DLZ Ohio, Inc.

Project: CUY 271
Job No.: 1122-1001-90
Subject: Wall WS1, Panels 1-3

Made By: ASP Date: 3/17/2014
Chk'd By: LNB Date: 3/17/2014

Stability Analysis - Replacement Wall (Cantilever Design

Total Height = 7.38 ft
wall ht.over retained soil = 0.00 ft

Loading information:

*Live Load Surchage:	4.29	ft
Railing Load P:	54.000	k
Ultimate Adhesion:	0.00	ksf
Ka =	0.28	
Kp =	3.54	
soil weight:	0.130	kcf
concrete weight:	0.150	kcf
DL =	0.64	k/ft
LL =	0.00	k/ft
x_{SS} =	2.57	ft
fc' =	4,000	psi
fy =	60,000	psi

Wall geometry:

t_{heel} =	1.500	ft
w_{heel} =	6.000	ft
t_{toe} =	1.500	ft
w_{toe} =	2.000	ft
w_1 =	1.500	ft
w_2 =	1.500	ft
a =	0.000	ft
b =	0.000	ft
w_{foot} =	9.500	ft
h_{wall} =	5.880	ft
h_{soil} =	5.880	ft
D =	0.000	ft

Shear key (yes/no): no
t_{key} = 0.00 ft
w_{key} = 0.00 ft
x_{key} = 0.00 ft

Inclined slope behind wall:
1000000 : 1
θ = 0.00 degrees
$H = (w_{heel}+c)\tan\theta + h_{soil} + t_{heel}$
H = 7.38 ft
c = 0.000 ft

Summary:

Overturning:	O.K.
Sliding:	O.K.
Max. bearing:	O.K.
Total Wall Ht =	7.38 ft
Elev Dif =	7.38 ft
w_{foot} / H =	1.287

* for LL Surcharge within 1' of retaining wall (AASHTO T 3.11.6.4-2)

Footing bearing on = soil rock/soil

Total concrete required: 23.070 ft^2/ft

Calculate forces acting on wall:

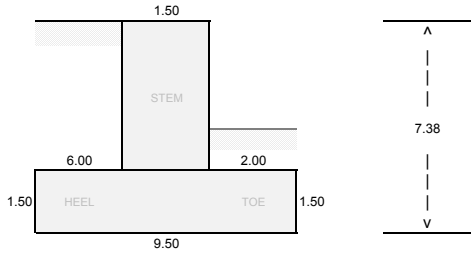
SS	0.640 k/ft	DL + LL	Superstructure loads
$P_{1(active)}$	0.991 k/ft	0.5*soilwt*H^2*Ka	Active force from weight of soil behind wall
$P_{h1(active)}$	0.991 k/ft	0.5*soilwt*H^2*Ka * cos(θ)	Horizontal component of active force behind wall
$P_{v1(active)}$	0.000001 k/ft	0.5*soilwt*H^2*Ka * sin(θ)	Vertical component of active force behind wall
$P_{surcharge}$	1.151 k/ft	surcharge*soilwt*Ka*H	Horizontal force from live load behind the wall
$F_{h2(passive)}$	0.000 k/ft	0.5*soilwt*(D+tkey)^2*(Kp)	Max available passive resistance in front of the wall
$F_{h2(active)}$	0.000 k/ft	0.5*soilwt*D^2*Ka	Horizontal force from soil in front of the wall (at rest)
$P_{railing\ load}$ =	2.289 k/ft	p_railing/(2*(TotalHeight+32/12)+3.5)	Horizontal force from railing live load

Load Comb.	γ_{DC}	γ_{EV}	γ_{LS}	γ_{EH}	γ_{CT}	Application
Strength Ia	0.90	1.00	1.75	1.50	0.00	Sliding, Overturning
Strength Ib	1.25	1.35	1.75	1.50	0.00	Bearing, Wall Strength
Extreme IIa	0.90	1.00	0.50	1.50	1.00	Sliding, Overturning
Extreme IIb	1.25	1.35	0.50	1.50	1.00	Bearing
Service I	1.00	1.00	1.00	1.00	0.00	Wall Crack Control

Load Combination = Strength Ia

Calculate Weights and Moment about toe, Mo:

Segment	Area (ft^2)	density (kcf)	Load Type	Load Factor	Weight (kips/ft)	Arm (ft)	Moment (k-ft/ft)
1	11.250	0.150	DC	0.900	1.519	5.750	8.733
2	3.000	0.150	DC	0.900	0.405	1.000	0.405
3	0.000	0.150	DC	0.900	0.000	2.000	0.000
4	8.820	0.150	DC	0.900	1.191	2.750	3.274
5	0.000	0.150	DC	0.900	0.000	3.500	0.000
6	35.280	0.130	EV	1.000	4.586	6.500	29.812
7	0.000	0.130	EV	1.000	0.000	3.500	0.000
8	0.000	0.130	EV	1.000	0.000	7.500	0.000
9	0.000	0.130	EV	1.000	0.000	1.000	0.000
10	0.000	0.150	DC	0.900	0.000	0.000	0.000
11	Vert. SS DL		DC	0.900	0.576	2.570	1.480
12	Vert. SS LL		LL	1.750	0.000	2.570	0.000
				Σ Fy =	8.276	Σ Mo =	43.703



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Made By: ASP Date: 3/17/2014
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M_o(resisting) = 45.183 k-ft/ft = $\sum$ Mo + γ_{EV}*$P_{v1(active)}$*w_{foot} + γ_{DC}*DL*x_{ss}

M_o(driving) = 11.093 k-ft/ft = γ_{LS}*$P_{surcharge}$*H/2 + γ_{EH}*$P_{h1(active)}$*H/3 + γ_{CT}*$P_{railing\ load}$*(TotalHeight+32/12)

Fx(driving) = 3.502 k/ft = γ_{LS}*$P_{surcharge}$ + γ_{EH}*$P_{h1(active)}$ + γ_{CT}*$P_{railing\ load}$

Load Combination = Strength Ib

Calculate Weights and Moment about toe, Mo:

Segment	Area (ft^2)	density (kcf)	Load Type	Load Factor	Weight (kips/ft)	Arm (ft)	Moment (k-ft/ft)
1	11.250	0.150	DC	1.250	2.109	5.750	12.129
2	3.000	0.150	DC	1.250	0.563	1.000	0.563
3	0.000	0.150	DC	1.250	0.000	2.000	0.000
4	8.820	0.150	DC	1.250	1.654	2.750	4.548
5	0.000	0.150	DC	1.250	0.000	3.500	0.000
6	35.280	0.130	EV	1.350	6.192	6.500	40.246
7	0.000	0.130	EV	1.350	0.000	3.500	0.000
8	0.000	0.130	EV	1.350	0.000	7.500	0.000
9	0.000	0.130	EV	1.350	0.000	1.000	0.000
10	0.000	0.150	DC	1.250	0.000	0.000	0.000
11	Vert. SS DL		DC	1.250	0.799	2.570	2.055
12	Vert. SS LL		LL	1.750	0.000	2.570	0.000
				$\sum$ Fy =	11.317	$\sum$ Mo =	59.540

M_o(resisting) = 61.595 k-ft/ft = $\sum$ Mo + γ_{EV}*$P_{v1(active)}$*w_{foot} + γ_{DC}*DL*x_{ss}

M_o(driving) = 11.093 k-ft/ft = γ_{LS}*$P_{surcharge}$*H/2 + γ_{EH}*$P_{h1(active)}$*H/3 + γ_{CT}*$P_{railing\ load}$*(TotalHeight+32/12)

Fx(driving) = 3.502 k/ft = γ_{LS}*$P_{surcharge}$ + γ_{EH}*$P_{h1(active)}$ + γ_{CT}*$P_{railing\ load}$

Load Combination = Extreme IIa

Calculate Weights and Moment about toe, Mo:

Segment	Area (ft^2)	density (kcf)	Load Type	Load Factor	Weight (kips/ft)	Arm (ft)	Moment (k-ft/ft)
1	11.250	0.150	DC	0.900	1.519	5.750	8.733
2	3.000	0.150	DC	0.900	0.405	1.000	0.405
3	0.000	0.150	DC	0.900	0.000	2.000	0.000
4	8.820	0.150	DC	0.900	1.191	2.750	3.274
5	0.000	0.150	DC	0.900	0.000	3.500	0.000
6	35.280	0.130	EV	1.000	4.586	6.500	29.812
7	0.000	0.130	EV	1.000	0.000	3.500	0.000
8	0.000	0.130	EV	1.000	0.000	7.500	0.000
9	0.000	0.130	EV	1.000	0.000	1.000	0.000
10	0.000	0.150	DC	0.900	0.000	0.000	0.000
11	Vert. SS DL		DC	0.900	0.576	2.570	1.480
12	Vert. SS LL		LL	0.500	0.000	2.570	0.000
				$\sum$ Fy =	8.276	$\sum$ Mo =	43.703

M_o(resisting) = 45.183 k-ft/ft = $\sum$ Mo + γ_{EV}*$P_{v1(active)}$*w_{foot} + γ_{DC}*DL*x_{ss}

M_o(driving) = 28.777 k-ft/ft = γ_{LS}*$P_{surcharge}$*H/2 + γ_{EH}*$P_{h1(active)}$*H/3 + γ_{CT}*$P_{railing\ load}$*(TotalHeight+32/12)

Fx(driving) = 4.351 k/ft = γ_{LS}*$P_{surcharge}$ + γ_{EH}*$P_{h1(active)}$ + γ_{CT}*$P_{railing\ load}$

Load Combination = Extreme IIb

Calculate Weights and Moment about toe, Mo:

Segment	Area (ft^2)	density (kcf)	Load Type	Load Factor	Weight (kips/ft)	Arm (ft)	Moment (k-ft/ft)
1	11.250	0.150	DC	1.250	2.109	5.750	12.129
2	3.000	0.150	DC	1.250	0.563	1.000	0.563
3	0.000	0.150	DC	1.250	0.000	2.000	0.000
4	8.820	0.150	DC	1.250	1.654	2.750	4.548
5	0.000	0.150	DC	1.250	0.000	3.500	0.000
6	35.280	0.130	EV	1.350	6.192	6.500	40.246
7	0.000	0.130	EV	1.350	0.000	3.500	0.000
8	0.000	0.130	EV	1.350	0.000	7.500	0.000
9	0.000	0.130	EV	1.350	0.000	1.000	0.000
10	0.000	0.150	DC	1.250	0.000	0.000	0.000
11	Vert. SS DL		DC	1.250	0.799	2.570	2.055
12	Vert. SS LL		LL	0.500	0.000	2.570	0.000

∑ Fy = 11.317 ∑ Mo = 59.540

M_o(resisting) = 61.595 k-ft/ft = ∑ Mo + γ_{EV}*$P_{v1(active)}$*w_{foot} + γ_{DC}*DL*x_{ss}
M_o(driving) = 28.777 k-ft/ft = γ_{LS}*$P_{surcharge}$*H/2 + γ_{EH}*$P_{h1(active)}$*H/3 + γ_{CT}*$P_{railing\ load}$*(TotalHeight+32/12)

Fx(driving) = 4.351 k/ft = γ_{LS}*$P_{surcharge}$ + γ_{EH}*$P_{h1(active)}$ + γ_{CT}*$P_{railing\ load}$

Load Combination = Service I
Calculate Weights and Moment about toe, Mo:

Segment	Area (ft^2)	density (kcf)	Load Type	Load Factor	Weight (kips/ft)	Arm (ft)	Moment (k-ft/ft)
1	11.250	0.150	DC	1.000	1.688	5.750	9.703
2	3.000	0.150	DC	1.000	0.450	1.000	0.450
3	0.000	0.150	DC	1.000	0.000	2.000	0.000
4	8.820	0.150	DC	1.000	1.323	2.750	3.638
5	0.000	0.150	DC	1.000	0.000	3.500	0.000
6	35.280	0.130	EV	1.000	4.586	6.500	29.812
7	0.000	0.130	EV	1.000	0.000	3.500	0.000
8	0.000	0.130	EV	1.000	0.000	7.500	0.000
9	0.000	0.130	EV	1.000	0.000	1.000	0.000
10	0.000	0.150	DC	1.000	0.000	0.000	0.000
11	Vert. SS DL		DC	1.000	0.640	2.570	1.644
12	Vert. SS LL		LL	1.000	0.000	2.570	0.000

∑ Fy = 8.686 ∑ Mo = 45.247

M_o(resisting) = 46.891 k-ft/ft = ∑ Mo + γ_{EV}*$P_{v1(active)}$*w_{foot} + γ_{DC}*DL*x_{ss}
M_o(driving) = 6.687 k-ft/ft = γ_{LS}*$P_{surcharge}$*H/2 + γ_{EH}*$P_{h1(active)}$*H/3 + γ_{CT}*$P_{railing\ load}$*(TotalHeight+32/12)

Fx(driving) = 2.143 k/ft = γ_{LS}*$P_{surcharge}$ + γ_{EH}*$P_{h1(active)}$ + γ_{CT}*$P_{railing\ load}$

Factored Loads and Moments Summary

Load Combination	Vertical Load, Fy (k)	Resisting Moment*, Mr (k-ft)	Horizontal Load, Fx (k)	Overturning Moment, Mo (k-ft)	Mr - Mo, ΣM (k-ft)
Strength Ia	8.276	45.183	3.502	11.093	34.090
Strength Ib	11.317	61.595	3.502	11.093	50.502
Extreme IIa	8.276	45.183	4.351	28.777	16.406
Extreme IIb	11.317	61.595	4.351	28.777	32.818
Service I	8.686	46.891	2.143	6.687	40.204

* Ignoring passive soil pressure

B = 9.500 ft

CHECK OVERTURNING

x_o = middle width resultant location for overturning = *0.667* *[AASHTO Section 11.6.3.3]*
e_{max} = maximum eccentricity = B*(x_o/2) = 3.167 ft.

For Strength Ia:
e = eccentricity = (B/2) - ΣM/F_V = 0.631 ft. O.K.

For Extreme Event IIa:
e = eccentricity = (B/2) - ΣM/F_V = 2.768 ft. O.K.

CHECK BEARING RESISTANCE

x_b = middle width resultant location for bearing on rock = *0.333* *[AASHTO Section 11.6.3.2]*
e_b = eccentricity for bearing = B*(x_b/2) = 1.583 ft.

For Strength Ib:
e = eccentricity = (B/2) - ΣM/F_V = 0.287 ft.

e = 0.287 ft. < e_b = 1.583 ft.

Soil
σ_{vmax} = maximum vertical stress = F_V/(B-2e) = 1.268 ksf *[AASHTO Section 11.6.3.2]*

Rock with e < e_b
σ_{vmax} = maximum vertical stress = (F_V/B)*[1 + 6*(e/B)] = - ksf *[AASHTO Section 11.6.3.2]*
σ_{vmin} = minimum vertical stress = (F_V/B)*[1 - 6*(e/B)] = - ksf *[AASHTO Section 11.6.3.2]*

Rock with e > e_b

σ_{vmax} = maximum vertical stress = $(2*F_V)/(3*[(B/2) - e])$ = - ksf *[AASHTO Section 11.6.3.2]*

σ_{vmin} = minimum vertical stress = - ksf *[AASHTO Section 11.6.3.2]*

q_n = nominal bearing resistance = *19.100* ksf

φ_b = resistance factor for bearing = *0.450* *[AASHTO Table 10.5.5.2.2-1]*

q_R = factored bearing resistance = φ_b*q_n = *8.595* ksf *[AASHTO Section 10.6.3.1.1]*

σ_{vmax} = 1.268 ksf < q_R = 8.595 ksf O.K.

For Extreme IIb:

e = eccentricity = $(B/2) - \Sigma M/F_V$ = 1.850 ft.

e = 1.850 ft. > e_b = 1.583 ft.

Soil

σ_{vmax} = maximum vertical stress = $F_V/(B-2e)$ = 1.951 ksf *[AASHTO Section 11.6.3.2]*

e < e_h

σ_{vmax} = maximum vertical stress = $(F_V/B)*[1 + 6*(e/B)]$ = - ksf *[AASHTO Section 11.6.3.2]*

σ_{vmin} = minimum vertical stress = $(F_V/B)*[1 - 6*(e/B)]$ = - ksf *[AASHTO Section 11.6.3.2]*

e > e_h

σ_{vmax} = maximum vertical stress = $(2*F_V)/(3*[(B/2) - e])$ = - ksf *[AASHTO Section 11.6.3.2]*

σ_{vmin} = minimum vertical stress = - ksf *[AASHTO Section 11.6.3.2]*

q_n = nominal bearing resistance = *19.100* ksf

φ_b = resistance factor for bearing = *1.000* *[AASHTO Section 10.5.5.3.3]*

q_R = factored bearing resistance = φ_b*q_n = *19.100* ksf *[AASHTO Section 10.6.3.1.1]*

σ_{vmax} = 1.951 ksf < q_R = 19.100 ksf O.K.

CHECK SLIDING **(Note: Equations below will need to be modified for Cohesive soil)**

δ = *32.00* deg

Sliding Resistance = R_R

$R_R = \varphi*R_n = \varphi_t*R_t + \varphi_{ep}*Q_{ep}$ *[AASHTO Section 10.6.3.4]*

For Strength Ia:

φ_τ = *0.85*

R_τ = 5.172 kip = V*tanδ = 8.28 x tan(32.00)

$\varphi_\tau*R_\tau$ = 4.396 kip

φ_{ep} = *0.50* *[AASHTO Table 10.5.5.2.2-1]*

Q_{ep} = 0.000 kip

$\varphi_{ep}*Q_{ep}$ = 0.000 kip

R_R = 4.396 kip = 4.40 + 0.00

R_R = 4.396 kip > F_H = 3.502 kip O.K.

For Extreme IIa:

φ_τ = *0.85*

R_τ = 5.172 kip = V*tanδ = 8.28 x tan(32.00)

$\varphi_\tau*R_\tau$ = 4.396 kip

φ_{ep} = *0.50* *[AASHTO Table 10.5.5.2.2-1]*

Q_{ep} = 0.000 kip

$\varphi_{ep}*Q_{ep}$ = 0.000 kip

R_R = 4.396 kip = 4.40 + 0.00

R_R = 4.396 kip > F_H = 4.351 kip O.K.

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Project: CUY 271
Job No.: 1122-1001-90
Subject: Wall WS1, Panels 4-6

Made By: ASP Date: 3/17/2014
Chk'd By: LNB Date: 3/17/2014

Stability Analysis - Replacement Wall (Cantilever Design

Total Height = 8.42 ft
wall ht.over retained soil = 0.00 ft

Loading information:

*Live Load Surchage:	3.97	ft
Railing Load P:	54.000	k
Ultimate Adhesion:	0.00	ksf
Ka =	0.28	
Kp =	3.54	
soil weight:	0.130	kcf
concrete weight:	0.150	kcf
DL =	0.64	k/ft
LL =	0.00	k/ft
x_{SS} =	2.57	ft
fc' =	4,000	psi
fy =	60,000	psi

Wall geometry:

t_{heel} =	1.500	ft
w_{heel} =	6.000	ft
t_{toe} =	1.500	ft
w_{toe} =	2.000	ft
w_1 =	1.500	ft
w_2 =	1.500	ft
a =	0.000	ft
b =	0.000	ft
w_{foot} =	9.500	ft
h_{wall} =	6.920	ft
h_{soil} =	6.920	ft
D =	0.000	ft

Shear key (yes/no): no
t_{key} = 0.00 ft
w_{key} = 0.00 ft
x_{key} = 0.00 ft

Inclined slope behind wall:
1000000 : 1
⍺ = 0.00 degrees
$H = (w_{heel}+c)\tan⍺ + h_{soil} + t_{heel}$
H = 8.42 ft
c = 0.000 ft

Summary:

Overturning:	O.K.
Sliding:	O.K.
Max. bearing:	O.K.
Total Wall Ht =	8.42 ft
Elev Dif =	8.42 ft
w_{foot} / H =	1.128

* for LL Surcharge within 1' of retaining wall (AASHTO T 3.11.6.4-2)

Footing bearing on = soil rock/soil

Total concrete required: 24.630 ft^2/ft

Calculate forces acting on wall:

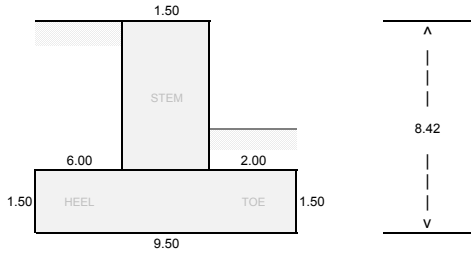
SS	0.640 k/ft	DL + LL	Superstructure loads
$P_{1(active)}$	1.290 k/ft	0.5*soilwt*H^2*Ka	Active force from weight of soil behind wall
$P_{h1(active)}$	1.290 k/ft	0.5*soilwt*H^2*Ka * cos(⍺)	Horizontal component of active force behind wall
$P_{v1(active)}$	0.000001 k/ft	0.5*soilwt*H^2*Ka * sin(⍺)	Vertical component of active force behind wall
$P_{surcharge}$	1.218 k/ft	surcharge*soilwt*Ka*H	Horizontal force from live load behind the wall
$F_{h2(passive)}$	0.000 k/ft	0.5*soilwt*(D+tkey)^2*(Kp)	Max available passive resistance in front of the wall
$F_{h2(active)}$	0.000 k/ft	0.5*soilwt*D^2*Ka	Horizontal force from soil in front of the wall (at rest)
$P_{railing\ load}$ =	2.103 k/ft	p_railing/(2*(TotalHeight+32/12)+3.5)	Horizontal force from railing live load

Load Comb.	γ_{DC}	γ_{EV}	γ_{LS}	γ_{EH}	γ_{CT}	Application
Strength Ia	0.90	1.00	1.75	1.50	0.00	Sliding, Overturning
Strength Ib	1.25	1.35	1.75	1.50	0.00	Bearing, Wall Strength
Extreme IIa	0.90	1.00	0.50	1.50	1.00	Sliding, Overturning
Extreme IIb	1.25	1.35	0.50	1.50	1.00	Bearing
Service I	1.00	1.00	1.00	1.00	0.00	Wall Crack Control

Load Combination = Strength Ia

Calculate Weights and Moment about toe, Mo:

Segment	Area (ft^2)	density (kcf)	Load Type	Load Factor	Weight (kips/ft)	Arm (ft)	Moment (k-ft/ft)
1	11.250	0.150	DC	0.900	1.519	5.750	8.733
2	3.000	0.150	DC	0.900	0.405	1.000	0.405
3	0.000	0.150	DC	0.900	0.000	2.000	0.000
4	10.380	0.150	DC	0.900	1.401	2.750	3.854
5	0.000	0.150	DC	0.900	0.000	3.500	0.000
6	41.520	0.130	EV	1.000	5.398	6.500	35.084
7	0.000	0.130	EV	1.000	0.000	3.500	0.000
8	0.000	0.130	EV	1.000	0.000	7.500	0.000
9	0.000	0.130	EV	1.000	0.000	1.000	0.000
10	0.000	0.150	DC	0.900	0.000	0.000	0.000
11	Vert. SS DL		DC	0.900	0.576	2.570	1.480
12	Vert. SS LL		LL	1.750	0.000	2.570	0.000
				Σ Fy =	9.298	Σ Mo =	49.555



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M_o(resisting) = 51.035 k-ft/ft = $\sum$ Mo + γ_{EV}*$P_{v1(active)}$*w_{foot} + γ_{DC}*DL*x_{ss}

M_o(driving) = 14.406 k-ft/ft = γ_{LS}*$P_{surcharge}$*H/2 + γ_{EH}*$P_{h1(active)}$*H/3 + γ_{CT}*$P_{railing\ load}$*(TotalHeight+32/12)

Fx(driving) = 4.067 k/ft = γ_{LS}*$P_{surcharge}$ + γ_{EH}*$P_{h1(active)}$ + γ_{CT}*$P_{railing\ load}$

Load Combination = Strength Ib

Calculate Weights and Moment about toe, Mo:

Segment	Area (ft^2)	density (kcf)	Load Type	Load Factor	Weight (kips/ft)	Arm (ft)	Moment (k-ft/ft)
1	11.250	0.150	DC	1.250	2.109	5.750	12.129
2	3.000	0.150	DC	1.250	0.563	1.000	0.563
3	0.000	0.150	DC	1.250	0.000	2.000	0.000
4	10.380	0.150	DC	1.250	1.946	2.750	5.352
5	0.000	0.150	DC	1.250	0.000	3.500	0.000
6	41.520	0.130	EV	1.350	7.287	6.500	47.364
7	0.000	0.130	EV	1.350	0.000	3.500	0.000
8	0.000	0.130	EV	1.350	0.000	7.500	0.000
9	0.000	0.130	EV	1.350	0.000	1.000	0.000
10	0.000	0.150	DC	1.250	0.000	0.000	0.000
11	Vert. SS DL		DC	1.250	0.799	2.570	2.055
12	Vert. SS LL		LL	1.750	0.000	2.570	0.000
				$\sum$ Fy =	12.704	$\sum$ Mo =	67.462

M_o(resisting) = 69.517 k-ft/ft = $\sum$ Mo + γ_{EV}*$P_{v1(active)}$*w_{foot} + γ_{DC}*DL*x_{ss}

M_o(driving) = 14.406 k-ft/ft = γ_{LS}*$P_{surcharge}$*H/2 + γ_{EH}*$P_{h1(active)}$*H/3 + γ_{CT}*$P_{railing\ load}$*(TotalHeight+32/12)

Fx(driving) = 4.067 k/ft = γ_{LS}*$P_{surcharge}$ + γ_{EH}*$P_{h1(active)}$ + γ_{CT}*$P_{railing\ load}$

Load Combination = Extreme IIa

Calculate Weights and Moment about toe, Mo:

Segment	Area (ft^2)	density (kcf)	Load Type	Load Factor	Weight (kips/ft)	Arm (ft)	Moment (k-ft/ft)
1	11.250	0.150	DC	0.900	1.519	5.750	8.733
2	3.000	0.150	DC	0.900	0.405	1.000	0.405
3	0.000	0.150	DC	0.900	0.000	2.000	0.000
4	10.380	0.150	DC	0.900	1.401	2.750	3.854
5	0.000	0.150	DC	0.900	0.000	3.500	0.000
6	41.520	0.130	EV	1.000	5.398	6.500	35.084
7	0.000	0.130	EV	1.000	0.000	3.500	0.000
8	0.000	0.130	EV	1.000	0.000	7.500	0.000
9	0.000	0.130	EV	1.000	0.000	1.000	0.000
10	0.000	0.150	DC	0.900	0.000	0.000	0.000
11	Vert. SS DL		DC	0.900	0.576	2.570	1.480
12	Vert. SS LL		LL	0.500	0.000	2.570	0.000
				$\sum$ Fy =	9.298	$\sum$ Mo =	49.555

M_o(resisting) = 51.035 k-ft/ft = $\sum$ Mo + γ_{EV}*$P_{v1(active)}$*w_{foot} + γ_{DC}*DL*x_{ss}

M_o(driving) = 31.315 k-ft/ft = γ_{LS}*$P_{surcharge}$*H/2 + γ_{EH}*$P_{h1(active)}$*H/3 + γ_{CT}*$P_{railing\ load}$*(TotalHeight+32/12)

Fx(driving) = 4.648 k/ft = γ_{LS}*$P_{surcharge}$ + γ_{EH}*$P_{h1(active)}$ + γ_{CT}*$P_{railing\ load}$

Load Combination = Extreme IIb

Calculate Weights and Moment about toe, Mo:

Segment	Area (ft^2)	density (kcf)	Load Type	Load Factor	Weight (kips/ft)	Arm (ft)	Moment (k-ft/ft)
1	11.250	0.150	DC	1.250	2.109	5.750	12.129
2	3.000	0.150	DC	1.250	0.563	1.000	0.563
3	0.000	0.150	DC	1.250	0.000	2.000	0.000
4	10.380	0.150	DC	1.250	1.946	2.750	5.352
5	0.000	0.150	DC	1.250	0.000	3.500	0.000
6	41.520	0.130	EV	1.350	7.287	6.500	47.364
7	0.000	0.130	EV	1.350	0.000	3.500	0.000
8	0.000	0.130	EV	1.350	0.000	7.500	0.000
9	0.000	0.130	EV	1.350	0.000	1.000	0.000
10	0.000	0.150	DC	1.250	0.000	0.000	0.000
11	Vert. SS DL		DC	1.250	0.799	2.570	2.055
12	Vert. SS LL		LL	0.500	0.000	2.570	0.000

∑ Fy = 12.704 ∑ Mo = 67.462

M_o(resisting) = 69.517 k-ft/ft = ∑ Mo + γ_{EV}*$P_{v1(active)}$*w_{foot} + γ_{DC}*DL*x_{ss}
M_o(driving) = 31.315 k-ft/ft = γ_{LS}*$P_{surcharge}$*H/2 + γ_{EH}*$P_{h1(active)}$*H/3 + γ_{CT}*$P_{railing\ load}$*(TotalHeight+32/12)

Fx(driving) = 4.648 k/ft = γ_{LS}*$P_{surcharge}$ + γ_{EH}*$P_{h1(active)}$ + γ_{CT}*$P_{railing\ load}$

Load Combination = Service I
Calculate Weights and Moment about toe, Mo:

Segment	Area (ft^2)	density (kcf)	Load Type	Load Factor	Weight (kips/ft)	Arm (ft)	Moment (k-ft/ft)
1	11.250	0.150	DC	1.000	1.688	5.750	9.703
2	3.000	0.150	DC	1.000	0.450	1.000	0.450
3	0.000	0.150	DC	1.000	0.000	2.000	0.000
4	10.380	0.150	DC	1.000	1.557	2.750	4.282
5	0.000	0.150	DC	1.000	0.000	3.500	0.000
6	41.520	0.130	EV	1.000	5.398	6.500	35.084
7	0.000	0.130	EV	1.000	0.000	3.500	0.000
8	0.000	0.130	EV	1.000	0.000	7.500	0.000
9	0.000	0.130	EV	1.000	0.000	1.000	0.000
10	0.000	0.150	DC	1.000	0.000	0.000	0.000
11	Vert. SS DL		DC	1.000	0.640	2.570	1.644
12	Vert. SS LL		LL	1.000	0.000	2.570	0.000

∑ Fy = 9.732 ∑ Mo = 51.163

M_o(resisting) = 52.807 k-ft/ft = ∑ Mo + γ_{EV}*$P_{v1(active)}$*w_{foot} + γ_{DC}*DL*x_{ss}
M_o(driving) = 8.749 k-ft/ft = γ_{LS}*$P_{surcharge}$*H/2 + γ_{EH}*$P_{h1(active)}$*H/3 + γ_{CT}*$P_{railing\ load}$*(TotalHeight+32/12)

Fx(driving) = 2.508 k/ft = γ_{LS}*$P_{surcharge}$ + γ_{EH}*$P_{h1(active)}$ + γ_{CT}*$P_{railing\ load}$

Factored Loads and Moments Summary

Load Combination	Vertical Load, Fy (k)	Resisting Moment*, Mr (k-ft)	Horizontal Load, Fx (k)	Overturning Moment, Mo (k-ft)	Mr - Mo, ΣM (k-ft)
Strength Ia	9.298	51.035	4.067	14.406	36.629
Strength Ib	12.704	69.517	4.067	14.406	55.112
Extreme IIa	9.298	51.035	4.648	31.315	19.720
Extreme IIb	12.704	69.517	4.648	31.315	38.202
Service I	9.732	52.807	2.508	8.749	44.058

* Ignoring passive soil pressure

B = 9.500 ft

CHECK OVERTURNING

x_o = middle width resultant location for overturning = *0.667* *[AASHTO Section 11.6.3.3]*
e_{max} = maximum eccentricity = B*(x_o/2) = 3.167 ft.

For Strength Ia:
e = eccentricity = (B/2) - ΣM/F_V = 0.811 ft. O.K.

For Extreme Event IIa:
e = eccentricity = (B/2) - ΣM/F_V = 2.629 ft. O.K.

CHECK BEARING RESISTANCE

x_b = middle width resultant location for bearing on rock = *0.333* *[AASHTO Section 11.6.3.2]*
e_b = eccentricity for bearing = B*(x_b/2) = 1.583 ft.

For Strength Ib:
e = eccentricity = (B/2) - ΣM/F_V = 0.412 ft.

e = 0.412 ft. < e_b = 1.583 ft.

Soil
σ_{vmax} = maximum vertical stress = F_V/(B-2e) = 1.464 ksf *[AASHTO Section 11.6.3.2]*

Rock with e < e_b
σ_{vmax} = maximum vertical stress = (F_V/B)*[1 + 6*(e/B)] = - ksf *[AASHTO Section 11.6.3.2]*
σ_{vmin} = minimum vertical stress = (F_V/B)*[1 - 6*(e/B)] = - ksf *[AASHTO Section 11.6.3.2]*

Rock with e > e_b

σ_{vmax} = maximum vertical stress = $(2*F_V)/(3*[(B/2) - e])$ = - ksf *[AASHTO Section 11.6.3.2]*

σ_{vmin} = minimum vertical stress = - ksf *[AASHTO Section 11.6.3.2]*

q_n = nominal bearing resistance = *19.100* ksf

φ_b = resistance factor for bearing = *0.450* *[AASHTO Table 10.5.5.2.2-1]*

q_R = factored bearing resistance = φ_b*q_n = *8.595* ksf *[AASHTO Section 10.6.3.1.1]*

σ_{vmax} = 1.464 ksf < q_R = 8.595 ksf O.K.

For Extreme IIb:

e = eccentricity = $(B/2) - \Sigma M/F_V$ = 1.743 ft.

e = 1.743 ft. > e_b = 1.583 ft.

Soil

σ_{vmax} = maximum vertical stress = $F_V/(B-2e)$ = 2.112 ksf *[AASHTO Section 11.6.3.2]*

e < e_b

σ_{vmax} = maximum vertical stress = $(F_V/B)*[1 + 6*(e/B)]$ = - ksf *[AASHTO Section 11.6.3.2]*

σ_{vmin} = minimum vertical stress = $(F_V/B)*[1 - 6*(e/B)]$ = - ksf *[AASHTO Section 11.6.3.2]*

e > e_b

σ_{vmax} = maximum vertical stress = $(2*F_V)/(3*[(B/2) - e])$ = - ksf *[AASHTO Section 11.6.3.2]*

σ_{vmin} = minimum vertical stress = - ksf *[AASHTO Section 11.6.3.2]*

q_n = nominal bearing resistance = *19.100* ksf

φ_b = resistance factor for bearing = *1.000* *[AASHTO Section 10.5.5.3.3]*

q_R = factored bearing resistance = φ_b*q_n = *19.100* ksf *[AASHTO Section 10.6.3.1.1]*

σ_{vmax} = 2.112 ksf < q_R = 19.100 ksf O.K.

CHECK SLIDING **(Note: Equations below will need to be modified for Cohesive soil)**

δ = *32.00* deg

Sliding Resistance = R_R

$R_R = \varphi*R_n = \varphi_t*R_t + \varphi_{ep}*Q_{ep}$ *[AASHTO Section 10.6.3.4]*

For Strength Ia:

φ_t = *0.85*

R_t = 5.810 kip = V*tanδ = 9.30 x tan(32.00)

φ_t*R_t = 4.939 kip

φ_{ep} = *0.50* *[AASHTO Table 10.5.5.2.2-1]*

Q_{ep} = 0.000 kip

$\varphi_{ep}*Q_{ep}$ = 0.000 kip

R_R = 4.939 kip = 4.94 + 0.00

R_R = 4.939 kip > F_H = 4.067 kip O.K.

For Extreme IIa:

φ_t = *0.85*

R_t = 5.810 kip = V*tanδ = 9.30 x tan(32.00)

φ_t*R_t = 4.939 kip

φ_{ep} = *0.50* *[AASHTO Table 10.5.5.2.2-1]*

Q_{ep} = 0.000 kip

$\varphi_{ep}*Q_{ep}$ = 0.000 kip

R_R = 4.939 kip = 4.94 + 0.00

R_R = 4.939 kip > F_H = 4.648 kip O.K.

DLZ Ohio, Inc.

Project: CUY 271
Job No.: 1122-1001-90
Subject: Wall WS1, Panels 7-8

Made By: ASP Date: 3/17/2014
Chk'd By: LNB Date: 3/17/2014

Stability Analysis - Replacement Wall (Cantilever Design

Total Height = 9.32 ft
wall ht.over retained soil = 0.00 ft

Loading information:			**Wall geometry:**			**Summary:**	
*Live Load Surchage:	3.70 ft	t_{heel} =	1.500 ft	Shear key (yes/no):	no	Overturning:	O.K.
Railing Load P:	54.000 k	w_{heel} =	6.000 ft	t_{key} =	0.00 ft	Sliding:	O.K.
Ultimate Adhesion:	0.00 ksf	t_{toe} =	1.500 ft	w_{key} =	0.00 ft	Max. bearing:	O.K.
Ka =	0.28	w_{toe} =	2.000 ft	x_{key} =	0.00 ft		
Kp =	3.54	w_1 =	1.500 ft				
soil weight:	0.130 kcf	w_2 =	1.500 ft	Inclined slope behind wall:			
concrete weight:	0.150 kcf	a =	0.000 ft		1000000 : 1		
DL =	0.64 k/ft	b =	0.000 ft	◊ =	0.00 degrees		
LL =	0.00 k/ft	w_{foot}=	9.500 ft	H = $(w_{heel}+c)\tan◊ + h_{soil} + t_{heel}$			
x_{SS} =	2.57 ft	h_{wall} =	7.820 ft	H =	9.32 ft	Total Wall Ht =	9.32 ft
fc' =	4,000 psi	h_{soil} =	7.820 ft			Elev Dif =	9.32 ft
fy =	60,000 psi	D =	0.000 ft	c =	0.000 ft	w_{foot} / H =	1.019

* for LL Surcharge within 1' of retaining wall (AASHTO T 3.11.6.4-2)

Footing bearing on = soil rock/soil

Total concrete required: 25.980 ft^2/ft

Calculate forces acting on wall:

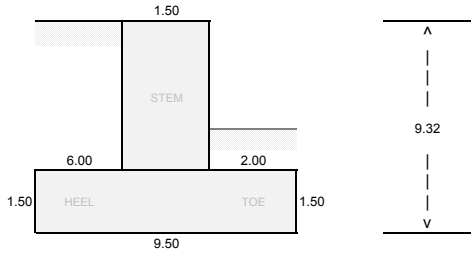
SS	0.640 k/ft	DL + LL	Superstructure loads
$P_{1(active)}$	1.581 k/ft	0.5*soilwt*H^2*Ka	Active force from weight of soil behind wall
$P_{h1(active)}$	1.581 k/ft	0.5*soilwt*H^2*Ka * cos(◊)	Horizontal component of active force behind wall
$P_{v1(active)}$	0.000002 k/ft	0.5*soilwt*H^2*Ka * sin(◊)	Vertical component of active force behind wall
$P_{surcharge}$	1.257 k/ft	surcharge*soilwt*Ka*H	Horizontal force from live load behind the wall
$F_{h2(passive)}$	0.000 k/ft	0.5*soilwt*(D+tkey)^2*(Kp)	Max available passive resistance in front of the wall
$F_{h2(active)}$	0.000 k/ft	0.5*soilwt*D^2*Ka	Horizontal force from soil in front of the wall (at rest)
$P_{railing\ load}$ =	1.966 k/ft	p_railing/(2*(TotalHeight+32/12)+3.5)	Horizontal force from railing live load

Load Comb.	γ_{DC}	γ_{EV}	γ_{LS}	γ_{EH}	γ_{CT}	Application
Strength Ia	0.90	1.00	1.75	1.50	0.00	Sliding, Overturning
Strength Ib	1.25	1.35	1.75	1.50	0.00	Bearing, Wall Strength
Extreme IIa	0.90	1.00	0.50	1.50	1.00	Sliding, Overturning
Extreme IIb	1.25	1.35	0.50	1.50	1.00	Bearing
Service I	1.00	1.00	1.00	1.00	0.00	Wall Crack Control

Load Combination = Strength Ia

Calculate Weights and Moment about toe, Mo:

Segment	Area (ft^2)	density (kcf)	Load Type	Load Factor	Weight (kips/ft)	Arm (ft)	Moment (k-ft/ft)
1	11.250	0.150	DC	0.900	1.519	5.750	8.733
2	3.000	0.150	DC	0.900	0.405	1.000	0.405
3	0.000	0.150	DC	0.900	0.000	2.000	0.000
4	11.730	0.150	DC	0.900	1.584	2.750	4.355
5	0.000	0.150	DC	0.900	0.000	3.500	0.000
6	46.920	0.130	EV	1.000	6.100	6.500	39.647
7	0.000	0.130	EV	1.000	0.000	3.500	0.000
8	0.000	0.130	EV	1.000	0.000	7.500	0.000
9	0.000	0.130	EV	1.000	0.000	1.000	0.000
10	0.000	0.150	DC	0.900	0.000	0.000	0.000
11	Vert. SS DL		DC	0.900	0.576	2.570	1.480
12	Vert. SS LL		LL	1.750	0.000	2.570	0.000
				Σ Fy =	10.183	Σ Mo =	54.619



M_o(resisting) = 56.099 k-ft/ft = $\sum$ Mo + γ_{EV}*$P_{v1(active)}$*w_{foot} + γ_{DC}*DL*x_{ss}

M_o(driving) = 17.614 k-ft/ft = γ_{LS}*$P_{surcharge}$*H/2 + γ_{EH}*$P_{h1(active)}$*H/3 + γ_{CT}*$P_{railing\ load}$*(TotalHeight+32/12)

Fx(driving) = 4.570 k/ft = γ_{LS}*$P_{surcharge}$ + γ_{EH}*$P_{h1(active)}$ + γ_{CT}*$P_{railing\ load}$

Load Combination = Strength Ib

Calculate Weights and Moment about toe, Mo:

Segment	Area (ft^2)	density (kcf)	Load Type	Load Factor	Weight (kips/ft)	Arm (ft)	Moment (k-ft/ft)
1	11.250	0.150	DC	1.250	2.109	5.750	12.129
2	3.000	0.150	DC	1.250	0.563	1.000	0.563
3	0.000	0.150	DC	1.250	0.000	2.000	0.000
4	11.730	0.150	DC	1.250	2.199	2.750	6.048
5	0.000	0.150	DC	1.250	0.000	3.500	0.000
6	46.920	0.130	EV	1.350	8.234	6.500	53.524
7	0.000	0.130	EV	1.350	0.000	3.500	0.000
8	0.000	0.130	EV	1.350	0.000	7.500	0.000
9	0.000	0.130	EV	1.350	0.000	1.000	0.000
10	0.000	0.150	DC	1.250	0.000	0.000	0.000
11	Vert. SS DL		DC	1.250	0.799	2.570	2.055
12	Vert. SS LL		LL	1.750	0.000	2.570	0.000
				$\sum$ Fy =	13.905	$\sum$ Mo =	74.319

M_o(resisting) = 76.373 k-ft/ft = $\sum$ Mo + γ_{EV}*$P_{v1(active)}$*w_{foot} + γ_{DC}*DL*x_{ss}

M_o(driving) = 17.614 k-ft/ft = γ_{LS}*$P_{surcharge}$*H/2 + γ_{EH}*$P_{h1(active)}$*H/3 + γ_{CT}*$P_{railing\ load}$*(TotalHeight+32/12)

Fx(driving) = 4.570 k/ft = γ_{LS}*$P_{surcharge}$ + γ_{EH}*$P_{h1(active)}$ + γ_{CT}*$P_{railing\ load}$

Load Combination = Extreme IIa

Calculate Weights and Moment about toe, Mo:

Segment	Area (ft^2)	density (kcf)	Load Type	Load Factor	Weight (kips/ft)	Arm (ft)	Moment (k-ft/ft)
1	11.250	0.150	DC	0.900	1.519	5.750	8.733
2	3.000	0.150	DC	0.900	0.405	1.000	0.405
3	0.000	0.150	DC	0.900	0.000	2.000	0.000
4	11.730	0.150	DC	0.900	1.584	2.750	4.355
5	0.000	0.150	DC	0.900	0.000	3.500	0.000
6	46.920	0.130	EV	1.000	6.100	6.500	39.647
7	0.000	0.130	EV	1.000	0.000	3.500	0.000
8	0.000	0.130	EV	1.000	0.000	7.500	0.000
9	0.000	0.130	EV	1.000	0.000	1.000	0.000
10	0.000	0.150	DC	0.900	0.000	0.000	0.000
11	Vert. SS DL		DC	0.900	0.576	2.570	1.480
12	Vert. SS LL		LL	0.500	0.000	2.570	0.000
				$\sum$ Fy =	10.183	$\sum$ Mo =	54.619

M_o(resisting) = 56.099 k-ft/ft = $\sum$ Mo + γ_{EV}*$P_{v1(active)}$*w_{foot} + γ_{DC}*DL*x_{ss}

M_o(driving) = 33.855 k-ft/ft = γ_{LS}*$P_{surcharge}$*H/2 + γ_{EH}*$P_{h1(active)}$*H/3 + γ_{CT}*$P_{railing\ load}$*(TotalHeight+32/12)

Fx(driving) = 4.965 k/ft = γ_{LS}*$P_{surcharge}$ + γ_{EH}*$P_{h1(active)}$ + γ_{CT}*$P_{railing\ load}$

Load Combination = Extreme IIb

Calculate Weights and Moment about toe, Mo:

Segment	Area (ft^2)	density (kcf)	Load Type	Load Factor	Weight (kips/ft)	Arm (ft)	Moment (k-ft/ft)
1	11.250	0.150	DC	1.250	2.109	5.750	12.129
2	3.000	0.150	DC	1.250	0.563	1.000	0.563
3	0.000	0.150	DC	1.250	0.000	2.000	0.000
4	11.730	0.150	DC	1.250	2.199	2.750	6.048
5	0.000	0.150	DC	1.250	0.000	3.500	0.000
6	46.920	0.130	EV	1.350	8.234	6.500	53.524
7	0.000	0.130	EV	1.350	0.000	3.500	0.000
8	0.000	0.130	EV	1.350	0.000	7.500	0.000
9	0.000	0.130	EV	1.350	0.000	1.000	0.000
10	0.000	0.150	DC	1.250	0.000	0.000	0.000
11	Vert. SS DL		DC	1.250	0.799	2.570	2.055
12	Vert. SS LL		LL	0.500	0.000	2.570	0.000

∑ Fy = 13.905 ∑ Mo = 74.319

M_o(resisting) = 76.373 k-ft/ft = ∑ Mo + γ_{EV}*$P_{v1(active)}$*w_{foot} + γ_{DC}*DL*x_{ss}
M_o(driving) = 33.855 k-ft/ft = γ_{LS}*$P_{surcharge}$*H/2 + γ_{EH}*$P_{h1(active)}$*H/3 + γ_{CT}*$P_{railing\ load}$*(TotalHeight+32/12)

Fx(driving) = 4.965 k/ft = γ_{LS}*$P_{surcharge}$ + γ_{EH}*$P_{h1(active)}$ + γ_{CT}*$P_{railing\ load}$

Load Combination = Service I
Calculate Weights and Moment about toe, Mo:

Segment	Area (ft^2)	density (kcf)	Load Type	Load Factor	Weight (kips/ft)	Arm (ft)	Moment (k-ft/ft)
1	11.250	0.150	DC	1.000	1.688	5.750	9.703
2	3.000	0.150	DC	1.000	0.450	1.000	0.450
3	0.000	0.150	DC	1.000	0.000	2.000	0.000
4	11.730	0.150	DC	1.000	1.760	2.750	4.839
5	0.000	0.150	DC	1.000	0.000	3.500	0.000
6	46.920	0.130	EV	1.000	6.100	6.500	39.647
7	0.000	0.130	EV	1.000	0.000	3.500	0.000
8	0.000	0.130	EV	1.000	0.000	7.500	0.000
9	0.000	0.130	EV	1.000	0.000	1.000	0.000
10	0.000	0.150	DC	1.000	0.000	0.000	0.000
11	Vert. SS DL		DC	1.000	0.640	2.570	1.644
12	Vert. SS LL		LL	1.000	0.000	2.570	0.000

∑ Fy = 10.636 ∑ Mo = 56.283

M_o(resisting) = 57.927 k-ft/ft = ∑ Mo + γ_{EV}*$P_{v1(active)}$*w_{foot} + γ_{DC}*DL*x_{ss}
M_o(driving) = 10.767 k-ft/ft = γ_{LS}*$P_{surcharge}$*H/2 + γ_{EH}*$P_{h1(active)}$*H/3 + γ_{CT}*$P_{railing\ load}$*(TotalHeight+32/12)

Fx(driving) = 2.837 k/ft = γ_{LS}*$P_{surcharge}$ + γ_{EH}*$P_{h1(active)}$ + γ_{CT}*$P_{railing\ load}$

Factored Loads and Moments Summary

Load Combination	Vertical Load, Fy (k)	Resisting Moment*, Mr (k-ft)	Horizontal Load, Fx (k)	Overturning Moment, Mo (k-ft)	Mr - Mo, ΣM (k-ft)
Strength Ia	10.183	56.099	4.570	17.614	38.485
Strength Ib	13.905	76.373	4.570	17.614	58.759
Extreme IIa	10.183	56.099	4.965	33.855	22.244
Extreme IIb	13.905	76.373	4.965	33.855	42.518
Service I	10.636	57.927	2.837	10.767	47.160

* Ignoring passive soil pressure

B = 9.500 ft

CHECK OVERTURNING

x_o = middle width resultant location for overturning = *0.667* *[AASHTO Section 11.6.3.3]*
e_{max} = maximum eccentricity = B*(x_o/2) = 3.167 ft.

For Strength Ia:
e = eccentricity = (B/2) - ΣM/F_V = 0.971 ft. O.K.

For Extreme Event IIa:
e = eccentricity = (B/2) - ΣM/F_V = 2.565 ft. O.K.

CHECK BEARING RESISTANCE

x_b = middle width resultant location for bearing on rock = *0.333* *[AASHTO Section 11.6.3.2]*
e_b = eccentricity for bearing = B*(x_b/2) = 1.583 ft.

For Strength Ib:
e = eccentricity = (B/2) - ΣM/F_V = 0.524 ft.

e = 0.524 ft. < e_b = 1.583 ft.

Soil
σ_{vmax} = maximum vertical stress = F_V/(B-2e) = 1.645 ksf *[AASHTO Section 11.6.3.2]*

Rock with e < e_b
σ_{vmax} = maximum vertical stress = (F_V/B)*[1 + 6*(e/B)] = - ksf *[AASHTO Section 11.6.3.2]*
σ_{vmin} = minimum vertical stress = (F_V/B)*[1 - 6*(e/B)] = - ksf *[AASHTO Section 11.6.3.2]*

Rock with e > e_b

σ_{vmax} = maximum vertical stress = $(2*F_V)/(3*[(B/2) - e])$ = - ksf *[AASHTO Section 11.6.3.2]*

σ_{vmin} = minimum vertical stress = - ksf *[AASHTO Section 11.6.3.2]*

q_n = nominal bearing resistance = *19.100* ksf

φ_b = resistance factor for bearing = *0.450* *[AASHTO Table 10.5.5.2.2-1]*

q_R = factored bearing resistance = φ_b*q_n = *8.595* ksf *[AASHTO Section 10.6.3.1.1]*

σ_{vmax} = 1.645 ksf < q_R = 8.595 ksf O.K.

For Extreme IIb:

e = eccentricity = $(B/2) - \Sigma M/F_V$ = 1.692 ft.

e = 1.692 ft. > e_b = 1.583 ft.

Soil

σ_{vmax} = maximum vertical stress = $F_V/(B-2e)$ = 2.274 ksf *[AASHTO Section 11.6.3.2]*

e < e_b

σ_{vmax} = maximum vertical stress = $(F_V/B)*[1 + 6*(e/B)]$ = - ksf *[AASHTO Section 11.6.3.2]*

σ_{vmin} = minimum vertical stress = $(F_V/B)*[1 - 6*(e/B)]$ = - ksf *[AASHTO Section 11.6.3.2]*

e > e_b

σ_{vmax} = maximum vertical stress = $(2*F_V)/(3*[(B/2) - e])$ = - ksf *[AASHTO Section 11.6.3.2]*

σ_{vmin} = minimum vertical stress = - ksf *[AASHTO Section 11.6.3.2]*

q_n = nominal bearing resistance = *19.100* ksf

φ_b = resistance factor for bearing = *1.000* *[AASHTO Section 10.5.5.3.3]*

q_R = factored bearing resistance = φ_b*q_n = *19.100* ksf *[AASHTO Section 10.6.3.1.1]*

σ_{vmax} = 2.274 ksf < q_R = 19.100 ksf O.K.

CHECK SLIDING **(Note: Equations below will need to be modified for Cohesive soil)**

δ = *32.00* deg

Sliding Resistance = R_R

$R_R = \varphi*R_n = \varphi_t*R_t + \varphi_{ep}*Q_{ep}$ *[AASHTO Section 10.6.3.4]*

For Strength Ia:

φ_t = *0.85*

R_t = 6.363 kip = V*tanδ = 10.18 x tan(32.00)

φ_t*R_t = 5.408 kip

φ_{ep} = *0.50* *[AASHTO Table 10.5.5.2.2-1]*

Q_{ep} = 0.000 kip

$\varphi_{ep}*Q_{ep}$ = 0.000 kip

R_R = 5.408 kip = 5.41 + 0.00

R_R = 5.408 kip > F_H = 4.570 kip O.K.

For Extreme IIa:

φ_t = *0.85*

R_t = 6.363 kip = V*tanδ = 10.18 x tan(32.00)

φ_t*R_t = 5.408 kip

φ_{ep} = *0.50* *[AASHTO Table 10.5.5.2.2-1]*

Q_{ep} = 0.000 kip

$\varphi_{ep}*Q_{ep}$ = 0.000 kip

R_R = 5.408 kip = 5.41 + 0.00

R_R = 5.408 kip > F_H = 4.965 kip O.K.

DLZ Ohio, Inc.

Project: CUY 271
Job No.: 1122-1001-90
Subject: Wall WS1, Panels 9-10

Made By: ASP Date: 3/17/2014
Chk'd By: LNB Date: 3/17/2014

Stability Analysis - Replacement Wall (Cantilever Design

Total Height = 10.35 ft
wall ht.over retained soil = 0.00 ft

Loading information:

*Live Load Surchage:	3.45	ft
Railing Load P:	54.000	k
Ultimate Adhesion:	0.00	ksf
Ka =	0.28	
Kp =	3.54	
soil weight:	0.130	kcf
concrete weight:	0.150	kcf
DL =	0.64	k/ft
LL =	0.00	k/ft
x_{SS} =	2.57	ft
fc' =	4,000	psi
fy =	60,000	psi

Wall geometry:

t_{heel} =	1.500	ft
w_{heel} =	6.000	ft
t_{toe} =	1.500	ft
w_{toe} =	2.000	ft
w_1 =	1.500	ft
w_2 =	1.500	ft
a =	0.000	ft
b =	0.000	ft
w_{foot} =	9.500	ft
h_{wall} =	8.850	ft
h_{soil} =	8.850	ft
D =	0.000	ft

Shear key (yes/no): no
t_{key} = 0.00 ft
w_{key} = 0.00 ft
x_{key} = 0.00 ft

Inclined slope behind wall:
1000000 : 1
ϑ = 0.00 degrees
$H = (w_{heel}+c)\tan\vartheta + h_{soil} + t_{heel}$
H = 10.35 ft
c = 0.000 ft

Summary:

Overturning:	O.K.
Sliding:	O.K.
Max. bearing:	O.K.
Total Wall Ht =	10.35 ft
Elev Dif =	10.35 ft
w_{foot} / H =	0.918

* for LL Surcharge within 1' of retaining wall (AASHTO T 3.11.6.4-2)

Footing bearing on = soil rock/soil

Total concrete required: 27.525 ft^2/ft

Calculate forces acting on wall:

SS	0.640 k/ft	DL + LL	Superstructure loads
$P_{1(active)}$	1.950 k/ft	0.5*soilwt*H^2*Ka	Active force from weight of soil behind wall
$P_{h1(active)}$	1.950 k/ft	0.5*soilwt*H^2*Ka * cos(ϑ)	Horizontal component of active force behind wall
$P_{v1(active)}$	0.000002 k/ft	0.5*soilwt*H^2*Ka * sin(ϑ)	Vertical component of active force behind wall
$P_{surcharge}$	1.299 k/ft	surcharge*soilwt*Ka*H	Horizontal force from live load behind the wall
$F_{h2(passive)}$	0.000 k/ft	0.5*soilwt*(D+tkey)^2*(Kp)	Max available passive resistance in front of the wall
$F_{h2(active)}$	0.000 k/ft	0.5*soilwt*D^2*Ka	Horizontal force from soil in front of the wall (at rest)
$P_{railing\ load}$ =	1.828 k/ft	p_railing/(2*(TotalHeight+32/12)+3.5)	Horizontal force from railing live load

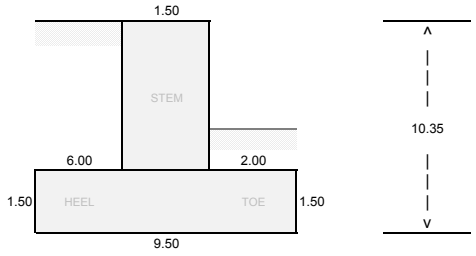
Load Comb.	γ_{DC}	γ_{EV}	γ_{LS}	γ_{EH}	γ_{CT}	Application
Strength Ia	0.90	1.00	1.75	1.50	0.00	Sliding, Overturning
Strength Ib	1.25	1.35	1.75	1.50	0.00	Bearing, Wall Strength
Extreme IIa	0.90	1.00	0.50	1.50	1.00	Sliding, Overturning
Extreme IIb	1.25	1.35	0.50	1.50	1.00	Bearing
Service I	1.00	1.00	1.00	1.00	0.00	Wall Crack Control

Load Combination = Strength Ia

Calculate Weights and Moment about toe, Mo:

Segment	Area (ft^2)	density (kcf)	Load Type	Load Factor	Weight (kips/ft)	Arm (ft)	Moment (k-ft/ft)
1	11.250	0.150	DC	0.900	1.519	5.750	8.733
2	3.000	0.150	DC	0.900	0.405	1.000	0.405
3	0.000	0.150	DC	0.900	0.000	2.000	0.000
4	13.275	0.150	DC	0.900	1.792	2.750	4.928
5	0.000	0.150	DC	0.900	0.000	3.500	0.000
6	53.100	0.130	EV	1.000	6.903	6.500	44.870
7	0.000	0.130	EV	1.000	0.000	3.500	0.000
8	0.000	0.130	EV	1.000	0.000	7.500	0.000
9	0.000	0.130	EV	1.000	0.000	1.000	0.000
10	0.000	0.150	DC	0.900	0.000	0.000	0.000
11	Vert. SS DL		DC	0.900	0.576	2.570	1.480
12	Vert. SS LL		LL	1.750	0.000	2.570	0.000

Σ Fy = 11.194 Σ Mo = 60.415



DLZ Ohio, Inc.

Project: CUY 271
Job No.: 1122-1001-90
Subject: Wall WS1, Panels 9-10

Made By: ASP Date: 3/17/2014
Chk'd By: LNB Date: 3/17/2014

M_o(resisting) = 61.895 k-ft/ft = $\sum$ Mo + γ_{EV}*$P_{v1(active)}$*w_{foot} + γ_{DC}*DL*x_{ss}

M_o(driving) = 21.852 k-ft/ft = γ_{LS}*$P_{surcharge}$*H/2 + γ_{EH}*$P_{h1(active)}$*H/3 + γ_{CT}*$P_{railing\ load}$*(TotalHeight+32/12)

Fx(driving) = 5.197 k/ft = γ_{LS}*$P_{surcharge}$ + γ_{EH}*$P_{h1(active)}$ + γ_{CT}*$P_{railing\ load}$

Load Combination = Strength Ib

Calculate Weights and Moment about toe, Mo:

Segment	Area (ft^2)	density (kcf)	Load Type	Load Factor	Weight (kips/ft)	Arm (ft)	Moment (k-ft/ft)
1	11.250	0.150	DC	1.250	2.109	5.750	12.129
2	3.000	0.150	DC	1.250	0.563	1.000	0.563
3	0.000	0.150	DC	1.250	0.000	2.000	0.000
4	13.275	0.150	DC	1.250	2.489	2.750	6.845
5	0.000	0.150	DC	1.250	0.000	3.500	0.000
6	53.100	0.130	EV	1.350	9.319	6.500	60.574
7	0.000	0.130	EV	1.350	0.000	3.500	0.000
8	0.000	0.130	EV	1.350	0.000	7.500	0.000
9	0.000	0.130	EV	1.350	0.000	1.000	0.000
10	0.000	0.150	DC	1.250	0.000	0.000	0.000
11	Vert. SS DL		DC	1.250	0.799	2.570	2.055
12	Vert. SS LL		LL	1.750	0.000	2.570	0.000
				$\sum$ Fy =	15.279	$\sum$ Mo =	82.165

M_o(resisting) = 84.220 k-ft/ft = $\sum$ Mo + γ_{EV}*$P_{v1(active)}$*w_{foot} + γ_{DC}*DL*x_{ss}

M_o(driving) = 21.852 k-ft/ft = γ_{LS}*$P_{surcharge}$*H/2 + γ_{EH}*$P_{h1(active)}$*H/3 + γ_{CT}*$P_{railing\ load}$*(TotalHeight+32/12)

Fx(driving) = 5.197 k/ft = γ_{LS}*$P_{surcharge}$ + γ_{EH}*$P_{h1(active)}$ + γ_{CT}*$P_{railing\ load}$

Load Combination = Extreme IIa

Calculate Weights and Moment about toe, Mo:

Segment	Area (ft^2)	density (kcf)	Load Type	Load Factor	Weight (kips/ft)	Arm (ft)	Moment (k-ft/ft)
1	11.250	0.150	DC	0.900	1.519	5.750	8.733
2	3.000	0.150	DC	0.900	0.405	1.000	0.405
3	0.000	0.150	DC	0.900	0.000	2.000	0.000
4	13.275	0.150	DC	0.900	1.792	2.750	4.928
5	0.000	0.150	DC	0.900	0.000	3.500	0.000
6	53.100	0.130	EV	1.000	6.903	6.500	44.870
7	0.000	0.130	EV	1.000	0.000	3.500	0.000
8	0.000	0.130	EV	1.000	0.000	7.500	0.000
9	0.000	0.130	EV	1.000	0.000	1.000	0.000
10	0.000	0.150	DC	0.900	0.000	0.000	0.000
11	Vert. SS DL		DC	0.900	0.576	2.570	1.480
12	Vert. SS LL		LL	0.500	0.000	2.570	0.000
				$\sum$ Fy =	11.194	$\sum$ Mo =	60.415

M_o(resisting) = 61.895 k-ft/ft = $\sum$ Mo + γ_{EV}*$P_{v1(active)}$*w_{foot} + γ_{DC}*DL*x_{ss}

M_o(driving) = 37.250 k-ft/ft = γ_{LS}*$P_{surcharge}$*H/2 + γ_{EH}*$P_{h1(active)}$*H/3 + γ_{CT}*$P_{railing\ load}$*(TotalHeight+32/12)

Fx(driving) = 5.402 k/ft = γ_{LS}*$P_{surcharge}$ + γ_{EH}*$P_{h1(active)}$ + γ_{CT}*$P_{railing\ load}$

Load Combination = Extreme IIb

Calculate Weights and Moment about toe, Mo:

Segment	Area (ft^2)	density (kcf)	Load Type	Load Factor	Weight (kips/ft)	Arm (ft)	Moment (k-ft/ft)
1	11.250	0.150	DC	1.250	2.109	5.750	12.129
2	3.000	0.150	DC	1.250	0.563	1.000	0.563
3	0.000	0.150	DC	1.250	0.000	2.000	0.000
4	13.275	0.150	DC	1.250	2.489	2.750	6.845
5	0.000	0.150	DC	1.250	0.000	3.500	0.000
6	53.100	0.130	EV	1.350	9.319	6.500	60.574
7	0.000	0.130	EV	1.350	0.000	3.500	0.000
8	0.000	0.130	EV	1.350	0.000	7.500	0.000
9	0.000	0.130	EV	1.350	0.000	1.000	0.000
10	0.000	0.150	DC	1.250	0.000	0.000	0.000
11	Vert. SS DL		DC	1.250	0.799	2.570	2.055
12	Vert. SS LL		LL	0.500	0.000	2.570	0.000

Σ Fy = 15.279 Σ Mo = 82.165

M_o(resisting) = 84.220 k-ft/ft = Σ Mo + γ_{EV}*$P_{v1(active)}$*w_{foot} + γ_{DC}*DL*x_{ss}

M_o(driving) = 37.250 k-ft/ft = γ_{LS}*$P_{surcharge}$*H/2 + γ_{EH}*$P_{h1(active)}$*H/3 + γ_{CT}*$P_{railing\ load}$*(TotalHeight+32/12)

Fx(driving) = 5.402 k/ft = γ_{LS}*$P_{surcharge}$ + γ_{EH}*$P_{h1(active)}$ + γ_{CT}*$P_{railing\ load}$

Load Combination = Service I

Calculate Weights and Moment about toe, Mo:

Segment	Area (ft^2)	density (kcf)	Load Type	Load Factor	Weight (kips/ft)	Arm (ft)	Moment (k-ft/ft)
1	11.250	0.150	DC	1.000	1.688	5.750	9.703
2	3.000	0.150	DC	1.000	0.450	1.000	0.450
3	0.000	0.150	DC	1.000	0.000	2.000	0.000
4	13.275	0.150	DC	1.000	1.991	2.750	5.476
5	0.000	0.150	DC	1.000	0.000	3.500	0.000
6	53.100	0.130	EV	1.000	6.903	6.500	44.870
7	0.000	0.130	EV	1.000	0.000	3.500	0.000
8	0.000	0.130	EV	1.000	0.000	7.500	0.000
9	0.000	0.130	EV	1.000	0.000	1.000	0.000
10	0.000	0.150	DC	1.000	0.000	0.000	0.000
11	Vert. SS DL		DC	1.000	0.640	2.570	1.644
12	Vert. SS LL		LL	1.000	0.000	2.570	0.000

Σ Fy = 11.671 Σ Mo = 62.142

M_o(resisting) = 63.786 k-ft/ft = Σ Mo + γ_{EV}*$P_{v1(active)}$*w_{foot} + γ_{DC}*DL*x_{ss}

M_o(driving) = 13.448 k-ft/ft = γ_{LS}*$P_{surcharge}$*H/2 + γ_{EH}*$P_{h1(active)}$*H/3 + γ_{CT}*$P_{railing\ load}$*(TotalHeight+32/12)

Fx(driving) = 3.248 k/ft = γ_{LS}*$P_{surcharge}$ + γ_{EH}*$P_{h1(active)}$ + γ_{CT}*$P_{railing\ load}$

Factored Loads and Moments Summary

Load Combination	Vertical Load, Fy (k)	Resisting Moment*, Mr (k-ft)	Horizontal Load, Fx (k)	Overturning Moment, Mo (k-ft)	Mr - Mo, ΣM (k-ft)
Strength Ia	11.194	61.895	5.197	21.852	40.043
Strength Ib	15.279	84.220	5.197	21.852	62.368
Extreme IIa	11.194	61.895	5.402	37.250	24.644
Extreme IIb	15.279	84.220	5.402	37.250	46.970
Service I	11.671	63.786	3.248	13.448	50.339

* Ignoring passive soil pressure

B = 9.500 ft

CHECK OVERTURNING

x_o = middle width resultant location for overturning = *0.667* *[AASHTO Section 11.6.3.3]*

e_{max} = maximum eccentricity = B*(x_o/2) = 3.167 ft.

For Strength Ia:

e = eccentricity = (B/2) - ΣM/F_V = 1.173 ft. O.K.

For Extreme Event IIa:

e = eccentricity = (B/2) - ΣM/F_V = 2.549 ft. O.K.

CHECK BEARING RESISTANCE

x_b = middle width resultant location for bearing on rock = *0.333* *[AASHTO Section 11.6.3.2]*

e_b = eccentricity for bearing = B*(x_b/2) = 1.583 ft.

For Strength Ib:

e = eccentricity = (B/2) - ΣM/F_V = 0.668 ft.

e = 0.668 ft. < e_b = 1.583 ft.

Soil

σ_{vmax} = maximum vertical stress = F_V/(B-2e) = 1.872 ksf *[AASHTO Section 11.6.3.2]*

Rock with e < e_b

σ_{vmax} = maximum vertical stress = (F_V/B)*[1 + 6*(e/B)] = - ksf *[AASHTO Section 11.6.3.2]*

σ_{vmin} = minimum vertical stress = (F_V/B)*[1 - 6*(e/B)] = - ksf *[AASHTO Section 11.6.3.2]*

Rock with e > e_b

σ_{vmax} = maximum vertical stress = $(2*F_V)/(3*[(B/2) - e])$ = - ksf *[AASHTO Section 11.6.3.2]*

σ_{vmin} = minimum vertical stress = - ksf *[AASHTO Section 11.6.3.2]*

q_n = nominal bearing resistance = *19.100* ksf

φ_b = resistance factor for bearing = *0.450* *[AASHTO Table 10.5.5.2.2-1]*

q_R = factored bearing resistance = φ_b*q_n = *8.595* ksf *[AASHTO Section 10.6.3.1.1]*

σ_{vmax} = 1.872 ksf < q_R = 8.595 ksf O.K.

For Extreme IIb:

e = eccentricity = $(B/2) - \Sigma M/F_V$ = 1.676 ft.

e = 1.676 ft. > e_b = 1.583 ft.

Soil

σ_{vmax} = maximum vertical stress = $F_V/(B-2e)$ = 2.485 ksf *[AASHTO Section 11.6.3.2]*

e < e_b

σ_{vmax} = maximum vertical stress = $(F_V/B)*[1 + 6*(e/B)]$ = - ksf *[AASHTO Section 11.6.3.2]*

σ_{vmin} = minimum vertical stress = $(F_V/B)*[1 - 6*(e/B)]$ = - ksf *[AASHTO Section 11.6.3.2]*

e > e_b

σ_{vmax} = maximum vertical stress = $(2*F_V)/(3*[(B/2) - e])$ = - ksf *[AASHTO Section 11.6.3.2]*

σ_{vmin} = minimum vertical stress = - ksf *[AASHTO Section 11.6.3.2]*

q_n = nominal bearing resistance = *19.100* ksf

φ_b = resistance factor for bearing = *1.000* *[AASHTO Section 10.5.5.3.3]*

q_R = factored bearing resistance = φ_b*q_n = *19.100* ksf *[AASHTO Section 10.6.3.1.1]*

σ_{vmax} = 2.485 ksf < q_R = 19.100 ksf O.K.

CHECK SLIDING **(Note: Equations below will need to be modified for Cohesive soil)**

δ = *32.00* deg

Sliding Resistance = R_R

$R_R = \varphi*R_n = \varphi_t*R_t + \varphi_{ep}*Q_{ep}$ *[AASHTO Section 10.6.3.4]*

For Strength Ia:

φ_τ = *0.85*

R_τ = 6.995 kip = V*tanδ = 11.19 x tan(32.00)

$\varphi_\tau*R_\tau$ = 5.946 kip

φ_{ep} = *0.50* *[AASHTO Table 10.5.5.2.2-1]*

Q_{ep} = 0.000 kip

$\varphi_{ep}*Q_{ep}$ = 0.000 kip

R_R = 5.946 kip = 5.95 + 0.00

R_R = 5.946 kip > F_H = 5.197 kip O.K.

For Extreme IIa:

φ_τ = *0.85*

R_τ = 6.995 kip = V*tanδ = 11.19 x tan(32.00)

$\varphi_\tau*R_\tau$ = 5.946 kip

φ_{ep} = *0.50* *[AASHTO Table 10.5.5.2.2-1]*

Q_{ep} = 0.000 kip

$\varphi_{ep}*Q_{ep}$ = 0.000 kip

R_R = 5.946 kip = 5.95 + 0.00

R_R = 5.946 kip > F_H = 5.402 kip O.K.

DLZ Ohio, Inc.

Project: CUY 271
Job No.: 1122-1001-90
Subject: Wall WS1, Panels 11-13

Made By: ASP Date: 3/17/2014
Chk'd By: LNB Date: 3/17/2014

Stability Analysis - Replacement Wall (Cantilever Design

Total Height = 12.39 ft
wall ht.over retained soil = 0.00 ft

Loading information:

*Live Load Surchage:	3.14	ft
Railing Load P:	54.000	k
Ultimate Adhesion:	0.00	ksf
Ka =	0.28	
Kp =	3.54	
soil weight:	0.130	kcf
concrete weight:	0.150	kcf
DL =	0.64	k/ft
LL =	0.00	k/ft
x_{SS} =	2.57	ft
fc' =	4,000	psi
fy =	60,000	psi

Wall geometry:

t_{heel} =	1.500	ft
w_{heel} =	6.000	ft
t_{toe} =	1.500	ft
w_{toe} =	2.000	ft
w_1 =	1.500	ft
w_2 =	1.500	ft
a =	0.000	ft
b =	0.000	ft
w_{foot} =	9.500	ft
h_{wall} =	10.890	ft
h_{soil} =	10.890	ft
D =	0.000	ft

Shear key (yes/no): no
t_{key} = 0.00 ft
w_{key} = 0.00 ft
x_{key} = 0.00 ft

Inclined slope behind wall:
1000000 : 1
θ = 0.00 degrees
$H = (w_{heel}+c)\tan\theta + h_{soil} + t_{heel}$
H = 12.39 ft
c = 0.000 ft

Summary:

Overturning:	O.K.
Sliding:	O.K.
Max. bearing:	O.K.
Total Wall Ht =	12.39 ft
Elev Dif =	12.39 ft
w_{foot} / H =	0.767

* for LL Surcharge within 1' of retaining wall (AASHTO T 3.11.6.4-2)

Footing bearing on = soil rock/soil

Total concrete required: 30.585 ft^2/ft

Calculate forces acting on wall:

SS	0.640 k/ft	DL + LL	Superstructure loads
$P_{1(active)}$	2.794 k/ft	0.5*soilwt*H^2*Ka	Active force from weight of soil behind wall
$P_{h1(active)}$	2.794 k/ft	0.5*soilwt*H^2*Ka * cos(θ)	Horizontal component of active force behind wall
$P_{v1(active)}$	0.000003 k/ft	0.5*soilwt*H^2*Ka * sin(θ)	Vertical component of active force behind wall
$P_{surcharge}$	1.417 k/ft	surcharge*soilwt*Ka*H	Horizontal force from live load behind the wall
$F_{h2(passive)}$	0.000 k/ft	0.5*soilwt*(D+tkey)^2*(Kp)	Max available passive resistance in front of the wall
$F_{h2(active)}$	0.000 k/ft	0.5*soilwt*D^2*Ka	Horizontal force from soil in front of the wall (at rest)
$P_{railing\ load}$ =	1.607 k/ft	p_railing/(2*(TotalHeight+32/12)+3.5)	Horizontal force from railing live load

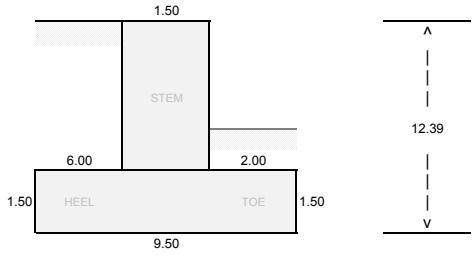
Load Comb.	γ_{DC}	γ_{EV}	γ_{LS}	γ_{EH}	γ_{CT}	Application
Strength Ia	0.90	1.00	1.75	1.50	0.00	Sliding, Overturning
Strength Ib	1.25	1.35	1.75	1.50	0.00	Bearing, Wall Strength
Extreme IIa	0.90	1.00	0.50	1.50	1.00	Sliding, Overturning
Extreme IIb	1.25	1.35	0.50	1.50	1.00	Bearing
Service I	1.00	1.00	1.00	1.00	0.00	Wall Crack Control

Load Combination = Strength Ia

Calculate Weights and Moment about toe, Mo:

Segment	Area (ft^2)	density (kcf)	Load Type	Load Factor	Weight (kips/ft)	Arm (ft)	Moment (k-ft/ft)
1	11.250	0.150	DC	0.900	1.519	5.750	8.733
2	3.000	0.150	DC	0.900	0.405	1.000	0.405
3	0.000	0.150	DC	0.900	0.000	2.000	0.000
4	16.335	0.150	DC	0.900	2.205	2.750	6.064
5	0.000	0.150	DC	0.900	0.000	3.500	0.000
6	65.340	0.130	EV	1.000	8.494	6.500	55.212
7	0.000	0.130	EV	1.000	0.000	3.500	0.000
8	0.000	0.130	EV	1.000	0.000	7.500	0.000
9	0.000	0.130	EV	1.000	0.000	1.000	0.000
10	0.000	0.150	DC	0.900	0.000	0.000	0.000
11	Vert. SS DL		DC	0.900	0.576	2.570	1.480
12	Vert. SS LL		LL	1.750	0.000	2.570	0.000

Σ Fy = 13.199 Σ Mo = 71.894



M_o(resisting) = 73.374 k-ft/ft = $\sum$ Mo + γ_{EV}*$P_{v1(active)}$*w_{foot} + γ_{DC}*DL*x_{ss}

M_o(driving) = 32.668 k-ft/ft = γ_{LS}*$P_{surcharge}$*H/2 + γ_{EH}*$P_{h1(active)}$*H/3 + γ_{CT}*$P_{railing\ load}$*(TotalHeight+32/12)

Fx(driving) = 6.670 k/ft = γ_{LS}*$P_{surcharge}$ + γ_{EH}*$P_{h1(active)}$ + γ_{CT}*$P_{railing\ load}$

Load Combination = Strength Ib

Calculate Weights and Moment about toe, Mo:

Segment	Area (ft^2)	density (kcf)	Load Type	Load Factor	Weight (kips/ft)	Arm (ft)	Moment (k-ft/ft)
1	11.250	0.150	DC	1.250	2.109	5.750	12.129
2	3.000	0.150	DC	1.250	0.563	1.000	0.563
3	0.000	0.150	DC	1.250	0.000	2.000	0.000
4	16.335	0.150	DC	1.250	3.063	2.750	8.423
5	0.000	0.150	DC	1.250	0.000	3.500	0.000
6	65.340	0.130	EV	1.350	11.467	6.500	74.537
7	0.000	0.130	EV	1.350	0.000	3.500	0.000
8	0.000	0.130	EV	1.350	0.000	7.500	0.000
9	0.000	0.130	EV	1.350	0.000	1.000	0.000
10	0.000	0.150	DC	1.250	0.000	0.000	0.000
11	Vert. SS DL		DC	1.250	0.799	2.570	2.055
12	Vert. SS LL		LL	1.750	0.000	2.570	0.000
				$\sum$ Fy =	18.001	$\sum$ Mo =	97.706

M_o(resisting) = 99.761 k-ft/ft = $\sum$ Mo + γ_{EV}*$P_{v1(active)}$*w_{foot} + γ_{DC}*DL*x_{ss}

M_o(driving) = 32.668 k-ft/ft = γ_{LS}*$P_{surcharge}$*H/2 + γ_{EH}*$P_{h1(active)}$*H/3 + γ_{CT}*$P_{railing\ load}$*(TotalHeight+32/12)

Fx(driving) = 6.670 k/ft = γ_{LS}*$P_{surcharge}$ + γ_{EH}*$P_{h1(active)}$ + γ_{CT}*$P_{railing\ load}$

Load Combination = Extreme IIa

Calculate Weights and Moment about toe, Mo:

Segment	Area (ft^2)	density (kcf)	Load Type	Load Factor	Weight (kips/ft)	Arm (ft)	Moment (k-ft/ft)
1	11.250	0.150	DC	0.900	1.519	5.750	8.733
2	3.000	0.150	DC	0.900	0.405	1.000	0.405
3	0.000	0.150	DC	0.900	0.000	2.000	0.000
4	16.335	0.150	DC	0.900	2.205	2.750	6.064
5	0.000	0.150	DC	0.900	0.000	3.500	0.000
6	65.340	0.130	EV	1.000	8.494	6.500	55.212
7	0.000	0.130	EV	1.000	0.000	3.500	0.000
8	0.000	0.130	EV	1.000	0.000	7.500	0.000
9	0.000	0.130	EV	1.000	0.000	1.000	0.000
10	0.000	0.150	DC	0.900	0.000	0.000	0.000
11	Vert. SS DL		DC	0.900	0.576	2.570	1.480
12	Vert. SS LL		LL	0.500	0.000	2.570	0.000
				$\sum$ Fy =	13.199	$\sum$ Mo =	71.894

M_o(resisting) = 73.374 k-ft/ft = $\sum$ Mo + γ_{EV}*$P_{v1(active)}$*w_{foot} + γ_{DC}*DL*x_{ss}

M_o(driving) = 45.886 k-ft/ft = γ_{LS}*$P_{surcharge}$*H/2 + γ_{EH}*$P_{h1(active)}$*H/3 + γ_{CT}*$P_{railing\ load}$*(TotalHeight+32/12)

Fx(driving) = 6.506 k/ft = γ_{LS}*$P_{surcharge}$ + γ_{EH}*$P_{h1(active)}$ + γ_{CT}*$P_{railing\ load}$

Load Combination = Extreme IIb

Calculate Weights and Moment about toe, Mo:

Segment	Area (ft^2)	density (kcf)	Load Type	Load Factor	Weight (kips/ft)	Arm (ft)	Moment (k-ft/ft)
1	11.250	0.150	DC	1.250	2.109	5.750	12.129
2	3.000	0.150	DC	1.250	0.563	1.000	0.563
3	0.000	0.150	DC	1.250	0.000	2.000	0.000
4	16.335	0.150	DC	1.250	3.063	2.750	8.423
5	0.000	0.150	DC	1.250	0.000	3.500	0.000
6	65.340	0.130	EV	1.350	11.467	6.500	74.537
7	0.000	0.130	EV	1.350	0.000	3.500	0.000
8	0.000	0.130	EV	1.350	0.000	7.500	0.000
9	0.000	0.130	EV	1.350	0.000	1.000	0.000
10	0.000	0.150	DC	1.250	0.000	0.000	0.000
11	Vert. SS DL		DC	1.250	0.799	2.570	2.055
12	Vert. SS LL		LL	0.500	0.000	2.570	0.000

DLZ Ohio, Inc.

Project: CUY 271
Job No.: 1122-1001-90
Subject: Wall WS1, Panels 11-13

Made By: ASP Date: 3/17/2014
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Σ Fy = 18.001 Σ Mo = 97.706

M_o(resisting) = 99.761 k-ft/ft = Σ Mo + γ_{EV}*$P_{v1(active)}$*w_{foot} + γ_{DC}*DL*x_{ss}

M_o(driving) = 45.886 k-ft/ft = γ_{LS}*$P_{surcharge}$*H/2 + γ_{EH}*$P_{h1(active)}$*H/3 + γ_{CT}*$P_{railing\ load}$*(TotalHeight+32/12)

Fx(driving) = 6.506 k/ft = γ_{LS}*$P_{surcharge}$ + γ_{EH}*$P_{h1(active)}$ + γ_{CT}*$P_{railing\ load}$

Load Combination = Service I

Calculate Weights and Moment about toe, Mo:

Segment	Area (ft^2)	density (kcf)	Load Type	Load Factor	Weight (kips/ft)	Arm (ft)	Moment (k-ft/ft)
1	11.250	0.150	DC	1.000	1.688	5.750	9.703
2	3.000	0.150	DC	1.000	0.450	1.000	0.450
3	0.000	0.150	DC	1.000	0.000	2.000	0.000
4	16.335	0.150	DC	1.000	2.450	2.750	6.738
5	0.000	0.150	DC	1.000	0.000	3.500	0.000
6	65.340	0.130	EV	1.000	8.494	6.500	55.212
7	0.000	0.130	EV	1.000	0.000	3.500	0.000
8	0.000	0.130	EV	1.000	0.000	7.500	0.000
9	0.000	0.130	EV	1.000	0.000	1.000	0.000
10	0.000	0.150	DC	1.000	0.000	0.000	0.000
11	Vert. SS DL		DC	1.000	0.640	2.570	1.644
12	Vert. SS LL		LL	1.000	0.000	2.570	0.000

Σ Fy = 13.722 Σ Mo = 73.748

M_o(resisting) = 75.391 k-ft/ft = Σ Mo + γ_{EV}*$P_{v1(active)}$*w_{foot} + γ_{DC}*DL*x_{ss}

M_o(driving) = 20.316 k-ft/ft = γ_{LS}*$P_{surcharge}$*H/2 + γ_{EH}*$P_{h1(active)}$*H/3 + γ_{CT}*$P_{railing\ load}$*(TotalHeight+32/12)

Fx(driving) = 4.211 k/ft = γ_{LS}*$P_{surcharge}$ + γ_{EH}*$P_{h1(active)}$ + γ_{CT}*$P_{railing\ load}$

Factored Loads and Moments Summary

Load Combination	Vertical Load, Fy (k)	Resisting Moment*, Mr (k-ft)	Horizontal Load, Fx (k)	Overturning Moment, Mo (k-ft)	Mr - Mo, ΣM (k-ft)
Strength Ia	13.199	73.374	6.670	32.668	40.705
Strength Ib	18.001	99.761	6.670	32.668	67.092
Extreme IIa	13.199	73.374	6.506	45.886	27.488
Extreme IIb	18.001	99.761	6.506	45.886	53.875
Service I	13.722	75.391	4.211	20.316	55.075

* Ignoring passive soil pressure

B = 9.500 ft

CHECK OVERTURNING

x_o = middle width resultant location for overturning = *0.667* *[AASHTO Section 11.6.3.3]*

e_{max} = maximum eccentricity = B*(x_o/2) = 3.167 ft.

For Strength Ia:

e = eccentricity = (B/2) - ΣM/F_V = 1.666 ft. O.K.

For Extreme Event IIa:

e = eccentricity = (B/2) - ΣM/F_V = 2.667 ft. O.K.

CHECK BEARING RESISTANCE

x_b = middle width resultant location for bearing on rock = *0.333* *[AASHTO Section 11.6.3.2]*

e_b = eccentricity for bearing = B*(x_b/2) = 1.583 ft.

For Strength Ib:

e = eccentricity = (B/2) - ΣM/F_V = 1.023 ft.

e = 1.023 ft. < e_b = 1.583 ft.

Soil

σ_{vmax} = maximum vertical stress = F_V/(B-2e) = 2.415 ksf *[AASHTO Section 11.6.3.2]*

Rock with e < e_b

σ_{vmax} = maximum vertical stress = (F_V/B)*[1 + 6*(e/B)] = - ksf *[AASHTO Section 11.6.3.2]*

σ_{vmin} = minimum vertical stress = (F_V/B)*[1 - 6*(e/B)] = - ksf *[AASHTO Section 11.6.3.2]*

Rock with e > e_b

σ_{vmax} = maximum vertical stress = $(2*F_V)/(3*[(B/2) - e])$ = - ksf *[AASHTO Section 11.6.3.2]*

σ_{vmin} = minimum vertical stress = - ksf *[AASHTO Section 11.6.3.2]*

q_n = nominal bearing resistance = *19.100* ksf

φ_b = resistance factor for bearing = *0.450* *[AASHTO Table 10.5.5.2.2-1]*

q_R = factored bearing resistance = φ_b*q_n = *8.595* ksf *[AASHTO Section 10.6.3.1.1]*

σ_{vmax} = 2.415 ksf < q_R = 8.595 ksf O.K.

For Extreme IIb:

e = eccentricity = $(B/2) - \Sigma M/F_V$ = 1.757 ft.

e = 1.757 ft. > e_b = 1.583 ft.

Soil

σ_{vmax} = maximum vertical stress = $F_V/(B-2e)$ = 3.007 ksf *[AASHTO Section 11.6.3.2]*

e < e_b

σ_{vmax} = maximum vertical stress = $(F_V/B)*[1 + 6*(e/B)]$ = - ksf *[AASHTO Section 11.6.3.2]*

σ_{vmin} = minimum vertical stress = $(F_V/B)*[1 - 6*(e/B)]$ = - ksf *[AASHTO Section 11.6.3.2]*

e > e_b

σ_{vmax} = maximum vertical stress = $(2*F_V)/(3*[(B/2) - e])$ = - ksf *[AASHTO Section 11.6.3.2]*

σ_{vmin} = minimum vertical stress = - ksf *[AASHTO Section 11.6.3.2]*

q_n = nominal bearing resistance = *19.100* ksf

φ_b = resistance factor for bearing = *1.000* *[AASHTO Section 10.5.5.3.3]*

q_R = factored bearing resistance = φ_b*q_n = *19.100* ksf *[AASHTO Section 10.6.3.1.1]*

σ_{vmax} = 3.007 ksf < q_R = 19.100 ksf O.K.

CHECK SLIDING **(Note: Equations below will need to be modified for Cohesive soil)**

δ = *32.00* deg

Sliding Resistance = R_R

$R_R = \varphi*R_n = \varphi_t*R_t + \varphi_{ep}*Q_{ep}$ *[AASHTO Section 10.6.3.4]*

For Strength Ia:

φ_τ = *0.85*

R_τ = 8.248 kip = V*tanδ = 13.20 x tan(32.00)

$\varphi_\tau*R_\tau$ = 7.010 kip

φ_{ep} = *0.50* *[AASHTO Table 10.5.5.2.2-1]*

Q_{ep} = 0.000 kip

$\varphi_{ep}*Q_{ep}$ = 0.000 kip

R_R = 7.010 kip = 7.01 + 0.00

R_R = 7.010 kip > F_H = 6.670 kip O.K.

For Extreme IIa:

φ_τ = *0.85*

R_τ = 8.248 kip = V*tanδ = 13.20 x tan(32.00)

$\varphi_\tau*R_\tau$ = 7.010 kip

φ_{ep} = *0.50* *[AASHTO Table 10.5.5.2.2-1]*

Q_{ep} = 0.000 kip

$\varphi_{ep}*Q_{ep}$ = 0.000 kip

R_R = 7.010 kip = 7.01 + 0.00

R_R = 7.010 kip > F_H = 6.506 kip O.K.