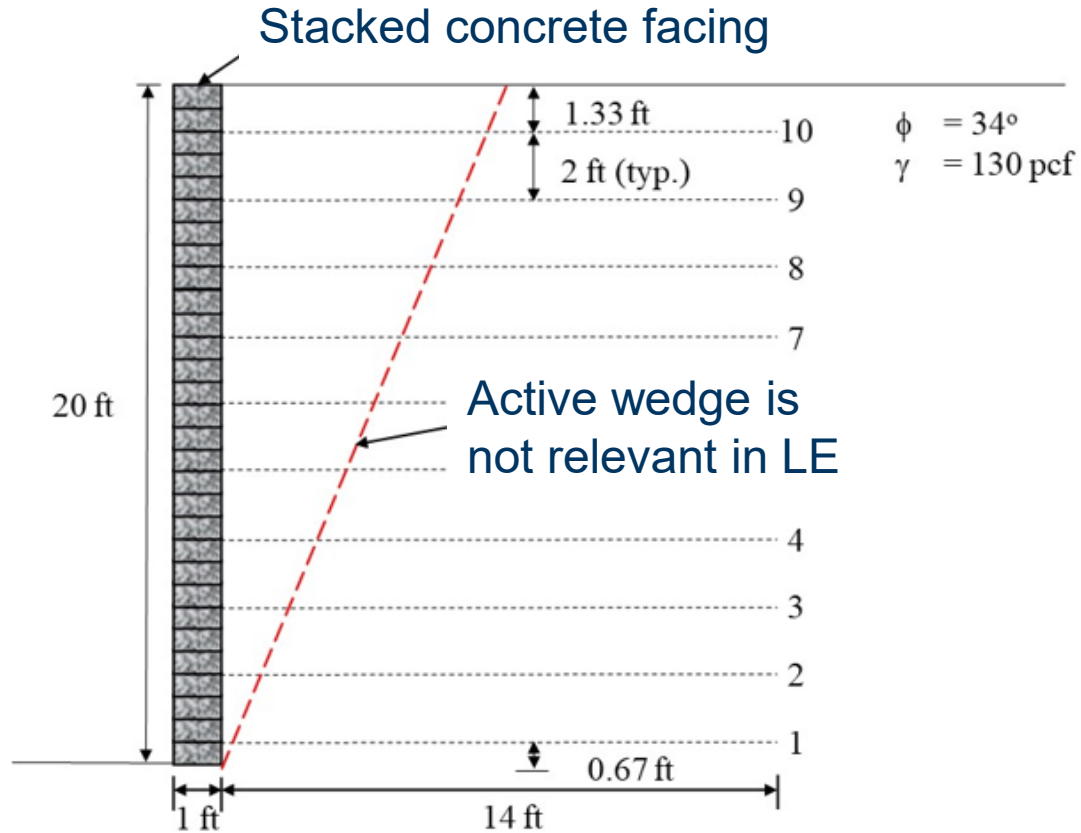


Lesson 5:

ReSSA+: Demonstration

Problem – Mechanical Connector



Property	Design Value
Find T_{\max} for design	
$RF_{ID} RF_{CR} RF_D = RF$	$1.12 \times 1.5 \times 1.3 = 2.18$
Coverage ratio, R_c	1.0
Facing unit weight, γ_{block} (pcf)	120
Facing block height (ft)	0.67
Facing block width, W_u (ft)	1.0
Connection strength as fraction of T_{ult} , CR_u	0.75

Baseline Solution: Stage I

Objective: Find $T_{\max} \rightarrow T_{\text{ult}} = 1.5 \text{ LTDS} = 1.5 \text{ RF}_{\text{id}} \text{ RF}_{\text{d}} \text{ RF}_{\text{cr}} T_{\max}$

The screenshot shows the 'Main Menu' of a software application. It features several panels for configuration and analysis. The 'Geometry' panel includes 'SIMPLIFIED', 'TIERED', and 'GENERAL' options. The 'Reinforcing Material' panel includes 'GEOSYNTHETIC' and 'METALLIC' options. A 'Working with ReSSA+' panel contains a 'Project Identification' icon. An 'Input Data' panel is located below these. The bottom section is divided into two main analysis modes: 'Rotational Failure Mode: Bishop Analysis' and 'Translational Failure Mode: Spencer Analysis'. Under the Bishop Analysis mode, the 'Baseline Solution' option is highlighted with a red box. Below it, there are two sub-sections: 'Global Stability' and 'Baseline Solution'. Each sub-section contains a 'Define search domain' box, a 'RUN' button, and a 'VIEW RESULTS' button. The 'Translational Failure Mode: Spencer Analysis' section also contains two sub-sections: 'TRANSLATIONAL FAILURE MODE (Direct Sliding)' and 'THREE-PART WEDGE Failure Mechanism using:'. The latter sub-section includes options for 'Points on a Mesh' and 'Points Along a Line', along with 'RUN' and 'VIEW RESULTS' buttons.

Define Search Domain to Determine T_{max} and T_o

Search Domain for ROTATIONAL ANALYSIS – Top-Down Method

Search of critical circles is limited to user's defined range of entry points. Input only the range of x (program will calculate the corresponding y):

All X values are in [ft]

X1 to X2 Other...

Circles Start points (upper part)

From X1 value = 101

to X2 value = 137.5

Number of START points (between X1 and X2), Ns: 50

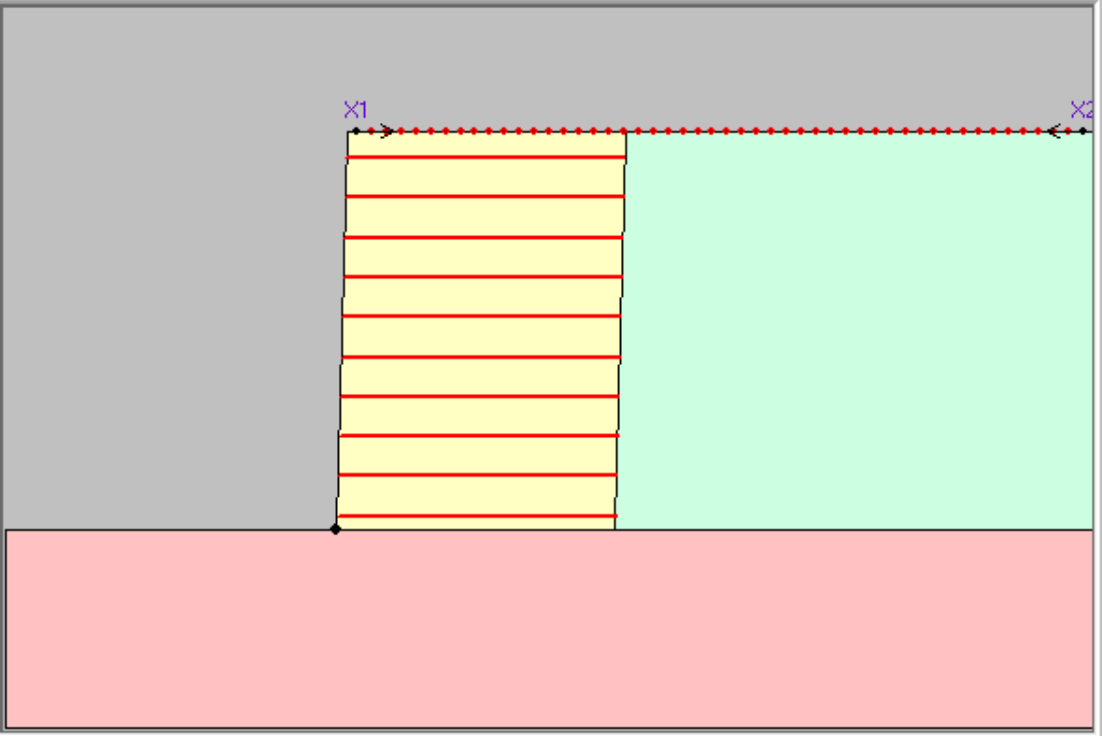
Targeted Fs on strength of soils:

Cohes. Fs-cohesion: 1 Read Note

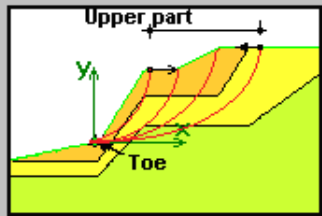
Friction Fs-phi: 1

Consideration of facing units should be carefully considered:

Facing Elements



Upper part



Toe

X = 93.26 ft.
Y = 121.34 ft.

Each reinforcement layer is divided into: 50 segments. Values should be between 10 - 200

Gridlines

1234567

Method of Stability Analysis : Comprehensive Bishop ROR = 0.0

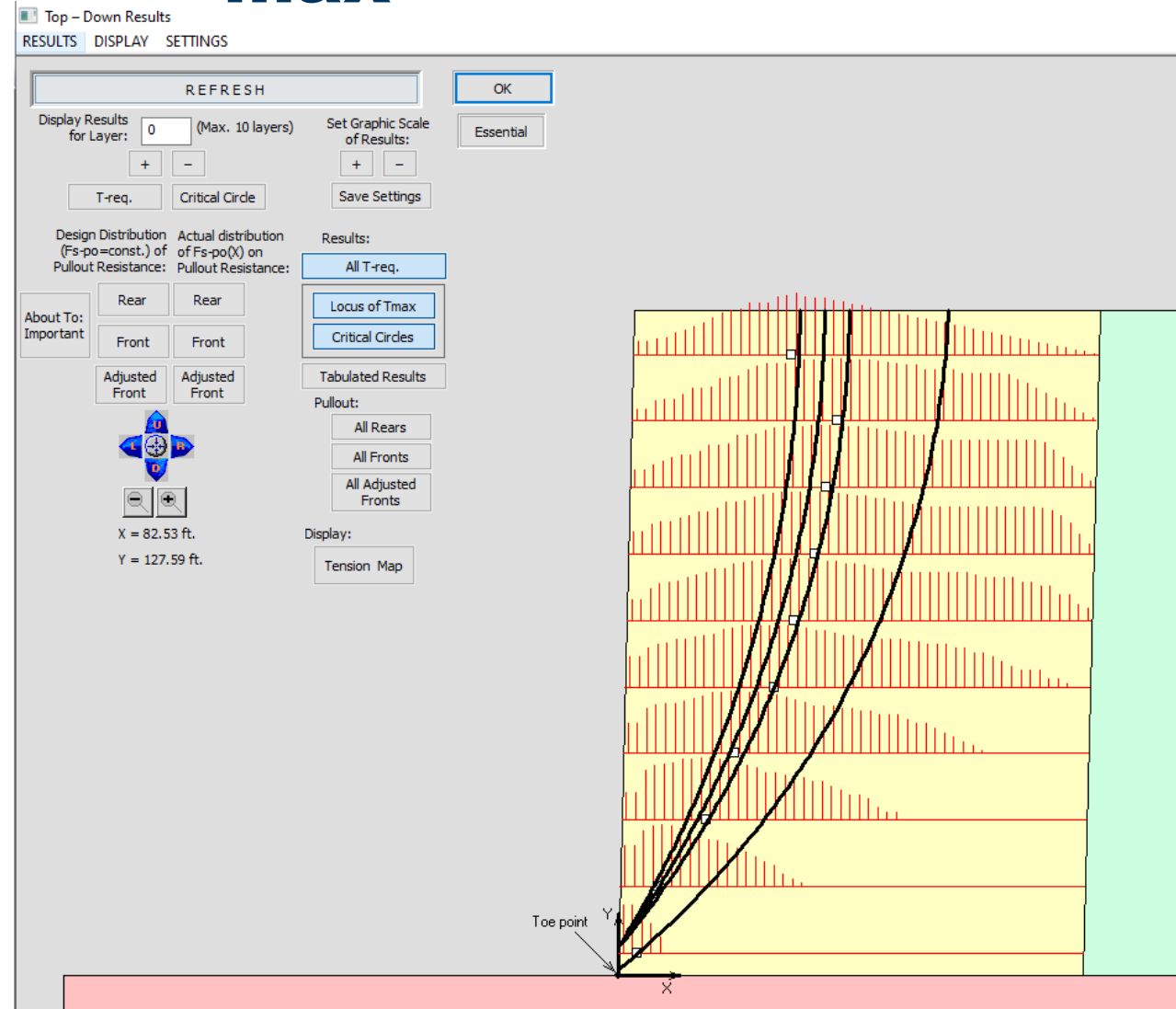
DEFAULT

OK Cancel

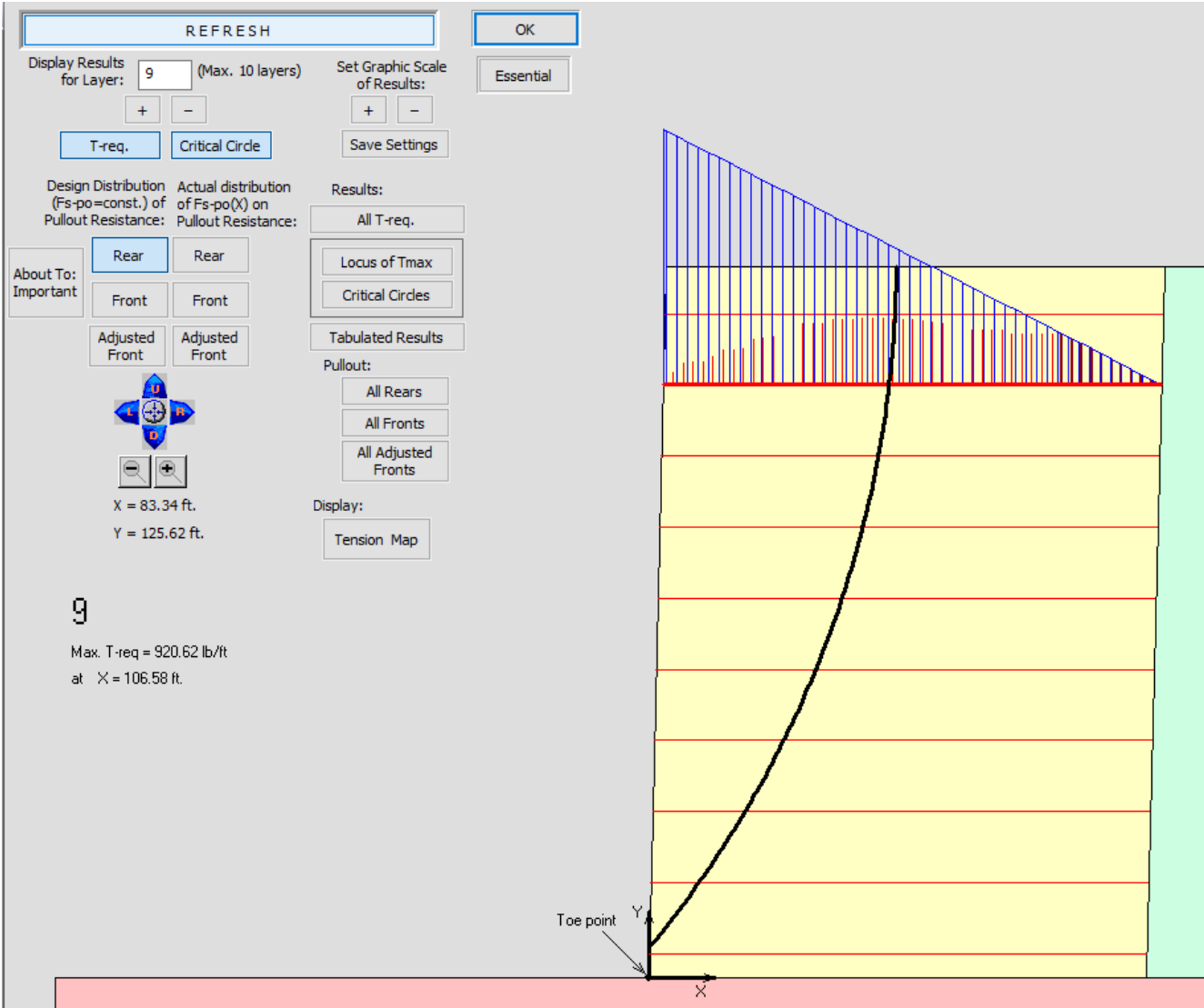
Run and Get $T_{req}(x)$, Locus of T_{max} , Circles Defining T_{max}

If reinforcement strength is same as $T_{req}(x)$, any circle through layers will have the same $F_s=1.0$
→ All circles are equally critical →
Therefore, baseline results are rendered based on which we have to select reinforcement with adequate T_{ult} ensuring sufficient margins of safety

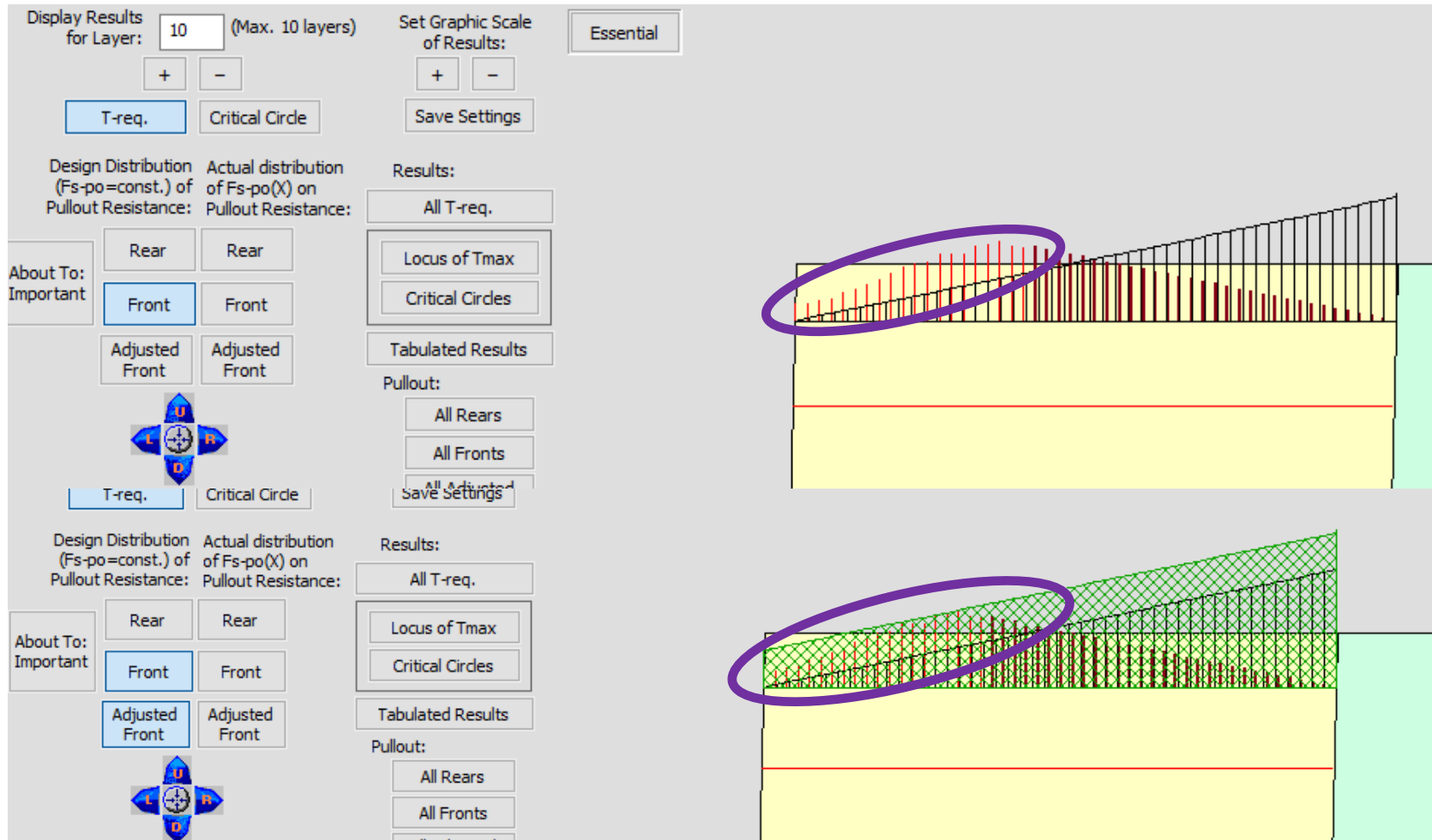
Note: There is well-defined Active Wedge as postulated in most simplified designs



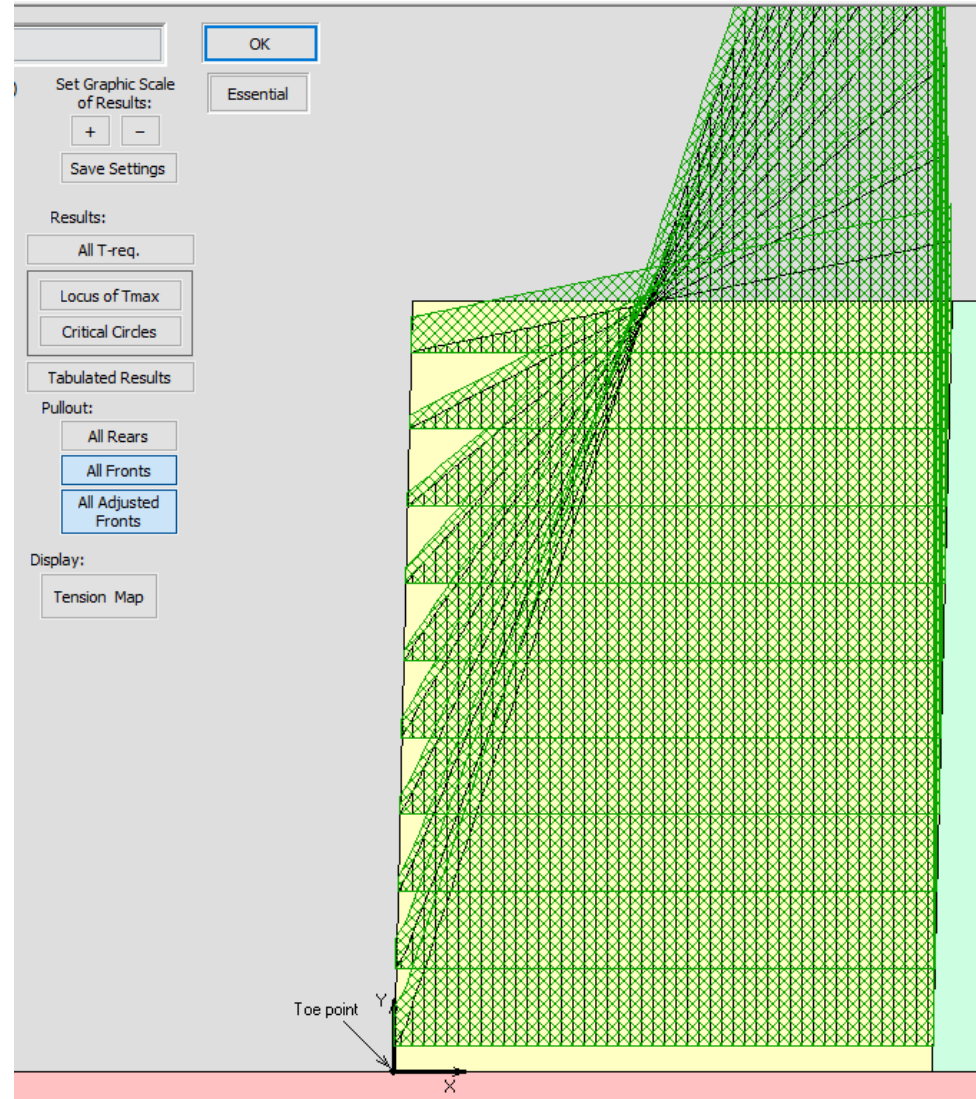
Circle for Layer 9 Determining T_{max} . Note that Treq is limited by Pullout Resistance thus Shedding load to layers below



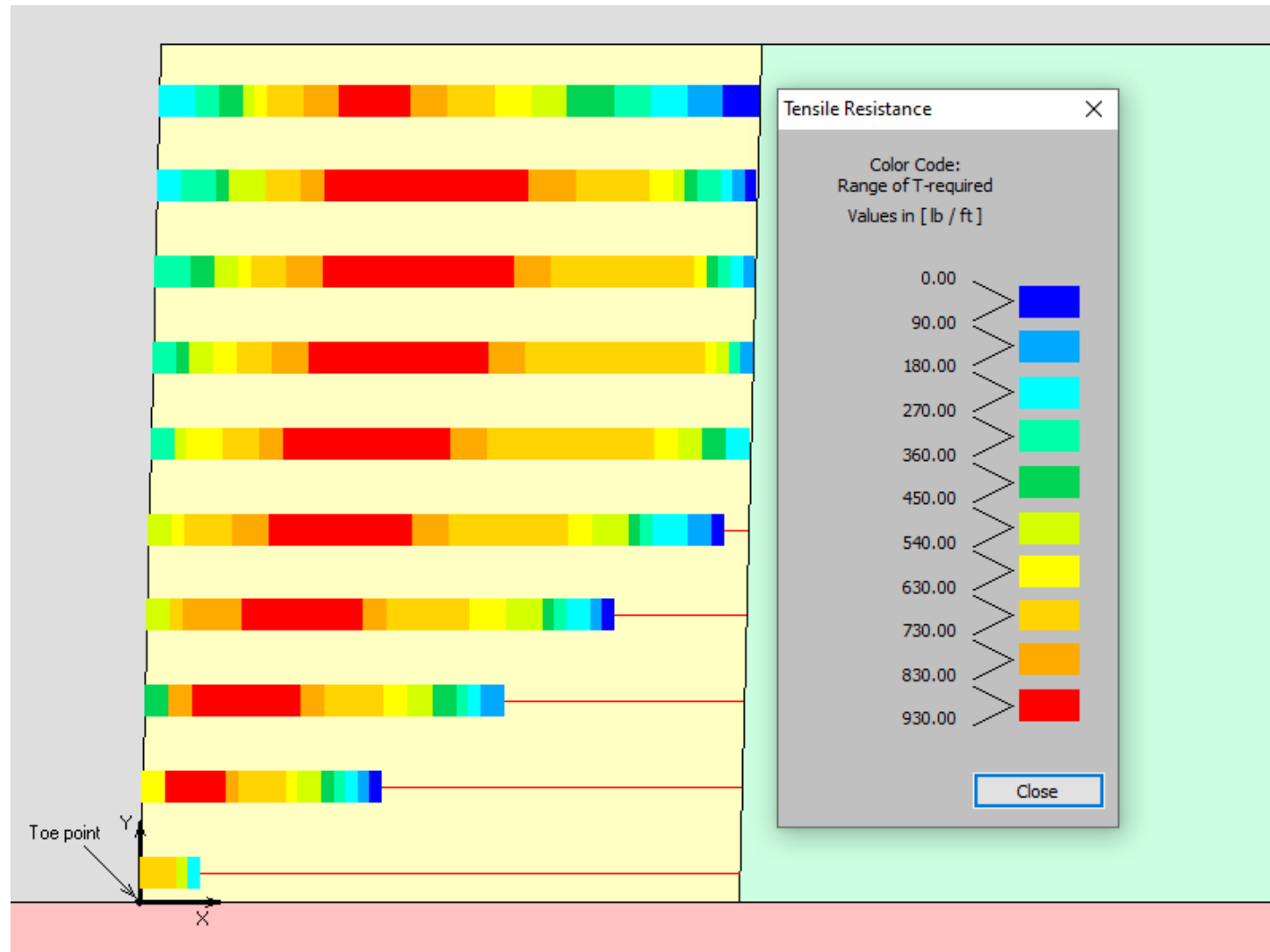
Determining To: For Treq, frontend pullout resistance must be satisfied



All Adjusted Front Pullouts



Tension Map: Color Coded Visual of Treq

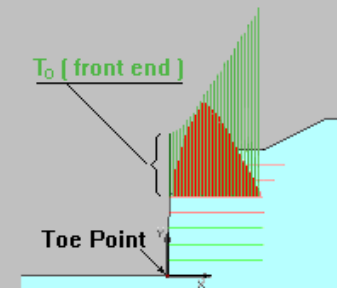
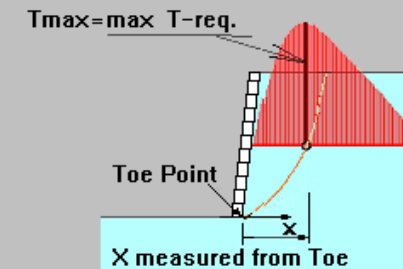
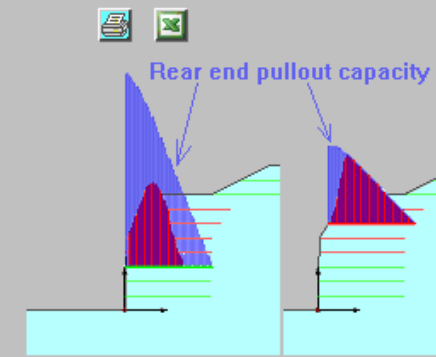


Tabulated Results

Tabulated Results – Stage I ("Internal Stability")

Layer No.	Height from Toe [ft]	Current input of LTDS * [lb/ft]	Fs-reinf. = LTDS / Tmax	T-required		Current input of CoSt ** [lb/ft]	Fs-conn. = CoSt / To	Connection load, To (front end) [lb/ft]	To/ Tmax [%]	T max affected by rear end pullout	Input pullout resist. at rear-end, Tr-o [lb/ft]	Coverage Ratio, Rc
				T max [lb/ft]	Located at X from Toe [ft]							
1	0.67	920.79	1.30	709.94	0.58	690.59	1.44	479.63	68	No	0.00	1.00
2	2.67	920.79	1.00	920.62	1.19	690.59	1.80	383.71	42	No	0.00	1.00
3	4.67	920.79	1.00	920.62	2.64	690.59	3.60	191.85	21	No	0.00	1.00
4	6.67	920.79	1.00	920.62	3.53	690.59	3.15	219.26	24	No	0.00	1.00
5	8.67	920.79	1.00	920.62	4.70	690.59	3.15	219.26	24	No	0.00	1.00
6	10.67	920.79	1.00	920.62	5.31	690.59	5.30	130.19	14	Yes	0.00	1.00
7	12.67	920.79	1.00	920.62	5.92	690.59	3.60	191.85	21	Yes	0.00	1.00
8	14.67	920.79	1.00	920.62	6.25	690.59	4.20	164.45	18	Yes	0.00	1.00
9	16.67	920.79	1.00	920.62	6.58	690.59	4.03	171.30	19	Yes	0.00	1.00
10	18.67	920.79	1.02	903.94	5.23	690.59	1.57	438.52	49	Yes	0.00	1.00

LTDS is based on T_{ult} and RF specified in Global Stability

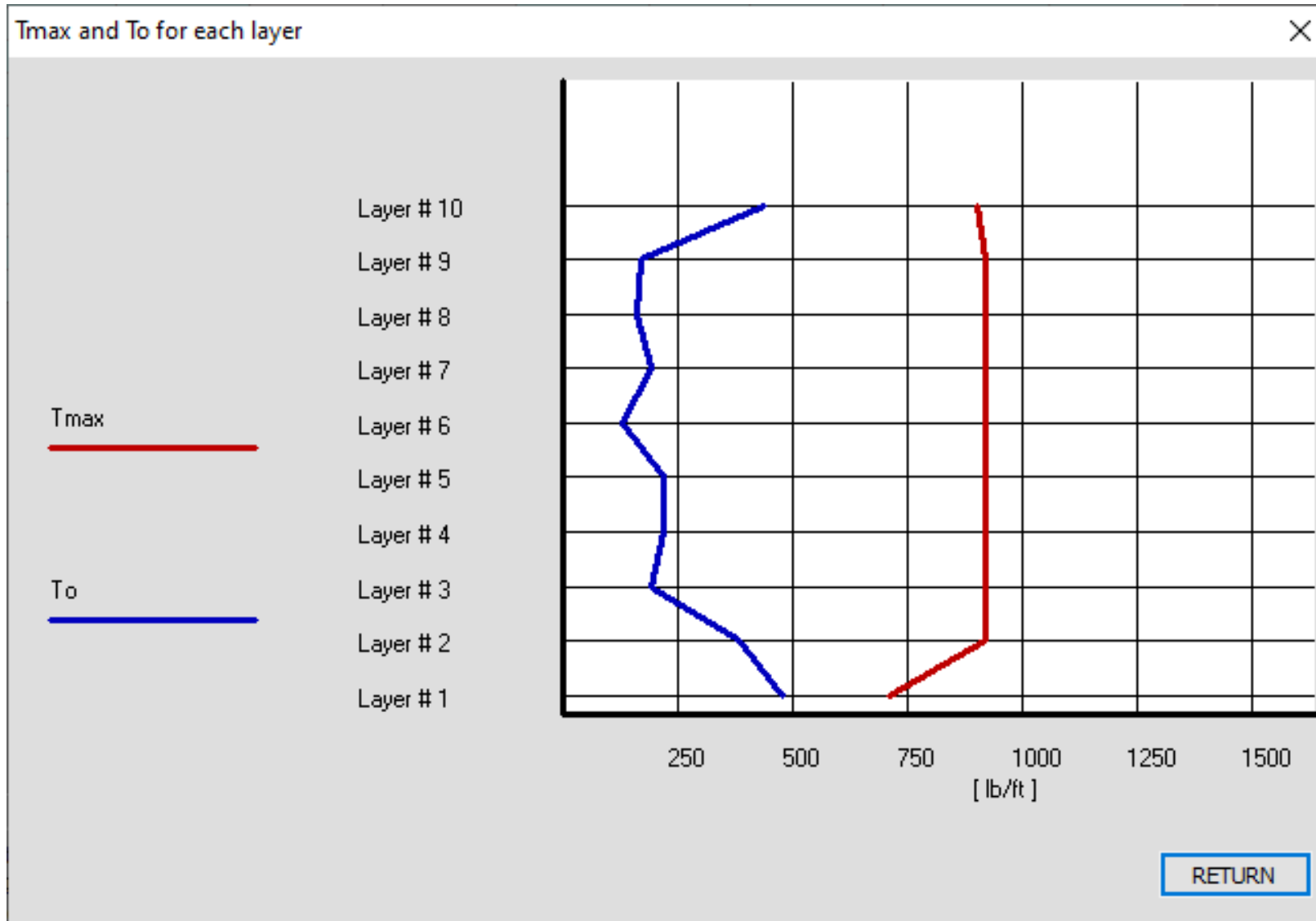


* LTDS = Long-Term Design Strength = $T_{ult} / (RF_{id} * RF_{d} * RF_{cr} * RF_{a})$ where T_{ult} and RF are specified in Global Stability.
 Fs-reinf. = "Factor of safety" on geosynthetic (reinforcement) strength considering the specified target Fs on soil strength and LTDS specified in Global Stability.
 ** CoSt = Connection Strength = % of LTDS available at front-end as currently specified in input of Reinforcement in Global Stability.
 Fs-conn. = "Factor of safety" on connection strength considering the strength specified in Global stability and the calculated connection load in Baseline Solution.

$T_{req}(x)$ is calculated for a limit equilibrium state where Fs anywhere is constant. Therefore, T_o is the connection load at such a limit state. However, connection load can be highly volatile as its value also depends on the relative movement of the face. In addition, loads during construction might be larger than calculated at a limit state. Finally, at working load conditions, higher than calculated connection loads might occur, possibly constraining movements.

It is suggested that you read and understand the commentary in FHWA-HIF-17-004, Section 10.5, pp.105-108, including Fig 10-37.

Display T_{max} and T_o Distributions



Estimate Horizontal Displacement

Estimated Horizontal Displacement, d, at Face of Slope for Specified Fs

Layer No.	Height from Toe [ft]	Current input of LTDS [lb/ft]	Tensile Modulus of Geosynthetics, J, at 2% strain [lb/ft]	Horizontal Displacement at Face of Slope, d [inch]
1	0.67	920.79	34000	0.28
2	2.67	920.79	34000	1.17
3	4.67	920.79	34000	1.88
4	6.67	920.79	34000	2.49
5	8.67	920.79	34000	3.05
6	10.67	920.79	34000	3.38
7	12.67	920.79	34000	3.48
8	14.67	920.79	34000	3.38
9	16.67	920.79	34000	3.20
10	18.67	920.79	34000	2.44

NOTES:

- The approximated horizontal displacement at the face of the slope is appropriate for limit state; i.e., when your specified $F_s=1.0$ in top-down approach leading to full mobilization of the soil strength considering rotational slip surfaces.
- The approximated horizontal displacement, d, is calculated following this expression:

$$d = \sum_{i=1}^n \left(\frac{T_i}{J} \right) \Delta X_i$$
 Where: T_i is the force calculated at segment i and ΔX_i is the length of segment i.
 That is, $\Delta X_i = L / n$ where L is length of the considered reinforcement layer and n is the number of segments along a layer specified in your data (between 50 and 200). J is the tensile modulus of the reinforcement having unit of [Force/Length]. Typically, J is determined at 2% geosynthetic strain.
- The displacement d is solely due to estimated cumulative elongation of the reinforcement. It does not reflect possible translational movement of the reinforced mass. To avoid translational movement, conduct 2-part wedge global stability analysis (in Global Stability mode) verifying that for the selected layout of reinforcement the global F_s is adequate, typically >1.3 .

CALCULATE

5 [inch]

DEFAULT OK Cancel

Back to Main Menu - Global Stability

- Stage II Design

Main Menu

The screenshot shows a software interface with a light blue background. At the top left, the text 'Main Menu' is displayed. Below it, there are several panels. On the left, a 'Geometry' panel contains three buttons: 'SIMPLIFIED', 'TIERED', and 'GENERAL'. In the center, a 'Reinforcing Material' panel contains two buttons: 'GEOSYNTHETIC' and 'METALLIC'. On the right, there is a 'Working with ReSSA +' button and a 'Project Identification' panel featuring a yellow 'ID' icon. A horizontal bar labeled 'Input Data' spans the width of the interface. Below this bar, the interface is divided into two main sections. The left section is titled 'Rotational Failure Mode: Bishop Analysis' and contains a 'Global Stability' button (highlighted with a red border), a 'Baseline Solution' button, and two sub-panels. The first sub-panel is for 'Global Stability' with a 'Define search domain for Global Stability' button, a 'RUN' button, and a 'VIEW RESULTS' button. The second sub-panel is for 'Baseline Solution' with a 'Define search domain for baseline solution to determine Tmax and To' button, a 'RUN' button, and a 'VIEW RESULTS' button. The right section is titled 'Translational Failure Mode: Spencer Analysis' and contains two sub-panels. The first sub-panel is for 'TRANSLATIONAL FAILURE MODE (Direct Sliding)' with a 'Define search domain for TRANSLATIONAL FAILURE MODE (Direct Sliding)' button, a 'RUN' button, and a 'VIEW RESULTS' button. The second sub-panel is for 'THREE-PART WEDGE Failure Mechanism' with a 'Define search domain for THREE-PART WEDGE Failure Mechanism using:' label, two buttons for 'Points on a Mesh' and 'Points Along a Line', a 'RUN' button, and a 'VIEW RESULTS' button.

Geometry

SIMPLIFIED

TIERED

GENERAL

Reinforcing Material

GEOSYNTHETIC

METALLIC

Working with ReSSA +

Project Identification

Input Data

Rotational Failure Mode: Bishop Analysis

Global Stability

Baseline Solution

Define search domain for Global Stability

RUN

VIEW RESULTS

Define search domain for baseline solution to determine Tmax and To

RUN

VIEW RESULTS

Translational Failure Mode: Spencer Analysis

Define search domain for TRANSLATIONAL FAILURE MODE (Direct Sliding)

RUN

VIEW RESULTS

Define search domain for THREE-PART WEDGE Failure Mechanism using:

Points on a Mesh

Points Along a Line

RUN

VIEW RESULTS

Specified T_{ult} /RF Renders $F_s=1.0$ – Recall Internal Stability

Geosynthetic Reinforcement -- Multi Type

Total number of reinforcement layers at or above Toe, To modify click on -----> Modify configuration (elevation, length, type)

Layers below Toe elevation (max. 10) : No Yes

Optional data retrieval from :

	Geosynthetic Designated Name	Geosynthetic Ultimate Strength, T_{ult} [lb/ft]	Reduction Factor for Installation Damage, RF_{id}	Reduction Factor for Durability, RF_d	Reduction Factor for Creep, RF_c	Additional Reduction Factor, RF_a	Coverage Ratio, R_c
1	Type Red	2011.00	1.12	1.30	1.50	1.00	1.00
2							
3							
4							
5							

Click on numeral to delete reinforcement type

$$T_{available} = \frac{T_{ult} \cdot R_c}{RF_{id} \cdot RF_d \cdot RF_c \cdot RF_a} \quad T_{allowable} \leq T_{available}$$

Reinforcement Quantities

Interaction Parameters

DEFAULT

OK Cancel

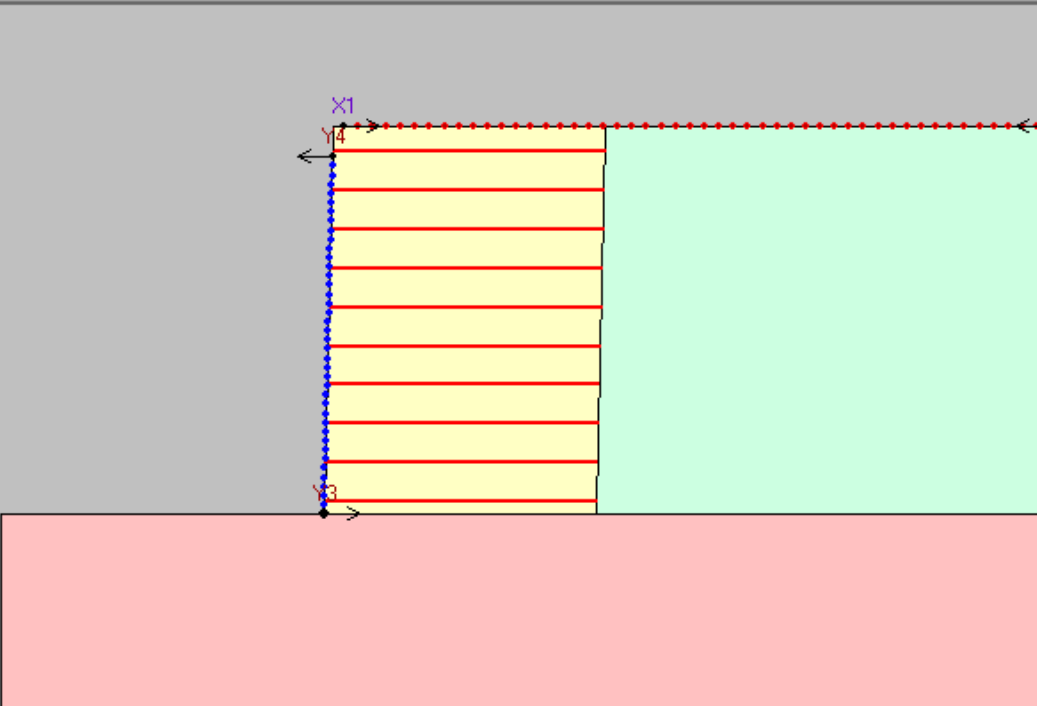
To Ascertain Results in Internal Stability, Run Global – Define Search

Search Domain for ROTATIONAL ANALYSIS -- General Geometry

Search of critical circles is limited to user's defined range of entry and exit points. Input only the range of x (program will calculate the corresponding y):
All X values are in [ft]

Circles Start points (upper part)
From X1 value = 101
to X2 value = 137.5

Circles Exit points (lower part)
X3 to X4 | **Y3 to Y4** | Other...
From Y3 value = 100
to Y4 value = 118.4



Upper part
Lower part
Toe

X = 95.40 ft.
Y = 121.40 ft.

Exclusion Zone

Select "N"

Method of Stability Analysis : ROR = 0.00
 Comprehensive Bishop
 AASHTO/FHWA - Bishop

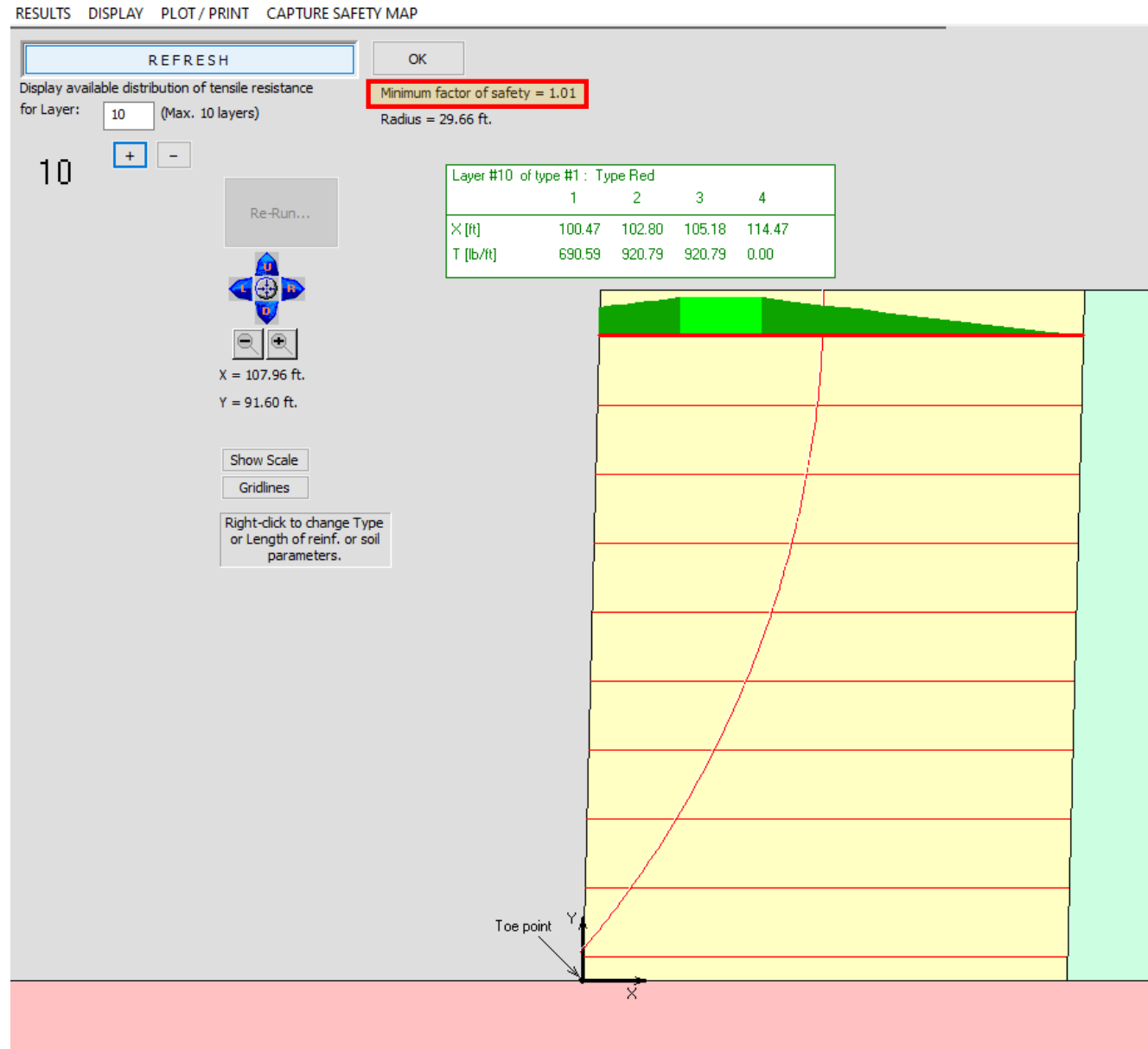
Gridlines
1234567

Display all specified circles

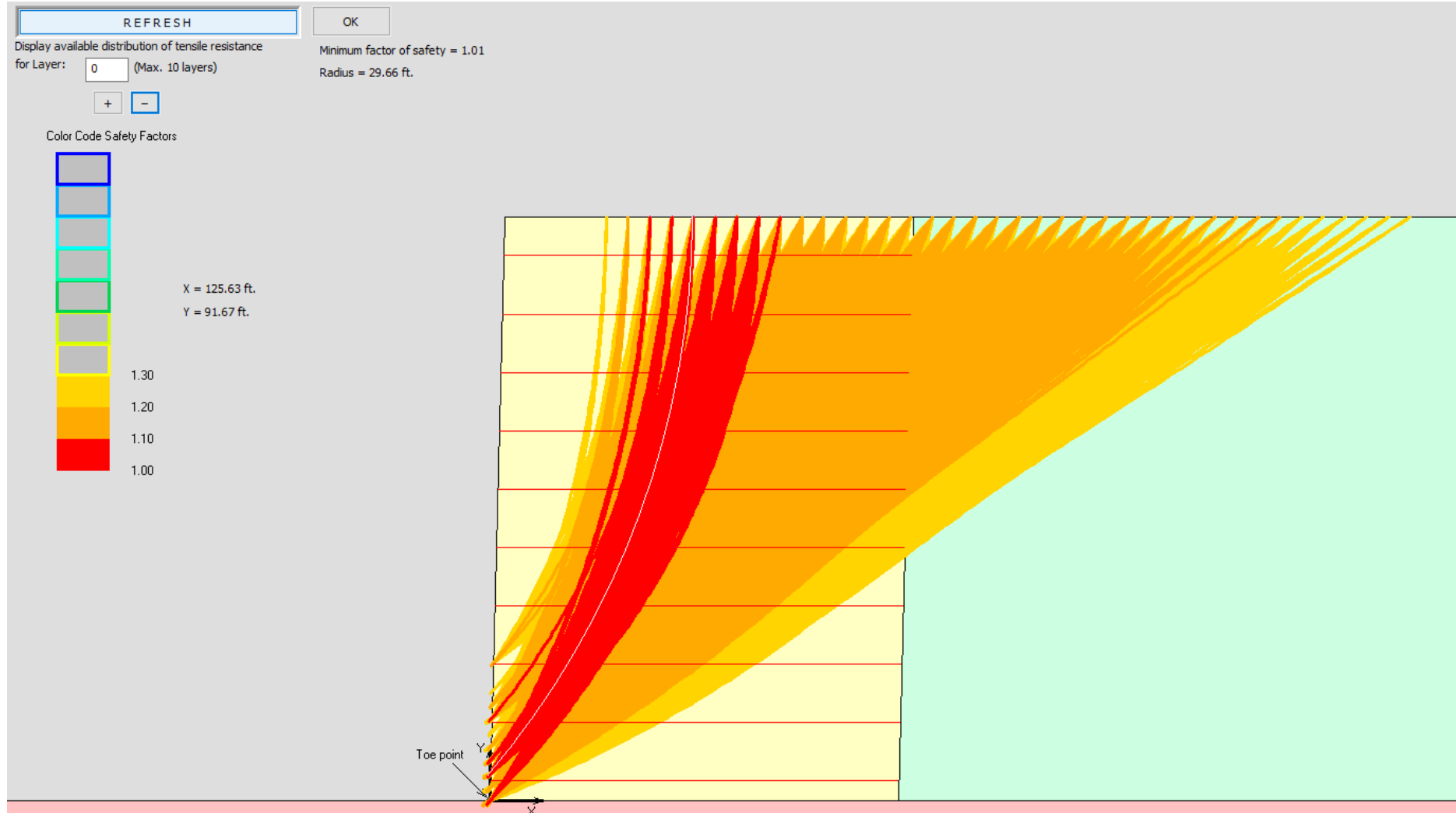
OK Cancel

DEFAULT

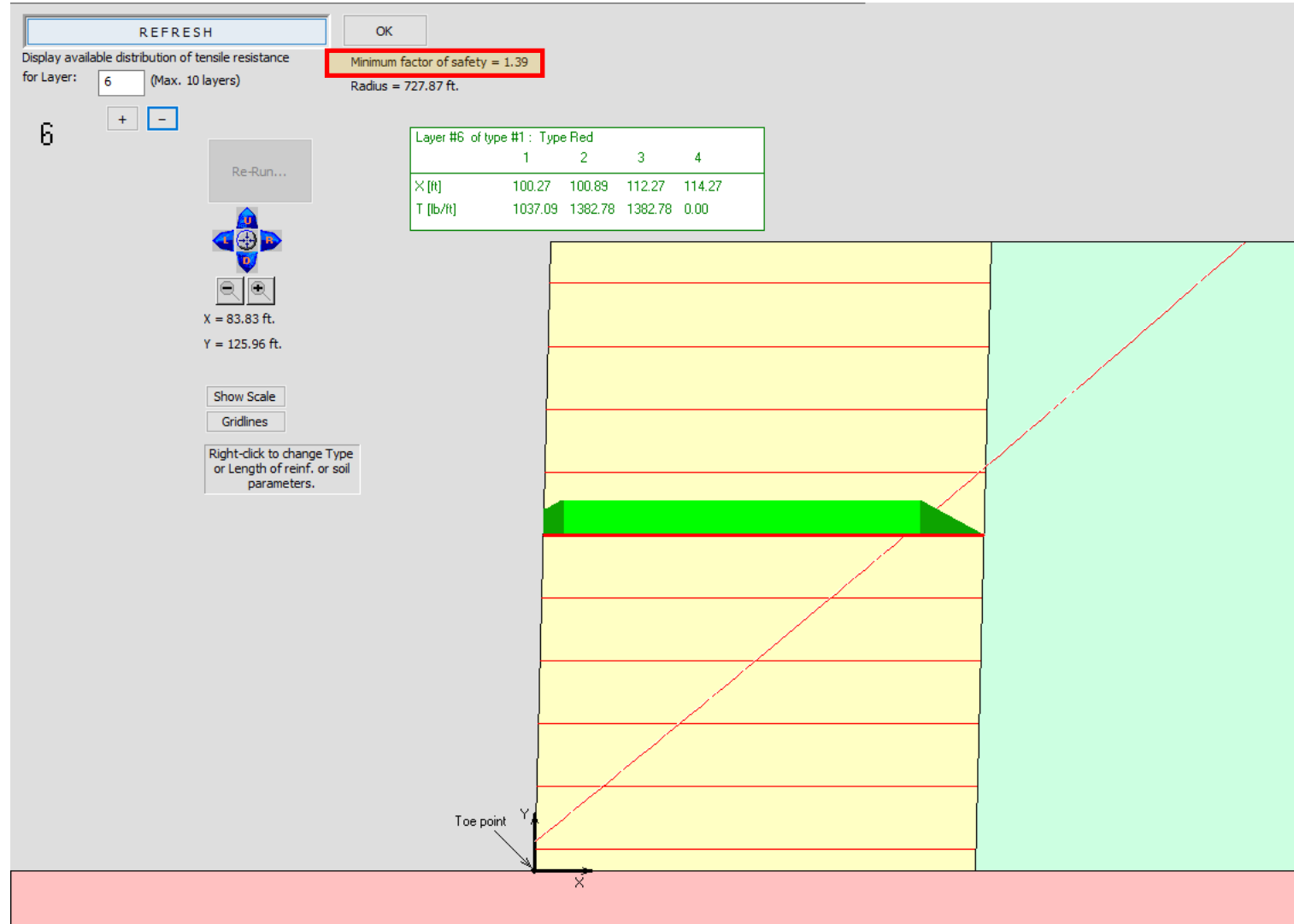
Run and Get $F_s=1.01$ OK



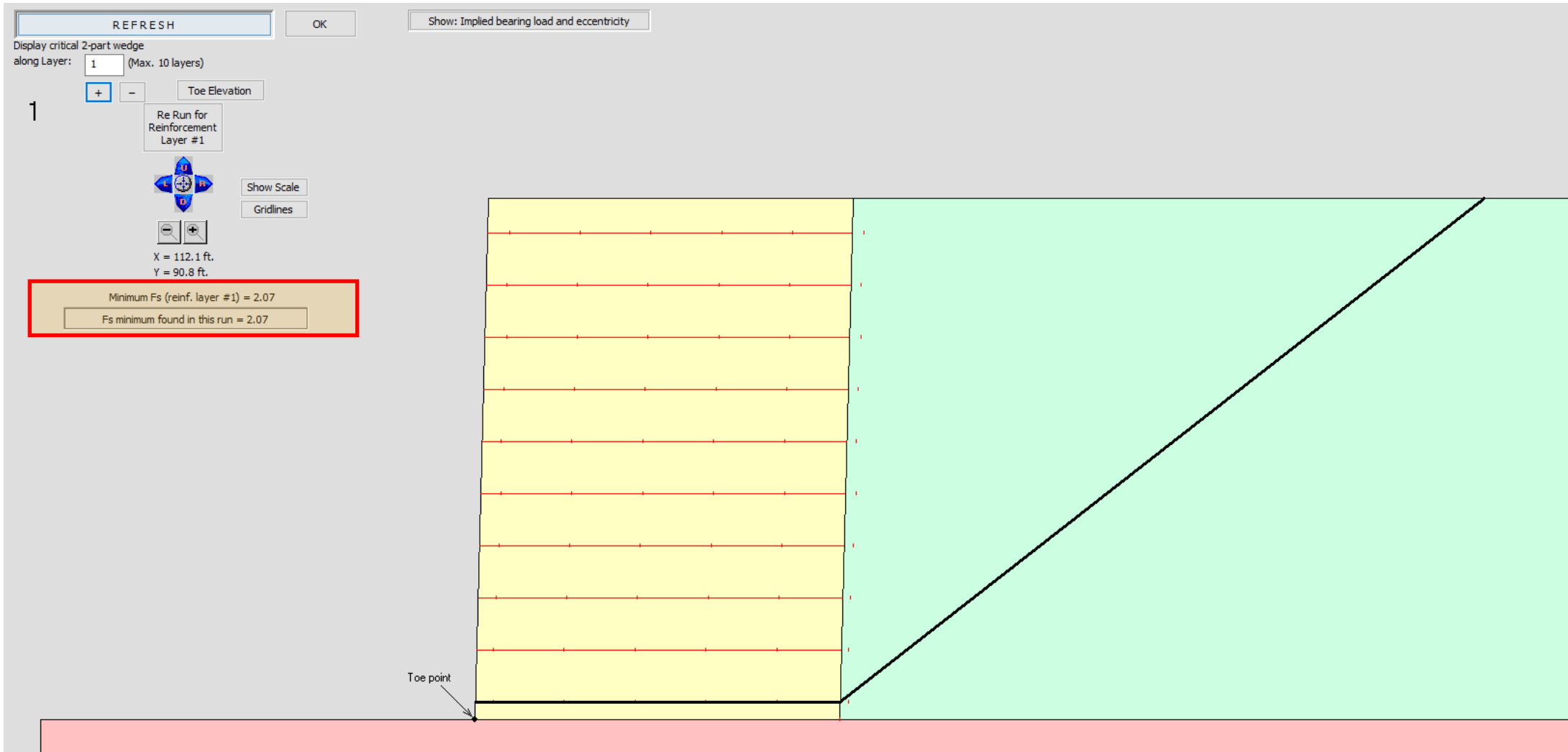
Safety Map Showing the Spatial Distribution of Fs on Soil Strength



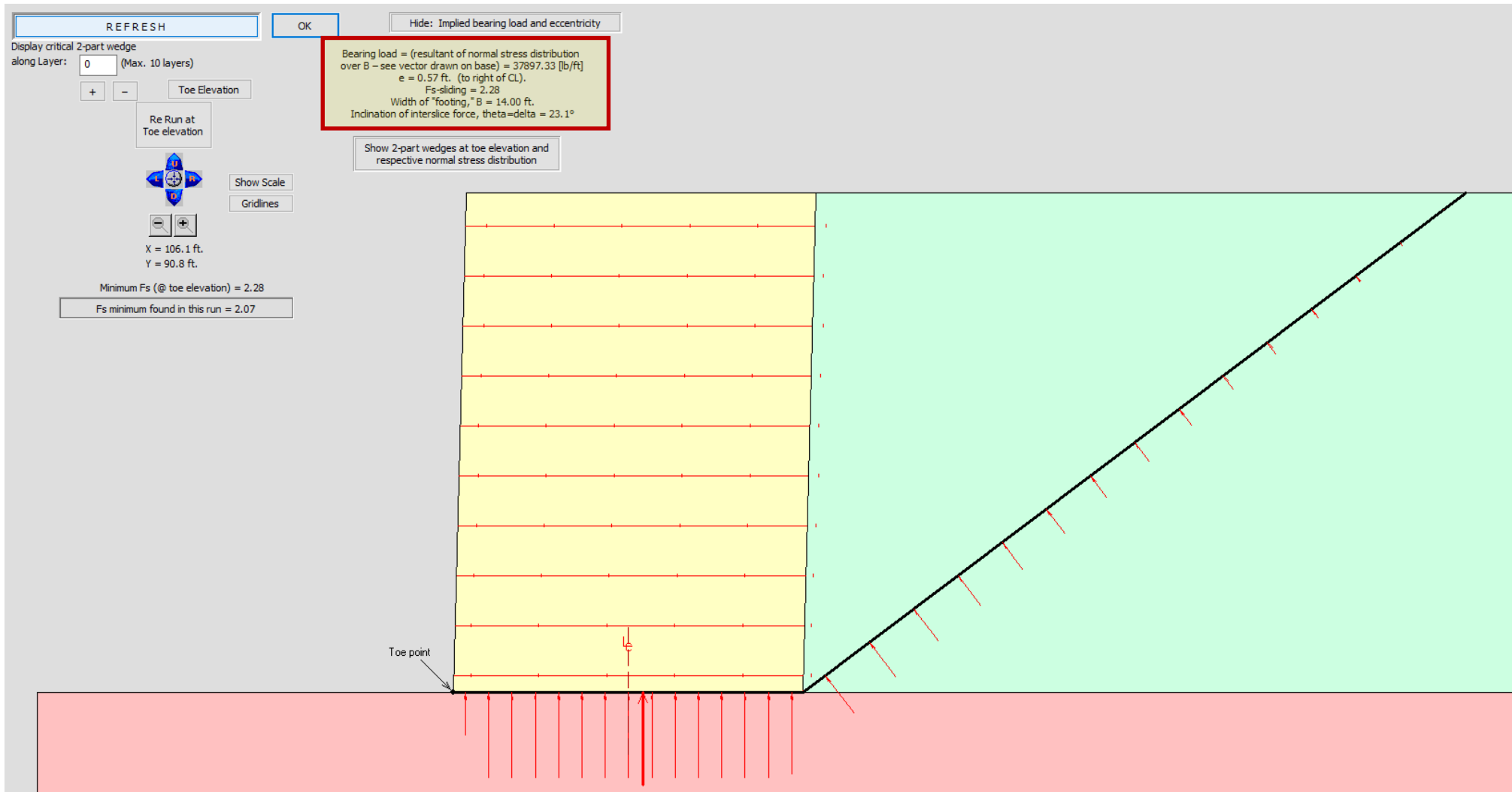
Stage II: $T_{ult} = 1.5 \text{ RF } T_{max} = 3020 \text{ lb/ft}$ Run Global Stab.: $F_s = 1.39 > 1.30 \text{ OK}$



Run 2 Part Wedge Sliding using Spencer – $F_s=2.07$ OK



Using Spencer: Get Normal Stress → e, R and Meyerhof $\sigma_v = R/(L-2e)$



Let's get some seismic excitation

Seismic Parameters

Ground acceleration :

Horizontal ground acceleration coefficient, $A_o =$

ReSSA is using in computations the design seismic horizontal acceleration

(press F1 for explanation)

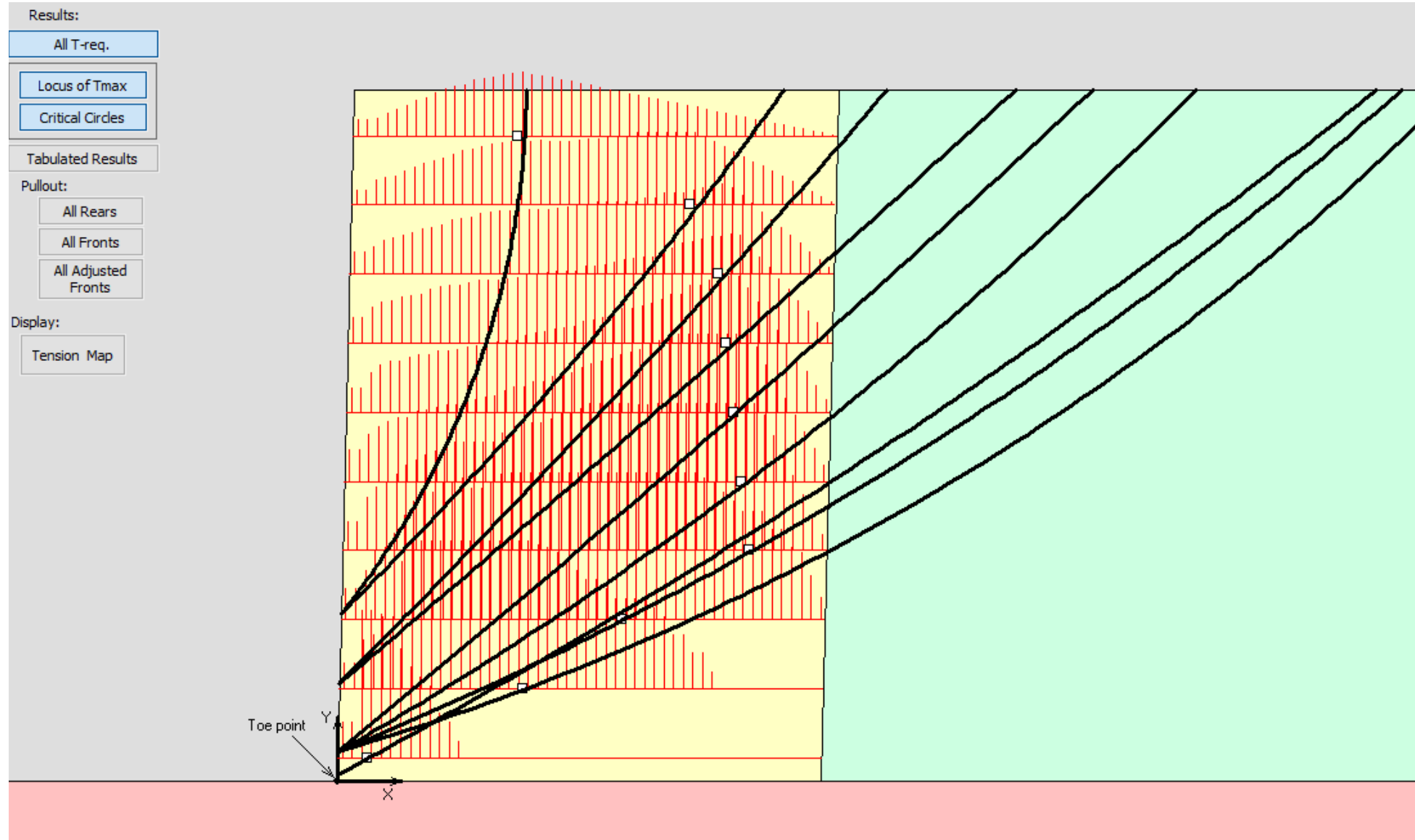
$K_h = A_m =$ $\times A_o = 0.250$

Vertical ground acceleration coefficient, k_v + (down) $k_v =$ $\times k_h = 0.000$
 -- (up) $k_v =$ $\times k_h = 0.000$

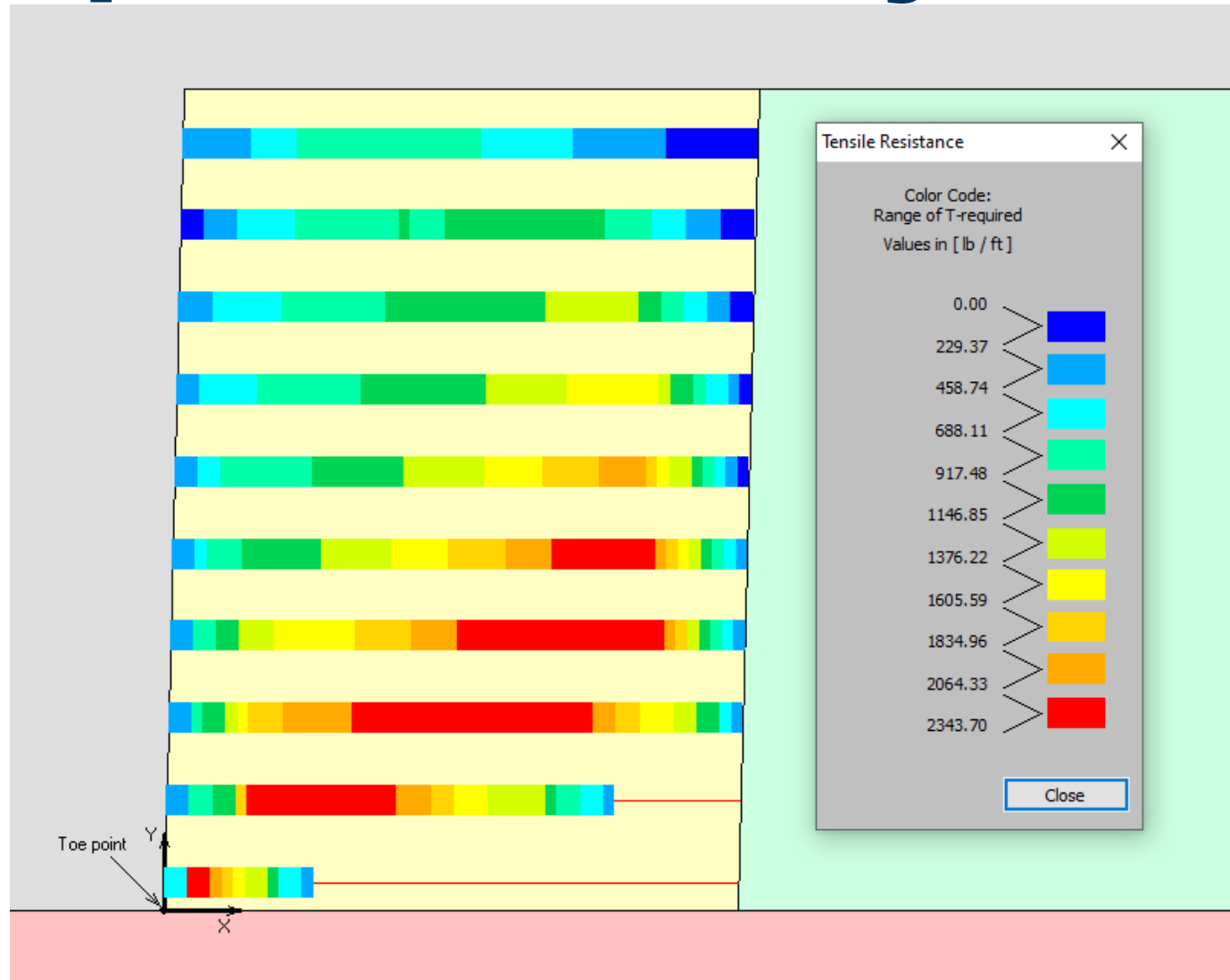
In case of ponding water (such as in reservoirs or water-front structures), should the seismic coefficient be applied also to the water surface surcharge? NO YES

NOTE: Seismic coefficient is not applied to surcharge loads. If deemed necessary, you can adjust Q and omega (see surcharge in General Geometry Mode) to reflect the effects of horizontal acceleration.

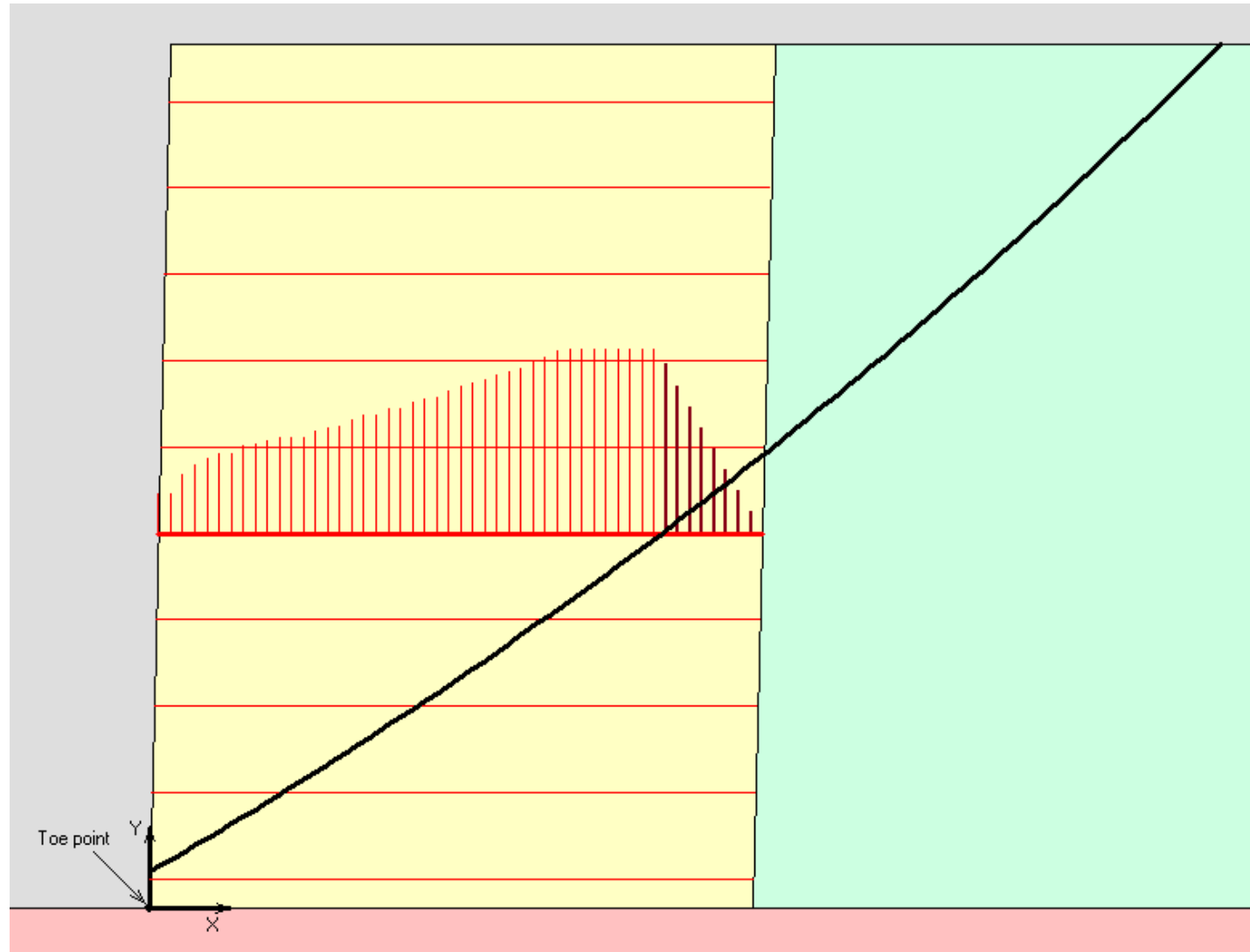
Change RFcr=1.0 and Run Baseline



Tension Map Indicates the Impact of Compound Stability



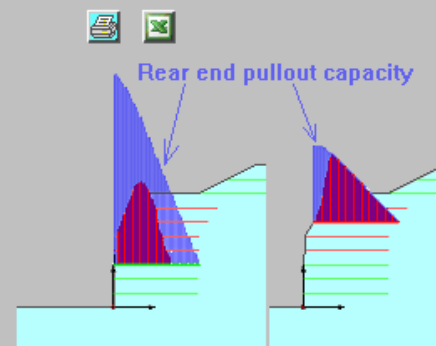
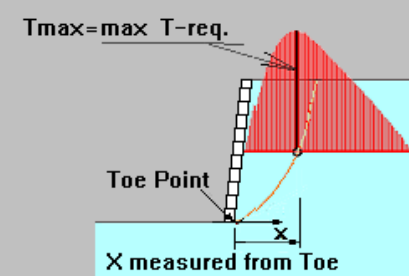
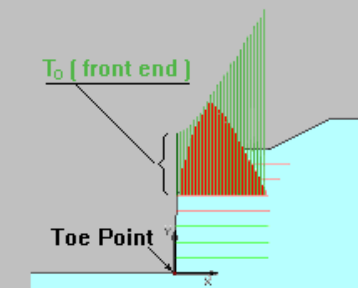
Under Seismic Loading Pullout May Play Significant Role



While Tmax increases, taking RFcr=1.0 Renders Adequate Reinforcement Strength → System is stable

Tabulated Results – Stage I ("Internal Stability")

Layer No.	Height from Toe [ft]	Current input of LTDS * [lb/ft]	Fs-reinf. = LTDS / Tmax	T-required		Current input of CoSt ** [lb/ft]	Fs-conn. = CoSt / To	Connection load, To (front end) [lb/ft]	To/ Tmax [%]	T max affected by rear end pullout	Input pullout resist. at rear-end, Tr-o [lb/ft]	Coverage Ratio, Rc
				T max [lb/ft]	Located at X from Toe [ft]							
1	0.67	2074.18	0.99	2085.22	0.86	1555.63	1.08	1445.75	69	No	0.00	1.00
2	2.67	2074.18	0.99	2085.22	5.39	1555.63	9.87	157.59	8	No	0.00	1.00
3	4.67	2074.18	1.00	2081.98	8.24	1555.63	7.09	219.26	11	Yes	0.00	1.00
4	6.67	2074.18	1.00	2081.98	11.93	1555.63	5.97	260.37	13	Yes	0.00	1.00
5	8.67	2074.18	1.00	2081.98	11.70	1555.63	7.09	219.26	11	Yes	0.00	1.00
6	10.67	2074.18	1.07	1935.49	11.47	1555.63	8.11	191.85	10	Yes	0.00	1.00
7	12.67	2074.18	1.34	1545.10	11.24	1555.63	6.88	226.11	15	Yes	0.00	1.00
8	14.67	2074.18	1.61	1287.13	11.01	1555.63	7.09	219.26	17	Yes	0.00	1.00
9	16.67	2074.18	2.02	1029.16	10.22	1555.63	6.68	232.96	23	Yes	0.00	1.00
10	18.67	2074.18	2.29	903.94	5.23	1555.63	3.29	472.78	52	Yes	0.00	1.00

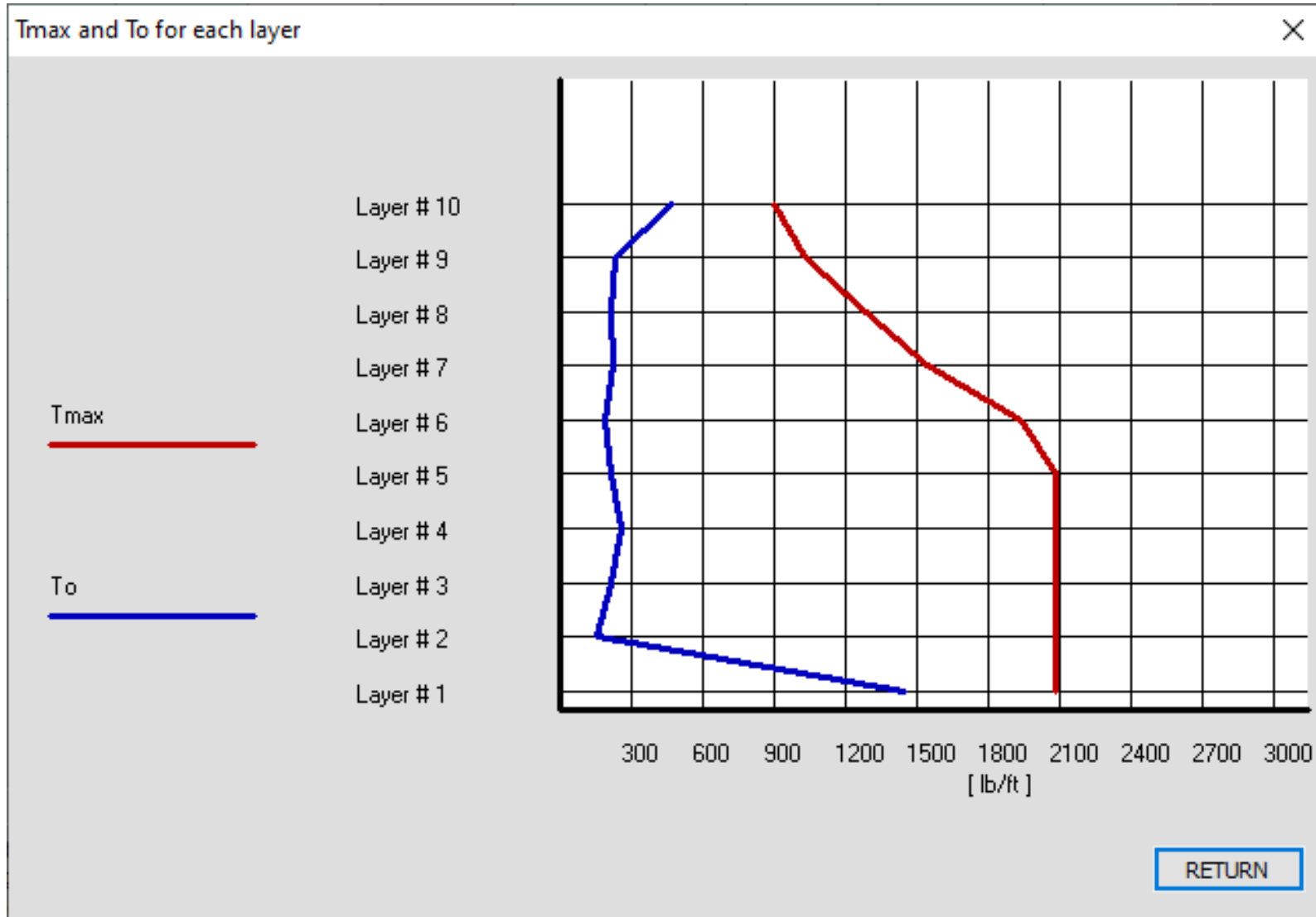




* LTDS = Long-Term Design Strength = $T_{ult} / (RF_{id} * RF_d * RF_{cr} * RF_a)$ where T_{ult} and RF are specified in Global Stability.
 Fs-reinf. = "Factor of safety" on geosynthetic (reinforcement) strength considering the specified target F_s on soil strength and LTDS specified in Global Stability.
 ** CoSt = Connection Strength = % of LTDS available at front-end as currently specified in input of Reinforcement in Global Stability.
 Fs-conn. = "Factor of safety" on connection strength considering the strength specified in Global stability and the calculated connection load in Baseline Solution.

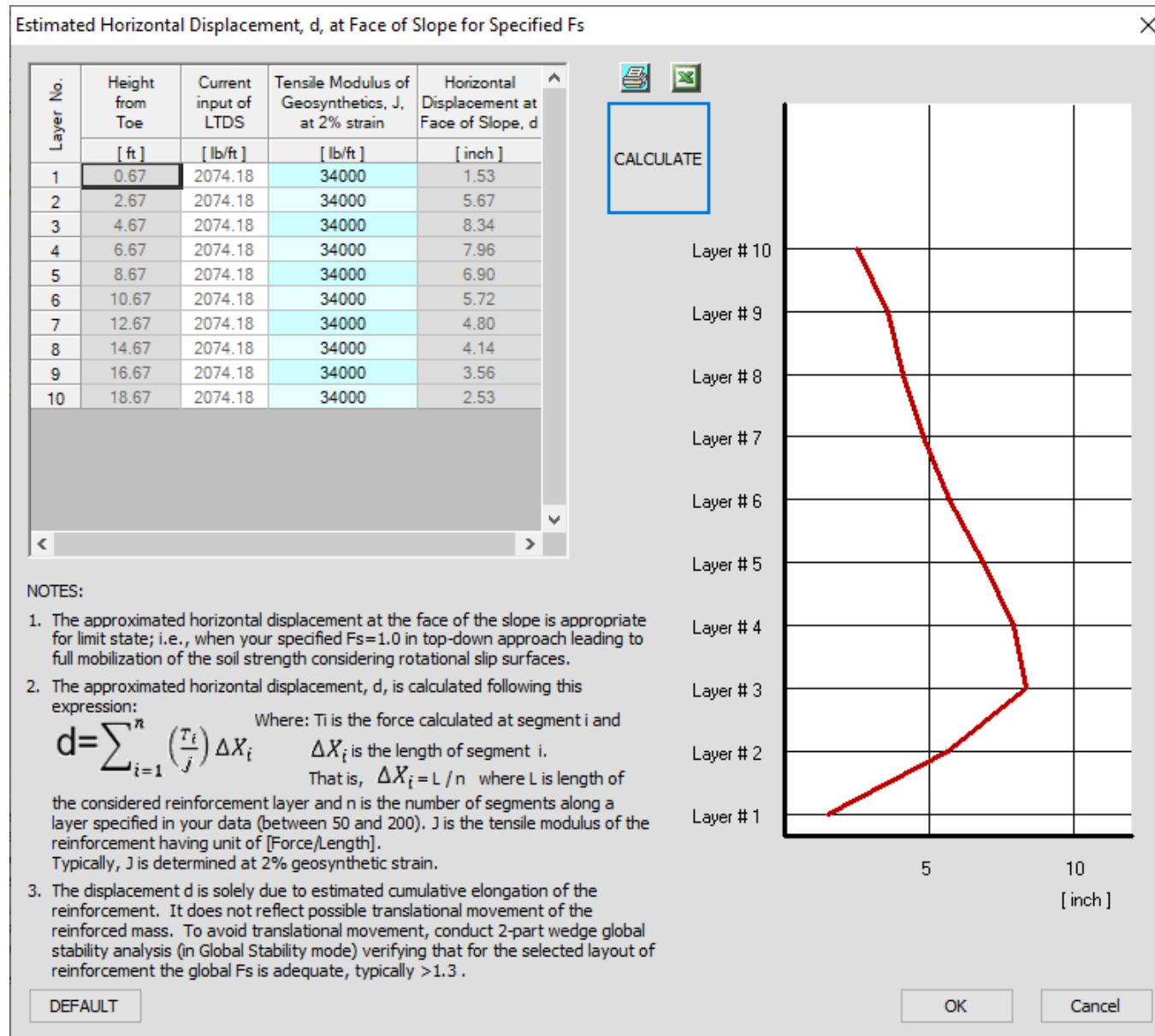
Treq(x) is calculated for a limit equilibrium state where F_s anywhere is constant. Therefore, T_o is the connection load at such a limit state. However, connection load can be highly volatile as its value also depends on the relative movement of the face. In addition, loads during construction might be larger than calculated at a limit state. Finally, at working load conditions, higher than calculated connection loads might occur, possibly constraining movements.

It is suggested that you read and understand the commentary in FHWA-HIF-17-004, Section 10.5, pp.105-108, including Fig 10-37.

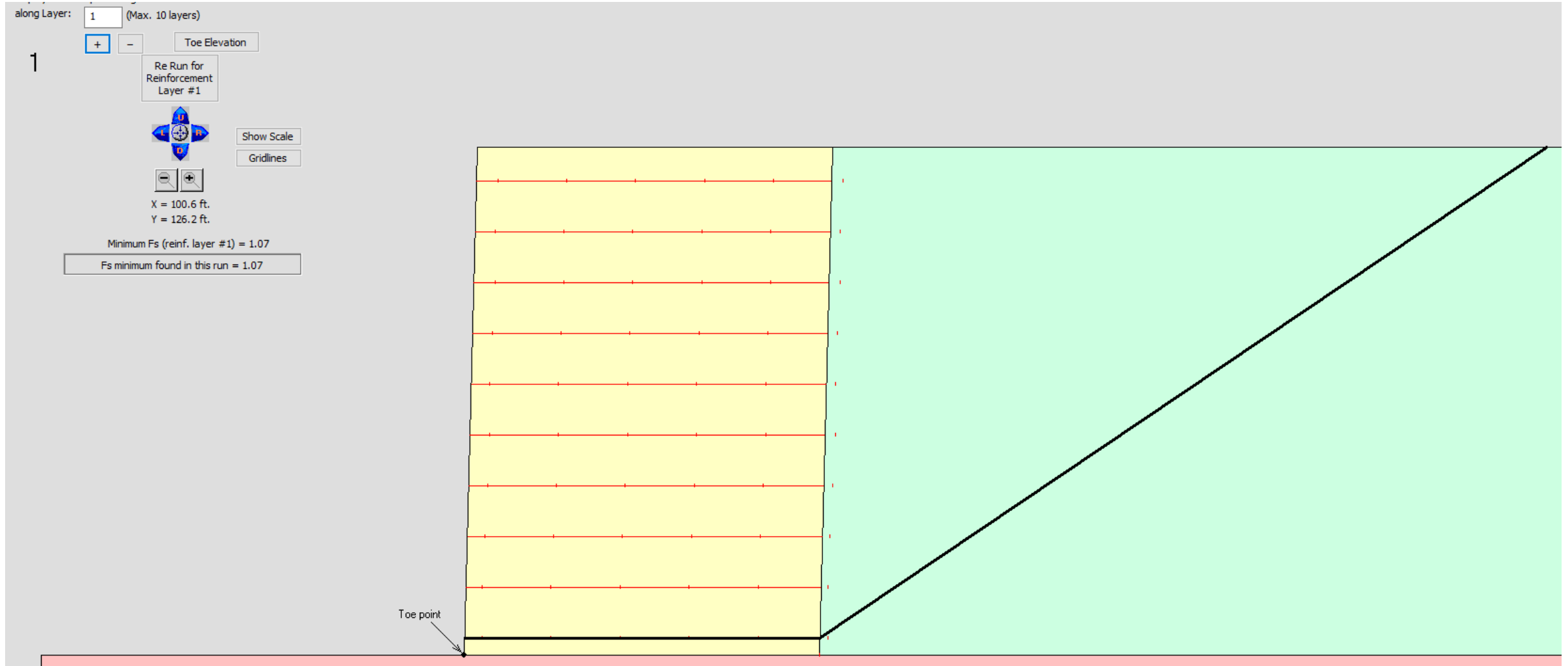
Impact of Compound Failure is Manifested in Required high T_{max} and T_o at Bottom Layers



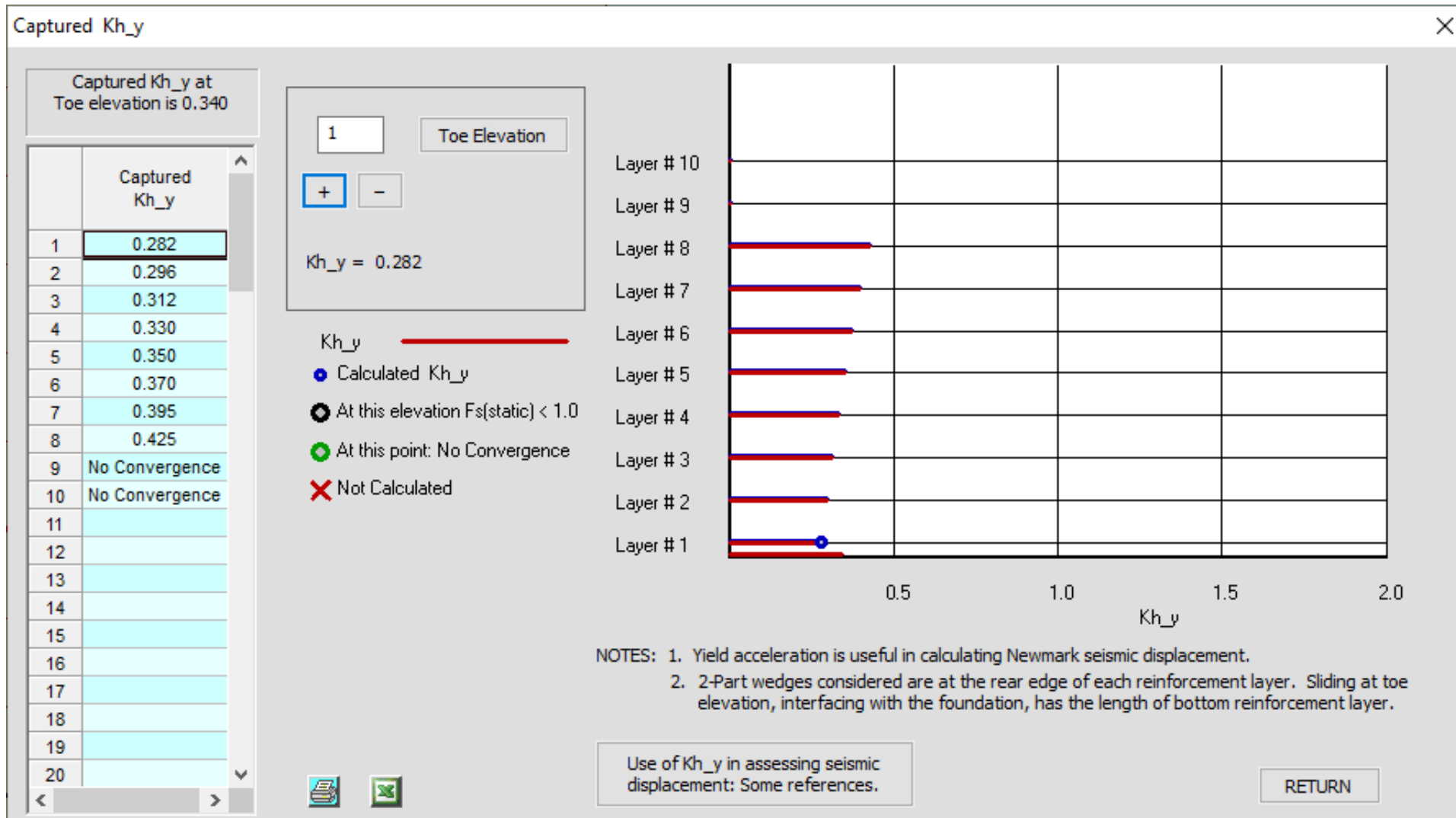
Also Displacement is large at Bottom Layers



Global Stability Sliding: $F_s=1.07$ OK



K_{h-y} at Each Elevation – Can be used for seismic displacement



Sliding: What if $A_o=0.7$ ($K_h=0.35$)?

Seismic Parameters

Ground acceleration: Yes No

Horizontal ground acceleration coefficient, $A_o = 0.7$

ReSSA is using in computations the design seismic horizontal acceleration

$K_h = A_m = 0.5 \times A_o = 0.350$ (press F1 for explanation)

Vertical ground acceleration coefficient, k_v

+ (down) $k_v = 0$ x $k_h = 0.000$

- (up) $k_v = 0$ x $k_h = 0.000$

In case of ponding water (such as in reservoirs or water-front structures), should the seismic coefficient be applied also to the water surface surcharge?

NO YES

NOTE: Seismic coefficient is not applied to surcharge loads. If deemed necessary, you can adjust Q and omega (see surcharge in General Geometry Mode) to reflect the effects of horizontal acceleration.

DEFAULT OK Cancel

