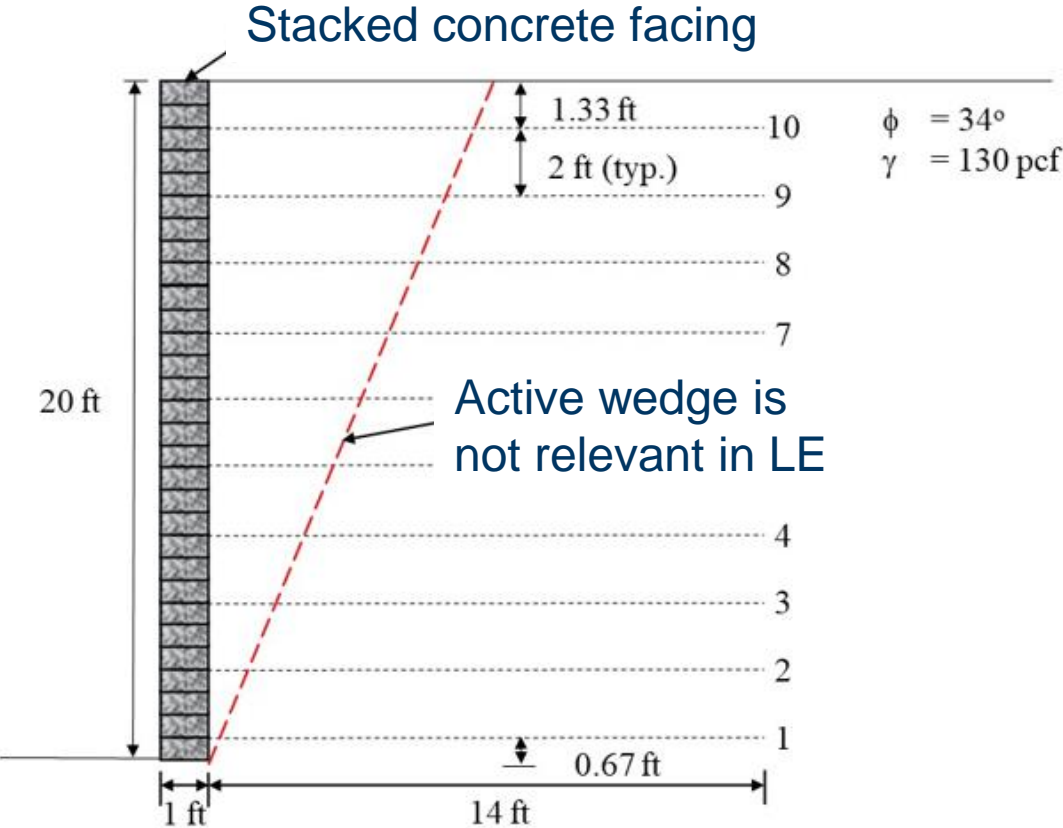


# **Lesson 5:**

## **ReSSA+ Software: Demonstration**

**Prepared and Presented by Dov Leshchinsky.  
Live Demonstration was in Geosynthetics 2021. The following  
screenshots replicate the actual demonstration.  
This demonstration provides an instructive use of ReSSA+**

# 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, $\gamma_{\text{block}}$ (pcf)            | 120                                 |
| Facing block height (ft)                                     | 0.67                                |
| Facing block width, $W_u$ (ft)                               | 1.0                                 |
| Connection strength as fraction of $T_{\text{ult}}$ , $CR_u$ | 0.75                                |

# Baseline Solution: Stage I

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

Main Menu

Geometry

SIMPLIFIED

TIERED

GENERAL

Reinforcing Material

GEOSYNTHETIC

METALLIC

Working with ReSSA+

ID

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  $T_{\max}$  and  $T_o$

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

# 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 Friction Fs-phi: 1 Read Note

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

Method of Stability Analysis : Comprehensive Bishop ROR = 0.0

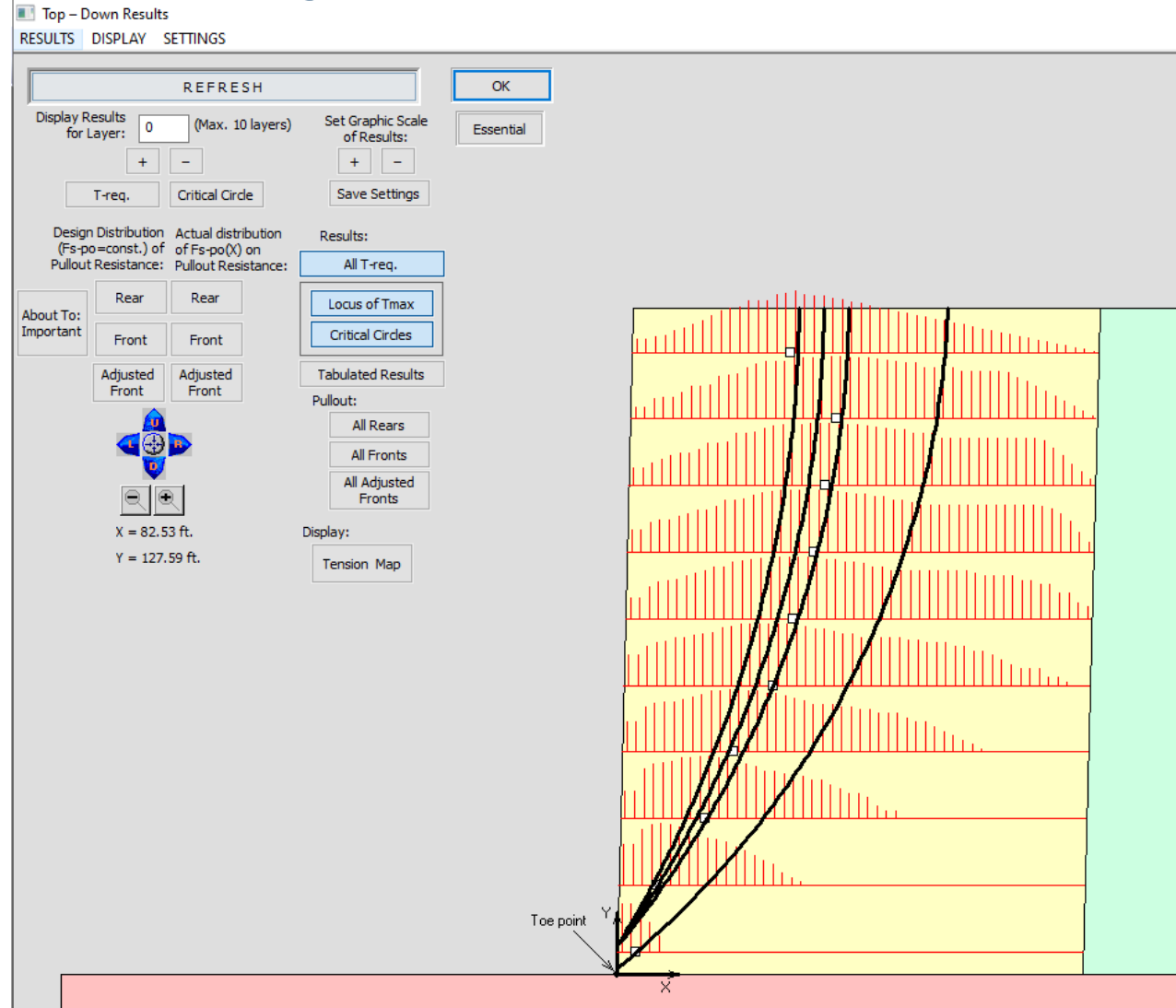
Gridlines 1234567

OK Cancel

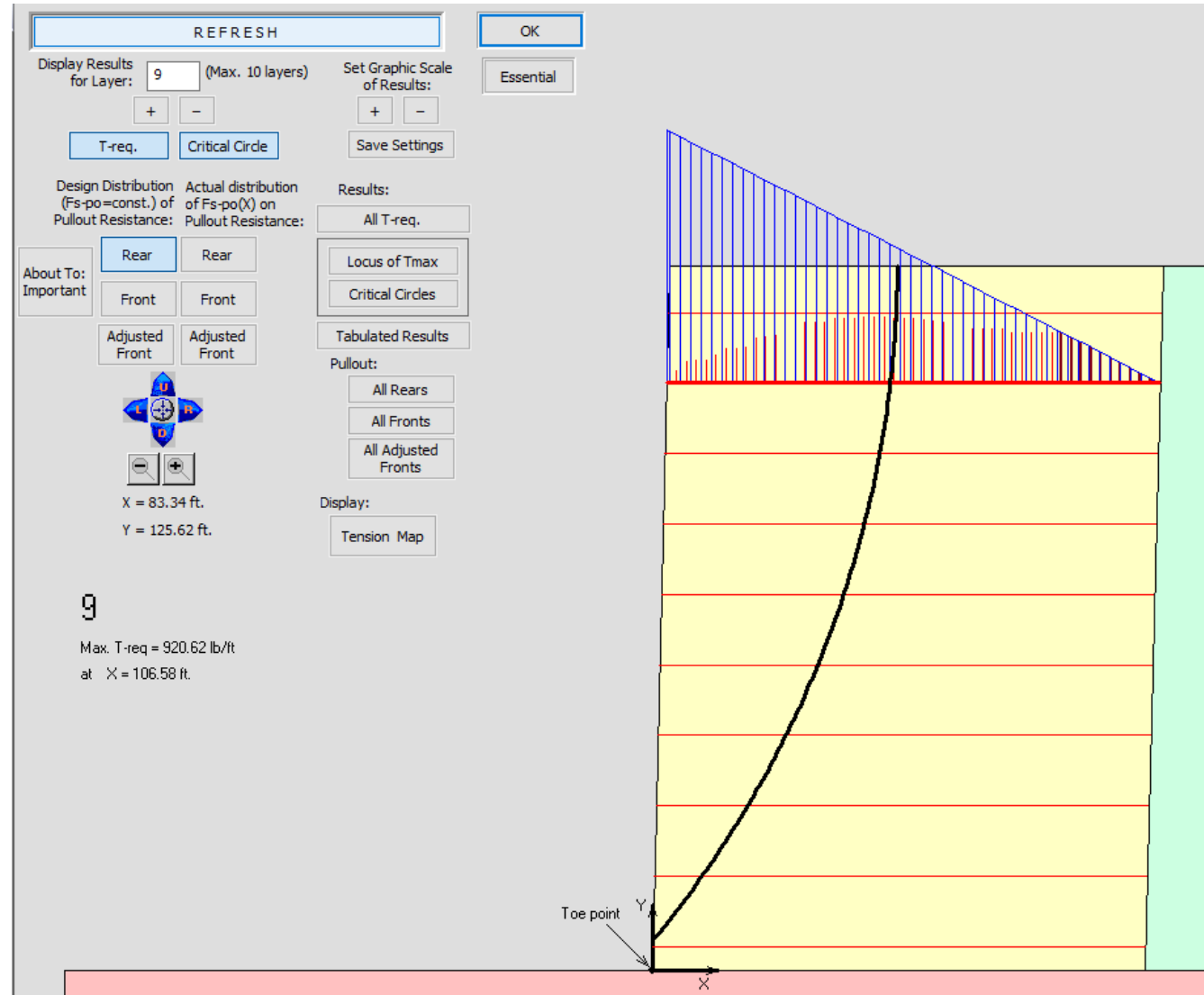
# Run and Get $T_{req}(x)$ , Locus of $T_{max}$ , Circles Defining $T_{max}$

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

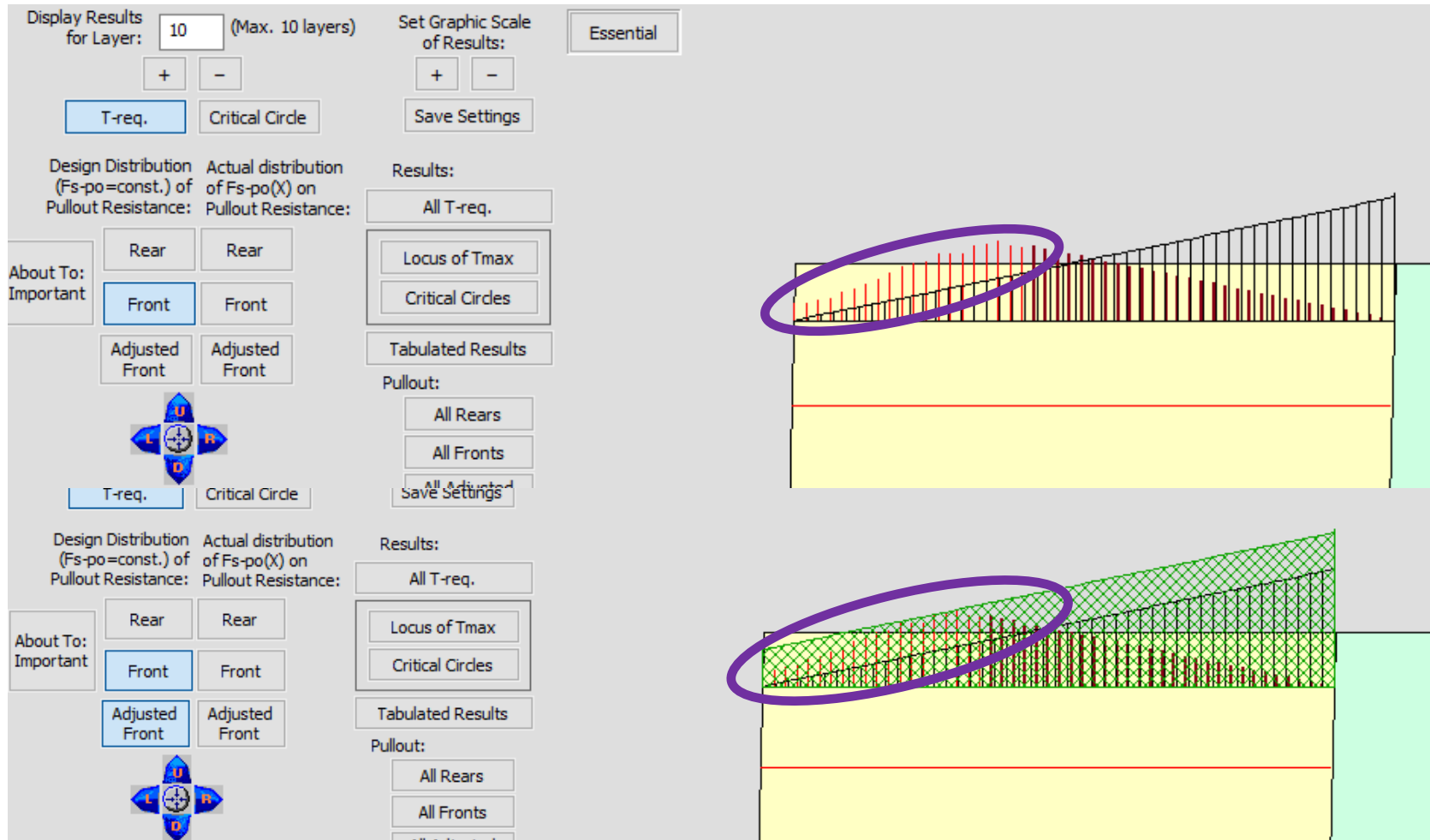
**Note:** There is **NO** well-defined Active Wedge as postulated in most simplified designs



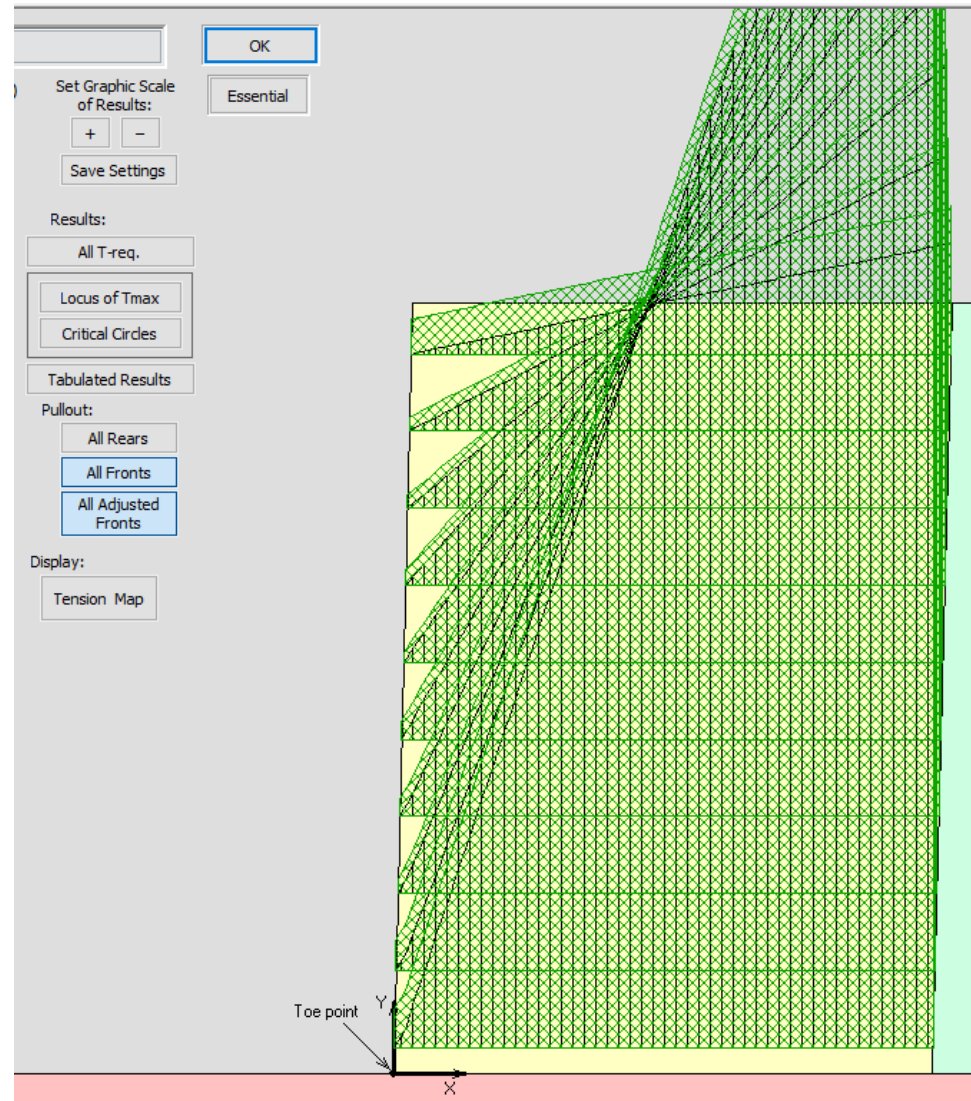
# Circle for Layer 9 Determining $T_{max}$ . Note that $T_{req}$ is limited by Pullout Resistance thus Shedding load to layers below



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

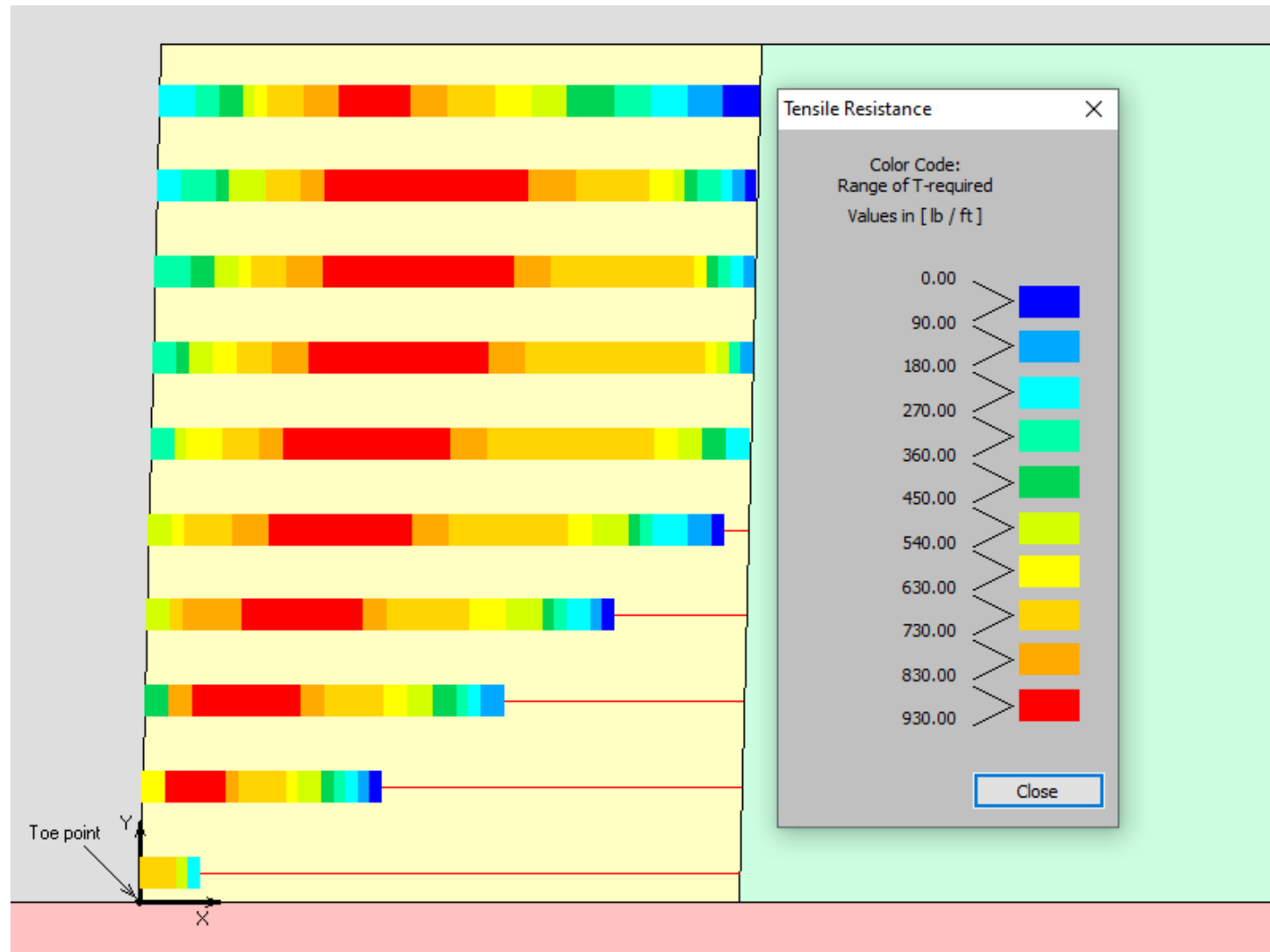


# All Adjusted Front Pullouts





# Tension Map: Color Coded Visual of Treq



# Tabulated Results

Tabulated Results – Stage I ("Internal Stability")

| Layer No. | Height from Toe<br>[ ft ] | Current input of LTDS *<br>[ lb/ft ] | Fs-reinf. = LTDS / Tmax | T-required         |                                 | Current input of CoSt **<br>[ lb/ft ] | Fs-conn. = CoSt / To | Connection load, To (front end)<br>[ lb/ft ] | To/ Tmax [%] | T max affected by rear end pullout | Input pullout resist. at rear-end, Tr-o<br>[ lb/ft ] | Coverage Ratio, Rc |
|-----------|---------------------------|--------------------------------------|-------------------------|--------------------|---------------------------------|---------------------------------------|----------------------|--|--------------|------------------------------------|--|--------------------|
|           |                           |                                      |                         | T max<br>[ lb/ft ] | Located at X from Toe<br>[ 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 =  $T_{ult} / (R_{Fd} * R_{Fd} * R_{Fcr} * R_{Fa})$  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.

Treq(x) is calculated for a limit equilibrium state where Fs anywhere is constant. Therefore, To 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.

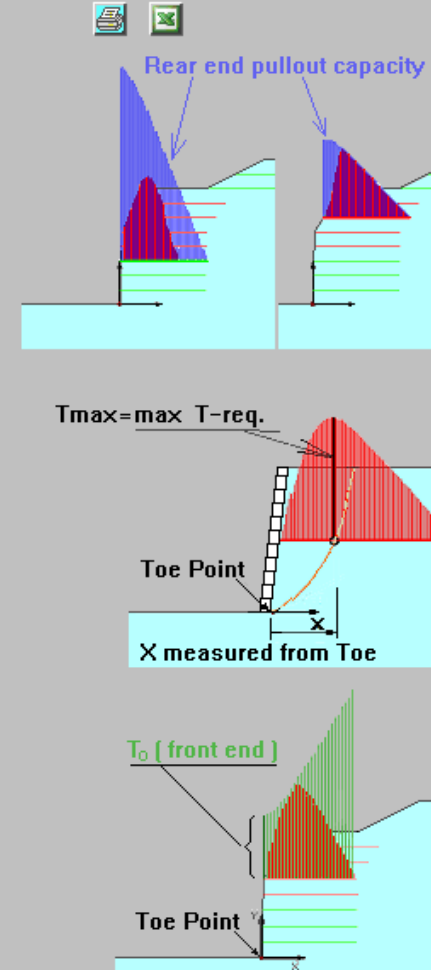
Open FHWA-HIF-17-004

Display Tmax and To for each layer

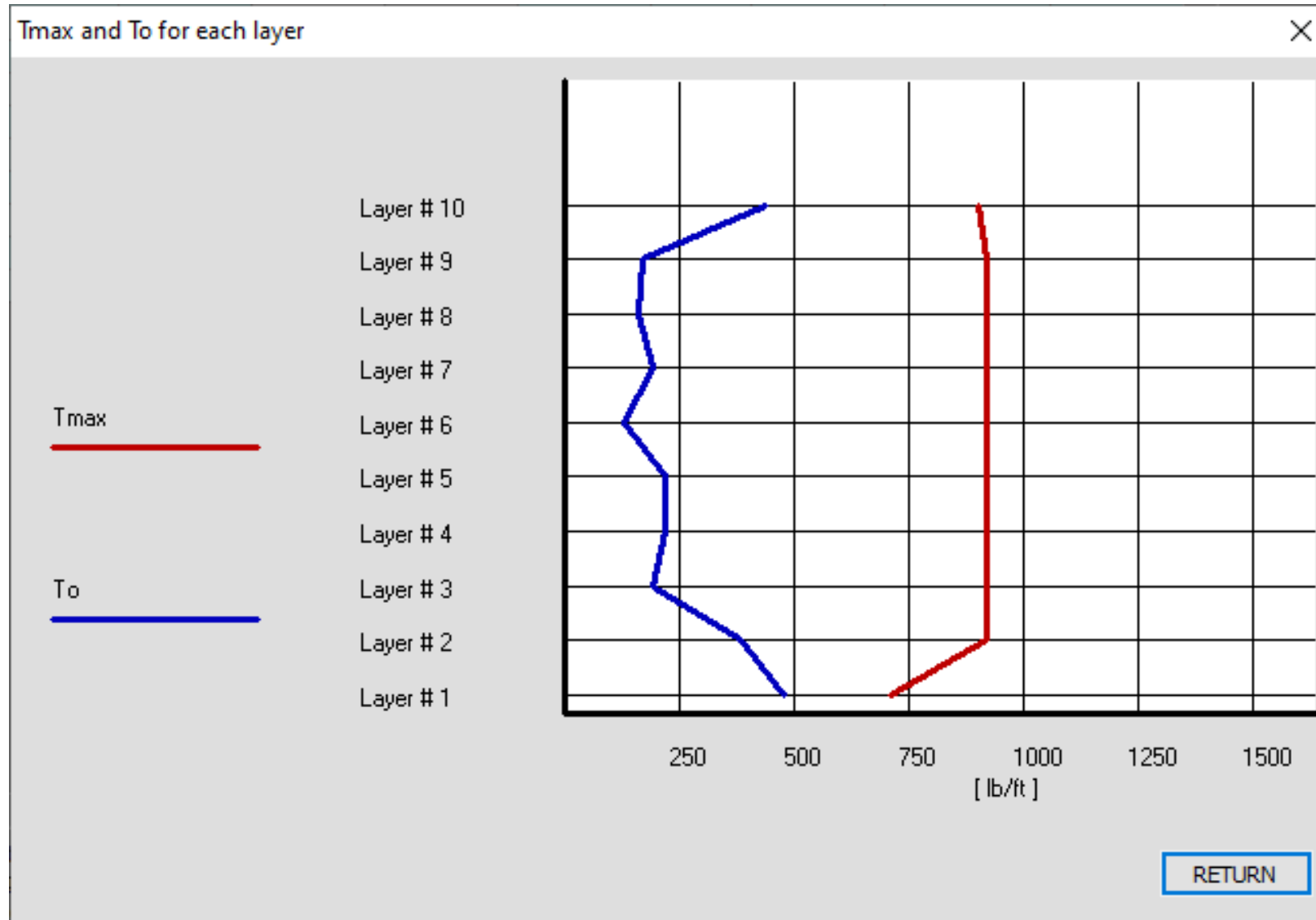
Pullout details: min(Fs) Front / Rear

Display Horizontal Displacements

RETURN



# 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<br>[ ft ] | Current input of LTDS<br>[ lb/ft ] | Tensile Modulus of Geosynthetics, J, at 2% strain<br>[ lb/ft ] | Horizontal Displacement at Face of Slope, d<br>[ 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  |

CALCULATE

Layer # 10

Layer # 9

Layer # 8

Layer # 7

Layer # 6

Layer # 5

Layer # 4

Layer # 3

Layer # 2

Layer # 1

5

[ inch ]

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

$\Delta X_i$  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  $>1.3$ .

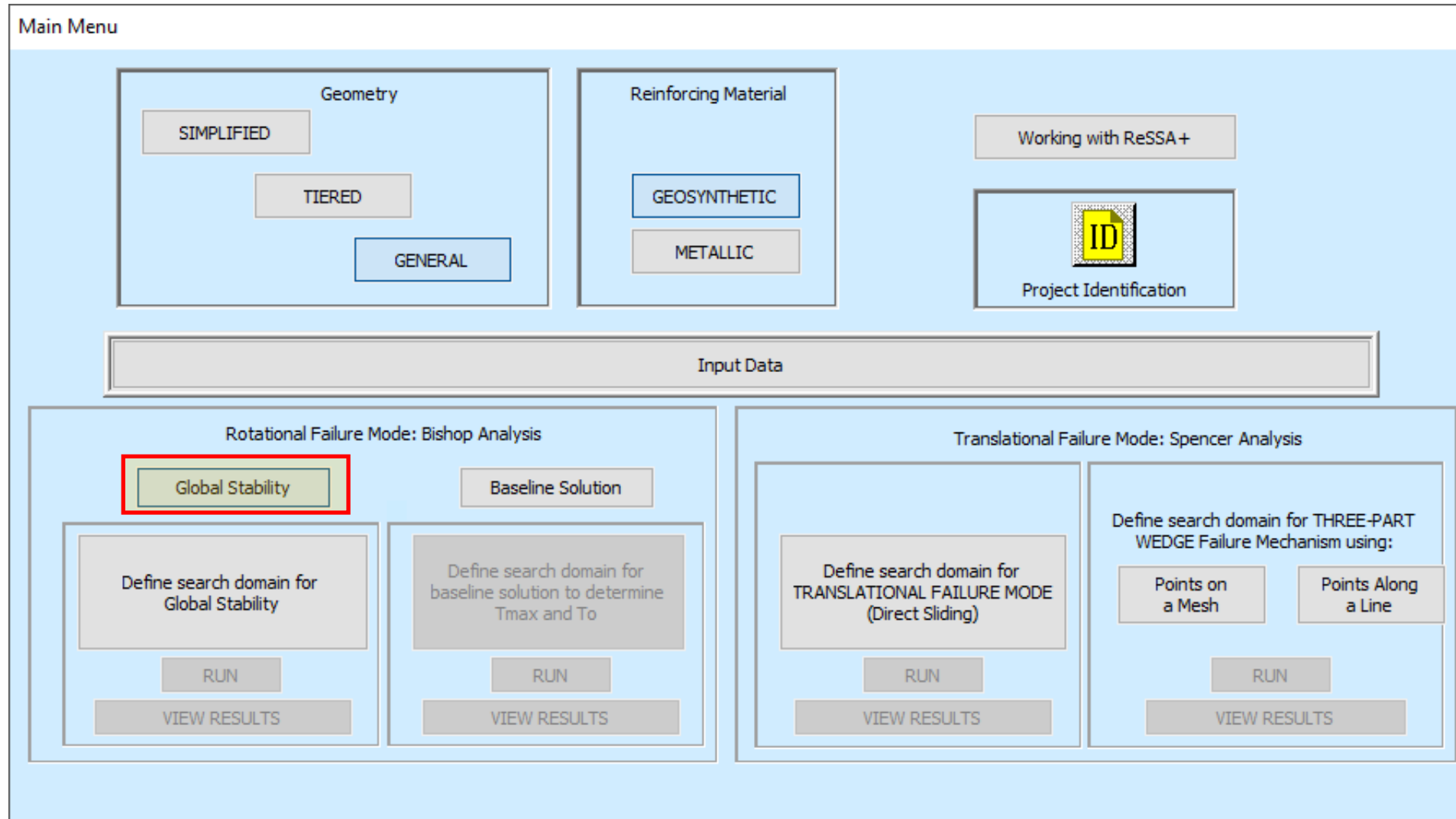
DEFAULT

OK

Cancel

# Back to Main Menu - Global Stability

## – Stage II Design



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

$$RF=1.12 \ 1.3 \ 1.50 = 2.184$$

$$LTDS=2011/2.184=921 \text{ lb/ft}$$

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, $T_{ult}$<br>[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

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

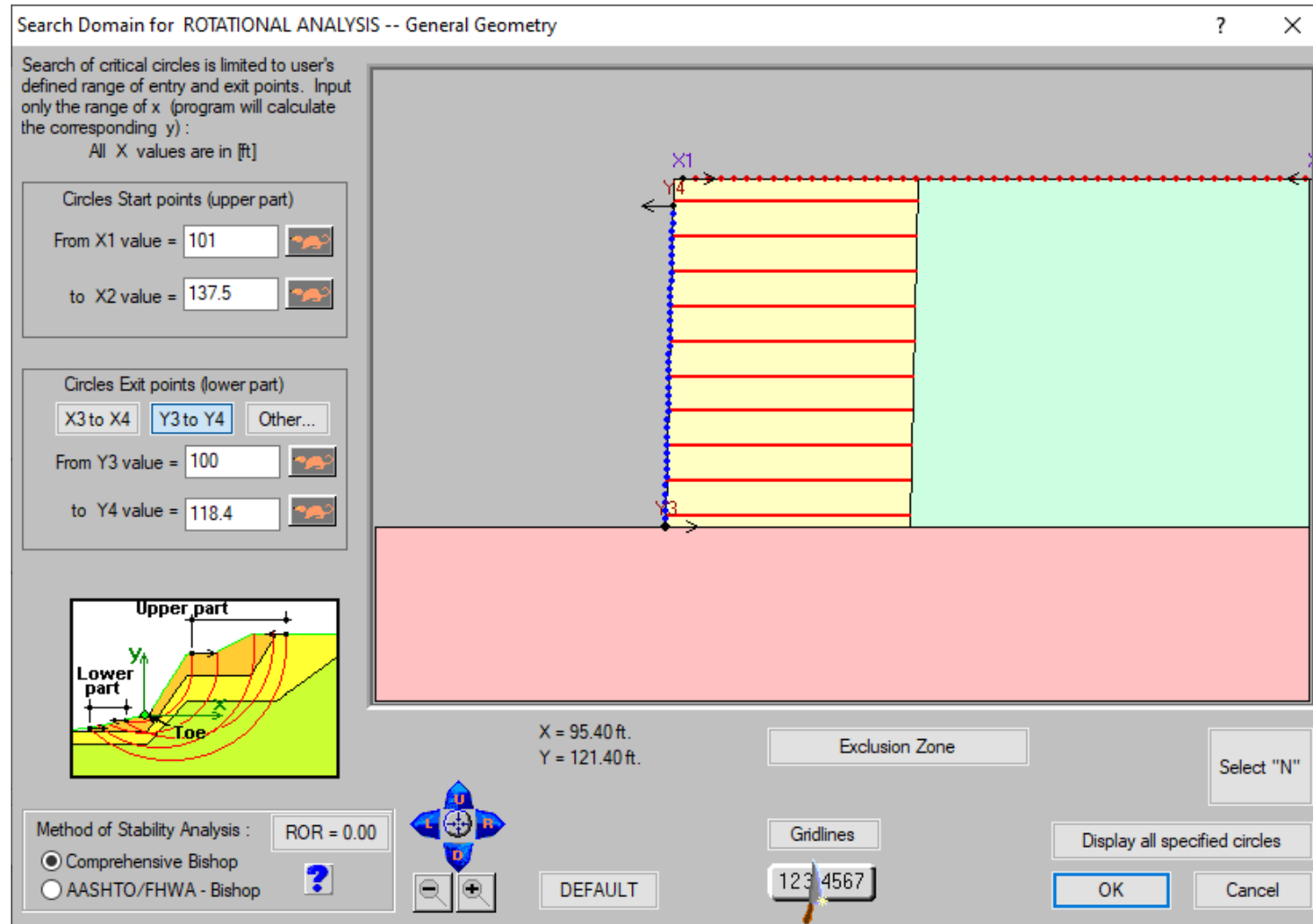
Reinforcement Quantities

Interaction Parameters

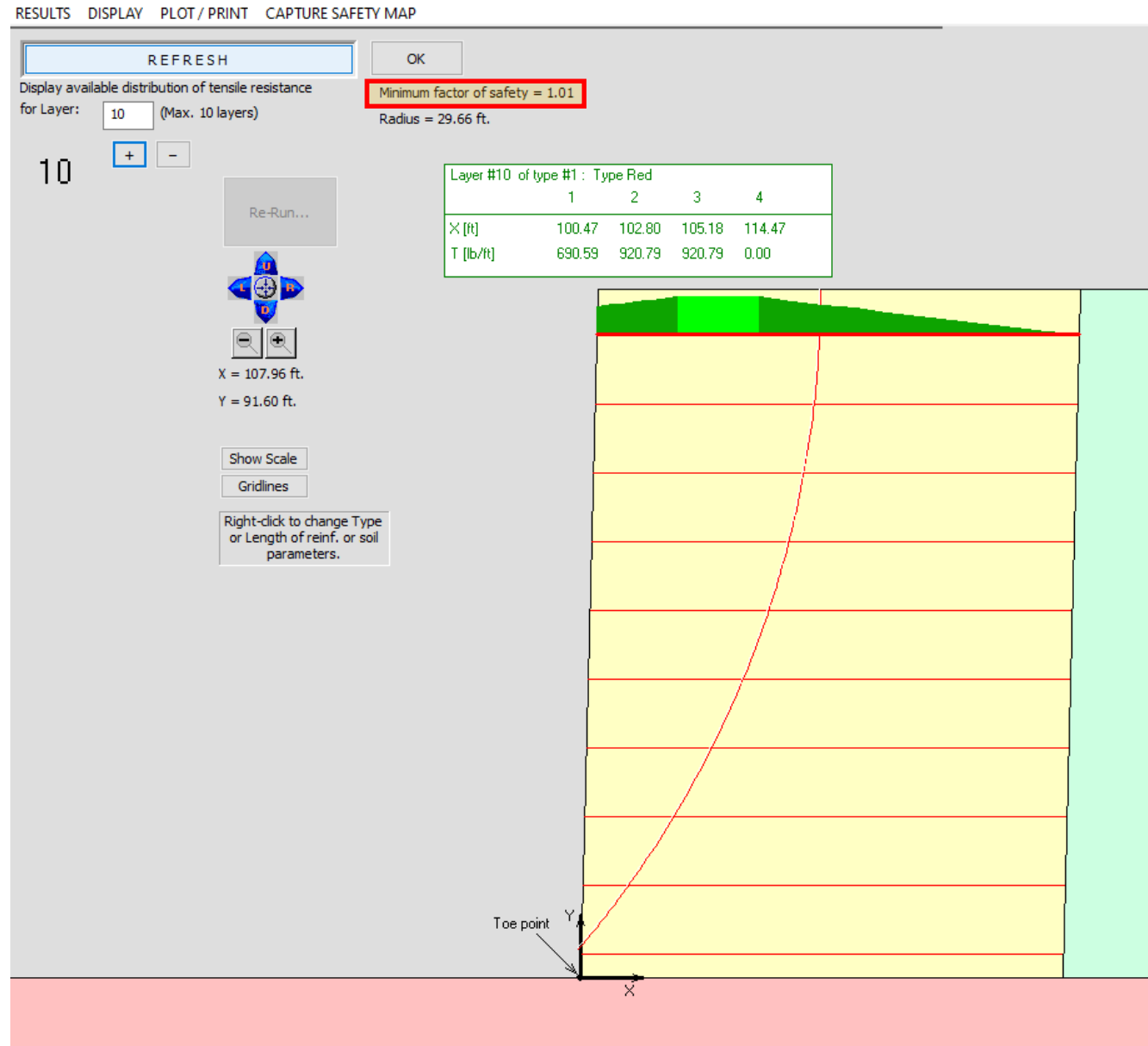
DEFAULT

OK Cancel

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

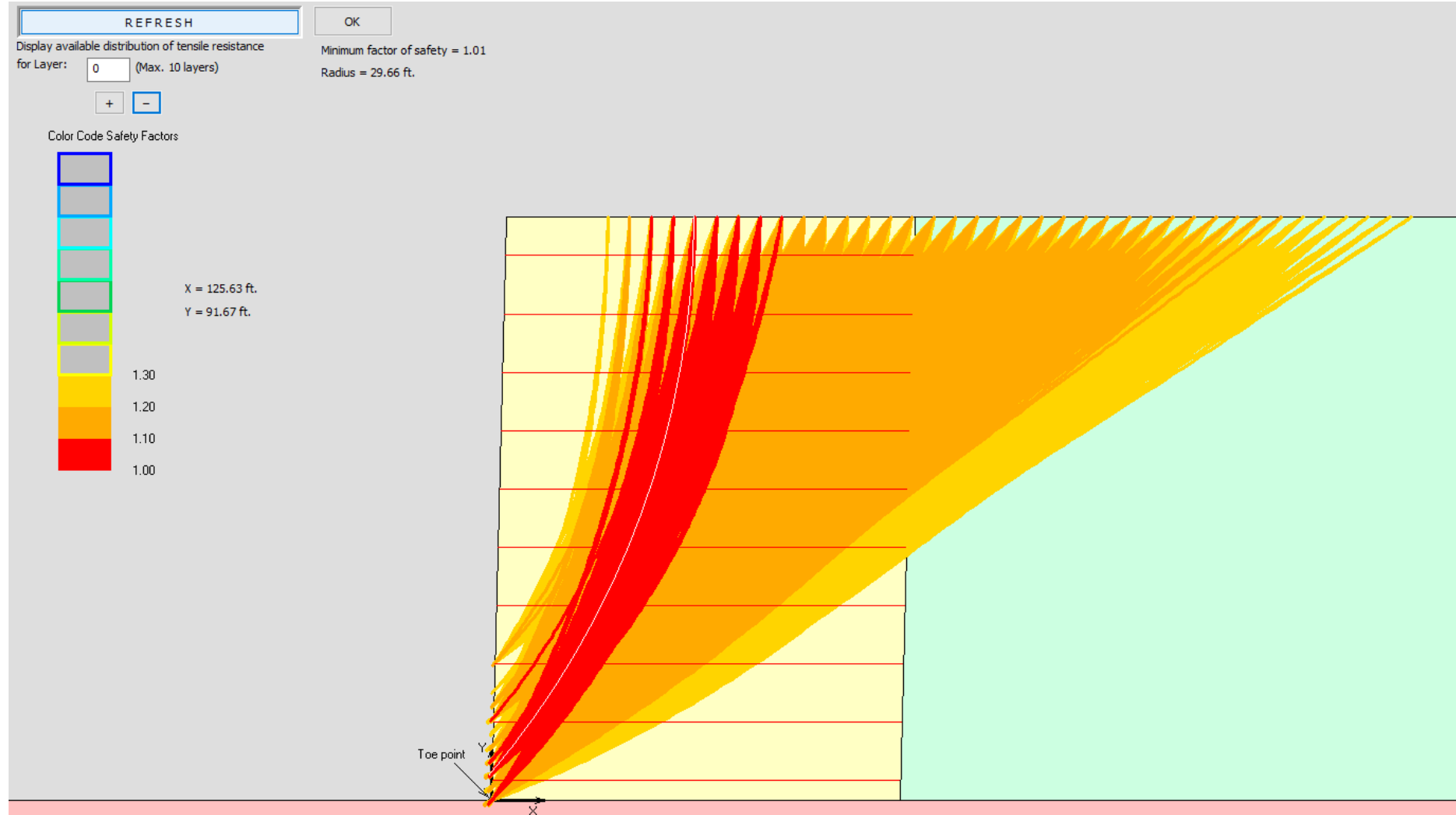


# Run and Get $F_s=1.01$ OK

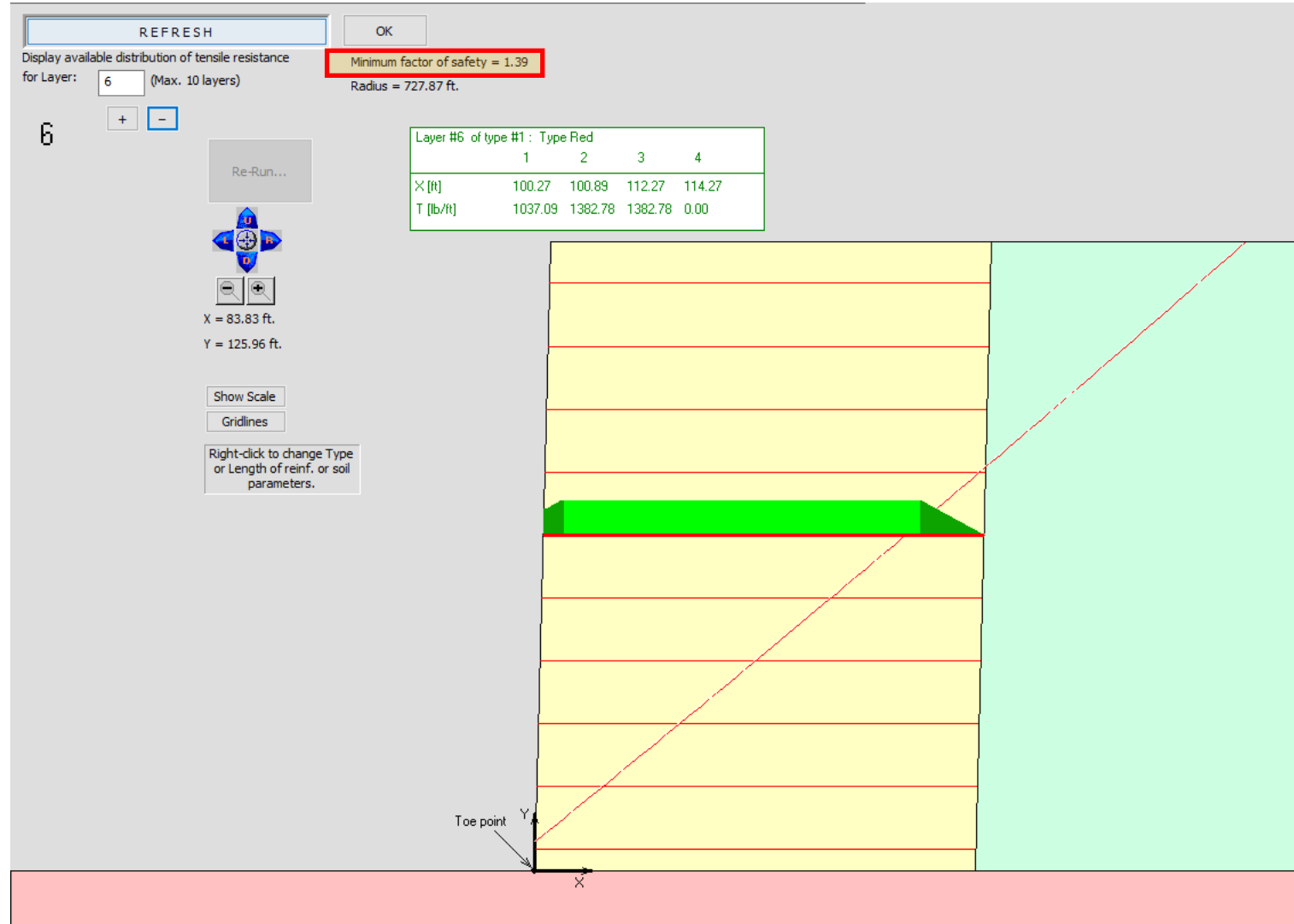




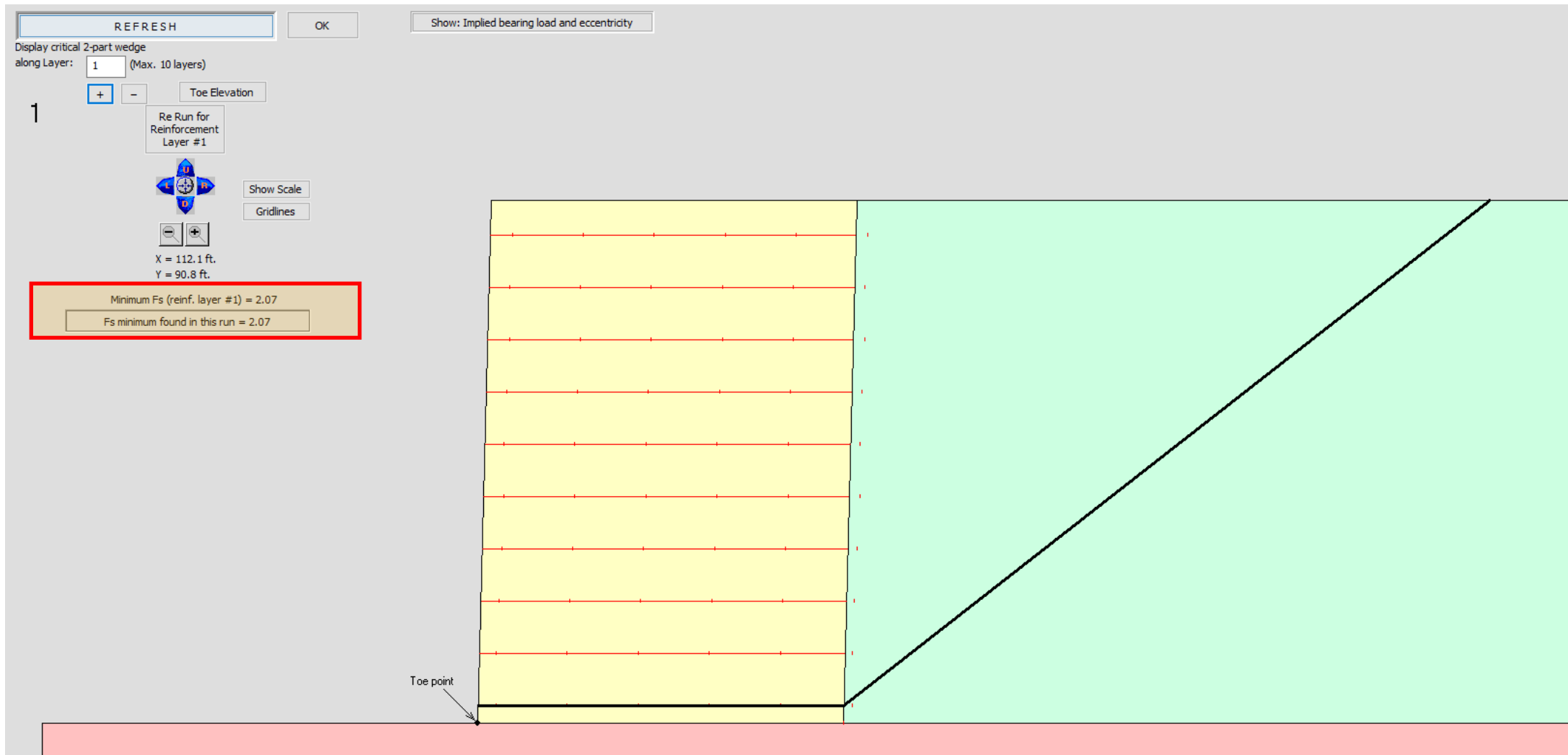
# Safety Map Showing the Spatial Distribution of $F_s$ on Soil Strength



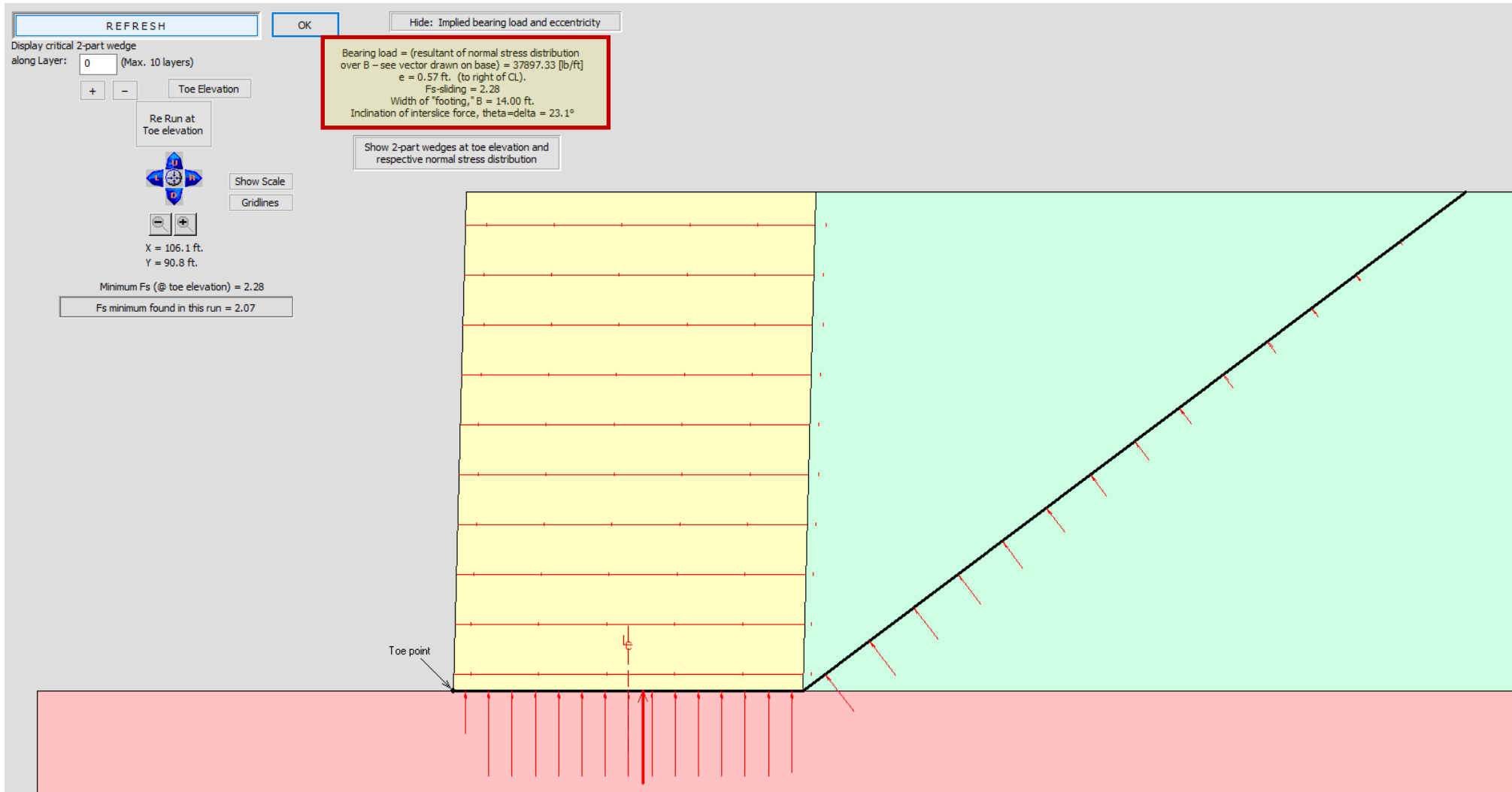
**Stage II:  $T_{ult} = 1.5 \text{ RF } T_{max} = 3020 \text{ lb/ft}$**   
**Run Global Stab.:  $F_s = 1.39 > 1.30 \text{ OK}$**



# 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)  $k_v =$    $\times k_h = 0.000$

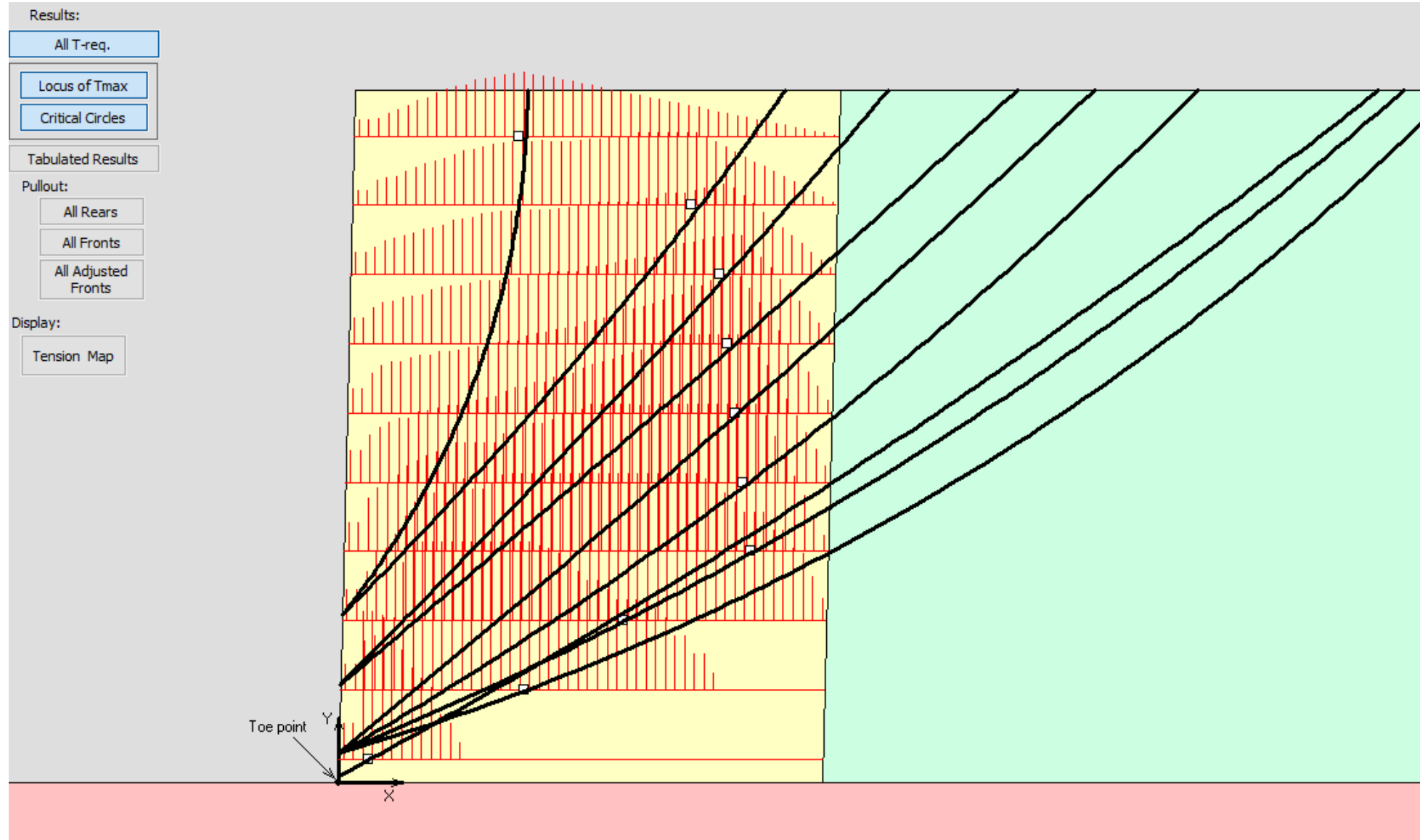
---

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

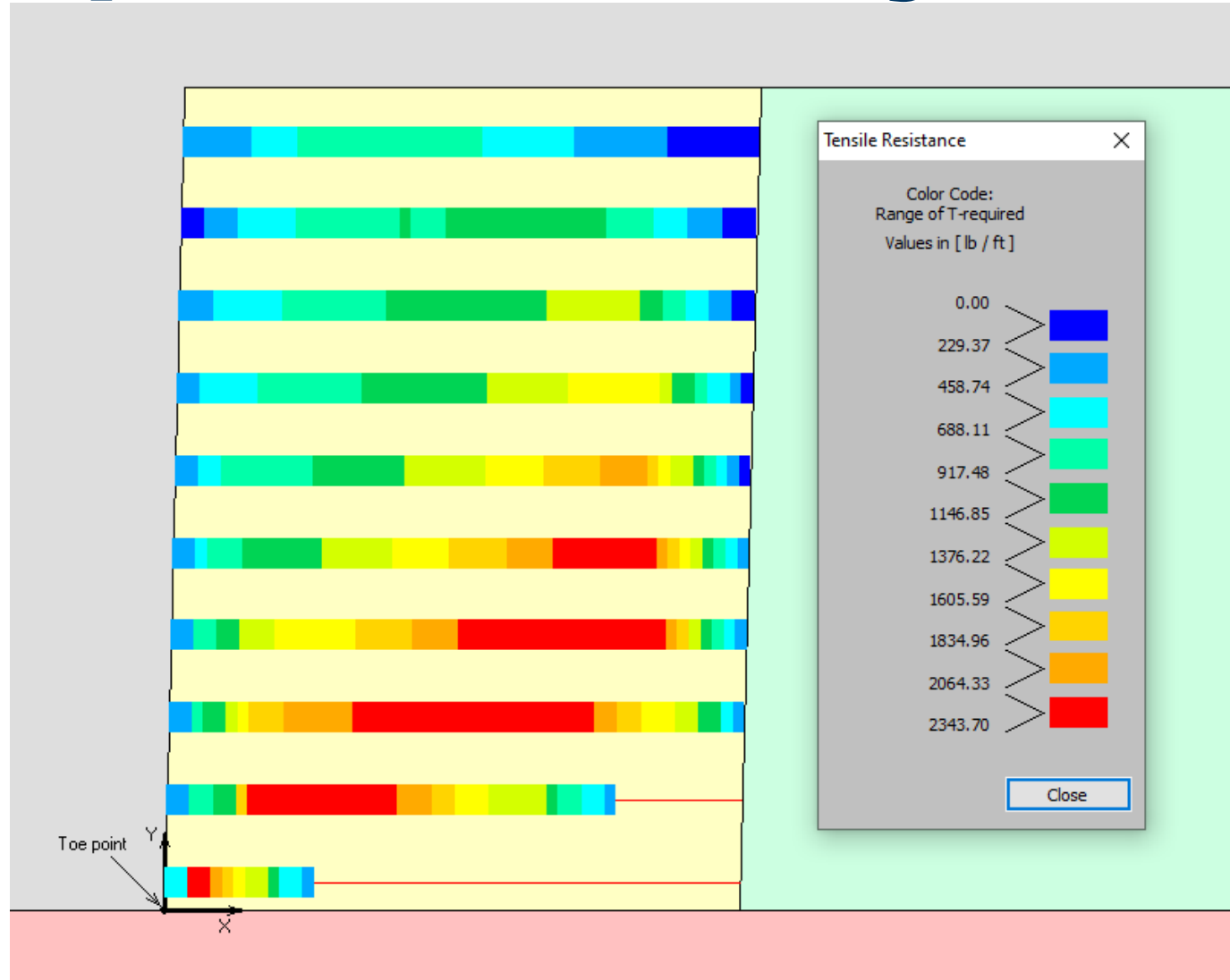
---

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.

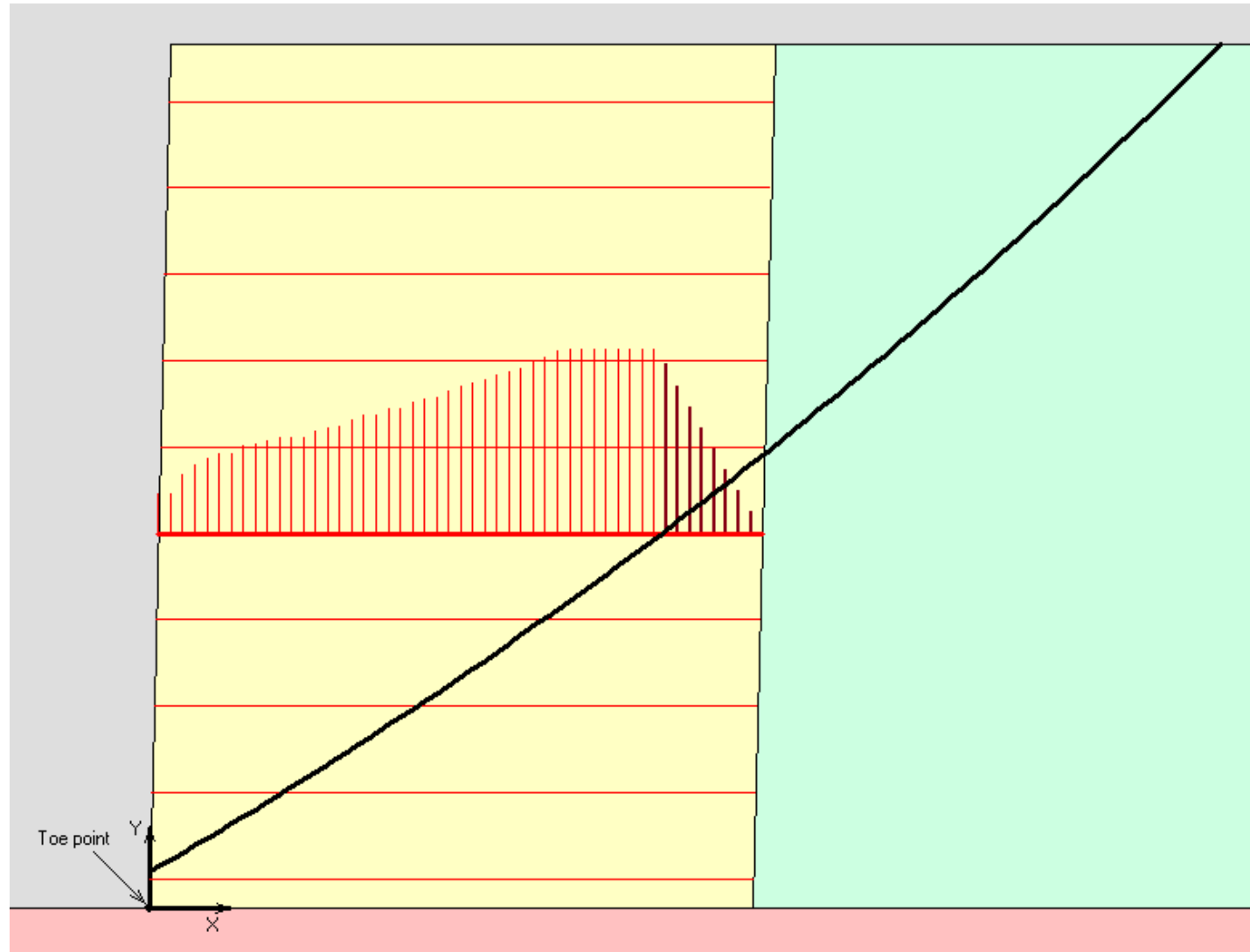
# Change RFcr=1.0 and Run Baseline



# 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 | Current input of LTDS * | Fs-reinf. = LTDS / Tmax | T-required |                       | Current input of CoSt ** | Fs-conn. = CoSt / To | Connection load, To (front end) | To/ Tmax [%] | T max affected by rear end pullout | Input pullout resist. at rear-end, Tr-o | Coverage Ratio, Ro |
|-----------|-----------------|-------------------------|-------------------------|------------|-----------------------|--------------------------|----------------------|---------------------------------|--------------|------------------------------------|---|--------------------|
|           | [ ft ]          |                         |                         | T max      | Located at X from Toe |                          |                      |                                 |              |                                    |   |                    |
|           | [ lb/ft ]       |                         |                         | [ lb/ft ]  | [ ft ]                | [ lb/ft ]                |                      | [ lb/ft ]                       |              |                                    | [ lb/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 =  $T_{ult} / (RF_d * R_{Fd} * RF_{cr} * RF_a)$  where  $T_{ult}$  and  $RF$  are specified in Global Stability.

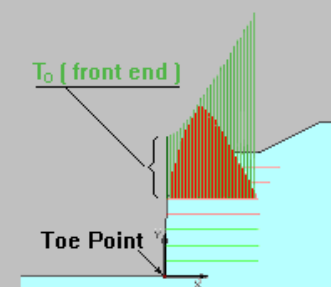
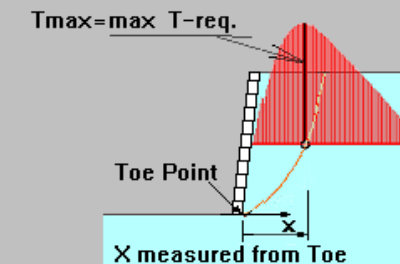
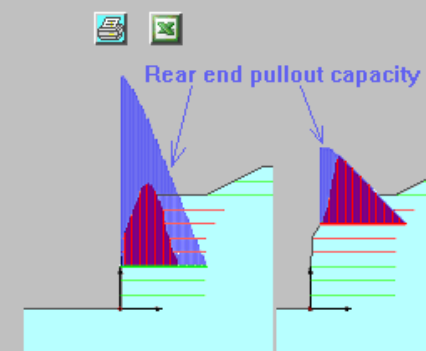
Fs-reinf. = "Factor of safety" on geosynthetic (reinforcement) strength considering the specified target Fs on soil strength and LTDS specified in Global Stability.

\*\* 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.

Treq(x) is calculated for a limit equilibrium state where Fs anywhere is constant. Therefore, To 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.



Open FHWA-HIF-17-004

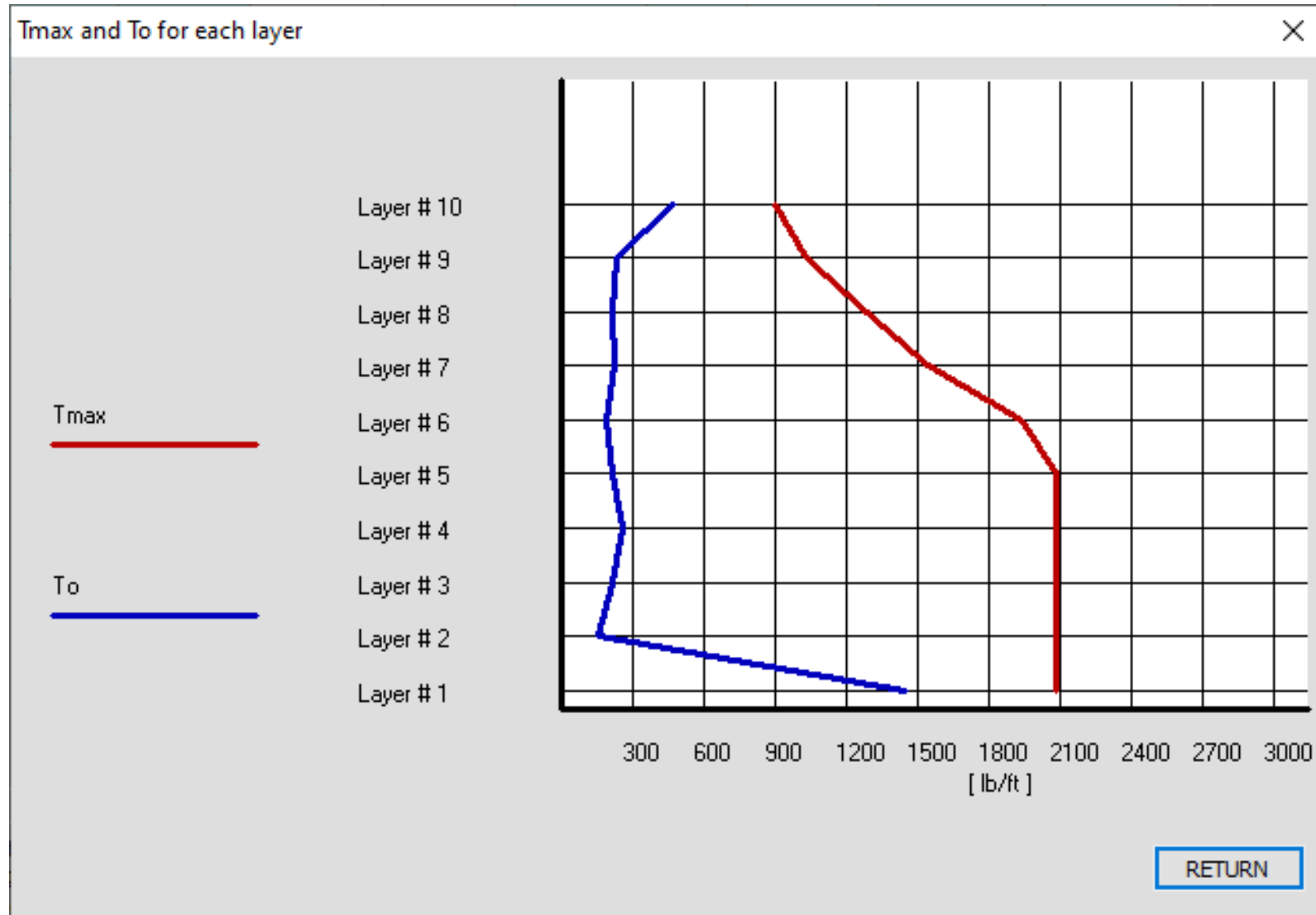
Display Tmax and To for each layer

Pullout details: min(Fs) Front / Rear

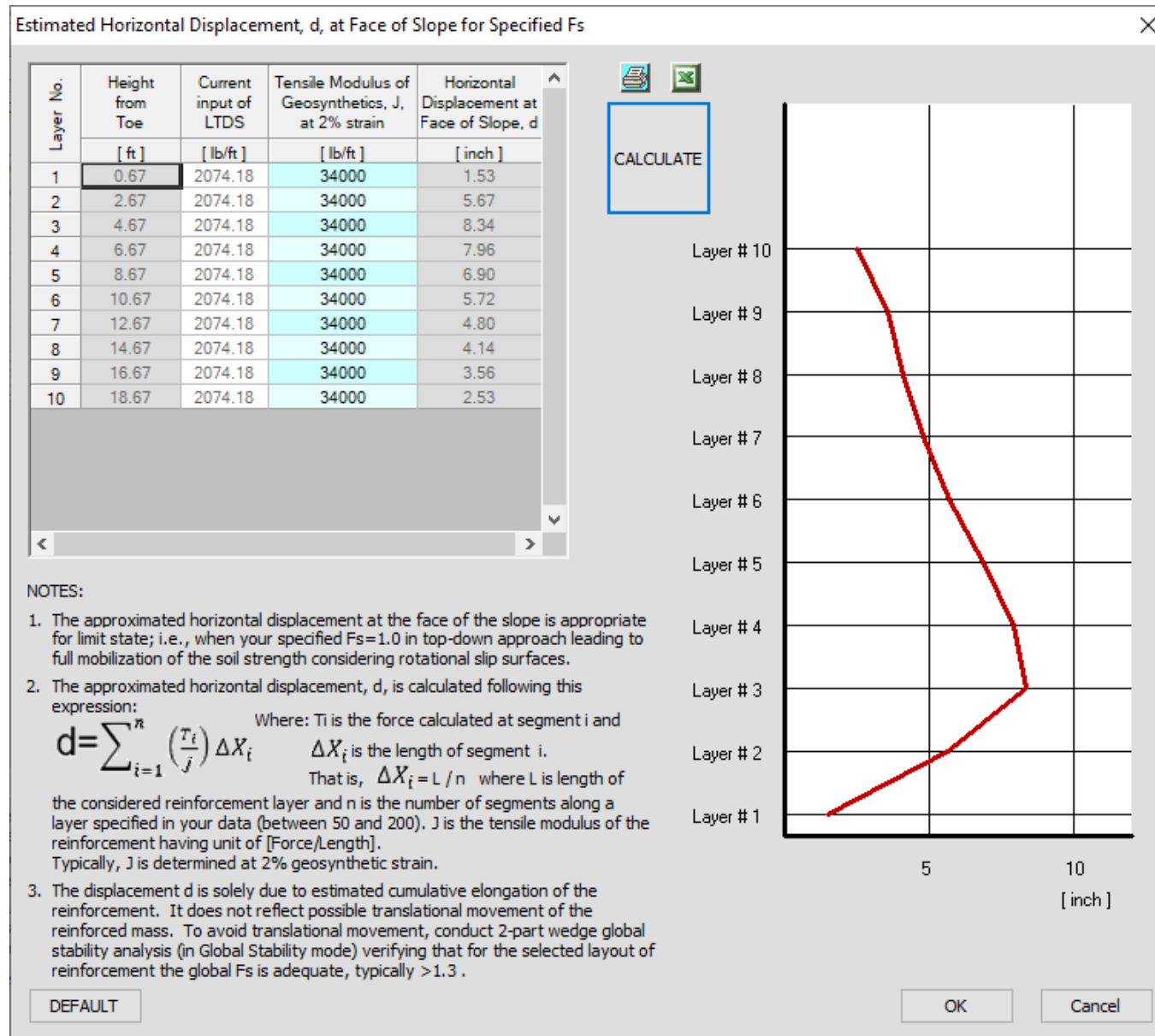
Display Horizontal Displacements

RETURN

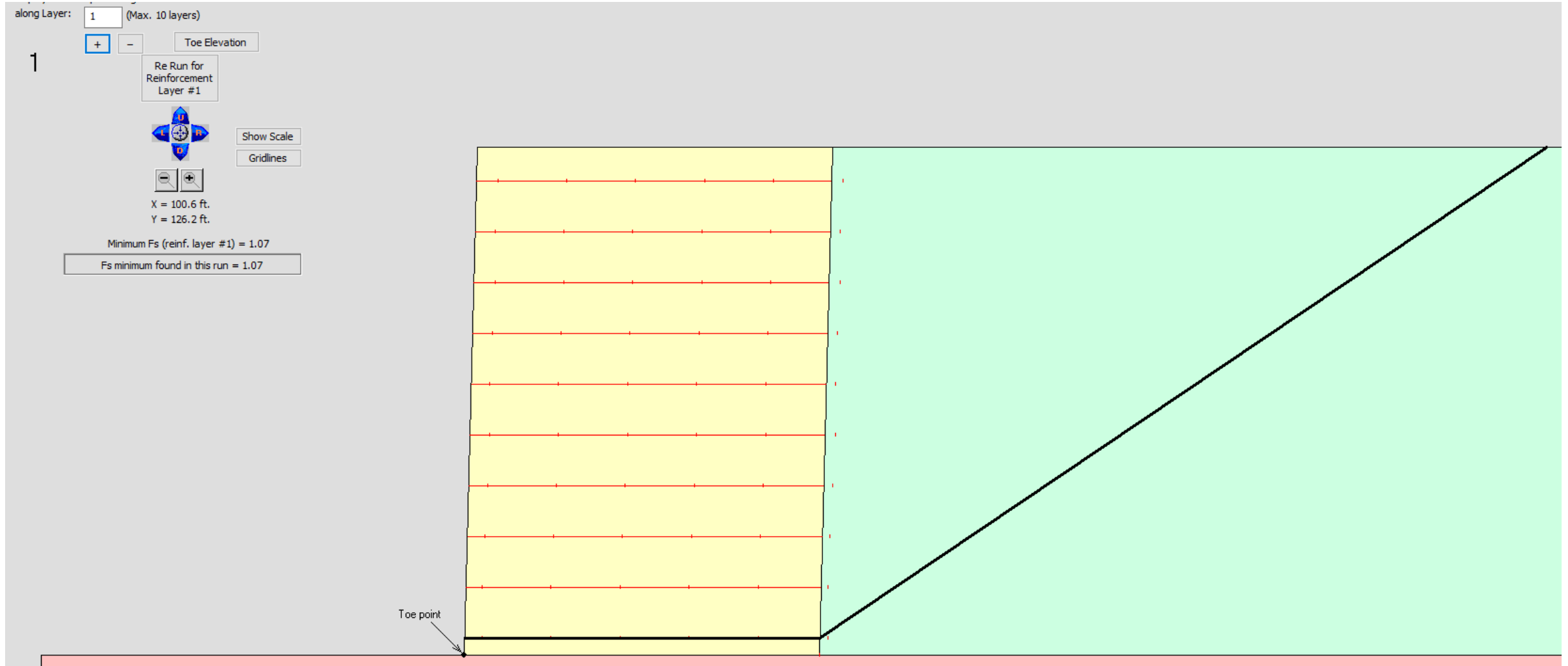
# Impact of Compound Failure is Manifested in Required high $T_{\max}$ and $T_o$ at Bottom Layers



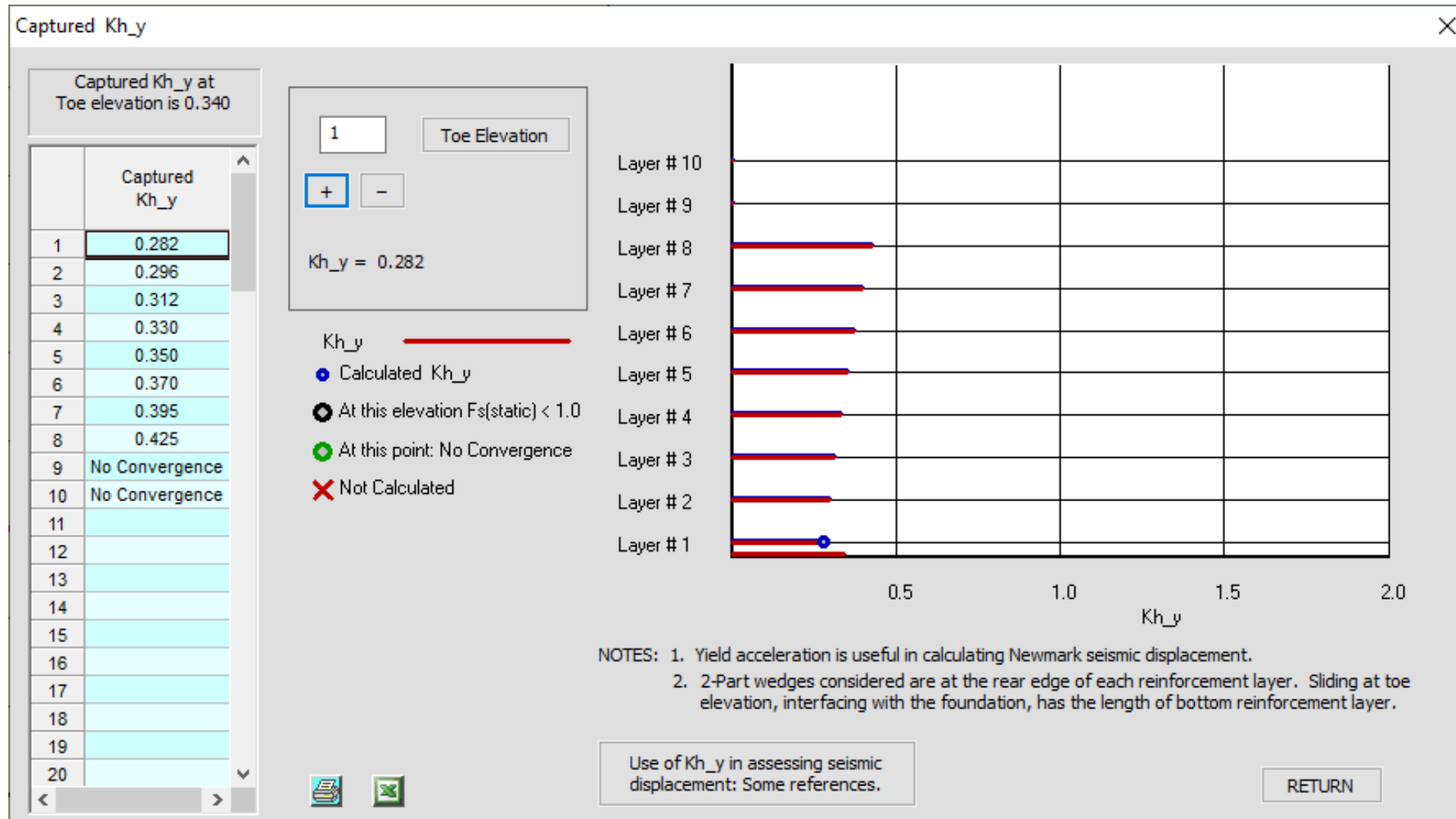
# Also Displacement is large at Bottom Layers



# 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:

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.

