St. Helens - Riverwalk

Structural Calculations

St. Helens, Oregon

STRUCTURAL
REGISTERED PROFESSIONAL
ENGINEER
79,377PE
Sean Clark
Sean Clark 2024.01.25 11:09:27-08'00'
OREGON
SEP 13, 2011
SEAN M. CLARK
RENEWS: 12-31-2025

Prepared By:
Otak, Inc.
700 Washington Street, Suite 300
Vancouver, WA 98660

February 2, 2024

Otak

Design Criteria

Retaining Walls (MSE & CIP) and Guardrails

Risk Category II

Reference next sheet for minimum design loads

Seismic : $S_{DS} = 0.664g$ (From Geotech Report)

Wind = 120mph (ultimate)

Exposure D

$\sigma_a = 2{,}000psf$ (May be increased by 1.5 for Wind/Seismic)

$\gamma_p = 250pcf$

$\mu = 0.40$

For CIP walls: $\gamma_a = 35pcf$

Seismic = $7(H^2)$ @ $0.6(H)$

project St. Helens-RiverWalk job# 20028 date Jan. '24 by BC

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265 Strand Street, St. Helens, OR 97051
Phone: (503) 397-6272 Fax: (503) 397-4016
www.sthelensoregon.gov

Climatic and Geographic Design Criteria for the City of St Helens

Based on the 2021 Oregon Residential Specialty Code (ORSC)

Snow Load = Site specific ground snow loads, shall be those set forth in the online lookup tool at www.snowloads.seao.org/lookup.html and adjusted per Table R301.2.3.1. Minimum ground snow load for prescriptive design is 36psf. Minimum roof snow load for engineered design is 25psf.

Ultimate Design Wind Speed = 120mph (Columbia County Special Wind Region)

Wind Exposure Category = Determined by site conditions (see R301.2.1.3 2021 ORSC)

Seismic Category = D_1

Weathering = Moderate

Frost Line Depth = 12 inches

Decay = Moderate

Strand St & Cowlitz St, St Helens, OR 97051, USA

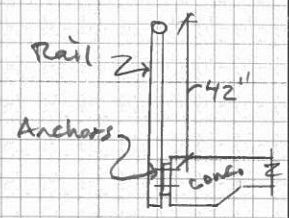
Latitude, Longitude: 45.8622831, -122.7965645

Date	6/3/2022, 11:12:38 AM
Design Code Reference Document	ASCE7-16
Risk Category	II
Site Class	D - Default (See Section 11.4.3)

Type	Value	Description
S_S	0.829	MCE_R ground motion. (for 0.2 second period)
S_1	0.398	MCE_R ground motion. (for 1.0s period)
S_{MS}	0.995	Site-modified spectral acceleration value
S_{M1}	null -See Section 11.4.8	Site-modified spectral acceleration value
S_{DS}	0.664	Numeric seismic design value at 0.2 second SA
S_{D1}	null -See Section 11.4.8	Numeric seismic design value at 1.0 second SA

Type	Value	Description
SDC	null -See Section 11.4.8	Seismic design category
F_a	1.2	Site amplification factor at 0.2 second
F_v	null -See Section 11.4.8	Site amplification factor at 1.0 second
PGA	0.379	MCE_G peak ground acceleration
F_{PGA}	1.221	Site amplification factor at PGA
PGA_M	0.462	Site modified peak ground acceleration
T_L	16	Long-period transition period in seconds
SsRT	0.829	Probabilistic risk-targeted ground motion. (0.2 second)
SsUH	0.932	Factored uniform-hazard (2% probability of exceedance in 50 years) spectral acceleration
SsD	1.5	Factored deterministic acceleration value. (0.2 second)
S1RT	0.398	Probabilistic risk-targeted ground motion. (1.0 second)
S1UH	0.459	Factored uniform-hazard (2% probability of exceedance in 50 years) spectral acceleration.
S1D	0.638	Factored deterministic acceleration value. (1.0 second)
PGAd	0.521	Factored deterministic acceleration value. (Peak Ground Acceleration)
C_{RS}	0.89	Mapped value of the risk coefficient at short periods
C_{R1}	0.867	Mapped value of the risk coefficient at a period of 1 s

Guardrail Connection



Section

Typical vert Spacing = 6'-0" o.c.

$P_{ASD} = 50plf(6') = 300^{\#}$

Top of rail is 42" above walking surface

Distance to anchor centroid = 12"/2 + 42" = 4.0'

$M_{ASD} = 300^{\#}(4') = 14.4\ k\cdot in$

$M_u = 1.6(14.4k\cdot in) = 23.0\ k\cdot in = 1{,}920\ lb\cdot ft$

used Anchor Designer: All ✓'s OK

use: (4) 1/2" ø Titen HD concrete screws w/ 3 1/4" Nominal Embedment depth

Size back plate: Check 9" square w/ 6" anchor spacing

$P_u = \frac{23.0k\cdot in}{6"} = 3.83k$ in

$M_u = \frac{3.83k(6")}{4} = 5.75\ k\cdot in$

$t_{pl} = \left(\frac{4(5.75k\cdot in)}{0.9(36ksi)(9"/2)}\right)^{1/2} = 0.397" < 1/2"$ ✓OK

Check weld:

$S_{weld} = (6")^2/3 = 12.0\ in^3/in$

$f_b = \frac{23.0k\cdot in}{12.0in^2} = 1.92\ k/in$

# of req'd 16th's $= \frac{1.92\ k/in}{1.392\ k/in} = 1.38 < 3.0$ ✓OK

use: PL 1/2 x 9 x 0'-9" A36 w/ 3/16" Fillet welds, each side of vert, 6" long

If Symmetric

- See next sheet for eccentric/off set connection (For prying action

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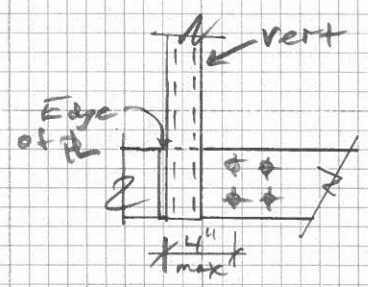
Guardrail Connection

Max vert spacing = 6'-0"

$M_u = 1{,}920$ lb·ft $= 23.0$ k·in

$V_u = 480^{\#}$



Elevation View

used Anchor Designer: All ✓'s OK

use: (4) 1/2" ϕ Titen HD concrete screws w/ 4" nominal embedment depth

Check back plate:

$M_{u\,max} = 2.307k(4" - 1"/2) = 8.07$ k·in

$t_{PL} = \left(\frac{4(8.07k\cdot in)}{0.6(36ksi)(12"/2)}\right)^{1/2} = 0.499" < 1/2"$ ✓OK

use: PL 1/2 x 12 x continuous A36 (1" thick plate called out)

Check vert:

Smallest vert = PL 1" x 4"

$\frac{L_b d}{t^2} = \frac{48"(4")}{(1")^2} = 192$

$M_y = 1/6(1")(4")^2(36ksi) = 96$ k·in

$\phi M_n = 0.9\left[1.52 - 0.274(192)\left(\frac{36}{29{,}000}\right)\right](96k\cdot in) = 125.7$ k·in

$\Rightarrow$ 125.7 k·in > 23 k·in ✓OK

HSS 2x2x1/8, $Z_x = 0.584 in^3$

$\phi M_n = 0.9(46ksi)(0.584in^3) = 24.2$ k·in > 23.0 k·in ✓OK

use: PL 1x4 A36 for verts (HSS 2x2x1/8 called out)

Check weld: $S_w = (10")^2/3 = 33.3 in^3/in$

$f_b = \frac{23.0k\cdot in}{33.3in^2} = 0.69k/in$

# of 16ths $= \frac{0.69k/in}{1.392k/in} = 0.496 < 3.0$ ✓OK

use: 3/16" welds, each side, full height (10" vertical welds, 1/4" called out

project St. Helens - Riverwalk job# 20028 date Oct. 2022 by bc

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1.Project information

Customer company:
Customer contact name:
Customer e-mail:
Comment:

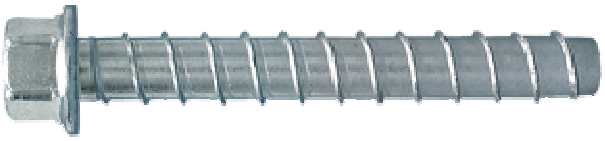
Project description:
Location:
Fastening description:

2. Input Data & Anchor Parameters

General
Design method:ACI 318-14
Units: Imperial units

Anchor Information:
Anchor type: Concrete screw
Material: Carbon Steel
Diameter (inch): 0.500
Nominal Embedment depth (inch): 4.000
Effective Embedment depth, h_{ef} (inch): 2.990
Code report: ICC-ES ESR-2713
Anchor category: 1
Anchor ductility: No
h_{min} (inch): 6.25
c_{ac} (inch): 4.50
C_{min} (inch): 1.75
S_{min} (inch): 3.00

Recommended Anchor
Anchor Name: Titen HD® - 1/2"Ø Titen HD, hnom:4" (102mm)
Code Report: ICC-ES ESR-2713



Base Material
Concrete: Normal-weight
Concrete thickness, h (inch): 12.00
State: Uncracked
Compressive strength, f'_c (psi): 3500
$\Psi_{c,V}$: 1.4
Reinforcement condition: B tension, B shear
Supplemental reinforcement: No
Reinforcement provided at corners: No
Ignore concrete breakout in tension: No
Ignore concrete breakout in shear: No
Ignore 6do requirement: Not applicable
Build-up grout pad: No

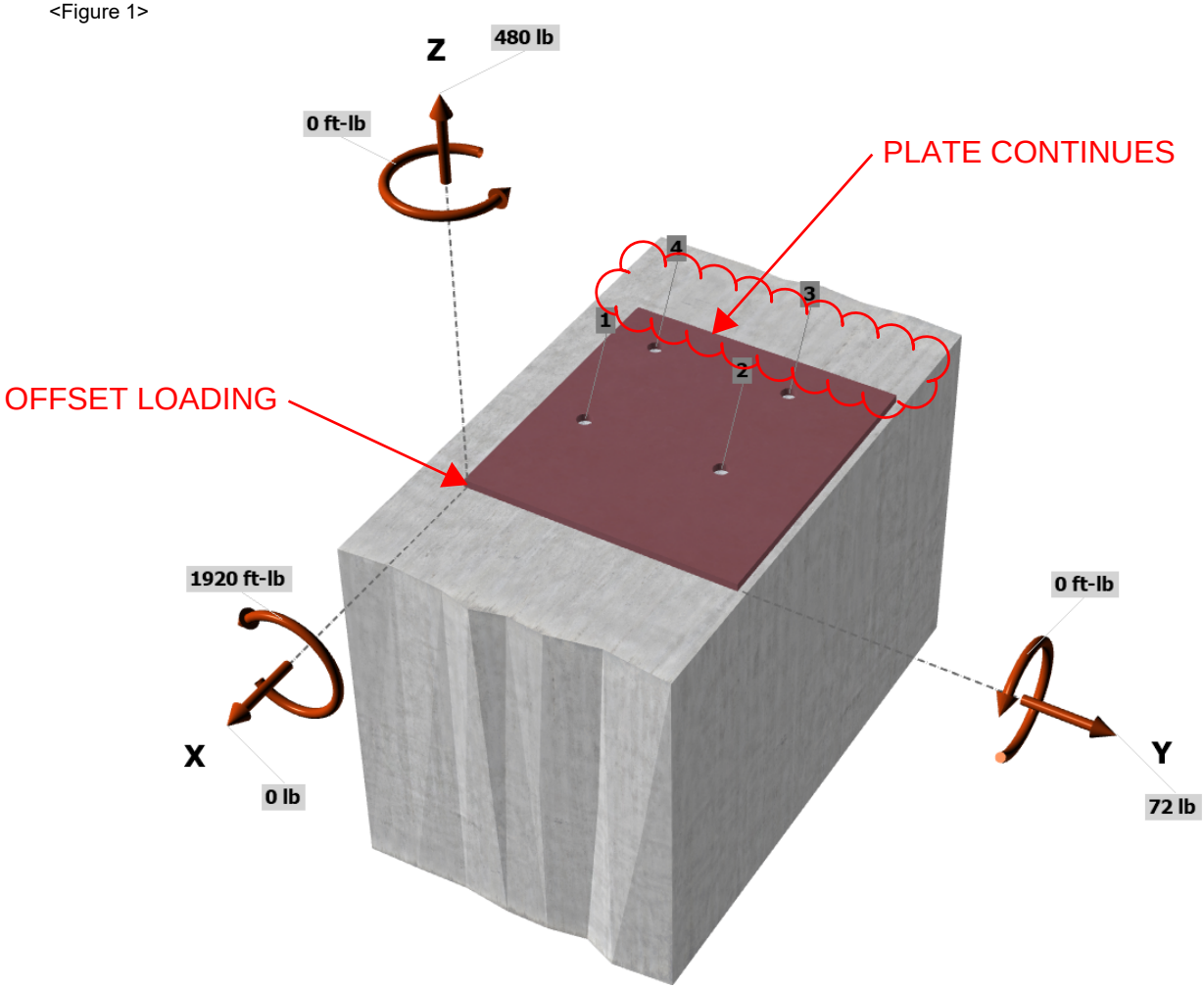
Base Plate
Length x Width x Thickness (inch): 9.50 x 8.75 x 0.25

Load and Geometry
Load factor source: ACI 318 Section 5.3
Load combination: not set
Seismic design: No
Anchors subjected to sustained tension: Not applicable
Apply entire shear load at front row: No
Anchors only resisting wind and/or seismic loads: No

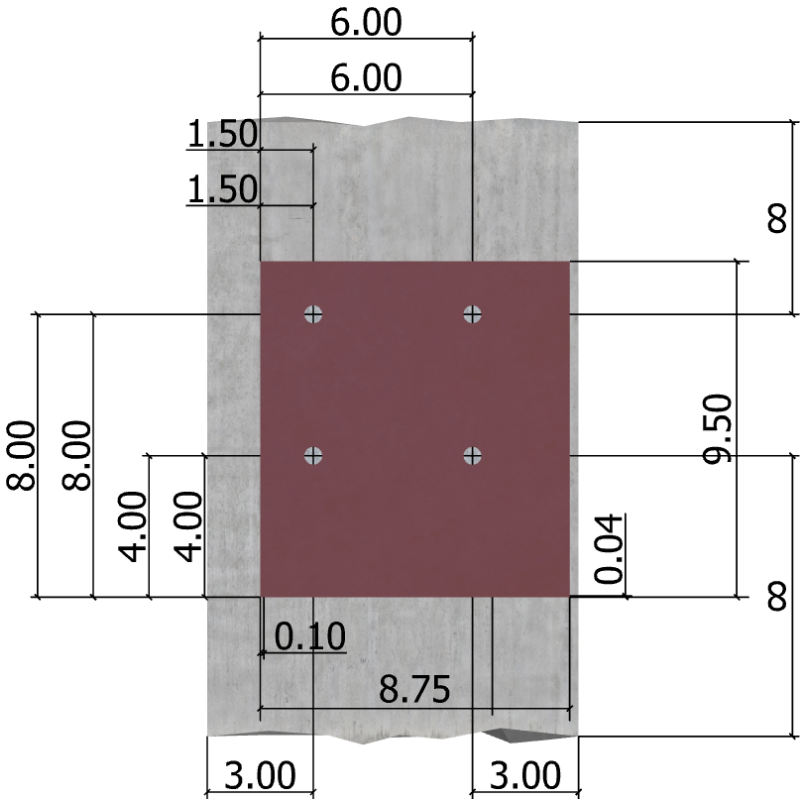
Strength level loads:

N_{ua} [lb]: 480
V_{uax} [lb]: 0
V_{uay} [lb]: 72
M_{ux} [ft-lb]: 1920
M_{uy} [ft-lb]: 0
M_{uz} [ft-lb]: 0

<Figure 1>



<Figure 2>

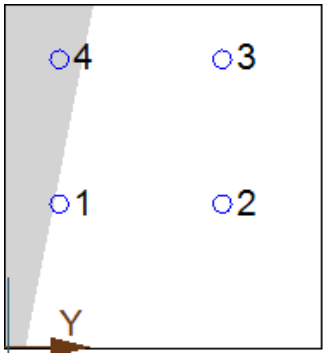


3. Resulting Anchor Forces

Anchor	Tension load, N_{ua} (lb)	Shear load x, V_{uax} (lb)	Shear load y, V_{uay} (lb)	Shear load combined, $\sqrt{(V_{uax})^2+(V_{uay})^2}$ (lb)
1	73.5	26.6	41.7	49.5
2	2306.6	-26.6	41.7	49.5
3	1913.4	-26.6	-5.7	27.2
4	0.0	26.6	-5.7	27.2
Sum	4293.5	0.0	72.0	153.4

Maximum concrete compression strain (‰): 0.18
Maximum concrete compression stress (psi): 770
Resultant tension force (lb): 4294
Resultant compression force (lb): 3814
Eccentricity of resultant tension forces in x-axis, e'_{Nx} (inch): 1.42
Eccentricity of resultant tension forces in y-axis, e'_{Ny} (inch): 0.45
Eccentricity of resultant shear forces in x-axis, e'_{Vx} (inch): 0.00
Eccentricity of resultant shear forces in y-axis, e'_{Vy} (inch): 0.00

<Figure 3>



4. Steel Strength of Anchor in Tension (Sec. 17.4.1)

N_{sa} (lb)	ϕ	ϕN_{sa} (lb)
20130	0.65	13085

5. Concrete Breakout Strength of Anchor in Tension (Sec. 17.4.2)

$N_b = k_c \lambda_a \sqrt{f'_c} h_{ef}^{1.5}$ (Eq. 17.4.2.2a)

k_c	λ_a	f'_c (psi)	h_{ef} (in)	N_b (lb)
24.0	1.00	3500	2.990	7341

$\phi N_{cbg} = \phi\,(A_{Nc} / A_{Nco})\,\Psi_{ec,N}\,\Psi_{ed,N}\,\Psi_{c,N}\,\Psi_{cp,N} N_b$ (Sec. 17.3.1 & Eq. 17.4.2.1b)

A_{Nc} (in²)	A_{Nco} (in²)	$c_{a,min}$ (in)	$\Psi_{ec,N}$	$\Psi_{ed,N}$	$\Psi_{c,N}$	$\Psi_{cp,N}$	N_b (lb)	ϕ	ϕN_{cbg} (lb)
124.13	80.46	3.00	0.690	0.901	1.00	0.997	7341	0.65	4560

8. Steel Strength of Anchor in Shear (Sec. 17.5.1)

V_{sa} (lb)	ϕ_{grout}	ϕ	$\phi_{grout}\phi V_{sa}$ (lb)
7455	1.0	0.60	4473

9. Concrete Breakout Strength of Anchor in Shear (Sec. 17.5.2)

Shear perpendicular to edge in y-direction:

$V_{by} = \min|7(l_e / d_a)^{0.2} \sqrt{d_a} \lambda_a \sqrt{f'_c} c_{a1}^{1.5};\ 9\lambda_a \sqrt{f'_c} c_{a1}^{1.5}|$ (Eq. 17.5.2.2a & Eq. 17.5.2.2b)

l_e (in)	d_a (in)	λ_a	f'_c (psi)	c_{a1} (in)	V_{by} (lb)
2.99	0.500	1.00	3500	3.00	2176

$\phi V_{cbgy} = \phi\,(A_{Vc} / A_{Vco})\,\Psi_{ec,V}\,\Psi_{ed,V}\,\Psi_{c,V}\,\Psi_{h,V} V_{by}$ (Sec. 17.3.1 & Eq. 17.5.2.1b)

A_{Vc} (in²)	A_{Vco} (in²)	$\Psi_{ec,V}$	$\Psi_{ed,V}$	$\Psi_{c,V}$	$\Psi_{h,V}$	V_{by} (lb)	ϕ	ϕV_{cbgy} (lb)
40.50	40.50	1.000	1.000	1.400	1.000	2176	0.70	2132

Shear parallel to edge in y-direction:

$V_{bx} = \min|7(l_e / d_a)^{0.2}\sqrt{d_a}\lambda_a\sqrt{f'_c}c_{a1}^{1.5};\ 9\lambda_a\sqrt{f'_c}c_{a1}^{1.5}|$ (Eq. 17.5.2.2a & Eq. 17.5.2.2b)

l_e (in)	d_a (in)	λ_a	f'_c (psi)	c_{a1} (in)	V_{bx} (lb)
2.99	0.500	1.00	3500	3.00	2176

$\phi V_{cbgy} = \phi\ (2)(A_{Vc} / A_{Vco})\Psi_{ec,V}\Psi_{ed,V}\Psi_{c,V}\Psi_{h,V}V_{bx}$ (Sec. 17.3.1, 17.5.2.1(c) & Eq. 17.5.2.1b)

A_{Vc} (in^2)	A_{Vco} (in^2)	$\Psi_{ec,V}$	$\Psi_{ed,V}$	$\Psi_{c,V}$	$\Psi_{h,V}$	V_{bx} (lb)	ϕ	ϕV_{cbgy} (lb)
58.50	40.50	1.000	1.000	1.400	1.000	2176	0.70	6160

10. Concrete Pryout Strength of Anchor in Shear (Sec. 17.5.3)

$\phi V_{cp} = \phi k_{cp}N_{cb} = \phi k_{cp}(A_{Nc} / A_{Nco})\Psi_{ed,N}\Psi_{c,N}\Psi_{cp,N}N_b$ (Sec. 17.3.1 & Eq. 17.5.3.1a)

k_{cp}	A_{Nc} (in^2)	A_{Nco} (in^2)	$\Psi_{ed,N}$	$\Psi_{c,N}$	$\Psi_{cp,N}$	N_b (lb)	ϕ	ϕV_{cp} (lb)
2.0	34.05	80.46	0.901	1.000	0.997	7341	0.70	3904

11. Results

Interaction of Tensile and Shear Forces (Sec. 17.6.)

Tension	Factored Load, N_{ua} (lb)	Design Strength, ϕN_n (lb)	Ratio	Status
Steel	2307	13085	0.18	Pass
Concrete breakout	**4294**	**4560**	**0.94**	**Pass (Governs)**

Shear	Factored Load, V_{ua} (lb)	Design Strength, ϕV_n (lb)	Ratio	Status
Steel	49	4473	0.01	Pass
T Concrete breakout y+	**42**	**2132**	**0.02**	**Pass (Governs)**
|| Concrete breakout y+	**53**	**6160**	**0.01**	**Pass (Governs)**
Pryout	49	3904	0.01	Pass

Interaction check	$N_{ua}/\phi N_n$	$V_{ua}/\phi V_n$	Combined Ratio	Permissible	Status
Sec. 17.6..1	0.94	0.00	94.2%	1.0	Pass

1/2"Ø Titen HD, hnom:4" (102mm) meets the selected design criteria.

12. Warnings

- Designer must exercise own judgement to determine if this design is suitable.

- Refer to manufacturer's product literature for hole cleaning and installation instructions.

Guardrail - Pickets

(2) Types of guardrail infill (Pickets):

1" x 3/4"

1/2" x 1/4" ← Controls by Inspection

Pickets @ 4" o.c. max : $P = 50^{\#} / 3\text{-pickets} = 16.7^{\#}$

Height of picket = 40" max

$$M_{ASD} = \frac{16.7^{\#}(40")}{4} = 0.167 \text{ k·in}$$

$$\frac{L_b d}{t^2} = \frac{40"(1/2")}{(1/4")^2} = 320$$

$$M_y = 1/6\,(1/4")(1/2")^2(36\text{ksi}) = 0.375 \text{ k·in}$$

$$M_n/\Omega = [1.52 - 0.274(320)(\tfrac{36}{29{,}000})](0.375 \text{ k·in})(\tfrac{1}{1.67})$$

$$\Rightarrow M_n/\Omega = \underline{0.317 \text{ k·in} > 0.167 \text{ k·in} \checkmark \text{OK}}$$

Use: Guardrail Infill/pickets: Min. PL 1/4 x 1/2 x 3'-4" A36 (PL 1 x 4 x 3'-4" A36 also adequate)

Check bottom rail: Span = 6'/2 = 3.0'

$$P_{ASD} = 300^{\#}$$

$$M_{ASD} = \frac{300^{\#}(3')}{4} = 2.70 \text{ k·in}$$

$$t_{PL} = \left(\frac{4(2.70 \text{ k·in})}{0.6(36\text{ksi})(4")}\right)^{1/2} = \underline{0.354" < 1.0" \checkmark \text{OK}}$$

Use: PL 1 x 4 x Cont. A36 Support w/ stiffener @ every 3'-0", min.

project St. Helens-Riverwalk job# 20028 date Oct. 2022 by BL

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MSE WALL DESIGN WORKBOOK

Designer: Sean Clark
Date: 2/21/2022
Firm: Otak

Project Name: St Helens - Riverwalk
Project No: 20028

Comments:

Design gabion retaining wall with cantilevered overlook. This workbook: 14.5' wall with surcharges for future wall and fill. [Wall calculations based on gabion faced MSE wall. Gabions are 36" tall x 36" wide x 6' long. Wall reinforced with Miragrid 7xt/10xt reinforcement at 1.5' spacing per geotechnical report from NV5. Fill to be gravel backfill according to Geotech report.]

MSE Wall Design - Design Inputs and Constants

Resistance Factors

ϕ(bearing)	0.65	Table 11.5.7-1
ϕt(sliding)	1	Table 11.5.7-1
ϕep(sliding)	1	Table 11.5.7-1
ϕpo	0.9	Table 11.5.7-1
ϕt,g	0.9	Table 11.5.7-1

Soil Properties

ϕf	32	degrees	(Internal friction angle of foundation soil)
ϕr	36	degrees	(Internal friction angle of reinforced soil)
ϕr	36	degrees	(Internal friction angle of retained soil)
γs,f	110	pcf	(Weight of gabion fill)
γs,r	120	pcf	(Weight of reinforced fill)
γs,r	120	pcf	(Weight of retained fill)

Facing Properties

B	3	feet	(width of one gabion basket)
H_1	1.5	feet	(height of one gabion basket)
L_1	12	feet	(length of one gabion basket, along wall)
Batter:		degrees	(enter batter in degrees or in slope, batter in degrees
	0.083333	slope	calculated below)
Batter:	4.76	degrees	
H2	0	feet	(minimum embed of wall toe)

Geogrid 1 Properties

L	22.5	feet	(min. length of geogrid)
b	12	feet	(unit width of reinforcing, roll width)
Sv	1.5	feet	(geogrid vertical spacing)
Sh	12	feet	(geogrid horizontal spacing, Sh=b for continuous)
T_{ult} (MARV)	5900	lbs	(Ultimate Tensile Strength per manuf.)
RF_{CR}	1.45		(Strength reduction for creep, per WSDOT QPL App. D)
RF_{ID}	1.12		(Strength reduction for installation damage, WSDOT QPL App. D)
RF_D	1.3		(Strength reduction for degradation damage, WSDOT QPL App. D)
F*	0.487		(Pullout friction factor, Fig. 11.10.6.3.2-2)
α	0.8		(Scale Effect Corr. Factor, Table 11.10.6.3.2-1)
C	2		(Overall reinf. Surface area geometry factor, 2.0 for strip, grid, and sheet type)
Rc	1		(Reinforcement coverage ratio)
Ψ	63.00	degrees	(angle of boundry between active and resistance zones)

Geogrid 2 Properties

T_{ult} (MARV)	9500	lbs	(Ultimate Tensile Strength per manuf.)
RF_{CR}	1.45		(Strength reduction for creep, per WSDOT QPL App. D)
RF_{ID}	1.12		(Strength reduction for installation damage, WSDOT QPL App. D)
RF_D	1.3		(Strength reduction for degradation damage, WSDOT QPL App. D)

Laterial Earth Pressure Coefficients

δ	0	degrees	(Table 3.11.5.3-1)
β	0	degrees	(Slope of backfill from horizontal)
θ	94.76	degrees	(Angle of back of wall, 90 = vertical)
Γ	2.53		(coefficient, active earth pressure calc)
k_a	0.229		(active earth pressure coefficient)
k_0	0.412		(at-rest earth pressure coefficient)
k_p	3		(passive earth pressure coefficient, Sect. 3.11.5.4)
As	0	g	(site adjusted peak ground acceleration)
C1	0.5		(adjustment to kh to account for allowed displacement of the wall face under seismic loads)
k_h	0.000		

Other Loads

LS	100	psf	(Live load surcharge)
ES	0	psf	(Future Earth Fill surcharge)
DS	0	psf	(Future Gabion Wall surcharge)

Strength I Load Factors

$\gamma_{DC,max}$	1.25	(Dead Load Factor, maximum)
$\gamma_{DC,min}$	0.90	(Dead Load Factor, minimum)
$\gamma_{EV,max}$	1.35	(Vertical Earth Pressure Factor, minimum)
$\gamma_{EV,min}$	1.00	(Vertical Earth Pressure Factor, minimum)
$\gamma_{EH,max}$	1.50	(Horizontal Earth Pressure Factor)
$\gamma_{EH,min}$	0.90	(Horizontal Earth Pressure Factor)
γ_{LL}	1.75	(Live Load Factor)
$\gamma_{ES,\ max}$	1.50	(Earth Surcharge Load Factor, maximum)
$\gamma_{ES,\ min}$	0.75	(Earth Surcharge Load Factor, minimum)

Service I Load Factors

γ_{DC}	1.00	(Dead Load Factor, maximum)
γ_{EV}	1.00	(Vertical Earth Pressure Factor, minimum)
γ_{EH}	1.00	(Horizontal Earth Pressure Factor)
γ_{LL}	1.00	(Live Load Factor)

Extreme Event I Load Factors

γ_{DC}	0.90	(Dead Load Factor, maximum)
γ_{EV}	1.00	(Vertical Earth Pressure Factor, minimum)
γ_{EH}	1.50	(Horizontal Earth Pressure Factor)
γ_{LL}	1.00	(Live Load Factor)
γ_{EQ}	1.00	(Earthquake Load Factor)

Capacity

qult	3077	psf	(ultimate bearing pressure)
qall	2000	psf	(allowable bearing pressure)
δ	0.40		(coefficient of sliding friction)

MSE Wall Design - Wall Heights and Reinforcement Layers

Gabion No.	H	No. layers re'q	DC Facing (k)	EV_{RZ} (k)	EV_{SB} (k)	Pi (k/FOW)	T_{md} (k/layer/FOW)
1	3	2	0.495	8.1	0.00	0.00	0.000
2	6	4	0.99	16.2	0.00	0.00	0.000
3	9	6	1.485	24.3	0.00	0.00	0.000
4	12	8	1.98	32.4	0.00	0.00	0.000
5	15	10	2.475	40.5	0.00	0.00	0.000

									Rupture			Pullout					
Layer No.	Z (ft)	h (ft)	P_{EH} (k/FOW)	$P_{LS,h}$ (k/FOW)	$q_{LS,V}$ (ksf)	$q_{ES,V}$ (ksf)	$P_{DS,h}$ (k/FOW)	$q_{DS,V}$ (ksf)	$\sigma_{v,max}$ (ksf)	$\sigma_{h,max}$ (ksf)	T_{max} (k)	La (ft)	Le (ft)	Zp (ft)	$\sigma_{v,po}$ (ksf)	$\sigma_{h,po}$ (ksf)	T_{po} (k)
0	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.100	0.031	0.046	7.64	14.86	0.00	0.000	0.000	0.000
1	1.50	1.50	0.42	0.03	0.10	0.00	0.00	0.00	0.280	0.087	0.130	6.88	15.62	1.50	0.180	0.056	0.084
2	3.00	3.00	0.91	0.07	0.10	0.00	0.00	0.00	0.460	0.142	0.214	6.11	16.39	3.00	0.360	0.111	0.167
3	4.50	4.50	1.46	0.10	0.10	0.00	0.00	0.00	0.640	0.198	0.297	5.35	17.15	4.50	0.540	0.167	0.251
4	6.00	6.00	2.06	0.14	0.10	0.00	0.00	0.00	0.820	0.254	0.381	4.59	17.91	6.00	0.720	0.223	0.334
5	7.50	7.50	2.73	0.17	0.10	0.00	0.00	0.00	1.000	0.310	0.464	3.82	18.68	7.50	0.900	0.279	0.418
6	9.00	9.00	3.47	0.21	0.10	0.00	0.00	0.00	1.180	0.365	0.548	3.06	19.44	9.00	1.080	0.334	0.502
7	10.50	10.50	4.26	0.24	0.10	0.00	0.00	0.00	1.360	0.421	0.632	2.29	20.21	10.50	1.260	0.390	0.585
8	12.00	12.00	5.12	0.28	0.10	0.00	0.00	0.00	1.540	0.477	0.715	1.53	20.97	12.00	1.440	0.446	0.669
9	13.50	13.50	6.04	0.31	0.10	0.00	0.00	0.00	1.720	0.533	0.799	0.76	21.74	13.50	1.620	0.502	0.752
10	15.00	15.00	7.02	0.34	0.10	0.00	0.00	0.00	1.900	0.588	0.882	0.00	22.50	15.00	1.800	0.557	0.836

*Calc for PEH includes height of final fill above back of reinforced zone

H	Height of wall facing
DC Facing	Dead Load of wall facing
EV_{RZ} (k)	Vertical earth pressure from reinforced zone
EV_{SB} (k)	Vertical earth pressure from sloped backfill
Z	Depth of reinforcing layer from top of wall
h	Depth of reinfocing layer from ground surface at back of reinforced soil zone
P_{EH}	Total horizontal earth force @ Z
P_{LS}	Horizontal Force due to live load surcharge
$P_{LS,V}$	Vertical Force due to live load surcharge
$\sigma_{v,max}$	Maximum vertical stress in reinforcing layer
$\sigma_{h,max}$	Maximum factored horizontal stress in reinforcing layer
T_{max}	Maximum factored load in reinforcement
La	Length of active zone
Le	Length of resistance zone
Zp	Depth of reinforcing layer from ground surface at beginning of resistance zone
$\sigma_{v,po}$	Vertical stress in reinforcing layer for pullout calculation
$\sigma_{h,po}$	Factored horizontal stress in reinforcing layer for pullout calculation
T_{po}	Factored load in reinforcement for pullout
Pi	Horizontal force due to seismic load on the active zone
T_{md}	Additional force at each layer due to seismic load

MSE Wall Design - Reinforcement

Design Reinforcement layers at each layer, max wall height

ϕTnr_1	2.515	k	Capacity of first type geogrid
ϕTnr_2	4.050	k	Capacity of second type geogrid

			STR1					
Layer No.	Z (ft)	h (ft)	T_{max} (k)	T_{po} (k)	Le (ft)	Check Rupture	Le_{min} (ft)	Check Pullout
0	0.00	0.00	0.05	0.00	14.86	OK, G1	#DIV/0!	#DIV/0!
1	1.50	1.50	0.13	0.08	15.62	OK, G1	0.66	OK
2	3.00	3.00	0.21	0.17	16.39	OK, G1	0.66	OK
3	4.50	4.50	0.30	0.25	17.15	OK, G1	0.66	OK
4	6.00	6.00	0.38	0.33	17.91	OK, G1	0.66	OK
5	7.50	7.50	0.46	0.42	18.68	OK, G1	0.66	OK
6	9.00	9.00	0.55	0.50	19.44	OK, G1	0.66	OK
7	10.50	10.50	0.63	0.59	20.21	OK, G1	0.66	OK
8	12.00	12.00	0.72	0.67	20.97	OK, G1	0.66	OK
9	13.50	13.50	0.80	0.75	21.74	OK, G1	0.66	OK
10	15.00	15.00	0.88	0.84	22.50	OK, G1	0.66	OK

MSE Wall Design - Reinforcement

Design Reinforcement layers at each layer, max wall height

ϕTnr_1	2.515	k	Capacity of first type geogrid
ϕTnr_2	4.050	k	Capacity of second type geogrid

		EE1								
Layer No.	Z (ft)	T_{md} (k)	$\sigma_{h,\,max}$ (ksf)	T_{max+md} (k)	Check Rupture	$\sigma_{h,\,po}$ (ksf)	T_{po+md} (k)	Le, min (ft)	Check Pullout	Geogrid Type
0	0.00	0.000	0.023	0.034	OK, G1	0.000	0.000	#DIV/0!	#DIV/0!	G1
1	1.50	0.000	0.064	0.096	OK, G1	0.133	0.200	1.585	OK	G1
2	3.00	0.000	0.105	0.158	OK, G1	0.267	0.400	1.585	OK	G1
3	4.50	0.000	0.147	0.220	OK, G1	0.400	0.600	1.585	OK	G1
4	6.00	0.000	0.188	0.282	OK, G1	0.533	0.800	1.585	OK	G1
5	7.50	0.000	0.229	0.344	OK, G1	0.667	1.000	1.585	OK	G1
6	9.00	0.000	0.271	0.406	OK, G1	0.800	1.200	1.585	OK	G1
7	10.50	0.000	0.312	0.468	OK, G1	0.933	1.400	1.585	OK	G1
8	12.00	0.000	0.353	0.530	OK, G1	1.067	1.600	1.585	OK	G1
9	13.50	0.000	0.394	0.592	OK, G1	1.200	1.800	1.585	OK	G1
10	15.00	0.000	0.436	0.654	OK, G1	1.333	2.000	1.585	OK	G1

MSE Wall Design - Sliding and Eccentricity

Check sliding and eccentricity at each wall height

Sliding, No Facing

Sliding, No Facing

H (ft)	DC Facing (k)	EV_{RZ} (k)	EV_{SB} (k)	$P_{EH,h}$ (k/FOW)	$P_{EH,v}$ (k/FOW)	$P_{LS,h}$ (k/FOW)	$P_{ES,V}$ (k/FOW)	$P_{DS,V}$ (k/FOW)	V (no facing) (k)	ϕR_t	ϕR_{ep}	ϕR_{total}	Vu (k)	Sliding Check
3	NA	8.1	0.00	0.91	0.00	0.07	0.00	NA	8.10	3.24	0.18	3.42	1.48	OK
6	NA	16.2	0.00	2.06	0.00	0.14	0.00	NA	16.20	6.48	0.18	6.66	3.34	OK
9	NA	24.3	0.00	3.47	0.00	0.21	0.00	NA	24.30	9.72	0.18	9.90	5.56	OK
12	NA	32.4	0.00	5.12	0.00	0.28	0.00	NA	32.40	12.96	0.18	13.14	8.16	OK
15	NA	40.5	0.00	7.02	0.00	0.34	0.00	NA	40.50	16.20	0.18	16.38	11.13	OK

Sliding, with Facing

Sliding, with Facing

H (ft)	DC Facing (k)	EV_{RZ} (k)	EV_{SB} (k)	$P_{EH,h}$ (k/FOW)	$P_{EH,v}$ (k/FOW)	$P_{LS,h}$ (k/FOW)	$P_{ES,V}$ (k/FOW)	$P_{DS,V}$ (k/FOW)	V (w/ facing) (k)	ϕR_t	ϕR_{ep}	ϕR_{total}	Vu (k)	Sliding Check
3	0.495	8.1	0.00	0.91	0.00	0.07	0.00	0.00	8.72	3.49	0.18	3.67	1.48	OK
6	0.99	16.2	0.00	2.06	0.00	0.14	0.00	0.00	17.44	6.98	0.18	7.16	3.34	OK
9	1.485	24.3	0.00	3.47	0.00	0.21	0.00	0.00	26.16	10.46	0.18	10.64	5.56	OK
12	1.98	32.4	0.00	5.12	0.00	0.28	0.00	0.00	34.88	13.95	0.18	14.13	8.16	OK
15	2.475	40.5	0.00	7.02	0.00	0.34	0.00	0.00	43.59	17.44	0.18	17.62	11.13	OK

Eccentricity, No Facing

Eccentricity, No Facing

H (ft)	DC Facing (k)	EV_{RZ} (k)	EV_{SB} (k)	$P_{EH,h}$ (k/FOW)	$P_{EH,v}$ (k/FOW)	$P_{LS,h}$ (k/FOW)	$P_{ES,V}$ (k/FOW)	$P_{DS,V}$ (k/FOW)	$X_{(DC)}$ (ft)	$X_{(EVRZ)}$ (ft)	$X_{(EVSB)}$ (ft)	$X_{(PEHh)}$ (ft)	$X_{(PEHV)}$ (ft)	$X_{(PLSh)}$ (ft)	$X_{(PESv)}$ (ft)	∑V (no facing) (k)	∑Mc (no facing) (kft)	e (no facing) (ft)	Check
3	NA	8.1	0.00	0.91	0.00	0.07	0.00	NA	NA	0	3.75	1.43	11.25	1.50	0.00	8.10	2.13	0.26	OK
6	NA	16.2	0.00	2.06	0.00	0.14	0.00	NA	NA	0	3.75	2.76	11.25	3.00	0.00	16.20	9.27	0.57	OK
9	NA	24.3	0.00	3.47	0.00	0.21	0.00	NA	NA	0	3.75	4.02	11.25	4.50	0.00	24.30	22.52	0.93	OK
12	NA	32.4	0.00	5.12	0.00	0.28	0.00	NA	NA	0	3.75	5.23	11.25	6.00	0.00	32.40	43.01	1.33	OK
15	NA	40.5	0.00	7.02	0.00	0.34	0.00	NA	NA	0	3.75	6.40	11.25	7.50	0.00	40.50	71.85	1.77	OK

Eccentricity, with Facing

Eccentricity, with Facing

H (ft)	DC Facing (k)	EV_{RZ} (k)	EV_{SB} (k)	$P_{EH,h}$ (k/FOW)	$P_{EH,v}$ (k/FOW)	$P_{LS,h}$ (k/FOW)	$P_{ES,V}$ (k/FOW)	$P_{DS,V}$ (k/FOW)	$X_{(DC)}$ (ft)	$X_{(EVRZ)}$ (ft)	$X_{(EVSB)}$ (ft)	$X_{(PEHh)}$ (ft)	$X_{(PEHV)}$ (ft)	$X_{(PLSh)}$ (ft)	$X_{(PESv)}$ (ft)	∑V (w/ facing) (k)	∑Mc (w/ facing) (kft)	e (w/ facing) (ft)	Check
3	0.495	8.1	0.00	0.91	0.00	0.07	0.00	0.00	11.25	1.5	5.25	1.43	11.25	1.50	1.50	8.72	-7.31	-0.84	OK
6	0.99	16.2	0.00	2.06	0.00	0.14	0.00	0.00	11.25	1.5	5.25	2.76	11.25	3.00	1.50	17.44	-9.62	-0.55	OK
9	1.485	24.3	0.00	3.47	0.00	0.21	0.00	0.00	11.25	1.5	5.25	4.02	11.25	4.50	1.50	26.16	-5.80	-0.22	OK
12	1.98	32.4	0.00	5.12	0.00	0.28	0.00	0.00	11.25	1.5	5.25	5.23	11.25	6.00	1.50	34.88	5.25	0.15	OK
15	2.475	40.5	0.00	7.02	0.00	0.34	0.00	0.00	11.25	1.5	5.25	6.40	11.25	7.50	1.50	43.59	24.65	0.57	OK

MSE Wall Design - Design Inputs and Constants

Resistance Factors

ϕ(bearing)	0.65	Table 11.5.7-1
ϕt(sliding)	1	Table 11.5.7-1
ϕep(sliding)	1	Table 11.5.7-1
ϕpo	0.9	Table 11.5.7-1
ϕt,g	0.9	Table 11.5.7-1

Soil Properties

ϕf	32	degrees	(Internal friction angle of foundation soil)
ϕr	36	degrees	(Internal friction angle of reinforced soil)
ϕr	36	degrees	(Internal friction angle of retained soil)
γs,f	110	pcf	(Weight of gabion fill)
γs,r	120	pcf	(Weight of reinforced fill)
γs,r	120	pcf	(Weight of retained fill)

Facing Properties

B	3	feet	(width of one gabion basket)
H_1	1.5	feet	(height of one gabion basket)
L_1	12	feet	(length of one gabion basket, along wall)
Batter:		degrees	(enter batter in degrees or in slope, batter in degrees
	0.083333	slope	calculated below)
Batter:	4.76	degrees	
H2	0	feet	(minimum embed of wall toe)

Geogrid 1 Properties

L	22.5	feet	(min. length of geogrid)
b	12	feet	(unit width of reinforcing, roll width)
Sv	1.5	feet	(geogrid vertical spacing)
Sh	12	feet	(geogrid horizontal spacing, Sh=b for continuous)
T_{ult} (MARV)	5900	lbs	(Ultimate Tensile Strength per manuf.)
RF_{CR}	1.45		(Strength reduction for creep, per WSDOT QPL App. D)
RF_{ID}	1.12		(Strength reduction for installation damage, WSDOT QPL App. D)
RF_D	1.3		(Strength reduction for degradation damage, WSDOT QPL App. D)
F*	0.487		(Pullout friction factor, Fig. 11.10.6.3.2-2)
α	0.8		(Scale Effect Corr. Factor, Table 11.10.6.3.2-1)
C	2		(Overall reinf. Surface area geometry factor, 2.0 for strip, grid, and sheet type)
Rc	1		(Reinforcement coverage ratio)
Ψ	63.00	degrees	(angle of boundry between active and resistance zones)

Geogrid 2 Properties

T_{ult} (MARV)	9500	lbs	(Ultimate Tensile Strength per manuf.)
RF_{CR}	1.45		(Strength reduction for creep, per WSDOT QPL App. D)
RF_{ID}	1.12		(Strength reduction for installation damage, WSDOT QPL App. D)
RF_D	1.3		(Strength reduction for degradation damage, WSDOT QPL App. D)

Laterial Earth Pressure Coefficients

δ	0	degrees	(Table 3.11.5.3-1)
β	0	degrees	(Slope of backfill from horizontal)
θ	94.76	degrees	(Angle of back of wall, 90 = vertical)
Γ	2.53		(coefficient, active earth pressure calc)
k_a	0.229		(active earth pressure coefficient)
k_0	0.412		(at-rest earth pressure coefficient)
k_p	3		(passive earth pressure coefficient, Sect. 3.11.5.4)
As	0.664	g	(site adjusted peak ground acceleration)
C1	0.5		(adjustment to kh to account for allowed displacement of the wall face under seismic loads)
k_h	0.332		

Other Loads

LS	100	psf	(Live load surcharge)
ES	0	psf	(Future Earth Fill surcharge)
DS	0	psf	(Future Gabion Wall surcharge)

Strength I Load Factors

$\gamma_{DC,max}$	1.25	(Dead Load Factor, maximum)
$\gamma_{DC,min}$	0.90	(Dead Load Factor, minimum)
$\gamma_{EV,max}$	1.35	(Vertical Earth Pressure Factor, minimum)
$\gamma_{EV,min}$	1.00	(Vertical Earth Pressure Factor, minimum)
$\gamma_{EH,max}$	1.50	(Horizontal Earth Pressure Factor)
$\gamma_{EH,min}$	0.90	(Horizontal Earth Pressure Factor)
γ_{LL}	1.75	(Live Load Factor)
$\gamma_{ES,\ max}$	1.50	(Earth Surcharge Load Factor, maximum)
$\gamma_{ES,\ min}$	0.75	(Earth Surcharge Load Factor, minimum)

Service I Load Factors

γ_{DC}	1.00	(Dead Load Factor, maximum)
γ_{EV}	1.00	(Vertical Earth Pressure Factor, minimum)
γ_{EH}	1.00	(Horizontal Earth Pressure Factor)
γ_{LL}	1.00	(Live Load Factor)

Extreme Event I Load Factors

γ_{DC}	0.90	(Dead Load Factor, maximum)
γ_{EV}	1.00	(Vertical Earth Pressure Factor, minimum)
γ_{EH}	1.50	(Horizontal Earth Pressure Factor)
γ_{LL}	1.00	(Live Load Factor)
γ_{EQ}	1.00	(Earthquake Load Factor)

Capacity

qult	4615	psf	(ultimate bearing pressure)
qall	3000	psf	(allowable bearing pressure, with seismic)
δ	0.40		(coefficient of sliding friction)

MSE Wall Design - Wall Heights and Reinforcement Layers

Gabion No.	H	No. layers re'q	DC Facing (k)	EV_{RZ} (k)	EV_{SB} (k)	Pi (k/FOW)	T_{md} (k/layer/FOW)
1	3	2	0.495	8.1	0.00	0.09	0.046
2	6	4	0.99	16.2	0.00	0.37	0.091
3	9	6	1.485	24.3	0.00	0.82	0.137
4	12	8	1.98	32.4	0.00	1.46	0.183
5	15	10	2.475	40.5	0.00	2.28	0.228

									Rupture			Pullout					
Layer No.	Z (ft)	h (ft)	P_{EH} (k/FOW)	$P_{LS,h}$ (k/FOW)	$q_{LS,V}$ (ksf)	$q_{ES,V}$ (ksf)	$P_{DS,h}$ (k/FOW)	$q_{DS,V}$ (ksf)	$\sigma_{v,max}$ (ksf)	$\sigma_{h,max}$ (ksf)	T_{max} (k)	La (ft)	Le (ft)	Zp (ft)	$\sigma_{v,po}$ (ksf)	$\sigma_{h,po}$ (ksf)	T_{po} (k)
0	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.100	0.031	0.046	7.64	14.86	0.00	0.000	0.000	0.000
1	1.50	1.50	0.42	0.03	0.10	0.00	0.00	0.00	0.280	0.087	0.130	6.88	15.62	1.50	0.180	0.056	0.084
2	3.00	3.00	0.91	0.07	0.10	0.00	0.00	0.00	0.460	0.142	0.214	6.11	16.39	3.00	0.360	0.111	0.167
3	4.50	4.50	1.46	0.10	0.10	0.00	0.00	0.00	0.640	0.198	0.297	5.35	17.15	4.50	0.540	0.167	0.251
4	6.00	6.00	2.06	0.14	0.10	0.00	0.00	0.00	0.820	0.254	0.381	4.59	17.91	6.00	0.720	0.223	0.334
5	7.50	7.50	2.73	0.17	0.10	0.00	0.00	0.00	1.000	0.310	0.464	3.82	18.68	7.50	0.900	0.279	0.418
6	9.00	9.00	3.47	0.21	0.10	0.00	0.00	0.00	1.180	0.365	0.548	3.06	19.44	9.00	1.080	0.334	0.502
7	10.50	10.50	4.26	0.24	0.10	0.00	0.00	0.00	1.360	0.421	0.632	2.29	20.21	10.50	1.260	0.390	0.585
8	12.00	12.00	5.12	0.28	0.10	0.00	0.00	0.00	1.540	0.477	0.715	1.53	20.97	12.00	1.440	0.446	0.669
9	13.50	13.50	6.04	0.31	0.10	0.00	0.00	0.00	1.720	0.533	0.799	0.76	21.74	13.50	1.620	0.502	0.752
10	15.00	15.00	7.02	0.34	0.10	0.00	0.00	0.00	1.900	0.588	0.882	0.00	22.50	15.00	1.800	0.557	0.836

*Calc for PEH includes height of final fill above back of reinforced zone

H Height of wall facing
DC Facing Dead Load of wall facing
EV_{RZ} (k) Vertical earth pressure from reinforced zone
EV_{SB} (k) Vertical earth pressure from sloped backfill
Z Depth of reinforcing layer from top of wall
h Depth of reinfocing layer from ground surface at back of reinforced soil zone
P_{EH} Total horizontal earth force @ Z
P_{LS} Horizontal Force due to live load surcharge
$P_{LS,V}$ Vertical Force due to live load surcharge
$\sigma_{v,max}$ Maximum vertical stress in reinforcing layer
$\sigma_{h,max}$ Maximum factored horizontal stress in reinforcing layer
T_{max} Maximum factored load in reinforcement
La Length of active zone
Le Length of resistance zone
Zp Depth of reinforcing layer from ground surface at beginning of resistance zone
$\sigma_{v,po}$ Vertical stress in reinforcing layer for pullout calculation
$\sigma_{h,po}$ Factored horizontal stress in reinforcing layer for pullout calculation
T_{po} Factored load in reinforcement for pullout
Pi Horizontal force due to seismic load on the active zone
T_{md} Additional force at each layer due to seismic load

MSE Wall Design - Reinforcement

Design Reinforcement layers at each layer, max wall height

ϕTnr_1	2.515	k	Capacity of first type geogrid
ϕTnr_2	4.050	k	Capacity of second type geogrid

			STR1					
Layer No.	Z (ft)	h (ft)	T_{max} (k)	T_{po} (k)	Le (ft)	Check Rupture	Le_{min} (ft)	Check Pullout
0	0.00	0.00	0.05	0.00	14.86	OK, G1	#DIV/0!	#DIV/0!
1	1.50	1.50	0.13	0.08	15.62	OK, G1	0.66	OK
2	3.00	3.00	0.21	0.17	16.39	OK, G1	0.66	OK
3	4.50	4.50	0.30	0.25	17.15	OK, G1	0.66	OK
4	6.00	6.00	0.38	0.33	17.91	OK, G1	0.66	OK
5	7.50	7.50	0.46	0.42	18.68	OK, G1	0.66	OK
6	9.00	9.00	0.55	0.50	19.44	OK, G1	0.66	OK
7	10.50	10.50	0.63	0.59	20.21	OK, G1	0.66	OK
8	12.00	12.00	0.72	0.67	20.97	OK, G1	0.66	OK
9	13.50	13.50	0.80	0.75	21.74	OK, G1	0.66	OK
10	15.00	15.00	0.88	0.84	22.50	OK, G1	0.66	OK

MSE Wall Design - Reinforcement

Design Reinforcement layers at each layer, max wall height

ϕTnr_1	2.515	k	Capacity of first type geogrid
ϕTnr_2	4.050	k	Capacity of second type geogrid

		EE1								
Layer No.	Z (ft)	T_{md} (k)	$\sigma_{h,\ max}$ (ksf)	T_{max+md} (k)	Check Rupture	$\sigma_{h,\ po}$ (ksf)	T_{po+md} (k)	Le, min (ft)	Check Pullout	Geogrid Type
0	0.00	0.000	0.023	0.034	OK, G1	0.000	0.000	#DIV/0!	#DIV/0!	G1
1	1.50	0.046	0.064	0.142	OK, G1	0.133	0.246	1.947	OK	G1
2	3.00	0.046	0.105	0.204	OK, G1	0.267	0.446	1.766	OK	G1
3	4.50	0.091	0.147	0.312	OK, G1	0.400	0.691	1.826	OK	G1
4	6.00	0.091	0.188	0.373	OK, G1	0.533	0.891	1.766	OK	G1
5	7.50	0.137	0.229	0.481	OK, G1	0.667	1.137	1.802	OK	G1
6	9.00	0.137	0.271	0.543	OK, G1	0.800	1.337	1.766	OK	G1
7	10.50	0.183	0.312	0.651	OK, G1	0.933	1.583	1.792	OK	G1
8	12.00	0.183	0.353	0.712	OK, G1	1.067	1.783	1.766	OK	G1
9	13.50	0.228	0.394	0.820	OK, G1	1.200	2.028	1.786	OK	G1
10	15.00	0.228	0.436	0.882	OK, G1	1.333	2.228	1.766	OK	G1

MSE Wall Design - Sliding and Eccentricity

Check sliding and eccentricity at each wall height

Sliding, No Facing

Sliding, No Facing

H (ft)	DC Facing (k)	EV_{RZ} (k)	EV_{SB} (k)	$P_{EH,h}$ (k/FOW)	$P_{EH,v}$ (k/FOW)	$P_{LS,h}$ (k/FOW)	$P_{ES,V}$ (k/FOW)	$P_{DS,V}$ (k/FOW)	V (no facing) (k)	ϕR_t	ϕR_{ep}	ϕR_{total}	Vu (k)	Sliding Check
3	NA	8.1	0.00	0.91	0.00	0.07	0.00	NA	8.10	3.24	0.18	3.42	1.48	OK
6	NA	16.2	0.00	2.06	0.00	0.14	0.00	NA	16.20	6.48	0.18	6.66	3.34	OK
9	NA	24.3	0.00	3.47	0.00	0.21	0.00	NA	24.30	9.72	0.18	9.90	5.56	OK
12	NA	32.4	0.00	5.12	0.00	0.28	0.00	NA	32.40	12.96	0.18	13.14	8.16	OK
15	NA	40.5	0.00	7.02	0.00	0.34	0.00	NA	40.50	16.20	0.18	16.38	11.13	OK

Sliding, with Facing

Sliding, with Facing

H (ft)	DC Facing (k)	EV_{RZ} (k)	EV_{SB} (k)	$P_{EH,h}$ (k/FOW)	$P_{EH,v}$ (k/FOW)	$P_{LS,h}$ (k/FOW)	$P_{ES,V}$ (k/FOW)	$P_{DS,V}$ (k/FOW)	V (w/ facing) (k)	ϕR_t	ϕR_{ep}	ϕR_{total}	Vu (k)	Sliding Check
3	0.495	8.1	0.00	0.91	0.00	0.07	0.00	0.00	8.72	3.49	0.18	3.67	1.48	OK
6	0.99	16.2	0.00	2.06	0.00	0.14	0.00	0.00	17.44	6.98	0.18	7.16	3.34	OK
9	1.485	24.3	0.00	3.47	0.00	0.21	0.00	0.00	26.16	10.46	0.18	10.64	5.56	OK
12	1.98	32.4	0.00	5.12	0.00	0.28	0.00	0.00	34.88	13.95	0.18	14.13	8.16	OK
15	2.475	40.5	0.00	7.02	0.00	0.34	0.00	0.00	43.59	17.44	0.18	17.62	11.13	OK

Eccentricity, No Facing

Eccentricity, No Facing

H (ft)	DC Facing (k)	EV_{RZ} (k)	EV_{SB} (k)	$P_{EH,h}$ (k/FOW)	$P_{EH,v}$ (k/FOW)	$P_{LS,h}$ (k/FOW)	$P_{ES,V}$ (k/FOW)	$P_{DS,V}$ (k/FOW)	$X_{(DC)}$ (ft)	$X_{(EVRZ)}$ (ft)	$X_{(EVSB)}$ (ft)	$X_{(PEHh)}$ (ft)	$X_{(PEHV)}$ (ft)	$X_{(PLSh)}$ (ft)	$X_{(PESv)}$ (ft)	∑V (no facing) (k)	∑Mc (no facing) (kft)	e (no facing) (ft)	Check
3	NA	8.1	0.00	0.91	0.00	0.07	0.00	NA	NA	0	3.75	1.43	11.25	1.50	0.00	8.10	2.13	0.26	OK
6	NA	16.2	0.00	2.06	0.00	0.14	0.00	NA	NA	0	3.75	2.76	11.25	3.00	0.00	16.20	9.27	0.57	OK
9	NA	24.3	0.00	3.47	0.00	0.21	0.00	NA	NA	0	3.75	4.02	11.25	4.50	0.00	24.30	22.52	0.93	OK
12	NA	32.4	0.00	5.12	0.00	0.28	0.00	NA	NA	0	3.75	5.23	11.25	6.00	0.00	32.40	43.01	1.33	OK
15	NA	40.5	0.00	7.02	0.00	0.34	0.00	NA	NA	0	3.75	6.40	11.25	7.50	0.00	40.50	71.85	1.77	OK

Eccentricity, with Facing

Eccentricity, with Facing

H (ft)	DC Facing (k)	EV_{RZ} (k)	EV_{SB} (k)	$P_{EH,h}$ (k/FOW)	$P_{EH,v}$ (k/FOW)	$P_{LS,h}$ (k/FOW)	$P_{ES,V}$ (k/FOW)	$P_{DS,V}$ (k/FOW)	$X_{(DC)}$ (ft)	$X_{(EVRZ)}$ (ft)	$X_{(EVSB)}$ (ft)	$X_{(PEHh)}$ (ft)	$X_{(PEHV)}$ (ft)	$X_{(PLSh)}$ (ft)	$X_{(PESv)}$ (ft)	∑V (w/ facing) (k)	∑Mc (w/ facing) (kft)	e (w/ facing) (ft)	Check
3	0.495	8.1	0.00	0.91	0.00	0.07	0.00	0.00	11.25	1.5	5.25	1.43	11.25	1.50	1.50	8.72	-7.31	-0.84	OK
6	0.99	16.2	0.00	2.06	0.00	0.14	0.00	0.00	11.25	1.5	5.25	2.76	11.25	3.00	1.50	17.44	-9.62	-0.55	OK
9	1.485	24.3	0.00	3.47	0.00	0.21	0.00	0.00	11.25	1.5	5.25	4.02	11.25	4.50	1.50	26.16	-5.80	-0.22	OK
12	1.98	32.4	0.00	5.12	0.00	0.28	0.00	0.00	11.25	1.5	5.25	5.23	11.25	6.00	1.50	34.88	5.25	0.15	OK
15	2.475	40.5	0.00	7.02	0.00	0.34	0.00	0.00	11.25	1.5	5.25	6.40	11.25	7.50	1.50	43.59	24.65	0.57	OK

Retaining walls - CIP Conc.

Soil properties : $\gamma_a = 35$ pcf, $\gamma_f = 250$ pcf

$\sigma_a = 3{,}000$ psf, $\sigma_{a\ wind/seismic} = 3{,}000$ psf

$\mu = 0.35$ (Native soil) $\mu = 0.40$ (Gravel)

Seismic $= 7(H)^2$ @ $0.60H$

Size Wall for varying heights :

Seismic :

4'-0" ⇒ $P_{EQ} = 7(4')^2 = 112^{\#}$ @ 2.40'

6'-0" ⇒ $P_{EQ} = 7(6')^2 = 252^{\#}$ @ 3.60'

7'-6" ⇒ $P_{EQ} = 7(7.5')^2 = 394^{\#}$ @ 4.50'

9'-6" ⇒ $P_{EQ} = 7(9.5')^2 = 632^{\#}$ @ 5.70'

use:

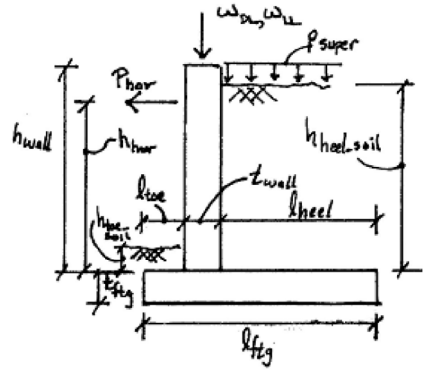
8" thick wall w/ 12" thick footing w/ 12" toe	
0'-4'	#5 @ 16" o.c. Wall + FTG X 3'-8"
4'-6'	#5 @ 12" o.c. Wall + FTG X 4'-0"
6'-7.5'	#5 @ 8" o.c. Wall + @ 10" o.c. FTG X 5'-8"
7.5'-9.5'	#5 @ 4" o.c. Wall + @ 6" o.c. FTG X 6'-4"

Sheet No.:_____

Project: St. Helens - Riverwalk - Retaining Wall
Project No.: 20028
Client:
Subject:

Engineer: SC
File: Ret-Wall_4-ft.mcdx
Date:
Rev.:

Retaining wall analysis and design



Material properties:

$\gamma_{conc} := 150 \cdot pcf$

$\gamma_{soil} := 120 \cdot pcf$

$\gamma_{EFP_a} := 35 \cdot pcf$

$\gamma_{EFP_p} := 250 \cdot pcf$

$\mu_{sliding} := .40$

$q_{all_brg} := 2000 \cdot psf$

$FS := 1.5$

Loading on wall:

$h_{heel_soil} := 4 \cdot ft + 0 \cdot in$

$h_{toe_soil} := 12 \cdot in$

$p_{super} := 100.0 \cdot psf$

$\omega_{DL_super} := 0.0 \cdot klf$

$\omega_{LL_super} := 0.0 \cdot klf$

$P_{hor} := 0.0 \cdot kips$

$h_{hor} := 0 \cdot ft$

Wall geometry:

$h_{wall} := 4 \cdot ft + 0 \cdot in$

$t_{wall} := 8 \cdot in$

$p_{wall} := 100 \cdot psf$

$h_{key} := 0 \cdot in$

$l_{key} := 0 \cdot in$

$t_{ftg} := 1 \cdot ft + 0 \cdot in$

$l_{toe} := 1 \cdot ft + 0 \cdot in$

$l_{ftg} := 2 \cdot ft + 8 \cdot in$

$l_{heel} := l_{ftg} - l_{toe} - t_{wall}$

$l_{heel} = 1\ ft$

$b_{nom} := 1 \cdot ft$

$\omega_1 := \omega_{DL_super} + \omega_{LL_super}$ $\qquad \omega_1 = 0\ \frac{kips}{ft}$

$P_{ftg} := \gamma_{conc} \cdot (l_{ftg} \cdot t_{ftg} + l_{key} \cdot h_{key}) \cdot b_{nom}$ $\qquad P_{ftg} = 0.4\ kips$

$P_{wall} := p_{wall} \cdot h_{wall} \cdot b_{nom}$ $\qquad P_{wall} = 0.4\ kips$

$P_{heel_soil} := (\gamma_{soil} \cdot h_{heel_soil} + p_{super}) \cdot l_{heel} \cdot b_{nom}$ $\qquad P_{heel_soil} = 0.58\ kips$

$P_{toe_soil} := \gamma_{soil} \cdot h_{toe_soil} \cdot l_{toe} \cdot b_{nom}$ $\qquad P_{toe_soil} = 0.12\ kips$

$P_{total} := P_{ftg} + P_{wall} + P_{heel_soil} + P_{toe_soil} + \omega_1 \cdot b_{nom}$ $\qquad P_{total} = 1.5\ kips$

$$M_{OT} := \left(\frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot (h_{heel_soil} + t_{ftg})^2 \cdot \left(\frac{t_{ftg} + h_{heel_soil}}{3} \right) + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot (h_{heel_soil} + t_{ftg}) \cdot b_{nom} \cdot \left(\frac{t_{ftg} + h_{heel_soil}}{2} \right) + P_{hor} \cdot (t_{ftg} + h_{hor}) \right) \cdot FS$$

$M_{OT} = 1.641\ ft \cdot kips$

$$M_{OT_resisting} := P_{ftg} \cdot \frac{l_{ftg}}{2} + P_{wall} \cdot \left(l_{toe} + \frac{t_{wall}}{2} \right) + \omega_1 \cdot b_{nom} \cdot \left(l_{toe} + \frac{t_{wall}}{2} \right) + P_{heel_soil} \cdot \left(l_{ftg} - \frac{l_{heel}}{2} \right) + P_{toe_soil} \cdot \frac{l_{toe}}{2}$$

$M_{OT_resisting} = 2.383\ ft \cdot kips$

$$H_{sliding} := \left(\frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot \left(h_{heel_soil} + h_{key} + t_{ftg}\right)^2 + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot b_{nom} \cdot \left(h_{heel_soil} + h_{key} + t_{ftg}\right) + P_{hor} \right) \cdot FS$$

$H_{sliding} = 0.875\ kips$

$$H_{resisting} := \left(P_{ftg} + P_{wall} + P_{heel_soil} + 0 \cdot P_{toe_soil} + \omega_1 \cdot b_{nom}\right) \cdot \mu_{sliding} + \frac{1}{2} \cdot \gamma_{EFP_p} \cdot b_{nom} \cdot \left(\left(h_{toe_soil} + t_{ftg} + h_{key}\right)^2 - h_{toe_soil}^{\ 2}\right)$$

$H_{resisting} = 0.927\ kips$

<u>Soil pressures due to gravity and overturning forces:</u>

Footing size: $B_1 := b_{nom}$ $\quad B_1 = 1\ ft$

$B_2 := l_{ftg}$ $\quad B_2 = 2.667\ ft$

$A := B_1 \cdot B_2$ $\quad A = 2.667\ ft^2$

Moment at mid-width of footing:

$$M := \left(\begin{array}{l} \frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot \left(h_{heel_soil}\right)^2 \cdot \left(\frac{h_{heel_soil}}{3}\right) \\ + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot \left(h_{heel_soil}\right) \cdot b_{nom} \cdot \left(\frac{h_{heel_soil}}{2}\right) \\ + \frac{0 \cdot -1}{2} \cdot \gamma_{EFP_p} \cdot b_{nom} \cdot \left(h_{toe_soil} + t_{ftg}\right)^2 \cdot \left(\frac{h_{toe_soil}}{3}\right) \\ + P_{hor} \cdot \left(t_{ftg} + h_{hor}\right) + P_{toe_soil} \cdot \left(\frac{l_{ftg}}{2} - \frac{l_{toe}}{2}\right) + \left(P_{wall} + \omega_1 \cdot b_{nom}\right) \cdot \left(\frac{l_{ftg}}{2} - l_{toe} - \frac{t_{wall}}{2}\right) \\ + -P_{heel_soil} \cdot \left(\frac{l_{ftg}}{2} - \frac{l_{heel}}{2}\right) \end{array} \right)$$

$M = 0.223\ ft \cdot kips$

Eccentricity of soil pressure resultant:

$e := \frac{M}{P_{total}}$ $\quad e = 0.149\ ft$ $\quad \frac{B_2}{6} = 0.444\ ft$

Maximum soil pressures:

$$q_{max_prime} := \begin{cases} \left(\frac{P_{total}}{A} \cdot \left(1 + \frac{6 \cdot e}{B_2}\right)\right) & \text{if } e \le \frac{B_2}{6} \\ \frac{2 \cdot P_{total}}{3 \cdot A \cdot \left(0.5 - \frac{e}{B_2}\right)} & \text{else} \end{cases}$$

$q_{max_prime} = 751\ psf$

$q_{max_prime} < q_{all_brg} = 1$

$$q_{min_prime} := \begin{cases} \left(\frac{P_{total}}{A} \cdot \left(1 - \frac{6 \cdot e}{B_2}\right)\right) & \text{if } e \le \frac{B_2}{6} \\ 0 \cdot psf & \text{else} \end{cases}$$

$q_{min_prime} = 374\ psf$

<u>Forces in wall at the base of wall:</u>

$$M_{wall} := \left(\frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot \left(h_{heel_soil}\right)^2 \cdot \frac{h_{heel_soil}}{3} + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot \left(h_{heel_soil}\right) \cdot b_{nom} \cdot \left(\frac{h_{heel_soil}}{2}\right) + P_{hor} \cdot \left(h_{hor}\right)\right)$$

$$V_{wall} := \left(\frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot \left(h_{heel_soil}\right)^2 + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot \left(h_{heel_soil}\right) \cdot b_{nom} + P_{hor}\right)$$

$1.6 \cdot M_{wall} = 0.971\ ft \cdot kips$

$1.6 \cdot V_{wall} = 0.635\ kips$

$$M_{footing} := P_{heel_soil} \cdot \frac{l_{heel}}{2} + p_{super} \cdot b_{nom} \cdot \frac{l_{heel}^2}{2}$$

$M_{footing} = 0.34\ ft \cdot kips$

$1.6 \cdot M_{footing} = 0.544\ ft \cdot kips$

Reinforced concrete retaining wall design:

Loads and geometry:

Factored moment: $M_u := 1.6 \cdot M_{wall}$ $\quad M_u = 1\ ft \cdot kips$

Factored shear force: $V_u := 1.6 \cdot V_{wall}$ $\quad V_u = 0.6\ kips$

Slab strip width: $b := b_{nom}$

Wall thickness: $h := t_{wall}$

Cover to reinforcing: $d_{cg} := 4 \cdot in$

Depth to reinforcing: $d := h - d_{cg}$ $\quad d = 4\ in$

Material properties / Design parameters:

Strength reduction factors: Bending: $\phi_b := 0.9$

Shear: $\phi_v := 0.75$

Concrete compressive strength: $f_{c_p} := 4 \cdot ksi$

Steel yield strength: $f_y := 60 \cdot ksi$

Whitney stress block depth ratio:

$$\beta_1 := \begin{cases} 0.85 & \text{if } f_{c_p} \le 4 \cdot ksi \\ \left(0.85 - 0.05 \cdot \left(f_{c_p} \cdot ksi^{-1} - 4\right)\right) & \text{else} \end{cases}$$

Minimum flexural reinforcing:

$\rho_{min} := 200 \cdot f_y^{-1} \cdot psi$ $\quad \rho_{min} = 0.0033$

Maximum flexural reinforcing:

$$\rho_{max} := 0.75 \cdot \left(\frac{0.85 \cdot \beta_1 \cdot f_{c_p}}{f_y} \cdot \frac{87 \cdot ksi}{87 \cdot ksi + f_y}\right)$$

$$\rho_{max} = 0.0214$$

Flexural design:

Required area of reinforcing: $A_{s_reqd} = 0.05\ in^2$

Area of flexural reinforcing:

$BarArea := 0.31 \cdot in^2$

$Spacing := 16 \cdot in$ $\quad A_s := BarArea \cdot \frac{b}{Spacing}$ $\quad A_s = 0.233\ in^2$

Reinforcing ratio: $\rho := \frac{A_s}{b \cdot d}$ $\quad \rho = 0.0048$

Compression block depth:

$$a := \frac{A_s \cdot f_y}{0.85 \cdot f_{c_p} \cdot b} \qquad a = 0.342\ in$$

Moment capacity:

$$\phi M_n := \phi_b \cdot \left(A_s \cdot f_y \cdot \left(d - \frac{a}{2}\right)\right) \qquad \phi M_n = 4\ ft \cdot kips$$

Shear design:

Area of shear reinforcing: $A_v := 0 \cdot in^2$

Spacing of stirrups: $s := 12 \cdot in$

Concrete shear capacity:

$$V_c := 2 \cdot \sqrt{f_{c_p} \cdot psi} \cdot b \cdot d \qquad V_c = 6.1\ kips$$

Steel shear capacity: $V_s := \frac{A_v \cdot f_y \cdot d}{s}$

$V_s = 0\ kips$

Shear capacity:

$$\phi V_n := \phi_v \cdot \left(V_c + V_s\right) \qquad \phi V_n = 4.6\ kips$$

$M_u < \phi M_n = 1$ $\quad \rho < \rho_{max} = 1$

$V_u < \phi V_n = 1$ $\quad z = 62\ \frac{kips}{in}$

Reinforced concrete retaining wall footing design:

Loads and geometry:

Factored moment: $M_u := 1.6 \cdot M_{footing}$

$M_u = 0.544\ ft \cdot kips$

Slab strip width: $b := 12 \cdot in$

Live to dead load ratio: $LLDLRatio := 3.5$

Wall thickness: $h := t_{ftg}$

Cover to reinforcing: $d_{cg} := 3.25 \cdot in$

Depth to reinforcing: $d := h - d_{cg}$ $\quad d = 8.75\ in$

Material properties / Design parameters:

Strength reduction factors: Bending: $\phi_b := 0.9$

Shear: $\phi_v := 0.85$

Concrete compressive strength: $f_{c_p} := 4 \cdot ksi$

Steel yield strength: $f_y := 60 \cdot ksi$

Whitney stress block depth ratio:

$$\beta_1 := \begin{cases} 0.85 & \text{if } f_{c_p} \le 4 \cdot ksi \\ \left(0.85 - 0.05 \cdot \left(f_{c_p} \cdot ksi^{-1} - 4\right)\right) & \text{else} \end{cases}$$

Minimum flexural reinforcing:

$\rho_{min} := 200 \cdot f_y^{-1} \cdot psi$ $\quad \rho_{min} = 0.0033$

Maximum flexural reinforcing:

$$\rho_{max} := 0.75 \cdot \left(\frac{0.85 \cdot \beta_1 \cdot f_{c_p}}{f_y} \cdot \frac{87 \cdot ksi}{87 \cdot ksi + f_y}\right)$$

$\rho_{max} = 0.0214$

Flexural design:

Required area of reinforcing: $A_{s_reqd} = 0.01\ in^2$

Area of flexural reinforcing:

$BarArea := 0.31 \cdot in^2$

$Spacing := 16 \cdot in$ $\quad A_s := BarArea \cdot \frac{b}{Spacing}$ $\quad A_s = 0.233\ in^2$

Reinforcing ratio: $\rho := \frac{A_s}{b \cdot d}$ $\quad \rho = 0.0022$

Compression block depth:

$a := \frac{A_s \cdot f_y}{0.85 \cdot f_{c_p} \cdot b}$ $\quad a = 0.342\ in$

Moment capacity:

$\phi M_n := \phi_b \cdot \left(A_s \cdot f_y \cdot \left(d - \frac{a}{2}\right)\right)$ $\quad \phi M_n = 9\ ft \cdot kips$

$M_u < \phi M_n = 1$ $\quad \rho < \rho_{max} = 1$

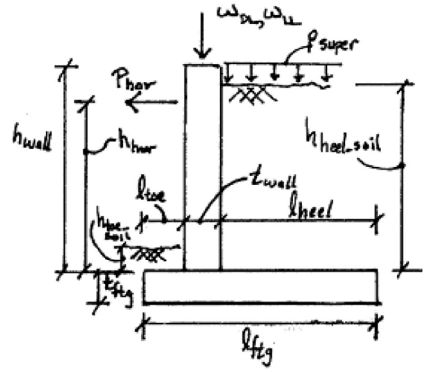
$V_u < \phi V_n = 1$ $\quad z = 13\ \frac{kips}{in}$

Sheet No.:_____

Project: St. Helens - Riverwalk - Retaining Wall
Project No.: 20028
Client:
Subject:

Engineer: SC
File: Ret-Wall_4-ft_EQ.mcdx
Date:
Rev.:

Retaining wall analysis and design



Material properties:

$\gamma_{conc} := 135 \cdot pcf$

$\gamma_{soil} := 108 \cdot pcf$

$\gamma_{EFP_a} := 35 \cdot pcf$

$\gamma_{EFP_p} := 250 \cdot pcf$

$\mu_{sliding} := .40$

$q_{all_brg} := 3000 \cdot psf$

$FS := 1.1$

Loading on wall:

$h_{heel_soil} := 4 \cdot ft + 0 \cdot in$

$h_{toe_soil} := 12 \cdot in$

$p_{super} := 0.0 \cdot psf$

$\omega_{DL_super} := 0.0 \cdot klf$

$\omega_{LL_super} := 0.0 \cdot klf$

$P_{hor} := 0.112 \cdot kips$

$h_{hor} := 2.40 \cdot ft$

Wall geometry:

$h_{wall} := 4 \cdot ft + 0 \cdot in$

$t_{wall} := 8 \cdot in$

$p_{wall} := 90 \cdot psf$

$h_{key} := 0 \cdot in$

$l_{key} := 0 \cdot in$

$t_{ftg} := 1 \cdot ft + 0 \cdot in$

$l_{toe} := 1 \cdot ft + 0 \cdot in$

$l_{ftg} := 2 \cdot ft + 8 \cdot in$

$l_{heel} := l_{ftg} - l_{toe} - t_{wall}$

$l_{heel} = 1\ ft$

$b_{nom} := 1 \cdot ft$

$\omega_1 := \omega_{DL_super} + \omega_{LL_super}$ $\qquad \omega_1 = 0\ \frac{kips}{ft}$

$P_{ftg} := \gamma_{conc} \cdot (l_{ftg} \cdot t_{ftg} + l_{key} \cdot h_{key}) \cdot b_{nom}$ $\qquad P_{ftg} = 0.36\ kips$

$P_{wall} := p_{wall} \cdot h_{wall} \cdot b_{nom}$ $\qquad P_{wall} = 0.36\ kips$

$P_{heel_soil} := (\gamma_{soil} \cdot h_{heel_soil} + p_{super}) \cdot l_{heel} \cdot b_{nom}$ $\qquad P_{heel_soil} = 0.432\ kips$

$P_{toe_soil} := \gamma_{soil} \cdot h_{toe_soil} \cdot l_{toe} \cdot b_{nom}$ $\qquad P_{toe_soil} = 0.108\ kips$

$P_{total} := P_{ftg} + P_{wall} + P_{heel_soil} + P_{toe_soil} + \omega_1 \cdot b_{nom}$ $\qquad P_{total} = 1.26\ kips$

$$M_{OT} := \left(\frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot (h_{heel_soil} + t_{ftg})^2 \cdot \left(\frac{t_{ftg} + h_{heel_soil}}{3} \right) + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot (h_{heel_soil} + t_{ftg}) \cdot b_{nom} \cdot \left(\frac{t_{ftg} + h_{heel_soil}}{2} \right) + P_{hor} \cdot (t_{ftg} + h_{hor}) \right) \cdot FS$$

$M_{OT} = 1.221\ ft \cdot kips$

$$M_{OT_resisting} := P_{ftg} \cdot \frac{l_{ftg}}{2} + P_{wall} \cdot \left(l_{toe} + \frac{t_{wall}}{2} \right) + \omega_1 \cdot b_{nom} \cdot \left(l_{toe} + \frac{t_{wall}}{2} \right) + P_{heel_soil} \cdot \left(l_{ftg} - \frac{l_{heel}}{2} \right) + P_{toe_soil} \cdot \frac{l_{toe}}{2}$$

$M_{OT_resisting} = 1.95\ ft \cdot kips$

$$H_{sliding} := \left(\begin{array}{l} \frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot \left(h_{heel_soil} + h_{key} + t_{ftg}\right)^2 \\ + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot b_{nom} \cdot \left(h_{heel_soil} + h_{key} + t_{ftg}\right) + P_{hor} \end{array} \right) \cdot FS$$

$H_{sliding} = 0.604\ kips$

$$H_{resisting} := \left(P_{ftg} + P_{wall} + P_{heel_soil} + 0 \cdot P_{toe_soil} + \omega_1 \cdot b_{nom}\right) \cdot \mu_{sliding} + \frac{1}{2} \cdot \gamma_{EFP_p} \cdot b_{nom} \cdot \left(\left(h_{toe_soil} + t_{ftg} + h_{key}\right)^2 - h_{toe_soil}^{\ 2}\right)$$

$H_{resisting} = 0.836\ kips$

<u>Soil pressures due to gravity and overturning forces:</u>

Footing size: $B_1 := b_{nom}$ $\quad B_1 = 1\ ft$

$B_2 := l_{ftg}$ $\quad B_2 = 2.667\ ft$

$A := B_1 \cdot B_2$ $\quad A = 2.667\ ft^2$

Moment at mid-width of footing:

$$M := \left(\begin{array}{l} \frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot \left(h_{heel_soil}\right)^2 \cdot \left(\frac{h_{heel_soil}}{3}\right) \\ + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot \left(h_{heel_soil}\right) \cdot b_{nom} \cdot \left(\frac{h_{heel_soil}}{2}\right) \\ + \frac{0 \cdot -1}{2} \cdot \gamma_{EFP_p} \cdot b_{nom} \cdot \left(h_{toe_soil} + t_{ftg}\right)^2 \cdot \left(\frac{h_{toe_soil}}{3}\right) \\ + P_{hor} \cdot \left(t_{ftg} + h_{hor}\right) + P_{toe_soil} \cdot \left(\frac{l_{ftg}}{2} - \frac{l_{toe}}{2}\right) + \left(P_{wall} + \omega_1 \cdot b_{nom}\right) \cdot \left(\frac{l_{ftg}}{2} - l_{toe} - \frac{t_{wall}}{2}\right) \\ + -P_{heel_soil} \cdot \left(\frac{l_{ftg}}{2} - \frac{l_{heel}}{2}\right) \end{array} \right)$$

$M = 0.484\ ft \cdot kips$

Eccentricity of soil pressure resultant:

$$e := \frac{M}{P_{total}}$$

$e = 0.384\ ft$ $\quad \frac{B_2}{6} = 0.444\ ft$

Maximum soil pressures:

$$q_{max_prime} := \left\| \begin{array}{l} \text{if } e \le \frac{B_2}{6} \\ \quad \left\| \left(\frac{P_{total}}{A} \cdot \left(1 + \frac{6 \cdot e}{B_2}\right)\right) \right. \\ \text{else} \\ \quad \left\| \frac{2 \cdot P_{total}}{3 \cdot A \cdot \left(0.5 - \frac{e}{B_2}\right)} \right. \end{array} \right\|$$

$q_{max_prime} = 881\ psf$

$q_{max_prime} < q_{all_brg} = 1$

$$q_{min_prime} := \begin{cases} \left(\frac{P_{total}}{A} \cdot \left(1 - \frac{6 \cdot e}{B_2}\right)\right) & \text{if } e \le \frac{B_2}{6} \\ 0 \cdot psf & \text{else} \end{cases}$$

$q_{min_prime} = 64\ psf$

<u>Forces in wall at the base of wall:</u>

$$M_{wall} := \left(\frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot \left(h_{heel_soil}\right)^2 \cdot \frac{h_{heel_soil}}{3} + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot \left(h_{heel_soil}\right) \cdot b_{nom} \cdot \left(\frac{h_{heel_soil}}{2}\right) + P_{hor} \cdot \left(h_{hor}\right)\right)$$

$$V_{wall} := \left(\frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot \left(h_{heel_soil}\right)^2 + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot \left(h_{heel_soil}\right) \cdot b_{nom} + P_{hor}\right)$$

$1.6 \cdot M_{wall} = 1.027\ ft \cdot kips$

$1.6 \cdot V_{wall} = 0.627\ kips$

$$M_{footing} := P_{heel_soil} \cdot \frac{l_{heel}}{2} + p_{super} \cdot b_{nom} \cdot \frac{l_{heel}^2}{2}$$

$M_{footing} = 0.216\ ft \cdot kips$

$1.6 \cdot M_{footing} = 0.346\ ft \cdot kips$

Reinforced concrete retaining wall design:

Loads and geometry:

Factored moment: $M_u := 1.6 \cdot M_{wall}$ $\quad M_u = 1\ ft \cdot kips$

Factored shear force: $V_u := 1.6 \cdot V_{wall}$ $\quad V_u = 0.6\ kips$

Slab strip width: $b := b_{nom}$

Wall thickness: $h := t_{wall}$

Cover to reinforcing: $d_{cg} := 4 \cdot in$

Depth to reinforcing: $d := h - d_{cg}$ $\quad d = 4\ in$

Material properties / Design parameters:

Strength reduction factors: Bending: $\phi_b := 0.9$

Shear: $\phi_v := 0.75$

Concrete compressive strength: $f_{c_p} := 4 \cdot ksi$

Steel yield strength: $f_y := 60 \cdot ksi$

Whitney stress block depth ratio:

$$\beta_1 := \begin{cases} 0.85 & \text{if } f_{c_p} \le 4 \cdot ksi \\ \left(0.85 - 0.05 \cdot \left(f_{c_p} \cdot ksi^{-1} - 4\right)\right) & \text{else} \end{cases}$$

Minimum flexural reinforcing:

$\rho_{min} := 200 \cdot f_y^{-1} \cdot psi$ $\quad \rho_{min} = 0.0033$

Maximum flexural reinforcing:

$$\rho_{max} := 0.75 \cdot \left(\frac{0.85 \cdot \beta_1 \cdot f_{c_p}}{f_y} \cdot \frac{87 \cdot ksi}{87 \cdot ksi + f_y}\right)$$

$$\rho_{max} = 0.0214$$

Flexural design:

Required area of reinforcing: $A_{s_reqd} = 0.06\ in^2$

Area of flexural reinforcing:

$BarArea := 0.31 \cdot in^2$

$Spacing := 16 \cdot in$ $\quad A_s := BarArea \cdot \frac{b}{Spacing}$ $\quad A_s = 0.233\ in^2$

Reinforcing ratio: $\rho := \frac{A_s}{b \cdot d}$ $\quad \rho = 0.0048$

Compression block depth:

$$a := \frac{A_s \cdot f_y}{0.85 \cdot f_{c_p} \cdot b} \qquad a = 0.342\ in$$

Moment capacity:

$$\phi M_n := \phi_b \cdot \left(A_s \cdot f_y \cdot \left(d - \frac{a}{2}\right)\right) \qquad \phi M_n = 4\ ft \cdot kips$$

Shear design:

Area of shear reinforcing: $A_v := 0 \cdot in^2$

Spacing of stirrups: $s := 12 \cdot in$

Concrete shear capacity:

$$V_c := 2 \cdot \sqrt{f_{c_p} \cdot psi} \cdot b \cdot d \qquad V_c = 6.1\ kips$$

Steel shear capacity: $V_s := \frac{A_v \cdot f_y \cdot d}{s}$

$V_s = 0\ kips$

Shear capacity:

$\phi V_n := \phi_v \cdot (V_c + V_s)$ $\quad \phi V_n = 4.6\ kips$

$M_u < \phi M_n = 1$ $\quad \rho < \rho_{max} = 1$

$V_u < \phi V_n = 1$ $\quad z = 66\ \frac{kips}{in}$

Reinforced concrete retaining wall footing design:

Loads and geometry:

Factored moment: $M_u := 1.6 \cdot M_{footing}$

$M_u = 0.346\ ft \cdot kips$

Slab strip width: $b := 12 \cdot in$

Live to dead load ratio: $LLDLRatio := 3.5$

Wall thickness: $h := t_{ftg}$

Cover to reinforcing: $d_{cg} := 3.25 \cdot in$

Depth to reinforcing: $d := h - d_{cg}$ $\quad d = 8.75\ in$

Material properties / Design parameters:

Strength reduction factors: Bending: $\phi_b := 0.9$

Shear: $\phi_v := 0.85$

Concrete compressive strength: $f_{c_p} := 4 \cdot ksi$

Steel yield strength: $f_y := 60 \cdot ksi$

Whitney stress block depth ratio:

$$\beta_1 := \begin{cases} 0.85 & \text{if } f_{c_p} \le 4 \cdot ksi \\ \left(0.85 - 0.05 \cdot \left(f_{c_p} \cdot ksi^{-1} - 4\right)\right) & \text{else} \end{cases}$$

Minimum flexural reinforcing:

$\rho_{min} := 200 \cdot f_y^{-1} \cdot psi$ $\quad \rho_{min} = 0.0033$

Maximum flexural reinforcing:

$$\rho_{max} := 0.75 \cdot \left(\frac{0.85 \cdot \beta_1 \cdot f_{c_p}}{f_y} \cdot \frac{87 \cdot ksi}{87 \cdot ksi + f_y}\right)$$

$\rho_{max} = 0.0214$

Flexural design:

Required area of reinforcing: $A_{s_reqd} = \left(8.78 \cdot 10^{-3}\right)\ in^2$

Area of flexural reinforcing:

$BarArea := 0.31 \cdot in^2$

$Spacing := 16 \cdot in$ $\quad A_s := BarArea \cdot \frac{b}{Spacing}$ $\quad A_s = 0.233\ in^2$

Reinforcing ratio: $\rho := \frac{A_s}{b \cdot d}$ $\quad \rho = 0.0022$

Compression block depth:

$a := \frac{A_s \cdot f_y}{0.85 \cdot f_{c_p} \cdot b}$ $\quad a = 0.342\ in$

Moment capacity:

$\phi M_n := \phi_b \cdot \left(A_s \cdot f_y \cdot \left(d - \frac{a}{2}\right)\right)$ $\quad \phi M_n = 9\ ft \cdot kips$

$M_u < \phi M_n = 1$ $\quad \rho < \rho_{max} = 1$

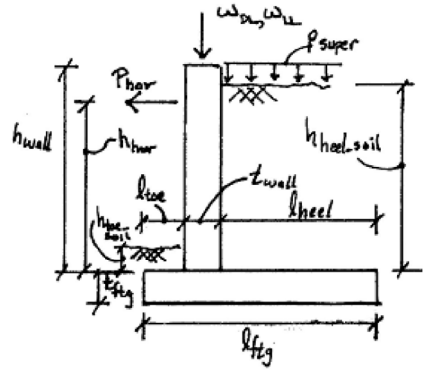
$V_u < \phi V_n = 1$ $\quad z = 8\ \frac{kips}{in}$

Sheet No.:_____

Project: St. Helens - Riverwalk - Retaining Wall
Project No.: 20028
Client:
Subject:

Engineer: SC
File: Ret-Wall_6-ft.mcdx
Date:
Rev.:

Retaining wall analysis and design



Material properties:

$\gamma_{conc} := 150 \cdot pcf$

$\gamma_{soil} := 120 \cdot pcf$

$\gamma_{EFP_a} := 35 \cdot pcf$

$\gamma_{EFP_p} := 250 \cdot pcf$

$\mu_{sliding} := .40$

$q_{all_brg} := 2000 \cdot psf$

$FS := 1.5$

Loading on wall:

$h_{heel_soil} := 6 \cdot ft + 0 \cdot in$

$h_{toe_soil} := 12 \cdot in$

$p_{super} := 100.0 \cdot psf$

$\omega_{DL_super} := 0.0 \cdot klf$

$\omega_{LL_super} := 0.0 \cdot klf$

$P_{hor} := 0.0 \cdot kips$

$h_{hor} := 0 \cdot ft$

Wall geometry:

$h_{wall} := 6 \cdot ft + 0 \cdot in$

$t_{wall} := 8 \cdot in$

$p_{wall} := 100 \cdot psf$

$h_{key} := 0 \cdot in$

$l_{key} := 0 \cdot in$

$t_{ftg} := 1 \cdot ft + 0 \cdot in$

$l_{toe} := 1 \cdot ft + 0 \cdot in$

$l_{ftg} := 4 \cdot ft + 0 \cdot in$

$l_{heel} := l_{ftg} - l_{toe} - t_{wall}$

$l_{heel} = 2.333\ ft$

$b_{nom} := 1 \cdot ft$

$\omega_1 := \omega_{DL_super} + \omega_{LL_super}$ $\qquad \omega_1 = 0\ \frac{kips}{ft}$

$P_{ftg} := \gamma_{conc} \cdot (l_{ftg} \cdot t_{ftg} + l_{key} \cdot h_{key}) \cdot b_{nom}$ $\qquad P_{ftg} = 0.6\ kips$

$P_{wall} := p_{wall} \cdot h_{wall} \cdot b_{nom}$ $\qquad P_{wall} = 0.6\ kips$

$P_{heel_soil} := (\gamma_{soil} \cdot h_{heel_soil} + p_{super}) \cdot l_{heel} \cdot b_{nom}$ $\qquad P_{heel_soil} = 1.913\ kips$

$P_{toe_soil} := \gamma_{soil} \cdot h_{toe_soil} \cdot l_{toe} \cdot b_{nom}$ $\qquad P_{toe_soil} = 0.12\ kips$

$P_{total} := P_{ftg} + P_{wall} + P_{heel_soil} + P_{toe_soil} + \omega_1 \cdot b_{nom}$ $\qquad P_{total} = 3.233\ kips$

$$M_{OT} := \left(\frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot (h_{heel_soil} + t_{ftg})^2 \cdot \left(\frac{t_{ftg} + h_{heel_soil}}{3} \right) + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot (h_{heel_soil} + t_{ftg}) \cdot b_{nom} \cdot \left(\frac{t_{ftg} + h_{heel_soil}}{2} \right) + P_{hor} \cdot (t_{ftg} + h_{hor}) \right) \cdot FS$$

$M_{OT} = 4.073\ ft \cdot kips$

$$M_{OT_resisting} := P_{ftg} \cdot \frac{l_{ftg}}{2} + P_{wall} \cdot \left(l_{toe} + \frac{t_{wall}}{2} \right) + \omega_1 \cdot b_{nom} \cdot \left(l_{toe} + \frac{t_{wall}}{2} \right) + P_{heel_soil} \cdot \left(l_{ftg} - \frac{l_{heel}}{2} \right) + P_{toe_soil} \cdot \frac{l_{toe}}{2}$$

$M_{OT_resisting} = 7.481\ ft \cdot kips$

$$H_{sliding} := \left(\frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot \left(h_{heel_soil} + h_{key} + t_{ftg}\right)^2 + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot b_{nom} \cdot \left(h_{heel_soil} + h_{key} + t_{ftg}\right) + P_{hor} \right) \cdot FS$$

$H_{sliding} = 1.593\ kips$

$$H_{resisting} := \left(P_{ftg} + P_{wall} + P_{heel_soil} + 0 \cdot P_{toe_soil} + \omega_1 \cdot b_{nom}\right) \cdot \mu_{sliding} + \frac{1}{2} \cdot \gamma_{EFP_p} \cdot b_{nom} \cdot \left(\left(h_{toe_soil} + t_{ftg} + h_{key}\right)^2 - h_{toe_soil}^{\ 2}\right)$$

$H_{resisting} = 1.62\ kips$

<u>Soil pressures due to gravity and overturning forces:</u>

Footing size: $B_1 := b_{nom}$ $\quad B_1 = 1\ ft$

$B_2 := l_{ftg}$ $\quad B_2 = 4\ ft$

$A := B_1 \cdot B_2$ $\quad A = 4\ ft^2$

Moment at mid-width of footing:

$$M := \left(\begin{array}{l} \frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot \left(h_{heel_soil}\right)^2 \cdot \left(\frac{h_{heel_soil}}{3}\right) \\ + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot \left(h_{heel_soil}\right) \cdot b_{nom} \cdot \left(\frac{h_{heel_soil}}{2}\right) \\ + \frac{0 \cdot -1}{2} \cdot \gamma_{EFP_p} \cdot b_{nom} \cdot \left(h_{toe_soil} + t_{ftg}\right)^2 \cdot \left(\frac{h_{toe_soil}}{3}\right) \\ + P_{hor} \cdot \left(t_{ftg} + h_{hor}\right) + P_{toe_soil} \cdot \left(\frac{l_{ftg}}{2} - \frac{l_{toe}}{2}\right) + \left(P_{wall} + \omega_1 \cdot b_{nom}\right) \cdot \left(\frac{l_{ftg}}{2} - l_{toe} - \frac{t_{wall}}{2}\right) \\ + -P_{heel_soil} \cdot \left(\frac{l_{ftg}}{2} - \frac{l_{heel}}{2}\right) \end{array} \right)$$

$M = 0.771\ ft \cdot kips$

Eccentricity of soil pressure resultant:

$e := \frac{M}{P_{total}}$ $\quad e = 0.238\ ft$ $\quad \frac{B_2}{6} = 0.667\ ft$

Maximum soil pressures:

$$q_{max_prime} := \begin{cases} \left(\frac{P_{total}}{A} \cdot \left(1 + \frac{6 \cdot e}{B_2}\right)\right) & \text{if } e \le \frac{B_2}{6} \\ \frac{2 \cdot P_{total}}{3 \cdot A \cdot \left(0.5 - \frac{e}{B_2}\right)} & \text{else} \end{cases}$$

$q_{max_prime} = 1097\ psf$

$q_{max_prime} < q_{all_brg} = 1$

$$q_{min_prime} := \begin{cases} \left(\frac{P_{total}}{A} \cdot \left(1 - \frac{6 \cdot e}{B_2}\right)\right) & \text{if } e \le \frac{B_2}{6} \\ 0 \cdot psf & \text{else} \end{cases}$$

$q_{min_prime} = 519\ psf$

Forces in wall at the base of wall:

$$M_{wall} := \left(\frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot \left(h_{heel_soil}\right)^2 \cdot \frac{h_{heel_soil}}{3} + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot \left(h_{heel_soil}\right) \cdot b_{nom} \cdot \left(\frac{h_{heel_soil}}{2}\right) + P_{hor} \cdot \left(h_{hor}\right)\right)$$

$$V_{wall} := \left(\frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot \left(h_{heel_soil}\right)^2 + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot \left(h_{heel_soil}\right) \cdot b_{nom} + P_{hor}\right)$$

$1.6 \cdot M_{wall} = 2.856\ ft \cdot kips$

$1.6 \cdot V_{wall} = 1.288\ kips$

$$M_{footing} := P_{heel_soil} \cdot \frac{l_{heel}}{2} + p_{super} \cdot b_{nom} \cdot \frac{l_{heel}^2}{2}$$

$M_{footing} = 2.504\ ft \cdot kips$

$1.6 \cdot M_{footing} = 4.007\ ft \cdot kips$

Reinforced concrete retaining wall design:

Loads and geometry:

Factored moment: $M_u := 1.6 \cdot M_{wall}$ $\quad M_u = 2.9\ ft \cdot kips$

Factored shear force: $V_u := 1.6 \cdot V_{wall}$ $\quad V_u = 1.3\ kips$

Slab strip width: $b := b_{nom}$

Wall thickness: $h := t_{wall}$

Cover to reinforcing: $d_{cg} := 4 \cdot in$

Depth to reinforcing: $d := h - d_{cg}$ $\quad d = 4\ in$

Material properties / Design parameters:

Strength reduction factors: Bending: $\phi_b := 0.9$

Shear: $\phi_v := 0.75$

Concrete compressive strength: $f_{c_p} := 4 \cdot ksi$

Steel yield strength: $f_y := 60 \cdot ksi$

Whitney stress block depth ratio:

$$\beta_1 := \begin{cases} 0.85 & \text{if } f_{c_p} \le 4 \cdot ksi \\ \left(0.85 - 0.05 \cdot \left(f_{c_p} \cdot ksi^{-1} - 4\right)\right) & \text{else} \end{cases}$$

Minimum flexural reinforcing:

$\rho_{min} := 200 \cdot f_y^{-1} \cdot psi$ $\quad \rho_{min} = 0.0033$

Maximum flexural reinforcing:

$$\rho_{max} := 0.75 \cdot \left(\frac{0.85 \cdot \beta_1 \cdot f_{c_p}}{f_y} \cdot \frac{87 \cdot ksi}{87 \cdot ksi + f_y}\right)$$

$$\rho_{max} = 0.0214$$

Flexural design:

Required area of reinforcing: $A_{s_reqd} = 0.16\ in^2$

Area of flexural reinforcing:

$BarArea := 0.31 \cdot in^2$

$Spacing := 12 \cdot in$ $\quad A_s := BarArea \cdot \frac{b}{Spacing}$ $\quad A_s = 0.31\ in^2$

Reinforcing ratio: $\rho := \frac{A_s}{b \cdot d}$ $\quad \rho = 0.0065$

Compression block depth:

$$a := \frac{A_s \cdot f_y}{0.85 \cdot f_{c_p} \cdot b} \qquad a = 0.456\ in$$

Moment capacity:

$$\phi M_n := \phi_b \cdot \left(A_s \cdot f_y \cdot \left(d - \frac{a}{2}\right)\right) \qquad \phi M_n = 5.3\ ft \cdot kips$$

Shear design:

Area of shear reinforcing: $A_v := 0 \cdot in^2$

Spacing of stirrups: $s := 12 \cdot in$

Concrete shear capacity:

$$V_c := 2 \cdot \sqrt{f_{c_p} \cdot psi} \cdot b \cdot d \qquad V_c = 6.1\ kips$$

Steel shear capacity: $V_s := \frac{A_v \cdot f_y \cdot d}{s}$

$V_s = 0\ kips$

Shear capacity:

$$\phi V_n := \phi_v \cdot \left(V_c + V_s\right) \qquad \phi V_n = 4.6\ kips$$

$M_u < \phi M_n = 1$ $\quad \rho < \rho_{max} = 1$

$V_u < \phi V_n = 1$ $\quad z = 138\ \frac{kips}{in}$

Reinforced concrete retaining wall footing design:

Loads and geometry:

Factored moment: $M_u := 1.6 \cdot M_{footing}$

$M_u = 4.007\ ft \cdot kips$

Slab strip width: $b := 12 \cdot in$

Live to dead load ratio: $LLDLRatio := 3.5$

Wall thickness: $h := t_{ftg}$

Cover to reinforcing: $d_{cg} := 3.25 \cdot in$

Depth to reinforcing: $d := h - d_{cg}$ $\quad d = 8.75\ in$

Material properties / Design parameters:

Strength reduction factors: Bending: $\phi_b := 0.9$

Shear: $\phi_v := 0.85$

Concrete compressive strength: $f_{c_p} := 4 \cdot ksi$

Steel yield strength: $f_y := 60 \cdot ksi$

Whitney stress block depth ratio:

$$\beta_1 := \begin{cases} 0.85 & \text{if } f_{c_p} \le 4 \cdot ksi \\ \left(0.85 - 0.05 \cdot \left(f_{c_p} \cdot ksi^{-1} - 4\right)\right) & \text{else} \end{cases}$$

Minimum flexural reinforcing:

$\rho_{min} := 200 \cdot f_y^{-1} \cdot psi$ $\quad \rho_{min} = 0.0033$

Maximum flexural reinforcing:

$$\rho_{max} := 0.75 \cdot \left(\frac{0.85 \cdot \beta_1 \cdot f_{c_p}}{f_y} \cdot \frac{87 \cdot ksi}{87 \cdot ksi + f_y}\right)$$

$\rho_{max} = 0.0214$

Flexural design:

Required area of reinforcing: $A_{s_reqd} = 0.10\ in^2$

Area of flexural reinforcing:

$BarArea := 0.31 \cdot in^2$

$Spacing := 12 \cdot in$ $\quad A_s := BarArea \cdot \frac{b}{Spacing}$ $\quad A_s = 0.31\ in^2$

Reinforcing ratio: $\rho := \frac{A_s}{b \cdot d}$ $\quad \rho = 0.003$

Compression block depth:

$a := \frac{A_s \cdot f_y}{0.85 \cdot f_{c_p} \cdot b}$ $\quad a = 0.456\ in$

Moment capacity:

$\phi M_n := \phi_b \cdot \left(A_s \cdot f_y \cdot \left(d - \frac{a}{2}\right)\right)$ $\quad \phi M_n = 11.9\ ft \cdot kips$

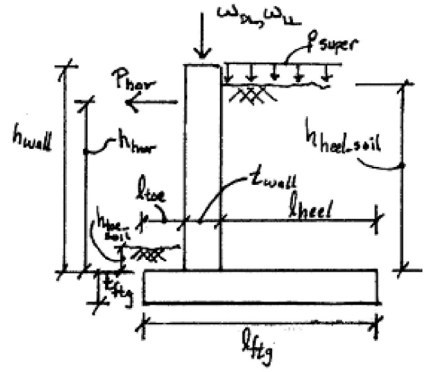
$M_u < \phi M_n = 1$ $\quad \rho < \rho_{max} = 1$

$V_u < \phi V_n = 1$ $\quad z = 73\ \frac{kips}{in}$

Project: St. Helens - Riverwalk - Retaining Wall
Project No.: 20028
Client:
Subject:

Engineer: SC
File: Ret-Wall_6-ft_EQ.mcdx
Date:
Rev.:

Retaining wall analysis and design



Material properties:

$\gamma_{conc} := 135 \cdot pcf$

$\gamma_{soil} := 108 \cdot pcf$

$\gamma_{EFP_a} := 35 \cdot pcf$

$\gamma_{EFP_p} := 250 \cdot pcf$

$\mu_{sliding} := .40$

$q_{all_brg} := 3000 \cdot psf$

$FS := 1.1$

Loading on wall:

$h_{heel_soil} := 6 \cdot ft + 0 \cdot in$

$h_{toe_soil} := 12 \cdot in$

$p_{super} := 0.0 \cdot psf$

$\omega_{DL_super} := 0.0 \cdot klf$

$\omega_{LL_super} := 0.0 \cdot klf$

$P_{hor} := 0.252 \cdot kips$

$h_{hor} := 4.20 \cdot ft$

Wall geometry:

$h_{wall} := 6 \cdot ft + 0 \cdot in$

$t_{wall} := 8 \cdot in$

$p_{wall} := 90 \cdot psf$

$h_{key} := 0 \cdot in$

$l_{key} := 0 \cdot in$

$t_{ftg} := 1 \cdot ft + 0 \cdot in$

$l_{toe} := 1 \cdot ft + 0 \cdot in$

$l_{ftg} := 4 \cdot ft + 0 \cdot in$

$l_{heel} := l_{ftg} - l_{toe} - t_{wall}$

$l_{heel} = 2.333\ ft$

$b_{nom} := 1 \cdot ft$

$\omega_1 := \omega_{DL_super} + \omega_{LL_super}$ $\qquad \omega_1 = 0\ \frac{kips}{ft}$

$P_{ftg} := \gamma_{conc} \cdot (l_{ftg} \cdot t_{ftg} + l_{key} \cdot h_{key}) \cdot b_{nom}$ $\qquad P_{ftg} = 0.54\ kips$

$P_{wall} := p_{wall} \cdot h_{wall} \cdot b_{nom}$ $\qquad P_{wall} = 0.54\ kips$

$P_{heel_soil} := (\gamma_{soil} \cdot h_{heel_soil} + p_{super}) \cdot l_{heel} \cdot b_{nom}$ $\qquad P_{heel_soil} = 1.512\ kips$

$P_{toe_soil} := \gamma_{soil} \cdot h_{toe_soil} \cdot l_{toe} \cdot b_{nom}$ $\qquad P_{toe_soil} = 0.108\ kips$

$P_{total} := P_{ftg} + P_{wall} + P_{heel_soil} + P_{toe_soil} + \omega_1 \cdot b_{nom}$ $\qquad P_{total} = 2.7\ kips$

$$M_{OT} := \left(\frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot (h_{heel_soil} + t_{ftg})^2 \cdot \left(\frac{t_{ftg} + h_{heel_soil}}{3} \right) + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot (h_{heel_soil} + t_{ftg}) \cdot b_{nom} \cdot \left(\frac{t_{ftg} + h_{heel_soil}}{2} \right) + P_{hor} \cdot (t_{ftg} + h_{hor}) \right) \cdot FS$$

$M_{OT} = 3.642\ ft \cdot kips$

$$M_{OT_resisting} := P_{ftg} \cdot \frac{l_{ftg}}{2} + P_{wall} \cdot \left(l_{toe} + \frac{t_{wall}}{2} \right) + \omega_1 \cdot b_{nom} \cdot \left(l_{toe} + \frac{t_{wall}}{2} \right) + P_{heel_soil} \cdot \left(l_{ftg} - \frac{l_{heel}}{2} \right) + P_{toe_soil} \cdot \frac{l_{toe}}{2}$$

$M_{OT_resisting} = 6.138\ ft \cdot kips$

$$H_{sliding} := \left(\frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot \left(h_{heel_soil} + h_{key} + t_{ftg}\right)^2 + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot b_{nom} \cdot \left(h_{heel_soil} + h_{key} + t_{ftg}\right) + P_{hor} \right) \cdot FS$$

$H_{sliding} = 1.22\ kips$

$$H_{resisting} := \left(P_{ftg} + P_{wall} + P_{heel_soil} + 0 \cdot P_{toe_soil} + \omega_1 \cdot b_{nom}\right) \cdot \mu_{sliding} + \frac{1}{2} \cdot \gamma_{EFP_p} \cdot b_{nom} \cdot \left(\left(h_{toe_soil} + t_{ftg} + h_{key}\right)^2 - h_{toe_soil}^{\ 2}\right)$$

$H_{resisting} = 1.412\ kips$

<u>Soil pressures due to gravity and overturning forces:</u>

Footing size: $B_1 := b_{nom}$ $\quad B_1 = 1\ ft$

$B_2 := l_{ftg}$ $\quad B_2 = 4\ ft$

$A := B_1 \cdot B_2$ $\quad A = 4\ ft^2$

Moment at mid-width of footing:

$$M := \left(\begin{array}{l} \frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot \left(h_{heel_soil}\right)^2 \cdot \left(\frac{h_{heel_soil}}{3}\right) \\ + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot \left(h_{heel_soil}\right) \cdot b_{nom} \cdot \left(\frac{h_{heel_soil}}{2}\right) \\ + \frac{0 \cdot -1}{2} \cdot \gamma_{EFP_p} \cdot b_{nom} \cdot \left(h_{toe_soil} + t_{ftg}\right)^2 \cdot \left(\frac{h_{toe_soil}}{3}\right) \\ + P_{hor} \cdot \left(t_{ftg} + h_{hor}\right) + P_{toe_soil} \cdot \left(\frac{l_{ftg}}{2} - \frac{l_{toe}}{2}\right) + \left(P_{wall} + \omega_1 \cdot b_{nom}\right) \cdot \left(\frac{l_{ftg}}{2} - l_{toe} - \frac{t_{wall}}{2}\right) \\ + -P_{heel_soil} \cdot \left(\frac{l_{ftg}}{2} - \frac{l_{heel}}{2}\right) \end{array} \right)$$

$M = 1.832\ ft \cdot kips$

Eccentricity of soil pressure resultant:

$e := \frac{M}{P_{total}}$ $\quad e = 0.679\ ft$ $\quad \frac{B_2}{6} = 0.667\ ft$

Maximum soil pressures:

$$q_{max_prime} := \begin{cases} \text{if } e \le \frac{B_2}{6} \\ \quad \left(\frac{P_{total}}{A} \cdot \left(1 + \frac{6 \cdot e}{B_2}\right)\right) \\ \text{else} \\ \quad \frac{2 \cdot P_{total}}{3 \cdot A \cdot \left(0.5 - \frac{e}{B_2}\right)} \end{cases}$$

$q_{max_prime} = 1362\ psf$

$q_{max_prime} < q_{all_brg} = 1$

$$q_{min_prime} := \begin{cases} \left(\frac{P_{total}}{A} \cdot \left(1 - \frac{6 \cdot e}{B_2}\right)\right) & \text{if } e \le \frac{B_2}{6} \\ 0 \cdot psf & \text{else} \end{cases}$$

$q_{min_prime} = 0\ psf$

<u>Forces in wall at the base of wall:</u>

$$M_{wall} := \left(\frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot \left(h_{heel_soil}\right)^2 \cdot \frac{h_{heel_soil}}{3} + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot \left(h_{heel_soil}\right) \cdot b_{nom} \cdot \left(\frac{h_{heel_soil}}{2}\right) + P_{hor} \cdot \left(h_{hor}\right)\right)$$

$$V_{wall} := \left(\frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot \left(h_{heel_soil}\right)^2 + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot \left(h_{heel_soil}\right) \cdot b_{nom} + P_{hor}\right)$$

$1.6 \cdot M_{wall} = 3.709\ ft \cdot kips$

$1.6 \cdot V_{wall} = 1.411\ kips$

$$M_{footing} := P_{heel_soil} \cdot \frac{l_{heel}}{2} + p_{super} \cdot b_{nom} \cdot \frac{l_{heel}^2}{2}$$

$M_{footing} = 1.764\ ft \cdot kips$

$1.6 \cdot M_{footing} = 2.822\ ft \cdot kips$

Reinforced concrete retaining wall design:

Loads and geometry:

Factored moment: $M_u := 1.6 \cdot M_{wall}$ $\quad M_u = 3.7\ ft \cdot kips$

Factored shear force: $V_u := 1.6 \cdot V_{wall}$ $\quad V_u = 1.4\ kips$

Slab strip width: $b := b_{nom}$

Wall thickness: $h := t_{wall}$

Cover to reinforcing: $d_{cg} := 4 \cdot in$

Depth to reinforcing: $d := h - d_{cg}$ $\quad d = 4\ in$

Material properties / Design parameters:

Strength reduction factors: Bending: $\phi_b := 0.9$

Shear: $\phi_v := 0.75$

Concrete compressive strength: $f_{c_p} := 4 \cdot ksi$

Steel yield strength: $f_y := 60 \cdot ksi$

Whitney stress block depth ratio:

$$\beta_1 := \begin{cases} 0.85 & \text{if } f_{c_p} \le 4 \cdot ksi \\ \left(0.85 - 0.05 \cdot \left(f_{c_p} \cdot ksi^{-1} - 4\right)\right) & \text{else} \end{cases}$$

Minimum flexural reinforcing:

$\rho_{min} := 200 \cdot f_y^{-1} \cdot psi$ $\quad \rho_{min} = 0.0033$

Maximum flexural reinforcing:

$$\rho_{max} := 0.75 \cdot \left(\frac{0.85 \cdot \beta_1 \cdot f_{c_p}}{f_y} \cdot \frac{87 \cdot ksi}{87 \cdot ksi + f_y}\right)$$

$$\rho_{max} = 0.0214$$

Flexural design:

Required area of reinforcing: $A_{s_reqd} = 0.21\ in^2$

Area of flexural reinforcing:

$BarArea := 0.31 \cdot in^2$

$Spacing := 12 \cdot in$ $\quad A_s := BarArea \cdot \frac{b}{Spacing}$ $\quad A_s = 0.31\ in^2$

Reinforcing ratio: $\rho := \frac{A_s}{b \cdot d}$ $\quad \rho = 0.0065$

Compression block depth:

$$a := \frac{A_s \cdot f_y}{0.85 \cdot f_{c_p} \cdot b} \qquad a = 0.456\ in$$

Moment capacity:

$$\phi M_n := \phi_b \cdot \left(A_s \cdot f_y \cdot \left(d - \frac{a}{2}\right)\right) \qquad \phi M_n = 5.3\ ft \cdot kips$$

Shear design:

Area of shear reinforcing: $A_v := 0 \cdot in^2$

Spacing of stirrups: $s := 12 \cdot in$

Concrete shear capacity:

$$V_c := 2 \cdot \sqrt{f_{c_p} \cdot psi} \cdot b \cdot d \qquad V_c = 6.1\ kips$$

Steel shear capacity: $V_s := \frac{A_v \cdot f_y \cdot d}{s}$

$V_s = 0\ kips$

Shear capacity:

$$\phi V_n := \phi_v \cdot \left(V_c + V_s\right) \qquad \phi V_n = 4.6\ kips$$

$M_u < \phi M_n = 1$ $\quad \rho < \rho_{max} = 1$

$V_u < \phi V_n = 1$ $\quad z = 180\ \frac{kips}{in}$

Reinforced concrete retaining wall footing design:

Loads and geometry:

Factored moment: $M_u := 1.6 \cdot M_{footing}$

$M_u = 2.822\ ft \cdot kips$

Slab strip width: $b := 12 \cdot in$

Live to dead load ratio: $LLDLRatio := 3.5$

Wall thickness: $h := t_{ftg}$

Cover to reinforcing: $d_{cg} := 3.25 \cdot in$

Depth to reinforcing: $d := h - d_{cg}$ $\quad d = 8.75\ in$

Material properties / Design parameters:

Strength reduction factors: Bending: $\phi_b := 0.9$

Shear: $\phi_v := 0.85$

Concrete compressive strength: $f_{c_p} := 4 \cdot ksi$

Steel yield strength: $f_y := 60 \cdot ksi$

Whitney stress block depth ratio:

$$\beta_1 := \begin{cases} 0.85 & \text{if } f_{c_p} \le 4 \cdot ksi \\ \left(0.85 - 0.05 \cdot \left(f_{c_p} \cdot ksi^{-1} - 4\right)\right) & \text{else} \end{cases}$$

Minimum flexural reinforcing:

$\rho_{min} := 200 \cdot f_y^{-1} \cdot psi$ $\quad \rho_{min} = 0.0033$

Maximum flexural reinforcing:

$$\rho_{max} := 0.75 \cdot \left(\frac{0.85 \cdot \beta_1 \cdot f_{c_p}}{f_y} \cdot \frac{87 \cdot ksi}{87 \cdot ksi + f_y}\right)$$

$\rho_{max} = 0.0214$

Flexural design:

Required area of reinforcing: $A_{s_reqd} = 0.07\ in^2$

Area of flexural reinforcing:

$BarArea := 0.31 \cdot in^2$

$Spacing := 12 \cdot in$ $\quad A_s := BarArea \cdot \frac{b}{Spacing}$ $\quad A_s = 0.31\ in^2$

Reinforcing ratio: $\rho := \frac{A_s}{b \cdot d}$ $\quad \rho = 0.003$

Compression block depth:

$a := \frac{A_s \cdot f_y}{0.85 \cdot f_{c_p} \cdot b}$ $\quad a = 0.456\ in$

Moment capacity:

$\phi M_n := \phi_b \cdot \left(A_s \cdot f_y \cdot \left(d - \frac{a}{2}\right)\right)$ $\quad \phi M_n = 11.9\ ft \cdot kips$

$M_u < \phi M_n = 1$ $\quad \rho < \rho_{max} = 1$

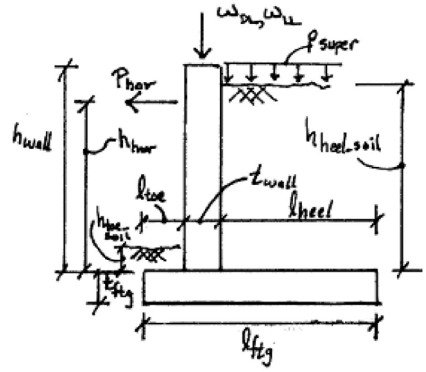
$V_u < \phi V_n = 1$ $\quad z = 52\ \frac{kips}{in}$

Sheet No.:_____

Project: St. Helens - Riverwalk - Retaining Wall
Project No.: 20028
Client:
Subject:

Engineer: SC
File: Ret-Wall_7.5-ft.mcdx
Date:
Rev.:

Retaining wall analysis and design



Material properties:

$\gamma_{conc} := 150 \cdot pcf$

$\gamma_{soil} := 120 \cdot pcf$

$\gamma_{EFP_a} := 35 \cdot pcf$

$\gamma_{EFP_p} := 250 \cdot pcf$

$\mu_{sliding} := .40$

$q_{all_brg} := 2000 \cdot psf$

$FS := 1.5$

Loading on wall:

$h_{heel_soil} := 7 \cdot ft + 6 \cdot in$

$h_{toe_soil} := 12 \cdot in$

$p_{super} := 100.0 \cdot psf$

$\omega_{DL_super} := 0.0 \cdot klf$

$\omega_{LL_super} := 0.0 \cdot klf$

$P_{hor} := 0.0 \cdot kips$

$h_{hor} := 0 \cdot ft$

Wall geometry:

$h_{wall} := 7 \cdot ft + 6 \cdot in$

$t_{wall} := 8 \cdot in$

$p_{wall} := 100 \cdot psf$

$h_{key} := 0 \cdot in$

$l_{key} := 0 \cdot in$

$t_{ftg} := 1 \cdot ft + 0 \cdot in$

$l_{toe} := 1 \cdot ft + 0 \cdot in$

$l_{ftg} := 5 \cdot ft + 0 \cdot in$

$l_{heel} := l_{ftg} - l_{toe} - t_{wall}$

$l_{heel} = 3.333\ ft$

$b_{nom} := 1 \cdot ft$

$\omega_1 := \omega_{DL_super} + \omega_{LL_super}$ $\qquad \omega_1 = 0\ \frac{kips}{ft}$

$P_{ftg} := \gamma_{conc} \cdot (l_{ftg} \cdot t_{ftg} + l_{key} \cdot h_{key}) \cdot b_{nom}$ $\qquad P_{ftg} = 0.75\ kips$

$P_{wall} := p_{wall} \cdot h_{wall} \cdot b_{nom}$ $\qquad P_{wall} = 0.75\ kips$

$P_{heel_soil} := (\gamma_{soil} \cdot h_{heel_soil} + p_{super}) \cdot l_{heel} \cdot b_{nom}$ $\qquad P_{heel_soil} = 3.333\ kips$

$P_{toe_soil} := \gamma_{soil} \cdot h_{toe_soil} \cdot l_{toe} \cdot b_{nom}$ $\qquad P_{toe_soil} = 0.12\ kips$

$P_{total} := P_{ftg} + P_{wall} + P_{heel_soil} + P_{toe_soil} + \omega_1 \cdot b_{nom}$ $\qquad P_{total} = 4.953\ kips$

$$M_{OT} := \left(\frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot (h_{heel_soil} + t_{ftg})^2 \cdot \left(\frac{t_{ftg} + h_{heel_soil}}{3} \right) + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot (h_{heel_soil} + t_{ftg}) \cdot b_{nom} \cdot \left(\frac{t_{ftg} + h_{heel_soil}}{2} \right) + P_{hor} \cdot (t_{ftg} + h_{hor}) \right) \cdot FS$$

$M_{OT} = 6.954\ ft \cdot kips$

$$M_{OT_resisting} := P_{ftg} \cdot \frac{l_{ftg}}{2} + P_{wall} \cdot \left(l_{toe} + \frac{t_{wall}}{2} \right) + \omega_1 \cdot b_{nom} \cdot \left(l_{toe} + \frac{t_{wall}}{2} \right) + P_{heel_soil} \cdot \left(l_{ftg} - \frac{l_{heel}}{2} \right) + P_{toe_soil} \cdot \frac{l_{toe}}{2}$$

$M_{OT_resisting} = 14.046\ ft \cdot kips$

$$H_{sliding} := \left(\frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot \left(h_{heel_soil} + h_{key} + t_{ftg}\right)^2 + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot b_{nom} \cdot \left(h_{heel_soil} + h_{key} + t_{ftg}\right) + P_{hor} \right) \cdot FS$$

$H_{sliding} = 2.268\ kips$

$$H_{resisting} := \left(P_{ftg} + P_{wall} + P_{heel_soil} + 0 \cdot P_{toe_soil} + \omega_1 \cdot b_{nom}\right) \cdot \mu_{sliding} + \frac{1}{2} \cdot \gamma_{EFP_p} \cdot b_{nom} \cdot \left(\left(h_{toe_soil} + t_{ftg} + h_{key}\right)^2 - h_{toe_soil}^{\ 2}\right)$$

$H_{resisting} = 2.308\ kips$

<u>Soil pressures due to gravity and overturning forces:</u>

Footing size: $B_1 := b_{nom}$ $\quad B_1 = 1\ ft$

$B_2 := l_{ftg}$ $\quad B_2 = 5\ ft$

$A := B_1 \cdot B_2$ $\quad A = 5\ ft^2$

Moment at mid-width of footing:

$$M := \left(\begin{array}{l} \frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot \left(h_{heel_soil}\right)^2 \cdot \left(\frac{h_{heel_soil}}{3}\right) \\ + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot \left(h_{heel_soil}\right) \cdot b_{nom} \cdot \left(\frac{h_{heel_soil}}{2}\right) \\ + \frac{0 \cdot -1}{2} \cdot \gamma_{EFP_p} \cdot b_{nom} \cdot \left(h_{toe_soil} + t_{ftg}\right)^2 \cdot \left(\frac{h_{toe_soil}}{3}\right) \\ + P_{hor} \cdot \left(t_{ftg} + h_{hor}\right) + P_{toe_soil} \cdot \left(\frac{l_{ftg}}{2} - \frac{l_{toe}}{2}\right) + \left(P_{wall} + \omega_1 \cdot b_{nom}\right) \cdot \left(\frac{l_{ftg}}{2} - l_{toe} - \frac{t_{wall}}{2}\right) \\ + -P_{heel_soil} \cdot \left(\frac{l_{ftg}}{2} - \frac{l_{heel}}{2}\right) \end{array} \right)$$

$M = 1.618\ ft \cdot kips$

Eccentricity of soil pressure resultant:

$e := \frac{M}{P_{total}}$ $\quad e = 0.327\ ft$ $\quad \frac{B_2}{6} = 0.833\ ft$

Maximum soil pressures:

$$q_{max_prime} := \begin{cases} \left(\frac{P_{total}}{A} \cdot \left(1 + \frac{6 \cdot e}{B_2}\right)\right) & \text{if } e \le \frac{B_2}{6} \\ \frac{2 \cdot P_{total}}{3 \cdot A \cdot \left(0.5 - \frac{e}{B_2}\right)} & \text{else} \end{cases}$$

$q_{max_prime} = 1379\ psf$

$q_{max_prime} < q_{all_brg} = 1$

$$q_{min_prime} := \begin{cases} \left(\frac{P_{total}}{A} \cdot \left(1 - \frac{6 \cdot e}{B_2}\right)\right) & \text{if } e \le \frac{B_2}{6} \\ 0 \cdot psf & \text{else} \end{cases}$$

$q_{min_prime} = 602\ psf$

Forces in wall at the base of wall:

$$M_{wall} := \left(\frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot \left(h_{heel_soil}\right)^2 \cdot \frac{h_{heel_soil}}{3} + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot \left(h_{heel_soil}\right) \cdot b_{nom} \cdot \left(\frac{h_{heel_soil}}{2}\right) + P_{hor} \cdot \left(h_{hor}\right)\right)$$

$$V_{wall} := \left(\frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot \left(h_{heel_soil}\right)^2 + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot \left(h_{heel_soil}\right) \cdot b_{nom} + P_{hor}\right)$$

$1.6 \cdot M_{wall} = 5.25\ ft \cdot kips$

$1.6 \cdot V_{wall} = 1.925\ kips$

$$M_{footing} := P_{heel_soil} \cdot \frac{l_{heel}}{2} + p_{super} \cdot b_{nom} \cdot \frac{l_{heel}^2}{2}$$

$M_{footing} = 6.111\ ft \cdot kips$

$1.6 \cdot M_{footing} = 9.778\ ft \cdot kips$

Reinforced concrete retaining wall design:

Loads and geometry:

Factored moment: $M_u := 1.6 \cdot M_{wall}$ $\quad M_u = 5.3\ ft \cdot kips$

Factored shear force: $V_u := 1.6 \cdot V_{wall}$ $\quad V_u = 1.9\ kips$

Slab strip width: $b := b_{nom}$

Wall thickness: $h := t_{wall}$

Cover to reinforcing: $d_{cg} := 4 \cdot in$

Depth to reinforcing: $d := h - d_{cg}$ $\quad d = 4\ in$

Material properties / Design parameters:

Strength reduction factors: Bending: $\phi_b := 0.9$

Shear: $\phi_v := 0.75$

Concrete compressive strength: $f_{c_p} := 4 \cdot ksi$

Steel yield strength: $f_y := 60 \cdot ksi$

Whitney stress block depth ratio:

$$\beta_1 := \begin{cases} 0.85 & \text{if } f_{c_p} \le 4 \cdot ksi \\ \left(0.85 - 0.05 \cdot \left(f_{c_p} \cdot ksi^{-1} - 4\right)\right) & \text{else} \end{cases}$$

Minimum flexural reinforcing:

$\rho_{min} := 200 \cdot f_y^{-1} \cdot psi$ $\quad \rho_{min} = 0.0033$

Maximum flexural reinforcing:

$$\rho_{max} := 0.75 \cdot \left(\frac{0.85 \cdot \beta_1 \cdot f_{c_p}}{f_y} \cdot \frac{87 \cdot ksi}{87 \cdot ksi + f_y}\right)$$

$$\rho_{max} = 0.0214$$

Flexural design:

Required area of reinforcing: $A_{s_reqd} = 0.31\ in^2$

Area of flexural reinforcing:

$BarArea := 0.31 \cdot in^2$

$Spacing := 8 \cdot in$ $\quad A_s := BarArea \cdot \frac{b}{Spacing}$ $\quad A_s = 0.465\ in^2$

Reinforcing ratio: $\rho := \frac{A_s}{b \cdot d}$ $\quad \rho = 0.0097$

Compression block depth:

$$a := \frac{A_s \cdot f_y}{0.85 \cdot f_{c_p} \cdot b} \qquad a = 0.684\ in$$

Moment capacity:

$$\phi M_n := \phi_b \cdot \left(A_s \cdot f_y \cdot \left(d - \frac{a}{2}\right)\right) \qquad \phi M_n = 7.7\ ft \cdot kips$$

Shear design:

Area of shear reinforcing: $A_v := 0 \cdot in^2$

Spacing of stirrups: $s := 12 \cdot in$

Concrete shear capacity:

$$V_c := 2 \cdot \sqrt{f_{c_p} \cdot psi} \cdot b \cdot d \qquad V_c = 6.1\ kips$$

Steel shear capacity: $V_s := \frac{A_v \cdot f_y \cdot d}{s}$

$V_s = 0\ kips$

Shear capacity:

$$\phi V_n := \phi_v \cdot \left(V_c + V_s\right) \qquad \phi V_n = 4.6\ kips$$

$M_u < \phi M_n = 1$ $\quad \rho < \rho_{max} = 1$

$V_u < \phi V_n = 1$ $\quad z = 173\ \frac{kips}{in}$

Reinforced concrete retaining wall footing design:

Loads and geometry:

Factored moment: $M_u := 1.6 \cdot M_{footing}$

$M_u = 9.778\ ft \cdot kips$

Slab strip width: $b := 12 \cdot in$

Live to dead load ratio: $LLDLRatio := 3.5$

Wall thickness: $h := t_{ftg}$

Cover to reinforcing: $d_{cg} := 3.25 \cdot in$

Depth to reinforcing: $d := h - d_{cg}$ $\quad d = 8.75\ in$

Material properties / Design parameters:

Strength reduction factors: Bending: $\phi_b := 0.9$

Shear: $\phi_v := 0.85$

Concrete compressive strength: $f_{c_p} := 4 \cdot ksi$

Steel yield strength: $f_y := 60 \cdot ksi$

Whitney stress block depth ratio:

$$\beta_1 := \begin{cases} 0.85 & \text{if } f_{c_p} \le 4 \cdot ksi \\ \left(0.85 - 0.05 \cdot \left(f_{c_p} \cdot ksi^{-1} - 4\right)\right) & \text{else} \end{cases}$$

Minimum flexural reinforcing:

$\rho_{min} := 200 \cdot f_y^{-1} \cdot psi$ $\quad \rho_{min} = 0.0033$

Maximum flexural reinforcing:

$$\rho_{max} := 0.75 \cdot \left(\frac{0.85 \cdot \beta_1 \cdot f_{c_p}}{f_y} \cdot \frac{87 \cdot ksi}{87 \cdot ksi + f_y}\right)$$

$\rho_{max} = 0.0214$

Flexural design:

Required area of reinforcing: $A_{s_reqd} = 0.25\ in^2$

Area of flexural reinforcing:

$BarArea := 0.31 \cdot in^2$

$Spacing := 12 \cdot in$ $\quad A_s := BarArea \cdot \frac{b}{Spacing}$ $\quad A_s = 0.31\ in^2$

Reinforcing ratio: $\rho := \frac{A_s}{b \cdot d}$ $\quad \rho = 0.003$

Compression block depth:

$a := \frac{A_s \cdot f_y}{0.85 \cdot f_{c_p} \cdot b}$ $\quad a = 0.456\ in$

Moment capacity:

$\phi M_n := \phi_b \cdot \left(A_s \cdot f_y \cdot \left(d - \frac{a}{2}\right)\right)$ $\quad \phi M_n = 11.9\ ft \cdot kips$

$M_u < \phi M_n = 1$ $\quad \rho < \rho_{max} = 1$

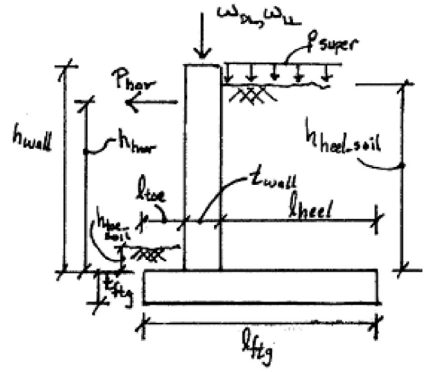
$V_u < \phi V_n = 1$ $\quad z = 179\ \frac{kips}{in}$

Sheet No.:_____

Project: St. Helens - Riverwalk - Retaining Wall
Project No.: 20028
Client:
Subject:

Engineer: SC
File: Ret-Wall_7.5-ft_EQ.mcdx
Date:
Rev.:

Retaining wall analysis and design



Material properties:

$\gamma_{conc} := 135 \cdot pcf$

$\gamma_{soil} := 108 \cdot pcf$

$\gamma_{EFP_a} := 35 \cdot pcf$

$\gamma_{EFP_p} := 250 \cdot pcf$

$\mu_{sliding} := .40$

$q_{all_brg} := 3000 \cdot psf$

$FS := 1.1$

Loading on wall:

$h_{heel_soil} := 7 \cdot ft + 6 \cdot in$

$h_{toe_soil} := 12 \cdot in$

$p_{super} := 0.0 \cdot psf$

$\omega_{DL_super} := 0.0 \cdot klf$

$\omega_{LL_super} := 0.0 \cdot klf$

$P_{hor} := 0.394 \cdot kips$

$h_{hor} := 4.50 \cdot ft$

Wall geometry:

$h_{wall} := 7 \cdot ft + 6 \cdot in$

$t_{wall} := 8 \cdot in$

$p_{wall} := 90 \cdot psf$

$h_{key} := 0 \cdot in$

$l_{key} := 0 \cdot in$

$t_{ftg} := 1 \cdot ft + 0 \cdot in$

$l_{toe} := 1 \cdot ft + 0 \cdot in$

$l_{ftg} := 5 \cdot ft + 0 \cdot in$

$l_{heel} := l_{ftg} - l_{toe} - t_{wall}$

$l_{heel} = 3.333\ ft$

$b_{nom} := 1 \cdot ft$

$\omega_1 := \omega_{DL_super} + \omega_{LL_super}$ $\qquad \omega_1 = 0\ \frac{kips}{ft}$

$P_{ftg} := \gamma_{conc} \cdot (l_{ftg} \cdot t_{ftg} + l_{key} \cdot h_{key}) \cdot b_{nom}$ $\qquad P_{ftg} = 0.675\ kips$

$P_{wall} := p_{wall} \cdot h_{wall} \cdot b_{nom}$ $\qquad P_{wall} = 0.675\ kips$

$P_{heel_soil} := (\gamma_{soil} \cdot h_{heel_soil} + p_{super}) \cdot l_{heel} \cdot b_{nom}$ $\qquad P_{heel_soil} = 2.7\ kips$

$P_{toe_soil} := \gamma_{soil} \cdot h_{toe_soil} \cdot l_{toe} \cdot b_{nom}$ $\qquad P_{toe_soil} = 0.108\ kips$

$P_{total} := P_{ftg} + P_{wall} + P_{heel_soil} + P_{toe_soil} + \omega_1 \cdot b_{nom}$ $\qquad P_{total} = 4.158\ kips$

$$M_{OT} := \left(\frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot (h_{heel_soil} + t_{ftg})^2 \cdot \left(\frac{t_{ftg} + h_{heel_soil}}{3} \right) + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot (h_{heel_soil} + t_{ftg}) \cdot b_{nom} \cdot \left(\frac{t_{ftg} + h_{heel_soil}}{2} \right) + P_{hor} \cdot (t_{ftg} + h_{hor}) \right) \cdot FS$$

$M_{OT} = 6.324\ ft \cdot kips$

$$M_{OT_resisting} := P_{ftg} \cdot \frac{l_{ftg}}{2} + P_{wall} \cdot \left(l_{toe} + \frac{t_{wall}}{2} \right) + \omega_1 \cdot b_{nom} \cdot \left(l_{toe} + \frac{t_{wall}}{2} \right) + P_{heel_soil} \cdot \left(l_{ftg} - \frac{l_{heel}}{2} \right) + P_{toe_soil} \cdot \frac{l_{toe}}{2}$$

$M_{OT_resisting} = 11.642\ ft \cdot kips$

$$H_{sliding} := \left(\frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot \left(h_{heel_soil} + h_{key} + t_{ftg}\right)^2 + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot b_{nom} \cdot \left(h_{heel_soil} + h_{key} + t_{ftg}\right) + P_{hor} \right) \cdot FS$$

$H_{sliding} = 1.824\ kips$

$$H_{resisting} := \left(P_{ftg} + P_{wall} + P_{heel_soil} + 0 \cdot P_{toe_soil} + \omega_1 \cdot b_{nom}\right) \cdot \mu_{sliding} + \frac{1}{2} \cdot \gamma_{EFP_p} \cdot b_{nom} \cdot \left(\left(h_{toe_soil} + t_{ftg} + h_{key}\right)^2 - h_{toe_soil}^{\ 2}\right)$$

$H_{resisting} = 1.995\ kips$

<u>Soil pressures due to gravity and overturning forces:</u>

Footing size: $B_1 := b_{nom}$ $\quad B_1 = 1\ ft$

$B_2 := l_{ftg}$ $\quad B_2 = 5\ ft$

$A := B_1 \cdot B_2$ $\quad A = 5\ ft^2$

Moment at mid-width of footing:

$$M := \left(\begin{array}{l} \frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot \left(h_{heel_soil}\right)^2 \cdot \left(\frac{h_{heel_soil}}{3}\right) \\ + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot \left(h_{heel_soil}\right) \cdot b_{nom} \cdot \left(\frac{h_{heel_soil}}{2}\right) \\ + \frac{0 \cdot -1}{2} \cdot \gamma_{EFP_p} \cdot b_{nom} \cdot \left(h_{toe_soil} + t_{ftg}\right)^2 \cdot \left(\frac{h_{toe_soil}}{3}\right) \\ + P_{hor} \cdot \left(t_{ftg} + h_{hor}\right) + P_{toe_soil} \cdot \left(\frac{l_{ftg}}{2} - \frac{l_{toe}}{2}\right) + \left(P_{wall} + \omega_1 \cdot b_{nom}\right) \cdot \left(\frac{l_{ftg}}{2} - l_{toe} - \frac{t_{wall}}{2}\right) \\ + -P_{heel_soil} \cdot \left(\frac{l_{ftg}}{2} - \frac{l_{heel}}{2}\right) \end{array} \right)$$

$M = 3.381\ ft \cdot kips$

Eccentricity of soil pressure resultant:

$e := \frac{M}{P_{total}}$ $\quad e = 0.813\ ft$ $\quad \frac{B_2}{6} = 0.833\ ft$

Maximum soil pressures:

$$q_{max_prime} := \begin{cases} \left(\frac{P_{total}}{A} \cdot \left(1 + \frac{6 \cdot e}{B_2}\right)\right) & \text{if } e \le \frac{B_2}{6} \\ \frac{2 \cdot P_{total}}{3 \cdot A \cdot \left(0.5 - \frac{e}{B_2}\right)} & \text{else} \end{cases}$$

$q_{max_prime} = 1643\ psf$

$q_{max_prime} < q_{all_brg} = 1$

$$q_{min_prime} := \begin{cases} \left(\frac{P_{total}}{A} \cdot \left(1 - \frac{6 \cdot e}{B_2}\right)\right) & \text{if } e \le \frac{B_2}{6} \\ 0 \cdot psf & \text{else} \end{cases}$$

$q_{min_prime} = 20\ psf$

<u>Forces in wall at the base of wall:</u>

$$M_{wall} := \left(\frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot \left(h_{heel_soil}\right)^2 \cdot \frac{h_{heel_soil}}{3} + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot \left(h_{heel_soil}\right) \cdot b_{nom} \cdot \left(\frac{h_{heel_soil}}{2}\right) + P_{hor} \cdot \left(h_{hor}\right)\right)$$

$$V_{wall} := \left(\frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot \left(h_{heel_soil}\right)^2 + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot \left(h_{heel_soil}\right) \cdot b_{nom} + P_{hor}\right)$$

$1.6 \cdot M_{wall} = 6.774\ ft \cdot kips$

$1.6 \cdot V_{wall} = 2.205\ kips$

$$M_{footing} := P_{heel_soil} \cdot \frac{l_{heel}}{2} + p_{super} \cdot b_{nom} \cdot \frac{l_{heel}^2}{2}$$

$M_{footing} = 4.5\ ft \cdot kips$

$1.6 \cdot M_{footing} = 7.2\ ft \cdot kips$

Reinforced concrete retaining wall design:

Loads and geometry:

Factored moment: $M_u := 1.6 \cdot M_{wall}$ $\quad M_u = 6.8\ ft \cdot kips$

Factored shear force: $V_u := 1.6 \cdot V_{wall}$ $\quad V_u = 2.2\ kips$

Slab strip width: $b := b_{nom}$

Wall thickness: $h := t_{wall}$

Cover to reinforcing: $d_{cg} := 4 \cdot in$

Depth to reinforcing: $d := h - d_{cg}$ $\quad d = 4\ in$

Material properties / Design parameters:

Strength reduction factors: Bending: $\phi_b := 0.9$

Shear: $\phi_v := 0.75$

Concrete compressive strength: $f_{c_p} := 4 \cdot ksi$

Steel yield strength: $f_y := 60 \cdot ksi$

Whitney stress block depth ratio:

$$\beta_1 := \begin{cases} 0.85 & \text{if } f_{c_p} \le 4 \cdot ksi \\ \left(0.85 - 0.05 \cdot \left(f_{c_p} \cdot ksi^{-1} - 4\right)\right) & \text{else} \end{cases}$$

Minimum flexural reinforcing:

$\rho_{min} := 200 \cdot f_y^{-1} \cdot psi$ $\quad \rho_{min} = 0.0033$

Maximum flexural reinforcing:

$$\rho_{max} := 0.75 \cdot \left(\frac{0.85 \cdot \beta_1 \cdot f_{c_p}}{f_y} \cdot \frac{87 \cdot ksi}{87 \cdot ksi + f_y}\right)$$

$$\rho_{max} = 0.0214$$

Flexural design:

Required area of reinforcing: $A_{s_reqd} = 0.41\ in^2$

Area of flexural reinforcing:

$BarArea := 0.31 \cdot in^2$

$Spacing := 8 \cdot in$ $\quad A_s := BarArea \cdot \frac{b}{Spacing}$ $\quad A_s = 0.465\ in^2$

Reinforcing ratio: $\rho := \frac{A_s}{b \cdot d}$ $\quad \rho = 0.0097$

Compression block depth:

$$a := \frac{A_s \cdot f_y}{0.85 \cdot f_{c_p} \cdot b} \qquad a = 0.684\ in$$

Moment capacity:

$$\phi M_n := \phi_b \cdot \left(A_s \cdot f_y \cdot \left(d - \frac{a}{2}\right)\right) \qquad \phi M_n = 7.7\ ft \cdot kips$$

Shear design:

Area of shear reinforcing: $A_v := 0 \cdot in^2$

Spacing of stirrups: $s := 12 \cdot in$

Concrete shear capacity:

$$V_c := 2 \cdot \sqrt{f_{c_p} \cdot psi} \cdot b \cdot d \qquad V_c = 6.1\ kips$$

Steel shear capacity: $V_s := \frac{A_v \cdot f_y \cdot d}{s}$

$V_s = 0\ kips$

Shear capacity:

$$\phi V_n := \phi_v \cdot \left(V_c + V_s\right) \qquad \phi V_n = 4.6\ kips$$

$M_u < \phi M_n = 1$ $\quad \rho < \rho_{max} = 1$

$V_u < \phi V_n = 1$ $\quad z = 223\ \frac{kips}{in}$

Reinforced concrete retaining wall footing design:

Loads and geometry:

Factored moment: $M_u := 1.6 \cdot M_{footing}$

$M_u = 7.2\ ft \cdot kips$

Slab strip width: $b := 12 \cdot in$

Live to dead load ratio: $LLDLRatio := 3.5$

Wall thickness: $h := t_{ftg}$

Cover to reinforcing: $d_{cg} := 3.25 \cdot in$

Depth to reinforcing: $d := h - d_{cg}$ $\quad d = 8.75\ in$

Material properties / Design parameters:

Strength reduction factors: Bending: $\phi_b := 0.9$

Shear: $\phi_v := 0.85$

Concrete compressive strength: $f_{c_p} := 4 \cdot ksi$

Steel yield strength: $f_y := 60 \cdot ksi$

Whitney stress block depth ratio:

$$\beta_1 := \begin{cases} 0.85 & \text{if } f_{c_p} \le 4 \cdot ksi \\ \left(0.85 - 0.05 \cdot \left(f_{c_p} \cdot ksi^{-1} - 4\right)\right) & \text{else} \end{cases}$$

Minimum flexural reinforcing:

$\rho_{min} := 200 \cdot f_y^{-1} \cdot psi$ $\quad \rho_{min} = 0.0033$

Maximum flexural reinforcing:

$$\rho_{max} := 0.75 \cdot \left(\frac{0.85 \cdot \beta_1 \cdot f_{c_p}}{f_y} \cdot \frac{87 \cdot ksi}{87 \cdot ksi + f_y}\right)$$

$\rho_{max} = 0.0214$

Flexural design:

Required area of reinforcing: $A_{s_reqd} = 0.19\ in^2$

Area of flexural reinforcing:

$BarArea := 0.31 \cdot in^2$

$Spacing := 12 \cdot in$ $\quad A_s := BarArea \cdot \frac{b}{Spacing}$ $\quad A_s = 0.31\ in^2$

Reinforcing ratio: $\rho := \frac{A_s}{b \cdot d}$ $\quad \rho = 0.003$

Compression block depth:

$a := \frac{A_s \cdot f_y}{0.85 \cdot f_{c_p} \cdot b}$ $\quad a = 0.456\ in$

Moment capacity:

$\phi M_n := \phi_b \cdot \left(A_s \cdot f_y \cdot \left(d - \frac{a}{2}\right)\right)$ $\quad \phi M_n = 11.9\ ft \cdot kips$

$M_u < \phi M_n = 1$ $\quad \rho < \rho_{max} = 1$

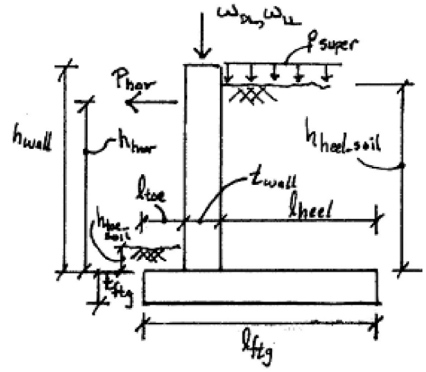
$V_u < \phi V_n = 1$ $\quad z = 132\ \frac{kips}{in}$

Sheet No.:_____

Project: St. Helens - Riverwalk - Retaining Wall
Project No.: 20028
Client:
Subject:

Engineer: SC
File: Ret-Wall_9.5-ft.mcdx
Date:
Rev.:

Retaining wall analysis and design



Material properties:

$\gamma_{conc} := 150 \cdot pcf$

$\gamma_{soil} := 120 \cdot pcf$

$\gamma_{EFP_a} := 35 \cdot pcf$

$\gamma_{EFP_p} := 250 \cdot pcf$

$\mu_{sliding} := .40$

$q_{all_brg} := 2000 \cdot psf$

$FS := 1.5$

Loading on wall:

$h_{heel_soil} := 9 \cdot ft + 6 \cdot in$

$h_{toe_soil} := 12 \cdot in$

$p_{super} := 100.0 \cdot psf$

$\omega_{DL_super} := 0.0 \cdot klf$

$\omega_{LL_super} := 0.0 \cdot klf$

$P_{hor} := 0.0 \cdot kips$

$h_{hor} := 0 \cdot ft$

Wall geometry:

$h_{wall} := 9 \cdot ft + 6 \cdot in$

$t_{wall} := 8 \cdot in$

$p_{wall} := 100 \cdot psf$

$h_{key} := 0 \cdot in$

$l_{key} := 0 \cdot in$

$t_{ftg} := 1 \cdot ft + 0 \cdot in$

$l_{toe} := 1 \cdot ft + 0 \cdot in$

$l_{ftg} := 6 \cdot ft + 4 \cdot in$

$l_{heel} := l_{ftg} - l_{toe} - t_{wall}$

$l_{heel} = 4.667\ ft$

$b_{nom} := 1 \cdot ft$

$\omega_1 := \omega_{DL_super} + \omega_{LL_super}$ $\qquad \omega_1 = 0\ \frac{kips}{ft}$

$P_{ftg} := \gamma_{conc} \cdot (l_{ftg} \cdot t_{ftg} + l_{key} \cdot h_{key}) \cdot b_{nom}$ $\qquad P_{ftg} = 0.95\ kips$

$P_{wall} := p_{wall} \cdot h_{wall} \cdot b_{nom}$ $\qquad P_{wall} = 0.95\ kips$

$P_{heel_soil} := (\gamma_{soil} \cdot h_{heel_soil} + p_{super}) \cdot l_{heel} \cdot b_{nom}$ $\qquad P_{heel_soil} = 5.787\ kips$

$P_{toe_soil} := \gamma_{soil} \cdot h_{toe_soil} \cdot l_{toe} \cdot b_{nom}$ $\qquad P_{toe_soil} = 0.12\ kips$

$P_{total} := P_{ftg} + P_{wall} + P_{heel_soil} + P_{toe_soil} + \omega_1 \cdot b_{nom}$ $\qquad P_{total} = 7.807\ kips$

$$M_{OT} := \left(\frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot (h_{heel_soil} + t_{ftg})^2 \cdot \left(\frac{t_{ftg} + h_{heel_soil}}{3} \right) + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot (h_{heel_soil} + t_{ftg}) \cdot b_{nom} \cdot \left(\frac{t_{ftg} + h_{heel_soil}}{2} \right) + P_{hor} \cdot (t_{ftg} + h_{hor}) \right) \cdot FS$$

$M_{OT} = 12.541\ ft \cdot kips$

$$M_{OT_resisting} := P_{ftg} \cdot \frac{l_{ftg}}{2} + P_{wall} \cdot \left(l_{toe} + \frac{t_{wall}}{2} \right) + \omega_1 \cdot b_{nom} \cdot \left(l_{toe} + \frac{t_{wall}}{2} \right) + P_{heel_soil} \cdot \left(l_{ftg} - \frac{l_{heel}}{2} \right) + P_{toe_soil} \cdot \frac{l_{toe}}{2}$$

$M_{OT_resisting} = 27.482\ ft \cdot kips$

$$H_{sliding} := \left(\frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot \left(h_{heel_soil} + h_{key} + t_{ftg}\right)^2 + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot b_{nom} \cdot \left(h_{heel_soil} + h_{key} + t_{ftg}\right) + P_{hor} \right) \cdot FS$$

$H_{sliding} = 3.353\ kips$

$$H_{resisting} := \left(P_{ftg} + P_{wall} + P_{heel_soil} + 0 \cdot P_{toe_soil} + \omega_1 \cdot b_{nom}\right) \cdot \mu_{sliding} + \frac{1}{2} \cdot \gamma_{EFP_p} \cdot b_{nom} \cdot \left(\left(h_{toe_soil} + t_{ftg} + h_{key}\right)^2 - h_{toe_soil}^{\ 2}\right)$$

$H_{resisting} = 3.45\ kips$

<u>Soil pressures due to gravity and overturning forces:</u>

Footing size: $B_1 := b_{nom}$ $\quad B_1 = 1\ ft$

$B_2 := l_{ftg}$ $\quad B_2 = 6.333\ ft$

$A := B_1 \cdot B_2$ $\quad A = 6.333\ ft^2$

Moment at mid-width of footing:

$$M := \left(\begin{array}{l} \frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot \left(h_{heel_soil}\right)^2 \cdot \left(\frac{h_{heel_soil}}{3}\right) \\ + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot \left(h_{heel_soil}\right) \cdot b_{nom} \cdot \left(\frac{h_{heel_soil}}{2}\right) \\ + \frac{0 \cdot -1}{2} \cdot \gamma_{EFP_p} \cdot b_{nom} \cdot \left(h_{toe_soil} + t_{ftg}\right)^2 \cdot \left(\frac{h_{toe_soil}}{3}\right) \\ + P_{hor} \cdot \left(t_{ftg} + h_{hor}\right) + P_{toe_soil} \cdot \left(\frac{l_{ftg}}{2} - \frac{l_{toe}}{2}\right) + \left(P_{wall} + \omega_1 \cdot b_{nom}\right) \cdot \left(\frac{l_{ftg}}{2} - l_{toe} - \frac{t_{wall}}{2}\right) \\ + -P_{heel_soil} \cdot \left(\frac{l_{ftg}}{2} - \frac{l_{heel}}{2}\right) \end{array} \right)$$

$M = 3.557\ ft \cdot kips$

Eccentricity of soil pressure resultant:

$e := \frac{M}{P_{total}}$ $\quad e = 0.456\ ft$ $\quad \frac{B_2}{6} = 1.056\ ft$

Maximum soil pressures:

$$q_{max_prime} := \begin{cases} \left(\frac{P_{total}}{A} \cdot \left(1 + \frac{6 \cdot e}{B_2}\right)\right) & \text{if } e \le \frac{B_2}{6} \\ \frac{2 \cdot P_{total}}{3 \cdot A \cdot \left(0.5 - \frac{e}{B_2}\right)} & \text{else} \end{cases}$$

$q_{max_prime} = 1765\ psf$

$q_{max_prime} < q_{all_brg} = 1$

$$q_{min_prime} := \begin{cases} \left(\frac{P_{total}}{A} \cdot \left(1 - \frac{6 \cdot e}{B_2}\right)\right) & \text{if } e \le \frac{B_2}{6} \\ 0 \cdot psf & \text{else} \end{cases}$$

$q_{min_prime} = 701\ psf$

<u>Forces in wall at the base of wall:</u>

$$M_{wall} := \left(\frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot \left(h_{heel_soil}\right)^2 \cdot \frac{h_{heel_soil}}{3} + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot \left(h_{heel_soil}\right) \cdot b_{nom} \cdot \left(\frac{h_{heel_soil}}{2}\right) + P_{hor} \cdot \left(h_{hor}\right)\right)$$

$$V_{wall} := \left(\frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot \left(h_{heel_soil}\right)^2 + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot \left(h_{heel_soil}\right) \cdot b_{nom} + P_{hor}\right)$$

$1.6 \cdot M_{wall} = 10.108\ ft \cdot kips$

$1.6 \cdot V_{wall} = 2.97\ kips$

$$M_{footing} := P_{heel_soil} \cdot \frac{l_{heel}}{2} + p_{super} \cdot b_{nom} \cdot \frac{l_{heel}^2}{2}$$

$M_{footing} = 14.591\ ft \cdot kips$

$1.6 \cdot M_{footing} = 23.346\ ft \cdot kips$

Reinforced concrete retaining wall design:

Loads and geometry:

Factored moment: $M_u := 1.6 \cdot M_{wall}$ $\quad M_u = 10.1\ ft \cdot kips$

Factored shear force: $V_u := 1.6 \cdot V_{wall}$ $\quad V_u = 3\ kips$

Slab strip width: $b := b_{nom}$

Wall thickness: $h := t_{wall}$

Cover to reinforcing: $d_{cg} := 4 \cdot in$

Depth to reinforcing: $d := h - d_{cg}$ $\quad d = 4\ in$

Material properties / Design parameters:

Strength reduction factors: Bending: $\phi_b := 0.9$

Shear: $\phi_v := 0.75$

Concrete compressive strength: $f_{c_p} := 4 \cdot ksi$

Steel yield strength: $f_y := 60 \cdot ksi$

Whitney stress block depth ratio:

$$\beta_1 := \begin{cases} 0.85 & \text{if } f_{c_p} \le 4 \cdot ksi \\ \left(0.85 - 0.05 \cdot \left(f_{c_p} \cdot ksi^{-1} - 4\right)\right) & \text{else} \end{cases}$$

Minimum flexural reinforcing:

$\rho_{min} := 200 \cdot f_y^{-1} \cdot psi$ $\quad \rho_{min} = 0.0033$

Maximum flexural reinforcing:

$$\rho_{max} := 0.75 \cdot \left(\frac{0.85 \cdot \beta_1 \cdot f_{c_p}}{f_y} \cdot \frac{87 \cdot ksi}{87 \cdot ksi + f_y}\right)$$

$\rho_{max} = 0.0214$

Flexural design:

Required area of reinforcing: $A_{s_reqd} = 0.64\ in^2$

Area of flexural reinforcing:

$BarArea := 0.31 \cdot in^2$

$Spacing := 4 \cdot in$ $\quad A_s := BarArea \cdot \frac{b}{Spacing}$ $\quad A_s = 0.93\ in^2$

Reinforcing ratio: $\rho := \frac{A_s}{b \cdot d}$ $\quad \rho = 0.0194$

Compression block depth:

$a := \frac{A_s \cdot f_y}{0.85 \cdot f_{c_p} \cdot b}$ $\quad a = 1.368\ in$

Moment capacity:

$\phi M_n := \phi_b \cdot \left(A_s \cdot f_y \cdot \left(d - \frac{a}{2}\right)\right)$ $\quad \phi M_n = 13.9\ ft \cdot kips$

Shear design:

Area of shear reinforcing: $A_v := 0 \cdot in^2$

Spacing of stirrups: $s := 12 \cdot in$

Concrete shear capacity:

$V_c := 2 \cdot \sqrt{f_{c_p} \cdot psi} \cdot b \cdot d$ $\quad V_c = 6.1\ kips$

Steel shear capacity: $V_s := \frac{A_v \cdot f_y \cdot d}{s}$

$V_s = 0\ kips$

Shear capacity:

$\phi V_n := \phi_v \cdot (V_c + V_s)$ $\quad \phi V_n = 4.6\ kips$

$M_u < \phi M_n = 1$ $\quad \rho < \rho_{max} = 1$

$V_u < \phi V_n = 1$ $\quad z = 172\ \frac{kips}{in}$

Reinforced concrete retaining wall footing design:

Loads and geometry:

Factored moment: $M_u := 1.6 \cdot M_{footing}$

$M_u = 23.346\ ft \cdot kips$

Slab strip width: $b := 12 \cdot in$

Live to dead load ratio: $LLDLRatio := 3.5$

Wall thickness: $h := t_{ftg}$

Cover to reinforcing: $d_{cg} := 3.25 \cdot in$

Depth to reinforcing: $d := h - d_{cg}$ $\quad d = 8.75\ in$

Material properties / Design parameters:

Strength reduction factors: Bending: $\phi_b := 0.9$

Shear: $\phi_v := 0.85$

Concrete compressive strength: $f_{c_p} := 4 \cdot ksi$

Steel yield strength: $f_y := 60 \cdot ksi$

Whitney stress block depth ratio:

$$\beta_1 := \begin{cases} 0.85 & \text{if } f_{c_p} \le 4 \cdot ksi \\ \left(0.85 - 0.05 \cdot \left(f_{c_p} \cdot ksi^{-1} - 4\right)\right) & \text{else} \end{cases}$$

Minimum flexural reinforcing:

$\rho_{min} := 200 \cdot f_y^{-1} \cdot psi$ $\quad \rho_{min} = 0.0033$

Maximum flexural reinforcing:

$$\rho_{max} := 0.75 \cdot \left(\frac{0.85 \cdot \beta_1 \cdot f_{c_p}}{f_y} \cdot \frac{87 \cdot ksi}{87 \cdot ksi + f_y}\right)$$

$\rho_{max} = 0.0214$

Flexural design:

Required area of reinforcing: $A_{s_reqd} = 0.63\ in^2$

WITHIN 5% - SAY OK

Area of flexural reinforcing:

$BarArea := 0.31 \cdot in^2$

$Spacing := 6 \cdot in$ $\quad A_s := BarArea \cdot \frac{b}{Spacing}$ $\quad A_s = 0.62\ in^2$

Reinforcing ratio: $\rho := \frac{A_s}{b \cdot d}$ $\quad \rho = 0.0059$

Compression block depth:

$a := \frac{A_s \cdot f_y}{0.85 \cdot f_{c_p} \cdot b}$ $\quad a = 0.912\ in$

Moment capacity:

$\phi M_n := \phi_b \cdot \left(A_s \cdot f_y \cdot \left(d - \frac{a}{2}\right)\right)$ $\quad \phi M_n = 23.1\ ft \cdot kips$

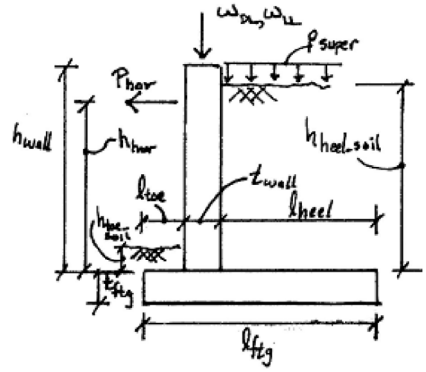
$M_u < \phi M_n = 0$ $\quad \rho < \rho_{max} = 1$

$V_u < \phi V_n = 1$ $\quad z = 219\ \frac{kips}{in}$

Project: St. Helens - Riverwalk - Retaining Wall
Project No.: 20028
Client:
Subject:

Engineer: SC
File: Ret-Wall_9.5-ft_EQ.mcdx
Date:
Rev.:

Retaining wall analysis and design



Material properties:

$\gamma_{conc} := 135 \cdot pcf$

$\gamma_{soil} := 108 \cdot pcf$

$\gamma_{EFP_a} := 35 \cdot pcf$

$\gamma_{EFP_p} := 250 \cdot pcf$

$\mu_{sliding} := .40$

$q_{all_brg} := 3000 \cdot psf$

$FS := 1.1$

Loading on wall:

$h_{heel_soil} := 9 \cdot ft + 6 \cdot in$

$h_{toe_soil} := 12 \cdot in$

$p_{super} := 0.0 \cdot psf$

$\omega_{DL_super} := 0.0 \cdot klf$

$\omega_{LL_super} := 0.0 \cdot klf$

$P_{hor} := 0.632 \cdot kips$

$h_{hor} := 5.70 \cdot ft$

Wall geometry:

$h_{wall} := 9 \cdot ft + 6 \cdot in$

$t_{wall} := 8 \cdot in$

$p_{wall} := 90 \cdot psf$

$h_{key} := 0 \cdot in$

$l_{key} := 0 \cdot in$

$t_{ftg} := 1 \cdot ft + 0 \cdot in$

$l_{toe} := 1 \cdot ft + 0 \cdot in$

$l_{ftg} := 6 \cdot ft + 4 \cdot in$

$l_{heel} := l_{ftg} - l_{toe} - t_{wall}$

$l_{heel} = 4.667\ ft$

$b_{nom} := 1 \cdot ft$

$\omega_1 := \omega_{DL_super} + \omega_{LL_super}$ $\qquad \omega_1 = 0\ \frac{kips}{ft}$

$P_{ftg} := \gamma_{conc} \cdot (l_{ftg} \cdot t_{ftg} + l_{key} \cdot h_{key}) \cdot b_{nom}$ $\qquad P_{ftg} = 0.855\ kips$

$P_{wall} := p_{wall} \cdot h_{wall} \cdot b_{nom}$ $\qquad P_{wall} = 0.855\ kips$

$P_{heel_soil} := (\gamma_{soil} \cdot h_{heel_soil} + p_{super}) \cdot l_{heel} \cdot b_{nom}$ $\qquad P_{heel_soil} = 4.788\ kips$

$P_{toe_soil} := \gamma_{soil} \cdot h_{toe_soil} \cdot l_{toe} \cdot b_{nom}$ $\qquad P_{toe_soil} = 0.108\ kips$

$P_{total} := P_{ftg} + P_{wall} + P_{heel_soil} + P_{toe_soil} + \omega_1 \cdot b_{nom}$ $\qquad P_{total} = 6.606\ kips$

$$M_{OT} := \left(\frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot (h_{heel_soil} + t_{ftg})^2 \cdot \left(\frac{t_{ftg} + h_{heel_soil}}{3} \right) + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot (h_{heel_soil} + t_{ftg}) \cdot b_{nom} \cdot \left(\frac{t_{ftg} + h_{heel_soil}}{2} \right) + P_{hor} \cdot (t_{ftg} + h_{hor}) \right) \cdot FS$$

$M_{OT} = 12.086\ ft \cdot kips$

$$M_{OT_resisting} := P_{ftg} \cdot \frac{l_{ftg}}{2} + P_{wall} \cdot \left(l_{toe} + \frac{t_{wall}}{2} \right) + \omega_1 \cdot b_{nom} \cdot \left(l_{toe} + \frac{t_{wall}}{2} \right) + P_{heel_soil} \cdot \left(l_{ftg} - \frac{l_{heel}}{2} \right) + P_{toe_soil} \cdot \frac{l_{toe}}{2}$$

$M_{OT_resisting} = 23.054\ ft \cdot kips$

$$H_{sliding} := \left(\frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot \left(h_{heel_soil} + h_{key} + t_{ftg}\right)^2 + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot b_{nom} \cdot \left(h_{heel_soil} + h_{key} + t_{ftg}\right) + P_{hor} \right) \cdot FS$$

$H_{sliding} = 2.818\ kips$

$$H_{resisting} := \left(P_{ftg} + P_{wall} + P_{heel_soil} + 0 \cdot P_{toe_soil} + \omega_1 \cdot b_{nom}\right) \cdot \mu_{sliding} + \frac{1}{2} \cdot \gamma_{EFP_p} \cdot b_{nom} \cdot \left(\left(h_{toe_soil} + t_{ftg} + h_{key}\right)^2 - h_{toe_soil}^{\ 2}\right)$$

$H_{resisting} = 2.974\ kips$

<u>Soil pressures due to gravity and overturning forces:</u>

Footing size: $B_1 := b_{nom}$ $\quad B_1 = 1\ ft$

$B_2 := l_{ftg}$ $\quad B_2 = 6.333\ ft$

$A := B_1 \cdot B_2$ $\quad A = 6.333\ ft^2$

Moment at mid-width of footing:

$$M := \left(\begin{array}{l} \frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot \left(h_{heel_soil}\right)^2 \cdot \left(\frac{h_{heel_soil}}{3}\right) \\ + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot \left(h_{heel_soil}\right) \cdot b_{nom} \cdot \left(\frac{h_{heel_soil}}{2}\right) \\ + \frac{0 \cdot -1}{2} \cdot \gamma_{EFP_p} \cdot b_{nom} \cdot \left(h_{toe_soil} + t_{ftg}\right)^2 \cdot \left(\frac{h_{toe_soil}}{3}\right) \\ + P_{hor} \cdot \left(t_{ftg} + h_{hor}\right) + P_{toe_soil} \cdot \left(\frac{l_{ftg}}{2} - \frac{l_{toe}}{2}\right) + \left(P_{wall} + \omega_1 \cdot b_{nom}\right) \cdot \left(\frac{l_{ftg}}{2} - l_{toe} - \frac{t_{wall}}{2}\right) \\ + -P_{heel_soil} \cdot \left(\frac{l_{ftg}}{2} - \frac{l_{heel}}{2}\right) \end{array} \right)$$

$M = 7.101\ ft \cdot kips$

Eccentricity of soil pressure resultant:

$e := \frac{M}{P_{total}}$ $\quad e = 1.075\ ft$ $\quad \frac{B_2}{6} = 1.056\ ft$

Maximum soil pressures:

$$q_{max_prime} := \begin{cases} \left(\frac{P_{total}}{A} \cdot \left(1 + \frac{6 \cdot e}{B_2}\right)\right) & \text{if } e \le \frac{B_2}{6} \\ \frac{2 \cdot P_{total}}{3 \cdot A \cdot \left(0.5 - \frac{e}{B_2}\right)} & \text{else} \end{cases}$$

$q_{max_prime} = 2105\ psf$

$q_{max_prime} < q_{all_brg} = 1$

$$q_{min_prime} := \begin{cases} \left(\frac{P_{total}}{A} \cdot \left(1 - \frac{6 \cdot e}{B_2}\right)\right) & \text{if } e \le \frac{B_2}{6} \\ 0 \cdot psf & \text{else} \end{cases}$$

$q_{min_prime} = 0\ psf$

<u>Forces in wall at the base of wall:</u>

$$M_{wall} := \left(\frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot \left(h_{heel_soil}\right)^2 \cdot \frac{h_{heel_soil}}{3} + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot \left(h_{heel_soil}\right) \cdot b_{nom} \cdot \left(\frac{h_{heel_soil}}{2}\right) + P_{hor} \cdot \left(h_{hor}\right)\right)$$

$$V_{wall} := \left(\frac{1}{2} \cdot \gamma_{EFP_a} \cdot b_{nom} \cdot \left(h_{heel_soil}\right)^2 + p_{super} \cdot \frac{\gamma_{EFP_a}}{\gamma_{soil}} \cdot \left(h_{heel_soil}\right) \cdot b_{nom} + P_{hor}\right)$$

$1.6 \cdot M_{wall} = 13.766\ ft \cdot kips$

$1.6 \cdot V_{wall} = 3.538\ kips$

$$M_{footing} := P_{heel_soil} \cdot \frac{l_{heel}}{2} + p_{super} \cdot b_{nom} \cdot \frac{l_{heel}^2}{2}$$

$M_{footing} = 11.172\ ft \cdot kips$

$1.6 \cdot M_{footing} = 17.875\ ft \cdot kips$

Reinforced concrete retaining wall design:

Loads and geometry:

Factored moment: $M_u := 1.6 \cdot M_{wall}$ $\quad M_u = 13.8\ ft \cdot kips$

Factored shear force: $V_u := 1.6 \cdot V_{wall}$ $\quad V_u = 3.5\ kips$

Slab strip width: $b := b_{nom}$

Wall thickness: $h := t_{wall}$

Cover to reinforcing: $d_{cg} := 4 \cdot in$

Depth to reinforcing: $d := h - d_{cg}$ $\quad d = 4\ in$

Material properties / Design parameters:

Strength reduction factors: Bending: $\phi_b := 0.9$

Shear: $\phi_v := 0.75$

Concrete compressive strength: $f_{c_p} := 4 \cdot ksi$

Steel yield strength: $f_y := 60 \cdot ksi$

Whitney stress block depth ratio:

$$\beta_1 := \begin{cases} 0.85 & \text{if } f_{c_p} \le 4 \cdot ksi \\ \left(0.85 - 0.05 \cdot \left(f_{c_p} \cdot ksi^{-1} - 4\right)\right) & \text{else} \end{cases}$$

Minimum flexural reinforcing:

$\rho_{min} := 200 \cdot f_y^{-1} \cdot psi$ $\quad \rho_{min} = 0.0033$

Maximum flexural reinforcing:

$$\rho_{max} := 0.75 \cdot \left(\frac{0.85 \cdot \beta_1 \cdot f_{c_p}}{f_y} \cdot \frac{87 \cdot ksi}{87 \cdot ksi + f_y}\right)$$

$\rho_{max} = 0.0214$

Flexural design:

Required area of reinforcing: $A_{s_reqd} = 0.92\ in^2$

Area of flexural reinforcing:

$BarArea := 0.31 \cdot in^2$

$Spacing := 4 \cdot in$ $\quad A_s := BarArea \cdot \frac{b}{Spacing}$ $\quad A_s = 0.93\ in^2$

Reinforcing ratio: $\rho := \frac{A_s}{b \cdot d}$ $\quad \rho = 0.0194$

Compression block depth:

$a := \frac{A_s \cdot f_y}{0.85 \cdot f_{c_p} \cdot b}$ $\quad a = 1.368\ in$

Moment capacity:

$\phi M_n := \phi_b \cdot \left(A_s \cdot f_y \cdot \left(d - \frac{a}{2}\right)\right)$ $\quad \phi M_n = 13.9\ ft \cdot kips$

Shear design:

Area of shear reinforcing: $A_v := 0 \cdot in^2$

Spacing of stirrups: $s := 12 \cdot in$

Concrete shear capacity:

$V_c := 2 \cdot \sqrt{f_{c_p} \cdot psi} \cdot b \cdot d$ $\quad V_c = 6.1\ kips$

Steel shear capacity: $V_s := \frac{A_v \cdot f_y \cdot d}{s}$

$V_s = 0\ kips$

Shear capacity:

$\phi V_n := \phi_v \cdot (V_c + V_s)$ $\quad \phi V_n = 4.6\ kips$

$M_u < \phi M_n = 1$ $\quad \rho < \rho_{max} = 1$

$V_u < \phi V_n = 1$ $\quad z = 235\ \frac{kips}{in}$

Reinforced concrete retaining wall footing design:

Loads and geometry:

Factored moment: $M_u := 1.6 \cdot M_{footing}$

$M_u = 17.875\ ft \cdot kips$

Slab strip width: $b := 12 \cdot in$

Live to dead load ratio: $LLDLRatio := 3.5$

Wall thickness: $h := t_{ftg}$

Cover to reinforcing: $d_{cg} := 3.25 \cdot in$

Depth to reinforcing: $d := h - d_{cg}$ $\quad d = 8.75\ in$

Material properties / Design parameters:

Strength reduction factors: Bending: $\phi_b := 0.9$

Shear: $\phi_v := 0.85$

Concrete compressive strength: $f_{c_p} := 4 \cdot ksi$

Steel yield strength: $f_y := 60 \cdot ksi$

Whitney stress block depth ratio:

$$\beta_1 := \begin{cases} 0.85 & \text{if } f_{c_p} \le 4 \cdot ksi \\ \left(0.85 - 0.05 \cdot \left(f_{c_p} \cdot ksi^{-1} - 4\right)\right) & \text{else} \end{cases}$$

Minimum flexural reinforcing:

$\rho_{min} := 200 \cdot f_y^{-1} \cdot psi$ $\quad \rho_{min} = 0.0033$

Maximum flexural reinforcing:

$$\rho_{max} := 0.75 \cdot \left(\frac{0.85 \cdot \beta_1 \cdot f_{c_p}}{f_y} \cdot \frac{87 \cdot ksi}{87 \cdot ksi + f_y}\right)$$

$\rho_{max} = 0.0214$

Flexural design:

Required area of reinforcing: $A_{s_reqd} = 0.47\ in^2$

Area of flexural reinforcing:

$BarArea := 0.31 \cdot in^2$

$Spacing := 6 \cdot in$ $\quad A_s := BarArea \cdot \frac{b}{Spacing}$ $\quad A_s = 0.62\ in^2$

Reinforcing ratio: $\rho := \frac{A_s}{b \cdot d}$ $\quad \rho = 0.0059$

Compression block depth:

$a := \frac{A_s \cdot f_y}{0.85 \cdot f_{c_p} \cdot b}$ $\quad a = 0.912\ in$

Moment capacity:

$\phi M_n := \phi_b \cdot \left(A_s \cdot f_y \cdot \left(d - \frac{a}{2}\right)\right)$ $\quad \phi M_n = 23.1\ ft \cdot kips$

$M_u < \phi M_n = 1$ $\quad \rho < \rho_{max} = 1$

$V_u < \phi V_n = 1$ $\quad z = 168\ \frac{kips}{in}$