars	TN	7.5	2.1	4	$ 2,825.00	$ 21,187.50
29	Precast concrete wall panels	10 in. thick	SF	1,900.0	1550	2	$ 22.68	$ 43,092.00
	Totals					26		$ 171,856.11
							Cost Per LF	$ 1,718.56
							Cost Per SF	$ 90.45

NORTH AMERICAN STEEL SHEET PILING ASSOCIATION
RETAINING WALL STUDY
Section 1.3 Summary of Costs and Construction Time, Each Wall

Slurry Wall

Pay Item No.	Item		Unit	Quantity	Daily Output (unit/day)	Time (day)	Unit Cost	Cost
07	Backfill structural	105 H.P., 150 ft. haul, sand &gravel	LCY	515.9	670	1	$ 2.02	$ 1,042.12
08	Borrow loading	Select granular fill	BCY	515.9	NA	-	$ 13.86	$ 7,150.37
10	Compaction, walk behind vibrating plate	12 in. lift, 2 passes	ECY	515.9	560	1	$ 0.78	$ 402.40
12	Evacuation, trench, common earth	14 ft to 20 ft deep, 1.5 cy hydraulic backhoe	BCY	515.9	480	2	$ 3.86	$ 1,991.37
16	Geotextile for subsurface drainage	Fabric, laid in trench, adverse conditions	SY	288.9	1600	1	$ 2.18	$ 629.80
17	Slurry Trench, excavated in wet soils	Backfilled w/3ksi concrete, no reinforcement	CF	11,691.0	333	36	$ 23.50	$ 274,738.50
20	Steel framed plywood	16ft to 20ft high	SFCA	2,000.0	400	5	$ 8.15	$ 16,300.00
21	Reinforcing steel, A615 Gr 60	10 - 50 ton job, # 3 to # 7 bars	TN	32.7	2.1	17	$ 2,825.00	$ 92,377.50
23	Concrete, ready mix	Normal weight, 3500 psi	CY	37.0	NA	-	$ 114.00	$ 4,218.00
26	Placing concrete, walls	15 in thk, pumped	CY	37.0	120	1	$ 35.00	$ 1,295.00
	Totals					64		$ 400,145.07
							Cost Per LF	$ 4,001.45

CHAPTER 2 TIED BACK STEEL SHEET PILE WALL

2.1 Design Calculations

Wall Properties

$H := 19 \cdot ft$	Exposed Wall height
$L := 100 \cdot ft$	Wall Length

Soil Properties

Retained Soil

$\gamma := 120 \cdot pcf$	Soil Density
$\phi f := 30 \cdot deg$	Angle of internal friction
$\delta := 0$	Angle of friction between soil and wall
$\beta := 90 \cdot deg$	Batter of Wall, where 90 degrees is vertical
$\alpha := 18 \cdot deg$	Slope of Retained Soil
$c := 0$	Soil Cohesion

Determine Coulomb's Passive Earth Pressure Coefficient, Kp

$$Kp := \frac{(\sin(\beta - \phi f))^2}{\sin(\beta)^2 \cdot \sin(\beta + \delta) \cdot \left[1 - \left(\sin(\phi f + \delta) \cdot \frac{\sin(\phi f + \alpha)}{\sin(\beta + \delta) \cdot \sin(\beta + \alpha)}\right)^{0.5}\right]^2}$$

$Kp = 5.33$ Coulomb's passive earth pressure coefficient

Determine Coulomb's Active Earth Pressure Coefficient, Ka

$$Ka := \frac{\sin(\beta + \phi f)^2}{\sin(\beta)^2 \cdot \sin(\beta - \delta) \cdot \left[1 + \sqrt{\left(\sin(\phi f + \delta) \cdot \frac{\sin(\phi f - \alpha)}{\sin(\beta - \delta) \cdot \sin(\alpha + \beta)}\right)}\right]^2}$$

$Ka = 0.424$ Coulomb's active earth pressure coefficient

Where:

$\beta = 90 \cdot deg$ $\delta = 0 \cdot deg$

$\phi f = 30 \cdot deg$ $\alpha = 18 \cdot deg$

See program results on pp 18 - 21.

2.1.1 Sheet Pile Design

Determine required Section Modulus

$M := 30.91 \cdot kip \cdot ft$ Maximum Moment from Computer Output (See Section 2.1.4)

Use A572 Steel $Fy := 50 \cdot ksi$

$Fb := 0.55 \cdot Fy$ $Fb = 27\ ksi$ Allowable Stress AASHTO table 10.32.1A

$Sx := \frac{M}{Fb}$ $Sx = 13.74 in^3$ Required Section Modulus

Use $Sx := 22.3 \cdot in^3$

Consider Deflection of Sheet Pile

$\Delta max := \frac{H}{360}$ $\Delta max = 0.63 \cdot in$ Allowable deflection

Where:

$H = 19 \cdot ft$ Exposed Wall Height

$\Delta := 0.70 \cdot in$ with $I := 132.8 \cdot in^4$ From Computer Output

Say OK

2.1.2 Grouted Soil Anchors

AASHTO Section 5.7

Fa = Force per unit length of wall = 4.09 k/ft @ 8' spacing = 32.7^k

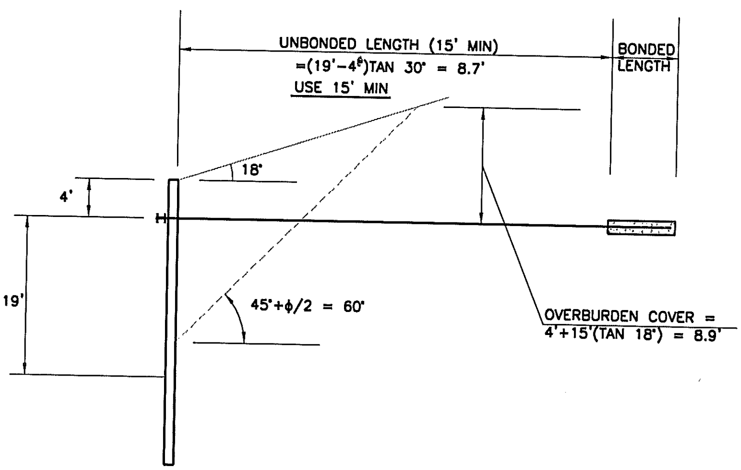
AASHTO Table 5.7.6.2 A

F_u = Presumptive Ultimate Load Transfer in Soil - 13 k/Lf in Dense Sand

Min Length of Grouted Anchor = $lg = \frac{(Fa \cdot SF)}{Fu}$

SF = Safety Factor = 2.50

$lg := \frac{(32.7 \cdot 2.50)}{13.0}$ = 6.3' use 6.5' min



Anchor Steel - ASTM722 Grade 150 fa = 0.55x150=82.5KSI

Asmin = 32.7/82.5 = 0.40 in^2 use 1"ϕ Rod min

Assume no corrosion protection required.

2.1.3 Waler Design

$w = 5.0 \frac{kip}{ft}$ Uniform Load on waler

$s = 8ft$ Tie Rod spacing

$Mw := \frac{w \cdot s^2}{8}$ $Mw = 40.0$ kip ft Maximum moment

$Vw := \frac{1}{2} \cdot w \cdot s$ $Vw = 20.0$ kip Maximum Shear

$Sw := \frac{Mw}{0.55 \cdot 50 \cdot ksi}$ $Sw = 17.5\ in^3$ Reqired section Modulus

$Aw := \frac{Vw}{0.4 \cdot 50 \cdot ksi}$ $Aw = 1.0\ in^2$ Required Web Area

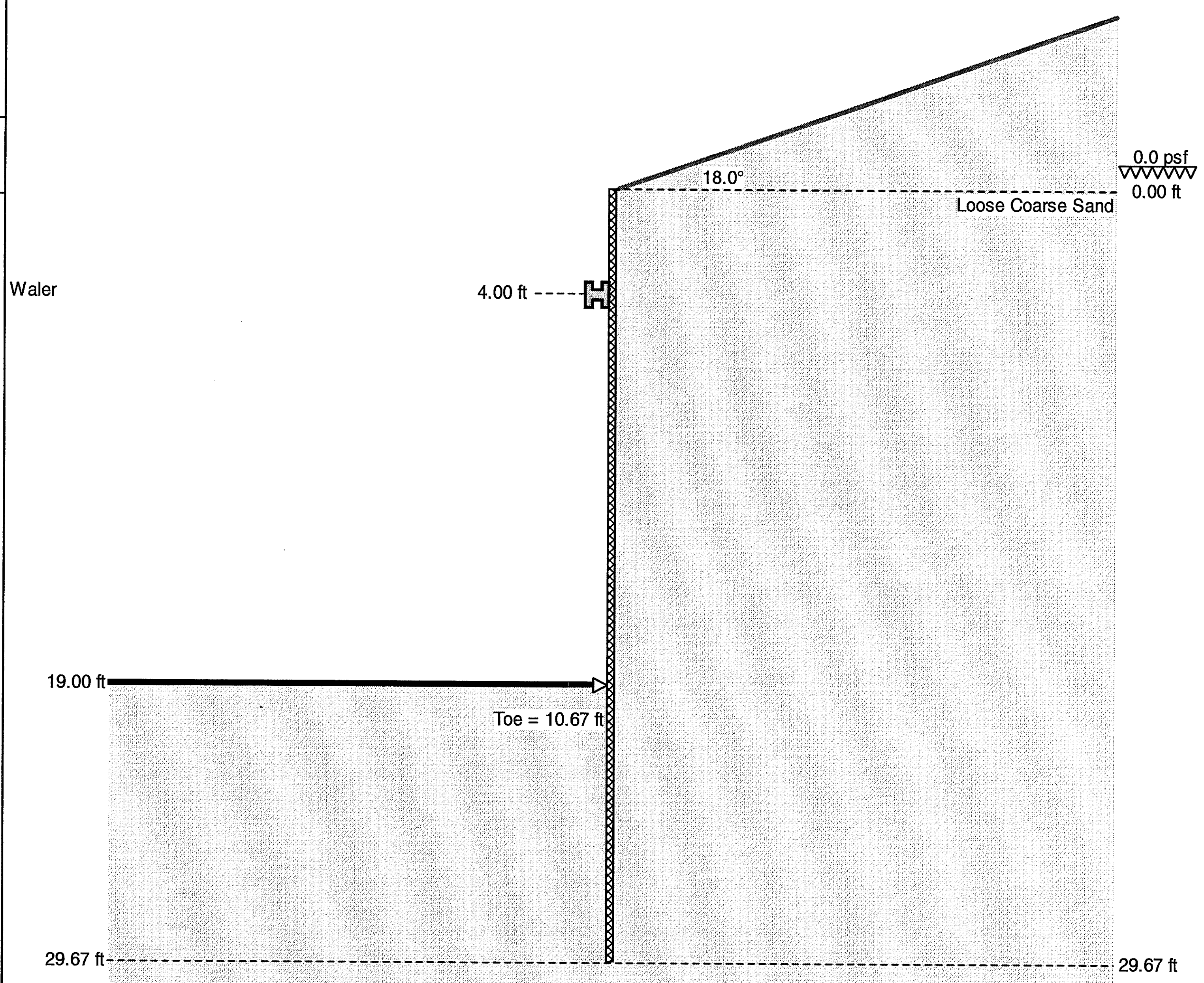
Use 2-C10x15.3 $Sw := 2 \cdot 13.5 \cdot in^3$ $Sw = 27.0 \cdot in^3$

$Aw := 2 \cdot 10 \cdot 0.240 \cdot in^2$ $Aw = 4.8 \cdot in^2$ OK

Client: North American Sheet Pile Association
Site: Austin, TX

Title: Permanent Retaining Wall Comparison Study
Designer: MHM / RCK
Ref: NASPA
Page: 1
Date: 4.1.08

Pressure: Coulomb
Toe: Free Earth Support



EIC Group, LLC
420 Route 46 East, Suite 1
Fairfield, NJ
Tel: 973.227.8660
Fax: 973.227.8661

SPW911, v2.20

Client: North American Sheet Pile Association
Site: Austin, TX

Title: Permanent Retaining Wall Comparison Study
Designer: MHM / RCK
Ref: NASPA
Page: 2
Date: 4.1.08

Pressure: Coulomb
Toe: Free Earth Support

Input Data

Depth Of Excavation = 19.00 ft   Depth Of Active Water = 100.00 ft   Water Density = 62.43 pcf
Surcharge = 0.0 psf   Depth Of Passive Water = 100.00 ft   Minimum Fluid Density = 31.82 pcf
Slope (active) = 18.0 degrees

Soil Profile — Active Side

Depth (ft)	Soil Name	γ (pcf)	γ' (pcf)	C (psf)	C_a (psf)	ϕ(°)	δ(°)	K_a	K_{ac}	K_p	K_{pc}
0.00	Loose Coarse Sand	106.28	68.73	0.0	0.0	30.0	0.0	0.42	0.00	5.33	0.00

Soil Profile — Passive Side

Depth (ft)	Soil Name	γ (pcf)	γ' (pcf)	C (psf)	C_a (psf)	ϕ(°)	δ(°)	K_a	K_{ac}	K_p	K_{pc}
0.00	Loose Coarse Sand	106.28	68.73	0.0	0.0	30.0	0.0	0.33	0.00	3.00	0.00

Solution

Sheet

Sheet Name	I (in^4/ft)	E (psi)	Z (in^3/ft)	f (psi)	Maximum Bending Moment (ftlb/ft)	Upstand (ft)	Toe (ft)	Pile Length (ft)
	156.90	3.04E+07	23.20	27000.0	52137.8	0.00	10.67	29.67

Load Model: Area Distribution

Supports

Depth (ft)	Type	Linear Load (lb/ft)
4.00	Waler	5103.4

Maxima

	Maximum	Depth
Bending Moment	30907.5 ftlb/ft	15.11 ft
Deflection	0.7 in	16.00 ft
Pressure	848.1 psf	19.00 ft
Shear Force	4743.0 lb/ft	4.00 ft

EIC Group, LLC
420 Route 46 East, Suite 1
Fairfield, NJ
Tel: 973.227.8660
Fax: 973.227.8661

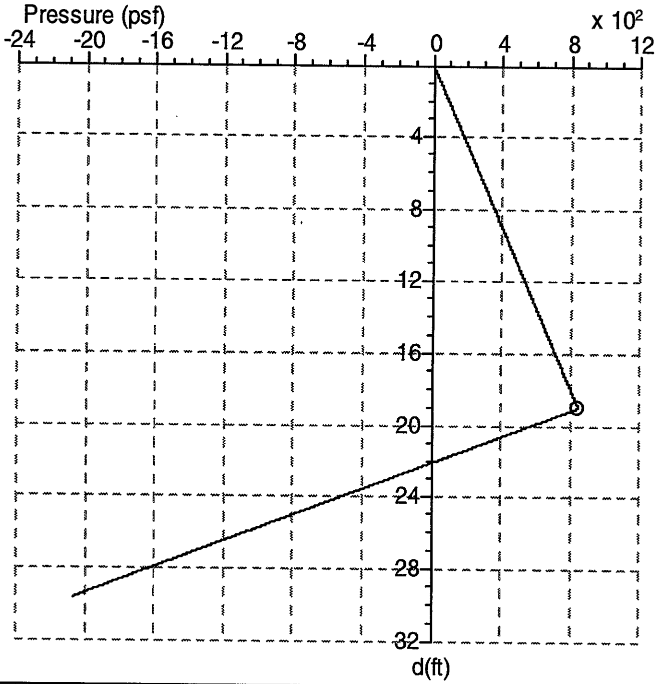
SPW911, v2.20

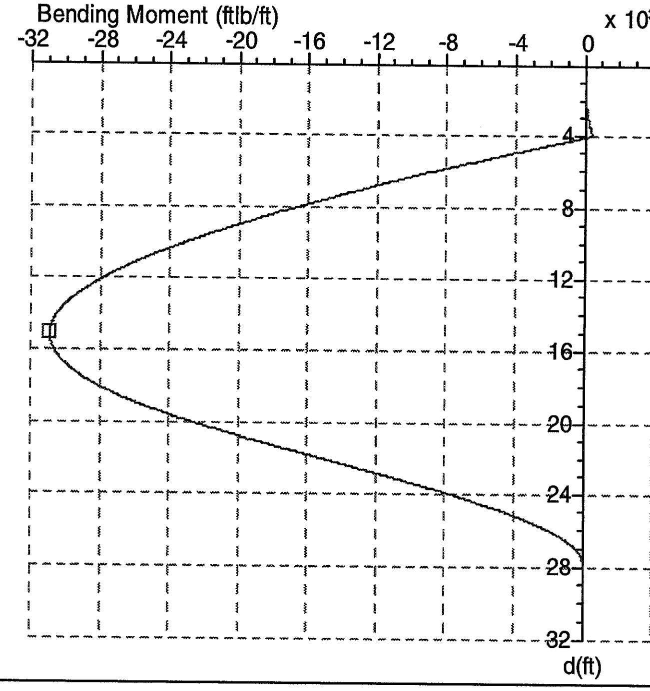
Client: North American Sheet Pile Association
Site: Austin, TX

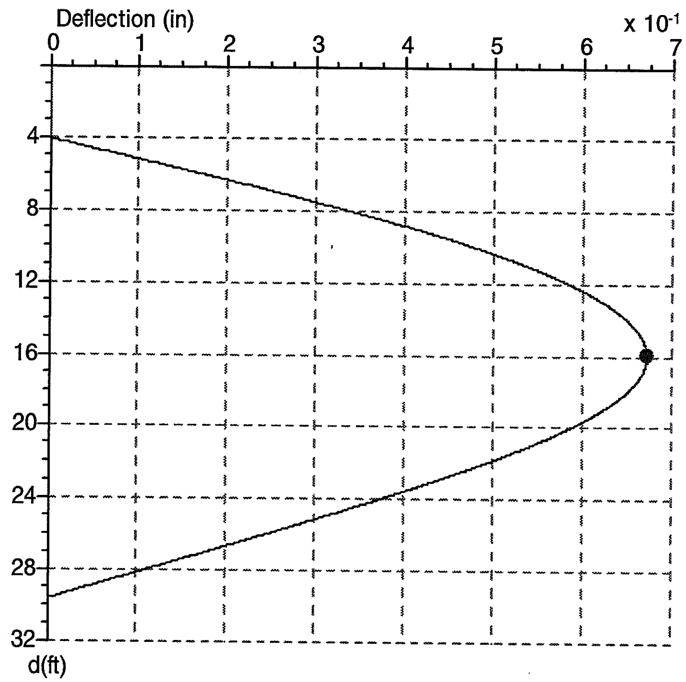
Title: Permanent Retaining Wall Comparison Study
Designer: MHM / RCK
Ref: NASPA
Page: 3
Date: 4.1.08

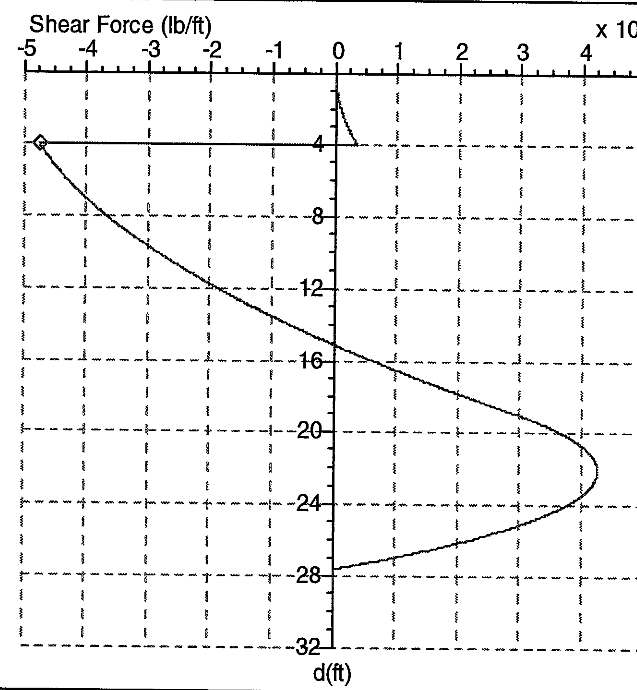
Pressure: Coulomb
Toe: Free Earth Support

	Maximum	d (ft)
○	848.1 psf	19.00
□	30907.5 ftlb/ft	15.11
◇	4743.0 lb/ft	4.00
●	0.7 in	16.00









EIC Group, LLC

420 Route 46 East, Suite 1
Fairfield, NJ
Tel: 973.227.8660
Fax: 973.227.8661

SPW911, v2.20

Client: North American Sheet Pile Association
Site: Austin, TX

Title: Permanent Retaining Wall Comparison Study
Designer: MHM / RCK
Ref: NASPA
Page: 4
Date: 4.1.08

Pressure: Coulomb
Toe: Free Earth Support

depth (ft)	P (psf)	M (ftlb/ft)	D (in)	F (lb/ft)
0.00	1.1	0.0	0.0	0.0
0.26	12.1	0.2	0.0	1.8
0.53	24.3	1.3	0.0	6.9
0.79	35.3	3.9	0.0	14.4
1.05	47.5	9.2	0.0	25.8
1.31	59.6	18.0	0.0	40.5
1.58	70.6	29.8	0.0	56.8
1.84	82.8	47.6	0.0	77.8
2.10	93.8	69.0	0.0	99.8
2.36	106.0	99.0	0.0	127.1
2.63	118.1	136.7	0.0	157.7
2.89	129.1	178.3	0.0	188.4
3.15	141.3	232.9	0.0	225.3
3.41	153.4	297.7	0.0	265.6
3.68	164.5	366.2	0.0	305.0
3.94	176.6	452.8	0.0	351.6
4.20	187.6	-566.9	0.0	-4706.6
4.46	199.8	-1818.9	0.0	-4653.8
4.73	211.9	-3056.5	0.1	-4597.6
4.99	223.0	-4168.4	0.1	-4543.7
5.25	235.1	-5376.2	0.1	-4481.3
5.51	247.3	-6567.2	0.1	-4415.5
5.78	258.3	-7740.4	0.2	-4352.9
6.04	270.4	-8895.1	0.2	-4280.8
6.30	281.5	-9927.9	0.2	-4212.5
6.56	293.6	-11044.6	0.2	-4134.1
6.83	305.8	-12140.3	0.2	-4052.4
7.09	316.8	-13117.3	0.3	-3975.3
7.35	328.9	-14170.2	0.3	-3887.3
7.62	340.0	-15106.9	0.3	-3804.5
7.88	352.1	-16114.0	0.3	-3710.2
8.14	364.3	-17183.7	0.4	-3612.7
8.40	375.3	-18051.4	0.4	-3521.1
8.67	387.4	-18980.0	0.4	-3417.2
8.93	399.6	-19880.7	0.4	-3310.0
9.19	410.6	-20674.6	0.4	-3209.7
9.45	422.8	-21519.7	0.4	-3096.2
9.72	433.8	-22261.5	0.5	-2990.2

depth (ft)	P (psf)	M (ftlb/ft)	D (in)	F (lb/ft)
9.98	445.9	-23047.8	0.5	-2870.4
10.24	458.1	-23802.0	0.5	-2747.3
10.50	469.1	-24523.3	0.5	-2632.5
10.77	481.3	-25210.8	0.5	-2503.1
11.03	493.4	-25863.6	0.5	-2370.4
11.29	504.4	-26426.2	0.6	-2246.9
11.55	516.6	-27010.5	0.6	-2107.9
11.82	527.6	-27509.4	0.6	-1978.6
12.08	539.8	-28021.9	0.6	-1833.3
12.34	551.9	-28495.5	0.6	-1684.7
12.60	562.9	-28891.7	0.6	-1546.7
12.87	575.1	-29322.9	0.6	-1391.8
13.13	586.1	-29644.6	0.6	-1248.1
13.39	598.3	-29958.1	0.6	-1086.8
13.66	610.4	-30228.6	0.6	-922.3
13.92	621.5	-30436.3	0.6	-769.9
14.18	633.6	-30622.1	0.7	-599.0
14.44	645.7	-30762.3	0.7	-424.9
14.71	656.8	-30849.4	0.7	-263.7
14.97	668.9	-30900.1	0.7	-83.3
15.23	680.0	-30904.4	0.7	83.6
15.49	692.1	-30862.4	0.7	270.4
15.76	704.2	-30770.7	0.7	460.5
16.02	715.3	-30643.3	0.7	636.1
16.28	727.4	-30473.5	0.7	832.5
16.54	739.6	-30236.8	0.7	1032.1
16.81	750.6	-29975.5	0.7	1216.5
17.07	762.7	-29636.7	0.7	1422.5
17.33	773.8	-29281.2	0.7	1612.6
17.59	785.9	-28879.8	0.7	1824.8
17.86	798.1	-28384.4	0.7	2040.4
18.12	809.1	-27884.5	0.6	2239.3
18.38	821.2	-27279.2	0.6	2461.1
18.64	832.3	-26740.3	0.6	2665.7
18.91	844.4	-26027.4	0.6	2893.9
19.17	796.3	-25254.7	0.6	3118.9
19.43	728.5	-24503.7	0.6	3306.6
19.69	653.9	-23710.5	0.6	3493.7

depth (ft)	P (psf)	M (ftlb/ft)	D (in)	F (lb/ft)
19.96	579.3	-22794.1	0.6	3660.5
20.22	511.5	-21925.4	0.6	3794.5
20.48	436.9	-20935.5	0.6	3922.6
20.75	369.1	-20008.9	0.6	4021.4
21.01	294.5	-19060.9	0.5	4110.8
21.27	220.0	-17998.2	0.5	4179.8
21.53	152.1	-17018.4	0.5	4225.0
21.80	77.6	-15930.3	0.5	4255.3
22.06	3.0	-14936.2	0.5	4265.3
22.32	-64.8	-13941.6	0.5	4256.9
22.58	-139.4	-12851.6	0.5	4228.2
22.85	-207.2	-11868.7	0.4	4184.5
23.11	-281.8	-10897.7	0.4	4117.0
23.37	-356.4	-9848.0	0.4	4029.3
23.63	-424.2	-8914.8	0.4	3932.0
23.90	-498.8	-7916.5	0.4	3805.5
24.16	-566.6	-7038.8	0.4	3672.9
24.42	-641.2	-6193.7	0.3	3507.8
24.68	-715.8	-5306.5	0.3	3322.3
24.95	-783.6	-4543.0	0.3	3136.1
25.21	-858.2	-3755.2	0.3	2911.9
25.47	-932.8	-3090.8	0.3	2667.4
25.73	-1000.6	-2479.8	0.3	2427.5
26.00	-1075.1	-1874.2	0.2	2144.3
26.26	-1142.9	-1388.4	0.2	1869.2
26.52	-1217.5	-968.4	0.2	1547.3
26.79	-1292.1	-587.1	0.2	1205.0
27.05	-1359.9	-318.4	0.2	876.3
27.31	-1434.5	-113.2	0.2	495.3
27.57	-1509.1	-8.0	0.1	94.1
27.84	-1576.9	0.0	0.1	0.0
28.10	-1651.5	0.0	0.1	0.0
28.36	-1719.3	0.0	0.1	0.0
28.62	-1793.9	0.0	0.1	0.0
28.89	-1868.5	0.0	0.0	0.0
29.15	-1936.3	0.0	0.0	0.0
29.41	-2010.9	0.0	0.0	0.0
29.67	-2071.9	0.0	0.0	0.0

EIC Group, LLC
420 Route 46 East, Suite 1
Fairfield, NJ
Tel: 973.227.8660
Fax: 973.227.8661

SPW911, v2.20

2.2 Quantity Calculations

2.2.1 Sheet Pile Quantity

Sheet Piling (Pay Item 02)

$Lp := 30 \cdot ft$ Length of Sheet Pile

$H = 19 \circ ft$ Height of Retained Soil

Proposed Sheet Pile Properties

$W := 30.3 \cdot in$ Width

$Ht := 13.52 \cdot in$ Height

$wt = 19.31 psf$

$Sx := 23.2 \cdot \frac{in^3}{ft}$ Section Modulus

$Ix := 156.9 \cdot \frac{in^4}{ft}$ Moment of Inertia

Total Weight of Sheet Piling (Pay Item 02)

$Wt := L \cdot Lp \cdot wt$ $Wt := 29.0$ Ton

Where :

$L = 100 \circ ft$ Wall Length

$Lp = 30 \circ ft$ Pile Length

$wt = 19.31$ psf Pile Weight/sf

2.2.2 Grouted Anchor and Tie Rod Quantity

Grouted Anchor (Pay Item 01)

12 Spaces @ 8' Spacing + 2' @ Each end = 100'

Install 13 Units @ (15' + 7') = 286LF

Anchor Rod Quantity (Pay Item 04)

$D := 1 \cdot in$ Rod Diameter

$ab = 0.85\ in^2$ Area of Rod

$wb := 3.01 \cdot \frac{lbf}{ft}$ Weight of Rod

$Lt := 22 \cdot ft$ Length of Rod

Determine Number of Rods

$N := \frac{L}{s} + 1$ $N = 13.5$ Use $N := 13$ Rods

Where : $L = 100 \cdot ft$ Wall Length

Determine Total Rod Weight (Pay Item 04)

$Wt := N \cdot Lt \cdot wb$ $Wt = 0.43$ Ton

2.2.3 Waler Quantity (Pay Item 03)

Use 2-C10x15.3 Walers

$w := 15.3 \cdot \frac{lbf}{ft}$ Weight of each waler

Determine Total Weight of Walers (Pay Item 03)

$Wt := 2 \cdot w \cdot L$ $Wt = 1.53$ Ton

Where : $L = 100 \cdot ft$ Wall Length

2.2.4 Excavation and Backfill

Refer to Figure 2-2

Additional Excavation for drainage stone

$A3 = 3x19 = 57ft^2$ Cross-sectional area of drainage stone

$Vd := A3 \cdot L$ $\quad Vd = 211yd^3$ Volume of stone for drainage behind wall

Total Excavation

$V := V + Vd$ $\quad V = 500yd^3$

Excavation Related Pay Items

Item 07 - Backfill Structural	$V = 0yd^3$
Item 08 - Select Granular Fill	$V = 211yd^3$
Item 09 - Compaction, Roller	$V = 0yd^3$
Item 10 - Compaction, Plate	$V10 := 3 \cdot ft \cdot 19 \cdot ft \cdot L \quad V10 = 211 \cdot yd^3$
Item 12 - Excavation	$V = 211yd^3$
Item 16 - Geotextile	$A16 := (3 \cdot ft + 19 \cdot ft) \cdot L \quad A16 = 244.4 \cdot yd^2$

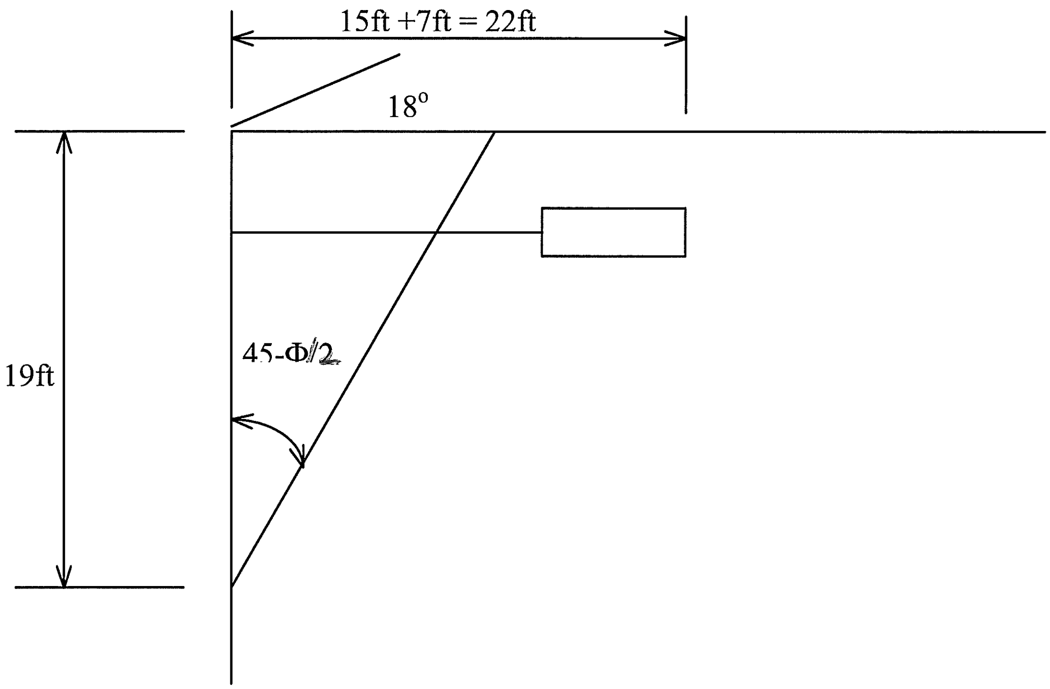


Figure 2-1
Grouted Anchor Configuration

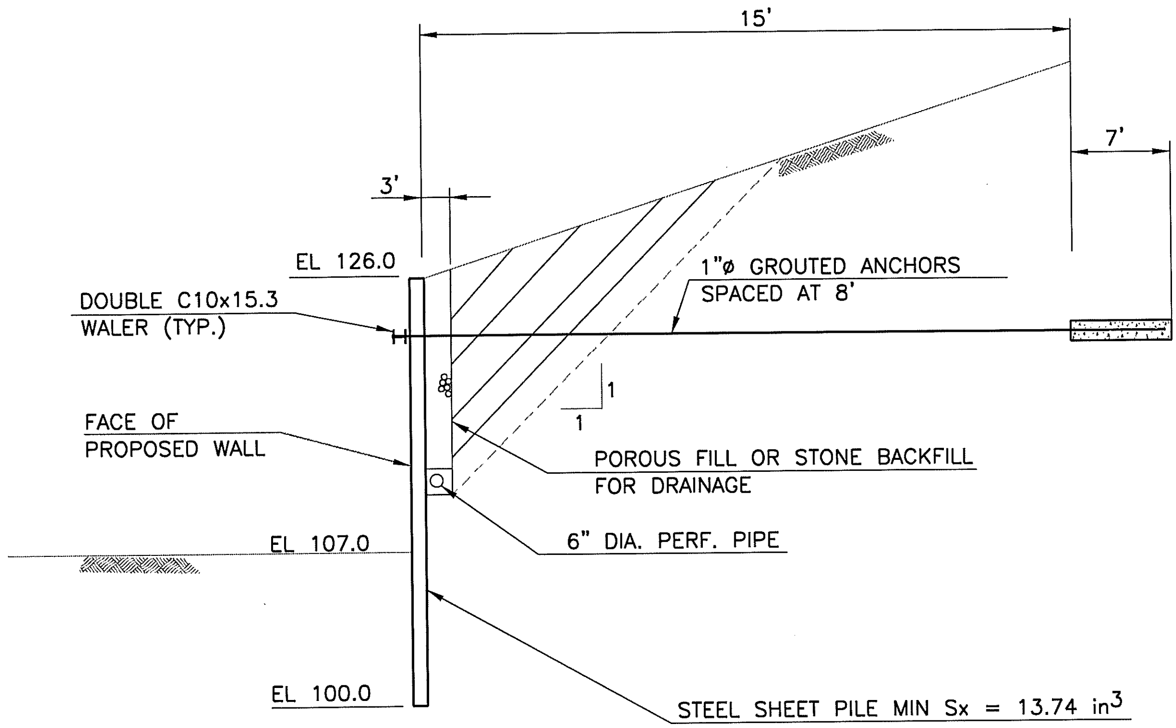


Figure 2-2
Excavation and Backfill Diagram

CHAPTER 3 CAST-IN-PLACE REINFORCED CONCRETE WALL

3.1 Design Calculations, Refer to Figures 3-1 & 3-2

WALL HEIGHT (TOP OF WALL TO BOTTOM OF FOOTING)= 26.00 FT
ANGLE OF INCLINED BACKFILL= 18 DEGREES
ANGLE OF INTERNAL FRICTION= 30 DEGREES
UNIT WEIGHT OF SOIL= 120 PCF

3.1.1 Stability

VERTICAL LOADS

PART	WIDTH (FT)	HEIGHT (FT)	AREA (FT^2)	UNIT WT. (KCF)	FORCE (K/FT)	ARM (FT)	MOMENT (K FT/FT)
1	1.75	21.00	36.75	0.150	5.51	5.63	31.01
2	2.25	18.00	20.25	0.150	3.04	7.25	22.02
3	6.50	5.00	32.50	0.150	4.88	3.25	15.84
4	12.50	4.50	56.25	0.150	8.44	12.75	107.58
5	2.25	18.00	20.25	0.120	2.43	8.00	19.44
6	2.25	3.50	7.88	0.120	0.95	7.63	7.21
7	10.25	21.50	220.38	0.120	26.45	13.88	366.92
8	12.50	4.06	25.38	0.120	3.05	14.83	45.18
Pv					6.53	19.00	124.16
				Fv=	61.26	Mr=	739.36

Ka= 0.39 (RANKINE COEFFICIENT WITH INCLINED BACKFILL)

Pa= 0.5*SOIL WT*H^2*Ka 21.15 K/FT H=30.06

Pv= Pa*SIN(BACKFILL ANGLE) 6.53 K/FT

HORIZONTAL LOADS

Ph= Pa*COS(BACKFILL ANGLE) 20.11 K/FT

Mo= Ph*(H/3) 201.53 K FT/FT

STABILITY CHECK

				MEETS CRITERIA?	
RESULTANT=	(Mr - Mo)/Fv	8.78	FT	YES	In middle third
OVERTURNING FS:	Mr/Mo	3.67		YES	>2.0
SLIDING FS=	Fv*(Coefficient)/Ph	1.52		YES	>1.5

Coeff.= 0.50 (AASHTO Table 5.5.2B) - Dense M-F Sand

BRG. PRESSURE

B=	19.00	FT	e=	0.72	FT

q(max)=	Fv/B*(1 + 6e/B)	3.96	KSF (T)	
q(min)=	Fv/B*(1 - 6e/B)	2.49	KSF (H)	
		1.98	TSF (T)	YES
		1.25	TSF (H)	YES

Assumed allowable bearing capacity for Dense Med-Fine Sand = 2TSF

3.1.2 Heel Design

MATERIAL PROPERTIES

fc'=	3,000	PSI	fc=	0.4*fc'	1,200	PSI
			fv=	0.95*fc'^1/2	52	PSI
fy=	60,000	PSI	Class B Concrete Grade 60 Reinforcement -			
fs=	24,000	PSI	Black - Uncoated			

n=	Es/Ec	9.2
k=	fc/(fc + fs/n)	0.315
j=	1 - k/3	0.895
K=	0.169	(ACI TABLE)

VERTICAL LOADS (NEGLECT VERTICAL COMPONENT OF ACTIVE EARTH FORCE)

PART	WIDTH (FT)	HEIGHT (FT)	AREA (FT^2)	UNIT WT. (KCF)	FORCE (K/FT)	ARM (FT)	MOMENT (K FT/FT)
4	10.25	4.50	46.13	0.150	6.92	5.13	35.46
7	10.25	21.50	220.38	0.120	26.45	5.13	135.53
8	10.50	2.03	20.81	0.120	2.50	6.83	17.06
				Fv=	35.86	M=	188.05

ASSUME BAR SIZE 10 DIAMETER= 1.270 IN

d=	HEEL DEPTH - 2" -(1/2*BAR DIAMETEF	51.37	IN	OK >dmin
dmin=	(M/K)^1/2	33.36	IN	

STEEL AREA

As= M/(fs*j*d) 2.05 IN^2

NOMINAL MOMENT CAPACITY (AASHTO 8.17.1.1)

0.9*Mn= 0.9*(As*fy*d*(1-0.59*(As*fy/fc'*b*d))) 326.84 K FT

CRACKING MOMENT (AASHTO 8.17.1.1)

1.2*Mcr= 1.2*(7.5*fc'^1/2)*S 239.57 K FT

IS 0.9*Mn >=1.2*Mcr ? YES

As (required)= 2.05 IN^2

PROVIDE BAR SIZE 10 AT 6 IN SPACING

BAR AREA= 1.27 IN^2 DIAMETER= 1.270 IN

As (provided)= 2.54 IN^2

HEEL DESIGN (CONTINUED)

CHECK SHEAR IN HEEL AT BACK FACE OF STEM (CRITICAL SECTION)

v=	V/(b*d)	58.18	PSI	NG >vc

CHECK DEVELOPMENT LENGTH OF BAR SIZE 10

Ldb=	MAX. 0.04*Ab*fy/(fc')^1/2 OR 0.0004*db* (AASHTO 8.25.1)				
Ldb=	55.6	IN	OR	30.5	IN
Ldb=	55.6	IN			

Ld=	Ldb*(As (required)/As (provided)) (AASHTO 8.25.3.2)	44.9	IN	(12 IN MIN.) (AASHTO 8.25.3.3)

3.1.3 Toe Design

ASSUME CRITICAL SECTION AT FACE OF STEM FOR M & V

q(max)= 3.96 KSF (T)

q(min)= 2.49 KSF (H)

BEARING PRESSURE AT FRONT FACE OF STEM

y= DISTANCE FROM PRESSURE DIAGRAM AT STEM TO MINIMUM PRESSURE

y= (q(max)-q(min))*((FOOTING WIDTH-TOE WIDTH)/FOOTING WIDTH) 1.10

PRESSURE AT FACE OF STEM= y+q(min) 3.59 KSF

PART	WIDTH (FT)	PRESS. (KSF)	FORCE (K/FT)	ARM (FT)	MOMENT (K FT/FT)
1	4.75	0.37	1.76	3.17	5.57
2	4.75	3.59	17.06	2.38	40.52
		Fv=	18.82	M=	46.09

ASSUME BAR SIZE 9 DIAMETER= 1.128 IN

d= TOE DEPTH - 3" -(1/2*BAR DIAMETER) 56.44 IN OK >dmin
dmin= (M/K)^1/2 19.91 IN

STEEL AREA
As= M/(fs*j*d) 0.46 IN^2

NOMINAL MOMENT CAPACITY (AASHTO 8.17.1.1)
0.9*Mn= 0.9*(As*fy*d*(1-0.59*(As*fy/fc'*b*d))) 166.51 K FT

CRACKING MOMENT (AASHTO 8.17.1.1)
1.2*Mcr= 1.2*(7.5*fc'^1/2)*S 295.77 K FT

IS 0.9*Mn >=1.2*Mcr ? NO, INCREASE AREA BY 33%
As (required)= 0.61 IN^2

PROVIDE BAR SIZE 8.00 AT 12 IN SPACING
BAR AREA= 0.79 IN^2 DIAMETER= 1.000 IN
As (provided)= 0.79 IN^2

CHECK SHEAR IN TOE AT FRONT FACE OF STEM CRITICAL SECTION)

v= V/(b*d) 33.33 PSI OK < vc

TOE DESIGN (CONTINUED)

CHECK DEVELOPMENT LENGTH OF BAR SIZE 8

Ldb=	MAX. 0.04*Ab*fy/(fc')^1/2 OR 0.0004*db* (AASHTO 8.25.1)					
Ldb=	34.6	IN	OR	27.1	IN	
Ldb=	34.6	IN				

Ld=	Ldb*(As (required)/As (provided)) (AASHTO 8.25.3.2)	26.7	IN	(12 IN MIN.) (AASHTO 8.25.3.3)

3.1.4 Stem Design

Flexure

1) Horizontal Loads (At Tenth Points From Top Of Wall To Top Of Heel)
2) Assume A No. 8 Bar Size For Initial Calc. Of D And Revise Based On Bar Size Chosen For As (p)

HT.	Ph	ARM	M	d	dmin	As	0.9*Mn	1.2*Mcr	As(r)	bar (p)	spc (p)	As (p)
FT	K/FT	FT	K FT/FT	IN	IN	IN^2	K FT/FT	K FT/FT	IN^2		IN	IN^2
TOP												
0.00	0.27	1.16	0.32	18.63	1.37	0.01	0.79	36.23	0.01	6	12	0.44
2.15	0.71	1.88	1.33	18.63	2.81	0.04	3.34	36.23	0.05	6	12	0.44
4.30	1.35	2.60	3.51	19.83	4.56	0.10	8.78	40.49	0.13	6	12	0.44
6.45	2.20	3.31	7.29	23.05	6.57	0.18	18.19	53.11	0.24	6	12	0.44
8.60	3.25	4.03	13.10	26.28	8.81	0.28	32.64	67.44	0.37	6	12	0.44
10.75	4.51	4.75	21.43	29.44	11.26	0.41	53.15	83.47	0.54	7	6	1.20
12.90	5.98	5.46	32.68	32.66	13.91	0.56	80.77	101.22	0.74	7	6	1.20
15.05	7.65	6.18	47.30	35.89	16.73	0.74	116.50	120.67	0.98	7	6	1.20
17.20	9.53	6.90	65.73	39.11	19.72	0.94	161.34	141.84	0.94	7	6	1.20
19.35	11.61	7.61	88.42	42.21	22.87	1.17	216.23	164.71	1.17	9	6	2.00
21.50	13.90	8.33	115.81	45.44	26.18	1.42	282.17	189.29	1.42	9	6	2.00
(BOT)												
3.50	1.09	2.33	2.54	18.63	3.87	0.08	6.35	36.23	0.10	6	12	0.44

BATTER IS LOCATED AT 3.50 FT FROM THE TOP OF THE WALL
BATTER WIDTH AT BOTTOM OF STEM AT HEEL IS 2.25 FT THICK
BATTER HEIGHT = 18.00 FT

STEM DESIGN (CONTINUED)

SHEAR
HORIZONTAL LOADS (AT TENTH POINTS FROM TOP OF WALL TO TOP OF HEEL)

HT.	Ph	v	
FT	K/FT	PSI	
(TOP)			
0.00	0.27	1.21	OK < vc
2.15	0.71	3.17	OK < vc
4.30	1.35	5.68	OK < vc
6.45	2.20	7.95	OK < vc
8.60	3.25	10.32	OK < vc
10.75	4.51	12.77	OK < vc
12.90	5.98	15.26	OK < vc
15.05	7.65	17.76	OK < vc
17.20	9.53	20.31	OK < vc
19.35	11.61	22.92	OK < vc
21.50	13.90	25.49	OK < vc
(BOT)			

CHECK DEVELOPMENT LENGTH OF BAR SIZE 9 BAR AREA= 1.00 IN^2
BAR DIA.= 1.128 IN

Ldb= MAX. 0.04*Ab*fy/(fc')^1/2 OR 0.0004*db*fy (AASHTO 8.25.1)
Ldb= 43.8 IN OR 27.1 IN
Ldb= 43.8 IN

Ld= Ldb*(As (required)/As (provided)) 31.2 IN (12 IN MIN.)
(AASHTO 8.25.3.2) (AASHTO 8.25.3.3)

CHECK LAP SPLICE LENGTH FOR DOWEL BAR

CLASS C SPLICE= 1.7*Ld 53.0 IN (12 IN MIN.)
(AASHTO 8.32.31)

SUMMARY

SECTION GEOMETRY

TOTAL WALL HEIGHT=	26.00	FT
FOOTING WIDTH=	19.00	FT
TOE WIDTH=	4.75	FT
TOE THICKNESS=	5.00	FT
HEEL WIDTH=	10.25	FT
HEEL THICKNESS=	4.50	FT
STEM THICKNESS=	1.75	FT
BATTER THICKNESS=	2.25	FT
BATTER HEIGHT=	18.00	FT

REINFORCING

HEEL	PROVIDE NUMBER	10	BARS AT	6	IN SPACES
	DEVELOPMENT LENGTH=	44.9	IN		
TOE	PROVIDE NUMBER	8	BARS AT	12	IN SPACES
	DEVELOPMENT LENGTH=	26.7	IN		
STEM	PROVIDE NUMBER	9	DOWELS AT	6	IN SPACES
	CLASS C SPLICE LENGTH=	53.0	IN		

3.2 Quantity Calculations

3.2.1 Concrete Quantity:

Footing: 4.5ftx (19ft– 4.75ft– 1.75ft) = 5ft x (4.75ft+ 1.75ft) = 88.8ft^3 = 3.3yd^3

Pay Item 25 = 3.3 x 100 = 330 yd^3

Stem: 1.75ft x (26ft – 5ft) + ½ x 18ft x 2.25ft = 57ft^3 = 2.1yd^3

Pay Item 26 = 2.1 x 100 = 210 yd^3

Total Concrete Quantity (Pay Item 23):

(89.6ft^3 + 57ft^3) = 146.6 ft$^{3=}$ 5.4yd^3/ft x 100 = 540 yd^3

Form in place, footing (Pay Item 18):

Contact area = (5ft + 4.5ft) x 100ft = 950ft^2

Forms in place, footing, Integral starter wall (Pay Item 19):

Length = 100ft

Forms in place, Steel Framed Plywood (Pay Item 20):

Contact area = 2 x 21.5ft x 100ft = 4300ft^2

3.2.2 Reinforcement Quantity: (Pay Item 21)

Stem Portion
EL. 105 to EL. 126

Front Bars: #4 @18" L = 26ft – 5ft – 0.5ft = 20.5ft
↑(3"CLR. E. end)

WT = 0.668 lb/ft x 20.5ft x 12"/18" = 9.13lb/ft width

Bars on Back Face:

#7@ 6" L = 14.5ft – 0.25ft = 14.25ft

WT = 2 x 2.044lb/ft x 14.25ft = <u>58.3 lb/ft</u>
↑ (per 12"width) ↑(wt. #7 bar)

-#6 @ 12" L = 22.5ft + 1ft – 14.5ft – 4.5ft + 3ft
(E1.122.5, Above, #7, frg, Lap)

L= 7.5'

WT= 1.502#/1 x 7.5' = 11.3lb/ft

-Longitudinal Bars: #4 @12" E Face L=1 ft

for front face: 26ft – 5ft = 21ft ie 21 spaces, use 22 bars

for back face: 23 bars

WT: (22 + 23) x 0.668lb/ft x 1 ft = 30lbs

Top Portion of Stem: #6@12" L = 26ft – 22.5ft + 1ft-0.25ft = 4.25ft

WT = 1.502lb/ft x 4.25ft = 6.4lb/ft

Total Reinforcement in Stem:

WT = 9.13lb + 58.3lb + 11.3lb + 30lb + 6.4lb = 115lb per 1 ft width

Footing: Transverse Bars #8@12" Bott
#10@6" Top

(8.6lb/ft + 2.7lb/ft)(19 – 0.5') = 209#
↑#10 ↑wt. #8 ↑3"clr
Ea. side

Longitudinal Bars: #5 @18" T & B
2 x 13 x 1.043lb/ft x 1ft = 27lb
↑ T of B ↑ bars/mat ↑ wt #5 ↑ width

Dowels: #9@6" 6.5ft + 4.5ft = 11ft

2 x 3.4lb/ft x 11ft = 75lb
↑ 2 bars/12" ↑ WT. #9

Total Reinforcement in Footing:
W = 209lb + 27lb + 75lb = 311lb per 1ft width

Total Reinforcement in Retaining Wall (Pay Item 21):
WT = 115lb + 311lb = 426lb per ft width x 100ft = 21.3 tons
↑ stem ↑ footing

3.2.3 Excavation and Backfill (See Figure 3-3)

Excavation:

Limits: From front face of wall to 2' beyond heel of footing
Then on 1 to 1 slope

Area 1: (19ft – 4.75ft + 2ft) x 26ft + ½ x 26ft x 26ft = 761ft^3 per ft

↑ ftg. ↑ toe ↑ beyond heel

Area 2: (4.75ft + 2ft) x (5ft + 2ft) + ½ x (7)^{2}ft^2 = 72 ft^3 per ft

Area 3: L = 19ft – 6.5ft + 2ft + 26ft = 40.5ft
H = 40.5ft Tan 18° = 13.2ft
½ x 40.5ft x 13.2ft = 267ft^3 per ft

Total Excavation: (761ft^3 + 72ft^3 + 267ft^3) 1/27 = 41 yd^3 per ft x 100ft = 4100yd^3

Excavation Related Pay Items

Item 07 – Backfill Structural V = 4100 yd^3

Item 08 – Select Granular Fill V = 4100 yd^3

Item 09 – Compaction Roller V = 4100 yd^3

Item 10 – Compaction Plate V = 1.5ft x 26ft x 100ft = 144yd^3

Item 12 – Excavation V = 4100 yd^3

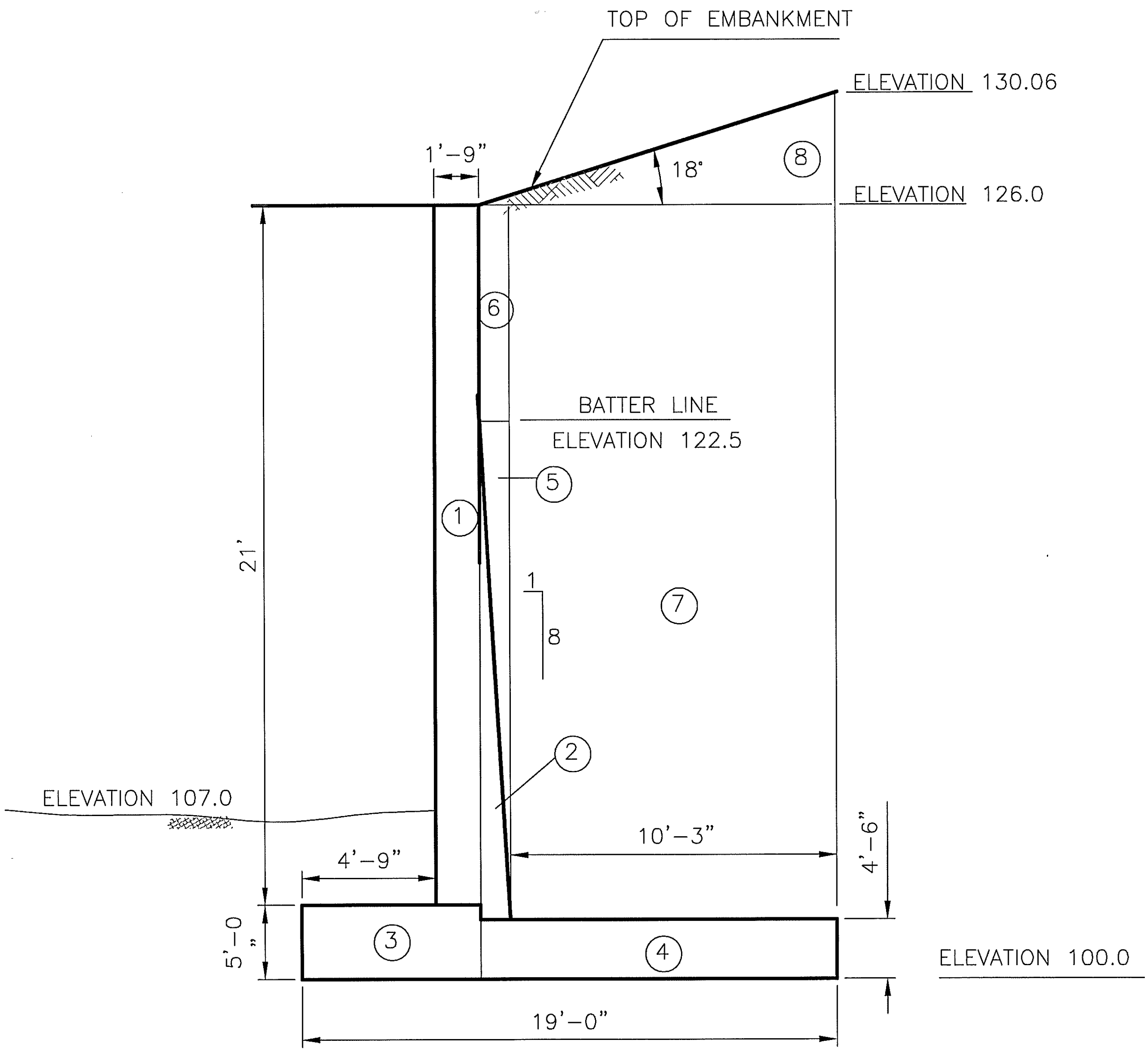


Figure 3-1
Proposed Reinforced Concrete Retaining Wall Configuration

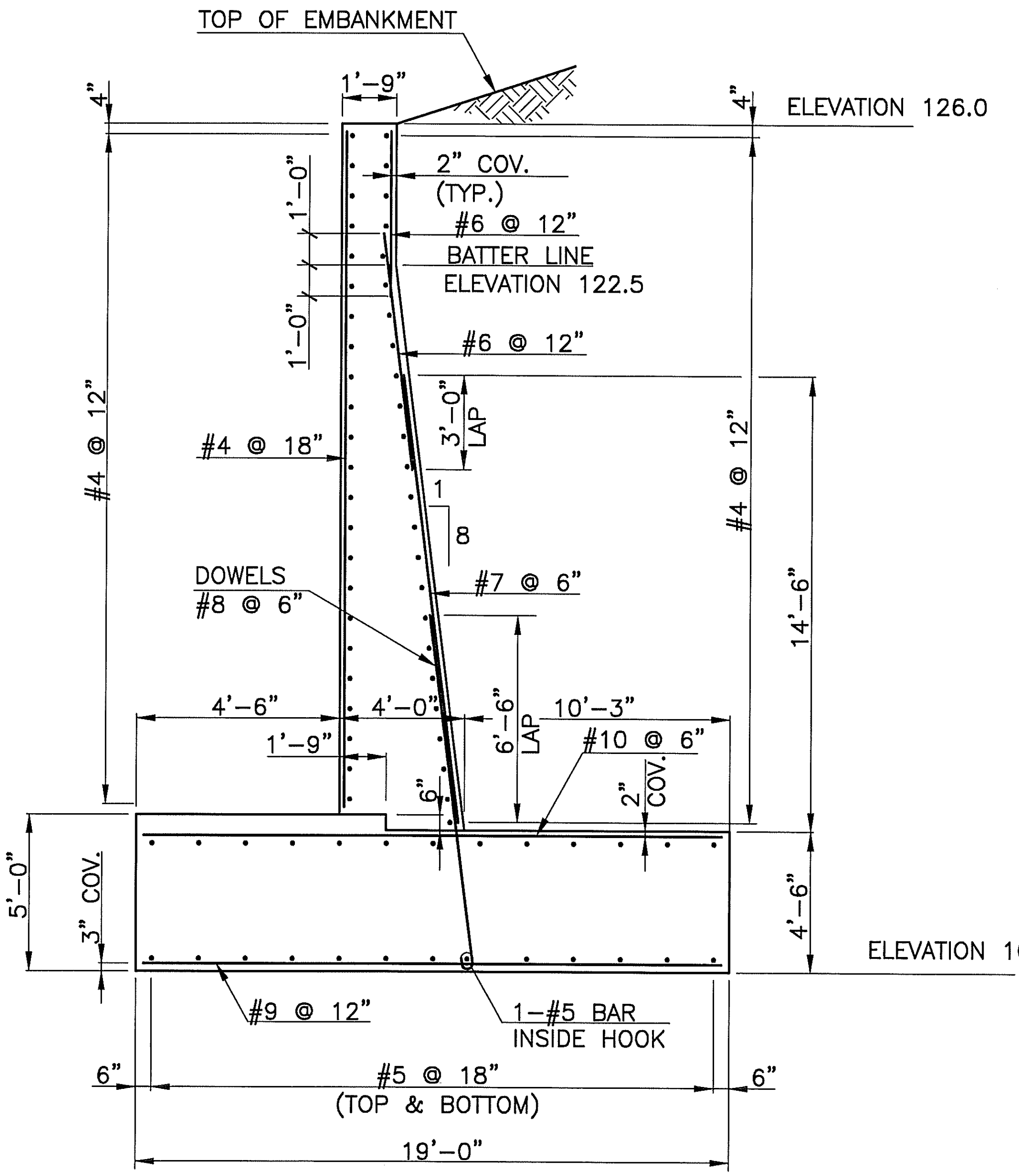


Figure 3-2
Proposed Reinforced Concrete Retaining Wall Section

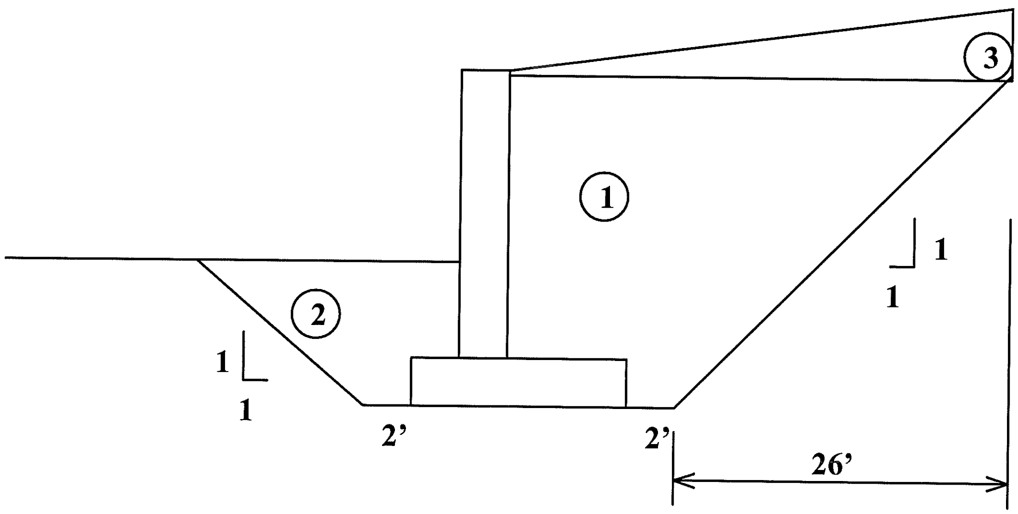


Figure 3-3
Retaining Wall Quantities

CHAPTER 4 CONCRETE MODULAR UNIT GRAVITY WALL

4.1 Design Calculations

Wall Properties - Stepped Modules

$H := 19 \cdot ft + 2 \cdot ft$	Wall height + Distance below grade
$L := 100 \cdot ft$	Wall Length

Soil Properties

Infill Soil Granular Backfill to fill voids of each unit

$\gamma i := 105 \cdot pcf$	Soil Density	Coarse Sand & Gravel
$\phi i := 36 \cdot deg$	Angle of Internal Friction	

Foundation Soil & Retained Soil

$\gamma f := 120 \cdot pcf$	Soil Density
$\phi f := 30 \cdot deg$	Angle of internal friction
$\delta := 22.5\ deg$	Angle of friction between soil and wall - AASHTO 5.9.2 = 3/4 ϕf
$\beta := 64 \cdot deg$	Batter of Wall, where 90 degrees is vertical - Match Modules
$\alpha := 18 \cdot deg$	Slope of Retained Soil
$c := 0$	Soil Cohesion

Determine Coulomb's Active Earth Pressure Coefficient, Ka
for retained granular fill

$$Ka := \frac{\sin(\beta + \phi i)^2}{\sin(\beta)^2 \cdot \sin(\beta - \delta) \cdot \left[1 + \sqrt{\left(\sin(\phi i + \delta) \cdot \frac{\sin(\phi i - \alpha)}{\sin(\beta - \delta) \cdot \sin(\alpha + \beta)} \right)} \right]^2}$$

$Ka = 0.825$ Coulomb's active earth pressure coefficient for fill material

Where:

$\beta = 64 \cdot deg$ $\delta := 22.5\ deg$

$\phi f := 30\ deg$ $\alpha = 18 \cdot deg$

4.1.1 Stability

Consider Overturning

$Mr := 264.6 \frac{kip \cdot ft}{ft}$ Resiting Moment, See Table 4.1

$Ph := \frac{1}{2} \cdot \gamma f \cdot Ka \cdot H^2 \cdot \cos(90 - \beta + \delta)$ Horizontal Load due to Active Soil Pressure

$Ph = 14.5 \frac{kip}{ft}$ Table 4.1

$z := \frac{H}{3}$ $z = 7.0 \cdot ft$ Overturning moment arm

$Mo := P \cdot z$ Overturning Moment due to active soil pressure

$Mo := 101.3 \frac{kip \cdot ft}{ft}$

Where:

$\gamma f := 120\ pcf$ $H = 21 \cdot ft$

$Ka = 0.825$ $\beta = 64 \cdot deg$

Determine Factor of Safety against Overturning, AASHTO 5.5.5

$FSo := \frac{Mr}{Mo}$ $\qquad$ $FSo = 2.6$ $\qquad$ > 2.0, O.K.

Where:

$$Mr := 264.6 \frac{kip \cdot ft}{ft}$$

$$Mo := 101.3 \frac{kip \cdot ft}{ft}$$

Consider Sliding

$k := \frac{2}{3}$ $\qquad$ See Appendix, Ref. 2, Pp. 434

$w := 45.7 \cdot \frac{kip}{ft}$ $\qquad$ Total Weight per ft of Wall, See Table 4.1 -100% Fill Weight

Determine Factor of Safety against Sliding, AASHTO 5.5.5

$FSs := \frac{w \cdot \tan(k \cdot \phi f) + Pv}{Ph}$ $\qquad$ $FSs = 2.11$ $\quad > \quad$ 1.5, OK

Where $Pv = 1/2 \cdot \gamma_f \cdot Ka \cdot H^2 \sin(90-\beta+\delta)$

Table 4.1

Parameters — See Fig. 4-1 for Wall Configuration

Retained Soil, Gravel & Sand	
Unit Weight	105 pcf
Ka	0.825

Soil In Concrete Voids, Gravel & Sand	
Unit Weight	105 pcf
Batter of Wall	26 degrees from 90 - equivalent

Concrete Modular Units

Unit	Unit Height	Unit Depth	Unit Weight*	Fill Volume	80% Fill Wt.	Total Net Wt	Wt per Ft
1	4	4	4,815	95.9	8,056	12,871	1,609
2	4	6	6,065	151.6	12,732	18,797	2,350
3	4	8	7,230	207.8	17,455	24,685	3,086
4	4	10	8,485	263.4	22,128	30,613	3,827
5	6	14	14,970	572.2	48,065	63,035	7,879
Totals:			41,565	1,291	108,436	150,001	18,750

* Weights given for Doublewal II Units for this example

		Resisting Moment, Mr			Overturning Mement, Mo				
Unit	Wt	Arm (ft)	Mr (ft-k)	Cummulative	Soil Depth	Ph** (horiz)	Arm	Mo	Safety Factor
1	1,609	2.0	3.2	3.2	3	0.30	1.00	0.30	
Soil above	24	2.8	0.1	3.3					11.1
2	2,350	3.0	7.0	10.3	7	1.61	2.33	3.75	
Soil above	1,110	5.0	5.5	15.9					4.2
3	3,086	4.0	12.3	28.2	11	3.97	3.67	14.55	
Soil above	2,382	6.0	14.3	42.5					2.9
4	3,827	5.0	19.1	61.6	15	7.38	5.00	36.90	
Soil above	3,498	9.0	31.5	93.1					2.5
5	7,879	7.0	55.2	148.3	21	14.46	7.00	101.25	
Soil above	9,695	12.0	116.3	264.6					2.6
Totals:	35,459		264.6						

** Ph = Ka*gamma*z^2/2*cos(90-beta+delta)

Total Weight = 38,847 (i.e. no reduction of fill weight) Check Sliding = 2.11
including vertical component of Pactive

Minimum Factor of Safety for Overturning = 2.0 (AASHTO 16th - 5.5.5)

4.1.2 Bearing Capacity of Substrate Soil

$\phi f = 30 \cdot deg$ Angle of internal friction

$Nc := 30.14$ From AASHTO Table 4.4.7.1A

$Ng := 22.4$

$B := 14 \cdot ft$ Width of bottom unit of wall, See Figure 4-1

$e := \frac{B}{2} - \frac{Mr - Mo}{w}$ $e = 1.27ft$ Eccentricity of resultant load from the midpoint of the bottom unit

$\frac{B}{6} = 2.33ft$ Kern distance OK, e is within Kern

$Lp := B - e \cdot 2$ $Lp = 11.46ft$ Effective Bearing Length

$\sigma := \frac{w}{B}$ $\sigma := .3.26\ ksf$ Bearing Stress on Foundation Soil

Where:

$w = 45.7 \frac{kip}{ft}$ Weight of the Wall

$q := \frac{1}{2} \cdot \gamma f \cdot Lp \cdot Ng$ $q = 15.4ksf$ Allowable Bearing Stress on Soil

Where:

$\gamma f := 120\ pcf$ Unit weight of soil

Determine Factor of Safety for Bearing, AASHTO 4.4.7.1.2

$FSb := \frac{q}{\sigma}$ $FSb = 4.7$ > 3 OK

4.2 Quantity Calculations

4.2.1 Modular Units

Concrete Quantity (Pay Item 23, 24 & 27)

$A := 277 \cdot ft^2$ Volume per 8' Section

$L = 100 \cdot ft$ Length of Wall

Volume = $V := A \cdot \frac{L}{8}$ $V = 128 \cdot yd^3$

Reinforcement Quantity (Pay Item 21)

$Ratio := 293 \cdot \frac{lbf}{yd^3}$ Assumed ratio of reinforcement to concrete

$Wt := V \cdot Ratio$ $Wt = 18.8$ ton

4.2.2 Footing

Concrete in Leveling Pad (Pay Item 23 & 25)

$A := 3 \cdot 1 \cdot ft^2 + 2 \cdot 1 \cdot ft^2$ $A = 5 \cdot ft^2$ Cross-Section Area

$L = 100 \cdot ft$ Length of Wall

Volume = $V := A \cdot L$ $V = 18.5 \cdot yd^3$

Reinforcement Quantity (Pay Item 21) 128 yd3

$Ratio := 293 \cdot \frac{lbf}{yd^3}$

$Wt := V \cdot Ratio$ $Wt = 2.7$ Ton

Concrete related Pay Items

Item 18 - Forms in place, footing $4 \cdot 1 \cdot ft \cdot L = 400 \cdot ft^2$

Item 21 - Reinforcing Steel 18.8 Ton + 2.7 Ton = 21.5 Ton

Item 23 - Concrete, Ready Mix $128yd^3 + 18.5yd^3 = 146.5yd^3$

Item 24 - Placing concrete, chute $128 \cdot yd^3$ (Assume for plant operations)

Item 25 - Placing concrete, pumped $18.5 \cdot yd^3$

Item 27 - Placing concrete, with crane $128 \cdot yd^3$ (Assume for field ops)

4.2.3 Excavation and Backfill

Excavation (Pay Item 12)

$A := 795 \cdot ft^2$ Cross-Section Area measured in CAD Sketch

$L = 100 \cdot ft$ Length of Wall

Volume = $A \cdot L = 2944 \cdot yd^3$

Backfill: Structural Fill (Pay Items 07 & 08)

$A := 500 \cdot ft^2$ Cross-Section Area measured in CAD Sketch

$L = 100 \cdot ft$ Length of Wall

Volume = $A \cdot L = 1852 \cdot yd^3$

Volume of Granular Backfill behind wall units (Pay Items 07 & 08)

$A := 92 \cdot ft^2$ Cross-Section Area measured in CAD Sketch

$L = 100 \cdot ft$ Length of Wall

Volume = $A \cdot L = 341 \cdot yd^3$

Volume of Granular Backfill inside wall units (Pay Item 07 & 08)

$A := 1291 \cdot ft^2$ CF per 8' Section

$L = 100 \cdot ft$ Length of Wall

Volume = $\frac{1291}{8} \cdot \frac{100}{27} = 598$ CY

Total Volume of Granular Backfill (Pay Items 07 & 08)

Volume = $341\ yd^3 + 598 yd^3 = 939 yd^3$

Geotextile around granular fill pocket (Pay Item 16)

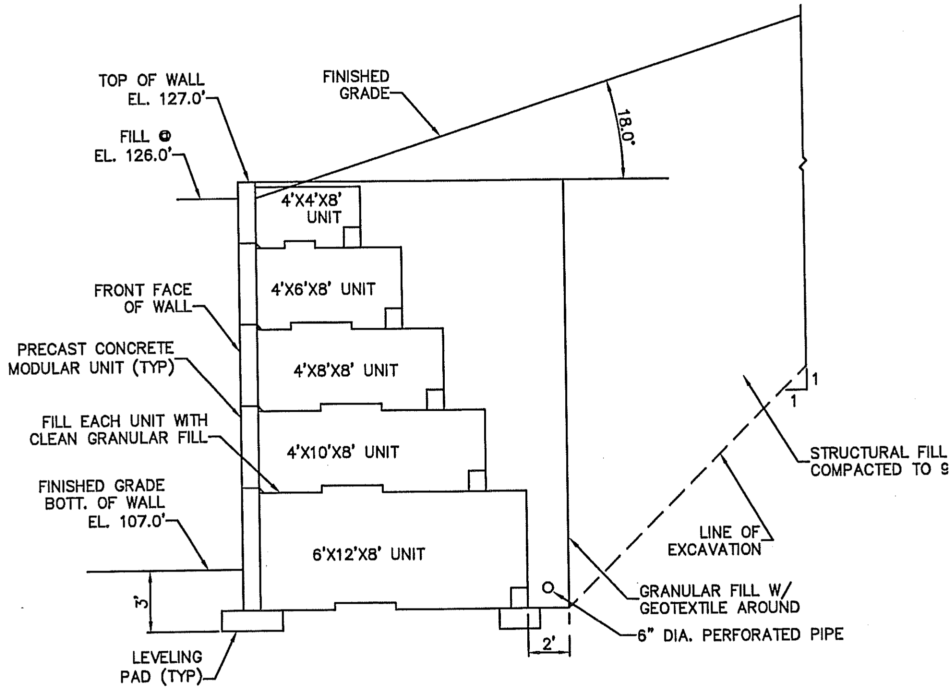
$W := 19 \cdot ft + 6 \cdot ft + 2 \cdot ft$ Length of Geotextile along Wall Cross-Section Area

$L = 100 \cdot ft$ Length of Wall

Area = $W \cdot L = 300 \cdot yd^2$

Excavation related Pay Items

Item 07 - Backfill Structural	$1852\ yd^3 + 939 yd^3 = 2791 yd^3$
Item 08 - Select Granular Fill	$2724 \cdot yd^3$
Item 09 - Compaction, Roller	$2724 \cdot yd^3$
Item 10 - Compaction, Plate	$1.5 \cdot ft \cdot 21 \cdot ft \cdot L = 117 \circ yd^3$
Item 12 - Excavation	$2944 \cdot yd^3$



CONCRETE MODULAR UNIT GRAVITY WALL
FIGURE 4–1

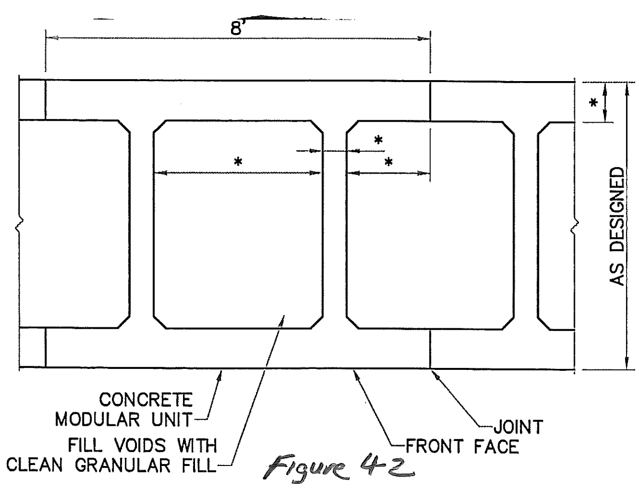


Figure 4-2

PARTIAL PLAN – CONCRETE MODULAR
UNIT GRAVITY WALL

* DIMENSIONS VARY AS PER MANUFACTURER

CHAPTER 5 MECHANICALLY STABILIZED EARTH WALL

5.1 Design Calculations

Wall Properties

$H := 19\cdot ft + 2\cdot ft$ Wall height + Embedment below grade

$L := 100\cdot ft$ Wall Length

Soil Properties

Infill Soil: Granular Backfill used as fill around reinforcement

$\gamma i := 105\cdot pcf$ Soil Density

$\phi i := 36\cdot deg$ Angle of Internal Friction

Foundation & Retained Soil

$\gamma f := 120\cdot pcf$ Soil Density

$\phi f := 30\cdot deg$ Angle of internal friction

$\delta := 0$ Angle of friction between soil and wall

$\beta := 90\cdot deg$ Batter of Wall, where 90 degrees is vertical

$\alpha := 18\cdot deg$ Slope of Retained Soil

$c := 0$ Soil Cohesion

Galvanized Steel Reinforcement Properties

$w := 2\cdot in$ Witdth of Reinforcement Strip

$sv := 2.5\cdot ft$ Vertical Spacing, Center to Center

$sh := 2\cdot ft$ Horizontal Spacing, Center to Center

$fy := 60\cdot ksi$ Yield Stress

$\phi u := 20\cdot deg$ Soil tie friction angle

Determine Coulomb's Active Earth Pressure Coefficient, Ka

$$Ka := \frac{\sin(\beta + \phi i)^2}{\sin(\beta)^2 \cdot \sin(\beta - \delta) \cdot \left[1 + \sqrt{\left(\sin(\phi i + \delta) \cdot \frac{\sin(\phi i - \alpha)}{\sin(\beta - \delta) \cdot \sin(\alpha + \beta)}\right)}\right]^2}$$

$Ka = 0.32$ Coulomb's active earth pressure coefficient for fill material

Where:

$\beta = 90 \cdot deg$ $\delta = 0 \cdot deg$

$\phi i = 36 \cdot deg$ $\alpha = 18 \cdot deg$

5.1.1 Stability

Determine Required Tie Requirements

$FS := 1.5$ Factor of Safety for bearing

$$t := \frac{\gamma i \cdot H \cdot Ka \cdot sv \cdot sh \cdot FS}{w \cdot fy} \qquad t = 0.44\ in \qquad \text{Required Tie Thickness}$$

Where:

$\gamma i = 105\ pcf$ $sv = 3 \cdot ft$ $fy = 35ksi$

$H = 21 \cdot ft$ $sh = 2 \cdot ft$

$Ka = 0.32$ $w = 2 \cdot in$

Consider Corrosion of Reinforcement: Assume the rate of corrosion is 0.001 in. per year and that there is a 100 year life span or per AASHTO

$t = 0.16\ in$ min

Use 1/4 in. thick ties $t := 0.25 \cdot in$

Analysis follows per FHWA software MSEW

Per output, use a Tie Length $Lt = 15ft$

TITLE PAGE
=============

PROJECT IDENTIFICATION: NASSPA Retaining Wall Study
Project Number:

Client: NASSPA
Designer: PJS
Station Number: Typical Section
Description: Corresponds to design section on Page 51 of 82 of NASSPA Report

Revised MSE Wall Design

Company's information:

Telephone #:
Fax #:
E-Mail:

File path and name: C:\Program Files\ADAMA\MSEW(2.0)\NASSPA1.BEN

Original date and time of creating this file: Thu Jul 13 15:24:27 2006
PROGRAM MODE: ANALYSIS of a SIMPLE STRUCTURE using METAL STRIPS as reinforcing material.

SOIL DATA

REINFORCED SOIL
- Unit weight, gamma = 105.0 lb/ft ^{3}
- Design value of internal angle of friction, phi = 36.0 °

RETAINED SOIL
- Unit weight, gamma = 120.0 lb/ft ^{3}
- Design value of internal angle of friction, phi = 30.0 °

FOUNDATION SOIL (Considered as an equivalent uniform soil)
- Equivalent unit weight, gamma_equiv. = 120.0 lb/ft ^{3}
- Equivalent internal angle of friction, phi_equiv. = 30.0 °
- Equivalent cohesion, c_equiv. = 0.0 lb/ft ^{2}

Water table does not affect bearing capacity

LATERAL EARTH PRESSURE COEFFICIENTS
Ka (internal stability) = 0.2596 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.3948 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

BEARING CAPACITY
Bearing capacity coefficients (calculated by MSEW): Nc = 30.14 N_gamma = 22.40

SEISMICITY
----- Not Applicable -----

INPUT DATA: Metal strips (Analysis)
===

D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [ksi]	65.3	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	2.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in²]	0.16	N/A	N/A	N/A	N/A
Ribbed steel strips.					
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0					
Friction angle along reinforcement-soil interface, ro					
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	36.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	1.80	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.73	N/A	N/A	N/A	N/A
Scale-effect correct. factor, alpha	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient with Depth

Z	K / Ka

0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20

INPUT DATA: Facia and Connection (Analysis)

FACIA type: Segmental precast concrete panels.
Depth of panel is 0.50 ft. Horizontal distance to Center of Gravity of panel is 0.25 ft.
Average unit weight of panel is gamma_f = 152.78 lb/ft ³

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00

D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd 21.00 [ft] {Embedded depth is E = 2.00 ft, and height above top of finished bottom grade is H = 19.00 ft }

Batter, omega 0.0 [deg]
Backslope, beta 18.0 [deg]
Backslope rise 100.0 [ft] Broken back equiv. angle, I = 18.00° (see Fig. 25 in DEMO 82)

U N I F O R M S U R C H A R G E
Uniformly distributed dead load is 0.0 [lb/ft ²]

ANALYSIS: CALCULATED FACTORS (Static conditions)

Bearing capacity, Fs = 3.69, Foundation Interface: Direct sliding, Fs = 1.580, Eccentricity, e/L = 0.1392.

#	Elevation [ft]	Length [ft]	Type #	CONNECTION Fs-overall [pullout resistance]	CONNECTION Fs-overall [connect. break]	CONNECTION Fs-overall [Metal strip strength]	Metal strip strength Fs	Pullout resistance Fs	Direct sliding Fs	Eccent. e/L
1	1.00	14.70	1	N/A	2.25	2.50	2.502	1.961	2.051	0.1257
2	3.46	14.70	1	N/A	2.19	2.44	2.436	1.789	2.228	0.0942
3	5.92	14.70	1	N/A	2.39	2.66	2.661	1.781	2.442	0.0650
4	8.38	14.70	1	N/A	2.69	2.98	2.985	1.729	2.705	0.0381
5	10.84	14.70	1	N/A	3.06	3.40	3.400	1.608	3.036	0.0129
6	13.30	14.70	1	N/A	3.62	4.02	4.024	1.639	3.463	-0.0115
7	15.76	14.70	1	N/A	4.62	5.13	5.129	1.790	4.022	-0.0375
8	18.22	14.70	1	N/A	6.62	7.36	7.357	2.009	4.743	-0.0719
9	20.69	14.70	1	N/A	16.63	18.48	18.482	3.326	5.427	-0.1471

↑ length of reinforcement = 14.7 ft

BEARING CAPACITY for GIVEN LAYOUT

	STATIC	SEISMIC	UNITS
Ultimate bearing capacity, q-ult	14257	N/A	[lb/ft ²]
Meyerhof stress, sigma_v	3861.9	N/A	[lb/ft ²]
Eccentricity, e	2.05	N/A	[ft]
Eccentricity, e/L	0.139	N/A	

	NASSPA1		
Fs calculated	3.69	N/A	
Base length	14.70	N/A	[ft]

DIRECT SLIDING for GIVEN LAYOUT

Along reinforced and foundation soils interface: Fs-static = 1.580

#	Metal strip Elevation [ft]	Metal strip Length [ft]	Fs Static	Fs Seismic	Metal strip type #
1	1.00	14.70	2.051	N/A	1
2	3.46	14.70	2.228	N/A	1
3	5.92	14.70	2.442	N/A	1
4	8.38	14.70	2.705	N/A	1
5	10.84	14.70	3.036	N/A	1
6	13.30	14.70	3.463	N/A	1
7	15.76	14.70	4.022	N/A	1
8	18.22	14.70	4.743	N/A	1
9	20.69	14.70	5.427	N/A	1

ECCENTRICITY for GIVEN LAYOUT

Along reinforced and foundation soils interface: e/L static = 0.1392

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e/L Static	e/L Seismic	Metal strip type #
1	1.00	14.70	0.1257	N/A	1
2	3.46	14.70	0.0942	N/A	1
3	5.92	14.70	0.0650	N/A	1
4	8.38	14.70	0.0381	N/A	1
5	10.84	14.70	0.0129	N/A	1
6	13.30	14.70	-0.0115	N/A	1
7	15.76	14.70	-0.0375	N/A	1
8	18.22	14.70	-0.0719	N/A	1
9	20.69	14.70	-0.1471	N/A	1

RESULTS for STRENGTH [Note: Actual Fs-overall = (Yield stress) / (Actual stress)]

#	Metal strip Elevation [ft]	Cover. ratio, Rc=b/Sh	Horiz. spacing, [ft]	Long-term strength [lb/ft]	Tmax [lb/ft]	Tmd [lb/ft]	Specified minimum Fs-overall static	Actual calculated Fs-overall static	Specified minimum Fs-overall seismic	Actual calculated Fs-overall seismic
1	1.00	0.067	2.461	4111	1642.92	N/A	N/A	2.502	N/A	N/A
2	3.46	0.067	2.461	4111	1687.40	N/A	N/A	2.436	N/A	N/A
3	5.92	0.067	2.461	4111	1545.21	N/A	N/A	2.661	N/A	N/A
4	8.38	0.067	2.461	4111	1377.28	N/A	N/A	2.985	N/A	N/A
5	10.84	0.067	2.461	4111	1209.02	N/A	N/A	3.400	N/A	N/A
6	13.30	0.067	2.461	4111	1021.59	N/A	N/A	4.024	N/A	N/A
7	15.76	0.067	2.461	4111	801.47	N/A	N/A	5.129	N/A	N/A
8	18.22	0.067	2.461	4111	558.79	N/A	N/A	7.357	N/A	N/A
9	20.69	0.067	2.461	4111	222.44	N/A	N/A	18.482	N/A	N/A

RESULTS for CONNECTION (static conditions)

#	M. Strips Elevation [ft]	Coverage ratio Rc=b/Sh	Horizontal spacing, Sh [ft]	Connection force, To [lb/ft]	Reduction factor for connect. break CRu	Long-term connect. strength, Tac (break criterion) [lb/ft]	M. Strips long-term strength [lb/ft]	Fs-overall connection break Spec.	Fs-overall connection break Actu	Fs-overall M. strips strength Spec.	Fs-overall M. strips strength Actu
1	1.00	0.067	2.461	1643	0.90	3700	4111	N/A	2.25	N/A	2.50
2	3.46	0.067	2.461	1687	0.90	3700	4111	N/A	2.19	N/A	2.44
3	5.92	0.067	2.461	1545	0.90	3700	4111	N/A	2.39	N/A	2.66
4	8.38	0.067	2.461	1377	0.90	3700	4111	N/A	2.69	N/A	2.98
5	10.84	0.067	2.461	1209	0.90	3700	4111	N/A	3.06	N/A	3.40

6	13.30	0.067	2.461	1022	0.90	3700	4111	N/A	3.62	N/A	4.02
7	15.76	0.067	2.461	801	0.90	3700	4111	N/A	4.62	N/A	5.13
8	18.22	0.067	2.461	559	0.90	3700	4111	N/A	6.62	N/A	7.36
9	20.69	0.067	2.461	222	0.90	3700	4111	N/A	16.63	N/A	18.48

RESULTS for PULLOUT
=====================

#	Metal strip Elevation [ft]	Coverage Ratio Rc=b/Sh	Tmax [lb/ft]	Tmd [lb/ft]	Le [ft]	La [ft]	Avail. Static Pullout Pr [lb/ft]	Specif. Static Fs	Actual Static Fs	Avail. Seismic Pullout Pr [lb/ft]	Specif. Seismic Fs	Actual Seismic Fs
1	1.00	0.067	1643	N/A	14.10	0.60	3221.5	N/A	1.961	0.0	N/A	N/A
2	3.46	0.067	1687	N/A	12.62	2.08	3019.1	N/A	1.789	0.0	N/A	N/A
3	5.92	0.067	1545	N/A	11.15	3.55	2752.3	N/A	1.781	0.0	N/A	N/A
4	8.38	0.067	1377	N/A	9.67	5.03	2381.7	N/A	1.729	0.0	N/A	N/A
5	10.84	0.067	1209	N/A	8.19	6.51	1944.5	N/A	1.608	0.0	N/A	N/A
6	13.30	0.067	1022	N/A	7.72	6.98	1674.3	N/A	1.639	0.0	N/A	N/A
7	15.76	0.067	801	N/A	7.72	6.98	1434.3	N/A	1.790	0.0	N/A	N/A
8	18.22	0.067	559	N/A	7.72	6.98	1122.9	N/A	2.009	0.0	N/A	N/A
9	20.69	0.067	222	N/A	7.72	6.98	739.9	N/A	3.326	0.0	N/A	N/A

Consider Overturning

$FS := 2.0$ Factor of Safety against overturning

Determine Resisting Moment

$W := \gamma i \cdot Lt \cdot H$ $W = 33 \frac{kip}{ft}$ Weight of soil resisting overturning

$x := \frac{Lt}{2}$ $x = 7.5ft$ Moment arm of resisting soil from face of wall

$Mr := W \cdot x$ $Mr = 248 \frac{kip\ ft}{ft}$ Resiting Moment

Determine Overturning Moment

$P := \frac{1}{2} \cdot \gamma i \cdot Ka \cdot H^2 \cdot \sin(\beta)$ $P = 7.4 \frac{kip}{ft}$ Horizontal Load due to Soil

$z := \frac{H}{3}$ $z = 7 \cdot ft$ Overturning moment arm

$Mo := P \cdot z$ $Mo = 51.9 \frac{kip\ ft}{ft}$ Overturning Moment

Determine Factor of Safety

$\frac{Mr}{Mo} = 4.80$ > 2.0, OK

Check Sliding

$k := \frac{2}{3}$ See Appendix, Ref. 2, Pp. 434

Determine Factor of Safety against Sliding, AASHTO 5.5.5

$FSs := \frac{W \cdot \tan(k \cdot \phi i)}{P}$ $FSs = 2.0$ > 1.5 OK

Where:

$P = 7.4 \frac{kip}{ft}$

$W = 33 \frac{kip}{ft}$

5.1.2 Bearing Capacity of Substrate Soil

$\phi f = 30 \cdot deg$ Angle of internal friction

$Nc := 30.14$ From AASHTO Table 4.4.7.1A

$Ng := 22.4$

$e := \frac{Lt}{2} - \frac{Mr - Mo}{W}$ $e = 1.56\ ft$ Eccentricity of resultant load from the midpoint of the retained soil

$Lp := Lt - e \cdot 2$ $Lp = 11.9$ Effective Length

$q := \frac{1}{2} \cdot \gamma f \cdot Lp \cdot Ng$ $q = 16.0\ ksf$ Allowable Bearing Stress on Soil

$\sigma := \gamma i \cdot H$ $\sigma := 2.21\ ksf$ Bearing Stress on Foundation Soil

Determine Factor of Safety for Bearing, AASHTO 4.4.7.1.2

$FSb := \frac{q}{\sigma}$ $FSb = 7.3$ > 3 OK

5.2 Quantity Calculations

5.2.1 Concrete

Wall Panels (Pay Item 29)

$A := H \cdot L$ $\quad A = 2100 \cdot ft^2$ $\quad$ Exposed wall area

$L = 100 \cdot ft$ $\quad$ Length of Wall

$H = 21 \cdot ft$ $\quad$ Height of Wall

$T := 7.5 \cdot in$ $\quad$ Assumed Wall Panel Thickness

$V := A \cdot T$ $\quad V = 48.6 \cdot yd^3$ $\quad$ Volume of Concrete in Wall Panels

Concrete in Leveling Pad (Pay Item 23)

$v := 3 \cdot ft \cdot 1 \cdot ft \cdot L$ $\quad v = 11.1 \cdot yd^3$ $\quad$ Volume in Concrete Leveling Pad

Formwork for Leveling Pad (Pay Item 25)

$Af := 2 \cdot 3 \cdot ft \cdot 100 \cdot ft$ $\quad Af = 600 \cdot ft^2$

5.2.2 Reinforcement Quantity in Wall Panels

Galvanized Ties (Pay Item 22 & 30)

$w = 2 \cdot in$ $\quad$ Tie Width

$t = 0.25 \cdot in$ $\quad$ Tie Thickness

Determine Tie Grid Matrix

$sv = 2.5 \cdot ft$ $\quad$ Vertical Spacing of Ties

$sh = 2 \cdot ft$ $\quad$ Horizontal Spacing of Ties

$Sv := \frac{H}{sv}$ $\quad Sv := 9$ $\quad$ Number of Vertical Ties

$Sh := \frac{L}{sh}$ $\quad Sh = 50$ $\quad$ Number of Horizontal Ties

Determine Total Weight of Tie Steel (Pay Item 30)

$Wt := Sv \cdot Sh \cdot w \cdot t \cdot Lt \cdot 490 \cdot \frac{lbf}{ft^3}$ $\quad Wt = 5.6$ Ton

Determine equivalent area of welded wire fabric for estimating (Pay Item 22)

$Aw := \frac{Wt}{58 \cdot lbf}$ $\quad Aw = 193$ $\quad$ CSF

Reinforcement Steel in Wall Panels and Leveling Pad (Pay Item 21)

$Ratio := 293 \cdot \frac{lbf}{yd^3}$ Assumed Ratio of Reinforcement Steel to Concrete

$Wt := V \cdot Ratio$ $Wt = 71.\ Ton$

Where $V = 48.6 \circ yd^3$ Volume of Concrete in Wall Panels

5.2.3 Excavation and Backfill

Volume of Granular Fill (Pay Item 07 & 08)

$V := H \cdot (15 \cdot ft + 3.5 \cdot ft) \cdot L$ $V = 1439 \circ yd^3$

Where :

$H = 21 \circ ft$ Wall Height

$15 \cdot ft + 3.5 \cdot ft$ Length Granular Fill

$L = 100 \circ ft$ Wall Length

Volume of Structural Fill (Pay Item 07 & 08)

$A := 970 \cdot ft^2 - H \cdot (15 \cdot ft + 3.5 \cdot ft)$ $A = 582 \circ ft^2$ Area of Fill

$V := A \cdot L$ $V = 2154 \circ yd^3$ Total Volume of Structural Fill

Where :

$H = 21 \circ ft$ Wall Height

$15 \cdot ft + 3.5 \cdot ft$ Length Granular Fill

$L = 100 \circ ft$ Wall Length

Geotextile (Pay Item 16)

$A := (H + 18.5 \cdot ft) \cdot L$ $A = 438.9 \circ yd^2$

Excavation related Pay Items

Item 07 - Backfill Structural	$1439 \cdot yd^3 + 2154 \cdot yd^3 = 3593 \circ yd^3$
Item 08 - Select Granular Fill	$3593 \cdot yd^3$
Item 09 - Compaction, Roller	$3593 \cdot yd^3$
Item 10 - Compaction, Plate	$1.5 \cdot ft \cdot 21 \cdot ft \cdot L = 117 \circ yd^3$
Item 12 - Excavation	$3593 \cdot yd^3$

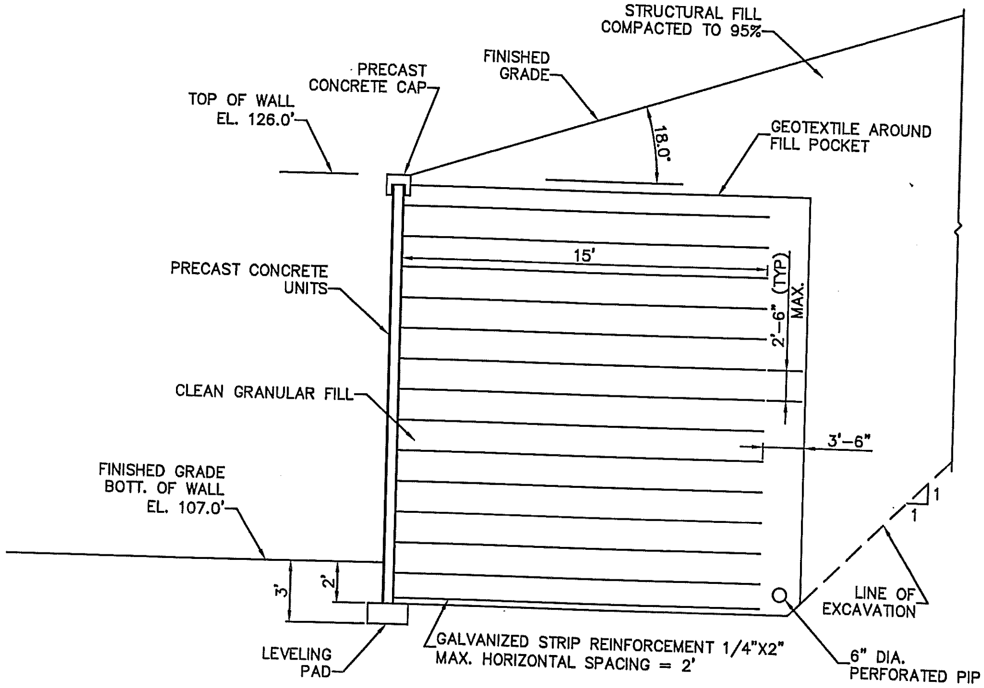


FIGURE 5-1
MECHANICALLY STABILIZED EARTH WALL

CHAPTER 6 SOLDIER PILE AND LAGGING WALL

6.1 Design Calculations

Wall Properties

$H := 19 \cdot ft$	Wall height
$L := 100 \cdot ft$	Wall Length

Retained Soil Properties

$\gamma f := 120 \cdot pcf$	Soil Density
$\phi f := 30 \cdot deg$	Angle of internal friction
$\delta := 0$	Angle of friction between soil and wall
$\beta := 90 \cdot deg$	Batter of Wall, where 90 degrees is vertical
$\alpha := 18 \cdot deg$	Slope of Retained Soil
$c := 0$	Soil Cohesion

Pile Properties

$Fy := 50 \cdot ksi$	Yield Strength

Determine Coulomb's Earth Pressure Coefficients

For passive pressure

$$Kp := \frac{(\sin(\beta - \phi f))^2}{\sin(\beta)^2 \cdot \sin(\beta + \delta) \cdot \left[1 - \left(\sin(\phi f + \delta) \cdot \frac{\sin(\phi f + \alpha)}{\sin(\beta + \delta) \cdot \sin(\beta + \alpha)}\right)^{0.5}\right]^2}$$

Kp = 5.33 Coulomb's passive earth pressure coefficient

FS := 1.5 Factor of Safety used for Kp
(Use in lieu of lengthening the pile later)

$Kp := \frac{Kp}{FS}$ Kp = 3.56 Value used for design

For active pressure

$$Ka := \frac{\sin(\beta + \phi f)^2}{\sin(\beta)^2 \cdot \sin(\beta - \delta) \cdot \left[1 + \sqrt{\left(\sin(\phi f + \delta) \cdot \frac{\sin(\phi f - \alpha)}{\sin(\beta - \delta) \cdot \sin(\alpha + \beta)}\right)}\right]^2}$$

Ka = 0.424 Coulombs active earth pressure coefficient

6.1.1 Pile Design

Determine Pressure Diagram

$S := 8 \cdot ft$ Spacing of soldier pile

$B = 14\ in$ Flange width of soldier pile

bf = effective width = 3.0B $bf = 3.5\ ft$ Effective width of pile including adjustment factor, Value must be less than soldier pile spacing

Consider Area 1, See Figure 6-2

Determine the pressure and force

$p1 := H \cdot \gamma f \cdot Ka$ $p1 = 0.966\ ksf$ Active pressure at exc. line

$f1 := \frac{1}{2} \cdot p1 \cdot H$ $f1 = 9.18\ \frac{kip}{ft}$ Total Force per ft. of width due to p1

$w1 := p1 \cdot S$ $w1 = 7.73\ \frac{kip}{ft}$ Maximum value of uniform Load (Used for lagging design)

$F1 := f1 \cdot S$ $F1 = 73.4\ kip$ Force of retained earth due to pressure p1

Determine associated moment arm

$T := 4 \cdot ft$ Distance of Tie Back from top of pile

$A1 := H - T - \frac{H}{3}$ $A1 = 8.67\ ft$ Moment Arm for F1 from tie back

$M1 := -F1 \cdot A1$ $M1 = -636.4\ kip\ ft$ Moment about Tie Back due to P1

Consider Area 2, See Sketch of Pressure Diagram, Fig. 6-2

Determine pressure and force

$p2 := p1$ $\quad p2 = 0.966\ ksf$ Active pressure at exc line, same as p1

$L2 := \frac{H \cdot Ka}{Kp - Ka}$ $\quad L2 = 2.57 \cdot ft$ Depth of A2 pressure

$f2 := \frac{1}{2} \cdot p2 \cdot L2$ $\quad f2 = 1.241\ \frac{kip}{ft}$ Total Force per ft. of width for Area 2

$w2 := p2 \cdot bf$ $\quad w2 = 3.38\ \frac{kip}{ft}$ Uniform Load

$F2 := f2 \cdot bf$ $\quad F2 = 4.3\ kip$ Force due to pressure p2

Determine associated moment arm

$A2 := A1 + \frac{H}{3} + \frac{L2}{3}$ $\quad A2 = 15.86 \cdot ft$ Moment arm for F2 from tieback

$M2 := -F2 \cdot A2$ $\quad M2 = -68.8\ kip\ ft$ Moment due to pressure in area 2

Consider Area 3, See sketch

$L3 := 7.0 \cdot ft$ Depth of pressure for area 3, note: this value is determined by trial and error so the the moment about the tieback is equal to 0.00

$p3 = \gamma f(Kp - Ka)lp3 = 2.64\ ksf$ Pressure of area 3 due to difference of active & passive pressure

$f3 := \frac{1}{2} \cdot \gamma f \cdot (Kp - Ka) \cdot L3^2$ $\quad f3 = 9.2\ \frac{kip}{ft}$ Total Force per ft. of width due to pressure p3

$w3 := p3 \cdot bf$ $\quad w3 = 9.24\ \frac{kip}{ft}$ Uniform load at bottom

$F3 := f3 \cdot bf$ $\quad F3 = 32.2\ kip$ Force due to pressure p3

Determine associated moment arm

$A3 := H - T + L2 + \frac{2 \cdot L3}{3}$ $A3 = 22.26\ ft$ Moment arm for force about tieback

$M3 := F3 \cdot A3$ $M3 = 716.8\ kip\ ft$

Sum moments about tie back - equal close to 0

$M := M1 + M2 + M3$

$M = +11.6\ kip\ ft > 0$ Therefore value of L3 above is OK

$F := F1 + F2 - F3$ $F3 = 45.5\ kip$ Tie Back Force

Determine Pile length and depth

$Depth := L2 + L3$ $Depth = 9.6 \circ ft$

$Length := L2 + L3 + H$ $Length = 28.6 \circ ft$

Use a 30 ft. pile $Lp := 30 \cdot ft$

Determine Pile Section Required

Determine the point of zero shear by summing the forces (Note: Assume zero shear is above the mud line)

$x := 15.0 \cdot ft$ Distance from top of grade determined by trial & error

$Px := \frac{1}{2} \cdot w1 \cdot \frac{x^2}{H}$ $Px = 45.5\ kip$ Horizontal force due to soil at depth x

$V := F - Px$ $V = 0.0\ kip$ Net shear at depth x, OK

Detemine Required Section Modulus

$M := F \cdot (x - T) - Px \cdot \frac{x}{3}$ $M = 273\ kip\ ft$

$Sx := \frac{M}{0.55 \cdot Fy}$ $Sx = 121\ in^3$ Use HP14 x 89 $Sx := 131 \cdot in^3$

6.1.2 Lagging Design

Design Lagging based on maximum load applied

Properties

$b := 10 \cdot in$	Height of Lagging Panel	$s := 12 \cdot in$	Space of Shear Reinf.
$h := 10 \cdot in$	Depth of Lagging Panel		
$fy := 60 \cdot ksi$	Use 60 ksi Reinforcing		
$fc := 3.5 \cdot ksi$	28 Day compressive strength of concrete		
$fs := 24 \cdot ksi$	Allowable tension in reinforcement		

$w := p1 \cdot b$ $\quad w = 0.805 \frac{kip}{ft}$ Uniform Load at exc line on lagging panel, Equal to pressure at excline x panel width

$S = 8 \cdot ft$ Span of Lagging, Conservative

Determine maximum moment, conservative to design as simply supported beam
Include a load factor of 1.3 for Earth Loads as per AASHTO Table 3.22.1A

$M := \frac{w \cdot S^2}{8} \cdot 1.3$ $\quad M = 8.37\ kip\ ft$ Maximum Moment

$V := 1.15 \cdot \frac{w \cdot S}{2} \cdot 1.3$ $\quad V = \blacksquare \cdot kip$ Maximum Shear

Determine the required reinforcement by service load design

$As := 3 \cdot 0.31 \cdot in^2$ $\quad As = 0.93 \cdot in^2$ Try 3 # 5 bars

$d := h - 3 \cdot in$ $\quad d = 7 \cdot in$ Use 3 in. clearance for Reinforcement

$Ts := As \cdot fs$ $\quad Ts = 22.3\ kip$ Tension & Compression Force

$kd := \frac{2 \cdot Ts}{fc \cdot b}$ $\quad kd = 1.28\ in$ Depth of compression block

$Ma := Ts \cdot \left(d - \frac{kd}{3}\right)$ $\quad Ma = 12.2\ kip\ ft \quad > \quad M = 8.37\ kip\ ft$

For Shear $\quad vc := 0.95 \cdot \sqrt{\frac{fc}{psi}} \cdot psi$ $\quad vc = 56.2\ psi$ Allow. Concrete Shear

$v := \frac{V}{b \cdot d}$ $\quad v = 68.8\ psi$ Total Shear

$Avr := \frac{(v - vc) \cdot b \cdot s}{fs}$ $\quad Avr = 0.06\ in^2 \quad < \quad Av := 0.62 \cdot in^2$ OK

Use 10"x10" Panels w/ 3 #5 Bars on E. Face

6.1.3 Grouted Anchor Design

Use 1" dia. Threadbar $Fa := 76.5 \cdot kip$ See Chapter 2

Bonded Length = FS x F/Fu = 44.7 x 2.5/13.0 = 8.6' Use 10'

6.2 Quantity Calculations

6.2.1 Pile Quantities

Soldier Piles, HP 14x89 (Pay Item 14)

$S = 8.0 \cdot ft$ Pile Spacing

$L = 100 \cdot ft$ Wall Length

$Np := \frac{L}{S} + 1$ $Np = 13.5$ Use $Np := 14$ Piles

$Lp = 30 \cdot ft$ Pile Length

$Qp := Lp \cdot Np$ $Qp = 420.0 \cdot ft$ Total Length of Soldier Pile

Grouted Anchor Quantity, one per pile (Pay Item 04)

14 Units x (15' + 10') = 350LF

6.2.2 Lagging Panel Quantities

Concrete Quantity in Lagging Panels

$H = 19 \cdot ft$ Height of Wall

$h = 10.0 \cdot in$ Depth of Lagging Panel

$Lp := 7 \cdot ft$ Length of Lagging Panel

$Nb := 13$ Number of Bays of Lagging Panel along wall

$Qc := Nb \cdot H \cdot h \cdot Lp$ $Qc = 53.4 \cdot yd^3$ Concrete Quantity

$A := H \cdot L$ $A = 1900 \cdot ft^2$ Exposed Wall Area (Pay Item 29)

6.2.3 Reinforcement Quantity in Lagging Panels (Pay Item 21)

$Lr := 6 \cdot 6.5 \cdot ft + 14 \cdot 8 \cdot in$ $\quad Lr = 48.3 \circ ft$ $\quad$ Total Bar Length Per Panel

$Npa := \frac{H}{b}$ $\quad Npa = 22.8$ $\quad Npa := 23$ $\quad$ Panels per bay

$wt := 1.043 \cdot \frac{lbf}{ft}$ $\quad$ Weight of No. 5 bar

$Nb = 13$ $\quad$ Number of bays

$Wr := Lr \cdot Nb \cdot Npa \cdot wt$

$Wr = 7.5\ Ton$ $\quad$ Total Weight of Reinforcement

6.2.4 Excavation and Backfill

Excavation (Pay Item 12)

$A := 350.4 \cdot ft^2$ $\quad$ Measured in Cad File

$V := A \cdot L$ $\quad V = 1298 \circ yd^3$ $\quad$ Volume of Excavation

Excavation for Tie Rods (Pay Item 11)

$T := 5 \cdot ft$ $\quad$ Assumed Trench width

$At := 402 \cdot ft^2$ $\quad$ Area of trench beyond Excavation, measured in CAD

$Np = 14$ $\quad$ Number of Tie Rod locations

$Vt := At \cdot T \cdot Nb$ $\quad Vt = 968 \circ yd^3$ $\quad$ Volume of Tie Rod Trench excavation

Granular Backfill Behind Wall, for drainage

$Qg := 2 \cdot ft \cdot H \cdot L$ $\quad Qg = 141 \circ yd^3$

Structural Fill

$Qs := V + Vt - Qg$ $\quad Qs = 2125 \circ yd^3$

Geotextile $\quad (19 \cdot ft + 2 \cdot ft) \cdot L = 233.3 \circ yd^2$ $\quad$ Pay Item 16

Excavation related Pay Items

Item 07 - Backfill Structural	$141 \cdot yd^3 + 2125 \cdot yd^3 = 2266 \cdot yd^3$
Item 08 - Select Granular Fill	$2266 \cdot yd^3$
Item 09 - Compaction, Roller	$2266 \cdot yd^3$
Item 10 - Compaction, Plate	$1.5 \cdot ft \cdot 19 \cdot ft \cdot L = 106 \cdot yd^3$
Item 11 - Excavation for Tie Rods	$968 \cdot yd^3$
Item 12 - Excavation	$1298 \cdot yd^3$

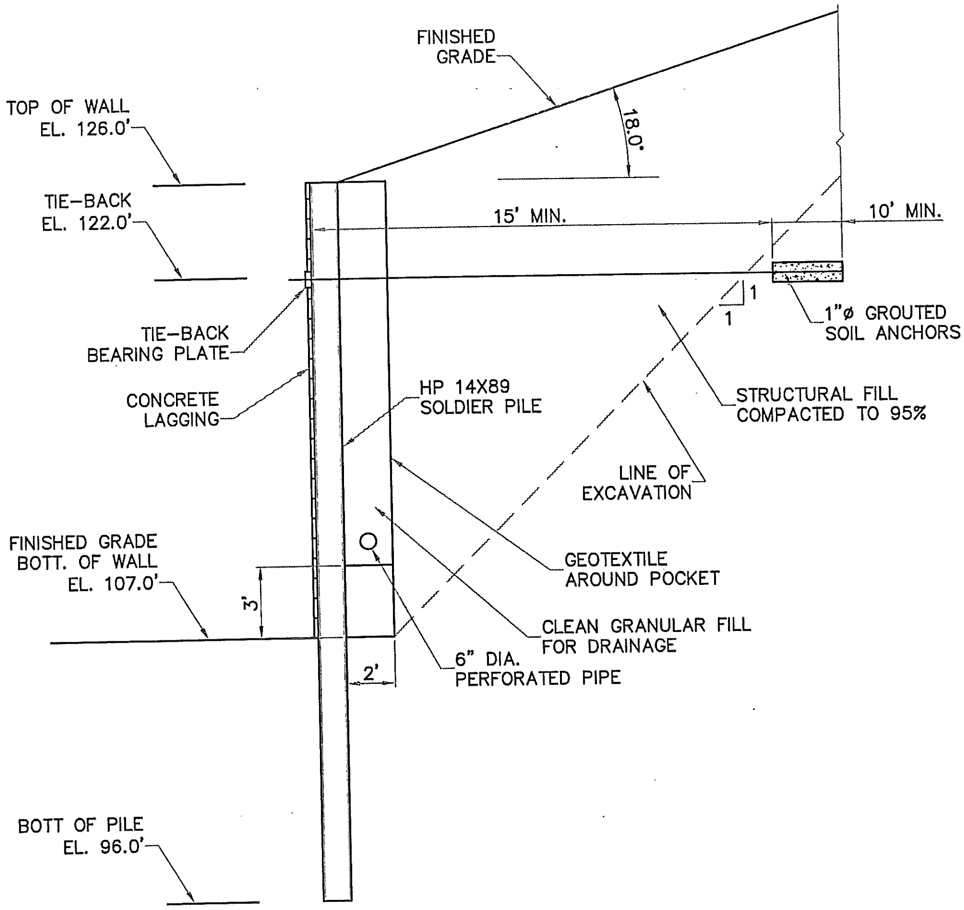
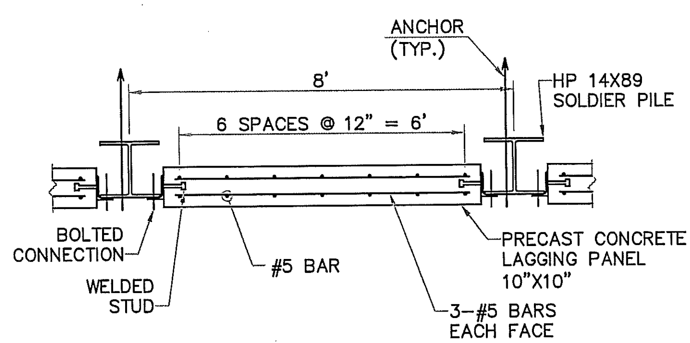


FIGURE 6-1
SOLDIER PILE AND LAGGING WALL



PARTIAL PLAN
SOLDIER PILE AND LAGGING WALL

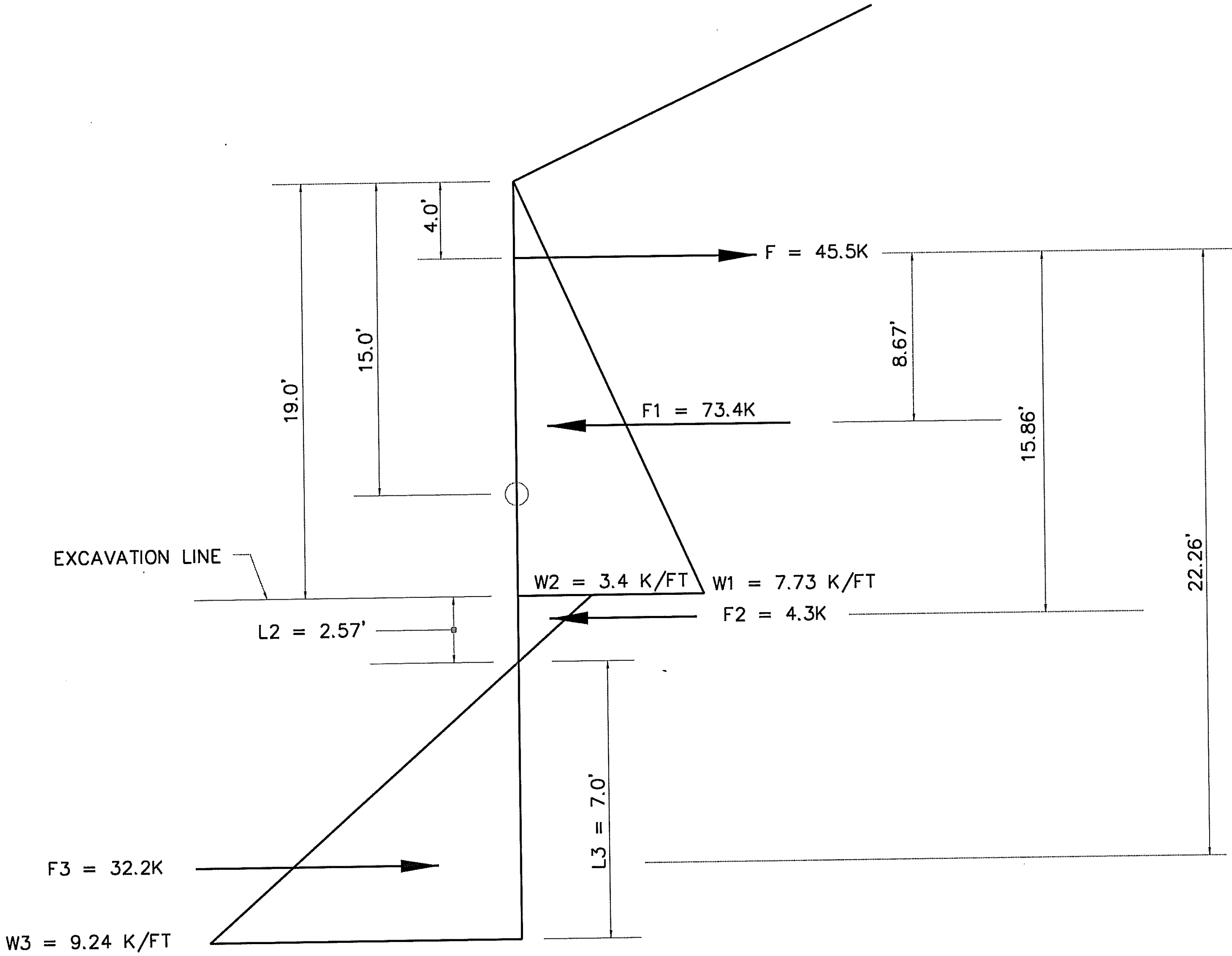


FIGURE 6–2
SOLDIER PILE AND LAGGING WALL
FORCE & PRESSURE DIAGRAM

CHAPTER 7 SLURRY WALL

7.1 Design Calculations

Wall Properties

$H := 19 \cdot ft$	Exposed Wall height
$L := 100 \cdot ft$	Wall Length

Retained Soil Properties

$\gamma f := 120 \cdot pcf$	Soil Density
$\phi f := 30 \cdot deg$	Angle of internal friction
$\delta := 0$	Angle of friction between soil and wall
$\beta := 90 \cdot deg$	Batter of Wall, where 90 degrees is vertical
$\alpha := 18 \cdot deg$	Slope of Retained Soil
$c := 0$	Soil Cohesion

Concrete and Reinforcement Properties

$fc := 4 \cdot ksi$	28 Day compressive strength
$fy := 60 \cdot ksi$	Yield strength of reinforcement

Determine Coulomb's Earth Pressure Coefficients

For passive pressure

$$Kp := \frac{(\sin(\beta - \phi f))^2}{\sin(\beta)^2 \cdot \sin(\beta + \delta) \cdot \left[1 - \left(\sin(\phi f + \delta) \cdot \frac{\sin(\phi f + \alpha)}{\sin(\beta + \delta) \cdot \sin(\beta + \alpha)}\right)^{0.5}\right]^2}$$

$Kp = 5.33$ Coulomb's passive earth pressure coefficient

$FS := 1.5$ Factor of Safety used for Kp
(Use in lieu of lengthening wall embedment depth later)

$Kp := \frac{Kp}{FS}$ $Kp = 3.56$ Value used for design

For active pressure

$$Ka := \frac{\sin(\beta + \phi f)^2}{\sin(\beta)^2 \cdot \sin(\beta - \delta) \cdot \left[1 + \sqrt{\left(\sin(\phi f + \delta) \cdot \frac{\sin(\phi f - \alpha)}{\sin(\beta - \delta) \cdot \sin(\alpha + \beta)}\right)}\right]^2}$$

$Ka = 0.424$ Coulombs active earth pressure coefficient

7.1.1 Cantilever Wall Design

Determine Pressure Diagram, Ref. 2, Pp. 458-462

Consider Area 1

Determine the pressure and force

$p1 := H \cdot \gamma f \cdot Ka$ $\quad p1 = 0.966\ ksf$ Active pressure at exc line

$f1 := \frac{1}{2} \cdot p1 \cdot H$ $\quad f1 = 9.18\ \frac{kip}{ft}$ Total Force per ft. of width due to p1

Consider Area 2

Determine pressure and force

$p2 := p1$ $\quad p2 = 0.966\ ksf$ Active pressure at exc line, same as p1

$L2 := \frac{H \cdot Ka}{Kp - Ka}$ $\quad L2 = 2.57 \cdot ft$ Depth of A2 pressure

$f2 := \frac{1}{2} \cdot p2 \cdot L2$ $\quad f2 = 1.241\ \frac{kip}{ft}$ Total Force per ft. of width for Area 2

Determine moment arms from point E for f1 & f2

$z1 := L2 + \frac{H}{3}$ $\quad z1 = 8.9 \cdot ft$ Moment arm for f1

$z2 := \frac{2}{3} \cdot L2$ $\quad z2 = 1.7 \cdot ft$ Moment arm for f2

Determine z & P

$P := f1 + f2$ $\quad P = 10.4\ \frac{kip}{ft}$ Horizontal force due to Passive Pressure

$z := \frac{f1 \cdot z1 + f2 \cdot z2}{f1 + f2}$ $\quad z = 8.0\ ft$ Distance from Point E

Determine L4 by trial and error

$p5 := \gamma f \cdot H \cdot Kp + \gamma f \cdot L2 \cdot (Kp - Ka)$ $\qquad p5 = 9.07$ ksf

$$A1 := \frac{p5}{\gamma f \cdot (Kp - Ka)} \qquad A1 = 24.1 \text{ ft}$$

$$A2 := \frac{8 \cdot (f1 + f2)}{\gamma f \cdot (Kp - Ka)} \qquad A2 = 221.6 \text{ ft}^2$$

$$A3 := \frac{6 \cdot P \cdot (2 \cdot z \cdot \gamma f \cdot (Kp - Ka) + p5)}{\gamma f^2 \cdot (Kp - Ka)^2} \qquad A3 = 6687.2 \text{ ft}^3$$

$$A4 := \frac{P \cdot (6 \cdot z \cdot p5 + 4 \cdot P)}{\gamma f^2 \cdot (Kp - Ka)^2} \qquad A4 = 35353.1 \text{ ft}^4$$

$L4 := 17.4$ ft $\qquad$ Solved by Trial and Error

$L4^4 + A1\ L4^3 - A2L4^2 - A3L4 - A4 = 0.8 ft^4$ $\qquad$ Close Enough to 0.0

Total distance below Exc Line Required

$D := L2 + L4 \qquad D = 20.0 \cdot ft$

Determine pressures and distances

$p4 := p5 + \gamma f \cdot L4 \cdot (Kp - Ka)$ $\qquad p4 = 15.6$ ksf

$p3 := \gamma f \cdot L4 \cdot (Kp - Ka)$ $\qquad p3 = 6.5$ ksf

$$L5 := \frac{p3 \cdot L4 - 2 \cdot P}{p3 + p4} \qquad L5 = 4.2 \text{ ft}$$

7.1.2 Wall Reinforcement Design

Determine Maximum Bending Moment

$zp := \sqrt{\frac{2 \cdot P}{(Kp - Ka) \cdot \gamma f}}$ $zp = 7.4\ ft$ Point of zero shear

$$Mmax := P \cdot (z + zp) - \left[\frac{1}{2} \cdot \gamma f \cdot zp^2 \cdot (Kp - Ka)\right] \cdot \frac{1}{3} \cdot zp$$

$Mmax = 135.5\ \frac{kip\ ft}{ft}$ Maximum service load moment

Design Reinforcement for slurry wall

$Mu = 1.3\ 1.3\ Mmax$ $Mu = 229\ \frac{kip\ ft}{ft}$ Factor Moment for Group I AASHTO LFD Loading

$\rho min := \frac{200}{\frac{fy}{psi}}$ $\rho min = 0.0033$ Grade 60

$b := 12 \cdot in$ Consider 12 in. wide wall segment

$h := 3 \cdot ft$ Wall thickness

$d := h - 4.5 \cdot in$ $d = 31.5 \cdot in$ Concrete depth to cl of reinforcement

$Asmin := b \cdot d \cdot \rho min$ $Asmin = 1.26\ in^2$ per 1 ft. width

Use No. 11 bars at 9 in. spacing

$As := 1.56 \cdot in^2 \cdot \frac{12}{9}$ $As = 2.1 \cdot in^2$ per 1 ft. width

$a = \frac{As\ fy}{0.85\ fc\ b}$ $a = 3.1\ in$ Depth of compression block

$\phi\ Mn = 0.9\ As\ fy \left(d - \frac{a}{2}\right)$ $\phi\ Mn = 281\ kip\ ft$ OK

$\phi\ Vc = 0.85\ 2 \sqrt{\frac{fc}{psi}}\ b \cdot d \cdot psi$ $\phi\ Vc = 40.6\ kip$

$\phi\ Vc + \phi Vs > V$ OK

7.2 Quantity Calculations

7.2.1 Concrete Quantity (Pay Item 23 & 26)

$Qf := (H + 1 \cdot ft) \cdot 6 \cdot in \cdot L$ $\quad Qf = 37.0 \, yd^3$ $\quad$ CIP Finish Wall Portion Only

Where: $H = 19 \, ft$ $\quad$ Exposed Wall Height

6" = Finish Wall Thickness

$L = 100 \, ft$ $\quad$ Wall Length

Formwork for finish wall (Pay Item 20)

$A := (H + 1 \cdot ft) \cdot L$ $\quad A = 2000 \, ft^2$

7.2.2 Reinforcement Quantity (Pay Item 21)

Vertical Bars, No. 11 @ 9" Each Face

$w11 := 5.313 \cdot \frac{lbf}{ft}$ $\quad$ Bar weight

$L11 := H + D - 0.5 \cdot ft$ $\quad L11 = 38.5 \, ft$ $\quad$ Bar Length

$N11 := \frac{L}{9 \cdot in}$ $\quad N11 = 133.3$ $\quad N11 := 134$ $\quad$ No of bars along length Each Face

$W11 := w11 \cdot L11 \cdot N11 \cdot 2$ $\quad W11 = 54800 \, lbf$ $\quad$ Weight of vert. bars

Horizontal Bars, No. 5 @ 12" Each Face

$w5 := 1.043 \cdot \frac{lbf}{ft}$ $\quad$ Bar Weight

$L5 := L - 0.5 \cdot ft$ $\quad L5 = 99.5 \, ft$ $\quad$ Bar Length

$N5 := \frac{H + D - 0.5 \cdot ft}{12 \cdot in}$ $\quad N5 = 38.5$ $\quad N5 := 39$ $\quad$ No of bars along height Each Face

$W5 := w5 \cdot L5 \cdot N5 \cdot 2$ $\quad W5 = 8095 \, lbf$ $\quad$ Weight of horiz bars

Finish Face Bars, #4 @ 12" Each Face

$w4 := 0.668 \cdot \frac{lbf}{ft}$ $\quad N4h := \frac{H + 1 \cdot ft - 0.5 \cdot ft}{12 \cdot in}$ $\quad N4h = 19.5$ $\quad N4h := 20$

$N4v := \frac{L}{12 \cdot in}$ $\quad N4v = 100$ $\quad L4 := H + 1 \cdot ft - 0.5 \cdot ft$ $\quad L4 = 19.5 \, ft$

$W4 := w4 \cdot (L5 \cdot N4h + L4 \cdot N4v)$ $\quad W4 = 2631.9 \, lbf$ $\quad$ Wt. of #4 bars

Total Weight of Reinforcement (Pay Item 21)

$W := W11 + W5 + W4$ $\quad W = 32.7 \, Ton$

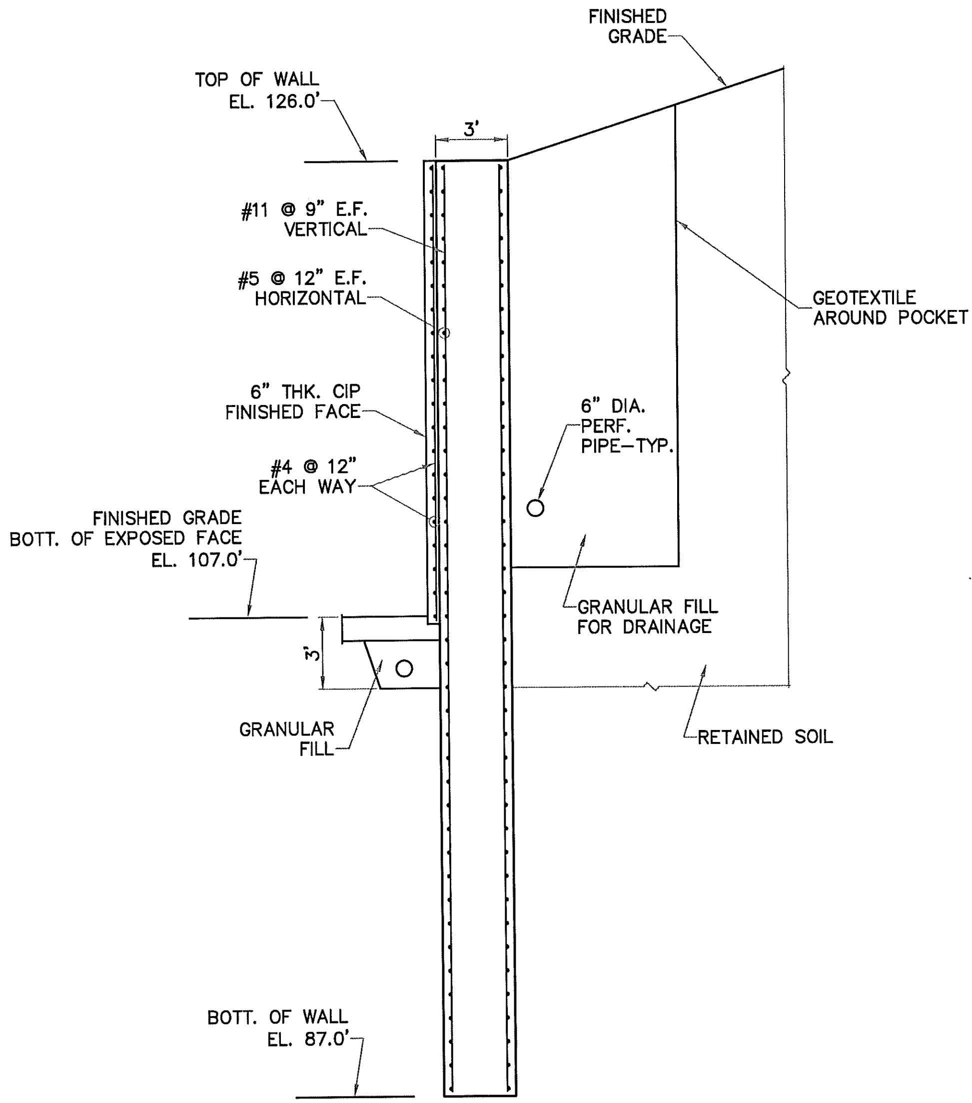


FIGURE 7–1
SLURRY WALL

7.2.3 Excavation and Backfill

Determine Quantity for drainage at front face of wall

$Ae := 7.3 \cdot ft^2$ Cross-Section Area Measured in CAD File

$Qe := Ae \cdot L$ $Qe = 27.0 \cdot yd^3$ Excavation and Backfill Quantity

Determine Quantity for drainage at back face of wall

$Agr := 132 \cdot ft^2$ Cross-Section Area Measured in CAD File

$Qgr := Agr \cdot L$ $Qgr = 488.9 \cdot yd^3$ Excavation and Backfill Quantity

Total Excavation and Backfill Quantity

$Qt := Qe + Qgr$ $Qt = 515.9 \cdot yd^3$

Slurry Trench Excavation and Backfill with concrete (Pay Item 17)

$Qt := (H + D) \cdot h \cdot L$ $Qt = 11690.6\ ft^3$

Where:

Where:	$H = 19 \cdot ft$	Exposed Wall Height
	$D = 20 \cdot ft$	Depth of wall below grade
	$h = 3 \cdot ft$	Wall Thickness
	$L = 100 \cdot ft$	Wall Length

Geotextile around drainage pocket (Pay Item 16)

$Agt := 26 \cdot ft \cdot L$ $Agt = 288.9 \cdot yd^2$

Excavation related Pay Items

Item 07 - Backfill Structural	$515.9 \cdot yd^3$
Item 08 - Select Granular Fill	$515.9 \cdot yd^3$
Item 10 - Compaction, Plate	$515.9 \cdot yd^3$
Item 12 - Excavation	$515.9 \cdot yd^3$

NORTH AMERICAN STEEL SHEET PILING ASSOCIATION
RETAINING WALL STUDY
Appendix A: RS Means Pay Items, Heavy Construction 2009

Item No.	Pay Item		RS Means Section Referenced			Unit	Daily Output	Unit Cost	Comment
01	Sheet piling, 15 ft deep excavation	22 psf, left in place	31 41	16.10	0020	TN	10.81	$ 2,050.00	Used for anchor wall
02	Sheet piling, 20 ft deep excavation	27 psf, left in place	31 41	16.10	0300	TN	12.95	$ 1,950.00	
03	Wales, connections & struts		31 41	16.10	2500	TN	NA	$ 300.00	
04	Tie rod, upset, 1.75 in. to 4 in. dia	with turnbuckle	31 41	16.10	3300	TN	NA	$ 2,700.00	
05	Grouted Anchors	difficult 30'	31 32	36.16	1420	LF	360.00	$ 20.20	
06	No Item								
07	Backfill structural	105 H.P., 150 ft. haul, sand &gravel	31 23	23.14	3200	LCY	670.00	$ 2.02	Does Not include materials
08	Borrow loading	Select granular fill	31 23	23.15	5000	BCY	NA	$ 13.86	Used to determine material price only (+ 10% profit)
09	Compaction, riding, vibrating roller	12 in. lift, 2 passes	31 23	23.23	5060	ECY	5200.00	$ 0.23	Primary compaction method
10	Compaction, walk behind vibrating plate	12 in. lift, 2 passes	31 23	23.23	7200	ECY	560.00	$ 0.78	Compaction method at wall edges, 18 in. width
11	Excavation, trench, common earth	6 ft to 10 ft deep, 1.5 cy hydraulic backhoe	31 23	16.13	0610	BCY	600.00	$ 3.10	Trench for Tie Backs
12	Excavation, trench, common earth	14 ft to 20 ft deep, 1.5 cy hydraulic backhoe	31 23	16.13	1310	BCY	480.00	$ 3.86	Main Excavating
13	Driven piles, H sections	HP10x42, to 50 ft. length	31 62	16.13	0400	VLF	610.00	$ 32.00	
14	Driven piles, H sections	HP14x117 to 50 ft. length	31 62	16.13	1400	VLF	510.00	$ 76.50	
15	Driven piles, complete pile driving setup	Mobilization, large	31 06	60.15	1200	EA	0.27	$ 22,000.00	
16	Geotextile for subsurface drainage	Fabric, laid in trench, adverse conditions	33 46	26.10	0110	SY	1600.00	$ 2.18	

NORTH AMERICAN STEEL SHEET PILING ASSOCIATION
RETAINING WALL STUDY
Appendix A: RS Means Pay Items, Heavy Construction 2009

Item No.	Pay Item		RS Means Section Referenced			Unit	Daily Output	Unit Cost	Comment
17	Slurry Trench, excavated in wet soils	Backfilled w/ 3ksi concrete, no reinforcement	31 56	23.20	0050	CF	333.00	$ 23.50	
18	Forms in place, footing	Continuous wall, plywood, 2x	03 11	13.45	0050	SFCA	440.00	$ 2.80	
19	Forms in place, footing	Integral starter wall, to 4 in	03 11	13.45	1000	LF	400.00	$ 5.55	
20	Steel framed plywood	16 ft to 20 ft high	03 11	13.85	9460	SFCA	400.00	$ 8.15	Used for forming walls
21	Reinforcing steel, A615 Gr 60	10 - 50 ton job, #3 to # 7 bars	03 21	10.60	1050	TN	2.10	$ 2,825.00	Reasonable fit for applicable walls
22	Welded wire fabric	6x6, W4xW4, 58psf/csf	03 22	05.50	0400	CSF	27.00	$ 94.00	Best match for strip steel reinforcing in CMU gravity wall
23	Concrete, ready mix	Normal weight, 3500 psi	03 30	05.35	0200	CY	NA	$ 114.00	Average strength for various components
24	Placing concrete, footings	Continuous, shallow, direct chute	03 31	05.70	1900	CY	120.00	$ 21.00	Assume for precasting operations of CMU gravity wall
25	Placing concrete, footings	Continuous, shallow pumped	03 31	05.70	1950	CY	150.00	$ 28.00	
26	Placing concrete, walls	15 in thk, pumped	03 31	05.70	5350	CY	120.00	$ 35.00	
27	Placing concrete	with crane	03 31	05.70	5400	CY	95.00	$ 53.50	Assume for placing precast segments of CMU gravity wall
28	No Item								
29	Precast concrete wall panels	10 in. thick	03 47	13.50	0100	SF	1550.00	$ 22.68	With 33.3% increase in material price for thickness
30	Galvanizing steel in shop	1 ton to 20 tons	05 05	13.50	5950	TN	NA	$ 875.00	For strip steel reinforcing in CMU gravity wall

North American Steel Sheet Piling Association

Retaining Wall Study

Appendix B: References

1. State of California, Department of transportation, Division of Structure Construction (1995), "Trenching and Shoring Manual", http://www.dot.ca.gov/hq/construction/construc.htm

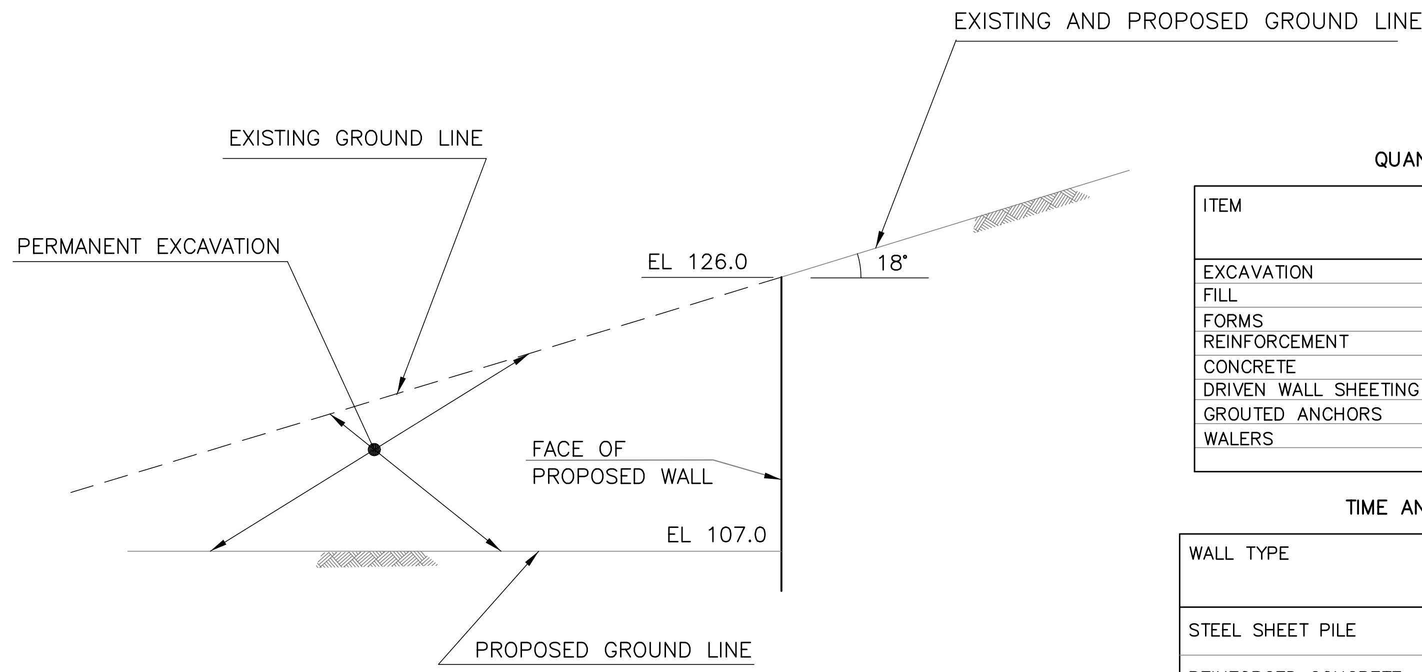
2. Das, B. M. (1999), "Principals of Foundation Engineering", 4th Edition, Brooks/Cole Publishing Company

3. "RS Means Heavy Construction Data 2009", 23rd Edition, Reed Construction Data, Kingston, MA

WALL CONSTRUCTION SEQUENCES

TIED BACK STEEL SHEET PILE WALL
1. EXCAVATE TO LIMITS INDICATED IN CROSS SECTION DETAIL.
2. INSTALL SHEET PILES TO DEPTH SHOWN.
3. INSTALL DRAINAGE SYSTEM AS INDICATED.
4. BACKFILL WALL IN 12 IN. LIFTS AFTER EA. ROW IS PLACED. COMPACT EACH LIFT UTILIZING VIBRATORY ROLLER AND HAND OPERATED EQUIPMENT AS NECESSARY.
5. WHEN THE ELEVATION OF THE GROUTED ANCHORS IS REACHED, INSTALL THE GROUTED ANCHORS.
6. CONTINUE BACKFILLING UNTIL COMPLETE.

REINFORCED CONCRETE WALL
1. EXCAVATE TO LIMITS INDICATED IN CROSS SECTION DETAIL.
2. PLACE FOOTING FORMWORK.
3. PLACE FOOTING STEEL.
4. POUR CONCRETE FOOTING.
5. SET FORMS FOR WALL STEM.
6. PLACE STEM STEEL.
7. POUR CONCRETE STEM.
8. BACKFILL WALL IN 12 IN. LIFTS. COMPACT EACH LIFT UTILIZING VIBRATORY ROLLER AND HAND OPERATED EQUIPMENT AS NECESSARY.



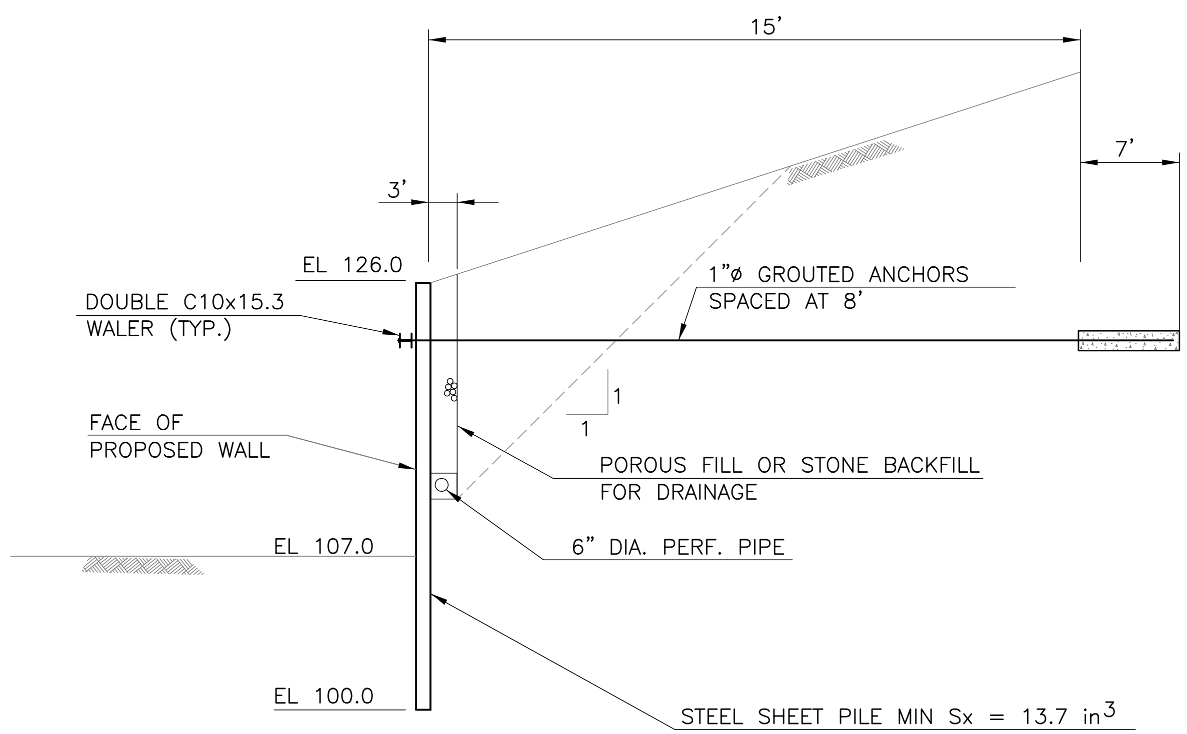
PROPOSED RETAINING WALL CONFIGURATION

QUANTITY COMPARISON TABLE

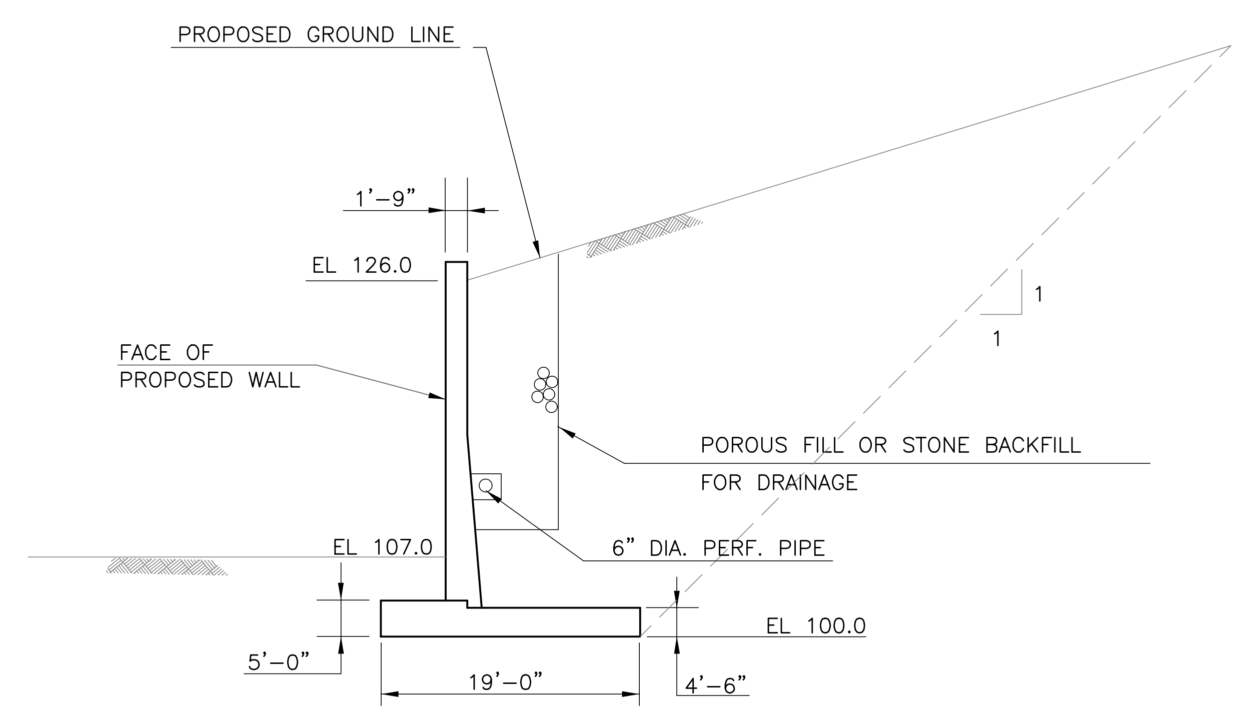
ITEM	UNIT	STEEL SHEET PILE WALL	REINFORCED CONCRETE WALL
EXCAVATION	CY	211	4,100
FILL	CY	211	4,100
FORMS	SF	NA	5,350
REINFORCEMENT	LBS	NA	43,000
CONCRETE	CY	NA	540
DRIVEN WALL SHEETING	TON	29.0	NA
GROUTED ANCHORS	LF	264	NA
WALERS	TON	1.5	NA

TIME AND COST COMPARISON TABLE

WALL TYPE	TIME TO CONSTRUCT FT/DAY	COST TO CONSTRUCT PER L.F.	COST TO CONSTRUCT PER S.F. EXPOSED
STEEL SHEET PILE	7.7	$906	$48
REINFORCED CONCRETE	2.2	$2,586	$136



TIED STEEL SHEET PILE WALL



NOTE: REINFORCEMENT STEEL NOT SHOWN FOR CLARITY. SEE CALCULATIONS.

CAST–IN–PLACE REINFORCED CONCRETE WALL

COST REVISED 10/09

SCALE: NTS
DATE: 1–06
DES. BY: MHM
DRN. BY: MHM
CHK. BY: RRS
PROJECT: NASSPA
FILE: WALLSTUDY

NJ Cert. of Auth. No. 24GA28097900

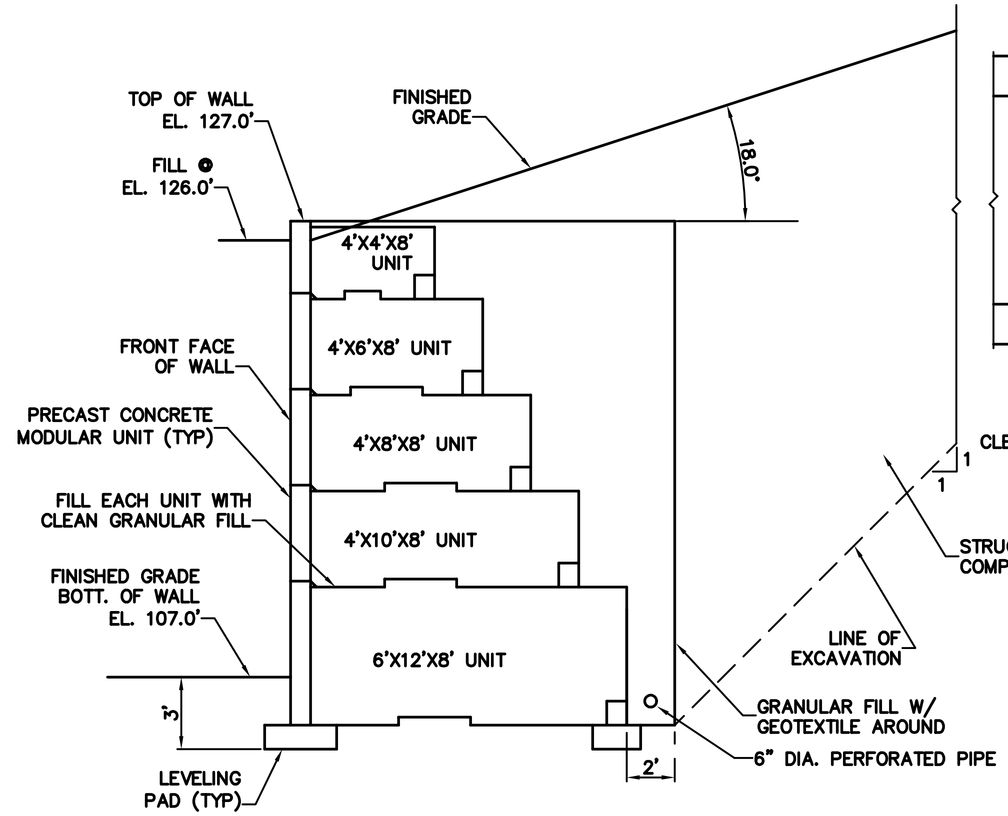
EIC Group LLC
420 Route 46 East, Suite 1
Fairfield, New Jersey 07004
Tel: 973.227.8660
Fax: 973.227.8661

◦ Engineering / Surveying
◦ Inspections
◦ Construction

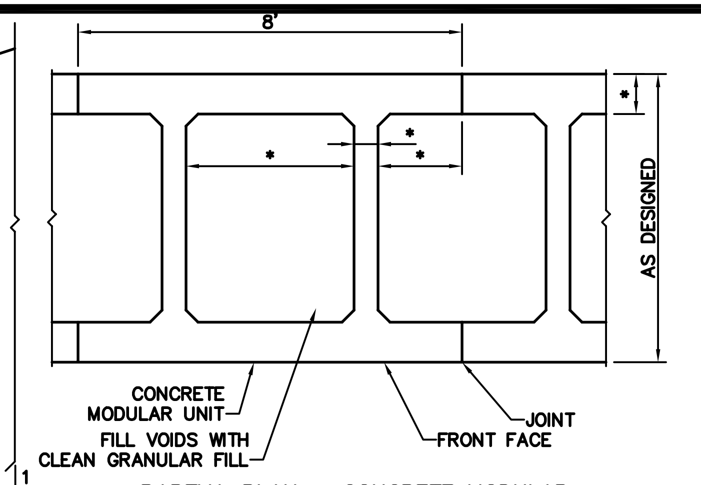
STEEL SHEET PILE WALL
REINFORCED CONCRETE WALL

NORTH AMERICAN
STEEL SHEET PILING ASSOCIATION
RETAINING WALL COMPARISON STUDY

SHEET No. 1 OF 3

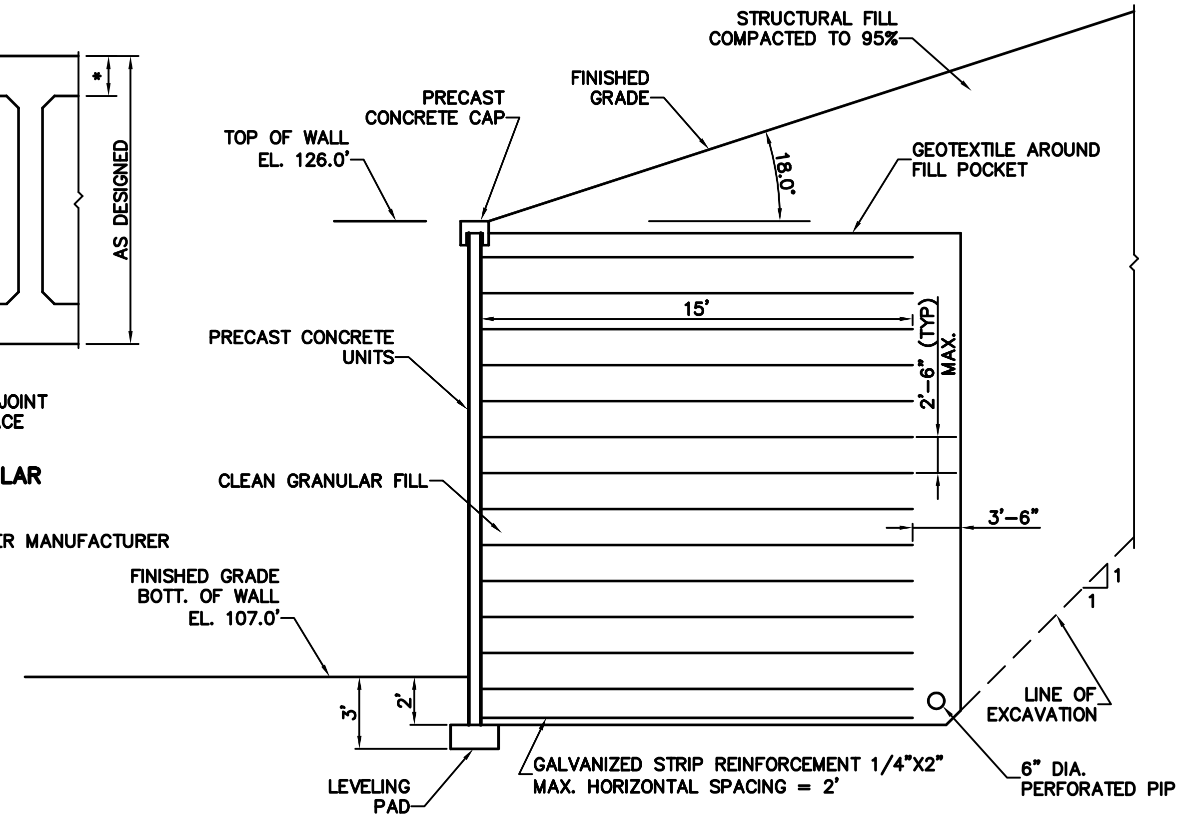


CONCRETE MODULAR UNIT GRAVITY WALL

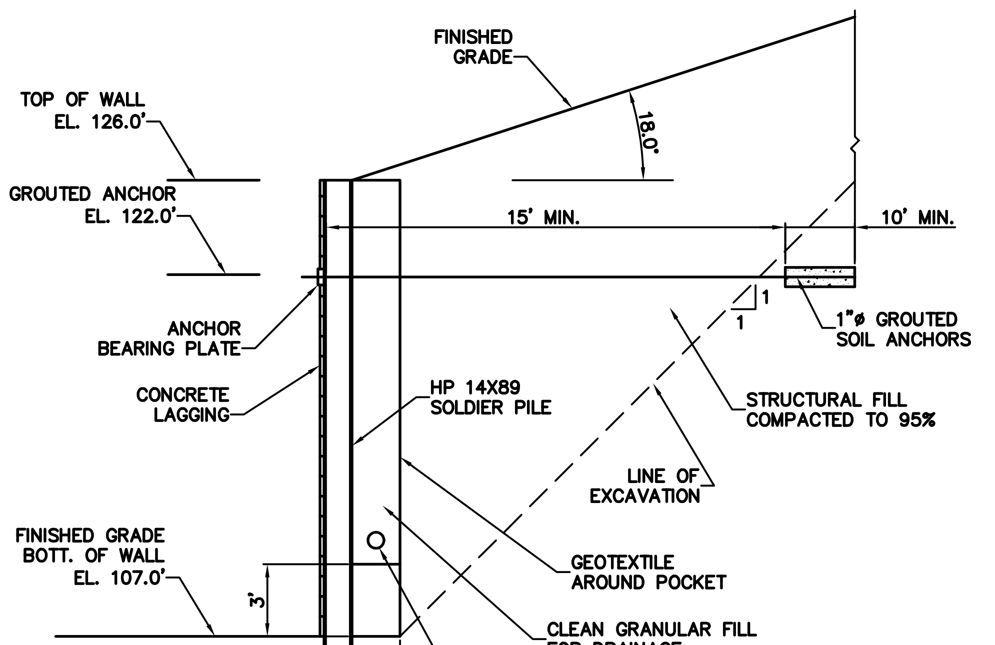


PARTIAL PLAN – CONCRETE MODULAR UNIT GRAVITY WALL

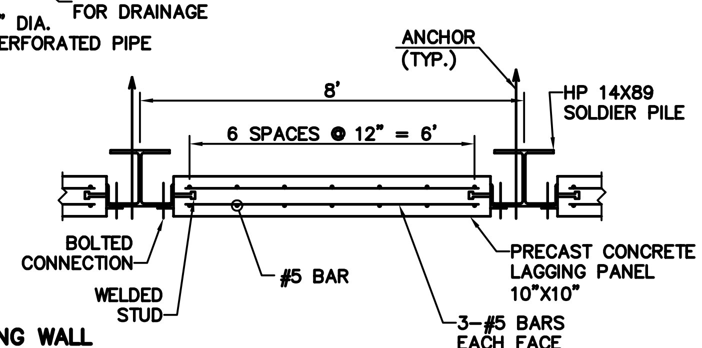
* DIMENSIONS VARY AS PER MANUFACTURER



MECHANICALLY STABILIZED EARTH WALL



SOLDIER PILE AND LAGGING WALL



PARTIAL PLAN

WALL CONSTRUCTION SEQUENCES

CONCRETE MODULAR UNIT GRAVITY WALL

1. EXCAVATE TO LIMITS INDICATED IN CROSS SECTION DETAIL.
2. INSTALL CONCRETE LEVELING PADS AS INDICATED.
3. PLACE CONCRETE MODULAR UNITS (1 ROW AT A TIME) AS SHOWN. FILL UNIT WITH CLEAN GRAVEL FILL.
4. INSTALL DRAINAGE SYSTEM AS INDICATED.
5. BACKFILL WALL IN 12 IN. LIFTS AFTER EA. ROW IS PLACED.
6. COMPACT EACH LIFT UTILIZING VIBRATORY ROLLER AND HAND OPERATED EQUIPMENT AS NECESSARY.

MECHANICALLY STABILIZED EARTH WALL

1. EXCAVATE TO LIMITS INDICATED IN CROSS SECTION DETAIL.
2. INSTALL CONCRETE LEVELING PAD AS INDICATED.
3. PLACE CONCRETE WALL PANELS (1 ROW AT A TIME) AS SHOWN.
4. BACKFILL WALL IN 12 IN. LIFTS.
5. COMPACT EACH LIFT UTILIZING VIBRATORY ROLLER AND HAND OPERATED EQUIPMENT AS NECESSARY.
6. ATTACH GALVANIZED STEEL REINFORCEMENT STRIPS AT EACH CONNECTION POINT DURING BACKFILL PROCEDURES.
7. INSTALL DRAINAGE SYSTEM AS INDICATED.

SOLDIER PILE AND LAGGING WALL

1. EXCAVATE TO LIMITS INDICATED IN CROSS SECTION DETAIL.
2. INSTALL SOLDIER PILES TO DEPTH SHOWN AT 8 FT. SPACING.
3. INSTALL DRAINAGE SYSTEM AS INDICATED.
4. PLACE CONCRETE LAGGING (2 TO 3 PANEL ROWS AT A TIME) AND BACKFILL WALL IN 12 IN. LIFTS.
5. COMPACT EACH LIFT UTILIZING VIBRATORY ROLLER AND HAND OPERATED EQUIPMENT AS NECESSARY.
6. WHEN THE ELEVATION OF THE SOIL ANCHOR IS REACHED, INSTALL THE SOIL ANCHOR.
7. CONTINUE INSTALLING CONCRETE LAGGING AND BACKFILL.

TIME AND COST COMPARISON TABLE

WALL TYPE	TIME TO CONSTRUCT FT/DAY	COST TO CONSTRUCT PER L.F.	COST TO CONSTRUCT PER S.F. EXPOSED
CONCRETE MODULAR UNIT GRAVITY WALL	2.6	$1,447	$76
MECHANICALLY STABILIZED EARTH WALL	2.1	$1,816	$96
SOLDIER PILE AND LAGGING WALL	4.2	$1,719	$90

QUANTITY COMPARISON TABLE

NO.	PAY ITEM	UNIT	CONCRETE MODULAR UNIT GRAVITY WALL	MSE WALL	SOLDIER PILE AND LAGGING WALL
01	SHT. PILE, 22 PSF	TN	NA	NA	NA
02	SHT. PILE, 27 PSF	TN	NA	NA	NA
03	WALES, CONN., STRUTS	TN	NA	NA	NA
04	GROUTED ANCHOR	LB	NA	NA	940.0
05	SOIL NAIL LAYOUT	EA	NA	NA	NA
06	INSTALL SOIL NAILS	EA	NA	NA	NA
07	BACKFILLING	CY	2,751.0	3,593.0	2,266.0
08	SELECT GRANULAR FILL	CY	2,724.0	3,593.0	2,266.0
09	COMPACTION, ROLLER	CY	2,724.0	3,593.0	2,266.0
10	COMPACTION, PLATE	CY	117.0	117.0	106.0
11	EXCAVATION, 6 TO 10 FT.	CY	NA	NA	968.0
12	EXCAVATION, 14 TO 20 FT.	CY	2,944.0	3,593.0	1,298.0
13	ANCHORS	LF	NA	NA	350.0
14	DRIVEN HP14X89	LF	NA	NA	420.0
15	PILE SETUP, LARGE	EA	NA	NA	1.0
16	GEOTEXTILE	SY	300.0	438.9	233.3
17	SLURRY TRENCH	CF	NA	NA	NA
18	FORMS IN PLACE, FOOTING	SF	400.0	NA	NA
19	FORMS, STARTER WALL	LF	NA	NA	NA
20	FORMS, STEEL FRAMED	SF	NA	NA	NA
21	REINFORCEMENT	TN	21.3	7.1	7.5
22	WELDED WIRE FABRIC	SF	NA	193.0	NA
23	CONCRETE, READY MIX	CY	142.5	11.1	NA
24	PLACING CONC, CHUTE	CY	124.0	NA	NA
25	PLACING CONC, PUMPED	CY	18.5	600.0	NA
26	PLACING CONC, WALLS	CY	NA	NA	NA
27	PLACING CONC, CRANE	CY	124.0	NA	NA
28	GUNITING SURFACE, 4 IN.	SF	NA	NA	NA
29	PRECAST WALL PANEL	SF	NA	2,100.0	1,900.0
30	GALVANIZING	TN	NA	5.6	NA

COST REVISED 10/09

NORTH AMERICAN STEEL SHEET PILING ASSOCIATION

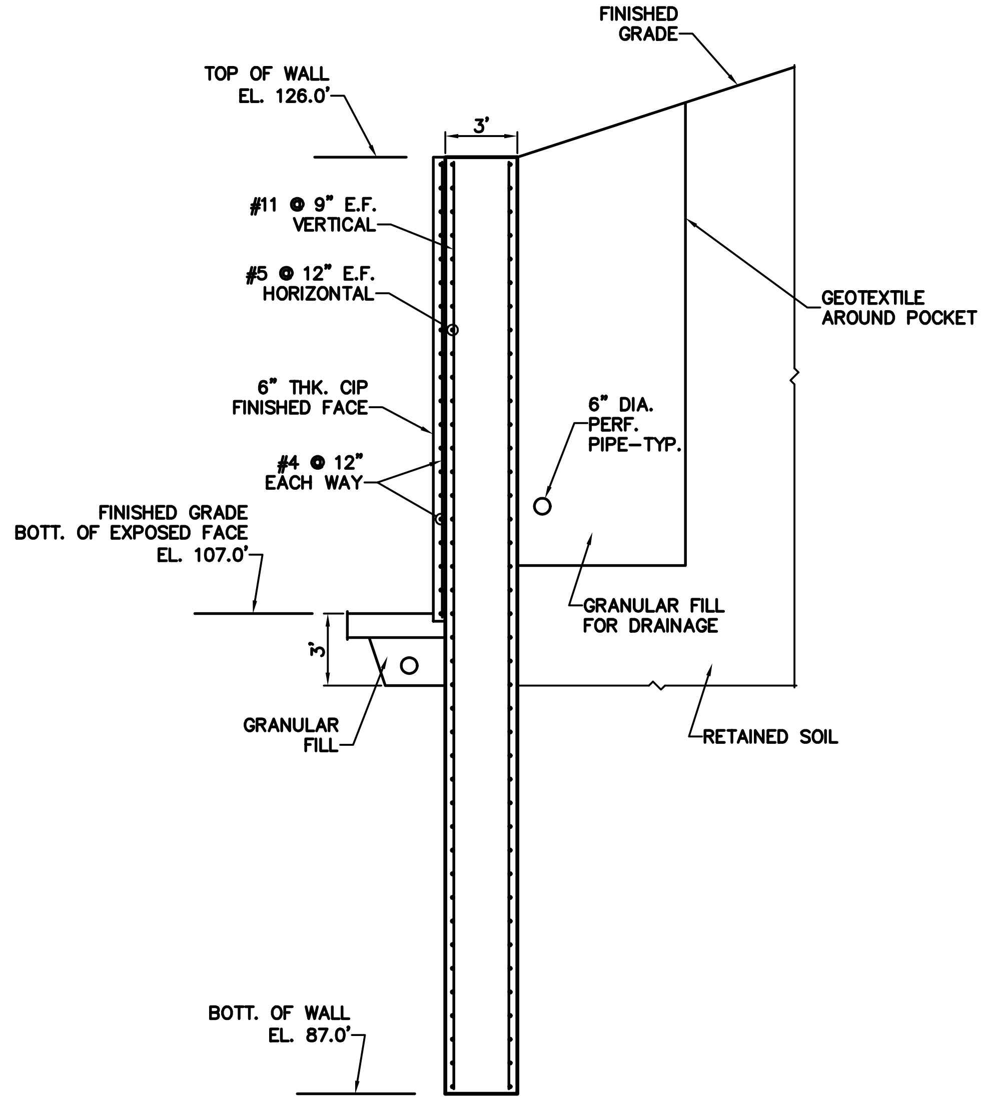
RETAINING WALL COMPARISON STUDY

CONCRETE MODULAR UNIT GRAVITY WALL
MECHANICALLY STABILIZED EARTH WALL
AND SOLDIER PILE AND LAGGING WALL

EIC Group LLC
420 Route 46 East, Suite 1
Fairfield, New Jersey 07004
Tel: 973.227.8660
Fax: 973.227.8661
NJ Cert. of Auth. No. 24GA28097900
◦ Engineering / Surveying
◦ Inspections
◦ Construction

SCALE:	NTS
DATE:	5–06
DES. BY:	RRS
DRN. BY:	RRS
CHK. BY:	MHM
PROJECT:	NASSPA
FILE:	WALLSTUDY

SHEET No. 2 OF 3



SLURRY WALL

WALL CONSTRUCTION SEQUENCES

SLURRY WALL

1. EXCAVATE FOR ALTERNATE PANEL LENGTHS OF 8 FT. TO 12 FT. WHILE FILLING EXCAVATION WITH A BENTONITE SLURRY.
2. PLACE REINFORCEMENT CAGE INTO EXCAVATED AREA.
3. PLACE TREMMIE CONCRETE BEGINNING AT BOTTOM OF EXCAVATION AND WORK UP WHILE COLLECTING BENTONITE SLURRY FOR RE-USE.
4. ALLOW APPROPRIATE CURE TIME, THEN BEGIN EXCAVATING BETWEEN SLURRY WALL PANELS WHILE PLACING BENTONITE SLURRY.
5. PLACE REINFORCEMENT CAGE INTO EXCAVATED AREA. PLACE TREMMIE CONCRETE BEGINNING AT BOTTOM OF EXCAVATION AND WORK UP WHILE COLLECTING BENTONITE
6. SLURRY FOR RE-USE.
7. ALLOW APPROPRIATE CURE TIME THEN EXCAVATE TO FINAL GRADE.

QUANTITY TABLE

NO.	PAY ITEM	UNIT	SLURRY WALL
01	SHT. PILE, 22 PSF	TN	NA
02	SHT. PILE, 27 PSF	TN	NA
03	WALES, CONN., STRUTS	TN	NA
04	TIE RODS	TN	NA
05	SOIL NAIL LAYOUT	EA	NA
06	INSTALL SOIL NAILS	EA	NA
07	BACKFILLING	CY	515.9
08	SELECT GRANULAR FILL	CY	515.9
09	COMPACTION, ROLLER	CY	NA
10	COMPACTION, PLATE	CY	515.9
11	EXCAVATION, 6 TO 10 FT.	CY	NA
12	EXCAVATION, 14 TO 20 FT.	CY	515.9
13	DRIVEN HP10X42	LF	NA
14	DRIVEN HP14X117	LF	NA
15	PILE SETUP, LARGE	EA	NA
16	GEOTEXTILE	SY	288.9
17	SLURRY TRENCH	CF	11,691.0
18	FORMS IN PLACE, FOOTING	SF	NA
19	FORMS, STARTER WALL	LF	NA
20	FORMS, STEEL FRAMED	SF	2,000.0
21	REINFORCEMENT	TN	32.7
22	WELDED WIRE FABRIC	SF	NA
23	CONCRETE, READY MIX	CY	37.0
24	PLACING CONC, CHUTE	CY	NA
25	PLACING CONC, PUMPED	CY	NA
26	PLACING CONC, WALLS	CY	37.0
27	PLACING CONC, CRANE	CY	NA
28	GUNITING SURFACE, 4 IN.	SF	NA
29	PRECAST WALL PANEL	SF	NA
30	GALVANIZING	TN	NA

TIME AND COST TABLE

WALL TYPE	TIME TO CONSTRUCT FT/DAY	COST TO CONSTRUCT	
		PER L.F.	PER S.F. EXPOSED
SLURRY WALL	1.5	$4,001	$211

COST REVISED 10/09

SCALE:	NTS
DATE:	5–06
DES. BY:	RRS
DRN. BY:	RRS
CHK. BY:	MHM
PROJECT:	NASSPA
FILE:	WALLSTUDY

NJ Cert. of Auth. No. 24GA28097900
EIC Group LLC
420 Route 46 East, Suite 1
Fairfield, New Jersey 07004
Tel: 973.227.8660
Fax: 973.227.8661
◦ Engineering / Surveying
◦ Inspections
◦ Construction

SLURRY WALL

NORTH AMERICAN
STEEL SHEET PILING ASSOCIATION
RETAINING WALL COMPARISON STUDY

SHEET No. 3 OF 3

NORTH AMERICAN STEEL SHEET PILING ASSOCIATION
500 Montgomery Street • Suite 400 • Alexandria, VA 22314 • 866.658.8667 • www.nasspa.com