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REVISIONS:	

JOB NO.:	
DRAWN BY:	MEJ
DESIGNED BY:	CH6

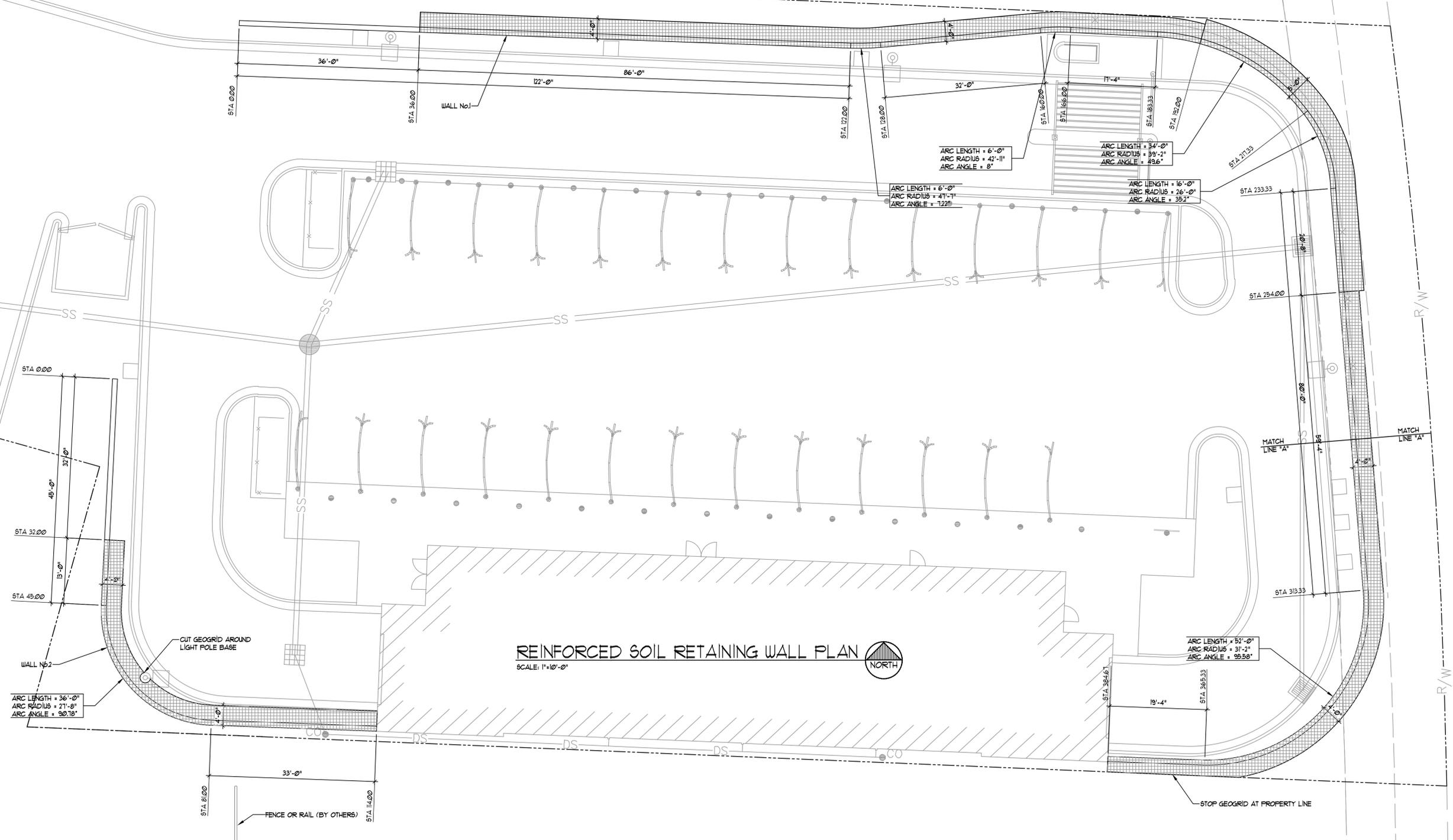
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**VERSALOK**  
 HARSCOPES  
 REINFORCED SOIL RETAINING WALL FOR:  
 CLUB CARWASH  
 1021 JEFFERSON CROSSING  
 LEE'S SUMMIT, MISSOURI

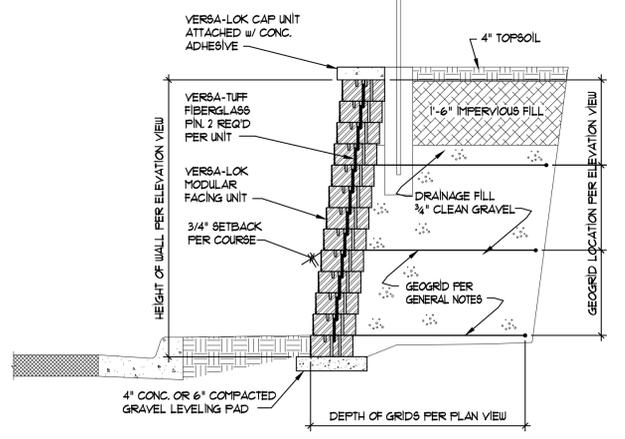
REINFORCED SOIL RETAINING WALL FOR:  
 CLUB CARWASH  
 1021 JEFFERSON CROSSING  
 LEE'S SUMMIT, MISSOURI

SHEET NO.:

RW1.1



**REINFORCED SOIL RETAINING WALL PLAN**  
 SCALE: 1" = 10'-0"



**REINFORCED SOIL RETAINING WALL SECTION**  
 SCALE: 1/2" = 1'-0"

**RETAINING WALL GENERAL NOTES**

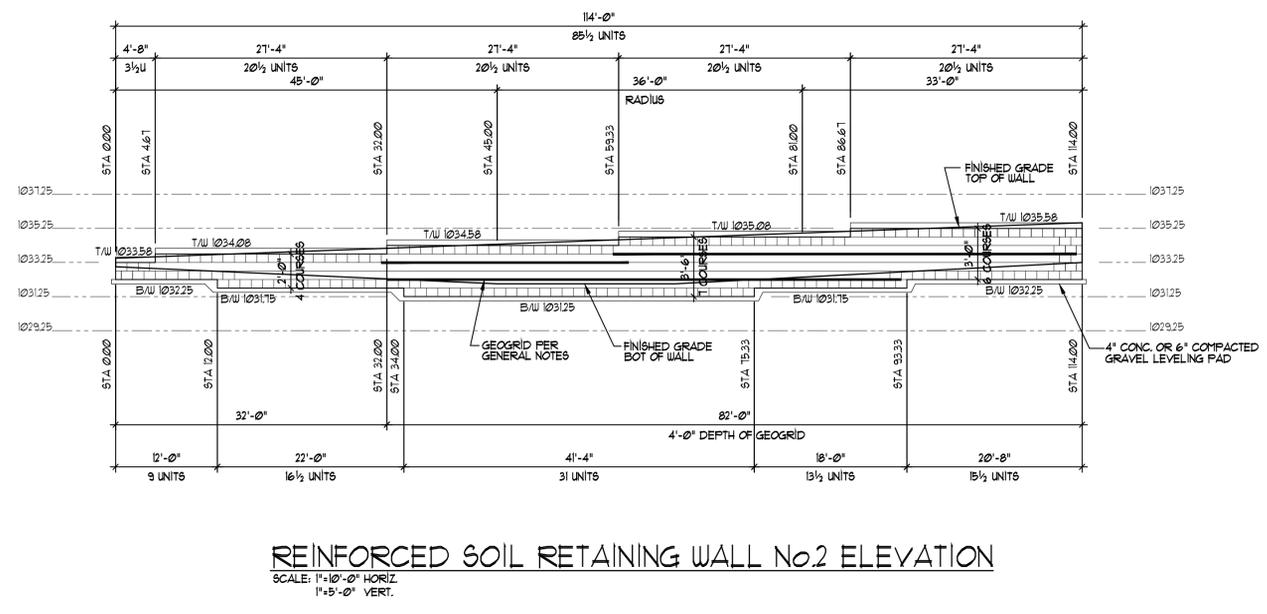
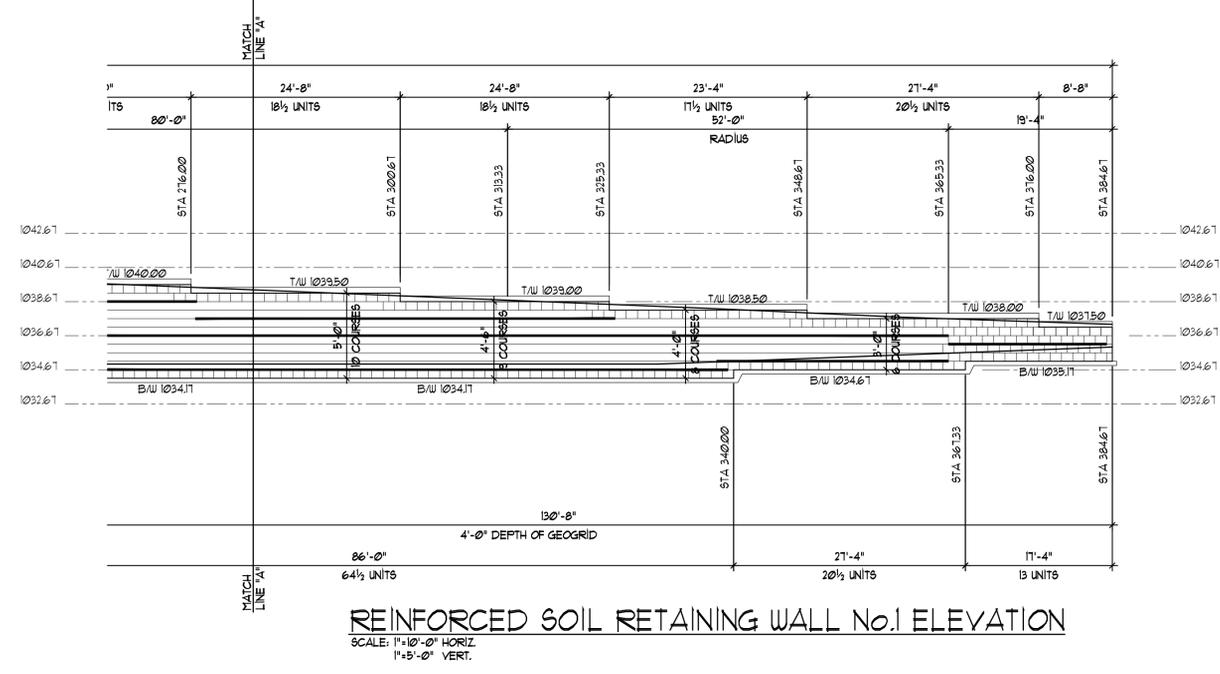
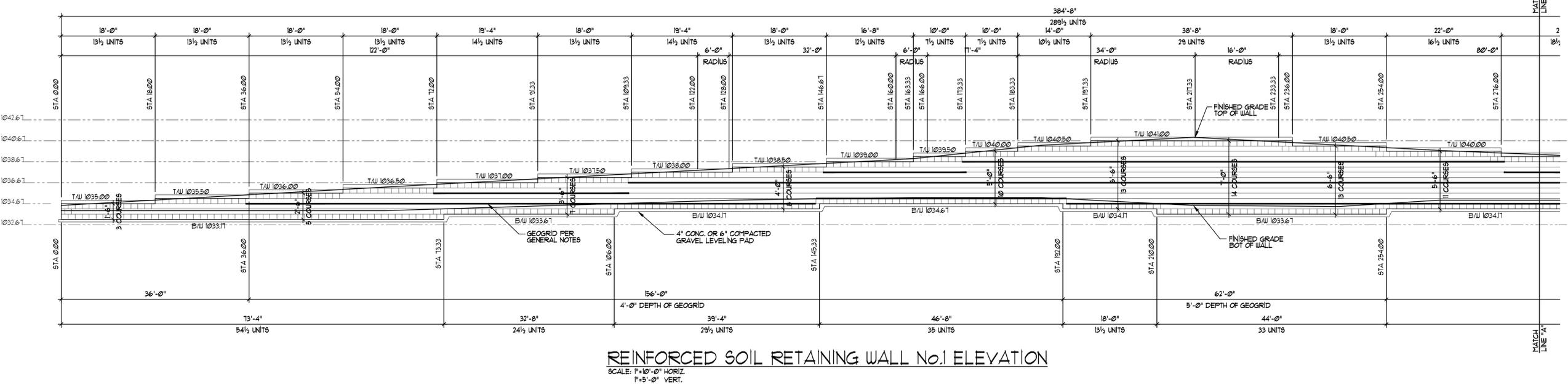
1. GENERAL REQUIREMENTS
  - A. Design and construction work for this project shall conform to the requirements of the 2018 International Building Code as amended by the local jurisdiction.
  - B. Design Loads:
    - Retained Soil:  $\phi = 26$  degrees
    - Backslope:  $0$  degrees
    - Applied Bearing Pressure: 1500 psf
  - C. DRAINAGE FILL shall consist of free draining crushed stone, 3/8" to 3/4", or coarse gravel. No more than 5% shall pass the No. 200 sieve with a maximum size of 1".
  - D. IMPERVIOUS FILL shall consist of material having a minimum plasticity index of 30. No more than 10% particles shall be retained on the No. 4 sieve and no less than 20% shall pass the No. 200 sieve. 1/2" inches of impervious fill shall extend over the reinforced zone.
  - E. The geogrid shall be a high density polyethylene expanded sheet or polyester woven fiber materials, specifically fabricated for use as soil reinforcement.
    - GEOGRID shall be one of the following:
      - Stratagrid 200 as manufactured by Strata Systems, Inc.
      - Miragrid 3XT as manufactured by Mirafi, Inc.
      - Versa-Grid 3D as manufactured by Versa-Lok
      - HF1000 as manufactured by Geostar
  - F. Excavation shall be to the lines and grades shown on the construction drawings. Care shall be taken not to disturb embankment materials beyond lines shown.
2. RETAINING WALL BLOCK SPECIFICATION:
  - A. Modular concrete facing units shall be VERSA-LOK Retaining Wall Units having a minimum 28 day compressive strength of 3000 psi and a maximum moisture absorption of 8 percent.
  - B. Connecting pins shall be 1/2 inch diameter non-corrosive, nylon/fiberglass VERS-TUFF pins.
3. FOUNDATION SOIL PREPARATION:
  - A. Foundation soil shall be excavated as required for leveling pad per drawings.
  - B. Foundation soil shall be examined by the Engineer of Record or Geotechnical Engineer to assure that the actual foundation soil strength meets or exceeds assumed design strength. Soils not meeting required strength shall be removed and replaced with acceptable material.
  - C. Over-excavated areas shall be filled with approved compacted backfill material.
4. BASE LEVELING PAD:
  - A. Leveling pad materials shall be placed as shown on the drawings, on undisturbed in situ soils to a minimum thickness of 4 inches for concrete or 6" of a gravel type materials.
  - B. Material shall be compacted so as to provide a level hard surface on which to place the first course of units. Compaction shall be done with a minimum of 3 passes of a tracked construction equipment or a vibratory compactor. Leveling pad shall be prepared to insure complete contact of retaining wall unit with base.
5. UNIT INSTALLATION:
  - A. First course of concrete wall units shall be placed on the base leveling pad. The units shall be checked for level and alignment and in full contact with base.
  - B. Units shall be placed side by side for full length of wall alignment. Alignment shall be done by means of a string line or offset from base line.
  - C. The contractor shall follow manufacturer's installation instructions when making radius curves.
  - D. Compact unit, fill, drainage fill, and backfill. Excess material shall be swept from top of units to install next course, insuring the area between each unit is completely filled prior to proceeding to next course.
  - E. Lay each course with the lip of the units placed against the back of the preceding course. Full units forward as far as possible. Backfill and compact soil behind wall units.
6. GEOGRID INSTALLATION:
  - A. The geogrid soil reinforcement shall be laid horizontally on compacted backfill or top of the concrete wall units. The next course of units shall be placed such that the geogrid is aligned to the backside and under the lip of the top units. Embed the geogrid a minimum of eight inches into the units. Full geogrid taut and anchor prior to placing backfill.
  - B. Slack in the geogrid at the wall unit connections shall be removed.
  - C. Geogrid shall be laid at the proper elevation and orientation as shown on the drawings.
  - D. Correct orientation (roll direction) of the geogrid shall be verified.
  - E. To tension geogrid, anchored geogrid shall be pulled taut to eliminate loose folds, and secured prior to and during backfill and compaction.
  - F. In outside corners and radii provide a minimum of 3 inches of backfill or drainage fill between overlapping geogrid layers.
7. FILL PLACEMENT:
  - A. Clean gravel backfill shall be compacted by a minimum of 3 passes of a tracked construction equipment or a vibratory compactor. Placement of clean rock fill shall be monitored during placement to assure that an equivalent maximum dry density of 95% standard proctor is achieved.
  - B. Backfill shall be placed, spread, and compacted in such a manner that minimizes the development of slack or loss of pretension of the geogrid.
  - C. Backfill shall be placed from the wall rearward into the embankment to insure that the geogrid remains taut.
  - D. Compact backfill within three feet of the back of the wall to prevent displacement of modular units.
  - E. Tracked construction equipment shall not be operated directly on the geogrid. A minimum backfill thickness of 6 inches shall be maintained to operate tracked vehicles over the geogrid. Turning of tracked vehicles shall be kept to a minimum to prevent tracks from displacing the fill and damaging the geogrid.
8. CAP INSTALLATION:
  - A. Cap units shall be placed over preceding course and on a bed of construction adhesive, pulled forward, backfilled and compacted in place to finished grade.
9. PROTECTION OF WORK:
  - A. At the end of each day's operation, slope backfill away from the facing to direct runoff away from runoff from adjacent areas from entering the retaining wall backfill.
  - B. A minimum of three feet shall be maintained between the face of the retaining wall and the operation of heavy equipment.
10. GLOBAL STABILITY:
  - A. Global stability has not been performed by this office on the retaining wall(s) or the site slopes.
  - B. External stability analysis for bearing capacity, global stability, and total and differential settlement shall be the responsibility of the owner and the Owner's Geotechnical Engineer. The geotechnical Engineer shall perform bearing capacity, settlement estimates, and global stability analysis based on the final wall design provided by this office and coordinate any required changes with VanDeurzen and Associates, P.A.



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**REINFORCED SOIL RETAINING WALL FOR:**  
**CLUB CARWASH**  
 1021 JEFFERSON CROSSING  
 LEE'S SUMMIT, MISSOURI  
**VERSALOK**  
 HARSCO PAVEMENTS

**SHEET NO.:**  
**RW1.2**



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**Club Carwash**  
1021 Jefferson Crossing  
Lee's Summit, Missouri

**VAN DEURZEN AND ASSOCIATES, P.A.**

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**Reinforced Soil Retaining Wall Design**



**VAN DEURZEN AND ASSOCIATES, P.A.**  
February 12, 2026

# Segmental Retaining Wall Design Calculations per NCMA

## Wall Geometry

Height $H_w := 7.33\text{-ft}$	Backslope $\beta := 0.0\text{-deg}$	Dead Load $q_d := 0\text{-psf}$	Live Load $q_l := 0\text{-psf}$	Distance to Slope $Z := 1.0\text{-ft}$	Wal below grade at toe $H_{\text{cmb}} := .67\text{-ft}$
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## Soil Properties

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

Height $H_u := 6\text{-in}$	Length $L_u := 16\text{-in}$	Width $W_u := 12\text{-in}$	Setback $\Delta_u := 1.0\text{-in}$	Center of Gravity $G_u := 6\text{-in}$	Batter $\omega := \text{atan}\left(\frac{\Delta_u}{H_u}\right)$ $\omega = 9.462\text{-deg}$
Infilled Unit Weight $\gamma_u := 120\text{-pcf}$					Hinge Height

$$H_h := \text{if}\left[\tan(\omega) = 0, H, \left[2 \cdot \frac{(W_u - G_u)}{\tan(\omega)}\right]\right] \Rightarrow H_h = 6\text{ ft} \quad [\text{Eq. 4-1}]$$

### Internal Interface Friction Angle

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

### Internal Active Earth Pressure

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

$[\text{Eq. 3-11}] \quad K_{a_i} = 0.213$

### External Interface Friction Angle

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

### External Active Earth Pressure

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

$[\text{Eq. 3-11}] \quad K_{a_e} = 0.276$

### Orientation of Critical Internal Failure Surface

$$\alpha_i := \text{atan}\left[\frac{-\tan(\phi_i - \beta) + \sqrt{\tan(\phi_i - \beta) \cdot (\tan(\phi_i - \beta) + \cot(\phi_i + \omega)) \cdot (1 + \tan(\delta_i - \omega) \cdot \cot(\phi_i + \omega))}}{1 + \tan(\delta_i - \omega) \cdot (\tan(\phi_i - \beta) + \cot(\phi_i + \omega))}\right] + \phi_i \quad [\text{Eq. 3-14}]$$

$\alpha_i = 53.553\text{-deg}$

### Orientation of Critical External Failure Surface

$$\alpha_e := \text{atan}\left[\frac{-\tan(\phi_e - \beta) + \sqrt{\tan(\phi_e - \beta) \cdot (\tan(\phi_e - \beta) + \cot(\phi_e + \omega)) \cdot (1 + \tan(\delta_e - \omega) \cdot \cot(\phi_e + \omega))}}{1 + \tan(\delta_e - \omega) \cdot (\tan(\phi_e - \beta) + \cot(\phi_e + \omega))}\right] + \phi_e \quad [\text{Eq. 3-14}]$$

$\alpha_e = 48.773\text{-deg}$

**Sliding**

**External Stability Analysis**

Given

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

**Overtuning**

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

$L_{sliding} = 2.986 \text{ ft}$

Given

$$\begin{aligned}
 & \left[ (L \cdot \gamma_c \cdot H) \cdot \left[ \frac{1}{2} \cdot (L + H \cdot \tan(\omega)) \right] \right] \dots \\
 & + \left[ \frac{1}{2} \cdot \gamma_c \cdot (L - W_u - Z) \cdot \left[ (L - W_u - Z) + \frac{(L - W_u - Z) \cdot \tan(\beta) \cdot \tan(\omega)}{1 - \tan(\beta) \cdot \tan(\omega)} \right] \cdot \tan(\beta) \right] \cdot \left[ H \cdot \tan(\omega) + W_u + Z + \frac{2}{3} \cdot (L - W_u - Z) \right] \\
 & + q_d \cdot \left[ (L - W_u - Z) + \frac{(L - W_u - Z) \cdot \tan(\beta) \cdot \tan(\omega)}{1 - \tan(\beta) \cdot \tan(\omega)} \right] \cdot \left[ \frac{Z + \left[ (L - W_u - Z) + \frac{(L - W_u - Z) \cdot \tan(\beta) \cdot \tan(\omega)}{1 - \tan(\beta) \cdot \tan(\omega)} \right]}{2} + H \cdot \tan(\omega) + \right. \\
 2.0 = & \frac{\left[ \frac{1}{2} \cdot K a_c \cdot \gamma_c \cdot \left[ H + \left[ (L - W_u - Z) + \frac{(L - W_u - Z) \cdot \tan(\beta) \cdot \tan(\omega)}{1 - \tan(\beta) \cdot \tan(\omega)} \right] \cdot \tan(\beta) \right]^2 \cdot \cos(\delta_e - \omega) \right] \cdot \left[ \frac{1}{3} \cdot \left[ H + \left[ (L - W_u - Z) + \frac{(L - W_u - Z) \cdot \tan(\beta) \cdot \tan(\omega)}{1 - \tan(\beta) \cdot \tan(\omega)} \right] \cdot \tan(\beta) \right] \right]}{\left[ (q_d + q_l) \cdot K a_c \cdot \left[ H + \left[ (L - W_u - Z) + \frac{(L - W_u - Z) \cdot \tan(\beta) \cdot \tan(\omega)}{1 - \tan(\beta) \cdot \tan(\omega)} \right] \cdot \tan(\beta) \right] \cdot \cos(\delta_e - \omega) \right] \cdot \left[ \frac{1}{2} \cdot \left[ H + \left[ (L - W_u - Z) + \frac{(L - W_u - Z) \cdot \tan(\beta) \cdot \tan(\omega)}{1 - \tan(\beta) \cdot \tan(\omega)} \right] \cdot \tan(\beta) \right] \right]}
 \end{aligned}$$

$L_{overtuning} := \text{Find}(L)$

$L_{overtuning} = 2.529 \text{ ft}$

$L_{\text{min}} := \max \left( \begin{matrix} L_{sliding} \\ L_{overtuning} \\ 0.6 \cdot H \end{matrix} \right)$

$L = 4.398 \text{ ft}$

Based on Overtuning and Sliding:

$L_{\text{min}} := 5.0 \cdot \text{ft}$  (Round up L)

**Eccentricity**

$$L' := L - W_u - Z$$

$$L' = 3 \text{ ft}$$

[Fig. 2-10] [Eq. 5-1]

$$L'' := \frac{(L - W_u - Z) \cdot \tan(\beta) \cdot \tan(\omega)}{1 - \tan(\beta) \cdot \tan(\omega)}$$

$$L'' = 0 \text{ ft}$$

[Fig. 2-10] [Eq. 5-2]

$$L_\beta := L' + L''$$

$$L_\beta = 3 \text{ ft}$$

[Fig. 2-10] [Eq. 5-3]

$$h := L_\beta \cdot \tan(\beta)$$

$$h = 0 \text{ ft}$$

[Fig. 2-10] [Eq. 5-4]

$$W_{ri} := L \cdot \gamma_i \cdot H$$

$$W_{ri} = 4031.5 \cdot \text{plf}$$

[Eq. 5-15]

$$X_{ri} := \frac{1}{2} \cdot (L + H \cdot \tan(\omega))$$

$$X_{ri} = 3.111 \text{ ft}$$

[Eq. 5-19]

$$W_{r\beta} := \frac{1}{2} \cdot \gamma_i \cdot (L' - Z) \cdot h$$

$$W_{r\beta} = 0 \cdot \text{plf}$$

[Eq. 5-16]

$$X_{r\beta} := H \cdot \tan(\omega) + W_u + \frac{2}{3} \cdot L_\beta + Z$$

$$X_{r\beta} = 5.222 \text{ ft}$$

[Eq. 5-20]

$$X_{q\beta} := \frac{Z + L_\beta}{2} + [(H + h) \cdot \tan(\omega)] + W_u$$

$$X_{q\beta} = 4.222 \text{ ft}$$

[Eq. 5-21]

Actual Height of wall:

$$H_s := (H + h)$$

$$H_s = 7.33 \text{ ft}$$

Earth Pressures:

$$P_{sH} := \left[ \frac{1}{2} \cdot K a_e \cdot \gamma_e \cdot (H + h)^2 \cdot \cos(\delta_e - \omega) \right]$$

$$P_{sH} = 853.894 \cdot \text{plf}$$

[Eq. 5-6]

$$Y_s := \frac{1}{3} \cdot (H + h)$$

$$Y_s = 2.443 \text{ ft}$$

[Eq. 5-9]

$$P_{qH} := (q_d + q_l) \cdot K a_e \cdot (H + h) \cdot \cos(\delta_e - \omega)$$

$$P_{qH} = 0 \cdot \text{plf}$$

[Eq. 5-8]

$$Y_q := \frac{1}{2} \cdot (H + h)$$

$$Y_q = 3.665 \text{ ft}$$

[Eq. 5-10]

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

$$\bar{e} = -0.0933 \text{ ft}$$

[Eq. 5-25]

**Check**

$$\bar{e} := \text{if}(e \leq 0, 0.075L, e)$$

$$e = 0.375 \text{ ft}$$

Surcharge is applied over:  $(L' + L'') = 3 \text{ ft}$ 

$$B := L - 2 \cdot e$$

$$B = 4.25 \text{ ft}$$

[Eq. 5-24]

## Bearing Capacity

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

$$Q_a = 948.588 \cdot \text{psf}$$

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

$$N_q = 11.854$$

[Fig. 4-5]

$$N_c := \text{if}[\phi_f = 0, 5.14, (N_q - 1) \cdot \cot(\phi_f)]$$

$$N_c = 22.254$$

[Fig. 4-5]

$$N_\gamma := 2 \cdot (N_q + 1) \cdot \tan(\phi_f)$$

$$N_\gamma = 12.539$$

[Fig. 4-5]

$$Q_{ult} := c_f \cdot N_c + \frac{1}{2} \cdot \gamma_f \cdot B \cdot N_\gamma + \gamma_f \cdot H_{emb} \cdot N_q$$

$$Q_{ult} = 4150.479 \cdot \text{psf}$$

[Eq. 4-20]

$$FS_{\text{bearing}} := \frac{Q_{ult}}{Q_a}$$

$$FS_{\text{bearing}} = 4.375$$

[Eq. 4-19]

## Internal Stability

### Reinforcement Properties

### Geogrid Design Data

Backfill Soil

Type := (gravel)

1 2 3 4 5 6 7 8 9

Geogrid Number

$$\text{Type}^T = (411 \ 834 \ 1199 \ 1336 \ 2004 \ 2508 \ 3011 \ 3873 \ 7914)$$

GN1 := 4

GN2 := 2

$$\text{inter}^T = (1145 \ 1145 \ 1145 \ 1145 \ 1145 \ 1145 \ 0)$$

$$\text{slope}^T = (38 \ 38 \ 38 \ 38 \ 38 \ 38 \ 0)$$

$$\text{maxc}^T = (4540 \ 4540 \ 4540 \ 4540 \ 4540 \ 4540 \ 0) \quad x := 4..1 \quad x \text{ is the number of grids at the top of the wall of a different type}$$

$$T_a := \text{Type}_{GN1} \cdot \text{plf} \quad T_a = 1336 \cdot \text{plf}$$

$$T_{a2} := \text{Type}_{GN2} \cdot \text{plf} \quad T_{a2} = 834 \cdot \text{plf}$$

$$a_{cs} := \text{inter}_{GN1} \cdot \text{plf} \quad a_{cs} = 1145 \cdot \text{plf}$$

$$\lambda_{cs} := \text{slope}_{GN1} \cdot \text{deg} \quad \lambda_{cs} = 38 \cdot \text{deg}$$

$$V_{cs\text{max}} := \text{maxc}_{GN1} \cdot \text{plf} \quad V_{cs\text{max}} = 4540 \cdot \text{plf}$$

$$a_{cs2} := \text{inter}_{GN2} \cdot \text{plf} \quad a_{cs2} = 1145 \cdot \text{plf}$$

$$\lambda_{cs2} := \text{slope}_{GN2} \cdot \text{deg} \quad \lambda_{cs2} = 38 \cdot \text{deg}$$

$$V_{cs\text{max}2} := \text{maxc}_{GN2} \cdot \text{plf} \quad V_{cs\text{max}2} = 4540 \cdot \text{plf}$$

### Tension in Geogrid

Number of Grids:  $n_g := 3$   
 Grid Spacing (ft):  
 Spacing1 := 2  
 Spacing2 := 1.67  
 # of grids for that spacing:  
 $n_1 := 3$   
 $n_2 := 0$   
 Depth of first grid (ft):  
 $h_1 := 2.33$   
 Length of grids:  
 $L_1 := 5.0$     $L_2 := 5.0$     $L_r := \frac{L}{ft}$   
 Make all zero when using one geogrid

**Note:** make sure that the elevations don't excide the height of the wall (H) H = 7.33 ft

top := length(E)      p := 2.. top      top = 3  
 grids := length(E)    n := 1.. top       $l := 1.. grids - 1$

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

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

$$T_{ax} := \frac{L \cdot T_a}{L}$$

$$T_a = \begin{pmatrix} 1336 \\ 1336 \\ 1336 \end{pmatrix} \cdot \text{plf}$$

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

$$T_a^T = (834 \ 834 \ 834 \ 834) \cdot \text{plf}$$

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

$$D^T = (0 \ 3.33 \ 5.33 \ 7.33) \text{ ft}$$

**Total Applied Tensile Strength in the Geosynthetic reinf.:**

$$F_{g_n} := \int_{D_n}^{D_{(n+1)}} (\gamma_i \cdot D + q_1 + q_d) \cdot K_{a_i} \cdot \cos(\delta_i - \omega) \cdot dD \quad [\text{Eq. 5-36}]$$

$$F_g^T = (127.198 \ 198.673 \ 290.439) \cdot \text{plf}$$

**Safety factor:**

$$FS_{ten_n} := \frac{T_{a_n}}{F_{g_n}}$$

$$FS_{ten}^T = (6.557 \ 4.198 \ 2.872)$$

## Pullout Capacity

### Anchorage Length of Geosynthetic

$$L_{a_n} := L_n - W_u - [(H + h) - E_n] \cdot \tan(90 \cdot \text{deg} - \alpha_i) + [(H + h) - E_n] \cdot \tan(\omega) \quad [\text{Eq. 5-46}]$$

$$L_a^T = (1.141 \quad 2.284 \quad 3.428) \text{ ft}$$

**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

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

$$d^T = (2.33 \quad 4.33 \quad 6.33) \text{ ft}$$

### Anchorage Capacity

$$AC_n := 2 \cdot L_{a_n} \cdot C_i \cdot (d_n \cdot \gamma_i + q_d) \cdot \tan(\phi_i) \quad [\text{Eq. 5-45}]$$

$$AC^T = (255.749 \quad 951.846 \quad 2088.193) \cdot \text{plf}$$

$$F_g^T = (127.198 \quad 198.673 \quad 290.439) \cdot \text{plf}$$

### Safety Factor

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

$$FS_{po}^T = (2.011 \quad 4.791 \quad 7.19)$$

## Internal Sliding

### Reduced reinforcement length

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

$$\Delta L^T = (0 \quad 1.419 \quad 1.419) \text{ ft}$$

$$L'_s := L_n - W_u - \Delta L_n \quad [\text{Eq. 5-50}]$$

$$L'_s{}^T = (4 \quad 2.581 \quad 2.581) \text{ ft}$$

### Length of sloping ground

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

$$L_{s\beta}^T = (3 \quad 1.581 \quad 1.581) \text{ ft}$$

### Height of slope above crest of wall

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

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

### Weight of reduced reinforced area

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

$$W'_{ri}{}^T = (1025 \quad 1229 \quad 1797) \cdot \text{plf}$$

### Weight of wedge beyond reinforced soil zone

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

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

### Friction developed by weight

$$R'_s := C_{dsi} \cdot \left[ q_d \cdot (L_{s\beta}_n + Z) + W'_{ri}_n + W'_{r\beta}_n \right] \cdot \tan(\phi_i) \quad [\text{Eq. 5-49}]$$

$$R'_s{}^T = (512 \quad 614 \quad 898) \cdot \text{plf}$$

### Shear capacity of facing elements

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

$$V_u{}^T = (1363 \quad 1551 \quad 1708) \cdot \text{plf}$$

### Driving Forces

From retained soil

$$P'_s := \left[ \frac{1}{2} \cdot K_a \cdot \gamma_e \cdot (E_n + h'_n)^2 \cdot \cos(\delta_e - \omega) \right] \quad [\text{Eq. 5-6}]$$

$$P'_s{}^T = (86 \quad 298 \quad 637) \cdot \text{plf}$$

From surcharge

$$P'_{qn} := (q_d + q_1) \cdot K_a \cdot (E_n + h'_n) \cdot \cos(\delta_e - \omega) \quad [\text{Eq. 5-8}]$$

$$P'_{qn}{}^T = (0 \quad 0 \quad 0) \cdot \text{plf}$$

### Factor of safety against internal sliding

$$P'_a := P'_s + P'_{qn} \quad [\text{Eq. 5-11}]$$

$$P'_a{}^T = (86 \quad 298 \quad 637) \cdot \text{plf}$$

$$FS_{sl}_n := \frac{R'_s + V_u}{(P'_a)} \quad [\text{Eq. 5-48}]$$

$$FS_{sl}{}^T = (21.743 \quad 7.267 \quad 4.092)$$

## Local Stability of Facing Units

### Facing Connection Strength

$$T_{\text{conn}_n} := \min \left[ V_{\text{csm}_{\text{max}_n}}, a_{\text{cs}_n} + \left( \text{if}(E_n > H_h, H_h, E_n) \cdot \gamma_u \cdot W_u \right) \cdot \tan(\lambda_{\text{cs}_n}) \right] \quad [\text{Eq. 5-59}]$$

$$T_{\text{conn}}^T = (1363 \ 1551 \ 1708) \cdot \text{plf}$$

$$FS_{\text{conn}_n} := \frac{T_{\text{conn}_n}}{F_{g_n}} \quad FS_{\text{conn}}^T = (10.719 \ 7.807 \ 5.879)$$

### Resistance to Bulging

Shear capacity at each geogrid layer

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

$$V_u^T = (1363 \ 1551 \ 1708) \cdot \text{plf}$$

Driving Force at each geogrid layer

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

$$P_a^T = (62 \ 215 \ 460) \cdot \text{plf}$$

Sum of tension in reinforcement layers above layer being considered

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

$$F^T = (0 \ 127 \ 326 \ 616) \cdot \text{plf}$$

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

$$FS_{\text{sc}}^T = (21.895 \ 17.651 \ 12.767)$$

### Maximum unreinforced height of SRW units

$$y := E_1 = 2.33 \text{ ft}$$

$$q_l := 0 \cdot \text{psf}$$

Moment equilibrium

Driving Moments

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

$$P'_s = 62.273 \cdot \text{plf}$$

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

$$P'_a := P'_s + P'_q \quad [\text{Eq. 4-4}] \quad \boxed{P'_a = 62.273 \cdot \text{plf}}$$

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

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

$$M'_o := P'_s \cdot Y'_s + P'_q \cdot Y'_q \quad [\text{Eq. 4-17}] \quad \boxed{M'_o = 48.37 \cdot \text{lbft}}$$

**Resisting Moments**

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

$$X'_w := G_u + \frac{1}{2} \cdot (y) \cdot \tan(\omega) \quad [\text{Eq. 4-16}] \quad \boxed{X'_w = 0.694 \text{ ft}}$$

$$M'_r := W'_w \cdot X'_w \quad [\text{Eq. 4-15}] \quad \boxed{M'_r = 194.089 \text{ ft} \cdot \text{plf}}$$

$$FS_{ot} := \frac{M'_r}{M'_o} \quad [\text{Eq. 4-14}] \quad \boxed{FS_{ot} = 4.013}$$

**Factor of Safety against Shear failure**

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

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

1363.447
1363.447
21.895
21.895
21.895
21.895

**Summary**

Wall Height H = 7.33 ft

Unreinforced Stability FS<sub>ot</sub> = 4.013

FS<sub>bearing</sub> = 4.375

Applied Bearing Stress Q<sub>a</sub> = 949 · 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)
$E_n =$	$L_n =$	$\frac{F_{g_n}}{\text{plf}} =$	$\frac{T_{a_n}}{\text{plf}} =$	$L_{a_n} =$	$\frac{AC_n}{\text{plf}} =$	$FS_{ten_n} =$	$FS_{po_n} =$	$FS_{sl_n} =$	$FS_{conn_n} =$	$FS_{sc_n} =$
2.33 ft	5 ft	127	834	1.14 ft	256	6.56	2.01	21.74	10.72	21.89
4.33	5	199	834	2.28	952	4.2	4.79	7.27	7.81	17.65
6.33	5	290	834	3.43	2088	2.87	7.19	4.09	5.88	12.77

# Segmental Retaining Wall Design Calculations per NCMA

## Wall Geometry

Height $H_w := 5.83 \cdot \text{ft}$	Backslope $\beta := 0.0 \cdot \text{deg}$	Dead Load $q_d := 0 \cdot \text{psf}$	Live Load $q_l := 0 \cdot \text{psf}$	Distance to Slope $Z := 1.0 \cdot \text{ft}$	Wal below grade at toe $H_{\text{cmb}} := .67 \cdot \text{ft}$
---	--	--	--	---	---

## Soil Properties

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

## Segmental Unit Properties

Height $H_u := 6 \cdot \text{in}$	Length $L_u := 16 \cdot \text{in}$	Width $W_u := 12 \cdot \text{in}$	Setback $\Delta_u := 1.0 \cdot \text{in}$	Center of Gravity $G_u := 6 \cdot \text{in}$	Batter $\omega := \text{atan}\left(\frac{\Delta_u}{H_u}\right)$ $\omega = 9.462 \cdot \text{deg}$
Infilled Unit Weight $\gamma_u := 120 \cdot \text{pcf}$					Hinge Height

$$H_h := \text{if} \left[ \tan(\omega) = 0, H, \left[ 2 \cdot \frac{(W_u - G_u)}{\tan(\omega)} \right] \right] \Rightarrow H_h = 6 \text{ ft} \quad [\text{Eq. 4-1}]$$

### Internal Interface Friction Angle

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

### Internal Active Earth Pressure

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

$[\text{Eq. 3-11}] \quad K_{a_i} = 0.213$

### External Interface Friction Angle

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

### External Active Earth Pressure

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

$[\text{Eq. 3-11}] \quad K_{a_e} = 0.276$

### Orientation of Critical Internal Failure Surface

$$\alpha_i := \text{atan} \left[ \frac{-\tan(\phi_i - \beta) + \sqrt{(\tan(\phi_i - \beta) \cdot (\tan(\phi_i - \beta) + \cot(\phi_i + \omega)) \cdot (1 + \tan(\delta_i - \omega) \cdot \cot(\phi_i + \omega)))}}{1 + \tan(\delta_i - \omega) \cdot (\tan(\phi_i - \beta) + \cot(\phi_i + \omega))} \right] + \phi_i \quad [\text{Eq. 3-14}]$$

$\alpha_i = 53.553 \cdot \text{deg}$

### Orientation of Critical External Failure Surface

$$\alpha_e := \text{atan} \left[ \frac{-\tan(\phi_e - \beta) + \sqrt{(\tan(\phi_e - \beta) \cdot (\tan(\phi_e - \beta) + \cot(\phi_e + \omega)) \cdot (1 + \tan(\delta_e - \omega) \cdot \cot(\phi_e + \omega)))}}{1 + \tan(\delta_e - \omega) \cdot (\tan(\phi_e - \beta) + \cot(\phi_e + \omega))} \right] + \phi_e \quad [\text{Eq. 3-14}]$$

$\alpha_e = 48.773 \cdot \text{deg}$

**Sliding**

**External Stability Analysis**

Given

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

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

$L_{sliding} = 2.375 \text{ ft}$

**Overtuning**

Given

$$\begin{aligned}
 & \left[ (L \cdot \gamma_c \cdot H) \cdot \left[ \frac{1}{2} \cdot (L + H \cdot \tan(\omega)) \right] \right] \dots \\
 & + \left[ \frac{1}{2} \cdot \gamma_c \cdot (L - W_u - Z) \cdot \left[ (L - W_u - Z) + \frac{(L - W_u - Z) \cdot \tan(\beta) \cdot \tan(\omega)}{1 - \tan(\beta) \cdot \tan(\omega)} \right] \cdot \tan(\beta) \right] \cdot \left[ H \cdot \tan(\omega) + W_u + Z + \frac{2}{3} \cdot (L - W_u - Z) \right] \\
 & + q_d \cdot \left[ (L - W_u - Z) + \frac{(L - W_u - Z) \cdot \tan(\beta) \cdot \tan(\omega)}{1 - \tan(\beta) \cdot \tan(\omega)} \right] \cdot \left[ Z + \frac{(L - W_u - Z) \cdot \tan(\beta) \cdot \tan(\omega)}{1 - \tan(\beta) \cdot \tan(\omega)} \right] + H \cdot \tan(\omega) + \\
 2.0 = & \frac{\left[ \frac{1}{2} \cdot K a_c \cdot \gamma_c \cdot \left[ H + \left[ (L - W_u - Z) + \frac{(L - W_u - Z) \cdot \tan(\beta) \cdot \tan(\omega)}{1 - \tan(\beta) \cdot \tan(\omega)} \right] \cdot \tan(\beta) \right]^2 \cdot \cos(\delta_e - \omega) \right] \cdot \left[ \frac{1}{3} \cdot \left[ H + \left[ (L - W_u - Z) + \frac{(L - W_u - Z) \cdot \tan(\beta) \cdot \tan(\omega)}{1 - \tan(\beta) \cdot \tan(\omega)} \right] \cdot \tan(\beta) \right] \right]}{\left[ (q_d + q_l) \cdot K a_c \cdot \left[ H + \left[ (L - W_u - Z) + \frac{(L - W_u - Z) \cdot \tan(\beta) \cdot \tan(\omega)}{1 - \tan(\beta) \cdot \tan(\omega)} \right] \cdot \tan(\beta) \right] \cdot \cos(\delta_e - \omega) \right] \cdot \left[ \frac{1}{2} \cdot \left[ H + \left[ (L - W_u - Z) + \frac{(L - W_u - Z) \cdot \tan(\beta) \cdot \tan(\omega)}{1 - \tan(\beta) \cdot \tan(\omega)} \right] \cdot \tan(\beta) \right] \right]}
 \end{aligned}$$

$L_{overtuning} := \text{Find}(L)$

$L_{overtuning} = 2.012 \text{ ft}$

$L_{\text{min}} := \max \left( \begin{matrix} L_{sliding} \\ L_{overtuning} \\ 0.6 \cdot H \end{matrix} \right)$

$L = 3.498 \text{ ft}$

Based on Overtuning and Sliding:

$L_{\text{min}} := 4.0 \text{ ft}$  (Round up L)

**Eccentricity**

$$L' := L - W_u - Z$$

$$L' = 2 \text{ ft}$$

[Fig. 2-10] [Eq. 5-1]

$$L'' := \frac{(L - W_u - Z) \cdot \tan(\beta) \cdot \tan(\omega)}{1 - \tan(\beta) \cdot \tan(\omega)}$$

$$L'' = 0 \text{ ft}$$

[Fig. 2-10] [Eq. 5-2]

$$L_\beta := L' + L''$$

$$L_\beta = 2 \text{ ft}$$

[Fig. 2-10] [Eq. 5-3]

$$h := L_\beta \cdot \tan(\beta)$$

$$h = 0 \text{ ft}$$

[Fig. 2-10] [Eq. 5-4]

$$W_{ri} := L \cdot \gamma_i \cdot H$$

$$W_{ri} = 2565.2 \cdot \text{plf}$$

[Eq. 5-15]

$$X_{ri} := \frac{1}{2} \cdot (L + H \cdot \tan(\omega))$$

$$X_{ri} = 2.486 \text{ ft}$$

[Eq. 5-19]

$$W_{r\beta} := \frac{1}{2} \cdot \gamma_i \cdot (L' - Z) \cdot h$$

$$W_{r\beta} = 0 \cdot \text{plf}$$

[Eq. 5-16]

$$X_{r\beta} := H \cdot \tan(\omega) + W_u + \frac{2}{3} \cdot L_\beta + Z$$

$$X_{r\beta} = 4.305 \text{ ft}$$

[Eq. 5-20]

$$X_{q\beta} := \frac{Z + L_\beta}{2} + [(H + h) \cdot \tan(\omega)] + W_u$$

$$X_{q\beta} = 3.472 \text{ ft}$$

[Eq. 5-21]

Actual Height of wall:

$$H_s := (H + h)$$

$$H_s = 5.83 \text{ ft}$$

Earth Pressures:

$$P_{sH} := \left[ \frac{1}{2} \cdot K a_e \cdot \gamma_e \cdot (H + h)^2 \cdot \cos(\delta_e - \omega) \right]$$

$$P_{sH} = 540.173 \cdot \text{plf}$$

[Eq. 5-6]

$$Y_s := \frac{1}{3} \cdot (H + h)$$

$$Y_s = 1.943 \text{ ft}$$

[Eq. 5-9]

$$P_{qH} := (q_d + q_l) \cdot K a_e \cdot (H + h) \cdot \cos(\delta_e - \omega)$$

$$P_{qH} = 0 \cdot \text{plf}$$

[Eq. 5-8]

$$Y_q := \frac{1}{2} \cdot (H + h)$$

$$Y_q = 2.915 \text{ ft}$$

[Eq. 5-10]

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

$$\bar{e} = -0.0766 \text{ ft}$$

[Eq. 5-25]

**Check**

$$\bar{e} := \text{if}(e \leq 0, 0.075L, e)$$

$$e = 0.3 \text{ ft}$$

Surcharge is applied over:  $(L' + L'') = 2 \text{ ft}$ 

$$B := L - 2 \cdot e$$

$$B = 3.4 \text{ ft}$$

[Eq. 5-24]

### Bearing Capacity

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

$$Q_a = 754.471 \cdot \text{psf}$$

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

$$N_q = 11.854$$

[Fig. 4-5]

$$N_c := \text{if}[\phi_f = 0, 5.14, (N_q - 1) \cdot \cot(\phi_f)]$$

$$N_c = 22.254$$

[Fig. 4-5]

$$N_\gamma := 2 \cdot (N_q + 1) \cdot \tan(\phi_f)$$

$$N_\gamma = 12.539$$

[Fig. 4-5]

$$Q_{ult} := c_f \cdot N_c + \frac{1}{2} \cdot \gamma_f \cdot B \cdot N_\gamma + \gamma_f \cdot H_{emb} \cdot N_q$$

$$Q_{ult} = 3510.999 \cdot \text{psf}$$

[Eq. 4-20]

$$FS_{\text{bearing}} := \frac{Q_{ult}}{Q_a}$$

$$FS_{\text{bearing}} = 4.654$$

[Eq. 4-19]

## Internal Stability

### Reinforcement Properties

#### Geogrid Design Data

Backfill Soil

Type := (gravel)

1 2 3 4 5 6 7 8 9

Geogrid Number

$$\text{Type}^T = (411 \ 834 \ 1199 \ 1336 \ 2004 \ 2508 \ 3011 \ 3873 \ 7914)$$

$$\text{GN1} := 4$$

$$\text{GN2} := 2$$

$$\text{inter}^T = (1145 \ 1145 \ 1145 \ 1145 \ 1145 \ 1145 \ 0)$$

$$\text{slope}^T = (38 \ 38 \ 38 \ 38 \ 38 \ 38 \ 0)$$

$$\text{maxc}^T = (4540 \ 4540 \ 4540 \ 4540 \ 4540 \ 4540 \ 0) \quad x := 4..1 \quad x \text{ is the number of grids at the top of the wall of a different type}$$

$$T_a := \text{Type}_{\text{GN1}} \cdot \text{plf} \quad T_a = 1336 \cdot \text{plf}$$

$$T_{a2} := \text{Type}_{\text{GN2}} \cdot \text{plf} \quad T_{a2} = 834 \cdot \text{plf}$$

$$a_{cs} := \text{inter}_{\text{GN1}} \cdot \text{plf} \quad a_{cs} = 1145 \cdot \text{plf}$$

$$\lambda_{cs} := \text{slope}_{\text{GN1}} \cdot \text{deg} \quad \lambda_{cs} = 38 \cdot \text{deg}$$

$$V_{cs\text{max}} := \text{maxc}_{\text{GN1}} \cdot \text{plf} \quad V_{cs\text{max}} = 4540 \cdot \text{plf}$$

$$a_{cs2} := \text{inter}_{\text{GN2}} \cdot \text{plf} \quad a_{cs2} = 1145 \cdot \text{plf}$$

$$\lambda_{cs2} := \text{slope}_{\text{GN2}} \cdot \text{deg} \quad \lambda_{cs2} = 38 \cdot \text{deg}$$

$$V_{cs\text{max}2} := \text{maxc}_{\text{GN2}} \cdot \text{plf} \quad V_{cs\text{max}2} = 4540 \cdot \text{plf}$$

### Tension in Geogrid

Number of Grids:  $n_g := 2$   
 Grid Spacing (ft):  
 Spacing1 := 2  
 Spacing2 := 1.67  
 # of grids for that spacing:  
 $n_1 := 2$   
 $n_2 := 0$   
 Depth of first grid (ft):  
 $h_1 := 2.33$   
 Length of grids:  
 $L_1 := 4.0$     $L_2 := 4.0$     $L_r := \frac{L}{ft}$   
 Make all zero when using one geogrid

Note: make sure that the elevations don't excide the height of the wall (H) H = 5.83 ft

top := length(E)    p := 2.. top    top = 2  
 grids := length(E)    n := 1.. top    l := 1.. grids - 1

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

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

$$T_x := \frac{L \cdot T_a}{L}$$

$$T_a = \begin{pmatrix} 1336 \\ 1336 \end{pmatrix} \cdot \text{plf}$$

$$L = \begin{pmatrix} 4 \\ 4 \end{pmatrix} \text{ ft}$$

$$T_a^T = (834 \ 834 \ 834 \ 834) \cdot \text{plf}$$

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

$$D^T = (0 \ 3.33 \ 5.83) \text{ ft}$$

**Total Applied Tensile Strength in the Geosynthetic reinf.:**

$$F_{g_n} := \int_{D_n}^{D_{(n+1)}} (\gamma_i \cdot D + q_1 + q_d) \cdot K a_i \cdot \cos(\delta_i - \omega) \cdot dD \quad [\text{Eq. 5-36}]$$

$$F_g^T = (127.198 \ 262.68) \cdot \text{plf}$$

**Safety factor:**

$$FS_{\text{ten}_n} := \frac{T_{a_n}}{F_{g_n}}$$

$$FS_{\text{ten}}^T = (6.557 \ 3.175)$$

## Pullout Capacity

### Anchorage Length of Geosynthetic

$$L_{a_n} := L_n - W_u - \left[ (H + h) - E_n \right] \cdot \tan(90 \cdot \text{deg} - \alpha_i) + \left[ (H + h) - E_n \right] \cdot \tan(\omega) \quad [\text{Eq. 5-46}]$$

$$L_{a_n}^T = (0.998 \quad 2.142) \text{ ft}$$

**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

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

$$d_n^T = (2.33 \quad 4.33) \text{ ft}$$

### Anchorage Capacity

$$AC_n := 2 \cdot L_{a_n} \cdot C_i \cdot (d_n \cdot \gamma_i + q_d) \cdot \tan(\phi_i) \quad [\text{Eq. 5-45}]$$

$$AC_n^T = (223.867 \quad 892.599) \cdot \text{plf}$$

$$F_g^T = (127.198 \quad 262.68) \cdot \text{plf}$$

### Safety Factor

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

$$FS_{po}^T = (1.76 \quad 3.398)$$

## Internal Sliding

### Reduced reinforcement length

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

$$\Delta L^T = (0 \quad 1.419) \text{ ft}$$

$$L'_s := L_n - W_u - \Delta L_n \quad [\text{Eq. 5-50}]$$

$$L'_s{}^T = (3 \quad 1.581) \text{ ft}$$

### Length of sloping ground

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

$$L_{s\beta}^T = (2 \ 0.581) \text{ ft}$$

### Height of slope above crest of wall

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

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

### Weight of reduced reinforced area

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

$$W'_{ri_n}{}^T = (769 \ 753) \cdot \text{plf}$$

### Weight of wedge beyond reinforced soil zone

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

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

### Friction developed by weight

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

$$R'_s{}^T = (384 \ 376) \cdot \text{plf}$$

### Shear capacity of facing elements

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

$$V_u{}^T = (1363 \ 1551) \cdot \text{plf}$$

### Driving Forces

From retained soil

$$P'_s := \left[ \frac{1}{2} \cdot K_a \cdot \gamma_e \cdot (E_n + h'_n)^2 \cdot \cos(\delta_e - \omega) \right] \quad [\text{Eq. 5-6}]$$

$$P'_s{}^T = (86 \ 298) \cdot \text{plf}$$

From surcharge

$$P'_{q_n} := (q_d + q_l) \cdot K_a \cdot (E_n + h'_n) \cdot \cos(\delta_e - \omega) \quad [\text{Eq. 5-8}]$$

$$P'_{q_n}{}^T = (0 \ 0) \cdot \text{plf}$$

### Factor of safety against internal sliding

$$P'_a := P'_s + P'_{q_n} \quad [\text{Eq. 5-11}]$$

$$P'_a{}^T = (86 \ 298) \cdot \text{plf}$$

$$FS_{sl_n} := \frac{R'_s + V_u}{(P'_a)} \quad [\text{Eq. 5-48}]$$

$$FS_{sl}{}^T = (20.258 \ 6.468)$$

## Local Stability of Facing Units

### Facing Connection Strength

$$T_{\text{conn}_n} := \min \left[ V_{\text{csm}_{\text{max}_n}}, a_{\text{cs}_n} + \left( \text{if}(E_n > H_h, H_h, E_n) \cdot \gamma_u \cdot W_u \right) \cdot \tan(\lambda_{\text{cs}_n}) \right] \quad [\text{Eq. 5-59}]$$

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

$$FS_{\text{conn}_n} := \frac{T_{\text{conn}_n}}{F_{g_n}} \quad FS_{\text{conn}}^T = (10.719 \ 5.904)$$

### Resistance to Bulging

Shear capacity at each geogrid layer

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

$$V_u^T = (1363 \ 1551) \cdot \text{plf}$$

Driving Force at each geogrid layer

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

$$P_a^T = (62 \ 215) \cdot \text{plf}$$

Sum of tension in reinforcement layers above layer being considered

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

$$F^T = (0 \ 127 \ 390) \cdot \text{plf}$$

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

$$FS_{\text{sc}}^T = (21.895 \ 17.651)$$

### Maximum unreinforced height of SRW units

$$y := E_1 = 2.33 \text{ ft}$$

$$q_u := 0 \cdot \text{psf}$$

Moment equilibrium

Driving Moments

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

$$P'_s = 62.273 \cdot \text{plf}$$

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

$$P'_a := P'_s + P'_q \quad [\text{Eq. 4-4}] \quad \boxed{P'_a = 62.273 \cdot \text{plf}}$$

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

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

$$M'_o := P'_s \cdot Y'_s + P'_q \cdot Y'_q \quad [\text{Eq. 4-17}] \quad \boxed{M'_o = 48.37 \cdot \text{lbft}}$$

**Resisting Moments**

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

$$X'_w := G_u + \frac{1}{2} \cdot (y) \cdot \tan(\omega) \quad [\text{Eq. 4-16}] \quad \boxed{X'_w = 0.694 \text{ ft}}$$

$$M'_r := W'_w \cdot X'_w \quad [\text{Eq. 4-15}] \quad \boxed{M'_r = 194.089 \text{ ft} \cdot \text{plf}}$$

$$FS_{ot} := \frac{M'_r}{M'_o} \quad [\text{Eq. 4-14}] \quad \boxed{FS_{ot} = 4.013}$$

**Factor of Safety against Shear failure**

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

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

1363.447
1363.447
21.895
21.895
21.895
21.895

**Summary**

Wal Height H = 5.83 ft

Unreinforced Stability FS<sub>ot</sub> = 4.013

FS<sub>bearing</sub> = 4.654

Applied Bearing Stress Q<sub>a</sub> = 754 · 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)
$E_n =$	$L_n =$	$\frac{F_{g_n}}{\text{plf}} =$	$\frac{T_{a_n}}{\text{plf}} =$	$L_{a_n} =$	$\frac{AC_n}{\text{plf}} =$	$FS_{ten_n} =$	$FS_{po_n} =$	$FS_{sl_n} =$	$FS_{conn_n} =$	$FS_{sc_n} =$
2.33	4	127	834	1	224	6.56	1.76	20.26	10.72	21.89
4.33	4	263	834	2.14	893	3.17	3.4	6.47	5.9	17.65