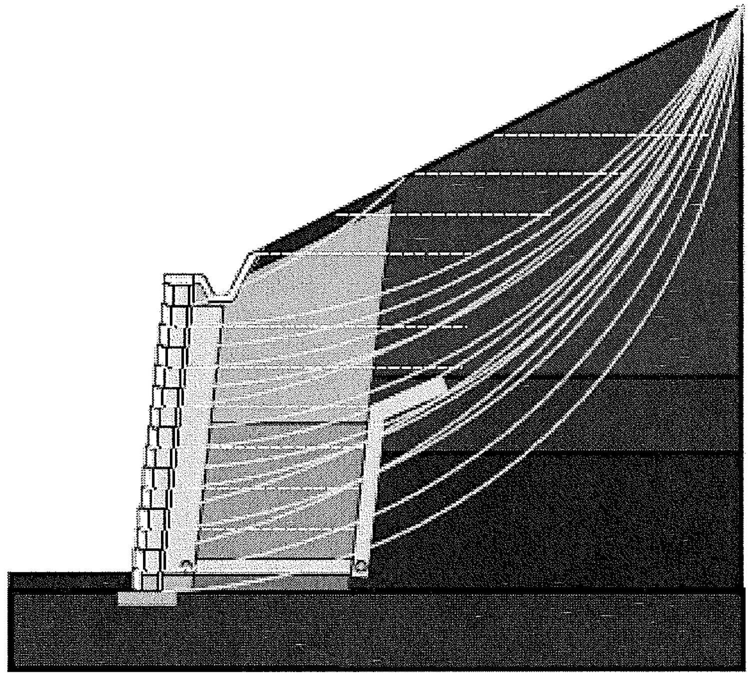
AB Walls 15 Reinforced Retaining Wall Hand Calculations

PROJECT NAME:	**SAMPLE HAND CALCULATIONS**
PROJECT NUMBER:	Preliminary
DATE:	
PREPARED BY:	

WALL NUMBER: Sample Project

CROSS SECTION: 4



These hand calculations are designed to match the output results from AB Walls. The users of these calculations are responsible for the correctness of the input and the results. The user is free to make any changes to any of the equation to alter the design methodology built into AB Walls. To match AB Walls, the user must input all design variables shown in all highlighted boxes.

INPUT INFORMATION

ALLAN BLOCK PARAMETERS

block height: $h := 8 \cdot in$

block depth: $t := 11.875 \cdot in$

block length: $l := 17.628 \cdot in$

unit percent concrete: $c := 60 \cdot \%$

unit percent voids: $v := 40 \cdot \%$

block setback: $\omega := 6.42deg$

WALL PARAMETERS

number of block courses: $n := 9$

total wall height: $H := n \cdot h = 6\,ft$

embedment depth in courses: $e := 1.245$

total embedment depth: $D := e \cdot h$

$D = 0.83\,ft$

geogrid length: $L := 4ft$ typical layers

$Ltop := 7ft$ top layers

BASE DIMENSIONS

footing width: $Lwidth := 2.00 \cdot ft$

footing depth: $Ldepth := 0.5 \cdot ft$

toe extension: $Ltoe := -0.5 \cdot ft$

geogrid length: $Lgrid := 0.0 \cdot ft$

ASHLAR BLEND (Reduction for Abby Blend included in Europa)

$ASHLAR := 2$

1=YES 2=NO

TUMBLE EUROPA COLLECTION

$TUMBLED := 2$

1=YES 2=NO

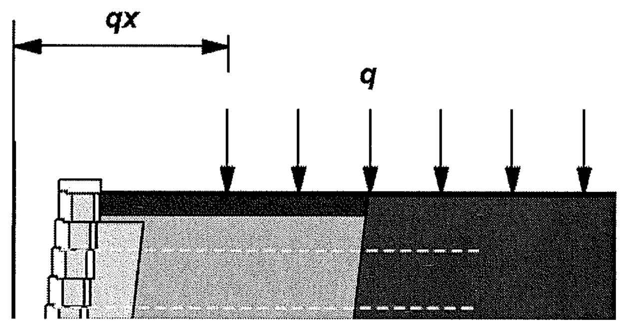
SURCHARGE PARAMETERS

surcharge: q := 100.0psf

qx := 7.5 · ft

surcharge type: xq := 1

Surcharge Type:
1=Live Load
2=Dead Load



LINE LOAD PARAMETERS

Surcharge Type:
1=Live Load
2=Dead Load

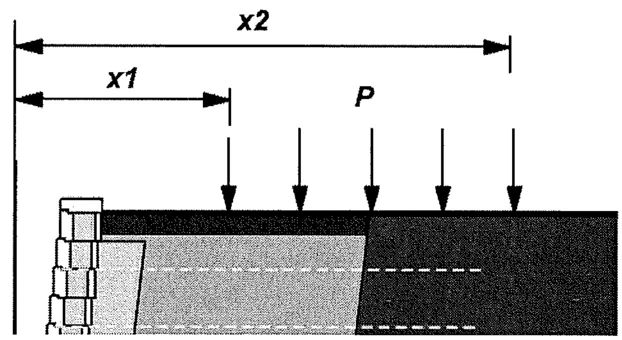
line load: P := 0 · psf

surcharge type: Stype := 1

Contact area boundaries from toe of wall:

starting point: x1 := 10 · ft

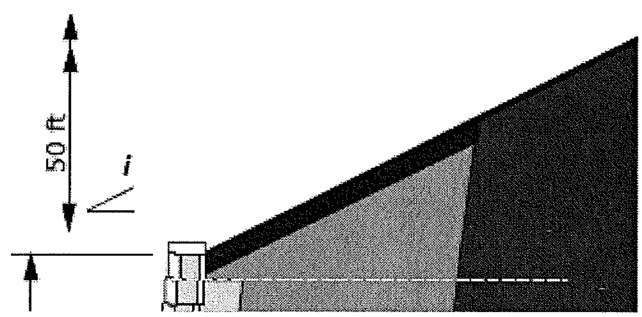
ending point: x2 := 20 · ft



BACKSLOPE PARAMETERS

backslope angle: i := 18.4deg

backslope height: hi := 2 · ft



Designers Notes:

1) hi is measured vertically from the top of the top block to the crest of the broken slope.

2) Typical backslopes above walls will not exceed a 2 to 1 horizontal to vertical ratio. The steeper the backslope, the worse affects that are placed on the wall. Applying a broken back slope to your wall design will greatly redue the pressures compared to a continous slope above.

USE TRIAL WEDGE METHOD FOR EXTERNAL STABILITY CALCULATIONS

TW := 2

1=YES
2=NO

SEISMIC FORCE ANALYSIS METHOD (SFAM) for INTERNAL CALCULATIONS:

SFAM := 3

Trapezoidal Wedge = 1

Active Wedge Weight = 2

Greater of the Two = 3

SEISMIC PARAMETERS

acceleration coefficient: Ao := 0.0

allowable lateral deflection:

internal: di := 3 · in

external: dr := 3 · in

Designers Note: Unreinforced slopes above cannot exceed the friction angle of the soil under static conditions. Under seismic conditions, the slope cannot exceed the friction angle of the soil minus the seismic inertial angle. See page 7 for calculations.

If the slope above needs to exceed these maximums, the designer can choose to run the external wall calculations using the Column's Trail Wedge method. If using Trial Wedge under seismic loading the designer must also run the internal calculations using the Trapezoidal Wedge method due to limitations in the Active Wedge weight method. See page 8.

SOIL PARAMETERS: USED IN EXTERNAL, INTERNAL AND BEARING CALCULATIONS

INFILL SOIL

friction angle: $\phi i := 30 \cdot deg$

unit weight: $\gamma i := 120 \cdot pcf$

RETAINED SOIL

friction angle: $\phi r := 30 \cdot deg$

unit weight: $\gamma r := 120 \cdot pcf$

FOUNDATION SOIL (Standard Method)

friction angle: $\phi f := 30 \cdot deg$

unit weight: $\gamma f := 120 \cdot pcf$

cohesion $cf := 0 \cdot psf$

LEVELING PAD SOIL

friction angle: $\phi lp := 36 \cdot deg$

MULTIPLE SOIL TYPE DESIGN PARAMETERS: USED IN INTERNAL COMPOUND STABILITY (ICS) CALCULATIONS ONLY

Designers Note: Modeling multiple soil types within the infill mass and the retained soils allows the designer the freedom to more accurately model the actual site conditions. As an example, using this option, the designer could model the lower half of the mass with No-Fines Concrete and the upper half with site soils.

Because this option is only available in the ICS portion of AB Walls, the user should input the lowest friction angle of the three possible in for the correct friction angle box above, used for external, internal and bearings. If the designer uses only the soil parameters above, all the parameters input below should match those above.

Infill Soils TOP (I 3)

friction angle:

$\phi i\_3 := 30 \cdot deg$

unit weight:

$\gamma i\_3 := 120 \cdot pcf$

Infill Soils MIDDLE (I 2)

friction angle:

$\phi i\_2 := 30 \cdot deg$

unit weight:

$\gamma i\_2 := 120 \cdot pcf$

Top of Soil I_2 Height:

$I\_2 := 0.6H$ $I\_2 = 3.6\,ft$

Infill Soils BOTTOM (I 1)

friction angle:

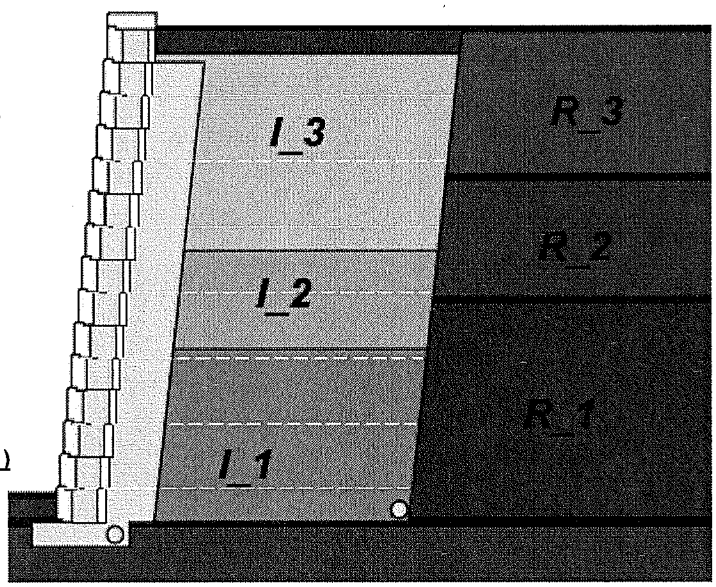
$\phi i\_1 := 30 \cdot deg$

unit weight:

$\gamma i\_1 := 120 \cdot pcf$

Top of Soil I_1 Height:

$I\_1 := 0.3H$ $I\_1 = 1.80\,ft$



Retained Soils TOP (R 1)

friction angle:

$\phi r\_3 := 30 \cdot deg$

unit weight:

$\gamma r\_3 := 120 \cdot pcf$

Retained Soils MIDDLE (R 1)

friction angle:

$\phi r\_2 := 30 \cdot deg$

unit weight:

$\gamma r\_2 := 120 \cdot pcf$

Top of Soil R_2 Height:

$R\_2 := 0.6H$

$R\_2 = 3.60\,ft$

Retained Soils BOTTOM (R 1)

friction angle:

$\phi r\_1 := 30 \cdot deg$

unit weight:

$\gamma r\_1 := 120 \cdot pcf$

Top of Soil R_1 Height:

$R\_1 := 0.3H$ $R\_1 = 1.80\,ft$

INTERNAL COMPOUND STABILITY Input Values from AB Walls:

$course := 0$

Static = $FSi := 1.69$ Seismic = $FSi\_siesmic := 1.69$

$Xc := 0.78ft$ $Yc := 11.87ft$ $Radius := 11.87ft$

$X2 := 0.99ft$ $Y2 := 0ft$ $Y1 := 8ft$ $X1 := 12ft$

Bearing Method:

$bearing := 1$

1=AB - Modified Meyerhof

2=NCMA

GEOGRID PARAMETERS

			long term allowable design strength	reduction factor for long term creep:
geogrid type A:	A := "Strata 200"	geogrid type A:	LTDS_A := 1613 · plf	RFcr_A := 1.61
geogrid type B:	B := "Strata 350"	geogrid type B:	LTDS_B := 2259 · plf	RFcr_B := 1.61

factor of safety geogrid overstress (Static): FSos_s := 1.5

factor of safety geogrid overstress (Seismic): FSos_d := 1.1

Geogrid Parameters for Pullout of soil:

Ci := 0.7 αpullout := 1.0

CONNECTION STRENGTH PARAMETERS

PEAK CONNECTION CAPACITY, in the form of a linear equation. y=Mx+B
where: y = connection strength and x = normal load

GEOGRID TYPE A

segment #1 y intercept: B1a := 1383plf

slope: M1a := tan(17.7966 · deg)

segment #2 y intercept: B2a := 1383 · plf

slope: M2a := tan(17.7966 · deg)

Intersecting Normal Load

$$Ninta := \frac{B2a - B1a}{M1a - M2a} \qquad Ninta = 0 \cdot \frac{lb}{ft}$$

Maximum tested value:

Max_A := 2087plf

GEOGRID TYPE B

segment #1 y intercept: B1b := 1257 · plf

slope: M1b := tan(12.1886 · deg)

segment #2 y intercept: B2b := 1257 · plf

slope: M2b := tan(12.1886 · deg)

Intersecting Normal Load

$$Nintb := \frac{B2b - B1b}{M1b - M2b} \qquad Nintb = 0 \cdot plf$$

Maximum tested value:

Max_B := 1979plf

BLOCK SHEAR PARAMETERS

NOTE: Block - Grid - Block AND Block - Block Shear Results are the same for block with a nominal 6 degree setback or greater:

SRW UNIT INTERFACE SHEAR DATA (Block - Block)

	Block setback greater than or equal to 6 degrees:		Block setback less than 6 degrees:	
apparent minimum ultimate shear capacity between segmental units:	au := 2671 · plf	au_max := 4706plf	au3 := 1018 · plf	au3_max := 6218plf
apparent angle of friction between segmental units for peak shear capacity:	λu := 38 · deg		λu3 := 61 · deg	

GEOSYNTHETIC-SRW UNIT INTERFACE SHEAR DATA (Block - Grid - Block)

apparent minimum ultimate service state shear capacity:	au' := 2671plf	au'_max := 4706plf	au3' := 1150plf	au3'_max := 5585plf
apparent angle of friction between segmental units for service state shear capacity:	λu' := 38 · deg		λu3' := 50 · deg	

Note: Shear Capacity Percentage is used only in the Internal Compound Stability Calculations. This value reduces the allowable face shear.

Shear_Capacity := 100% of tested values.

SELECT BLOCK LAYERS

number of geogrid layers: $g := 4$ layers

range of block layers: $k := n..0$

$unit_k := k$ $\quad Elev_k := (unit_k \cdot h)$

SRW Course #:
NOTE: Course #1 represents the top of leveling pad.

Course Elev:

Geogrid Position:
Type 0 for no geogrid and 1..g for geogrid:

$unit_k =$	$Elev_k =$ (ft)	$geo_k :=$	$Glength_k =$ (ft)
9	6	4	7
8	5.333	0	0
7	4.667	3	4
6	4	0	0
5	3.333	2	4
4	2.667	0	0
3	2	1	4
2	1.333	0	0
1	0.667	0	0
0	0		0

GEOGRID LAYOUT PARAMETERS

range of geogrid layers: $j := g..1$

geogrid coursing: $grid_j :=$	geogrid type: $type_j :=$	geogrid length: $length_j :=$	geogrid coursing: $Ee_j =$ (ft)
8	A	Ltop	5.333
6	A	L	4.000
4	A	L	2.667
2	A	L	1.333

$Ee_j := grid_j \cdot h$

GEOGRID LAYERS ABOVE THE WALL

Are there Geogrid layers above the wall? $Grid\_Above := 2$

1 for Yes 2 for No

How far above the top block to the first layer of grid: $Sabove := 1.0ft$

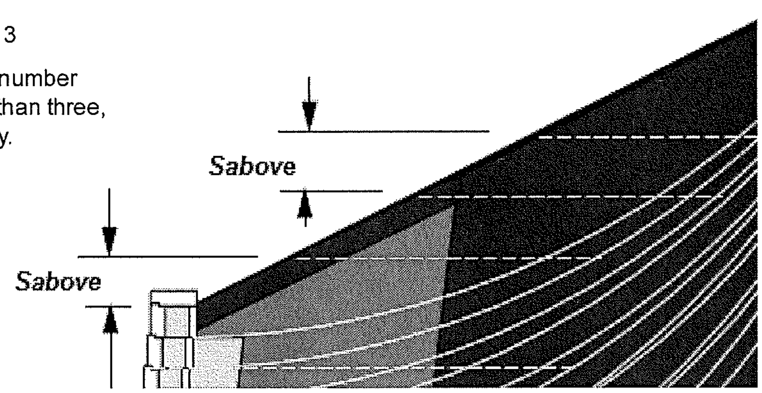
Spacing between layers: $Spacing := 1.50ft$

How many layers above wall are required: $Gabove := 3$

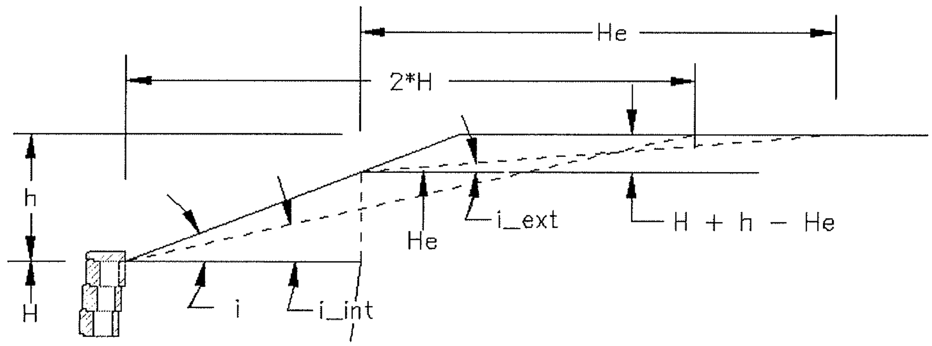
NOTE This spreadsheet is set up to have a maximum number of grid above the wall equal to three. if you have less than three, simply input 0 (zero) for the grid length in the Lga array.

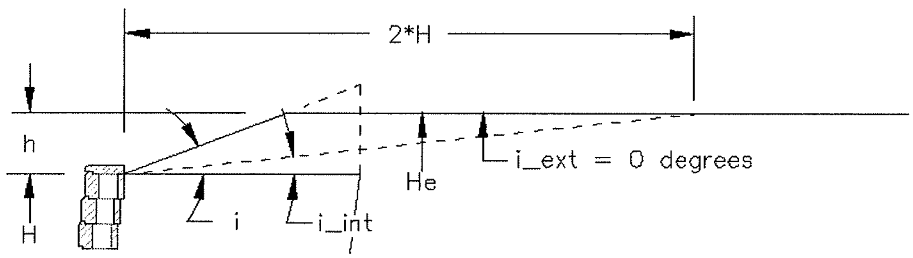
Length of Grid and Type: $Lgrid\_above := 6.5ft$

$Lga_{ga} :=$	$type\_GA_{ga} :=$
Lgrid_above	A
Lgrid_above	A
Lgrid_above	A



EFFECTIVE WALL HEIGHT AND BROKEN BACK SLOPE DETERMINATION





equivalent lip thickness:

$s := \text{if}(\omega > 5\text{deg}, 0.1829\text{ft}, 0.1412\text{ft}) = 0.183\,\text{ft}$

effective wall height:

$He := \text{if}[H + hi < [H + [L - (t - s)] \cdot \tan(i)], H + hi, H + [L - (t - s)] \cdot \tan(i)] = 7.062\,\text{ft}$

BROKEN BACK SLOPE CALCULATIONS, i' :

Determine the effective backslope angle:

Internal Calculations: $i\_int := \text{atan}\left(\dfrac{hi}{2H}\right) = 9.462 \cdot \text{deg}$

$i\_int := \text{if}(i\_int \geq i, i, i\_int) = 9.462 \cdot \text{deg}$

External Calculations:

$Hmax := He + He \cdot \tan(i) = 9.412\,\text{ft}$

$$i\_ext := \text{if}\left[H + hi < H + [L - (t - s)] \cdot \tan(i), 0\text{deg}, \text{if}\left[H + hi > Hmax, i, \text{atan}\left[\frac{hi - (He - H)}{He}\right]\right]\right]$$

$i\_ext := \text{if}(i\_ext \geq i, i, i\_ext) = 7.563 \cdot \text{deg}$

CALCULATION OF STATIC AND DYNAMIC EARTH PRESSURE COEFFICIENTS

weighted friction angle: $\phi wi := \dfrac{2}{3} \cdot \phi i$ $\phi wi = 20 \cdot \text{deg}$ $\phi wr := \dfrac{2}{3} \cdot \phi r$ $\phi wr = 20 \cdot \text{deg}$

wall batter: $\beta := 90 \cdot \text{deg} - \omega$

$\beta = 83.58 \cdot \text{deg}$

STATIC:

NOTE: IF USING TRIAL WEDGE METHOD FOR CALCULATING EXTERNAL STABILITY Kar AND Kaer WILL BE CALCULATED AS Kar_TW and Kaer_TW IN THE NEXT SECTION.

Active earth pressure coefficient:

Infill Soil

$$\Delta i\_static := \frac{\sin(\phi i + \phi wi) \cdot \sin(\phi i - i\_int)}{\sin(\beta - i\_int)} \qquad \Delta i\_static = 0.279$$

$$Kai := \left(\frac{\csc(\beta) \cdot \sin(\beta - \phi i)}{\sqrt{\sin(\beta + \phi wi)} + \text{if}\left(\Delta i\_static < 0, 0, \sqrt{\Delta i\_static}\right)} \right)^2 \qquad Kai = 0.286$$

Retained Soil

$$Kar := \left[\frac{\csc(\beta) \cdot \sin(\beta - \phi r)}{\sqrt{\sin(\beta + \phi wr)} + \sqrt{\left(\frac{\sin(\phi r + \phi wr) \cdot \sin(\phi r - i\_ext)}{\sin(\beta - i\_ext)} \right)}} \right]^2 \qquad Kar = 0.278$$

DYNAMIC: Seismic Coefficients:

Internal Stability

$Kv := 0$ $\quad Khi1 := (1.45 - Ao) \cdot Ao$ $\quad$ For: di=0 in

$Khi1 = 0$

External Stability

$Khr1 := \frac{Ao}{2}$ $\quad$ For: dr=0 in

$Khr1 = 0$

For di>=1 in

$$Khi2 := \text{if}\left[di = 0in, 0, 0.74 \cdot Ao \cdot \left(\frac{Ao \cdot 1 \cdot in}{di} \right)^{0.25} \right]$$

For dr>=1 in

$$Khr2 := \text{if}\left[dr = 0in, 0, 0.74 \cdot Ao \cdot \left(\frac{Ao \cdot 1 \cdot in}{dr} \right)^{0.25} \right]$$

$Khi := \text{if}(di = 0in, Khi1, Khi2) = 0$ $\qquad Khr := \text{if}(dr = 0in, Khr1, Khr2) = 0$

Seismic inertial angle:

Internal Stability

$$\theta i := \text{atan}\left(\frac{Khi}{1 + Kv} \right) = 0 \cdot deg$$

External Stability

$$\theta r := \text{atan}\left(\frac{Khr}{1 + Kv} \right) = 0 \cdot deg$$

Maximum Allowable Slopes in Seismic Conditions

When designing a wall subject to seismic or static loading the designer should understand that there are limitations to the steepness of unreinforced slopes that can be designed and built above any wall.

In static designs, the maximum unreinforced slope above any wall is limited to the internal friction angle of the soil. For seismic designs, the Mononobe-Okabe (M_O) soil mechanics theory gives designers the seismic earth pressure coefficient (Kae) to apply to their retaining wall by combining the effects of soil strength (ϕr), slopes above the wall (i), wall setback (ω), and seismic inertia angle (θr). This equation becomes limited by its mathematics when low strength soils, steep slopes, and high seismic accelerations are combined. This may be translated to say that for specific combinations of slope angles, soil strength and seismic acceleration the project changes from a segmental retaining wall design to a slope stability problem. With a closer look at these three limiting variables the maximum allowable slope in seismic conditions is:

$$i\_max := \phi r - \theta r \qquad i\_max = 30 \cdot deg$$

note = "Entered slope above does not exceed allowable unreinforced slope"

NOTE: Δi and Δr are calculated separately to assure that the denominator for the Kaei and Kaer equations do not go negative under the square root bracket. This only happens when high seismic loads are combined with steep slopes above and poor soils.

$$\Delta i\_dyn := \frac{\sin(\phi i + \phi wi) \cdot \sin(\phi i - i\_int - \theta i)}{\cos(\phi wi - \omega + \theta i) \cdot \cos(\omega + i\_int)} = 0.287 \qquad \Delta r\_dyn := \frac{\sin(\phi r + \phi wr) \cdot \sin(\phi r - i\_ext - \theta r)}{\cos(\phi wr - \omega + \theta r) \cdot \cos(\omega + i\_ext)} = 0.31$$

Dynamic earth pressure coefficient:

Infill Soil

$$Kaei := \frac{\left(\dfrac{\cos(\phi i + \omega - \theta i)^2}{\cos(\theta i) \cdot \cos(\omega)^2 \cdot \cos(\phi wi - \omega + \theta i)}\right)}{\left(1 + \text{if}\left(\Delta i\_dyn < 0, 0, \sqrt{\Delta i\_dyn}\right)\right)^2}$$

Retained Soil

$$Kaer := \frac{\left(\dfrac{\cos(\phi r + \omega - \theta r)^2}{\cos(\theta r) \cdot \cos(\omega)^2 \cdot \cos(\phi wr - \omega + \theta r)}\right)}{\left(1 + \text{if}\left(\Delta r\_dyn < 0, 0, \sqrt{\Delta r\_dyn}\right)\right)^2}$$

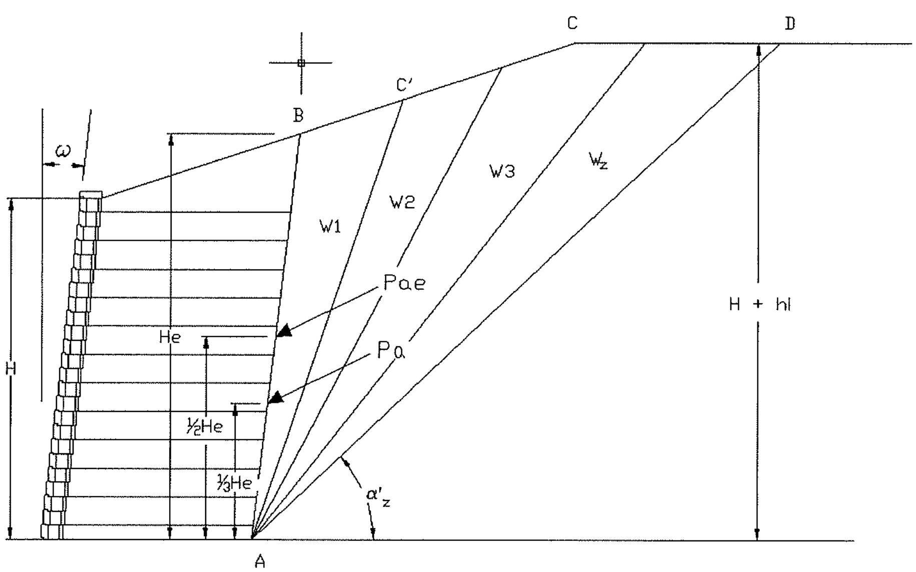
$Kaei := \text{if}(Ao = 0, 0, Kaei) \qquad Kaei = 0 \qquad Kaer := \text{if}(Ao = 0, 0, Kaer) \qquad Kaer = 0$

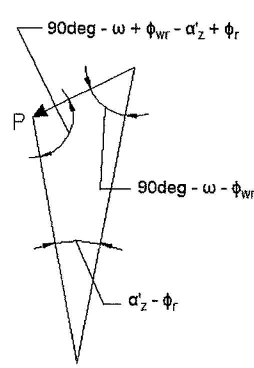
When a designers needs to design walls with slopes above steeper than the maximum allowed, they have the option of using the Coulomb Trial Wedge method. This method will provide the active earth force and pressure coefficient to allow the designer to complete the wall design. However, the maximum unreinforced slope described above still holds true. Therefore, if the geometry of the slope exceeds this maximum, they must strongly consider reinforcing the slope above using layers of geogrid and they must review the slope using a global stability program such as ReSSA from ADAMA Engineering (reslope.com), to determine the appropriate length, strength and spacing of the geogrid used to reinforce the slope above.

Trial Wedge Method of Determining Active Earth Pressure

The typical seismic design methodology described in this chapter adopts a pseudo-static approach and is generally based on the Mononobe - Okabe (M-O) method to calculate dynamic earth pressures. As described above in the maximum slope above calculation, there is a very distinct limitation to the M-O method. When the designer inputs a slope above the wall that has an incline angle above that exceeds the Internal Friction Angle of the soil minus the seismic inertial angle, the M-O equation for Kae becomes imaginary due to the denominator outputting a negative value. Therefore the maximum unreinforced stable slope above is relative to the magnitude of the seismic coefficient and the strength of soil used in the slope.

The Coulomb Trial Wedge method dates back to 1776 when Coulomb first presented his theory on Active Earth pressures and then again in 1875, when Culmann developed a graphical solution to Coulomb's theory. The Trial Wedge Method has similarities to global stability modeling in that you determine the weight above an inclined wedge behind the wall. By determining the worst case combination of weight and slope angle, the active earth forces for static and seismic conditions can be determined.





Static TW Force Equation:

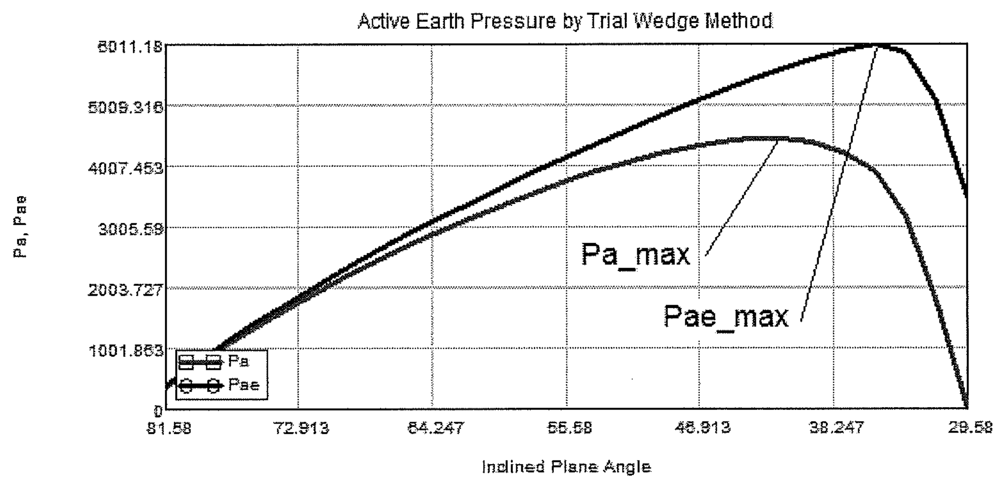
$$Pa = \frac{(\text{Weight of Wedge}) \sin(\alpha'_z - \phi_r)}{\sin(90deg - \omega + \phi_{wr} - \alpha'_z + \phi_r)}$$

Static and Dynamic TW Force Equation:

$$Pae = \frac{(\text{Weight of Wedge}) \dfrac{\sin(\alpha'_z + \theta_r - \phi_r)}{\cos(\theta_r)}}{\sin(90deg - \omega + \phi_{wr} - \alpha'_z + \phi_r)}$$

The Trial Wedge method however, does not have limitation due to slope steepness, soil strength or the magnitude of the seismic coefficient. The trial wedge calculations will provide lateral earth pressure forces no matter the geometry. With this in mind, when using the trial wedge method for walls that exceed the M-O maximum slope, it is mandatory that the user analyze the stability of the slope above the wall in a global stability modeling program. It is strongly recommended that the slope above be reinforced with layers of geogrid similar to those in the reinforced mass, with similar spacing and lengths.

The design process is straightforward using a computer program that allows rapid iterations of calculations to determine the maximum pressure, Pa (static) or Pae (seismic). Similar to a global stability analysis, determining the area of the wedges is the first step. The weight of each wedge is determined and applied downward onto the associated inclined wedge plane to determine the forward pressure. As the wedge weights increase and the inclined plane angle continues to rotate, the combination of weight and angle will combine to find a maximum forward force.



For external sliding, overturning and bearing safety factor equations, the Trial Wedge determined forces will replace those calculated by the standard Coulomb and M-O methods. Please note that the calculated Seismic Inertial Force (Pir) is calculated independently of the force method used. This means that Pir is additive to both M-O and Trial Wedge pressure results.

As in the standard Coulomb and M-O methods, the Trial Wedge pressures are applied to the back of the reinforced mass and divided into their horizontal and vertical components. Each are then applied at moment arm locations equal to 1/3*He for static and 1/2*He for seismic.

Active Earth Force by Trial Wedge Method:

The first excersise is to calculate the Total_Area$_z$ of each wedge and then each subsequent wedge thereafter. The total wedge area can then be multiplied by the unit weight of soil to determine the weight of wedge (W_Wedge_Area$_z$). The surcharge loading is additive to the wedge weight and no distintion is made between Live or Dead Load. The combined weights is given by W_Wedge$_z$.

Total_Area$_z$ = (ft^2)

0.894
1.805
2.738
3.694
4.678
5.693
6.743
7.833
8.968
10.153
11.396
12.703
14.083
15.546
17.105
18.772
20.565
22.501
24.613
26.882
29.323
31.965
34.84
37.988
41.459
45.316
...

W_Wedge_area$_z$ = ($\frac{lb}{ft}$)

107.23
216.63
328.54
443.33
561.4
683.2
809.21
939.99
1076.15
1218.38
1367.47
1524.31
1689.95
1865.58
2052.6
2252.67
2467.75
2700.17
2953.55
3225.8
3518.8
3835.81
4180.78
4558.54
4975.08
5437.88
...

W_Wedge$_z$ = ($\frac{lb}{ft}$)

107.234
216.634
328.544
443.331
561.402
683.199
809.214
939.993
1079.804
1255.877
1440.439
1634.605
1839.655
2057.078
2288.609
2536.29
2802.546
3090.275
3403.754
3741.738
4088.784
4471.818
4888.639
5345.088
5848.384
6407.567
7034.107
...

The Static Active Wedge Pressure Equation:

$$Pa\_Twedge_z := \begin{cases} 0\frac{lbf}{ft} & \text{if } W\_Wedge_z \cdot \frac{\sin(APrime_z - \phi r)}{\sin(90deg - \omega + \phi wr - APrime_z + \phi r)} < 0 \\ W\_Wedge_z \cdot \frac{\sin(APrime_z - \phi r)}{\sin(90deg - \omega + \phi wr - APrime_z + \phi r)} & \text{otherwise} \end{cases}$$

Determine the Maximum forward Static Force:

$$P_{a\_TW} := \max(Pa\_Twedge)$$

$$P_{a\_TW} = 944.37 \cdot plf$$

Kar can be back calculated by solving the typical active earth pressure equation for Kar and using the trial wedge determined active force:

$$Kar\_TW := \frac{P_{a\_TW}}{0.5 \cdot \gamma r \cdot He^2} \qquad Kar\_TW = 0.316$$

Divide the full Static force into horizontal and vertical components to be used in the Sliding and Overturning Safety Factor Equations:

$$P_{a\_TW\_h} := P_{a\_TW} \cdot \cos(\phi wr) = 887.418 \cdot plf$$

$$P_{a\_TW\_v} := P_{a\_TW} \cdot \sin(\phi wr) = 322.994 \cdot plf$$

Dynamic Earth Force by Trial Wedge Method is calculated in the same manner with the inclusion of the Seismic Inertial Angle:

$$Pae\_Twedge_z := \begin{cases} 0\frac{lbf}{ft} & \text{if } W\_Wedge_z \cdot \frac{\frac{\sin(APrime_z + \theta r - \phi r)}{\cos(\theta r)}}{\sin(90deg - \omega + \phi wr - APrime_z + \phi r)} < 0 \\ W\_Wedge_z \cdot \frac{\frac{\sin(APrime_z + \theta r - \phi r)}{\cos(\theta r)}}{\sin(90deg - \omega + \phi wr - APrime_z + \phi r)} & \text{otherwise} \end{cases}$$

Determine the Maximum forward Static Force:

$$P_{ae\_max} := \max(Pae\_Twedge)$$

$$P_{ae\_max} = 944.37 \cdot plf$$

Kaer can be back calculated by solving the typical active earth pressure equation for Kaer and using the trial wedge determined active force:

$$Kaer\_TW := \frac{P_{ae\_max}}{0.5 \cdot \gamma r \cdot He^2} \qquad Kaer\_TW = 0.316$$

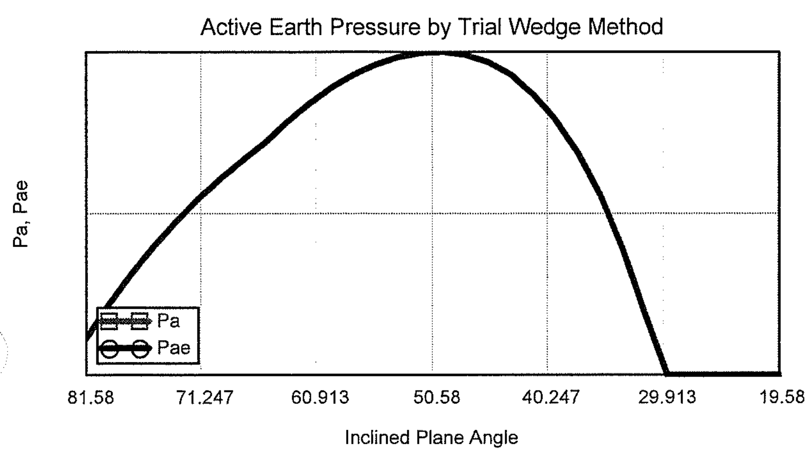
Subtract static force from the dynamic force to work with separate forces:

$$P_{ae\_TW} := P_{ae\_max} - P_{a\_TW} = 0 \cdot plf$$

Divide the full Seismic force into horizontal and vertical components to be used in the Sliding and Overturning Safety Factor Equations:

$$P_{ae\_TW\_h} := P_{ae\_TW} \cdot \cos(\phi wr) = 0 \cdot plf$$

$$P_{ae\_TW\_v} := P_{ae\_TW} \cdot \sin(\phi wr) = 0 \cdot plf$$

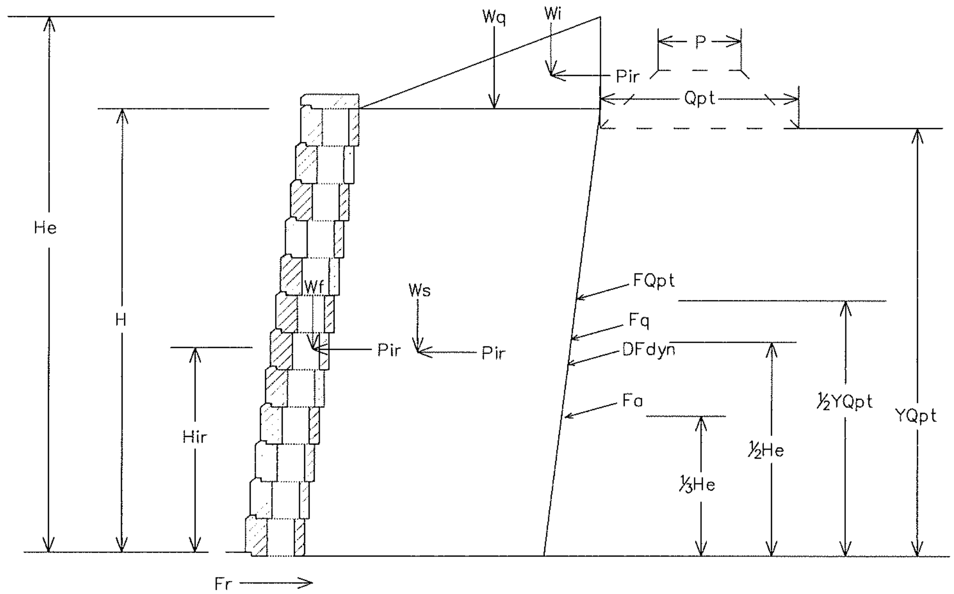


EXTERNAL STABILITY

Free Body Diagram

Where:

He=Effective Wall Height
H=Total Wall Height
Wi=Weight of the Backslope
Wq=Infill Surcharge Dead Load
Wf=Weight of the Allan Block Facing
Ws=Weight of the Geogrid Reinforced Soil Mass
Pir=Seismic Inertial Force for For Each Gravity Force
Hir=Pir Resultant Vertical Location
P=Point Load Surcharge
Qpt=Translated Point Load
DFdyn=Dynamic Earth Force
Fq=Surcharge Force
FQpt=Point Load Force
YQpt=Translated Point Load Vertical Location
Fa=Active Earth Force



concrete unit weight: $\gamma c := 135 \cdot pcf$

unit fill unit weight: $\gamma uf := 120 \cdot pcf$

DRIVING FORCE CALCULATIONS **(IF USING TRIAL WEDGE METHOD IGNORE THIS SECTION)**

ACTIVE EARTH FORCE:

$Fa := \frac{1}{2} \cdot Kar \cdot \gamma r \cdot He^2$ $\quad Fa = 832.988 \cdot plf$

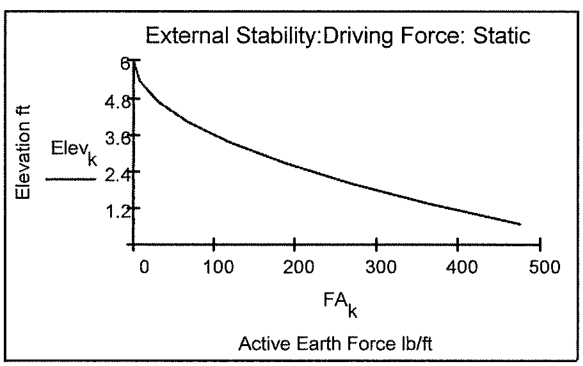
$Fah := Fa \cdot \cos(\phi wr)$ $\quad Fah = 782.753 \cdot plf$

$Fav := Fa \cdot \sin(\phi wr)$ $\quad Fav = 284.899 \cdot plf$

MOMENT ARMS:

$FaArmh := \frac{1}{3} \cdot He$ $\quad FaArmh = 2.354\,ft$

$FaArmv := L + s + \frac{1}{3} \cdot He \cdot \tan(\omega)$ $\quad FaArmv = 4.448\,ft$



DYNAMIC EARTH FORCE:

$Fae := \frac{1}{2} \cdot (1 + Kv) \cdot Kaer \cdot \gamma r \cdot He^2$ $\quad Fae = 0 \cdot plf$

Subtract static force from the dynamic force to work with separate forces:

$DFdyn := Fae - Fa = -832.988 \cdot plf$

$DFdyn := if\left(Ao = 0, 0\frac{lb}{ft}, DFdyn\right)$ $\quad DFdyn = 0 \cdot plf$

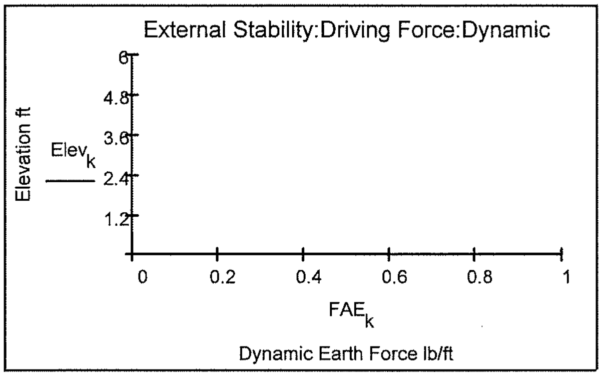
$DFdynh := DFdyn \cdot \cos(\phi wr)$ $\quad DFdynh = 0 \cdot plf$

$DFdynv := DFdyn \cdot \sin(\phi wr)$ $\quad DFdynv = 0 \cdot plf$

MOMENT ARMS:

$DFdynArmh := 0.5 \cdot He$ $\quad DFdynArmh = 3.531\,ft$

$DFdynArmv := L + s + 0.5 \cdot He \cdot \tan(\omega)$ $\quad DFdynArmv = 4.58\,ft$



Determine the furthest point back from the toe of the wall that ANY surcharge will apply force to the wall (MaxPoint):

$$ss1 := \frac{H}{\tan\left(45\cdot deg + \frac{\phi r}{2}\right)} \qquad ss2 := \frac{(ss1 + L + s - t - H\cdot\tan(\omega))\cdot\tan(i\_ext)\cdot\sin(90\cdot deg + i\_ext)}{\sin\left(45\cdot deg + \frac{\phi r}{2} - i\_ext\right)}\cdot\cos\left(45\cdot deg + \frac{\phi r}{2}\right)$$

$$MaxPoint := L + s + ss1 + ss2$$

$ss1 = 3.464\,ft$

$MaxPoint = 8.144\,ft$ $\qquad ss2 = 0.497\,ft$

If the surcharge is behind the mass determine the distance from the back of the mass to the face of the square foot surcharge (qx1):

$qx1 := [qx - (t + H\cdot\tan(\omega))]\cdot\tan(i\_ext)$ $\qquad qx1 = 0.775\,ft$

Determine the effective height of the square foot surcharge if the force is behind the mass (Yq_sf):

$$Yq\_sf := \left[(H + qx1) - (qx - L - s)\cdot\left(\tan\left(45\cdot deg + \frac{\phi r}{2}\right)\right)\right]\cdot\left[1 + \sin\left(45\cdot deg + \frac{\phi r}{2}\right)\cdot\left(\frac{\sin(90\cdot deg + \omega)\cdot\tan(\omega)}{\sin\left(45\cdot deg + \frac{\phi r}{2} - \omega\right)}\right)\right]$$

Determine the end of grid at the top of the wall:

$Yq\_sf = 1.153\,ft$

$Endg := L + s + H\cdot\tan(\omega)$ $\qquad Endg = 4.858\,ft$

Determine the effective height of the square foot surcharge to use if the force is behind the mass (He_q):

$He\_q := if(qx < MaxPoint, if(qx < Endg, He, Yq\_sf), 0ft)$ $\qquad He\_q = 1.153\,ft$

Determine the end of grid at the effective height of the square foot surcharge:

$EndgYq\_sf := L + s + He\_q\cdot\tan(\omega)$ $\qquad EndgYq\_sf = 4.313\,ft$

SQUARE FOOT SURCHARGE INLUENCE: **(IF USING TRIAL WEDGE METHOD IGNORE THIS SECTION)**

If the square foot surcharge acts above the mass the applied load is the q as input above. If the surcharge is applied only behind the mass the load is translated down into the soil to a point at which the force lines intersect the back of the mass. This translation through the soil causes the load to be distributed over a larger footprint. Because the square foot surcharge does not have an ending point like the x2 in the point load calculations the applied load is truncated at the Maxpoint location. The following, q_sfi. equation calculates the translated square foot surcharge.

$$q\_sfi := \frac{q\cdot(MaxPoint - qx)}{[(qx - EndgYq\_sf)\cdot 2 + (MaxPoint - qx)]} \qquad q\_sfi = 9.171\cdot psf$$

Surcharge based on its position relative to the reinforced mass:

$q\_sf := if(qx < MaxPoint, if(qx < Endg, q, q\_sfi), 0psf)$ $\qquad q\_sf = 9.171\cdot psf$

SQUARE FOOT SURCHARGE FORCE:

$Fq := if(qx < MaxPoint, if(qx < Endg, q \cdot Kar \cdot He, q\_sfi \cdot Kar \cdot He\_q), 0plf)$ $Fq = 2.944 \cdot plf$

MOMENT ARMS:

$Fqh := Fq \cdot \cos(\phi wr)$ $Fqh = 2.767 \cdot plf$ $FqArmh := 0.5 \cdot He\_q$ $FqArmh = 0.577\,ft$

$Fqv := if(xq = 2, Fq \cdot \sin(\phi wr), 0plf)$ $Fqv = 0 \cdot plf$ $FqArmv := L + s + 0.5 \cdot He\_q \cdot \tan(\omega)$ $FqArmv = 4.248\,ft$

LINE LOAD SURCHARGE: **(IF USING TRIAL WEDGE METHOD IGNORE THIS SECTION)**

If the surcharge is behind the mass determine the distance from the back of the mass to the face of the square foot surcharge (Qx1):

$Qx1 := [x1 - (t + H \cdot \tan(\omega))] \cdot \tan(i\_ext)$

Determine the effective height of the square foot surcharge if the force is behind the mass (YQ_pt):

$$YQ\_pt := \left[(H + Qx1) - (x1 - L - s) \cdot \left(\tan\left(45 \cdot deg + \frac{\phi r}{2}\right)\right)\right] \cdot \left[1 + \sin\left(45 \cdot deg + \frac{\phi r}{2}\right) \cdot \left(\frac{\sin(90 \cdot deg + \omega) \cdot \tan(\omega)}{\sin\left(45 \cdot deg + \frac{\phi r}{2} - \omega\right)}\right)\right]$$

$YQ\_pt = -3.326\,ft$

Determine the effective height of the line load surcharge to use if the force is behind the mass (He_Q):

$He\_Q := if(x1 < MaxPoint, if(x1 < Endg, He, YQ\_pt), 0ft)$ $He\_Q = 0\,ft$

Location of the end of the grid at the YQpt elevation:

$EndgYQ\_pt := L + s + He\_Q \cdot \tan(\omega)$ $EndgYQ\_pt = 4.183\,ft$

If the ending position of the line load surcharge (x2) is beyond the MaxPoint of influence the load is truncated at the MaxPoint location:

$x2 := if(x2 > MaxPoint, MaxPoint, x2) = 8.144\,ft$

If the line load surcharge acts above the mass the applied load is the P as input above. If the surcharge is applied only behind the mass the load is translated down into the soil to a point at which the force lines intersect the back of the mass. This translation through the soil causes the load to be distributed over a larger footprint. The following, Qpti. equation calculates the translated square foot surcharge.

$Qpi := \frac{P \cdot (x2 - x1)}{(x2 - x1)}$ $Qpi = 0 \cdot psf$ $Qpti := \frac{P \cdot (x2 - x1)}{[(x1 - EndgYQ\_pt) \cdot 2 + (x2 - x1)]}$ $Qpti = 0 \cdot psf$

Point Load Surcharge Influence

If the point load contacts only with the reinforced mass it will add stability to the wall structure, therefore the loads are only considered in the internal stability calculations.

$Qp := if\left(x2 \ge Endg, Qpi, 0\frac{lb}{ft^2}\right)$ $Qp = 0 \cdot psf$

If the point load contacts in beyond the reinforced mass and its influence zone buffer it will only affect the external stability. If it overlaps both the influence zone and retained soil it will effect both internal and external stability.

$Qpt := if(x1 \ge Endg, Qpti, Qpi)$ $Qpt = 0 \cdot psf$

If the point load contact beyond the reinforced mass plus its influence zone buffer it will have no effect on the wall, Qpt=0.

$Qpt := if(x1 < MaxPoint, Qpt, 0psf)$ $Qpt = 0 \cdot psf$

Note:

Qpt is the translated distributed point load surcharge used to determine the point load force that will be influencing the external stability of the retaining wall structure. Qpt is a function of the location of the contact area with respect to the geogrid reinforcement. Qp will be used to calculate the point load surcharge if it acts directly on top of the reinforced soil. No translation calculations are necessary for Qp because its applications area is on top of the reinforced mass and its influence zone buffer.

POINT LOAD SURCHARGE FORCE:

$FQpt := Qpt \cdot Kar \cdot He\_Q = 0 \cdot plf$

$FQpth := FQpt \cdot \cos(\phi wr) = 0 \cdot plf$

$FQptv := if(Stype = 2, FQpt \cdot \sin(\phi wr), 0plf) = 0 \cdot plf$

MOMENT ARM:

$FQptArmh := \frac{He\_Q}{2}$ $FQptArmh = 0\,ft$

$FQptArmv := L + s + .5 \cdot He\_Q \cdot \tan(\omega)$

$FQptArmv = 4.183\,ft$

POINT LOAD SURCHARGE WEIGHT:

$WQpt1 := Qpi \cdot (x2 - x1) = 0 \cdot plf$

$WQpt2 := Qpi \cdot (Endg - x1) = 0 \cdot plf$

$WQpt := if(x2 \le Endg, WQpt1, WQpt2)$

$WQpt := if(x1 > Endg, 0plf, WQpt)$

$WQpt = 0 \cdot plf$

MOMENT ARM:

$WQptArm1 := x1 + \frac{(x2 - x1)}{2}$ $WQptArm1 = 9.072\,ft$

$WQptArm2 := x1 + \left[\frac{(Endg - x1)}{2}\right]$ $WQptArm2 = 7.429\,ft$

$WQptArm := if(x2 \le Endg, WQptArm1, WQptArm2)$

$WQptArm = 7.429\,ft$

$WQp := if(Stype = 2, WQpt, 0plf)$ $WQp = 0 \cdot plf$

RESISTING FORCE CALCULATIONS:

WEIGHT OF THE BACKSLOPE: $Wi := 0.5 \cdot \gamma r \cdot (He - H) \cdot [L - (t - s)]$

$Wi = 203.531 \cdot plf$

MOMENT ARM:

$WiArm := \frac{2}{3} \cdot [L - (t - s)] + H \cdot \tan(\omega) + t$

$WiArm = 3.794\,ft$

Determine the position of the square foot surcharge (qp):

$qp := if[qx < Endg, if[qx > H \cdot \tan(\omega) + t, (Endg) - qx, L - (t - s)], 0ft]$ $qp = 0\,ft$

MOMENT ARM for Weight of Dead Load Surcharge:

$WqArm := if\left[qx < Endg, if\left[qx > H \cdot \tan(\omega) + t, \frac{1}{2}qp + qx, \frac{1}{2} \cdot [L - (t - s)] + H \cdot \tan(\omega) + t\right], 0ft\right]$ $WqArm = 0\,ft$

WEIGHT OF THE DEAD LOAD SURCHARGE: $Wq := if[xq = 2, (qp) \cdot q, 0plf]$ $Wq = 0 \cdot plf$

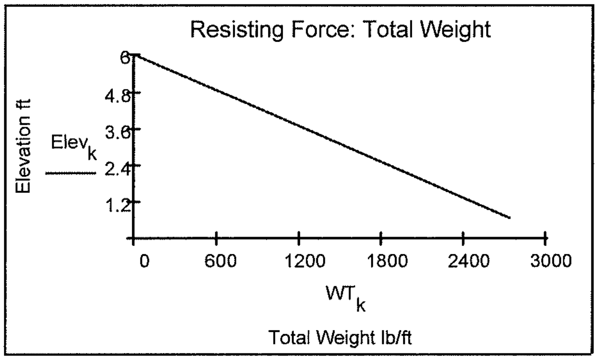
WEIGHT OF THE FACING: $Wf := H \cdot t \cdot (c \cdot \gamma c + v \cdot \gamma uf)$ $Wf = 765.937 \cdot plf$

WEIGHT OF THE REINFORCED SOIL MASS: $Ws := H \cdot [L - (t - s)] \cdot \gamma i$ $Ws = 2299.188 \cdot plf$

TOTAL WEIGHT: $Wt := Wf + Ws$ $Wt = 3065.125 \cdot plf$

MOMENT

$WtArm := 0.5 \cdot (L + s) + 0.5 \cdot H \cdot \tan(\omega)$ $WtArm = 2.429\,ft$



If Trial Wedge calculations are used, the active force calculated must replace the Cullomb active forces.

aa = "Not Using Trail Wedge"

$$Sliding\_Force\_Static := if\left(TW = 1, P_{a\_TW\_v}, Fav\right)$$

$$Sliding\_Force\_Seismic := if\left(TW = 1, P_{a\_TW\_v} + P_{ae\_TW\_v}, Fav + DFdynv\right)$$

The sliding calculations should use the less of the infill or foundation soils to calculated sliding resistance:

SLIDING RESISTANCE:

$$Sliding\_Friction\_Angle := \min(\phi i, \phi f) = 30 \cdot deg$$

$$Frstatic := (Sliding\_Force\_Static + Fqv + FQptv + Wi + Wq + Wf + Ws + WQp) \cdot \tan(Sliding\_Friction\_Angle)$$

$$Frstatic = 2051.646 \cdot plf$$

$$Frseismic := (Sliding\_Force\_Seismic + Fqv + FQptv + Wi + Wq + Wf + Ws + WQp) \cdot \tan(Sliding\_Friction\_Angle)$$

$$Frseismic = 2051.646 \cdot plf$$

SEISMIC INERTIAL FORCE:

The weight of each component of the wall structure has a horizontal inertial force acting at its centroid during a seismic event. The three components that have this inertial force are the block facing the reinforced soil mass and the backslope soil. The resultant Pir is the sum of all three. The weight of the reinforced soil mass and the backslope soil is based on a reinforcement length of 0.5H.

weight of the block face: $Wf = 765.937 \cdot plf$

weight of the reinforced soil mass: $Ws' := [0.5 \cdot H - (t - s)] \cdot \gamma i \cdot H$ $\quad Ws' = 1579.188 \cdot plf$

weight of the backslope soil: $Wi' := \frac{1}{2} \cdot [0.5 \cdot H - (t - s)]^2 \cdot \gamma r \cdot \tan(i)$ $\quad Wi' = 96.017 \cdot plf$

SEISMIC INERTIAL FORCE: $Pir := Khr \cdot (Wf + Ws' + Wi')$ $\quad Pir = 0 \cdot plf$

MOMENT ARM:

$$Hir := \frac{Khr \cdot Wf \cdot \frac{H}{2} + Khr \cdot Ws' \cdot \frac{H}{2} + Khr \cdot Wi' \cdot \left[H + \frac{1}{3} \cdot [0.5 \cdot H - (t - s)] \cdot \tan(i)\right]}{Pir} \qquad Hir = 0$$

EXTERNAL STABILITY FACTORS OF SAFETY

STATIC HORIZONTAL FORCE: aa = "Not Using Trail Wedge"

$$P_{a\_h} := if\left(TW = 1, P_{a\_TW\_h}, Fah + Fqh + FQpth\right) = 785.519 \cdot plf$$

SIESMIC HORIZONTAL FORCE:

$$P_{ae\_h} := if\left(TW = 1, P_{a\_TW\_h} + P_{ae\_TW\_h} + Pir, Fah + DFdynh + Fqh + FQpth + Pir\right) = 785.519 \cdot plf$$

FACTOR OF SAFETY FOR SLIDING:

Static Conditions: FSstaticsliding >= 1.5

$$FSstaticsliding := \frac{Frstatic}{P_{a\_h}}$$ FSstaticsliding = 2.61

Seismic Conditions: FSseicmicsliding >= 1.1

$$FSseismicsliding := \frac{Frseismic}{P_{ae\_h}}$$ FSseismicsliding = 2.61

FACTOR OF SAFETY FOR OVERTURNING:

NOTE For overturning calculations, we use the same moment arms for both M_O and Trial Wedge method. This is possible because we seperated the static and seismic forces in the Trial Wedge calculations above.

Static Conditions: FSstaticoverturning >= 2.0

STATIC OVERTURNING MOMENT: aa = "Not Using Trail Wedge"

$$M\_P_a := if(TW = 1, P_{a\_TW\_h} \cdot FaArmh, Fah \cdot FaArmh + Fqh \cdot FqArmh + FQpth \cdot FQptArmh)$$

$$www := if(TW = 1, P_{a\_TW\_v} \cdot FaArmv, Fav \cdot FaArmv + Fqv \cdot FqArmv + FQptv \cdot FQptArmv)$$

$$FSstaticoverturning := \frac{Wt \cdot WtArm + Wi \cdot WiArm + Wq \cdot WqArm + WQp \cdot WQptArm + www}{M\_P_a}$$

FSstaticoverturning = 5.143

Seismic Conditions: FSseismicoverturning >= 1.5

SIESMIC OVERTURNING MOMENT: aa = "Not Using Trail Wedge"

$$False := Fah \cdot FaArmh + DFdynh \cdot DFdynArmh + Fqh \cdot FqArmh + FQpth \cdot FQptArmh + Pir \cdot Hir$$

$$M\_P_{ae} := if(TW = 1, P_{a\_TW\_h} \cdot FaArmh + P_{ae\_TW\_h} \cdot DFdynArmh + Pir \cdot Hir, False)$$

$$False := Fav \cdot FaArmv + DFdynv \cdot DFdynArmv + Fqv \cdot FqArmv + FQptv \cdot FQptArmv$$

$$wwww := if(TW = 1, P_{a\_TW\_v} \cdot FaArmv + P_{ae\_TW\_v} \cdot DFdynArmv, False)$$

$$FSseismicoverturning := \frac{Wt \cdot WtArm + Wi \cdot WiArm + Wq \cdot WqArm + WQp \cdot WQptArm + wwww}{M\_P_{ae}}$$

FSseismicoverturning = 5.143

BEARING CAPACITY CALCULATIONS: Standard Method

aa = "Not Using Trail Wedge"

Vertical Force Resultant Using M_O Determined Forces:

$R_{M\_O} := Wf + Ws + Wi + Wq + Fav + DFdynv + Fqv + FQptv + WQpt$ $R_{M\_O} = 3553.555 \cdot plf$

Vertical Force Resultant Using Trial WedgeDetermined Forces:

$R_{TW} := Wf + Ws + Wi + Wq + P_{a\_TW\_v} + P_{ae\_TW\_v} + Fqv + FQptv + WQpt$ $R_{TW} = 3591.65 \cdot plf$

$R := if(TW = 1, R_{TW}, R_{M\_O})$ $R = 3553.555 \cdot plf$

Location of the Resultant Force:

$wwwww := if(TW = 1, P_{a\_TW\_v} \cdot FaArmv + P_{ae\_TW\_v} \cdot DFdynArmv, Fav \cdot FaArmv + DFdynv \cdot DFdynArmv)$

$positive := Wt \cdot WtArm + Wi \cdot WiArm + Wq \cdot WqArm + WQpt \cdot WQptArm + Fqv \cdot FqArmv + FQptv \cdot FQptArmv + wwwww$

$positive = 9484.51\,lb$

$False := Fah \cdot FaArmh + DFdynh \cdot DFdynArmh + Fqh \cdot FqArmh + FQpth \cdot FQptArmh$

$wwwwww := if(TW = 1, P_{a\_TW\_h} \cdot FaArmh + P_{ae\_TW\_h} \cdot DFdynArmh, False)$

$negative := Pir \cdot Hir + wwwwww$

$negative = 1844.27\,lb$

$x := \frac{positive - negative}{R}$ $x = 2.15\,ft$

Determine the eccentricity, E, of the resultant vertical force. If the eccentricity is negative the maximum bearing pressure occurs at the heal of the mass. Therefore, a negative eccentricity causes a decrease in pressure at the toe. For conservative calculations E will always be considered greater than or equal to zero.

$E := 0.5 \cdot (L + s) - x$ $E = -0.059\,ft$ $E1 := if(E < 0ft, 0ft, E)$ $E1 = 0\,ft$

Determine the average bearing pressure acting at the centerline of the wall.

$\sigma avg := \frac{R}{(L + s)}$ $\sigma avg = 849.543 \cdot psf$

Determine the moment about the centerline of the wall due to the resultant bearing load.

$Mcl := R \cdot E1$ $Mcl = 0\,lb \cdot \frac{ft}{ft}$

Section Modulus: $S := \frac{(1.0 \cdot ft) \cdot (L + s)^2}{6} = 2.916\,ft^3$

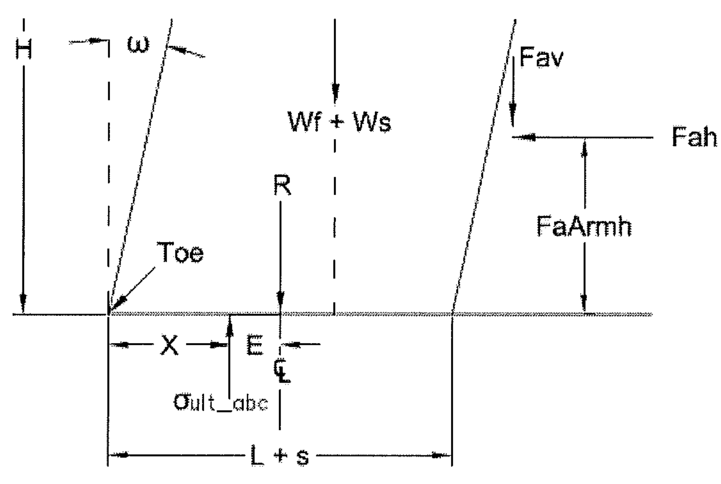
Differenced in bearing pressure due to the eccentric loading.

$\sigma mom := \frac{Mcl \cdot 1 \cdot ft}{S}$ $\sigma mom = 0 \cdot psf$

therefore:

$\sigma max := \sigma avg + |\sigma mom|$ $\sigma max = 849.543 \cdot psf$

$\sigma min := \sigma avg - |\sigma mom|$ $\sigma min = 849.543 \cdot psf$



ALLAN BLOCK BEARING PRESSURE ANALYSIS

ULTIMATE BEARING CAPACITY CALCULATION:

Meyerhof bearing capacity equation: σult=1/2*γf*Lwidth*Nγ + cf*Nc + γf*(Ldepth+D)*Nq

Where: $Nq := (\exp(\pi \cdot \tan(\phi f))) \cdot \left(\tan\left(45 \cdot deg + \frac{\phi f}{2}\right)\right)^2$ $\quad Nq = 18.401$

$Nc := (Nq - 1) \cdot \cot(\phi f)$ $\quad Nc = 30.14$

$N\gamma := (Nq - 1) \cdot \tan(1.4 \cdot \phi f)$ $\quad N\gamma = 15.668$

Therefore: $\sigma ult\_abc := \frac{1}{2} \cdot \gamma f \cdot Lwidth \cdot N\gamma + cf \cdot Nc + \gamma f \cdot (Ldepth + D) \cdot Nq = 4816.984 \cdot psf$

$FSbearing\_abc := \frac{\sigma ult\_abc}{\sigma max}$ $\quad FSbearing\_abc = 5.67$

Meyerhof Method as used by the NCMA:

Note: The NCMA bearing capacity method is less conservative than the Modified Meyerhof method utilized by Allan Block. The NCMA distributes the entire bearing load over the geogrid footprint and does not focus it on the size of the leveling pad. Therefore if the user chooses to use the Meyerhof NCMA method the σult equation simply uses L for the bearing width. Please note that the NCMA uses the Vesic equation for Nγ.

Vesic Nγ for NCMA Methodology: $N\gamma\_ves := 2 \cdot (Nq + 1) \cdot \tan(\phi f)$ $\quad N\gamma\_ves = 22.402$

Determine the effective length of the bearing pad

$b := (L + s) - 2E1$ $\quad b = 4.183\,ft$

Determine the applied load on the bearing pad

$Qa := \frac{(Wf + Ws + Wi + Wq + WQpt)}{b}$ $\quad Qa = 781.433 \cdot psf$

$\sigma ult\_ncma := \frac{1}{2} \cdot \gamma f \cdot b \cdot N\gamma\_ves + cf \cdot Nc + \gamma f \cdot D \cdot Nq$

$\sigma ult\_ncma = 7455.193 \cdot psf$

$FSbearing\_ncma := \frac{\sigma ult\_ncma}{Qa}$

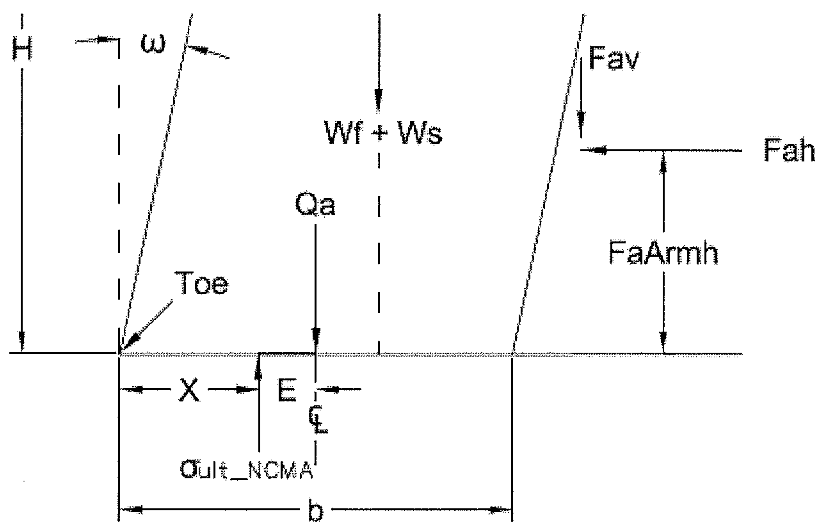
$FSbearing\_ncma = 9.54$

$\sigma ult := if(bearing = 1, \sigma ult\_abc, \sigma ult\_ncma)$

$\sigma max := if(bearing = 1, \sigma max, Qa)$

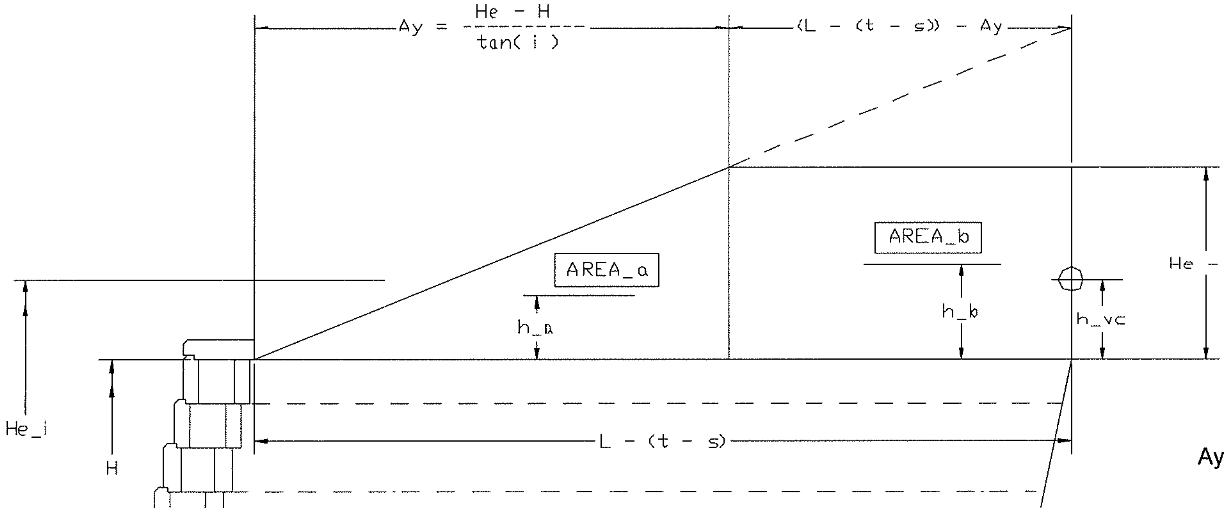
Factor of safety:

$FSbearing := \frac{\sigma ult}{\sigma max}$ $\quad FSbearing = 5.67$



NCMA BEARING PRESSURE ANALYSIS

INTERNAL STABILITY



$$Ay := \frac{(He - H)}{\tan(i)}$$

$Ay = 3.193\ ft$

Free Body Diagram

Where:
Gj =Depth to each geogrid layer

Acj =influence area of each geogrid layer

He_i =effective wall height for internal stability

h_vc = height above wall to the geometric vertical center of the slope

Area a

$a := 0.5(He - H) \cdot (Ay) = 1.696\ ft^2$

$h\_a := \frac{1}{3}(He - H) = 0.354\ ft$

$h\_vc := \left[\frac{(a \cdot h\_a + b \cdot h\_b)}{a + b}\right] = 0.354\ ft$

Area b

$b := (He - H) \cdot [[L - (t - s)] - Ay]$

$b = -0\ ft^2$

$h\_b := \frac{1}{2}(He - H)$

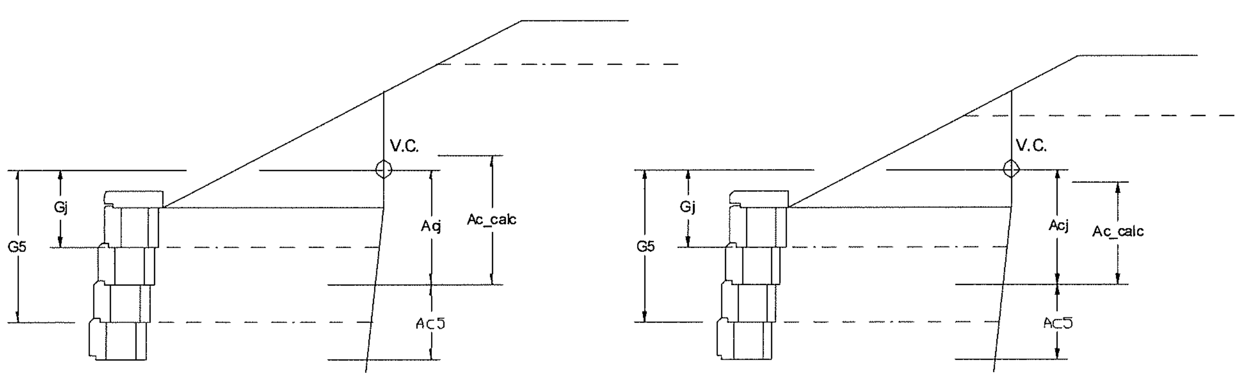
$h\_b = 0.531\ ft$

Internal Effective Height: $He\_i := H + h\_vc$

$He\_i = 6.354\ ft$

Note:
For internal stability calculations sample calculations will be shown for grid layer #1. All other grid layers will be shown through tabular calculations at the end of this section.

DETERMINATION OF THE FORCE ACTING ON EACH GRID LAYER



STATIC LOADS, use the subscript "s"

$a_i := \frac{(H + Sabove + grid_j \cdot h)}{2}$ $\quad b_i := \frac{(grid_j \cdot h + grid_{j-1} \cdot h)}{2}$

$a_g = 6.167\ ft$ $\quad H = 6\ ft$ $\quad b_g = 4.667\ ft$

$Sabove = 1\ ft$ $\quad He\_i = 6.354\ ft$ $\quad www_i := if(a_g < He\_i, a_g - b_g, He\_i - b_g)$

influence area:

$$Ac_j := \text{if}\left[j = 1, \text{if}\left(g < 2, He\_i, \frac{grid_{j+1} \cdot h + grid_j \cdot h}{2}\right), \text{if}\left[j = g, \text{if}\left(Grid\_Above = 1, www_j, He\_i - b_j\right), \frac{\left(grid_{j+1} \cdot h + grid_j \cdot h\right)}{2} - b_j\right]\right]$$

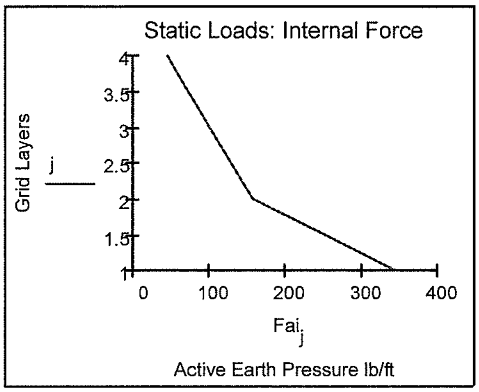
active earth pressure per grid layer:

$Ac_1 = 2\ ft$

$$RRR_j := \text{if}\left(Grid\_Above = 1, He\_i - a_j + He\_i - b_j, He\_i - b_j\right)$$

$$G1_j := 0.5 \cdot \text{if}\left[j = g, RRR_j, \text{if}\left[(j = 1), He\_i - \frac{\left(grid_{j+1} \cdot h + grid_j \cdot h\right)}{2} + He\_i, He\_i - \frac{\left(grid_{j+1} \cdot h + grid_j \cdot h\right)}{2} + He\_i - b_j\right]\right]$$

$$Fai_j := Kai \cdot \cos(\phi wi) \cdot \gamma i \cdot Ac_j \cdot G1_j$$



$$Fai_j = \begin{pmatrix} 45.894 \\ 101.181 \\ 158.489 \\ 345.185 \end{pmatrix} \cdot plf \qquad G1_j = \begin{pmatrix} 0.844 \\ 2.354 \\ 3.687 \\ 5.354 \end{pmatrix} ft$$

surcharge pressure:

$$Fqi_j := \text{if}\left(qx > Endg, 0plf, q \cdot Kai \cdot \cos(\phi wi) \cdot Ac_j\right) \qquad Fqi_1 = 0 \cdot plf$$

point load surcharge pressure:

$$FQpti_j := \text{if}\left[x1 > Endg, 0plf, Qpi \cdot (Kai \cdot \cos(\phi wi)) \cdot Ac_j\right] \qquad FQpti_1 = 0 \cdot plf$$

SEISMIC (DYNAMIC) LOADS: use the subscript, "d"

$$nnnn := \text{if}(\phi i - i > 0deg, \phi i - i, 0deg)$$

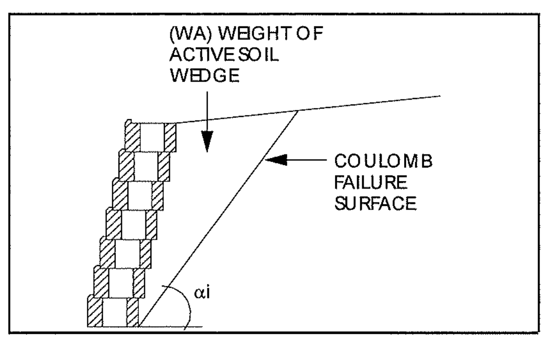
Inclination of Coulomb failure surface for internal stability (αi):

$$\alpha i := \text{atan}\left[\frac{-\tan(nnnn) + \sqrt{[\tan(nnnn) \cdot (\tan(\phi i - i) + \cot(\phi i + \omega)) \cdot (1 + \tan(\phi wi - \omega) \cdot \cot(\phi i + \omega))]}}{1 + \tan(\phi wi - \omega) \cdot (\tan(\phi i - i) + \cot(\phi i + \omega))}\right] + \phi i$$

Weight of the active wedge in the infill zone:

$\alpha i = 47.978 \cdot deg$

$$WAi := \frac{1}{2} \cdot \gamma i \cdot H^2 \cdot \left(\frac{\sin(90deg - \omega - \alpha i)}{\sin(\alpha i) \cdot \cos(\omega)}\right) \qquad WAi = 1703.308 \cdot plf$$



Weight of the active wedge in the backslope:

$$D1 := \frac{H \cdot \sin(90deg - \omega - \alpha i)}{\cos(\omega) \cdot \sin(\alpha i)} \qquad D1 = 4.731\ ft$$

$$D2 := \frac{D1 \cdot \sin(i) \cdot \sin(\alpha i)}{\sin(\alpha i - i)} \qquad D2 = 2.248\ ft$$

$$WAs := \text{if}\left(i > 0, \frac{1}{2} \cdot D1 \cdot D2 \cdot \gamma i, 0plf\right) \qquad WAs = 638.081 \cdot plf$$

dynamic earth pressure based on Active Wedge theory:

$$DFdyni\_SW_j := Khi \cdot (WAi + WAs) \cdot \frac{Ac_j}{He\_i}$$

$DFdyni\_SW_1 = 0 \cdot plf$

$\sum DFdyni\_SW = 0 \cdot plf$

dynamic earth pressure based on Trapezoidal theory:

$$DFdyni\_Trap_j := (0.5) \cdot (Kaei - Kai) \cdot \cos(\phi wi) \cdot \gamma i \cdot He\_i \cdot Ac_j$$

Active Wedge theory:

$DFdyni\_SW_j =$ (plf)

0
0
0
0

Trapezoidal theory:

$DFdyni\_Trap_j =$ (plf)

-172.816
-136.552
-136.552
-204.828

$$false_j := if\left(\sum DFdyni\_Trap > \sum DFdyni\_SW, DFdyni\_Trap_j, DFdyni\_SW_j\right)$$

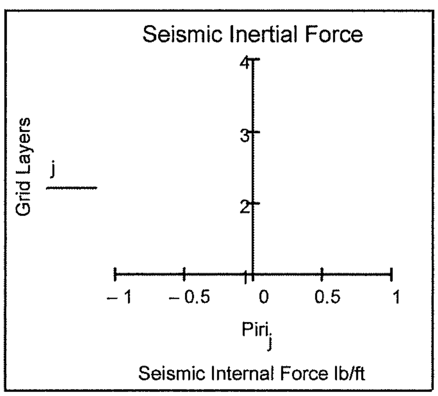
$$DFdyni_j := if(SFAM = 1, DFdyni\_Trap_j, if(SFAM = 2, DFdyni\_SW_j, false_j))$$

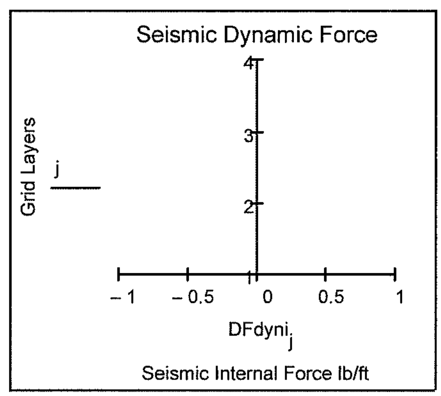
$DFdyni_1 = 0 \cdot plf$

$DynamicTheory_1 =$ "Active Wedge Theory"

seismic inertial force:

$Piri_j := Khi \cdot t \cdot (c \cdot \gamma c + v \cdot \gamma uf) \cdot Ac_j$ $\quad Piri_1 = 0 \cdot plf$

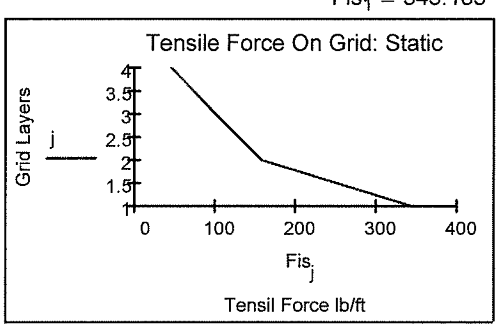




TENSILE FORCE ON EACH GRID:

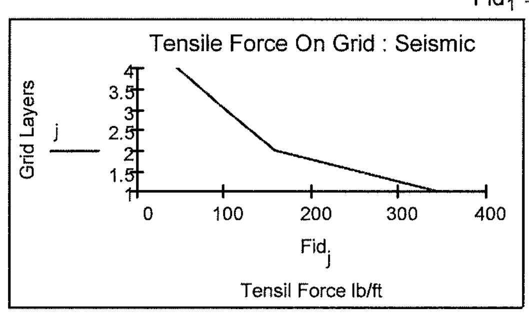
STATIC:

$Fis_j := Fai_j + Fqi_j + FQpti_j$ $\quad Fis_1 = 345.185 \cdot plf$



SEISMIC:

$Fid_j := Fai_j + Fqi_j + FQpti_j + DFdyni_j + Piri_j$ $\quad Fid_1 = 345.185 \cdot plf$



GEOGRID TENSILE OVERSTRESS

geogrid tensile strength

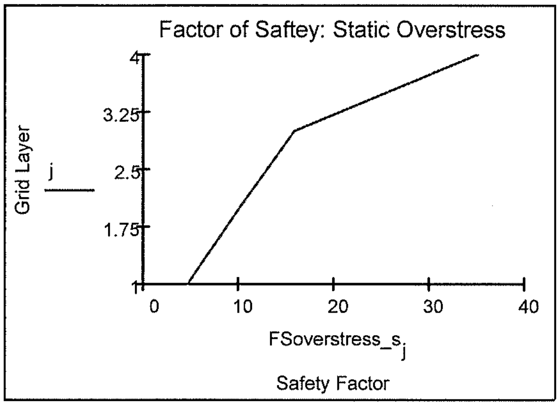
$LTDS_j := if(type_j = A, LTDS\_A, LTDS\_B)$ $LTDS_1 = 1613 \cdot plf$ $RFcr_j := if(type_j = A, RFcr\_A, RFcr\_B)$ $RFcr_1 = 1.61$

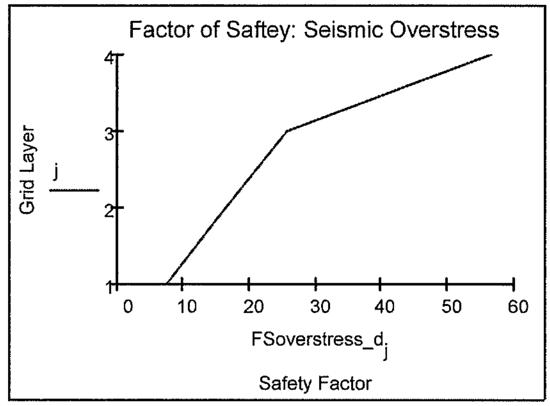
FACTOR OF SAFETY, Static:

$$FSoverstress\_s_j := \frac{LTDS_j}{Fis_j}$$ $FSoverstress\_s_1 = 4.673$

FACTOR OF SAFETY, Seismic:

$$FSoverstress\_d_j := \frac{LTDS_j \cdot RFcr_j}{Fid_j}$$ $FSoverstress\_d_1 = 7.523$





GEOGRID/BLOCK CONNECTION CAPACITY

normal load: $N_j := (H - grid_j \cdot h) \cdot (c \cdot \gamma c + v \cdot \gamma uf) \cdot t$ $N_1 = 595.729 \cdot plf$

peak connection strength:

$Fcs_j := if(type_j = A, if(N_j < Ninta, B1a + M1a \cdot N_j, B2a + M2a \cdot N_j), if(N_j < Nintb, B1b + M1b \cdot N_j, B2b + M2b \cdot N_j))$

Does calculated value exceed that maximum tested?:

$Fcs_j := if(type_j = A, if(Fcs_j < Max\_A, Fcs_j, Max\_A), if(Fcs_j < Max\_B, Fcs_j, Max\_B))$

$Fcs_1 = 1574.229 \cdot plf$

TUMBLED REDUCTION FACTOR

$TRF := if(TUMBLED = 1, 0.7, 1.0)$ $TRF = 1$

ASHLAR REDUCTION FACTOR

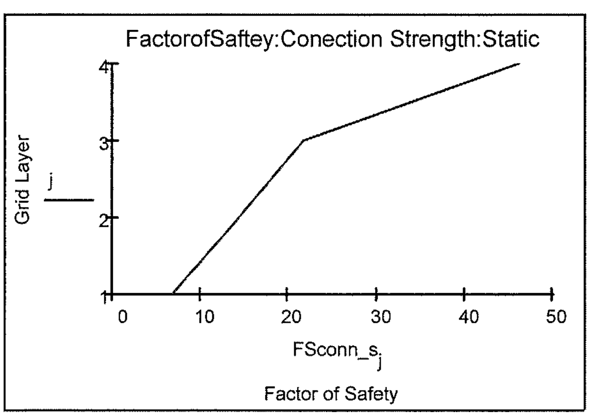
$ARF := if(ASHLAR = 1, 0.9, 1.0)$ $ARF = 1$

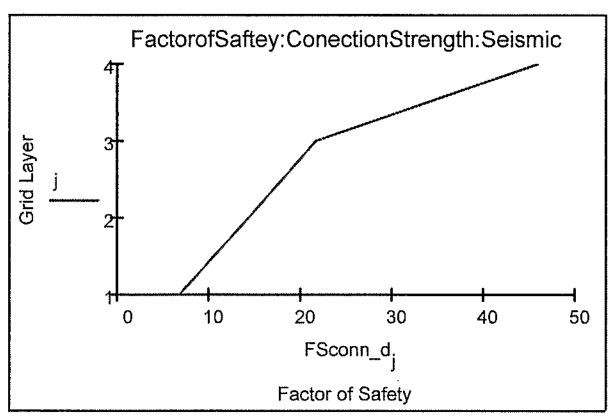
FACTOR OF SAFETY CONNECTION STRENGTH, Static:

$$FSconn\_s_j := \frac{(TRF \cdot ARF) \cdot Fcs_j}{Fis_j \cdot 0.667}$$ $FSconn\_s_1 = 6.837$

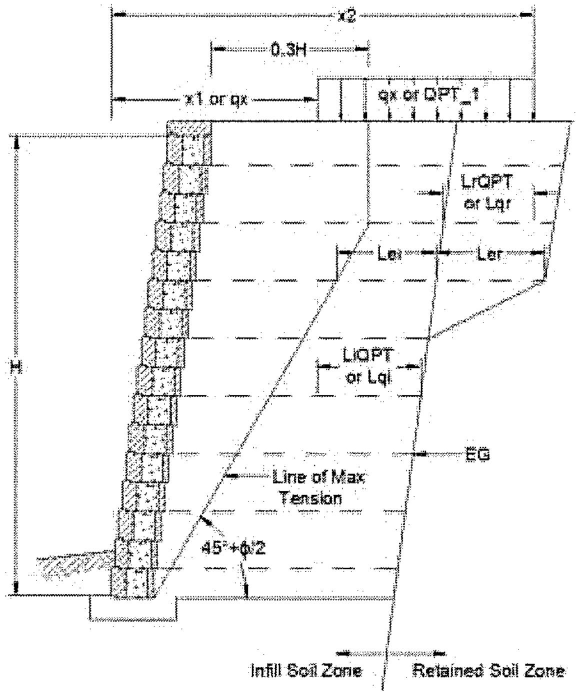
FACTOR OF SAFETY CONNECTION STRENGTH, Seismic

$$FSconn\_d_j := \frac{(TRF \cdot ARF) \cdot Fcs_j}{Fid_j \cdot 0.667}$$ $FSconn\_d_1 = 6.837$





GEOGRID PULLOUT FROM THE SOIL:



Equations for each segment of the line of maximum tension:

segment #1: y1=tan(45*deg+ϕ/2)*(x-t)

segment #2: x=(H)*(0.3+tan(ω)+t)

where: x=distance to the line of maximum tension

Setting these two equations equal to each other yields the elevation of their intersection point:

$$y\_int := \tan\left(45 \cdot deg + \frac{\phi i}{2}\right) \cdot [H \cdot (0.3 + \tan(\omega))]$$

$y\_int = 4.287\ ft$

Therefore the length of geogrid embedded beyond the line of maximum tension is the following:

End of Geogrid Location $EG_j := length_j + s + \tan(\omega) \cdot (grid_j \cdot h)$

Line of Maximum Tension for Bi-Linear - Static:

For geogrid elevation < yint

$$S\_MT1_j := \left(\frac{grid_j \cdot h}{\tan\left(45 \cdot deg + \frac{\phi i}{2}\right)}\right) + t$$

For geogrid elevations > yint

$S\_MT2_j := H \cdot (0.3 + \tan(\omega)) + t$

$S\_MT_j := if(grid_j \cdot h < y\_int, S\_MT1_j, S\_MT2_j)$

$EG_1 = 4.333\ ft$

$S\_MT_1 = 1.759\ ft$

Line of Maximum Tension for Linear Plane - dynamic:

$D\_MT_j := t + grid_j \cdot h \cdot \tan(90deg - \alpha i)$

$D\_MT_1 = 2.191\ ft$

geogrid embedment length within infill zone- Static:

$Lei\_s_j := if[length_j > L, EG_j - (length_j - L) - S\_MT_j, EG_j - S\_MT_j]$

$Lei\_s_1 = 2.574\ ft$

geogrid embedment length within retained zone- Static:

$Ler\_s_j := if[length_j > L, (length_j - L), 0]$

$Ler\_s_1 = 0\ ft$

geogrid embedment length within infill zone- dynamic:

$Lei\_d_j := if[length_j > L, EG_j - (length_j - L) - D\_MT_j, EG_j - D\_MT_j]$

$Lei\_d_1 = 2.142\ ft$

geogrid embedment length within retained zone- dynamic:

$Ler\_d_j := if[length_j > L, (length_j - L), 0]$

$Ler\_d_1 = 0\ ft$

geogrid length affected by surcharge within infill zone - Static:

$Lqi\_s_j := if[qx < EG_j - (length_j - L), if[qx > S\_MT_j, EG_j - qx - (length_j - L), EG_j - S\_MT_j - (length_j - L)], 0ft]$

$Lqi\_s_j := if(xq = 2, Lqi\_s_j, 0ft)$

$Lqi\_s_1 = 0\ ft$

geogrid length affected by surcharge within retained zone - Static:

$Lqr\_s_j := if[qx < EG_j, if[qx > EG_j - (length_j - L), EG_j - qx, (length_j - L)], 0ft]$

$Lqr\_s_j := if(xq = 2, Lqr\_s_j, 0ft)$

$Lqr\_s_1 = 0\ ft$

geogrid length affected by surcharge within infill zone- dynamic:

$Lqi\_d_j := if[qx < EG_j - (length_j - L), if[qx > D\_MT_j, EG_j - qx - (length_j - L), EG_j - D\_MT_j - (length_j - L)], 0ft]$

$Lqi\_d_j := if(xq = 2, Lqi\_d_j, 0ft)$

$Lqi\_d_1 = 0\ ft$

geogrid length affected by surcharge within infill zone- dynamic:

$Lqr\_d_j := if[qx < EG_j, if[qx > EG_j - (length_j - L), EG_j - qx, (length_j - L)], 0ft]$

$Lqr\_d_j := if(xq = 2, Lqr\_d_j, 0ft)$

$Lqr\_d_1 = 0\ ft$

geogrid length affected by a point load within the infill zone - Static:

For x1 < the line of maximum tension

$LiQpt1\_s_j := if\left[x2 < EG_j - \left(length_j - L\right), if\left[\left(x2 - S\_MT_j\right) > 0 \cdot ft, x2 - S\_MT_j, 0 \cdot ft\right], Lei\_s_j\right]$

For x1 > the line of maximum tension and x1 < the end of the infill zone

$LiQpt2\_s_j := if\left[x2 < EG_j - \left(length_j - L\right), x2 - x1, EG_j - x1 - \left(length_j - L\right)\right]$

For x1 >the end of the infill zone

$LiQpt3\_s_j := 0 \cdot ft$

$LiQpt\_s_j := if\left[x1 < S\_MT_j, LiQpt1\_s_j, if\left[x1 > EG_j - \left(length_j - L\right), LiQpt3\_s_j, LiQpt2\_s_j\right]\right]$

$LiQpt\_s_j := if\left(Stype = 1, 0 \cdot ft, LiQpt\_s_j\right)$ $LiQpt\_s_1 = 0\,ft$

point load retained geogrid length - Static:

For x1 < the infill zone

$LrQpt1\_s_j := if\left[x2 < EG_j, if\left[x2 - \left[EG_j - \left(length_j - L\right)\right] > 0 \cdot ft, x2 - \left[EG_j - \left(length_j - L\right)\right], 0 \cdot ft\right], Ler\_s_j\right]$

For x1 > the infill zone and x1 < the end of the geogrid

$LrQpt2\_s_j := if\left[x2 < EG_j, x2 - x1, EG_j - x1 - \left(length_j - L\right)\right]$

For x1 >the end of the geogrid

$LrQpt3\_s_j := 0 \cdot ft$

$LrQpt\_s_j := if\left[x1 < EG_j - \left(length_j - L\right), LrQpt1\_s_j, if\left(x1 > EG_j, LrQpt3\_s_j, LrQpt2\_s_j\right)\right]$

$LrQpt\_s_j := if\left(Stype = 1, 0 \cdot ft, LrQpt\_s_j\right)$ $LrQpt\_s_1 = 0\,ft$

geogrid length affected by a point load within the infill zone - Dynamic:

For x1 < the line of maximum tension

$LiQpt1\_d_j := if\left[x2 < EG_j - \left(length_j - L\right), if\left[\left(x2 - D\_MT_j\right) > 0 \cdot ft, x2 - D\_MT_j, 0 \cdot ft\right], Lei\_d_j\right]$

For x1 > the line of maximum tension and x1 < the end of the infill zone

$LiQpt2\_d_j := if\left[x2 < EG_j - \left(length_j - L\right), x2 - x1, EG_j - x1 - \left(length_j - L\right)\right]$

For x1 >the end of the infill zone

$LiQpt3\_d_j := 0 \cdot ft$

$LiQpt\_d_j := if\left[x1 < D\_MT_j, LiQpt1\_d_j, if\left[x1 > EG_j - \left(length_j - L\right), LiQpt3\_d_j, LiQpt2\_d_j\right]\right]$

$LiQpt\_d_j := if\left(Stype = 1, 0 \cdot ft, LiQpt\_d_j\right)$ $LiQpt\_d_1 = 0\,ft$

point load retained geogrid length - Static:

For x1 < the infill zone

$LrQpt1\_d_j := if\left[x2 < EG_j, if\left[x2 - \left[EG_j - \left(length_j - L\right)\right] > 0 \cdot ft, x2 - \left[EG_j - \left(length_j - L\right)\right], 0 \cdot ft\right], Ler\_d_j\right]$

For x1 > the infill zone and x1 < the end of the geogrid

$LrQpt2\_d_j := if\left[x2 < EG_j, x2 - x1, EG_j - x1 - \left(length_j - L\right)\right]$

For x1 >the end of the geogrid

$LrQpt3\_d_j := 0 \cdot ft$

$LrQpt\_d_j := if\left[x1 < EG_j - \left(length_j - L\right), LrQpt1\_d_j, if\left(x1 > EG_j, LrQpt3\_d_j, LrQpt2\_d_j\right)\right]$

$LrQpt\_d_j := if\left(Stype = 1, 0 \cdot ft, LrQpt\_d_j\right)$ $LrQpt\_d_1 = 0\,ft$

Determine the distance down to each layer of geogrid:

$$G_j := \text{if}\left(g < 2, He\_i - \sum Elev\_Grid, He\_i - grid_j \cdot h\right) \qquad G_1 = 5.021\ \text{ft}$$

pullout capacity - Static:

$$Fipo\_s_j := 2 \cdot Ci \cdot \tan(\phi i) \cdot \left[G_j \cdot \gamma i \cdot Lei\_s_j + q \cdot \left(Lqi\_s_j\right) + Qpi \cdot LiQpt\_s_j\right]$$

$$Frpo\_s_j := 2 \cdot Ci \cdot \tan(\phi r) \cdot \left[G_j \cdot \gamma r \cdot Ler\_s_j + q \cdot \left(Lqr\_s_j\right) + Qpi \cdot LrQpt\_s_j\right]$$

$$Fpo\_s_j := Fipo\_s_j + Frpo\_s_j \qquad Fpo\_s_1 = 1253.285 \cdot \text{plf}$$

pullout capacity - dynamic:

$$Fipo\_d_j := 2 \cdot Ci \cdot \tan(\phi i) \cdot \left[G_j \cdot \gamma i \cdot Lei\_d_j + q \cdot \left(Lqi\_d_j\right) + Qpi \cdot LiQpt\_d_j\right]$$

$$Frpo\_d_j := 2 \cdot Ci \cdot \tan(\phi r) \cdot \left[G_j \cdot \gamma r \cdot Ler\_d_j + q \cdot \left(Lqr\_d_j\right) + Qpi \cdot LrQpt\_d_j\right]$$

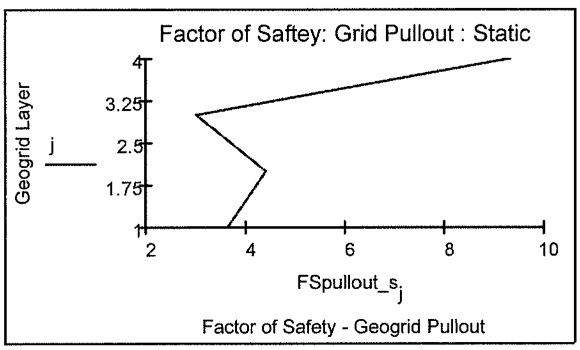
$$Fpo\_d_j := Fipo\_d_j + Frpo\_d_j \qquad Fpo\_d_1 = 1043.075 \cdot \text{plf}$$

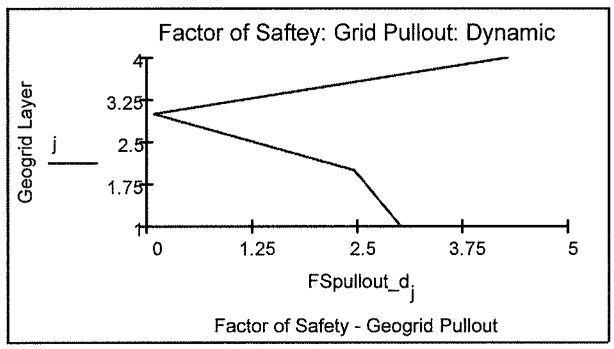
FACTOR OF SAFETY GEOGRID PULLOUT, static:

$$FSpullout\_s_j := \frac{Fpo\_s_j}{Fis_j} \qquad FSpullout\_s_1 = 3.631$$

FACTOR OF SAFETY GEOGRID PULLOUT, dynamic:

$$FSpullout\_d_j := \frac{Fpo\_d_j}{Fid_j} \qquad FSpullout\_d_1 = 3.022$$





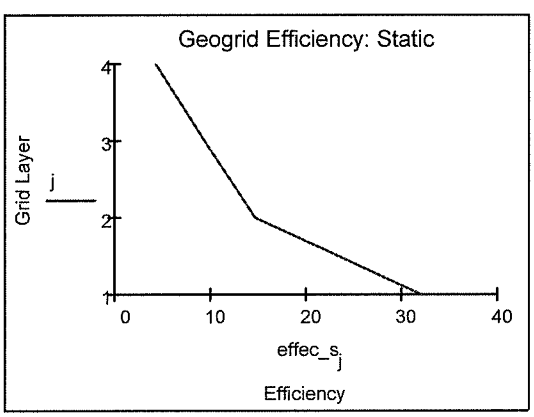
GEOGRID EFFICIENCY

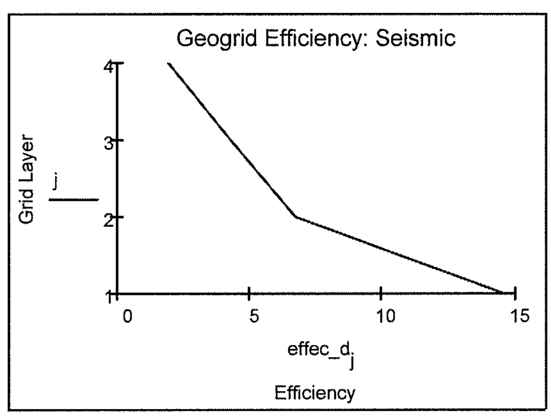
Static Conditions:

$$effec\_s_j := \frac{Fis_j}{LTDS_j \cdot \frac{1}{FSos\_s}} \cdot 100 \qquad effec\_s_1 = 32.1$$

Seismic Conditions:

$$effec\_d_j := \frac{Fid_j}{LTDS_j \cdot \frac{RFcr_j}{FSos\_d}} \cdot 100 \qquad effec\_d_1 = 14.621$$





LOCALIZED STABILITY, TOP OF THE WALL STABILITY

OCAL WALL PARAMETERS:

unreinforced height: $H\_top := H - grid_g \cdot h$ $H\_top = 0.667\,ft$

local weight of facing: $Wt\_top := H\_top \cdot t \cdot (c \cdot \gamma c + v \cdot \gamma uf)$ $Wt\_top = 85.104 \cdot plf$

SOIL AND SURCHARGE FORCES:

active force: $Fa\_top\_s := \frac{1}{2} \cdot Kai \cdot \gamma i \cdot H\_top^2$ $Fa\_top\_s = 7.623 \cdot plf$

$Fav\_top\_s := Fa\_top\_s \cdot \sin(\phi wi)$ $Fav\_top\_s = 2.607 \cdot plf$

$Fah\_top\_s := Fa\_top\_s \cdot \cos(\phi wi)$ $Fah\_top\_s = 7.163 \cdot plf$

dynamic force: $Fa\_top\_d := \frac{1}{2} \cdot (1 + Kv) \cdot Kaei \cdot \gamma i \cdot H\_top^2$ $Fa\_top\_d = 0 \cdot plf$

$DFdyn\_top := Fa\_top\_d - Fa\_top\_s$ $DFdyn\_top = -7.623 \cdot plf$

$DFdyn\_top := if(Ao = 0, 0plf, DFdyn\_top)$

$DFdynv\_top := DFdyn\_top \cdot \sin(\phi wi)$ $DFdynv\_top = 0 \cdot plf$

$DFdyn\_top = 0 \cdot plf$

$DFdynh\_top := DFdyn\_top \cdot \cos(\phi wi)$ $DFdynh\_top = 0 \cdot plf$

seismic inertial force: $Pir\_top := Khi \cdot (Wt\_top)$ $Pir\_top = 0 \cdot plf$

Determine the maximum point back where the any surcharge will not effect the wall:

$$ss\_top := \frac{H\_top}{\tan\left(45 \cdot deg + \frac{\phi i}{2}\right)}$$ $ss\_top = 0.385\,ft$

surcharge force:

$Fq\_top := if\left[[qx - (H \cdot \tan(\omega) + t)] < ss\_top, q \cdot Kai \cdot H\_top, 0\frac{lb}{ft}\right]$ $Fq\_top = 0 \cdot plf$

$Fqh\_top := Fq\_top \cdot \cos(\phi wi)$ $Fqh\_top = 0 \cdot plf$

$Fqv\_top := if(xq = 2, Fq\_top \cdot \sin(\phi wi), 0plf)$ $Fqv\_top = 0 \cdot plf$

point load surcharge:

$FQpt\_top := if\left[[x1 - (H \cdot \tan(\omega) + t)] < ss\_top, Qpt \cdot Kai \cdot H\_top, 0\frac{lb}{ft}\right]$

$FQpt\_top = 0 \cdot plf$

$FQpth\_top := FQpt\_top \cdot \cos(\phi wi)$ $FQpth\_top = 0 \cdot plf$

$FQptv\_top := if(Stype = 2, FQpt\_top \cdot \sin(\phi wi), 0plf)$ $FQptv\_top = 0 \cdot plf$

LOCAL SLIDNG RESISTANCE:
Total weight acting to resist sliding of the top of wall:

$Wtotalstatic := Wt\_top + Fav\_top\_s + Fqv\_top + FQptv\_top$

$Wtotalstatic = 87.711 \cdot plf$

$Wtotalseismic := Wt\_top + Fav\_top\_s + DFdynv\_top + Fqv\_top + FQptv\_top$

$Wtotalseismic = 87.711 \cdot plf$

local sliding resistance:

$Frt\_static := if(\omega < 6deg, au3 + Wtotalstatic \cdot \tan(\lambda u3), au3 + Wtotalstatic \cdot \tan(\lambda u3))$

$Frt\_static = 1176.236 \cdot plf$

$Frt\_seismic := if(\omega < 6deg, au3 + Wtotalseismic \cdot \tan(\lambda u3), au3 + Wtotalseismic \cdot \tan(\lambda u3))$

$Frt\_seismic = 1176.236 \cdot plf$

FACTOR OF SAFETY LOCAL SLIDING, Static:

$$FSsliding\_s\_top := \frac{Frt\_static}{(Fa\_top\_s + Fq\_top + FQpt\_top) \cdot \cos(\phi wi)}$$

$FSsliding\_s\_top = 164.199$

FACTOR OF SAFETY LOCAL SLIDING, Seismic:

$$FSsliding\_d\_top := \frac{Frt\_seismic}{(Fa\_top\_s + DFdyn\_top + Fq\_top + FQpt\_top + Pir\_top) \cdot \cos(\phi wi)}$$

$FSsliding\_d\_top = 164.199$

FACTOR OF SAFETY LOCAL OVERTURNING, Static:

$$num1 := Wt\_top \cdot \left[\frac{(H\_top \cdot \tan(\omega))}{2} + \frac{t}{2}\right] + Fav\_top\_s \cdot \left(\frac{H\_top \cdot \tan(\omega)}{3} + t\right) + (Fqv\_top + FQptv\_top) \cdot \left(\frac{H\_top \cdot \tan(\omega)}{2} + t\right)$$

$$FSoverturning\_s\_top := \frac{num1}{Fah\_top\_s \cdot \left(\frac{H\_top}{3}\right) + Fqh\_top \cdot \left(\frac{H\_top}{2}\right) + FQpth\_top \cdot \left(\frac{H\_top}{2}\right)}$$

$FSoverturning\_s\_top = 30.119$

FACTOR OF SAFETY LOCAL OVERTURNING, Seismic:

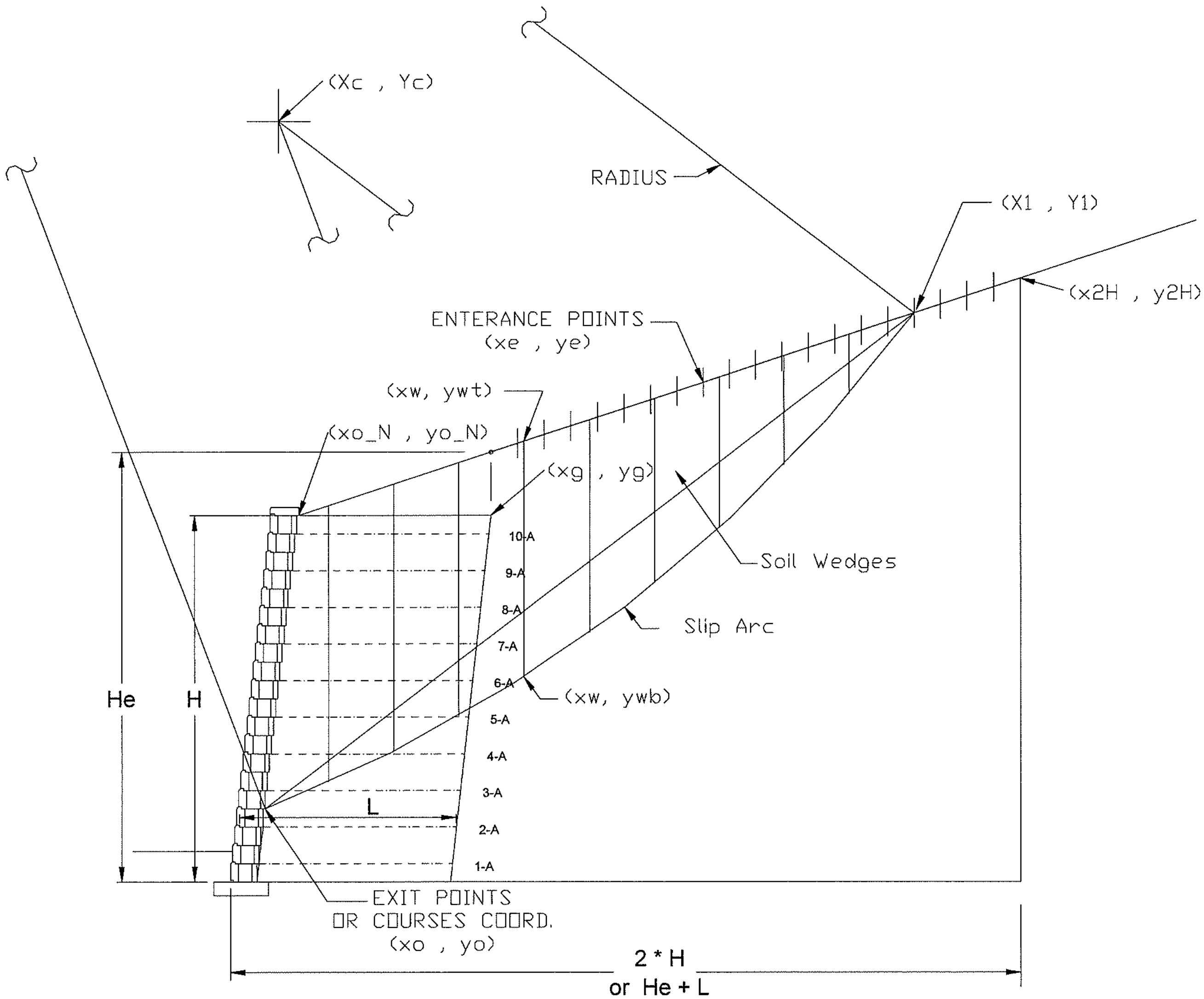
$num2 := num1 + DFdynv\_top \cdot (0.6 \cdot H\_top + t)$

$$Den1 := FQpth\_top \cdot \left(\frac{H\_top}{2}\right) + Pir\_top \cdot \left(\frac{H\_top}{2}\right)$$

$$FSoverturning\_d\_top := \frac{num2}{Fah\_top\_s \cdot \left(\frac{H\_top}{3}\right) + DFdynh\_top \cdot (0.6 \cdot H\_top) + Fqh\_top \cdot \left(\frac{H\_top}{2}\right) + Den1}$$

$FSoverturning\_d\_top = 30.119$

COMPOUND STABILITY CALCULATIONS



COURSING COORDINATES

range of courses: $courses := 0..n$

$xo_{courses} := t + courses \cdot h \cdot \tan(\omega) - h \cdot \tan(\omega)$

Block Course (courses =)	Course coord. x0 (xo = · ft)	Course Coord y0 (yo = · ft)
0	0.915	0.000
1	0.990	0.667
2	1.065	1.333
3	1.140	2.000
4	1.215	2.667
5	1.290	3.333
6	1.365	4.000
7	1.440	4.667
8	1.515	5.333
9	1.590	6.000

Working point at top of Facing (PT):

$yo_{courses} := courses \cdot h$

$xo_n = 1.59\,ft$

$yo_n = 6\,ft$

Working point at back of Reinforced Mass (PTG):

$xg := xo_n + (L - t + s)$

$y\_g := yo_n + (L - t + s) \cdot \tan(i)$

$yg := if(y\_g > H + hi, H + hi, y\_g)$

$xg = 4.783\,ft$ $yg = 7.062\,ft$

Working point at back of influence zone (2H or H' + grid length - block embedment):

2H :

$x2H1 := 2 \cdot H$ $x2H1 = 12\,ft$

$y2\_H1 := yo_n + (x2H1 - xo_n) \cdot \tan(i)$

$y2H1 := if(y2\_H1 > H + hi, H + hi, y2\_H1)$ $y2H1 = 8\,ft$

He + grid length - block embedment:

$xH\_g := L + He$ $xH\_g = 11.062\,ft$

$y\_H\_g := yo_n + (xH\_g - xo_n) \cdot \tan(i)$

$yH\_g := if(y\_H\_g > H + hi, H + hi, y\_H\_g)$ $yH\_g = 8\,ft$

$x2H := if(x2H1 < xH\_g, xH\_g, x2H1)$ $x2H = 12\,ft$

$y2H := if(x2H1 < xH\_g, yH\_g, y2H1)$ $y2H = 8\,ft$

Coordinates of Entrance Points (Equal to # of Courses):

	xe (· ft)
0	12
1	11.198
2	10.396
3	9.594
4	8.792
5	7.991
6	7.189
7	6.387
8	5.585
9	4.783
10	
11	

	ye (· ft)
0	8.000
1	8.000
2	8.000
3	8.000
4	8.000
5	8.000
6	7.863
7	7.596
8	7.329
9	7.062

Determine twenty equal divisions between back of reinforced mass and the horizontal limit:

$$division := \frac{(x2H - xg)}{n} \qquad division = 0.802\,ft$$

$xe_{courses} := x2H - division \cdot courses$

$y\_e_{courses} := yo_n + (xe_{courses} - xo_n) \cdot \tan(i)$

$ye_{courses} := if(y\_e_{courses} > H + hi, H + hi, y\_e_{courses})$

Input Values from AB Walls:

$course = 0$ $FSi = 1.69$

$Xc = 0.78\,ft$ $Yc = 11.87\,ft$ $Radius = 11.87\,ft$

$xo_{course} = 0.915\,ft$ $yo_{course} = 0\,ft$

$X1 = 12\,ft$ $Y1 = 8\,ft$

Chord Geometry:

$$chord := \left[(X1 - xo_{course})^2 + (Y1 - yo_{course})^2\right]^{0.5} = 13.671\,ft$$

$$chordslope := \left(\frac{Y1 - yo_{course}}{X1 - xo_{course}}\right)$$

$anglechord := atan(chordslope)$

$chordslope = 0.722$

$anglechord = 35.817 \cdot deg$

Wedge Thicknesses Relative to Slip Arc:

$w := 20$

$NoWedges := 0 .. w$

Note: This calculation fixes the number of soil wedges to 20.

$$wedge\_thick := \frac{(X1 - xo_{course})}{w}$$

This is the thickness of each wedge Relative to the selected Slip Arc length:

wedge_thick = 0.554 ft

$Elev_{course} = 0$ ft

wedge_thick = 0.554 ft

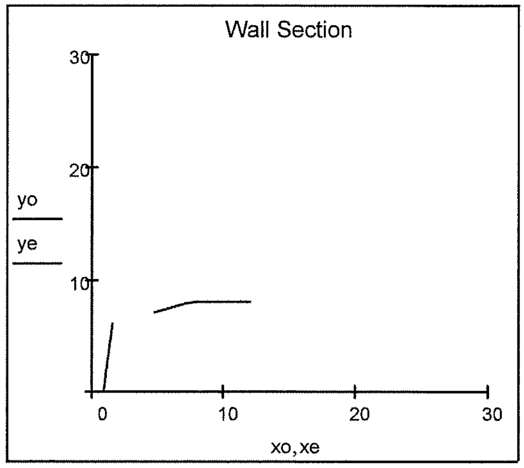
$xw_{NoWedges} := (wedge\_thick \cdot NoWedges) + xo_{course}$

Radius = 11.87 ft

$$ywb_{NoWedges} := Yc - \left[Radius^2 - (xw_{NoWedges} - Xc)^2\right]^{0.5}$$

$$yw\_t_{NoWedges} := yo_n + (xw_{NoWedges} - xo_n) \cdot \tan(i)$$

$$ywt_{NoWedges} := if(yw\_t_{NoWedges} > H + hi, H + hi, yw\_t_{NoWedges})$$



$xo_{course-1} = ▮$

Coordinates of intersection points of Arcs and Vertical Wedges:

$ywb_{NoWedges}$ = (ft)	$ywt_{NoWedges}$ = (ft)	$xw_{NoWedges}$ = (ft)
0.001	5.775	0.915
0.02	5.96	1.469
0.065	6.144	2.023
0.137	6.329	2.577
0.235	6.513	3.132
0.361	6.697	3.686
0.516	6.882	4.24
0.699	7.066	4.794
0.914	7.25	5.349
1.162	7.435	5.903
1.446	7.619	6.457
1.767	7.804	7.012
2.131	7.988	7.566
2.542	8	8.12
3.006	8	8.674
...	...	9.229
		...

Area of each of the 10 Wedges Relative to the chosen Arc Number:

$Area\_Wedge_0 = 1.36\,ft^2$

$Area\_Wedge_1 = 3.263\,ft^2$

$Area\_Wedge_2 = 3.401\,ft^2$

$Area\_Wedge_3 = 3.456\,ft^2$

$Area\_Wedge_4 = 3.496\,ft^2$

$Area\_Wedge_5 = 3.52\,ft^2$

$Area\_Wedge_6 = 3.529\,ft^2$

$Area\_Wedge_7 = 3.52\,ft^2$

$Area\_Wedge_8 = 3.494\,ft^2$

$Area\_Wedge_9 = 3.449\,ft^2$

$Area\_Wedge_{10} = 3.384\,ft^2$

$Area\_Wedge_{11} = 3.296\,ft^2$

$Area\_Wedge_{12} = 3.136\,ft^2$

$Area\_Wedge_{13} = 2.897\,ft^2$

$Area\_Wedge_{14} = 2.622\,ft^2$

$Area\_Wedge_{15} = 2.31\,ft^2$

$Area\_Wedge_{16} = 1.95\,ft^2$

$Area\_Wedge_{17} = 1.529\,ft^2$

$Area\_Wedge_{18} = 1.022\,ft^2$

$Area\_Wedge_{19} = 0.372\,ft^2$

Wedge Properties:

α = Angle from Horizontal to bottom of each wedge.

θ = Angle from Horizontal to relative Geogrid placement. Assumed to always be 0 degrees.

ϕ = Internal friction angle of either infill or retained soils.

γi = Unit weight of infill soil will be used for all Wedge weights.

Where : $m\_\alpha = \cos(\alpha) + [\sin(\alpha) * \tan(\phi)] / FS$

SURCHARGE PARAMETERS

Note: For Internal Compound Stability calculations, there will be no distinction between live and dead load surcharges. Both act on the sliding wedge in a similar way. The weight of all surcharges will be added to the weight of each particular soil wedge resulting in an addition to the resisting and sliding forces.

POINT LOAD SURCHARGE PARAMETERS

$P = 0 \cdot psf$

$x1 = 10\,ft$

$x2 = 8.144\,ft$

Weight of point load surcharge per wedge:

$Wt\_pt = Qpi * wedge\_thick$

$Wt\_pt_3 = 0 \cdot plf$

SQUARE FOOT SURCHARGE PARAMETERS

$q = 100 \cdot psf$

$qx = 7.5\,ft$

Weight of square foot surcharge per wedge:

$Wt\_Sf = q * wedge\_thick$ $\quad Wt\_Sf_3 = 0 \cdot plf$

Total weight of surcharges:

$Wt\_Sur := Wt\_Sf + Wt\_pt$

SOIL WEDGE PARAMETERS

Area_Wedge1 = (ft^2)	Area_Wedge2 = (ft^2)	Area_Wedge3 = (ft^2)	γ_1_{bbb} = (pcf)	γ_2_{bbb} = (pcf)	γ_3_{bbb} = (pcf)	Wt_Wedge = (plf)
0.81	0.451	0.099	120	120	120	163.178
0.974	0.998	1.292	120	120	120	391.617
0.942	0.998	1.461	120	120	120	408.074
0.895	0.998	1.563	120	120	120	414.684
0.832	0.998	1.666	120	120	120	419.488
0.755	0.998	1.768	120	120	120	422.431
0.661	0.998	1.87	120	120	120	423.446
0.55	0.998	1.972	120	120	120	422.442
0.422	0.998	2.074	120	120	120	419.308
0.275	0.998	2.177	120	120	120	413.904
0.107	0.998	2.279	120	120	120	406.053
-0.083	0.998	2.381	120	120	120	395.53
0	0.7	2.435	120	120	120	376.312
0	0.458	2.439	120	120	120	347.619
0	0.183	2.439	120	120	120	314.671
...	...	...	...	...	...	277.145
						...

SOIL WEDGE PARAMETERS

NoWedges =	Wt_Sur = (plf)	α_{bbb} = (deg)	θ = (deg)	ϕ = (deg)	$m\_\alpha1_{bbb}$ =	$m\_\alpha1\_seismic_{bbb}$ =
0	0	1.988	0	0	1.011	1.011
1	0	4.669	0	30	1.024	1.024
2	0	7.36	0	30	1.036	1.036
3	0	10.068	0	30	1.044	1.044
4	0	12.799	0	30	1.051	1.051
5	0	15.56	0	30	1.055	1.055
6	0	18.358	0	30	1.057	1.057
7	0	21.202	0	30	1.056	1.056
8	0	24.103	0	30	1.052	1.052
9	0	27.071	0	30	1.046	1.046
10	0	30.12	0	30	1.036	1.036
11	7	33.267	0	30	1.024	1.024
12	55	36.532	0	30	1.007	1.007
13	55	39.943	0	30	0.986	0.986
14	55	43.533	0	30	0.960	0.96
...	...	...	...	...	...	...

$\sum Wt\_Wedge = 6600.652 \cdot plf$ $\sum Wt\_Sur = 450 \cdot plf$

Sliding Resistance Due to Soil Weight, Surcharges and Soil Frictional Interaction:

$$Fr_{bbb} := \left(\frac{Wt\_Wedge_{bbb-1} + Wt\_Sur_{bbb-1}}{m\_\alpha1_{bbb}}\right) \cdot \tan(\phi_{bbb})$$

$$Fr\_seismic_{bbb} := \left(\frac{Wt\_Wedge_{bbb-1} + Wt\_Sur_{bbb-1}}{m\_\alpha1\_seismic_{bbb}}\right) \cdot \tan(\phi_{bbb})$$

Fr_{bbb} = (plf)	$Fr\_seismic_{bbb}$ = (plf)
93.16	93.16
220.70	220.70
227.52	227.52
229.26	229.26
230.48	230.48
231.18	231.18
231.36	231.36
230.99	230.99
230.05	230.05
228.48	228.48
226.20	226.20
226.83	226.83
247.56	247.56
236.00	236.00
222.51	222.51
206.74	...
...	

Sum of Resisting Forces (STATIC):

$\sum Fr = 4084.77 \cdot plf$

Sum of Resisting Forces (SEISMIC):

$\sum Fr\_seismic = 4084.77 \cdot plf$

Lateral Sliding Force:

$$Fs_{bbb} := (Wt\_Wedge_{bbb-1} + Wt\_Sur_{bbb-1}) \cdot \sin(\alpha_{bbb})$$

$Fs_{bbb} =$

5.661
31.878
52.279
72.495
92.929
113.313
133.365
152.782
171.237
188.367
203.765
220.577
257.005
258.764
254.914
...

$\cdot$ plf

$$\sum Fs = 3126.939 \cdot plf$$

SEISMIC PARAMETERS

$$Dyn\_CS := \sum Fs \cdot Khr \qquad Dyn\_CS = 0 \cdot plf$$

Sum of Lateral Sliding Forces:

$$\sum Fs + Dyn\_CS = 3126.94 \cdot plf$$

GEOGRID INTERACTION

$$xgrid1_k := if\left[Elev\_Grid_k \le Elev_{course}, 0ft, Xc + \left[\left|(Radius)^2 - (Elev_k - Yc)^2\right|\right]^{0.5}\right]$$

Note: geo course #0 represents the top of leveling pad.

$$ygrid1_k := if(geo_k > 0, if(xgrid1_k \le 0ft, 0ft, Elev_k), 0ft)$$

$$xgrid2_k := if(geo_k > 0, if(xgrid1_k \le 0ft, 0ft, xgrid1_k), 0ft)$$

Course Elevation:

courses =	geo =	Elev = (ft)
0	0	0.000
1	0	0.667
2	0	1.333
3	1	2.000
4	0	2.667
5	2	3.333
6	0	4.000
7	3	4.667
8	0	5.333
9	4	6.000

Coordinates of intersection points between Grid Layer elevation and Slip Arc:

ygrid1 = (ft)	xgrid2 = (ft)
0	0
0	0
0	0
2	7.374
0	0
3.333	9.028
0	0
4.667	10.214
0	0
6	11.097

Horizontal resistance Forces due to Geogrid layers at intersection with Slip Arc:

Note: The designer should determine the least amount of resisting force provided by each grid layer by calculating the resistance from both sides of the Slip Arc. The resisting force from the retained side is the embedment length (Le) combined with the confining pressure of the soil above. Similarly, the sliding wedge side is figured by combining the connection strength of that layer with the confining soil pressure above the effected grid length.

Retained side of Slip Arc Calculation:

ygrid = Elevation of Geogrid Layer at intersection with Slip Arc

Le_grid_b = Length of Geogrid beyond intersection with Slip Arc (the "_b" indicates "beyond" the Slip Arc)

Ngrid_b = The weight or confining pressure from soil above Le_grid_b

$$Le\_grid1 := Glength - (xgrid2 - ygrid1 \cdot \tan(\omega)) \qquad Le\_grid\_b_k := \text{if}\left(xgrid2_k = 0 \cdot ft, 0 \cdot ft, \text{if}\left(Le\_grid1_k \le 0, 0 \cdot ft, Le\_grid1_k\right)\right)$$

$$ygrid_k := \text{if}\left(Le\_grid\_b_k \le 0ft, 0ft, ygrid1_k\right) \qquad xgrid_k := \text{if}\left(ygrid_k = 0ft, 0ft, xgrid2_k\right)$$

Normal load above grid:

Grid between I_2 and top of wall

$$kkk_k := \left[\left[\left[yo_n + \left(xgrid1_k - xo_n\right) \cdot \tan(i\_int)\right] - ygrid_k\right] + \frac{\left[\left(xgrid1_k + Le\_grid\_b_k\right) \cdot \tan(i\_int)\right]}{2}\right] \cdot \gamma i\_3 \cdot Le\_grid\_b_k$$

Grid between I_1 and I_2

$$bbbb_k := \left[\left[\left[yo_n + \left(xgrid1_k - xo_n\right) \cdot \tan(i\_int)\right] - I\_2\right] + \frac{\left[\left(xgrid1_k + Le\_grid\_b_k\right) \cdot \tan(i\_int)\right]}{2}\right] \cdot \gamma i\_3$$

$$lll_k := \text{if}\left[ygrid_k > I\_1 \wedge ygrid_k < I\_2, \left[\left[\left(I\_2 - ygrid_k\right) \cdot \gamma i\_2 + bbbb_k\right] \cdot Le\_grid\_b_k\right], kkk_k\right]$$

Grid between I_1 and bottom of wall

$$Ngrid\_b_k := \text{if}\left[ygrid_k = 0 \cdot ft, 0 \cdot plf, \text{if}\left[ygrid_k < I\_1, \left[\left[\left(I\_1 - ygrid_k\right) \cdot \gamma i\_1 + (I\_2 - I\_1) \cdot \gamma i\_2 + bbbb_k\right] \cdot Le\_grid\_b_k\right], lll_k\right]\right]$$

$$Tgrid1_k := \text{if}\left(ygrid_k \le 0ft, 0 \cdot plf, \alpha pullout \cdot 2 \cdot Le\_grid\_b_k \cdot Ci \cdot \frac{Ngrid\_b_k}{1ft} \cdot \frac{\tan(\phi i)}{1.5}\right) \qquad \text{where:} \quad \phi i = 30 \cdot deg$$

Geogrid Layer strength is limited to it's LTDS:

$$Tgrid\_b_k := if\left(Tgrid1_k \le 0plf, 0plf, if\left(Tgrid1_k \ge LTDS_{geo_k}, LTDS_{geo_k}, Tgrid1_k\right)\right)$$

Allowable geogrid strength:

courses =	xgrid =	ygrid =	Le_grid_b =	Ngrid_b =	Tgrid_b =
0	0 · ft	0 · ft	0 · ft	0 · plf	0 · plf
1	0	0	0	0	0
2	0	0	0	0	0
3	0	0	0	0	0
4	0	0	0	0	0
5	0	0	0	0	0
6	0	0	0	0	0
7	0	0	0	0	0
8	0	0	0	0	0
9	0	0	0	0	0

Sum of Allowable grid strengths based on embedment depth beyond the Slip Arc:

$$Fg\_b := Tgrid\_b \cdot \cos(\alpha\_grid_w)$$

$$Fg\_b = 0 \cdot plf$$

Failure Wedge side of Slip Arc Calculation:

Soil resistance portion:

ygrid = Elevation of Geogrid Layer at intersection with Slip Arc

Le_grid_f = Length of Geogrid beyond intersection with Slip Arc (the "_f" indicates "in front" of the Slip Arc)

Ngrid_f = The weight or confining pressure from soil above Le_grid_b

$$Le\_grid2 := L - (t - s) - Le\_grid1 \qquad Le\_grid\_f_k := if\left(xgrid2_k = 0ft, 0ft, if\left(Le\_grid1_k \le 0.01ft, 0ft, Le\_grid2_k\right)\right)$$

Normal load above grid:

Grid between I_2 and top of wall

$$ggg_k := \left[\left[\left[yo_n + \left(xgrid2_k - xo_n\right) \cdot \tan(i\_int)\right] - ygrid_k\right] - \frac{\left[\left(xgrid2_k - xo_n\right) \cdot \tan(i\_int)\right]}{2}\right] \cdot \gamma i\_3 \cdot Le\_grid\_f_k$$

Grid between I_1 and I_2

$$bbbbb_k := \left[\left[\left[yo_n + \left(xgrid2_k - xo_n\right) \cdot \tan(i\_int)\right] - I\_2\right] - \frac{\left[\left(xgrid2_k - xo_n\right) \cdot \tan(i\_int)\right]}{2}\right] \cdot \gamma i\_3$$

$$fff_k := if\left[ygrid_k > I\_1 \wedge ygrid_k < I\_2, \left[\left[\left(I\_2 - ygrid_k\right) \cdot \gamma i\_2 + bbbbb_k\right] \cdot Le\_grid\_f_k\right], ggg_k\right]$$

Grid between I_1 and bottom of wall

$$Ngrid\_f_k := if\left[ygrid_k = 0 \cdot ft, 0 \cdot plf, if\left[ygrid_k < I\_1, \left[\left[\left(I\_1 - ygrid_k\right) \cdot \gamma i\_1 + (I\_2 - I\_1) \cdot \gamma i\_2 + bbbbb_k\right] \cdot Le\_grid\_f_k\right], fff_k\right]\right]$$

$$Tgrid2_k := if\left(ygrid_k \le 0ft, 0 \cdot plf, \alpha pullout \cdot 2 \cdot Le\_grid\_f_k \cdot Ci \cdot \frac{Ngrid\_f_k}{1ft} \cdot \frac{\tan(\phi i)}{1.5}\right)$$

where: $\phi i = 30 \cdot deg$

Geogrid Layer strength is limited to it's LTDS:

$$Tgrid\_f_k := if\left(Tgrid2_k \le 0plf, 0plf, if\left(Tgrid2_k \ge LTDS_{geo_k}, LTDS_{geo_k}, Tgrid2_k\right)\right)$$

Connection Capacity Portion:

Note: TRF and ARF are connection reductions for pattern walls and tumbled product.

$$Fcon\_f_k := if\left[Le\_grid\_f_k > 0ft, Fcs_{geo_k} \cdot (TRF \cdot ARF), 0plf\right]$$

Connection capacity:

courses =	xgrid = (ft)	ygrid = (ft)	Le_grid_f = (ft)	Ngrid_f = (·plf)	Tgrid_f = (·plf)	Fcon_f = (·plf)
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	0	0	0	0	0	0
9	0	0	0	0	0	0

Allowable geogrid strength:

$$Fg\_f := Tgrid\_f \cdot \cos(\alpha\_grid_w)$$

$Fg\_f = 0 \cdot plf$

$\sum Fcon\_f = 0 \cdot plf$

Sum of Allowable resistance on Wedge side:

$Fg\_f + \sum Fcon\_f = 0 \cdot plf$

$$Fg := if\left(Fg\_b \le Fg\_f + \sum Fcon\_f, Fg\_b, \sum Fg\_f + \sum Fcon\_f\right)$$

Allowable Resisting force from Geogrid: $Fg = 0 \cdot plf$

GEOGRID LAYERS ABOVE THE WALL

Are there Geogrid layers above the wall? $Grid\_Above = 2$ — 1 for Yes, 2 for No

How far above the top block to the first layer of grid: $Sabove = 1\ ft$

How many layers above wall are required: $Gabove = 3$

Spacing between layers: $Spacing = 1.5\ ft$

Length of Grid and Type:

$Lga_{ga} =$ (ft)	$type\_GA_{ga} =$
6.5	"Strata 200"
6.5	"Strata 200"
6.5	"Strata 200"

Starting and ending grid coordinates:

$$Elev\_GA_{ga} := if(Grid\_Above = 1, if(i\_int \le 0deg, 0ft, yo_n + Sabove + ga \cdot Spacing), 0ft)$$

$$Xga1_{ga} := if\left(Grid\_Above = 1, if\left(i\_int \le 0deg, 0ft, xo_n + \frac{Elev\_GA_{ga} - yo_n}{\tan(i\_int)}\right), 0ft\right)$$

$$Xga2_{ga} := if(Grid\_Above = 1, if(i\_int \le 0deg, 0ft, Xga1_{ga} + Lga_{ga}), 0ft)$$

Geogrid intersection point with Slip-Arc:

$$xgrid\_ga_{ga} := if\left[Grid\_Above = 1, Xc + \left[\left|(Radius)^2 - (Elev\_GA_{ga} - Yc)^2\right|\right]^{0.5}, 0ft\right]$$

$Elev\_GA_{ga} =$ (ft)	Start of grid: $Xga1_{ga} =$ (ft)	End of $Xga2_{ga} =$ (ft)	$xgrid\_ga_{ga} =$ (ft)	$\gamma i\_above_{ga} =$ (pcf)	$\phi i\_above_{ga} =$ (deg)
0	0	0	0	120	30
0	0	0	0	120	30
0	0	0	0	120	30

Grid Length in front of Slip-Arc:

$$Le\_GA\_f_{ga} := if(Xga1_{ga} \ge xgrid\_ga_{ga}, 0ft, if(Xga2_{ga} \le xgrid\_ga_{ga}, 0ft, xgrid\_ga_{ga} - Xga1_{ga}))$$

Grid Length behind Slip-Arc:

$$Le\_GA\_b_{ga} := if(Xga1_{ga} \ge xgrid\_ga_{ga}, 0ft, if(Xga2_{ga} \le xgrid\_ga_{ga}, 0ft, Xga2_{ga} - xgrid\_ga_{ga}))$$

Normal load above grid:

$$N\_GA\_f_{ga} := if\left[Le\_GA\_f_{ga} \le 0ft, 0plf, \frac{\gamma i\_above_{ga} \cdot \left[(xgrid\_ga_{ga} - Xga1_{ga}) \cdot Le\_GA\_f_{ga} \cdot \tan(i\_int)\right]}{2}\right]$$

$$Tgrid2\_GA\_f_{ga} := if\left(Le\_GA\_f_{ga} \le 0ft, 0 \cdot plf, \alpha pullout \cdot 2 \cdot Le\_GA\_f_{ga} \cdot Ci \cdot \frac{N\_GA\_f_{ga}}{1ft} \cdot \frac{\tan(\phi i\_above_{ga})}{1.5}\right)$$

Determine if the pullout of grid from soil is greater than the LTDS of the grid:

$$Tgrid\_GA\_f_{ga} := if(Le\_GA\_f_{ga} \le 0ft, 0plf, if(Tgrid2\_GA\_f_{ga} \ge LTDS_{Gabove}, LTDS_{Gabove}, Tgrid2\_GA\_f_{ga}))$$

$Le\_GA\_f_{ga} =$ (ft)	$N\_GA\_f_{ga} =$ (plf)	$Tgrid2\_GA\_f_{ga} =$ (plf)	$Tgrid\_GA\_f_{ga}$ (plf)	$\alpha\_grid\_GA_{ga} =$ (deg)
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0

Allowable geogrid strength:

$Fg\_GA\_f_{ga} := Tgrid\_GA\_f_{ga} \cdot \cos(\alpha\_grid\_GA_{ga})$

$Fg\_GA\_f_{ga} =$

0
0
0

$\cdot$ plf

Normal load above grid:

$$N\_GA\_b_{ga} := if\left[Le\_GA\_b_{ga} \le 0ft, 0plf, \gamma i\_above_{ga} \cdot \left[\frac{(Le\_GA\_f_{ga} \cdot \tan(i\_int) + Lga_{ga} \cdot \tan(i\_int))}{2}\right] \cdot Le\_GA\_b_{ga}\right]$$

$$Tgrid2\_GA\_b_{ga} := if\left(Le\_GA\_b_{ga} \le 0ft, 0 \cdot plf, \alpha pullout \cdot 2 \cdot Le\_GA\_b_{ga} \cdot Ci \cdot \frac{N\_GA\_b_{ga}}{1ft} \cdot \frac{\tan(\phi i\_above_{ga})}{1.5}\right)$$

Determine if the pullout of grid from soil is greater than the LTDS of the grid:

$$Tgrid\_GA\_b_{ga} := if(Le\_GA\_b_{ga} \le 0ft, 0plf, if(Tgrid2\_GA\_b_{ga} \ge LTDS_{Gabove}, LTDS_{Gabove}, Tgrid2\_GA\_b_{ga}))$$

$Le\_GA\_b_{ga} =$ (ft)	$N\_GA\_b_{ga} =$ ($\cdot$ plf)	$Tgrid2\_GA\_b_{ga} =$ ($\cdot$ plf)	$Tgrid\_GA\_b_{ga}$ ($\cdot$ plf)	$\alpha\_grid\_GA_{ga} =$ ($\cdot$ deg)
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0

Allowable geogrid strength:

$Fg\_GA\_b_{ga} := Tgrid\_GA\_b_{ga} \cdot \cos(\alpha\_grid\_GA_{ga})$

$Fg\_GA_{ga} := if(Fg\_GA\_f_{ga} < Fg\_GA\_b_{ga}, Fg\_GA\_f_{ga}, Fg\_GA\_b_{ga})$

$Fg\_GA\_b_{ga} =$

0
0
0

$\cdot$ plf

$Fg\_GA_{ga} =$

0
0
0

$\cdot$ plf

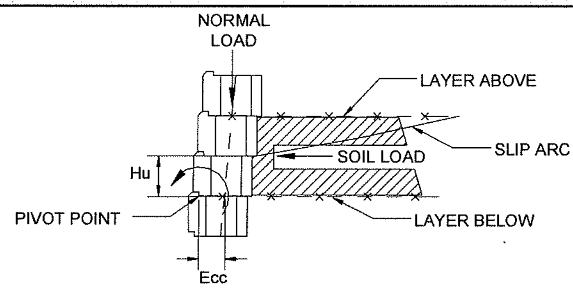
Allowable Resisting force from Geogrids placed above the wall:

$$\sum Fg\_GA = 0 \cdot plf$$

WALL FACING CONTRIBUTION

The Wall facing is subject to lateral forces from the soil load and a vertical normal load from the block facing. If the Slip Arc passes through the facing at a grid layer the shear strength of the Block-Grid-Block shear tests will be considered. If the Slip Arc passes between grid layers, we will determine the applied force on the back of the wall facing from the soil pressure between the upper and lower grid layers relative to the Slip Arc position. The combination of the Normal Load and Connection Strength will help form the resisting loads.

course = 0



NORMAL LOAD REQUIRED = (SOIL LOAD * Hu) / Ecc

Determine if the driving forces due to soil weight and surcharges exceed the resisting forced due to the soil friction and geogrid:

$$Drg\_Frc := \sum Fs - \left(\sum Fr + Fg + \sum Fg\_GA\right)$$

$Drg\_Frc = -957.832 \cdot plf$

$$Drg\_Frc\_Seis := \sum Fs - \left(\sum Fr\_seismic + Fg + \sum Fg\_GA\right)$$

$Drg\_Frc\_Seis = -957.832 \cdot plf$

If this value is POSITIVE the driving force has exceeded the resisting force and the sliding wedge has been mobilized. Then this net driving force should be applied to the back of the wall facing in the Wall Facing Contribution Section.

BLOCK SHEAR TEST RESULTS

Results are based on independent test lab findings.

NOTE: Block - Grid - Block AND Block - Block Shear Results are the same for AB Classic and AB Stones and slightly lower for AB Three, due to top lip configuration. Test values are on page 3:

NOTE: Arc Number zero exits between the bottom block and the base material, therefore the shear value will be the shear interaction between the block and base material soil.

User defined Shear Capacity: $Shear\_Capacity = 100 \cdot \%$

$$N\_CS_{courses} := (H - courses \cdot h) \cdot (c \cdot \gamma c + v \cdot \gamma uf) \cdot t$$

Block - Grid - Block SHEAR:

$$Vu\_BGB_{course} := if(\omega < 6 \cdot deg, au3' + N\_CS_{course} \cdot tan(\lambda u3'), au' + N\_CS_{course} \cdot tan(\lambda u'))$$

$Vu\_BGB_{course} = 3269.416 \cdot plf$

$N\_CS_{course} = 765.937 \cdot plf$

Shear at Arc Number Zero:

$N\_CS_0 = 765.937 \cdot plf$

$$Vo := N\_CS_0 \cdot tan(\phi lp)$$

$Vo = 556.486 \cdot plf$

Determine if the calculated shear is greater than the allowed shear:

$$Vu\_BGB_{course} := if(\omega < 6deg, if(Vu\_BGB_{course} > au3'\_max, au3'\_max, Vu\_BGB_{course}), if(Vu\_BGB_{course} > au'\_max, au'\_max, Vu\_BGB_{cc}$$

$$Vu\_BGB_{course} := Vu\_BGB_{course} \cdot Shear\_Capacity$$

$Vu\_BGB_{course} = 3269.416 \cdot plf$

Block - Block SHEAR:

$$Vu\_BB_{course} := if(\omega < 6deg, au3 + N\_CS_{course} \cdot tan(\lambda u3), au + N\_CS_{course} \cdot tan(\lambda u))$$

$Vu\_BB_{course} = 3269.416 \cdot plf$

Note:
These equations are based on the Allan Block shear strength. The equations were developed through empirical test data and is a function of the normal load acting at that point.

Determine if the calculated shear is greater than the allowed shear:

$Vu\_BB_{course} := if(\omega < 6deg, if(Vu\_BB_{course} > au3\_max, au3\_max, Vu\_BB_{course}), if(Vu\_BB_{course} > au\_max, au\_max, Vu\_BB_{course}))$

$Vu\_BB_{course} := Vu\_BB_{course} \cdot Shear\_Capacity$ $\quad Vu\_BB_{course} = 3269.416 \cdot plf$

Determine if the Slip Arc passes thought the facing at a grid layer:

$Grid\_Layer := if(Elev\_Grid_{course} = 0ft, "NO", "YES")$ $\quad Grid\_Layer = "NO"$

$Vu := if(Grid\_Layer = "YES", Vu\_BGB_{course}, Vu\_BB_{course})$ $\quad Vu = 3269.416 \cdot plf$

Determine the applied force due to soil forces:

Elevation of Slip Arc above leveling pad $Elev_{course} = 0\,ft$ $\quad course = 0$ $\quad Grid\_Layer = "NO"$

Elevation of grid layer above Slip Arc:

$Layer\_Above = 2\,ft$

Distance Below grade:

$H\_Above := H - Layer\_Above$ $\quad H\_Above = 4\,ft$

$h = 0.667\,ft$ $\quad grid\_crs\_num\_Above := \frac{Layer\_Above}{h}$ $\quad grid\_crs\_num\_Above = 3$

Elevation of grid layer below Slip Arc:

Distance Below grade:

$Layer\_Below = 0\,ft$ $\quad H\_Below := H - Layer\_Below$ $\quad H\_Below = 6\,ft$

$grid\_crs\_num\_Below := \frac{Layer\_Below}{h}$ $\quad grid\_crs\_num\_Below = 0$

$ccc := (H\_Below - H\_Above)$

Soil Load between grid layers or driving from above if applicable:

$$Soil\_Load := if\left(Grid\_Layer = "YES", 0 \cdot plf, if\left(Drg\_Frc > 0 \cdot plf, Drg\_Frc, \gamma i \cdot Kai \cdot \frac{H\_Above + H\_Below}{2} \cdot ccc\right)\right)$$

$$Soil\_Load\_Seis := if\left(Grid\_Layer = "YES", 0 \cdot plf, if\left(Drg\_Frc\_Seis > 0 \cdot plf, Drg\_Frc\_Seis, \gamma i \cdot Kai \cdot \frac{H\_Above + H\_Below}{2} \cdot ccc\right)\right)$$

$Soil\_Load = 343.044 \cdot plf$ $\quad Soil\_Load\_Seis = 343.044 \cdot plf$

Geogrid / Block Connection Capacity at Grid layer above Slip-Arc:

$N_{grid\_crs\_num\_Above} := (H - grid\_crs\_num\_Above \cdot h) \cdot (c \cdot \gamma c + v \cdot \gamma uf) \cdot t$

$na := N_{grid\_crs\_num\_Above}$ $\quad N_{grid\_crs\_num\_Above} = 510.625 \cdot plf$

$Fcs_{grid\_crs\_num\_Above, j} := if(type_j = A, if(na < Ninta, B1a + M1a \cdot na, B2a + M2a \cdot na), if(na < Nintb, B1b + M1b \cdot na, B2b + M2b \cdot na))$

$Fcon := Fcs_{grid\_crs\_num\_Above, 1} \cdot TRF \cdot ARF$ $\quad Fcon = 1546.91 \cdot plf$ $\quad course = 0$

Normal load required to prevent overturning:

$$Nreq := \frac{\left[Soil\_Load \cdot (Elev_{course} - Layer\_Below) - \left(\frac{Fcon}{1.5}\right) \cdot (Layer\_Above - Layer\_Below)\right]}{\frac{t}{2}}$$

$Nreq = -4168.516 \cdot plf$

$$Nreq\_seis := \frac{\left[Soil\_Load\_Seis \cdot (Elev_{course} - Layer\_Below) - \left(\frac{Fcon}{1.5}\right) \cdot (Layer\_Above - Layer\_Below)\right]}{\frac{t}{2}}$$

$Nreq\_seis = -4168.516 \cdot plf$

aaa = "Actual normal load exceeds the required, therefore the Block Shear can be used"

Therefore :

$Vu := if(N\_CS_{course} \geq Nreq, Vu, 0plf)$ $Vu = 3269.416 \cdot plf$

$Vu\_seis := if(N\_CS_{course} \geq Nreq\_seis, Vu, 0plf)$ $Vu\_seis = 3269.416 \cdot plf$

Distribution of Connection Strength at facing:

Above Slip Arc: $p := 0 .. \frac{32in}{h}$

$$G\_1_p := if\left[Elev\_Grid_{course+p} > 0 \cdot ft, \frac{(32 \cdot in - p \cdot h)}{32in} \cdot qqq_{course+p}, 0plf\right]$$

$$G\_1 = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 393.557 \\ 0 \end{pmatrix} \cdot plf$$

$\sum G\_1 = 393.557 \cdot plf$

Below Slip Arc: $p1 := 1 .. \frac{32in}{h}$

$$G\_2_{p1} := if\left[Elev_{course} - p1 \cdot h \leq 0 \cdot ft, 0 \cdot plf, if\left[Elev\_Grid_{course-p1} > 0 \cdot ft, \frac{(32 \cdot in - p1 \cdot h)}{32 \cdot in} \cdot qqq_{course-p1}, 0plf\right]\right]$$

$G\_2_{p1} =$

0
0
0
0

$\cdot plf$

$\sum G\_2 = 0 \cdot plf$

Frictional portion of base material (Vo): $Vo = 556.486 \cdot plf$

$$B\_Vo := if\left[Elev_{course} \geq 32 \cdot in, 0 \cdot plf, \frac{(32 \cdot in - course \cdot h)}{32 \cdot in} \cdot Vo\right]$$

$B\_Vo = 556.486 \cdot plf$

Sum of Connection Contribution $Conn := \sum G\_1 + \sum G\_2 + B\_Vo$ $Conn = 950.043 \cdot plf$

Determine the lesser of bock Shear OR Connection Contribution:

$Facing := if(Vu > Conn, Conn, Vu)$ $Facing = 950.043 \cdot plf$

$Facing\_seis := if(Vu\_seis > Conn, Conn, Vu)$ $Facing\_seis = 950.043 \cdot plf$

Safety Factor against Compound Failure for Arc Number:

course = 0

Note: All resisting forces are summed in the numerator and the sliding forces are summed in the denominator. This ratio is the Safety Factor for Internal Compound Stability.

STATIC RESULTS:

$$SF\_slip\_Arc := \frac{\sum Fr + Facing + Fg + \sum Fg\_GA}{\sum Fs}$$

SF_slip_Arc = 1.61

Initial input Safety Factor from AB Walls 10:

FSi = 1.69

SIESMIC RESULTS:

$$SF\_slip\_Arc\_seismic := \frac{\sum Fr\_seismic + Facing\_seis + Fg + \sum Fg\_GA}{\sum Fs + Dyn\_CS}$$

SF_slip_Arc_seismic = 1.610

Initial input Safety Factor from AB Walls 10:

FSi_siesmic = 1.69

$\sum Fr = 4084.771 \cdot plf$ $\sum Fr\_seismic = 4084.771 \cdot plf$ $Facing = 950.043 \cdot plf$

$\sum Fs = 3126.939 \cdot plf$ $Fg = 0 \cdot plf$ $\sum Fg\_GA = 0 \cdot plf$ $Dyn\_CS = 0 \cdot plf$

Compound Stability Summary:

Relative data for analyzed Slip Arc:

course = 0

Exit elevation above Base Material:

$Elev_{course} = 0\,ft$

Initial Safety Factor for instability:

FSi = 1.69

Entrance coordinates:

X1 = 12 ft Y1 = 8 ft

Iterated Safety Factor for instability:

SF_slip_Arc = 1.61

Coordinates for center of Slip Arc Circle:

Xc = 0.78 ft Yc = 11.87 ft

Radius of Slip Arc Circle:

Radius = 11.87 ft

$\sum Wt\_Wedge = 6600.652 \cdot plf$

$\sum Wt\_Sur = 450 \cdot plf$

ICS Soil Parameter Summary:

Infill Soils		Retained Soils	
Infill Soils TOP (I 3)		**Retained Soils TOP (R 1)**	
$\phi i\_3 = 30 \cdot deg$	$\gamma i\_3 = 120 \cdot pcf$	$\phi r\_3 = 30 \cdot deg$	$\gamma r\_3 = 120 \cdot pcf$
Infill Soils MIDDLE (I 2)		**Retained Soils MIDDLE (R 1)**	
$\phi i\_2 = 30 \cdot deg$	$\gamma i\_2 = 120 \cdot pcf$	$\phi r\_2 = 30 \cdot deg$	$\gamma r\_2 = 120 \cdot pcf$
Infill Soils BOTTOM (I 1)		**Retained Soils BOTTOM (R 1)**	
$\phi i\_1 = 30 \cdot deg$	$\gamma i\_1 = 120 \cdot pcf$	$\phi r\_1 = 30 \cdot deg$	$\gamma r\_1 = 120 \cdot pcf$

SUMMARY OF RESULTS

DESIGN PARAMETERS:

Wall Height: $H = 6 ft$

Block Setback: $\omega = 6.42 \cdot deg$

Backslope Angle: $i = 18.4 \cdot deg$

Backslope Height: $hi = 2 ft$

Surcharge Load: $q = 100 \cdot psf$ SurType = "Retained Soil Live Load"

Line Load Surcharge: $P = 0 \cdot plf$ SurTypePoint = "Live Load"

Point Load Location: $x1 = 10 ft$

$x2 = 8.144 ft$

Seismic Coefficient: $Ao = 0$

Allowable Deflection: $di = 0.25 ft$ $dr = 0.25 ft$

SOIL PARAMETERS:

Infill Soil:	Retained Soil:	Foundation Soil:
$\phi i = 30 \cdot deg$	$\phi r = 30 \cdot deg$	$\phi f = 30 \cdot deg$
$\gamma i = 120 \cdot pcf$	$\gamma r = 120 \cdot pcf$	$\gamma f = 120 \cdot pcf$
		$cf = 0 \cdot psf$

Controlling Dynamic Earth Pressure Theory:

$DynamicTheory_1$ = "Active Wedge Theory"

BLOCK TYPE AND PATTERN:

BlockType = "AB COLLECTION"

BlendType = "NO PATTERN"

EXTERNAL STABILITY:

Static Conditions:

Factor of Safety for Sliding: FSstaticsliding = 2.612

Factor of Safety for Overturning: FSstaticoverturning = 5.143

Seismic Conditions:

Factor of Safety for Sliding: FSseismicsliding = 2.612

Factor of Safety for Overturning: FSseismicoverturning = 5.143

GEOGRID PARAMETERS:

Geogrid Type A: A = "Strata 200"

Geogrid Type B: B = "Strata 350"

Number of Layers: g = 4 Layers

Geogrid Length: L = 4 ft

Ltop = 7 ft

Base Footing Dimensions:

Width of Footing: $Lwidth = 2.0 \cdot ft$

Toe Extension: $Ltoe = -0.5 \cdot ft$

Depth of Footing: $Ldepth = 0.5 \cdot ft$

Width of Reinforcement: $Lgrid = 0 \cdot ft$

When reinforcement is present it shall always be placed 6in from the bottom of the footing.

Bearing Capacity:

Ultimate Bearing Capacity: $\sigma ult = 4817 \cdot psf$

Bearing pressure: $\sigma max = 849.543 \cdot psf$

Factor of Safety: FSbearing = 5.67

Note:
The minimum footing dimensions are 6in deep by 24in wide. If the values specifying the footing dimensions are not greater than 6in X 24in, the minimum size should be used. When geogrid reinforcement is present the minimum footing depth shall be 12in to provide 6in of minimum cover above and below the geogrid.

INTERNAL STABILITY: Local Top of the Wall Stability

Static Conditions:

Factor of Safety for Sliding: FSsliding_s_top = 164.2

Factor of Safety for Overturning: FSoverturning_s_top = 30.12

Seismic Conditions:

Factor of Safety for Sliding: FSsliding_d_top = 164.2

Factor of Safety for Overturning: FSoverturning_d_top = 30.12

INTERNAL STABILITY:

Static Conditions:

Geogrid Length: L = 4 ft   Ltop = 7 ft

Geogrid Number	Geogrid Elev.	Tensile Force	Allowable Load	Factor Safety Overstress	Factor Safety Pullout Block:	Factor Safety Pullout, Soil:	Geogrid Efficiency, %
j =	Ee_j = (ft)	Fis_j = (plf)	$\frac{LTDS_j}{FSos\_s}$ = (plf)	$FSoverstress\_s_j$ =	$FSconn\_s_j$ =	$FSpullout\_s_j$ =	$effec\_s_j$ =
4	5.333	45.894	1075.333	35.146	46.072	9.316	4.268
3	4	101.181	1075.333	15.942	21.707	3.01	9.409
2	2.667	158.489	1075.333	10.177	14.375	4.409	14.739
1	1.333	345.185	1075.333	4.673	6.837	3.631	32.1