Woodside Ridge

Lots 152, 153 & 154
Lee's Summit, Missouri

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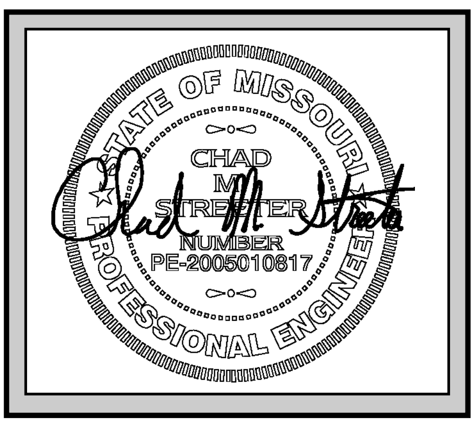
Reinforced Soil Retaining Wall Design



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Segmental Retaining Wall Design Calculations per NCMA

Wall Geometry

Height	Backslope	Dead Load	Live Load	Distance to Slope	Wall below grade at toe
$H := 11.0 \cdot ft$	$\beta := 10.0 \cdot deg$	$q_d := 0 \cdot psf$	$q_l := 0 \cdot psf$	$Z := 1.0 \cdot ft$	$H_{emb} := .67 \cdot ft$

Soil Properties

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

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

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

$$\omega = 7.125 \cdot deg$$

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] $Ka_i = 0.256$

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] $Ka_e = 0.339$

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]

$\alpha_i = 52.419 \cdot deg$

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]

$\alpha_e = 46.452 \cdot deg$

External Stability Analysis

Sliding

Given

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

$L_{sliding} := \text{Find}(L)$ $\quad$ $L_{sliding} = 6.035\ ft$

Overturning

Given

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

$L_{overturning} := \text{Find}(L)$ $\quad$ $L_{overturning} = 4.73\ ft$

$L := \max\left(\begin{pmatrix} L_{sliding} \\ L_{overturning} \\ 0.6\cdot H \end{pmatrix}\right)$ $\quad$ $L = 6.6\ ft$

Based on Overturning and Sliding: $L := 8.0\cdot ft$ *(Round up L)*

Eccentricity

$L' := L - W_u - Z$ $\quad L' = 6 \cdot ft$ [Fig. 2-10] [Eq. 5-1]

$L'' := \frac{(L - W_u - Z) \cdot \tan(\beta) \cdot \tan(\omega)}{1 - \tan(\beta) \cdot \tan(\omega)}$ $\quad L'' = 0.135\ ft$ [Fig. 2-10] [Eq. 5-2]

$L_\beta := L' + L''$ $\quad L_\beta = 6.135\ ft$ [Fig. 2-10] [Eq. 5-3]

$h := L_\beta \cdot \tan(\beta)$ $\quad h = 1.082\ ft$ [Fig. 2-10] [Eq. 5-4]

$W_{ri} := L \cdot \gamma_i \cdot H$ $\quad W_{ri} = 9680 \cdot plf$ [Eq. 5-15]

$X_{ri} := \frac{1}{2} \cdot (L + H \cdot \tan(\omega))$ $\quad X_{ri} = 4.688\ ft$ [Eq. 5-19]

$W_{r\beta} := \frac{1}{2} \cdot \gamma_i \cdot (L' - Z) \cdot h$ $\quad W_{r\beta} = 297.497 \cdot plf$ [Eq. 5-16]

$X_{r\beta} := H \cdot \tan(\omega) + W_u + \frac{2}{3} \cdot L_\beta + Z$ $\quad X_{r\beta} = 7.465\ ft$ [Eq. 5-20]

$X_{q\beta} := \frac{Z + L_\beta}{2} + [(H + h) \cdot \tan(\omega)] + W_u$ $\quad X_{q\beta} = 6.078\ ft$ [Eq. 5-21]

Actual Heigth of wall:

$H_s := (H + h)$ $\quad H_s = 12.082\ ft$

Earth Pressures:

$P_{sH} := \left[\frac{1}{2} \cdot Ka_e \cdot \gamma_e \cdot (H + h)^2 \cdot \cos(\delta_e - \omega)\right]$ $\quad P_{sH} = 2809.743 \cdot plf$ [Eq. 5-6]

$Y_s := \frac{1}{3} \cdot (H + h)$ $\quad Y_s = 4.027\ ft$ [Eq. 5-9]

$P_{qH} := (q_d + q_l) \cdot Ka_e \cdot (H + h) \cdot \cos(\delta_e - \omega)$ $\quad P_{qH} = 0 \cdot plf$ [Eq. 5-8]

$Y_q := \frac{1}{2} \cdot (H + h)$ $\quad Y_q = 6.041\ ft$ [Eq. 5-10]

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

$e = 0.3638\ ft$ [Eq. 5-25]

Check $\quad e := \text{if}(e \le 0, 0.075L, e)$ $\quad e = 0.364\ ft$

Surcharge is applied over: $(L' + L'') = 6.135\ ft$ $\quad B := L - 2 \cdot e$ $\quad B = 7.272\ ft$ [Eq. 5-24]

Bearing Capacity

$$Q_a := \frac{\left[W_{ri} + W_{r\beta} + (q_d + q_l)\cdot(L' + L'')\right]}{B}$$ $Q_a = 1371.964 \cdot psf$

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

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

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

$$Q_{ult} := c_f\cdot N_c + \frac{1}{2}\cdot\gamma_f\cdot B\cdot N_\gamma + \gamma_f\cdot H_{emb}\cdot N_q$$ $Q_{ult} = 6424.334\cdot psf$ [Eq. 4-20]

$$FS_{bearing} := \frac{Q_{ult}}{Q_a}$$ $FS_{bearing} = ▮$ [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): $h_1 := 3.67$

Length of grids: $L_1 := 8.0$ $L_2 := 8.0$ $L_r := \frac{L}{ft}$

Note: make sure that the elevations don't excide the height of the wall (H) $H = 11\,ft$

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

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

$$E = \begin{pmatrix} 3.67 \\ 5.67 \\ 7.67 \\ 9.67 \end{pmatrix} ft$$

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

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

$$L = \begin{pmatrix} 8 \\ 8 \\ 8 \\ 8 \end{pmatrix} ft$$

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

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

$$D^T = (0 \;\; 4.67 \;\; 6.67 \;\; 8.67 \;\; 11)\,ft$$

Total Applied Tensile Strength in the Geosynthetic reinf.:

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

$$F_g^T = (297.624 \;\; 309.512 \;\; 418.687 \;\; 625.453) \cdot plf$$

Safety factor:

$$FS_{ten_n} := \frac{T_{a_n}}{F_{g_n}} \qquad FS_{ten}^T = (2.802 \;\; 2.695 \;\; 1.992 \;\; 1.333)$$

Pullout Capacity

Anchorage Length of Geosynthetic

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

$$La^T = (1.578 \quad 2.867 \quad 4.156 \quad 5.445)\ ft$$

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

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

$$d^T = (4.4 \quad 6.242 \quad 8.084 \quad 9.926)\ ft$$

Anchorage Capacity

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

$$AC^T = (668.05 \quad 1722.134 \quad 3233.307 \quad 5201.567)\cdot plf$$

$$F_g^T = (297.624 \quad 309.512 \quad 418.687 \quad 625.453)\cdot plf$$

Safety Factor

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

$$FS_{po}^T = (2.245 \quad 5.564 \quad 7.722 \quad 8.316)$$

Internal Sliding

Reduced reinforcement length

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

$$\Delta L^T = (0 \quad 1.651 \quad 1.651 \quad 1.651)\ ft$$

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

$$L'^T_s = (7 \quad 5.349 \quad 5.349 \quad 5.349)\ ft$$

Length of sloping ground

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

$L_{s\beta}^{T} = (6.135\ \ 4.447\ \ 4.447\ \ 4.447)\ ft$

Height of slope above crest of wall

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

$h'^{T} = (1.082\ \ 0.784\ \ 0.784\ \ 0.784)\ ft$

Weight of reduced reinforced area

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

$W'_{ri}^{T} = (2826\ \ 3336\ \ 4513\ \ 5690) \cdot plf$

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]

$W'_{r\beta}^{T} = (365.04\ \ 191.78\ \ 191.78\ \ 191.78) \cdot plf$

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]

$R'_{s}^{T} = (1595\ \ 1764\ \ 2352\ \ 2940) \cdot plf$

Shear capacity of facing elements

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

$V_{u}^{T} = (1489\ \ 1677\ \ 1864\ \ 1895) \cdot plf$

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]

$P_{s}^{T} = (435\ \ 802\ \ 1376\ \ 2104) \cdot plf$

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]

$P_{q}^{T} = (0\ \ 0\ \ 0\ \ 0) \cdot plf$

Factor of safety against internal sliding

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

$P_{a}^{T} = (435\ \ 802\ \ 1376\ \ 2104) \cdot plf$

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

$FS_{sl}^{T} = (7.096\ \ 4.29\ \ 3.064\ \ 2.298)$

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]

$$T_{conn}^T = (1489\ \ 1677\ \ 1864\ \ 1895)\cdot plf$$

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

$$FS_{conn}^T = (5.003\ \ 5.417\ \ 4.452\ \ 3.03)$$

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]

$$V_u^T = (1489\ \ 1677\ \ 1864\ \ 1895)\cdot plf$$

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]

$$P_a^T = (184\ \ 439\ \ 803\ \ 1276)\cdot plf$$

Sum of tension in reinforcement layers above layer being considered

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

$$F^T = (0\ \ 298\ \ 607\ \ 1026\ \ 1651)\cdot plf$$

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

$$FS_{sc}^T = (8.101\ \ 11.881\ \ 9.525\ \ 7.572)$$

Maximum unreinforced height of SRW units

$y := E_1 = 3.67\,ft$ $q_l := 0\cdot psf$

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]

$$P'_s = 183.809\cdot plf$$

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

$P'_a := P'_s + P'_q$ [Eq. 4-4] $P'_a = 183.809 \cdot plf$

$Y'_s := \frac{1}{3} \cdot y$ [Eq. 4-7] $Y'_s = 1.223\ ft$

$Y'_q := \frac{1}{2} \cdot y$ [Eq. 4-8] $Y'_q = 1.84\ ft$

$M'_o := P'_s \cdot Y'_s + P'_q \cdot Y'_q$ [Eq. 4-17] $M'_o = 224.86 \cdot lbf$

Resisting Moments

$W'_w := y \cdot \gamma_u \cdot W_u$ [Eq. 4-9] $W'_w = 440.4 \cdot plf$

$X'_w := G_u + \frac{1}{2} \cdot (y) \cdot \tan(\omega)$ [Eq. 4-16] $X'_w = 0.729\ ft$

$M'_r := W'_w \cdot X'_w$ [Eq. 4-15] $M'_r = 321.217\ ft \cdot plf$

$FS_{ot} := \frac{M'_r}{M'_o}$ [Eq. 4-14] $FS_{ot} = 1.429$

Factor of Safety against Shear failure

$V'_u := a_{cs} + W'_w \cdot \tan(\lambda_{cs})$ [Eq. 4-25] $V'_u = \begin{pmatrix} 1489.078 \\ 1489.078 \\ \ldots \end{pmatrix} plf$

$FS_{sh} := \frac{V'_u}{P'_a}$ [Eq. 4-27] $FS_{sh} = \begin{pmatrix} 8.101 \\ 8.101 \\ 8.101 \\ 8.101 \end{pmatrix}$

Summary

Wall Height $H = 11\ ft$

Unreinforced Stability $FS_{ot} = 1.429$ $FS_{bearing} = 4.683$

Applied Bearing Stress $Q_a = 1372 \cdot psf$

Grid Elevation $E_n =$ (ft)	Geogrid Length $L_n =$ (ft)	Tensile Force $\frac{F_{g_n}}{plf} =$	Geogrid Strength $\frac{T_{a_n}}{plf} =$	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)** $FS_{sc_n} =$
3.67	8	298	834	1.58	668	2.8	2.24	7.1	5	8.1
5.67	8	310	834	2.87	1722	2.69	5.56	4.29	5.42	11.88
7.67	8	419	834	4.16	3233	1.99	7.72	3.06	4.45	9.53
9.67	8	625	834	5.45	5202	1.33	8.32	2.3	3.03	7.57

Segmental Retaining Wall Design Calculations per NCMA

Wall Geometry

Height	Backslope	Dead Load	Live Load	Distance to Slope	Wall below grade at toe
$H := 9.0 \cdot ft$	$\beta := 10.0 \cdot deg$	$q_d := 0 \cdot psf$	$q_l := 0 \cdot psf$	$Z := 1.0 \cdot ft$	$H_{emb} := .67 \cdot ft$

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

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

Internal Interface Friction Angle

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

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] $Ka_i = 0.256$

External Interface Friction Angle

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

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] $Ka_e = 0.339$

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]

$\alpha_i = 52.419 \cdot deg$

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]

$\alpha_e = 46.452 \cdot deg$

External Stability Analysis

Sliding

Given

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

$L_{sliding} := \text{Find}(L)$ $\quad$ $L_{sliding} = 4.885\ ft$

Overturning

Given

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

$L_{overturning} := \text{Find}(L)$ $\quad$ $L_{overturning} = 3.834\ ft$

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

Based on Overturning and Sliding: $L := 7.0\cdot ft$ *(Round up L)*

Eccentricity

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

$L'' := \frac{(L - W_u - Z) \cdot \tan(\beta) \cdot \tan(\omega)}{1 - \tan(\beta) \cdot \tan(\omega)}$ | $L'' = 0.113\ ft$ | [Fig. 2-10] [Eq. 5-2]

$L_\beta := L' + L''$ | $L_\beta = 5.113\ ft$ | [Fig. 2-10] [Eq. 5-3]

$h := L_\beta \cdot \tan(\beta)$ | $h = 0.902\ ft$ | [Fig. 2-10] [Eq. 5-4]

$W_{ri} := L \cdot \gamma_i \cdot H$ | $W_{ri} = 6930 \cdot plf$ | [Eq. 5-15]

$X_{ri} := \frac{1}{2} \cdot (L + H \cdot \tan(\omega))$ | $X_{ri} = 4.063\ ft$ | [Eq. 5-19]

$W_{r\beta} := \frac{1}{2} \cdot \gamma_i \cdot (L' - Z) \cdot h$ | $W_{r\beta} = 198.331 \cdot plf$ | [Eq. 5-16]

$X_{r\beta} := H \cdot \tan(\omega) + W_u + \frac{2}{3} \cdot L_\beta + Z$ | $X_{r\beta} = 6.533\ ft$ | [Eq. 5-20]

$X_{q\beta} := \frac{Z + L_\beta}{2} + [(H + h) \cdot \tan(\omega)] + W_u$ | $X_{q\beta} = 5.294\ ft$ | [Eq. 5-21]

Actual Heigth of wall:

$H_s := (H + h)$ | $H_s = 9.902\ ft$

Earth Pressures:

$P_{sH} := \left[\frac{1}{2} \cdot Ka_e \cdot \gamma_e \cdot (H + h)^2 \cdot \cos(\delta_e - \omega)\right]$ | $P_{sH} = 1887.145 \cdot plf$ | [Eq. 5-6]

$Y_s := \frac{1}{3} \cdot (H + h)$ | $Y_s = 3.301\ ft$ | [Eq. 5-9]

$P_{qH} := (q_d + q_l) \cdot Ka_e \cdot (H + h) \cdot \cos(\delta_e - \omega)$ | $P_{qH} = 0 \cdot plf$ | [Eq. 5-8]

$Y_q := \frac{1}{2} \cdot (H + h)$ | $Y_q = 4.951\ ft$ | [Eq. 5-10]

$e := \frac{\left[P_{sH} \cdot Y_s + P_{qH} \cdot Y_q - W_{ri} \cdot \left(X_{ri} - \frac{L}{2}\right) - W_{r\beta} \cdot \left(X_{r\beta} - \frac{L}{2}\right) - q_d \cdot (L_\beta) \cdot \left(X_{q\beta} - \frac{L}{2}\right)\right]}{W_{ri} + W_{r\beta} + q_d \cdot (L_\beta)}$ | $e = 0.2425\ ft$ | [Eq. 5-25]

Check $e := \text{if}(e \le 0, 0.075L, e)$ | $e = 0.243\ ft$

Surcharge is applied over: $(L' + L'') = 5.113\ ft$ $B := L - 2 \cdot e$ | $B = 6.515\ ft$ | [Eq. 5-24]

Bearing Capacity

$$Q_a := \frac{\left[W_{ri} + W_{r\beta} + \left(q_d + q_l\right)\cdot(L' + L'')\right]}{B}$$ $Q_a = 1094.148\cdot psf$

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

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

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

$$Q_{ult} := c_f\cdot N_c + \frac{1}{2}\cdot\gamma_f\cdot B\cdot N_\gamma + \gamma_f\cdot H_{emb}\cdot N_q$$ $Q_{ult} = 5854.474\cdot psf$ [Eq. 4-20]

$$FS_{bearing} := \frac{Q_{ult}}{Q_a}$$ $FS_{bearing} = 5.351$ [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: $n_g := 3$

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

# of grids for that spacing: $n_1 := 3$ $\quad$ $n_2 := 0$

Make all zero when using one geogrid

Depth of first grid (ft): $h_1 := 3.67$

Length of grids: $L_1 := 7.0$ $\quad$ $L_2 := 7.0$ $\quad$ $L_r := \frac{L}{ft}$

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

$top := length(E)$ $\quad$ $p := 2..top$ $\quad$ $top = 3$

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

$$E = \begin{pmatrix} 3.67 \\ 5.67 \\ 7.67 \end{pmatrix} ft$$

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

$$L = \begin{pmatrix} 7 \\ 7 \\ 7 \end{pmatrix} ft$$

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

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

$$D^T = (0 \quad 4.67 \quad 6.67 \quad 9)\,ft$$

Total Applied Tensile Strength in the Geosynthetic reinf.:

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

$$F_g^T = (297.624 \quad 309.512 \quad 498.264) \cdot plf$$

Safety factor:

$$FS_{ten_n} := \frac{T_{a_n}}{F_{g_n}} \qquad FS_{ten}^T = (2.802 \quad 2.695 \quad 1.674)$$

Pullout Capacity

Anchorage Length of Geosynthetic

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

$La^T = (1.983 \quad 3.272 \quad 4.562)\ ft$

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

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

$d^T = (4.208 \quad 6.05 \quad 7.893)\ ft$

Anchorage Capacity

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

$AC^T = (803.122 \quad 1905.307 \quad 3464.58)\cdot plf$

$F_g^T = (297.624 \quad 309.512 \quad 498.264)\cdot plf$

Safety Factor

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

$FS_{po}^T = (2.698 \quad 6.156 \quad 6.953)$

Internal Sliding

Reduced reinforcement length

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

$\Delta L^T = (0 \quad 1.651 \quad 1.651)\ ft$

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

$L'^T_s = (6 \quad 4.349 \quad 4.349)\ ft$

Length of sloping ground

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

$L_{s\beta}^{T} = (5.113\ \ 3.424\ \ 3.424)\ ft$

Height of slope above crest of wall

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

$h'^{T} = (0.902\ \ 0.604\ \ 0.604)\ ft$

Weight of reduced reinforced area

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

$W'_{ri}^{T} = (2422\ \ 2712\ \ 3669) \cdot plf$

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]

$W'_{r\beta}^{T} = (253.5\ \ 113.72\ \ 113.72) \cdot plf$

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]

$R'_{s}^{T} = (1338\ \ 1413\ \ 1891) \cdot plf$

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]

$V_{u}^{T} = (1489\ \ 1677\ \ 1864) \cdot plf$

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]

$P_{s}^{T} = (402\ \ 758\ \ 1318) \cdot plf$

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]

$P_{q}^{T} = (0\ \ 0\ \ 0) \cdot plf$

Factor of safety against internal sliding

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

$P_{a}^{T} = (402\ \ 758\ \ 1318) \cdot plf$

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

$FS_{sl}^{T} = (7.027\ \ 4.078\ \ 2.85)$

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]

$$T_{conn}^{T} = (1489 \quad 1677 \quad 1864)\cdot plf$$

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

$$FS_{conn}^{T} = (5.003 \quad 5.417 \quad 3.741)$$

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]

$$V_u^{T} = (1489 \quad 1677 \quad 1864)\cdot plf$$

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]

$$P_a^{T} = (184 \quad 439 \quad 803)\cdot plf$$

Sum of tension in reinforcement layers above layer being considered

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

$$F^{T} = (0 \quad 298 \quad 607 \quad 1105)\cdot plf$$

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

$$FS_{sc}^{T} = (8.101 \quad 11.881 \quad 9.525)$$

Maximum unreinforced height of SRW units

$y := E_1 = 3.67\ ft$ $\quad q_L := 0\cdot psf$

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]

$$P'_s = 183.809\cdot plf$$

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

$P'_a := P'_s + P'_q$ [Eq. 4-4] $P'_a = 183.809 \cdot plf$

$Y'_s := \frac{1}{3} \cdot y$ [Eq. 4-7] $Y'_s = 1.223\ ft$

$Y'_q := \frac{1}{2} \cdot y$ [Eq. 4-8] $Y'_q = 1.84\ ft$

$M'_o := P'_s \cdot Y'_s + P'_q \cdot Y'_q$ [Eq. 4-17] $M'_o = 224.86 \cdot lbf$

Resisting Moments

$W'_w := y \cdot \gamma_u \cdot W_u$ [Eq. 4-9] $W'_w = 440.4 \cdot plf$

$X'_w := G_u + \frac{1}{2} \cdot (y) \cdot \tan(\omega)$ [Eq. 4-16] $X'_w = 0.729\ ft$

$M'_r := W'_w \cdot X'_w$ [Eq. 4-15] $M'_r = 321.217\ ft \cdot plf$

$FS_{ot} := \frac{M'_r}{M'_o}$ [Eq. 4-14] $FS_{ot} = 1.429$

Factor of Safety against Shear failure

$V'_u := a_{cs} + W'_w \cdot \tan(\lambda_{cs})$ [Eq. 4-25] $V'_u = \begin{pmatrix} 1489.078 \\ 1489.078 \\ \ldots \end{pmatrix} plf$

$FS_{sh} := \frac{V'_u}{P'_a}$ [Eq. 4-27] $FS_{sh} = \begin{pmatrix} 8.101 \\ 8.101 \\ 8.101 \\ 8.101 \\ \ldots \end{pmatrix}$

Summary

Wall Height $H = 9\ ft$

Unreinforced Stability $FS_{ot} = 1.429$ $FS_{bearing} = 5.351$

Applied Bearing Stress $Q_a = 1094 \cdot psf$

Grid Elevation $E_n =$ (ft)	Geogrid Length $L_n =$ (ft)	Tensile Force $\frac{F_{g_n}}{plf} =$	Geogrid Strength $\frac{T_{a_n}}{plf} =$	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)** $FS_{sc_n} =$
3.67	7	298	834	1.98	803	2.8	2.7	7.03	5	8.1
5.67	7	310	834	3.27	1905	2.69	6.16	4.08	5.42	11.88
7.67	7	498	834	4.56	3465	1.67	6.95	2.85	3.74	9.53

Segmental Retaining Wall Design Calculations per NCMA

Wall Geometry

Height	Backslope	Dead Load	Live Load	Distance to Slope	Wall below grade at toe
$H := 7.0 \cdot ft$	$\beta := 10.0 \cdot deg$	$q_d := 0 \cdot psf$	$q_l := 0 \cdot psf$	$Z := 1.0 \cdot ft$	$H_{emb} := .67 \cdot ft$

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	Batter
$H_u := 8 \cdot in$	$L_u := 18 \cdot in$	$W_u := 12 \cdot in$	$\Delta_u := 1.0 \cdot in$	$G_u := 6 \cdot in$	$\omega := atan\left(\frac{\Delta_u}{H_u}\right)$

$\omega = 7.125 \cdot deg$

Infilled Unit Weight

$\gamma_u := 120 \cdot pcf$

Hinge Height

$$H_h := if\left[\tan(\omega) = 0, H, \left[2 \cdot \frac{(W_u - G_u)}{\tan(\omega)}\right]\right] \Rightarrow H_h = 8\ ft$$ [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] $Ka_i = 0.256$

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] $Ka_e = 0.339$

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]

$\alpha_i = 52.419 \cdot deg$

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]

$\alpha_e = 46.452 \cdot deg$

External Stability Analysis

Sliding

Given

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

$L_{sliding} := \text{Find}(L)$ $\quad L_{sliding} = 3.729\ \text{ft}$

Overturning

Given

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

$L_{overturning} := \text{Find}(L)$ $\quad L_{overturning} = 2.934\ \text{ft}$

$$L := \max\begin{pmatrix} L_{sliding} \\ L_{overturning} \\ 0.6\cdot H\end{pmatrix}$$ $\quad L = 4.2\ \text{ft}$

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]

$L'' := \frac{(L - W_u - Z) \cdot \tan(\beta) \cdot \tan(\omega)}{1 - \tan(\beta) \cdot \tan(\omega)}$ | $L'' = 0.068\ ft$ | [Fig. 2-10] [Eq. 5-2]

$L_\beta := L' + L''$ | $L_\beta = 3.068\ ft$ | [Fig. 2-10] [Eq. 5-3]

$h := L_\beta \cdot \tan(\beta)$ | $h = 0.541\ ft$ | [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]

$W_{r\beta} := \frac{1}{2} \cdot \gamma_i \cdot (L' - Z) \cdot h$ | $W_{r\beta} = 59.499 \cdot plf$ | [Eq. 5-16]

$X_{r\beta} := H \cdot \tan(\omega) + W_u + \frac{2}{3} \cdot L_\beta + Z$ | $X_{r\beta} = 4.92\ ft$ | [Eq. 5-20]

$X_{q\beta} := \frac{Z + L_\beta}{2} + [(H + h) \cdot \tan(\omega)] + W_u$ | $X_{q\beta} = 3.976\ ft$ | [Eq. 5-21]

Actual Heigth of wall:

$H_s := (H + h)$ | $H_s = 7.541\ ft$

Earth Pressures:

$P_{sH} := \left[\frac{1}{2} \cdot Ka_e \cdot \gamma_e \cdot (H + h)^2 \cdot \cos(\delta_e - \omega)\right]$ | $P_{sH} = 1094.585 \cdot plf$ | [Eq. 5-6]

$Y_s := \frac{1}{3} \cdot (H + h)$ | $Y_s = 2.514\ ft$ | [Eq. 5-9]

$P_{qH} := (q_d + q_l) \cdot Ka_e \cdot (H + h) \cdot \cos(\delta_e - \omega)$ | $P_{qH} = 0 \cdot plf$ | [Eq. 5-8]

$Y_q := \frac{1}{2} \cdot (H + h)$ | $Y_q = 3.77\ ft$ | [Eq. 5-10]

$e := \frac{\left[P_{sH} \cdot Y_s + P_{qH} \cdot Y_q - W_{ri} \cdot \left(X_{ri} - \frac{L}{2}\right) - W_{r\beta} \cdot \left(X_{r\beta} - \frac{L}{2}\right) - q_d \cdot (L_\beta) \cdot \left(X_{q\beta} - \frac{L}{2}\right)\right]}{W_{ri} + W_{r\beta} + q_d \cdot (L_\beta)}$ | $e = 0.2361\ ft$ | [Eq. 5-25]

Check | $e := if(e \le 0, 0.075L, e)$ | $e = 0.236\ ft$

Surcharge is applied over: $(L' + L'') = 3.068\ ft$ | $B := L - 2 \cdot e$ | $B = 4.528\ ft$ | [Eq. 5-24]

Bearing Capacity

$Q_a := \frac{\left[W_{ri} + W_{r\beta} + (q_d + q_l)\cdot(L' + L'')\right]}{B}$ $Q_a = 863.442 \cdot psf$

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

$Q_{ult} := c_f\cdot N_c + \frac{1}{2}\cdot\gamma_f\cdot B\cdot N_\gamma + \gamma_f\cdot H_{emb}\cdot N_q$ $Q_{ult} = 4359.481 \cdot psf$ [Eq. 4-20]

$FS_{bearing} := \frac{Q_{ult}}{Q_a}$ $FS_{bearing} = 5.049$ [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: $n_g := 3$

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

# of grids for that spacing: $n_1 := 3$ $n_2 := 0$

Make all zero when using one geogrid

Depth of first grid (ft): $h_1 := 3.67$

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) $H = 7\,ft$

$top := length(E)$ $p := 2..top$ $top = 3$

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

$$E = \begin{pmatrix} 3.67 \\ 5.67 \\ 7.67 \end{pmatrix} ft$$

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

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

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

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

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

$$D^T = (0 \quad 4.67 \quad 6.67 \quad 7)\,ft$$

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]

$$F_g^T = (297.624 \quad 309.512 \quad 61.563) \cdot plf$$

Safety factor:

$$FS_{ten_n} := \frac{T_{a_n}}{F_{g_n}} \qquad FS_{ten}^T = (2.802 \quad 2.695 \quad 13.547)$$

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]

$La^T = (1.505 \quad 2.794 \quad 4.083)$ 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]

$d^T = (3.939 \quad 5.781 \quad 7.623)$ 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]

$AC^T = (570.371 \quad 1554.313 \quad 2995.344)\cdot plf$

$F_g^T = (297.624 \quad 309.512 \quad 61.563)\cdot plf$

Safety Factor

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

$FS_{po}^T = (1.916 \quad 5.022 \quad 48.655)$

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]

$\Delta L^T = (0 \quad 1.651 \quad 1.651)$ ft

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

$L'_s{}^T = (4 \quad 2.349 \quad 2.349)$ 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]

$L_{s\beta}^{T} = (3.068 \quad 1.379 \quad 1.379)\ ft$

Height of slope above crest of wall

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

$h'^{T} = (0.541 \quad 0.243 \quad 0.243)\ ft$

Weight of reduced reinforced area

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

$W'_{ri}^{T} = (1615 \quad 1465 \quad 1982) \cdot plf$

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]

$W'_{r\beta}^{T} = (91.26 \quad 18.45 \quad 18.45) \cdot plf$

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]

$R'_{s}^{T} = (853 \quad 742 \quad 1000) \cdot plf$

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]

$V_{u}^{T} = (1489 \quad 1677 \quad 1864) \cdot plf$

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]

$P_{s}^{T} = (341 \quad 673 \quad 1205) \cdot plf$

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]

$P_{q}^{T} = (0 \quad 0 \quad 0) \cdot plf$

Factor of safety against internal sliding

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

$P_{a}^{T} = (341 \quad 673 \quad 1205) \cdot plf$

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

$FS_{sl}^{T} = (6.862 \quad 3.593 \quad 2.376)$

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]

$$T_{conn}^{T} = (1489\ \ 1677\ \ 1864)\cdot plf$$

$$FS_{conn_n} := \frac{T_{conn_n}}{F_{g_n}}$$ $$FS_{conn}^{T} = (5.003\ \ 5.417\ \ 30.28)$$

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]

$$V_u^{T} = (1489\ \ 1677\ \ 1864)\cdot plf$$

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]

$$P_a^{T} = (184\ \ 439\ \ 803)\cdot plf$$

Sum of tension in reinforcement layers above layer being considered

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

$$F^{T} = (0\ \ 298\ \ 607\ \ 669)\cdot plf$$

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

$$FS_{sc}^{T} = (8.101\ \ 11.881\ \ 9.525)$$

Maximum unreinforced height of SRW units

$y := E_1 = 3.67\ ft$ $q_l := 0\cdot psf$

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] $$P'_s = 183.809\cdot plf$$

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

$P'_a := P'_s + P'_q$ [Eq. 4-4] $P'_a = 183.809 \cdot plf$

$Y'_s := \frac{1}{3} \cdot y$ [Eq. 4-7] $Y'_s = 1.223\ ft$

$Y'_q := \frac{1}{2} \cdot y$ [Eq. 4-8] $Y'_q = 1.84\ ft$

$M'_o := P'_s \cdot Y'_s + P'_q \cdot Y'_q$ [Eq. 4-17] $M'_o = 224.86 \cdot lbf$

Resisting Moments

$W'_w := y \cdot \gamma_u \cdot W_u$ [Eq. 4-9] $W'_w = 440.4 \cdot plf$

$X'_w := G_u + \frac{1}{2} \cdot (y) \cdot \tan(\omega)$ [Eq. 4-16] $X'_w = 0.729\ ft$

$M'_r := W'_w \cdot X'_w$ [Eq. 4-15] $M'_r = 321.217\ ft \cdot plf$

$FS_{ot} := \frac{M'_r}{M'_o}$ [Eq. 4-14] $FS_{ot} = 1.429$

Factor of Safety against Shear failure

$V'_u := a_{cs} + W'_w \cdot \tan(\lambda_{cs})$ [Eq. 4-25] $V'_u = \begin{pmatrix} 1489.078 \\ 1489.078 \\ \ldots \end{pmatrix} plf$

$FS_{sh} := \frac{V'_u}{P'_a}$ [Eq. 4-27] $FS_{sh} = \begin{pmatrix} 8.101 \\ 8.101 \\ 8.101 \\ 8.101 \end{pmatrix}$

Summary

Wall Height $H = 7\ ft$

Unreinforced Stability $FS_{ot} = 1.429$ $FS_{bearing} = 5.049$

Applied Bearing Stress $Q_a = 863 \cdot psf$

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} =
3.67	5	298	834	1.5	570	2.8	1.92	6.86	5	8.1
5.67	5	310	834	2.79	1554	2.69	5.02	3.59	5.42	11.88
7.67	5	62	834	4.08	2995	13.55	48.66	2.38	30.28	9.53

Segmental Retaining Wall Design Calculations per NCMA

Wall Geometry

Height	Backslope	Dead Load	Live Load	Distance to Slope	Wall below grade at toe
$H := 6.33 \cdot ft$	$\beta := 10.0 \cdot deg$	$q_d := 0 \cdot psf$	$q_l := 0 \cdot psf$	$Z := 1.0 \cdot ft$	$H_{emb} := .67 \cdot ft$

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

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

Infilled Unit Weight

$\gamma_u := 120 \cdot pcf$

Hinge Height

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

Internal Interface Friction Angle

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

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] $Ka_i = 0.256$

External Interface Friction Angle

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

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] $Ka_e = 0.339$

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]

$\alpha_i = 52.419 \cdot deg$

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]

$\alpha_e = 46.452 \cdot deg$

External Stability Analysis

Sliding

Given

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

$L_{sliding} := \text{Find}(L)$ $\quad$ $L_{sliding} = 3.34\ \text{ft}$

Overturning

Given

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

$L_{overturning} := \text{Find}(L)$ $\quad$ $L_{overturning} = 2.631\ \text{ft}$

$$L := \max\left(\begin{pmatrix} L_{sliding} \\ L_{overturning} \\ 0.6\cdot H \end{pmatrix}\right) \quad L = 3.798\ \text{ft}$$

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]

$L'' := \frac{(L - W_u - Z)\cdot \tan(\beta)\cdot \tan(\omega)}{1 - \tan(\beta)\cdot \tan(\omega)}$ $L'' = 0.068\ ft$ [Fig. 2-10] [Eq. 5-2]

$L_\beta := L' + L''$ $L_\beta = 3.068\ ft$ [Fig. 2-10] [Eq. 5-3]

$h := L_\beta \cdot \tan(\beta)$ $h = 0.541\ ft$ [Fig. 2-10] [Eq. 5-4]

$W_{ri} := L\cdot \gamma_i \cdot H$ $W_{ri} = 3481.5 \cdot plf$ [Eq. 5-15]

$X_{ri} := \frac{1}{2}\cdot(L + H\cdot \tan(\omega))$ $X_{ri} = 2.896\ ft$ [Eq. 5-19]

$W_{r\beta} := \frac{1}{2}\cdot \gamma_i \cdot (L' - Z)\cdot h$ $W_{r\beta} = 59.499 \cdot plf$ [Eq. 5-16]

$X_{r\beta} := H\cdot \tan(\omega) + W_u + \frac{2}{3}\cdot L_\beta + Z$ $X_{r\beta} = 4.836\ ft$ [Eq. 5-20]

$X_{q\beta} := \frac{Z + L_\beta}{2} + [(H + h)\cdot \tan(\omega)] + W_u$ $X_{q\beta} = 3.893\ ft$ [Eq. 5-21]

Actual Heigth of wall:

$H_s := (H + h)$ $H_s = 6.871\ ft$

Earth Pressures:

$P_{sH} := \left[\frac{1}{2}\cdot Ka_e \cdot \gamma_e \cdot (H + h)^2 \cdot \cos(\delta_e - \omega)\right]$ $P_{sH} = 908.721 \cdot plf$ [Eq. 5-6]

$Y_s := \frac{1}{3}\cdot(H + h)$ $Y_s = 2.29\ ft$ [Eq. 5-9]

$P_{qH} := (q_d + q_l)\cdot Ka_e \cdot (H + h)\cdot \cos(\delta_e - \omega)$ $P_{qH} = 0 \cdot plf$ [Eq. 5-8]

$Y_q := \frac{1}{2}\cdot(H + h)$ $Y_q = 3.435\ ft$ [Eq. 5-10]

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

$e = 0.1595\ ft$ [Eq. 5-25]

Check $e := \text{if}(e \le 0, 0.075L, e)$ $e = 0.16\ ft$

Surcharge is applied over: $(L' + L'') = 3.068\ ft$ $B := L - 2\cdot e$ $B = 4.681\ ft$ [Eq. 5-24]

Bearing Capacity

$$Q_a := \frac{\left[W_{ri} + W_{r\beta} + (q_d + q_l)\cdot(L' + L'')\right]}{B}$$ $Q_a = 756.469\cdot psf$

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

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

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

$$Q_{ult} := c_f\cdot N_c + \frac{1}{2}\cdot\gamma_f\cdot B\cdot N_\gamma + \gamma_f\cdot H_{emb}\cdot N_q$$ $Q_{ult} = 4474.7\cdot psf$ [Eq. 4-20]

$$FS_{bearing} := \frac{Q_{ult}}{Q_a}$$ $FS_{bearing} = 5.915$ [Eq. 4-19]

Internal Stability

Reinforcement Properties

Geogrid Design Data

Backfill Soil $Type := (gravel)$

Geogrid Number

	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		

$GN1 := 4$ $GN2 := 2$

$x := 4..1$ 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:	Grig Spacing (ft):	# of grids for that spacing:	Depth of first grid (ft):	Length of grids:		
$n_g := 2$	$Spacing1 := 2$	$n_1 := 2$	$h_1 := 3.67$	$L_1 := 5.0$	$L_2 := 5.0$	$L_r := \frac{L}{ft}$
	$Spacing2 := 1.67$	$n_2 := 0$				

Make all zero when using one geogrid

Note: make sure that the elevations don't excide the height of the wall (H) $H = 6.33\ ft$

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

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

$E = \begin{pmatrix} 3.67 \\ 5.67 \end{pmatrix} ft$

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

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

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

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

$D^T = (0 \quad 4.67 \quad 6.33)\ ft$

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]

$F_g^T = (297.624 \quad 249.193) \cdot plf$

Safety factor:

$FS_{ten_n} := \frac{T_{a_n}}{F_{g_n}}$ $\quad FS_{ten}^T = (2.802 \quad 3.347)$

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]

$La^T = (1.937\ \ 3.226)\ ft$

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]

$d^T = (3.901\ \ 5.743)\ ft$

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]

$AC^T = (726.96\ \ 1782.741)\cdot plf$

$F_g^T = (297.624\ \ 249.193)\cdot plf$

Safety Factor

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

$FS_{po}^T = (2.443\ \ 7.154)$

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]

$\Delta L^T = (0\ \ 1.651)\ ft$

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

$L'^T_s = (4\ \ 2.349)\ ft$

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]

$L_{s\beta}{}^{T} = (3.068 \quad 1.379)\ ft$

Height of slope above crest of wall

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

$h'^{T} = (0.541 \quad 0.243)\ ft$

Weight of reduced reinforced area

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

$W'_{ri}{}^{T} = (1615 \quad 1465) \cdot plf$

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]

$W'_{r\beta}{}^{T} = (91.26 \quad 18.45) \cdot plf$

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]

$R'_{s}{}^{T} = (853 \quad 742) \cdot plf$

Shear capacity of facing elements

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

$V_u{}^{T} = (1489 \quad 1677) \cdot plf$

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]

$P_s{}^{T} = (341 \quad 673) \cdot plf$

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]

$P_q{}^{T} = (0 \quad 0) \cdot plf$

Factor of safety against internal sliding

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

$P_a{}^{T} = (341 \quad 673) \cdot plf$

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

$FS_{sl}{}^{T} = (6.862 \quad 3.593)$

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]

$T_{conn}^{T} = (1489 \quad 1677)\cdot plf$

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

$FS_{conn}^{T} = (5.003 \quad 6.728)$

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]

$V_u^{T} = (1489 \quad 1677)\cdot plf$

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]

$P_a^{T} = (184 \quad 439)\cdot plf$

Sum of tension in reinforcement layers above layer being considered

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

$F^{T} = (0 \quad 298 \quad 547)\cdot plf$

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

$FS_{sc}^{T} = (8.101 \quad 11.881)$

Maximum unreinforced height of SRW units

$y := E_1 = 3.67\ ft$ $\quad q_l := 0\cdot psf$

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]

$P'_s = 183.809\cdot plf$

$P'_q := (q_d + q_l) \cdot Ka_i \cdot (y) \cdot \cos(\delta_i - \omega)$	[Eq. 4-6]	$P'_q = 0 \cdot plf$
$P'_a := P'_s + P'_q$	[Eq. 4-4]	$P'_a = 183.809 \cdot plf$
$Y'_s := \frac{1}{3} \cdot y$	[Eq. 4-7]	$Y'_s = 1.223\ ft$
$Y'_q := \frac{1}{2} \cdot y$	[Eq. 4-8]	$Y'_q = 1.84\ ft$
$M'_o := P'_s \cdot Y'_s + P'_q \cdot Y'_q$	[Eq. 4-17]	$M'_o = 224.86 \cdot lbf$

Resisting Moments

$W'_w := y \cdot \gamma_u \cdot W_u$	[Eq. 4-9]	$W'_w = 440.4 \cdot plf$
$X'_w := G_u + \frac{1}{2} \cdot (y) \cdot \tan(\omega)$	[Eq. 4-16]	$X'_w = 0.729\ ft$
$M'_r := W'_w \cdot X'_w$	[Eq. 4-15]	$M'_r = 321.217\ ft \cdot plf$
$FS_{ot} := \frac{M'_r}{M'_o}$	[Eq. 4-14]	$FS_{ot} = 1.429$

Factor of Safety against Shear failure

$V'_u := a_{cs} + W'_w \cdot \tan(\lambda_{cs})$	[Eq. 4-25]	$V'_u = \begin{pmatrix} 1489.078 \\ 1489.078 \end{pmatrix}$ plf
$FS_{sh} := \frac{V'_u}{P'_a}$	[Eq. 4-27]	$FS_{sh} = \begin{pmatrix} 8.101 \\ 8.101 \\ 8.101 \\ 8.101 \end{pmatrix}$

Summary

Wall Height	$H = 6.33\ ft$	
Unreinforced Stability	$FS_{ot} = 1.429$	$FS_{bearing} = 5.915$
Applied Bearing Stress	$Q_a = 756 \cdot psf$	

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) $FS_{sc_n} =$
3.67	5	298	834	1.94	727	2.8	2.44	6.86	5	8.1
5.67	5	249	834	3.23	1783	3.35	7.15	3.59	6.73	11.88