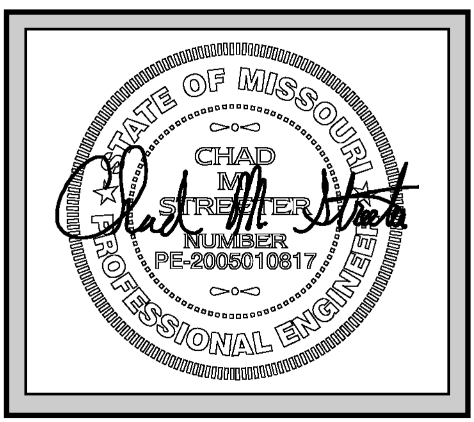
2524 NE Woodland Oaks

Lot 11 Woodland Oaks
Lee's Summit, Missouri

VAN DEURZEN AND ASSOCIATES, P.A.
CONSULTING STRUCTURAL ENGINEERS
11011 KING STREET, SUITE 130
COMMERCE TERRACE BUILDING D
OVERLAND PARK, KANSAS 66210
(913) 451 - 6305   FAX (913) 451 - 1021

Reinforced Soil Retaining Wall Design



VAN DEURZEN AND ASSOCIATES, P.A.
November 8, 2024

Segmental Retaining Wall Design Calculations per NCMA

Wall Geometry

Height	Backslope	Dead Load	Live Load	Distance to Slope	Wall below grade at toe
$H := 9.0 \cdot ft$	$\beta := 0.0 \cdot deg$	$q_d := 0 \cdot psf$	$q_l := 50 \cdot psf$	$Z := 1.0 \cdot ft$	$H_{emb} := .67 \cdot ft$

Soil Properties

Reinforced Soil (Internal)	Retained Soil (External)	Drainage Fill	Foundation Soil	Pullout
$\gamma_i := 110 \cdot pcf$	$\gamma_e := 120 \cdot pcf$	$\gamma_d := 110 \cdot pcf$	$\gamma_f := 120 \cdot pcf$	$C_i := 0.7$
$\phi_i := 32 \cdot deg$	$\phi_e := 26 \cdot deg$	$\phi_d := 32 \cdot deg$	$\phi_f := 26 \cdot deg$	
$C_{dsi} := 0.8$	$C_{dse} := 1.0$		$c_f := 0.0psf$	

Segmental Unit Properties

Height	Length	Width	Setback	Center of Gravity
$H_u := 8 \cdot in$	$L_u := 18 \cdot in$	$W_u := 12 \cdot in$	$\Delta_u := 1.0 \cdot in$	$G_u := 6 \cdot in$

Batter

$$\omega := atan\left(\frac{\Delta_u}{H_u}\right) \qquad \omega = 7.125 \cdot deg$$

Infilled Unit Weight

$\gamma_u := 120 \cdot pcf$

Hinge Height

$$H_h := if\left[tan(\omega) = 0, H, \left[2 \cdot \frac{(W_u - G_u)}{tan(\omega)}\right]\right] \Rightarrow H_h = 8\ ft$$ [Eq. 4-1]

Internal Interface Friction Angle

$$\delta_i := \frac{2}{3} \cdot \phi_i \qquad \delta_i = 21.33 \cdot deg$$ [Eq. 3-17]

Internal Active Earth Pressure

$$Ka_i := \frac{cos(\phi_i + \omega)^2}{cos(\omega)^2 \cdot cos(\omega - \delta_i) \cdot \left[1 + \sqrt{\left(\frac{sin(\phi_i + \delta_i) \cdot sin(\phi_i - \beta)}{cos(\omega - \delta_i) \cdot cos(\omega + \beta)}\right)}\right]^2}$$

[Eq. 3-11] $Ka_i = 0.228$

External Interface Friction Angle

$$\delta_e := if(\phi_i > \phi_e, \phi_e, \phi_i) \qquad \delta_e = 26 \cdot deg$$ [Eq. 3-16]

External Active Earth Pressure

$$Ka_e := \frac{cos(\phi_e + \omega)^2}{cos(\omega)^2 \cdot cos(\omega - \delta_e) \cdot \left[1 + \sqrt{\left[\frac{sin(\phi_e + \delta_e) \cdot sin((\phi_e - \beta))}{cos(\omega - \delta_e) \cdot cos(\omega + \beta)}\right]}\right]^2}$$

[Eq. 3-11] $Ka_e = 0.292$

Orientation of Critical Internal Failure Surface

$$\alpha_i := atan\left[\frac{-tan(\phi_i - \beta) + \sqrt{(tan(\phi_i - \beta)) \cdot (tan(\phi_i - \beta) + cot(\phi_i + \omega)) \cdot (1 + tan(\delta_i - \omega) \cdot cot(\phi_i + \omega))}}{1 + tan(\delta_i - \omega) \cdot (tan(\phi_i - \beta) + cot(\phi_i + \omega))}\right] + \phi_i$$

[Eq. 3-14]

$\alpha_i = 54.469 \cdot deg$

Orientation of Critical External Failure Surface

$$\alpha_e := atan\left[\frac{-tan(\phi_e - \beta) + \sqrt{tan(\phi_e - \beta) \cdot (tan(\phi_e - \beta) + cot(\phi_e + \omega)) \cdot (1 + tan(\delta_e - \omega) \cdot cot(\phi_e + \omega))}}{1 + tan(\delta_e - \omega) \cdot (tan(\phi_e - \beta) + cot(\phi_e + \omega))}\right] + \phi_e$$

[Eq. 3-14]

$\alpha_e = 49.572 \cdot deg$

External Stability Analysis

Sliding

Given

$$1.5 = \frac{\min\left[\begin{array}{l} C_{dse}\cdot\left[q_d\cdot\left[(L-W_u-Z)+\frac{(L-W_u-Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1-\tan(\beta)\cdot\tan(\omega)}\right]+L\cdot\gamma_e\cdot H \ldots \\ \quad +\frac{1}{2}\cdot\gamma_e\cdot(L-W_u-Z)\cdot\left[(L-W_u-Z)+\frac{(L-W_u-Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1-\tan(\beta)\cdot\tan(\omega)}\right]\cdot\tan(\beta)\right]\cdot\tan(\phi_e) \\ C_{dse}\cdot\left[q_d\cdot\left[(L-W_u-Z)+\frac{(L-W_u-Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1-\tan(\beta)\cdot\tan(\omega)}\right]+L\cdot\gamma_e\cdot H \ldots \\ \quad +\frac{1}{2}\cdot\gamma_e\cdot(L-W_u-Z)\cdot\left[(L-W_u-Z)+\frac{(L-W_u-Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1-\tan(\beta)\cdot\tan(\omega)}\right]\cdot\tan(\beta)\right]\cdot\tan(\phi_d) \\ C_{dse}\cdot\left[c_f\cdot L+\left[q_d\cdot\left[(L-W_u-Z)+\frac{(L-W_u-Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1-\tan(\beta)\cdot\tan(\omega)}\right]+L\cdot\gamma_e\cdot H \ldots \\ \quad +\frac{1}{2}\cdot\gamma_e\cdot(L-W_u-Z)\cdot\left[(L-W_u-Z)+\frac{(L-W_u-Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1-\tan(\beta)\cdot\tan(\omega)}\right]\cdot\tan(\beta)\right]\right]\cdot\tan(\phi_f) \end{array}\right]}{\begin{array}{l}\left[\frac{1}{2}\cdot Ka_e\cdot\gamma_e\cdot\left[H+\left[(L-W_u-Z)+\frac{(L-W_u-Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1-\tan(\beta)\cdot\tan(\omega)}\right]\cdot\tan(\beta)\right]^2\cdot\cos(\delta_e-\omega)\right]\ldots \\ +(q_d+q_l)\cdot Ka_e\cdot\left[H+\left[(L-W_u-Z)+\frac{(L-W_u-Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1-\tan(\beta)\cdot\tan(\omega)}\right]\cdot\tan(\beta)\right]\cdot\cos(\delta_e-\omega)\end{array}}$$

$L_{sliding} := \mathrm{Find}(L)$ $\qquad$ $L_{sliding} = 4.173\ \mathrm{ft}$

Overturning

Given

$$2.0 = \frac{\begin{array}{l}\left[(L\cdot\gamma_e\cdot H)\cdot\left[\frac{1}{2}\cdot(L+H\cdot\tan(\omega))\right]\right]\ldots \\ +\left[\frac{1}{2}\cdot\gamma_e\cdot(L-W_u-Z)\cdot\left[(L-W_u-Z)+\frac{(L-W_u-Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1-\tan(\beta)\cdot\tan(\omega)}\right]\cdot\tan(\beta)\right]\cdot\left[\left[H\cdot\tan(\omega)+W_u+Z+\frac{2}{3}\cdot(L-W_u-Z)\right]\cdots\right. \\ +q_d\cdot\left[(L-W_u-Z)+\frac{(L-W_u-Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1-\tan(\beta)\cdot\tan(\omega)}\right]\cdot\left[\frac{Z+\left[(L-W_u-Z)+\frac{(L-W_u-Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1-\tan(\beta)\cdot\tan(\omega)}\right]}{2}+H\cdot\tan(\omega)+\cdots\right.\end{array}}{\begin{array}{l}\left[\frac{1}{2}\cdot Ka_e\cdot\gamma_e\cdot\left[H+\left[(L-W_u-Z)+\frac{(L-W_u-Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1-\tan(\beta)\cdot\tan(\omega)}\right]\cdot\tan(\beta)\right]^2\cdot\cos(\delta_e-\omega)\right]\cdot\left[\frac{1}{3}\cdot\left[H+\left[(L-W_u-Z)+\frac{(L-W_u-Z)\cdot\tan(\beta)\cdot\cdots}{1-\tan(\beta)\cdot\tan(\omega)}\cdots\right.\right.\right. \\ +(q_d+q_l)\cdot Ka_e\cdot\left[\left[H+\left[(L-W_u-Z)+\frac{(L-W_u-Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1-\tan(\beta)\cdot\tan(\omega)}\right]\cdot\tan(\beta)\right]\cdot\cos(\delta_e-\omega)\right]\cdot\left[\frac{1}{2}\cdot\left[H+\left[(L-W_u-Z)+\frac{(L-W_u-Z)\cdot\tan(\cdots}{1-\tan(\beta)\cdot\cdots}\cdots\right.\right.\right.\end{array}}$$

$L_{overturning} := \mathrm{Find}(L)$ $\qquad$ $L_{overturning} = 3.596\ \mathrm{ft}$

$$L := \max\left(\begin{pmatrix} L_{sliding} \\ L_{overturning} \\ 0.6\cdot H \end{pmatrix}\right) \qquad L = 5.4\ \mathrm{ft}$$

Based on Overturning and Sliding: $L := 6.5\cdot\mathrm{ft}$ *(Round up L)*

Eccentricity

$L' := L - W_u - Z$ | $L' = 4.5 \cdot ft$ | [Fig. 2-10] [Eq. 5-1]

$L'' := \dfrac{(L - W_u - Z) \cdot \tan(\beta) \cdot \tan(\omega)}{1 - \tan(\beta) \cdot \tan(\omega)}$ | $L'' = 0\ ft$ | [Fig. 2-10] [Eq. 5-2]

$L_\beta := L' + L''$ | $L_\beta = 4.5\ ft$ | [Fig. 2-10] [Eq. 5-3]

$h := L_\beta \cdot \tan(\beta)$ | $h = 0\ ft$ | [Fig. 2-10] [Eq. 5-4]

$W_{ri} := L \cdot \gamma_i \cdot H$ | $W_{ri} = 6435 \cdot plf$ | [Eq. 5-15]

$X_{ri} := \dfrac{1}{2} \cdot (L + H \cdot \tan(\omega))$ | $X_{ri} = 3.813\ ft$ | [Eq. 5-19]

$W_{r\beta} := \dfrac{1}{2} \cdot \gamma_i \cdot (L' - Z) \cdot h$ | $W_{r\beta} = 0 \cdot plf$ | [Eq. 5-16]

$X_{r\beta} := H \cdot \tan(\omega) + W_u + \dfrac{2}{3} \cdot L_\beta + Z$ | $X_{r\beta} = 6.125\ ft$ | [Eq. 5-20]

$X_{q\beta} := \dfrac{Z + L_\beta}{2} + [(H + h) \cdot \tan(\omega)] + W_u$ | $X_{q\beta} = 4.875\ ft$ | [Eq. 5-21]

Actual Heigth of wall:

$H_s := (H + h)$ | $H_s = 9\ ft$

Earth Pressures:

$P_{sH} := \left[\dfrac{1}{2} \cdot Ka_e \cdot \gamma_e \cdot (H + h)^2 \cdot \cos(\delta_e - \omega)\right]$ | $P_{sH} = 1341.299 \cdot plf$ | [Eq. 5-6]

$Y_s := \dfrac{1}{3} \cdot (H + h)$ | $Y_s = 3\ ft$ | [Eq. 5-9]

$P_{qH} := (q_d + q_l) \cdot Ka_e \cdot (H + h) \cdot \cos(\delta_e - \omega)$ | $P_{qH} = 124.194 \cdot plf$ | [Eq. 5-8]

$Y_q := \dfrac{1}{2} \cdot (H + h)$ | $Y_q = 4.5\ ft$ | [Eq. 5-10]

$$e := \frac{\left[P_{sH} \cdot Y_s + P_{qH} \cdot Y_q - W_{ri} \cdot \left(X_{ri} - \frac{L}{2}\right) - W_{r\beta} \cdot \left(X_{r\beta} - \frac{L}{2}\right) - q_d \cdot (L_\beta) \cdot \left(X_{q\beta} - \frac{L}{2}\right)\right]}{W_{ri} + W_{r\beta} + q_d \cdot (L_\beta)}$$

$e = 0.1497\ ft$ | [Eq. 5-25]

Check $e := \text{if}(e \le 0, 0.075L, e)$ | $e = 0.15\ ft$

Surcharge is applied over: $(L' + L'') = 4.5\ ft$

$B := L - 2 \cdot e$ | $B = 6.201\ ft$ | [Eq. 5-24]

Bearing Capacity

$Q_a := \frac{\left[W_{ri} + W_{r\beta} + (q_d + q_l)\cdot(L' + L'')\right]}{B}$ — $Q_a = 1074.077\cdot psf$

$N_q := \tan\left(45\cdot deg + \frac{\phi_f}{2}\right)^2 \cdot \exp(\pi\cdot\tan(\phi_f))$ — $N_q = 11.854$ [Fig. 4-5]

$N_c := \text{if}\left[\phi_f = 0, 5.14, (N_q - 1)\cdot\cot(\phi_f)\right]$ — $N_c = 22.254$ [Fig. 4-5]

$N_\gamma := 2\cdot(N_q + 1)\cdot\tan(\phi_f)$ — $N_\gamma = 12.539$ [Fig. 4-5]

$Q_{ult} := c_f\cdot N_c + \frac{1}{2}\cdot\gamma_f\cdot B\cdot N_\gamma + \gamma_f\cdot H_{emb}\cdot N_q$ — $Q_{ult} = 5618.028\cdot psf$ [Eq. 4-20]

$FS_{bearing} := \frac{Q_{ult}}{Q_a}$ — $FS_{bearing} = 5.231$ [Eq. 4-19]

Internal Stability

Reinforcement Properties

Geogrid Design Data

Backfill Soil $Type := (gravel)$

	1	2	3	4	5	6	7	8	9
$Type^T =$	411	834	1199	1336	2004	2508	3011	3873	7914
$inter^T =$	1145	1145	1145	1145	1145	1145	0		
$slope^T =$	38	38	38	38	38	38	0		
$maxc^T =$	4540	4540	4540	4540	4540	4540	0		

Geogrid Number $GN1 := 4$ $GN2 := 2$

$x := 4..1$ x is the number of grids at the top of the wall of a different type

$T_a := Type_{GN1}\cdot plf$ $T_a = 1336\cdot plf$ $T_{a2} := Type_{GN2}\cdot plf$ $T_{a2} = 834\cdot plf$

$a_{cs} := inter_{GN1}\cdot plf$ $a_{cs} = 1145\cdot plf$ | $\lambda_{cs} := slope_{GN1}\cdot deg$ $\lambda_{cs} = 38\cdot deg$ | $V_{csmax} := maxc_{GN1}\cdot plf$ $V_{csmax} = 4540\cdot plf$

$a_{cs2} := inter_{GN2}\cdot plf$ $a_{cs2} = 1145\cdot plf$ | $\lambda_{cs2} := slope_{GN2}\cdot deg$ $\lambda_{cs2} = 38\cdot deg$ | $V_{csmax2} := maxc_{GN2}\cdot plf$ $V_{csmax2} = 4540\cdot plf$

Tension in Geogrid

Number of Grids: $n_g := 4$

Grig Spacing (ft): $Spacing1 := 2$ $Spacing2 := 1.67$

Make all zero when using one geogrid

# of grids for that spacing: $n_1 := 4$ $n_2 := 0$

Depth of first grid (ft): $h_1 := 2.33$

Length of grids: $L_1 := 6.5$ $L_2 := 6.5$ $L_r := \frac{L}{ft}$

Note: make sure that the elevations don't excide the height of the wall (H) $H = 9\,ft$

$top := length(E)$ $p := 2..top$ $top = 4$

$grids := length(E)$ $n := 1..top$ $l := 1..grids - 1$

$$E = \begin{pmatrix} 2.33 \\ 4.33 \\ 6.33 \\ 8.33 \end{pmatrix} ft$$

$$T_{a_x} := T_{a2} \quad T_{a_x} = \begin{pmatrix} 834 \\ 834 \\ 834 \\ 834 \end{pmatrix} \cdot plf \quad T_a := \overrightarrow{\frac{L \cdot T_a}{L}} \quad T_a = \begin{pmatrix} 1336 \\ 1336 \\ 1336 \\ 1336 \end{pmatrix} \cdot plf$$

$$L = \begin{pmatrix} 6.5 \\ 6.5 \\ 6.5 \\ 6.5 \end{pmatrix} ft$$

$$T_a^T = (834 \quad 834 \quad 834 \quad 834) \cdot plf$$

$$D_p := \frac{E_{p-1} + E_p}{2} \qquad D_1 := 0 \cdot ft \qquad D_{grids+1} := H$$

$$D^T = (0 \quad 3.33 \quad 5.33 \quad 7.33 \quad 9)\,ft$$

Total Applied Tensile Strength in the Geosynthetic reinf.:

$$F_{g_n} := \int_{D_n}^{D_{(n+1)}} (\gamma_i \cdot D + q_l + q_d) \cdot Ka_i \cdot \cos(\delta_i - \omega)\, dD$$ [Eq. 5-36]

$$F_g^T = (171.232 \quad 232.15 \quad 329.191 \quad 349.22) \cdot plf$$

Safety factor:

$$FS_{ten_n} := \frac{T_{a_n}}{F_{g_n}} \qquad FS_{ten}^T = (4.871 \quad 3.593 \quad 2.533 \quad 2.388)$$

Pullout Capacity

Anchorage Length of Geosynthetic

$$La_n := L_n - W_u - \left[(H+h) - E_n\right]\cdot\tan\left(90\cdot deg - \alpha_i\right) + \left[(H+h) - E_n\right]\cdot\tan(\omega)$$ [Eq. 5-46]

$La^T = (1.571 \quad 2.749 \quad 3.927 \quad 5.105)\ ft$

Note: If the anchorage length is less than 1ft then there is not enough embedment length and it has to be increased. Note that in some cases it might just be the top two grids.

Average Depth of overburden on Anchorage length

$$d_n := E_n + \left[\left(H - E_n\right)\cdot\tan\left(90\cdot deg - \alpha_i\right) + \frac{La_n}{2} - \left(Z + H\cdot\tan(\omega) - \Delta_u\right)\right]\cdot\tan(\beta)$$ [Eq. 5-47]

$d^T = (2.33 \quad 4.33 \quad 6.33 \quad 8.33)\ ft$

Anchorage Capacity

$$AC_n := 2\cdot La_n\cdot C_i\cdot\left(d_n\cdot\gamma_i + q_d\right)\cdot\tan\left(\phi_i\right)$$ [Eq. 5-45]

$AC^T = (352.158 \quad 1145.377 \quad 2392.117 \quad 4092.378)\cdot plf$

$F_g^T = (171.232 \quad 232.15 \quad 329.191 \quad 349.22)\cdot plf$

Safety Factor

$$FS_{po} := \overrightarrow{\frac{AC}{F_g}}$$ [Eq. 5-44]

$FS_{po}^T = (2.057 \quad 4.934 \quad 7.267 \quad 11.719)$

Internal Sliding

Reduced reinforcement length

$$\Delta L_{l+1} := \begin{cases} \left[\left(E_{l+1} - E_l\right)\cdot\left(\frac{1}{\tan\left(\alpha_e\right)} - \tan(\omega)\right)\right] & \text{if } n_g > 2 \\ Spacing1\cdot ft\cdot\left(\frac{1}{\tan\left(\alpha_e\right)} - \tan(\omega)\right) & \text{if } n_g = 2 \\ 0 & \text{if } n_g = 1 \end{cases}$$ [Eq. 5-51]

$\Delta L^T = (0 \quad 1.454 \quad 1.454 \quad 1.454)\ ft$

$$L'_{s_n} := L_n - W_u - \Delta L_n$$ [Eq. 5-50]

$L'_s{}^T = (5.5 \quad 4.046 \quad 4.046 \quad 4.046)\ ft$

Length of sloping ground

$$L_{s\beta_n} := L'_{s_n} + \frac{\left(L'_{s_n} - W_u\right)\cdot\tan(\beta)\cdot\tan(\omega)}{1 - \tan(\beta)\cdot\tan(\omega)} - Z$$ [Eq. 5-53 & 5-52]

$L_{s\beta}^T = (4.5 \quad 3.046 \quad 3.046 \quad 3.046)\ ft$

Height of slope above crest of wall

$h'_n := L_{s\beta_n} \cdot \tan(\beta)$ [Eq. 5-54]

$h'^T = (0 \quad 0 \quad 0 \quad 0)\ ft$

Weight of reduced reinforced area

$W'_{ri_n} := L'_{s_n} \cdot E_n \cdot \gamma_i$ [Eq. 5-55]

$W'_{ri}^T = (1410 \quad 1927 \quad 2817 \quad 3708) \cdot plf$

Weight of wedge beyond reinforced soil zone

$W'_{r\beta_n} := \frac{1}{2} \cdot \left(\left(L_{s\beta_n} \cdot h'_n\right)\right) \cdot \gamma_i$ [Eq. 5-56]

$W'_{r\beta}^T = (0 \quad 0 \quad 0 \quad 0) \cdot plf$

Friction developed by weight

$R'_{s_n} := C_{dsi} \cdot \left[q_d \cdot \left(L_{s\beta_n} + Z\right) + W'_{ri_n} + W'_{r\beta_n}\right] \cdot \tan\left(\phi_i\right)$ [Eq. 5-49]

$R'_s{}^T = (705 \quad 963 \quad 1408 \quad 1853) \cdot plf$

Shear capacity of facing elements

$V_{u_n} := \min\left[V_{csmax}, a_{cs} + \left(\text{if}\left(E_n > H_h, H_h, E_n\right) \cdot \gamma_u \cdot W_u\right) \cdot \tan\left(\lambda_{cs}\right)\right]$ [Eq. 4-25]

$V_u^T = (1363 \quad 1551 \quad 1738 \quad 1895) \cdot plf$

Driving Forces

From retained soil

$P_{s_n} := \left[\frac{1}{2} \cdot Ka_e \cdot \gamma_e \cdot \left(E_n + h'_n\right)^2 \cdot \cos\left(\delta_e - \omega\right)\right]$ [Eq. 5-6]

$P_s^T = (90 \quad 310 \quad 664 \quad 1149) \cdot plf$

From surcharge

$P_{q_n} := \left(q_d + q_l\right) \cdot Ka_e \cdot \left(E_n + h'_n\right) \cdot \cos\left(\delta_e - \omega\right)$ [Eq. 5-8]

$P_q^T = (32 \quad 60 \quad 87 \quad 115) \cdot plf$

Factor of safety against internal sliding

$P_{a_n} := P_{s_n} + P_{q_n}$ [Eq. 5-11]

$P_a^T = (122 \quad 370 \quad 751 \quad 1264) \cdot plf$

$FS_{sl_n} := \frac{R'_{s_n} + V_{u_n}}{\left(P_{a_n}\right)}$ [Eq. 5-48]

$FS_{sl}^T = (16.945 \quad 6.792 \quad 4.191 \quad 2.966)$

Local Stability of Facing Units

Facing Connection Strength

$$T_{conn_n} := \min\left[V_{csmax_n}, a_{cs_n} + \left(if\left(E_n > H_h, H_h, E_n\right)\cdot\gamma_u\cdot W_u\right)\cdot\tan\left(\lambda_{cs_n}\right)\right]$$ [Eq. 5-59]

$$T_{conn}^T = (1363 \quad 1551 \quad 1738 \quad 1895)\cdot plf$$

$$FS_{conn_n} := \frac{T_{conn_n}}{F_{g_n}}$$

$$FS_{conn}^T = (7.963 \quad 6.681 \quad 5.281 \quad 5.426)$$

Resistance to Bulging

Shear capacity at each geogrid layer

$$V_{u_n} := \min\left[V_{csmax}, a_{cs} + \left(if\left(E_n > H_h, H_h, E_n\right)\cdot\gamma_u\cdot W_u\right)\cdot\tan\left(\lambda_{cs}\right)\right]$$ [Eq. 4-25]

$$V_u^T = (1363 \quad 1551 \quad 1738 \quad 1895)\cdot plf$$

Driving Force at each geogrid layer

$$P_{a_n} := \left[\frac{1}{2}\cdot Ka_i\cdot\gamma_i\cdot\left(E_n\right)^2\cdot\cos\left(\delta_i - \omega\right)\right] + \left(q_d + q_l\right)\cdot Ka_i\cdot\left(E_n\right)\cdot\cos\left(\delta_i - \omega\right)$$ [Eq. 5-11]

$$P_a^T = (92 \quad 275 \quad 556 \quad 934)\cdot plf$$

Sum of tension in reinforcement layers above layer being considered

$$F_{n+1} := \sum_{i=1}^{n} F_{g_i}$$

$$F^T = (0 \quad 171 \quad 403 \quad 733 \quad 1082)\cdot plf$$

$$FS_{sc_n} := \frac{V_{u_n}}{P_{a_n} - F_n}$$ [Eq. 5-61]

$$FS_{sc}^T = (14.893 \quad 14.921 \quad 11.402 \quad 9.429)$$

Maximum unreinforced height of SRW units

$y := E_1 = 2.33\ ft$ $\quad q_l := 0\cdot psf$

Moment equilibrium

Driving Moments

$$P'_s := \left[\frac{1}{2}\cdot Ka_i\cdot\gamma_i\cdot(y)^2\cdot\cos\left(\delta_i - \omega\right)\right]$$ [Eq. 4-5]

$$P'_s = 65.854\cdot plf$$

$P'_q := (q_d + q_l) \cdot Ka_i \cdot (y) \cdot \cos(\delta_i - \omega)$ [Eq. 4-6] $P'_q = 0 \cdot plf$

$P'_a := P'_s + P'_q$ [Eq. 4-4] $P'_a = 65.854 \cdot plf$

$Y'_s := \frac{1}{3} \cdot y$ [Eq. 4-7] $Y'_s = 0.777\ ft$

$Y'_q := \frac{1}{2} \cdot y$ [Eq. 4-8] $Y'_q = 1.17\ ft$

$M'_o := P'_s \cdot Y'_s + P'_q \cdot Y'_q$ [Eq. 4-17] $M'_o = 51.15 \cdot lbf$

Resisting Moments

$W'_w := y \cdot \gamma_u \cdot W_u$ [Eq. 4-9] $W'_w = 279.6 \cdot plf$

$X'_w := G_u + \frac{1}{2} \cdot (y) \cdot \tan(\omega)$ [Eq. 4-16] $X'_w = 0.646\ ft$

$M'_r := W'_w \cdot X'_w$ [Eq. 4-15] $M'_r = 180.517\ ft \cdot plf$

$FS_{ot} := \frac{M'_r}{M'_o}$ [Eq. 4-14] $FS_{ot} = 3.529$

Factor of Safety against Shear failure

$V'_u := a_{cs} + W'_w \cdot \tan(\lambda_{cs})$ [Eq. 4-25]

$FS_{sh} := \frac{V'_u}{P'_a}$ [Eq. 4-27]

$V'_u = \begin{pmatrix} 1363.447 \\ 1363.447 \\ \ldots \end{pmatrix}$

$FS_{sh} = \begin{pmatrix} 20.704 \\ 20.704 \\ 20.704 \\ 20.704 \end{pmatrix}$

Summary

Wall Height $H = 9\ ft$

Unreinforced Stability $FS_{ot} = 3.529$ $FS_{bearing} = 5.231$

Applied Bearing Stress $Q_a = 1074 \cdot psf$

Grid Elevation	Geogrid Length	Tensile Force	Geogrid Strength	Anch. Length	Anch. Capacity	FS Grid Tension (1.0)	FS Pullout (1.5)	FS Int Sliding (1.5)	FS Conn (1.5)	FS Bulging (1.5)
E_n = (ft)	L_n = (ft)	$\frac{F_{g_n}}{plf}$ =	$\frac{T_{a_n}}{plf}$ =	La_n = (ft)	$\frac{AC_n}{plf}$ =	FS_{ten_n} =	FS_{po_n} =	FS_{sl_n} =	FS_{conn_n} =	FS_{sc_n} =
2.33	6.5	171	834	1.57	352	4.87	2.06	16.94	7.96	14.89
4.33	6.5	232	834	2.75	1145	3.59	4.93	6.79	6.68	14.92
6.33	6.5	329	834	3.93	2392	2.53	7.27	4.19	5.28	11.4
8.33	6.5	349	834	5.11	4092	2.39	11.72	2.97	5.43	9.43

Segmental Retaining Wall Design Calculations per NCMA

Wall Geometry

Height	Backslope	Dead Load	Live Load	Distance to Slope	Wall below grade at toe
$H := 7.0 \cdot ft$	$\beta := 0.0 \cdot deg$	$q_d := 0 \cdot psf$	$q_l := 50 \cdot psf$	$Z := 1.0 \cdot ft$	$H_{emb} := .67 \cdot ft$

Soil Properties

Reinforced Soil (Internal)

$\gamma_i := 110 \cdot pcf$

$\phi_i := 32 \cdot deg$

$C_{dsi} := 0.8$

Retained Soil (External)

$\gamma_e := 120 \cdot pcf$

$\phi_e := 26 \cdot deg$

$C_{dse} := 1.0$

Drainage Fill

$\gamma_d := 110 \cdot pcf$

$\phi_d := 32 \cdot deg$

Foundation Soil

$\gamma_f := 120 \cdot pcf$

$\phi_f := 26 \cdot deg$

$c_f := 0.0 psf$

Pullout

$C_i := 0.7$

Segmental Unit Properties

Height	Length	Width	Setback	Center of Gravity
$H_u := 8 \cdot in$	$L_u := 18 \cdot in$	$W_u := 12 \cdot in$	$\Delta_u := 1.0 \cdot in$	$G_u := 6 \cdot in$

Batter

$$\omega := \operatorname{atan}\left(\frac{\Delta_u}{H_u}\right)$$

$\omega = 7.125 \cdot deg$

Infilled Unit Weight

$\gamma_u := 120 \cdot pcf$

Hinge Height

$$H_h := \text{if}\left[\tan(\omega) = 0, H, \left[2 \cdot \frac{(W_u - G_u)}{\tan(\omega)}\right]\right] \Rightarrow H_h = 8\,ft$$

[Eq. 4-1]

Internal Interface Friction Angle

$$\delta_i := \frac{2}{3} \cdot \phi_i \qquad \delta_i = 21.33 \cdot deg$$

[Eq. 3-17]

Internal Active Earth Pressure

$$Ka_i := \frac{\cos(\phi_i + \omega)^2}{\cos(\omega)^2 \cdot \cos(\omega - \delta_i) \cdot \left[1 + \sqrt{\left(\frac{\sin(\phi_i + \delta_i) \cdot \sin(\phi_i - \beta)}{\cos(\omega - \delta_i) \cdot \cos(\omega + \beta)}\right)}\right]^2}$$

[Eq. 3-11] $Ka_i = 0.228$

External Interface Friction Angle

$$\delta_e := \text{if}(\phi_i > \phi_e, \phi_e, \phi_i) \qquad \delta_e = 26 \cdot deg$$

[Eq. 3-16]

External Active Earth Pressure

$$Ka_e := \frac{\cos(\phi_e + \omega)^2}{\cos(\omega)^2 \cdot \cos(\omega - \delta_e) \cdot \left[1 + \sqrt{\left[\frac{\sin(\phi_e + \delta_e) \cdot \sin((\phi_e - \beta))}{\cos(\omega - \delta_e) \cdot \cos(\omega + \beta)}\right]}\right]^2}$$

[Eq. 3-11] $Ka_e = 0.292$

Orientation of Critical Internal Failure Surface

$$\alpha_i := \operatorname{atan}\left[\frac{-\tan(\phi_i - \beta) + \sqrt{(\tan(\phi_i - \beta)) \cdot (\tan(\phi_i - \beta) + \cot(\phi_i + \omega)) \cdot (1 + \tan(\delta_i - \omega) \cdot \cot(\phi_i + \omega))}}{1 + \tan(\delta_i - \omega) \cdot (\tan(\phi_i - \beta) + \cot(\phi_i + \omega))}\right] + \phi_i$$

[Eq. 3-14]

$\alpha_i = 54.469 \cdot deg$

Orientation of Critical External Failure Surface

$$\alpha_e := \operatorname{atan}\left[\frac{-\tan(\phi_e - \beta) + \sqrt{\tan(\phi_e - \beta) \cdot (\tan(\phi_e - \beta) + \cot(\phi_e + \omega)) \cdot (1 + \tan(\delta_e - \omega) \cdot \cot(\phi_e + \omega))}}{1 + \tan(\delta_e - \omega) \cdot (\tan(\phi_e - \beta) + \cot(\phi_e + \omega))}\right] + \phi_e$$

[Eq. 3-14]

$\alpha_e = 49.572 \cdot deg$

External Stability Analysis

Sliding

Given

$$1.5 = \frac{\min\left[\begin{matrix} C_{dse}\cdot\left[q_d\cdot\left[(L-W_u-Z)+\frac{(L-W_u-Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1-\tan(\beta)\cdot\tan(\omega)}\right]+L\cdot\gamma_e\cdot H + \frac{1}{2}\cdot\gamma_e\cdot(L-W_u-Z)\cdot\left[(L-W_u-Z)+\frac{(L-W_u-Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1-\tan(\beta)\cdot\tan(\omega)}\right]\cdot\tan(\beta)\right]\cdot\tan(\phi_e) \\ C_{dse}\cdot\left[q_d\cdot\left[(L-W_u-Z)+\frac{(L-W_u-Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1-\tan(\beta)\cdot\tan(\omega)}\right]+L\cdot\gamma_e\cdot H + \frac{1}{2}\cdot\gamma_e\cdot(L-W_u-Z)\cdot\left[(L-W_u-Z)+\frac{(L-W_u-Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1-\tan(\beta)\cdot\tan(\omega)}\right]\cdot\tan(\beta)\right]\cdot\tan(\phi_d) \\ C_{dse}\cdot\left[c_f\cdot L+\left[q_d\cdot\left[(L-W_u-Z)+\frac{(L-W_u-Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1-\tan(\beta)\cdot\tan(\omega)}\right]+L\cdot\gamma_e\cdot H + \frac{1}{2}\cdot\gamma_e\cdot(L-W_u-Z)\cdot\left[(L-W_u-Z)+\frac{(L-W_u-Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1-\tan(\beta)\cdot\tan(\omega)}\right]\cdot\tan(\beta)\right]\cdot\tan(\phi_f)\right]\end{matrix}\right]}{\left[\frac{1}{2}\cdot Ka_e\cdot\gamma_e\cdot\left[H+\left[(L-W_u-Z)+\frac{(L-W_u-Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1-\tan(\beta)\cdot\tan(\omega)}\right]\cdot\tan(\beta)\right]^2\cdot\cos(\delta_e-\omega)\right] + (q_d+q_l)\cdot Ka_e\cdot\left[H+\left[(L-W_u-Z)+\frac{(L-W_u-Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1-\tan(\beta)\cdot\tan(\omega)}\right]\cdot\tan(\beta)\right]\cdot\cos(\delta_e-\omega)}$$

$L_{sliding} := \text{Find}(L)$ $\quad L_{sliding} = 3.324\ \text{ft}$

Overturning

Given

$$2.0 = \frac{\left[(L\cdot\gamma_e\cdot H)\cdot\left[\frac{1}{2}\cdot(L+H\cdot\tan(\omega))\right]\right] + \left[\frac{1}{2}\cdot\gamma_e\cdot(L-W_u-Z)\cdot\left[(L-W_u-Z)+\frac{(L-W_u-Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1-\tan(\beta)\cdot\tan(\omega)}\right]\cdot\tan(\beta)\right]\cdot\left[\left[H\cdot\tan(\omega)+W_u+Z+\frac{2}{3}\cdot(L-W_u-Z)\right]\cdots + q_d\cdot\left[(L-W_u-Z)+\frac{(L-W_u-Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1-\tan(\beta)\cdot\tan(\omega)}\right]\cdot\left[\frac{Z+\left[(L-W_u-Z)+\frac{(L-W_u-Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1-\tan(\beta)\cdot\tan(\omega)}\right]}{2}+H\cdot\tan(\omega)+\cdots\right.}{\left[\frac{1}{2}\cdot Ka_e\cdot\gamma_e\cdot\left[H+\left[(L-W_u-Z)+\frac{(L-W_u-Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1-\tan(\beta)\cdot\tan(\omega)}\right]\cdot\tan(\beta)\right]^2\cdot\cos(\delta_e-\omega)\right]\cdot\left[\frac{1}{3}\cdot\left[H+\left[(L-W_u-Z)+\frac{(L-W_u-Z)\cdot\tan(\beta)\cdot\text{ta}\cdots}{1-\tan(\beta)\cdot\tan(\omega)}\cdots\right. + (q_d+q_l)\cdot Ka_e\cdot\left[\left[H+\left[(L-W_u-Z)+\frac{(L-W_u-Z)\cdot\tan(\beta)\cdot\tan(\omega)}{1-\tan(\beta)\cdot\tan(\omega)}\right]\cdot\tan(\beta)\right]\cdot\cos(\delta_e-\omega)\right]\cdot\left[\frac{1}{2}\cdot\left[H+\left[(L-W_u-Z)+\frac{(L-W_u-Z)\cdot\tan(\cdots}{1-\tan(\beta)\cdot\text{ta}\cdots}\right.\right.}$$

$L_{overturning} := \text{Find}(L)$ $\quad L_{overturning} = 2.851\ \text{ft}$

$$L := \max\left(\begin{pmatrix} L_{sliding} \\ L_{overturning} \\ 0.6\cdot H\end{pmatrix}\right)$$

$L = 4.2\ \text{ft}$

Based on Overturning and Sliding: $L := 5.0\cdot\text{ft}$ *(Round up L)*

Eccentricity

$L' := L - W_u - Z$ | $L' = 3 \cdot ft$ | [Fig. 2-10] [Eq. 5-1]

$L'' := \frac{(L - W_u - Z) \cdot \tan(\beta) \cdot \tan(\omega)}{1 - \tan(\beta) \cdot \tan(\omega)}$ | $L'' = 0\ ft$ | [Fig. 2-10] [Eq. 5-2]

$L_\beta := L' + L''$ | $L_\beta = 3\ ft$ | [Fig. 2-10] [Eq. 5-3]

$h := L_\beta \cdot \tan(\beta)$ | $h = 0\ ft$ | [Fig. 2-10] [Eq. 5-4]

$W_{ri} := L \cdot \gamma_i \cdot H$ | $W_{ri} = 3850 \cdot plf$ | [Eq. 5-15]

$X_{ri} := \frac{1}{2} \cdot (L + H \cdot \tan(\omega))$ | $X_{ri} = 2.938\ ft$ | [Eq. 5-19]

$W_{r\beta} := \frac{1}{2} \cdot \gamma_i \cdot (L' - Z) \cdot h$ | $W_{r\beta} = 0 \cdot plf$ | [Eq. 5-16]

$X_{r\beta} := H \cdot \tan(\omega) + W_u + \frac{2}{3} \cdot L_\beta + Z$ | $X_{r\beta} = 4.875\ ft$ | [Eq. 5-20]

$X_{q\beta} := \frac{Z + L_\beta}{2} + [(H + h) \cdot \tan(\omega)] + W_u$ | $X_{q\beta} = 3.875\ ft$ | [Eq. 5-21]

Actual Heigth of wall:

$H_s := (H + h)$ | $H_s = 7\ ft$

Earth Pressures:

$P_{sH} := \left[\frac{1}{2} \cdot Ka_e \cdot \gamma_e \cdot (H + h)^2 \cdot \cos(\delta_e - \omega)\right]$ | $P_{sH} = 811.403 \cdot plf$ | [Eq. 5-6]

$Y_s := \frac{1}{3} \cdot (H + h)$ | $Y_s = 2.333\ ft$ | [Eq. 5-9]

$P_{qH} := (q_d + q_l) \cdot Ka_e \cdot (H + h) \cdot \cos(\delta_e - \omega)$ | $P_{qH} = 96.596 \cdot plf$ | [Eq. 5-8]

$Y_q := \frac{1}{2} \cdot (H + h)$ | $Y_q = 3.5\ ft$ | [Eq. 5-10]

$$e := \frac{\left[P_{sH} \cdot Y_s + P_{qH} \cdot Y_q - W_{ri} \cdot \left(X_{ri} - \frac{L}{2}\right) - W_{r\beta} \cdot \left(X_{r\beta} - \frac{L}{2}\right) - q_d \cdot (L_\beta) \cdot \left(X_{q\beta} - \frac{L}{2}\right)\right]}{W_{ri} + W_{r\beta} + q_d \cdot (L_\beta)}$$

$e = 0.1421\ ft$ | [Eq. 5-25]

Check $e := \text{if}(e \le 0, 0.075L, e)$ | $e = 0.142\ ft$

Surcharge is applied over: $(L' + L'') = 3\ ft$ | $B := L - 2 \cdot e$ | $B = 4.716\ ft$ | [Eq. 5-24]

Bearing Capacity

$Q_a := \frac{\left[W_{ri} + W_{r\beta} + (q_d + q_l)\cdot(L' + L'')\right]}{B}$ $\quad Q_a = 848.203\cdot psf$

$N_q := \tan\left(45\cdot deg + \frac{\phi_f}{2}\right)^2 \cdot \exp(\pi\cdot\tan(\phi_f))$ $\quad N_q = 11.854$ [Fig. 4-5]

$N_c := if[\phi_f = 0, 5.14, (N_q - 1)\cdot\cot(\phi_f)]$ $\quad N_c = 22.254$ [Fig. 4-5]

$N_\gamma := 2\cdot(N_q + 1)\cdot\tan(\phi_f)$ $\quad N_\gamma = 12.539$ [Fig. 4-5]

$Q_{ult} := c_f\cdot N_c + \frac{1}{2}\cdot\gamma_f\cdot B\cdot N_\gamma + \gamma_f\cdot H_{emb}\cdot N_q$ $\quad Q_{ult} = 4500.954\cdot psf$ [Eq. 4-20]

$FS_{bearing} := \frac{Q_{ult}}{Q_a}$ $\quad FS_{bearing} = 5.306$ [Eq. 4-19]

Internal Stability

Reinforcement Properties

Geogrid Design Data

Backfill Soil $\quad Type := (gravel)$

	1	2	3	4	5	6	7	8	9
$Type^T =$	411	834	1199	1336	2004	2508	3011	3873	7914
$inter^T =$	1145	1145	1145	1145	1145	1145	0		
$slope^T =$	38	38	38	38	38	38	0		
$maxc^T =$	4540	4540	4540	4540	4540	4540	0		

Geogrid Number $\quad GN1 := 4 \quad GN2 := 2$

$x := 4..1$ x is the number of grids at the top of the wall of a different type

$T_a := Type_{GN1}\cdot plf$ $\quad T_a = 1336\cdot plf$ $\quad T_{a2} := Type_{GN2}\cdot plf$ $\quad T_{a2} = 834\cdot plf$

$a_{cs} := inter_{GN1}\cdot plf$ $\quad a_{cs} = 1145\cdot plf$ | $\lambda_{cs} := slope_{GN1}\cdot deg$ $\quad \lambda_{cs} = 38\cdot deg$ | $V_{csmax} := maxc_{GN1}\cdot plf$ $\quad V_{csmax} = 4540\cdot plf$

$a_{cs2} := inter_{GN2}\cdot plf$ $\quad a_{cs2} = 1145\cdot plf$ | $\lambda_{cs2} := slope_{GN2}\cdot deg$ $\quad \lambda_{cs2} = 38\cdot deg$ | $V_{csmax2} := maxc_{GN2}\cdot plf$ $\quad V_{csmax2} = 4540\cdot plf$

Tension in Geogrid

Number of Grids: $n_g := 2$

Grig Spacing (ft): $Spacing1 := 2$ $Spacing2 := 1.67$

# of grids for that spacing: $n_1 := 2$ $n_2 := 0$

Make all zero when using one geogrid

Depth of first grid (ft): $h_1 := 2.33$

Length of grids: $L_1 := 5.0$ $L_2 := 5.0$ $L_r := \frac{L}{ft}$

Note: make sure that the elevations don't excide the height of the wall (H) $H = 7\,ft$

$top := length(E)$ $p := 2..top$ $top = 2$

$grids := length(E)$ $n := 1..top$ $l := 1..grids - 1$

$E = \begin{pmatrix} 2.33 \\ 4.33 \end{pmatrix} ft$

$T_{a_x} := T_{a2}$ $T_{a_x} = \begin{pmatrix} 834 \\ 834 \\ 834 \\ 834 \end{pmatrix} \cdot plf$

$T_a := \overrightarrow{\frac{L \cdot T_a}{L}}$ $T_a = \begin{pmatrix} 1336 \\ 1336 \end{pmatrix} \cdot plf$

$L = \begin{pmatrix} 5 \\ 5 \end{pmatrix} ft$

$T_a^T = (834\ \ 834\ \ 834\ \ 834) \cdot plf$

$D_p := \frac{E_{p-1} + E_p}{2}$ $D_1 := 0 \cdot ft$ $D_{grids+1} := H$

$D^T = (0\ \ 3.33\ \ 7)\,ft$

Total Applied Tensile Strength in the Geosynthetic reinf.:

$$F_{g_n} := \int_{D_n}^{D_{(n+1)}} \left(\gamma_i \cdot D + q_l + q_d\right) \cdot Ka_i \cdot \cos\left(\delta_i - \omega\right) dD$$ [Eq. 5-36]

$F_g^T = (171.232\ \ 500.34) \cdot plf$

Safety factor:

$FS_{ten_n} := \frac{T_{a_n}}{F_{g_n}}$ $FS_{ten}^T = (4.871\ \ 1.667)$

Pullout Capacity

Anchorage Length of Geosynthetic

$$La_n := L_n - W_u - \left[(H+h) - E_n\right]\cdot\tan\left(90\cdot deg - \alpha_i\right) + \left[(H+h) - E_n\right]\cdot\tan(\omega)$$ [Eq. 5-46]

$La^T = (1.249 \quad 2.427)\ ft$

Note: If the anchorage length is less than 1ft then there is not enough embedment length and it has to be increased. Note that in some cases it might just be the top two grids.

Average Depth of overburden on Anchorage length

$$d_n := E_n + \left[\left(H - E_n\right)\cdot\tan\left(90\cdot deg - \alpha_i\right) + \frac{La_n}{2} - \left(Z + H\cdot\tan(\omega) - \Delta_u\right)\right]\cdot\tan(\beta)$$ [Eq. 5-47]

$d^T = (2.33 \quad 4.33)\ ft$

Anchorage Capacity

$$AC_n := 2\cdot La_n\cdot C_i\cdot\left(d_n\cdot\gamma_i + q_d\right)\cdot\tan\left(\phi_i\right)$$ [Eq. 5-45]

$AC^T = (280.011 \quad 1011.301)\cdot plf$

$F_g^T = (171.232 \quad 500.34)\cdot plf$

Safety Factor

$$FS_{po} := \overrightarrow{\frac{AC}{F_g}}$$ [Eq. 5-44]

$FS_{po}^T = (1.635 \quad 2.021)$

Internal Sliding

Reduced reinforcement length

$$\Delta L_{l+1} := \begin{cases} \left[\left(E_{l+1} - E_l\right)\cdot\left(\dfrac{1}{\tan\left(\alpha_e\right)} - \tan(\omega)\right)\right] & \text{if } n_g > 2 \\ Spacing1\cdot ft\cdot\left(\dfrac{1}{\tan\left(\alpha_e\right)} - \tan(\omega)\right) & \text{if } n_g = 2 \\ 0 & \text{if } n_g = 1 \end{cases}$$ [Eq. 5-51]

$\Delta L^T = (0 \quad 1.454)\ ft$

$$L'_{s_n} := L_n - W_u - \Delta L_n$$ [Eq. 5-50]

$L'_s{}^T = (4 \quad 2.546)\ ft$

Length of sloping ground

$$L_{s\beta_n} := L'_{s_n} + \frac{\left(L'_{s_n} - W_u\right)\cdot\tan(\beta)\cdot\tan(\omega)}{1 - \tan(\beta)\cdot\tan(\omega)} - Z$$ [Eq. 5-53 & 5-52]

$L_{s\beta}^{T} = (3 \quad 1.546)\ ft$

Height of slope above crest of wall

$h'_n := L_{s\beta_n} \cdot \tan(\beta)$ [Eq. 5-54]

$h'^{T} = (0 \quad 0)\ ft$

Weight of reduced reinforced area

$W'_{ri_n} := L'_{s_n} \cdot E_n \cdot \gamma_i$ [Eq. 5-55]

$W'_{ri}^{T} = (1025 \quad 1213) \cdot plf$

Weight of wedge beyond reinforced soil zone

$W'_{r\beta_n} := \frac{1}{2} \cdot \left(\left(L_{s\beta_n} \cdot h'_n \right) \right) \cdot \gamma_i$ [Eq. 5-56]

$W'_{r\beta}^{T} = (0 \quad 0) \cdot plf$

Friction developed by weight

$R'_{s_n} := C_{dsi} \cdot \left[q_d \cdot \left(L_{s\beta_n} + Z \right) + W'_{ri_n} + W'_{r\beta_n} \right] \cdot \tan\left(\phi_i\right)$ [Eq. 5-49]

$R'_{s}^{T} = (512 \quad 606) \cdot plf$

Shear capacity of facing elements

$V_{u_n} := \min\left[V_{csmax}, a_{cs} + \left(\mathrm{if}\left(E_n > H_h, H_h, E_n\right) \cdot \gamma_u \cdot W_u \right) \cdot \tan\left(\lambda_{cs}\right) \right]$ [Eq. 4-25]

$V_{u}^{T} = (1363 \quad 1551) \cdot plf$

Driving Forces

From retained soil

$P_{s_n} := \left[\frac{1}{2} \cdot Ka_e \cdot \gamma_e \cdot \left(E_n + h'_n \right)^2 \cdot \cos\left(\delta_e - \omega \right) \right]$ [Eq. 5-6]

$P_{s}^{T} = (90 \quad 310) \cdot plf$

From surcharge

$P_{q_n} := \left(q_d + q_l \right) \cdot Ka_e \cdot \left(E_n + h'_n \right) \cdot \cos\left(\delta_e - \omega \right)$ [Eq. 5-8]

$P_{q}^{T} = (32 \quad 60) \cdot plf$

Factor of safety against internal sliding

$P_{a_n} := P_{s_n} + P_{q_n}$ [Eq. 5-11]

$P_{a}^{T} = (122 \quad 370) \cdot plf$

$FS_{sl_n} := \frac{R'_{s_n} + V_{u_n}}{\left(P_{a_n} \right)}$ [Eq. 5-48]

$FS_{sl}^{T} = (15.37 \quad 5.827)$

Local Stability of Facing Units

Facing Connection Strength

$$T_{conn_n} := \min\left[V_{csmax_n}, a_{cs_n} + \left(\text{if}\left(E_n > H_h, H_h, E_n\right)\cdot\gamma_u\cdot W_u\right)\cdot\tan\left(\lambda_{cs_n}\right)\right]$$ [Eq. 5-59]

$$T_{conn}^T = (1363 \quad 1551)\cdot plf$$

$$FS_{conn_n} := \frac{T_{conn_n}}{F_{g_n}}$$

$$FS_{conn}^T = (7.963 \quad 3.1)$$

Resistance to Bulging

Shear capacity at each geogrid layer

$$V_{u_n} := \min\left[V_{csmax}, a_{cs} + \left(\text{if}\left(E_n > H_h, H_h, E_n\right)\cdot\gamma_u\cdot W_u\right)\cdot\tan\left(\lambda_{cs}\right)\right]$$ [Eq. 4-25]

$$V_u^T = (1363 \quad 1551)\cdot plf$$

Driving Force at each geogrid layer

$$P_{a_n} := \left[\frac{1}{2}\cdot Ka_i\cdot\gamma_i\cdot\left(E_n\right)^2\cdot\cos\left(\delta_i - \omega\right)\right] + \left(q_d + q_l\right)\cdot Ka_i\cdot\left(E_n\right)\cdot\cos\left(\delta_i - \omega\right)$$ [Eq. 5-11]

$$P_a^T = (92 \quad 275)\cdot plf$$

Sum of tension in reinforcement layers above layer being considered

$$F_{n+1} := \sum_{i=1}^{n} F_{g_i}$$

$$F^T = (0 \quad 171 \quad 672)\cdot plf$$

$$FS_{sc_n} := \frac{V_{u_n}}{P_{a_n} - F_n}$$ [Eq. 5-61]

$$FS_{sc}^T = (14.893 \quad 14.921)$$

Maximum unreinforced height of SRW units

$y := E_1 = 2.33\ ft$ $\quad q_l := 0\cdot psf$

Moment equilibrium

Driving Moments

$$P'_s := \left[\frac{1}{2}\cdot Ka_i\cdot\gamma_i\cdot(y)^2\cdot\cos\left(\delta_i - \omega\right)\right]$$ [Eq. 4-5]

$$P'_s = 65.854\cdot plf$$

$P'_q := (q_d + q_l) \cdot Ka_i \cdot (y) \cdot \cos(\delta_i - \omega)$ [Eq. 4-6] $P'_q = 0 \cdot plf$

$P'_a := P'_s + P'_q$ [Eq. 4-4] $P'_a = 65.854 \cdot plf$

$Y'_s := \frac{1}{3} \cdot y$ [Eq. 4-7] $Y'_s = 0.777\ ft$

$Y'_q := \frac{1}{2} \cdot y$ [Eq. 4-8] $Y'_q = 1.17\ ft$

$M'_o := P'_s \cdot Y'_s + P'_q \cdot Y'_q$ [Eq. 4-17] $M'_o = 51.15 \cdot lbf$

Resisting Moments

$W'_w := y \cdot \gamma_u \cdot W_u$ [Eq. 4-9] $W'_w = 279.6 \cdot plf$

$X'_w := G_u + \frac{1}{2} \cdot (y) \cdot \tan(\omega)$ [Eq. 4-16] $X'_w = 0.646\ ft$

$M'_r := W'_w \cdot X'_w$ [Eq. 4-15] $M'_r = 180.517\ ft \cdot plf$

$FS_{ot} := \frac{M'_r}{M'_o}$ [Eq. 4-14] $FS_{ot} = 3.529$

Factor of Safety against Shear failure

$V'_u := a_{cs} + W'_w \cdot \tan(\lambda_{cs})$ [Eq. 4-25] $V'_u = \begin{pmatrix} 1363.447 \\ 1363.447 \\ \ldots \end{pmatrix}$

$FS_{sh} := \frac{V'_u}{P'_a}$ [Eq. 4-27] $FS_{sh} = \begin{pmatrix} 20.704 \\ 20.704 \\ 20.704 \\ 20.704 \end{pmatrix}$

Summary

Wall Height $H = 7\ ft$

Unreinforced Stability $FS_{ot} = 3.529$ $FS_{bearing} = 5.306$

Applied Bearing Stress $Q_a = 848 \cdot psf$

Grid Elevation $E_n =$ (ft)	Geogrid Length $L_n =$ (ft)	Tensile Force $\frac{Fg_n}{plf} =$	Geogrid Strength $\frac{Ta_n}{plf} =$	Anch. Length $La_n =$ (ft)	Anch. Capacity $\frac{AC_n}{plf} =$	FS Grid Tension **(1.0)** $FS_{ten_n} =$	FS Pullout **(1.5)** $FS_{po_n} =$	FS Int Sliding **(1.5)** $FS_{sl_n} =$	FS Conn **(1.5)** $FS_{conn_n} =$	FS Bulging **(1.5)** $FS_{sc_n} =$
2.33	5	171	834	1.25	280	4.87	1.64	15.37	7.96	14.89
4.33	5	500	834	2.43	1011	1.67	2.02	5.83	3.1	14.92