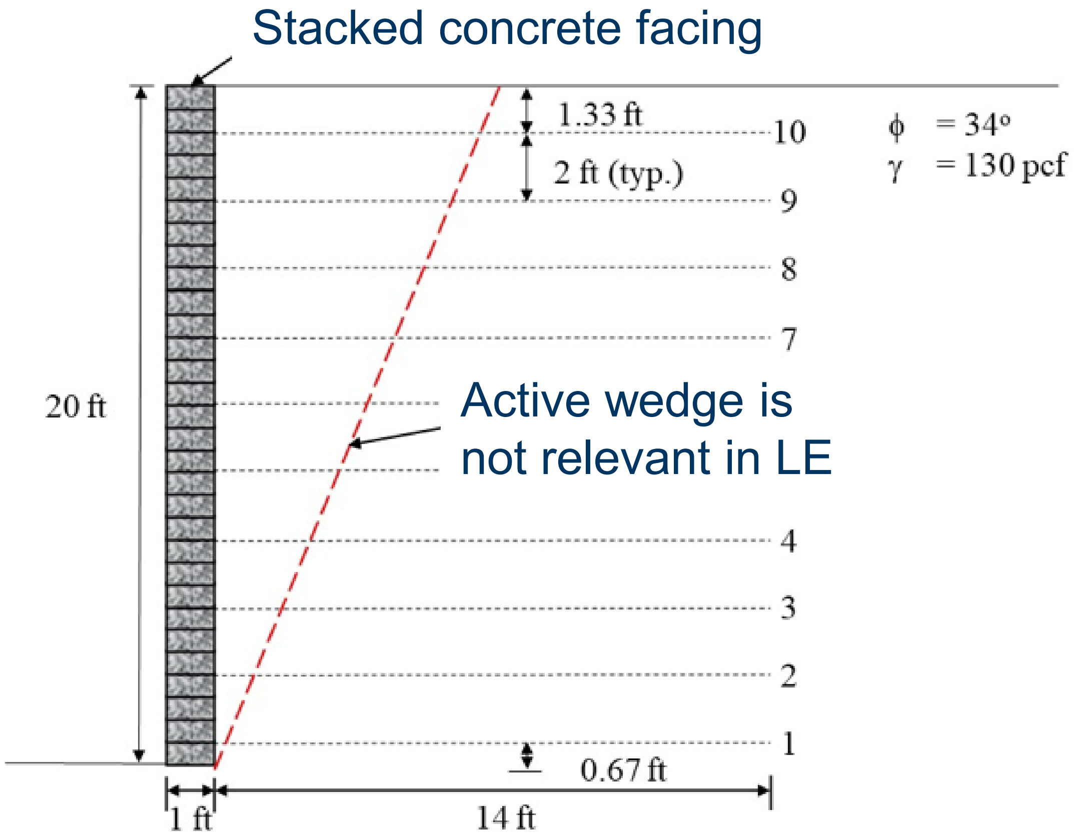
Lesson 5:

ReSSA+: Demonstration

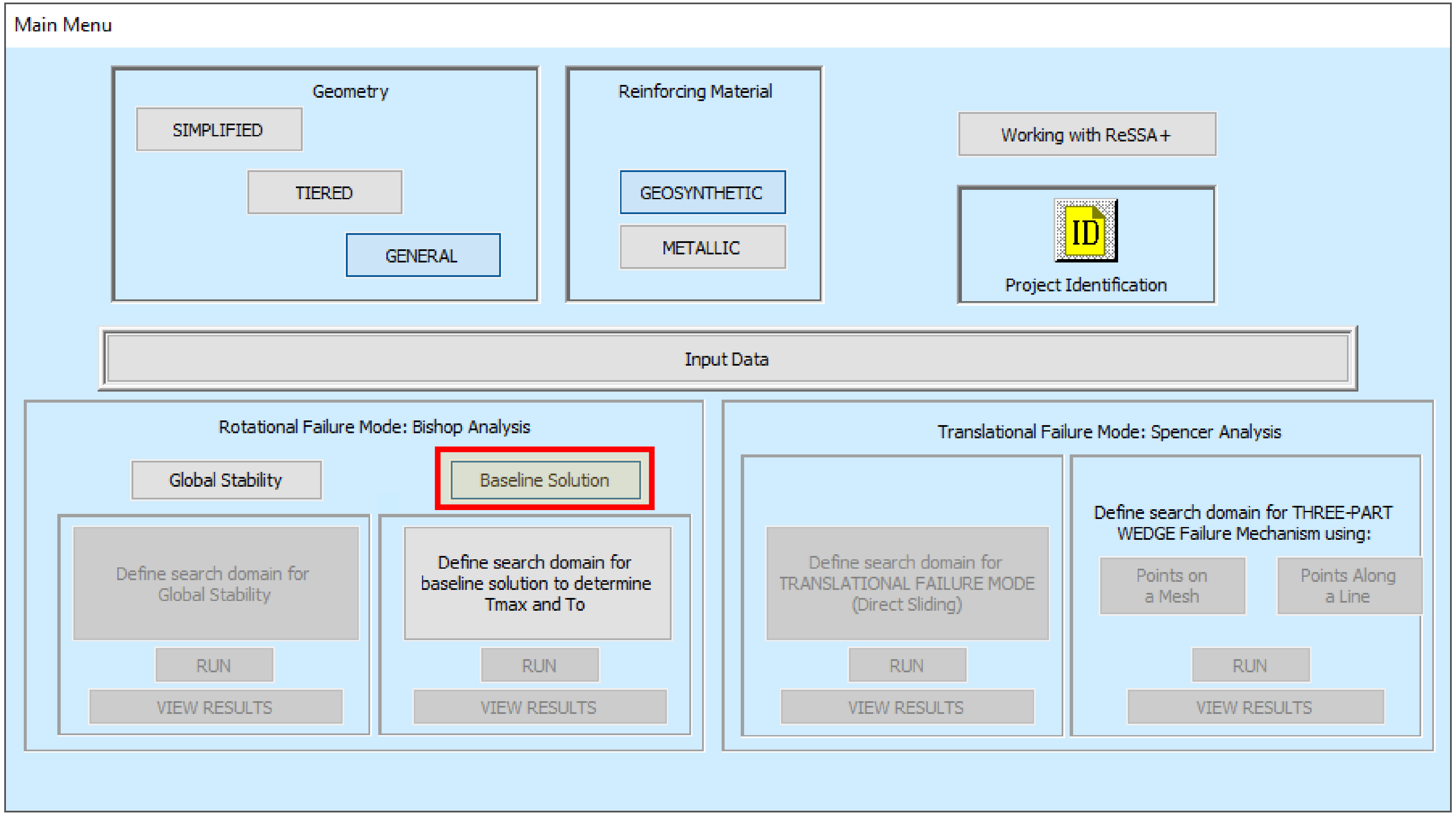
Problem – Mechanical Connector



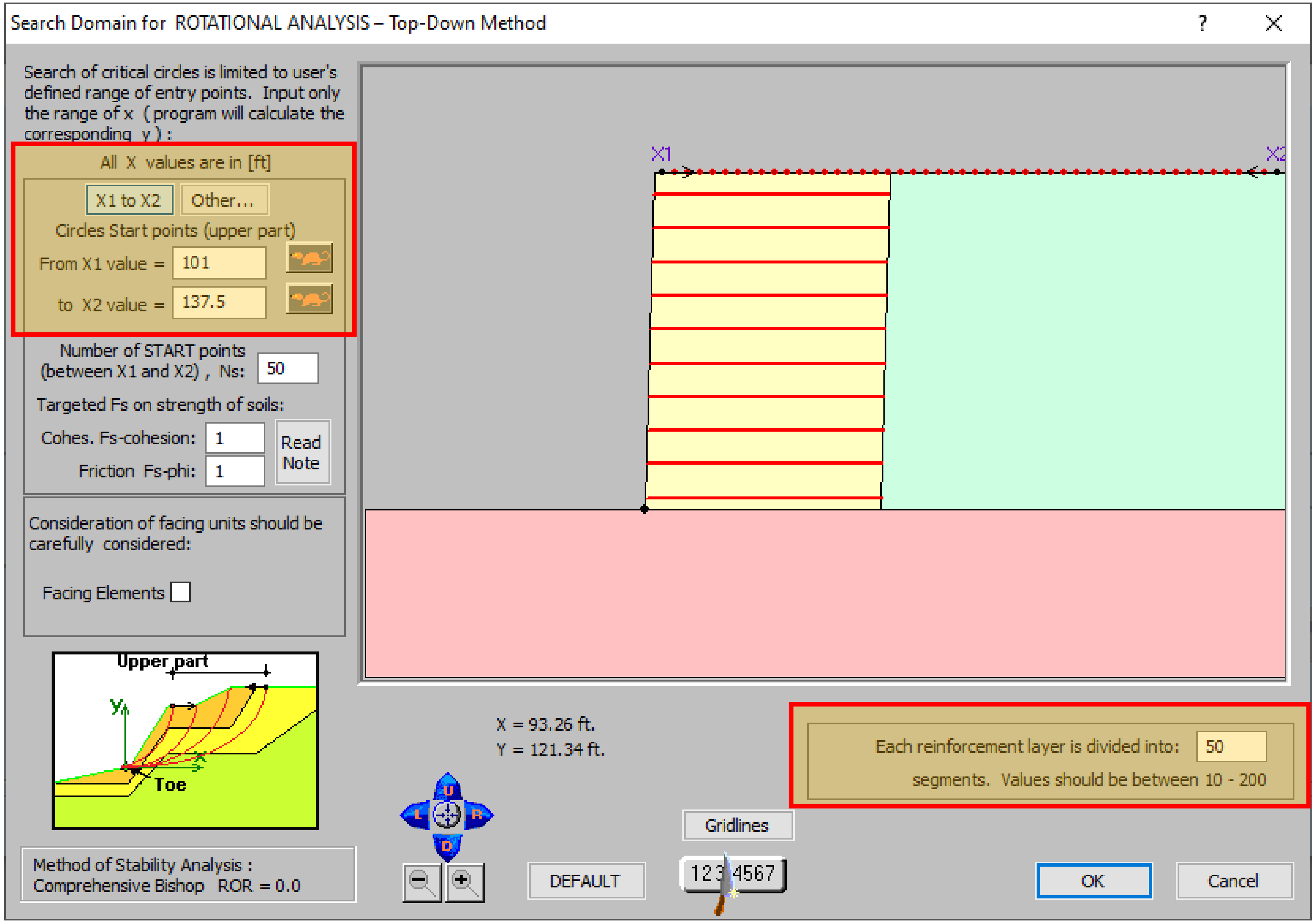
Property	Design Value
Find T_{max} for design	
$RF_{ID}\ RF_{CR}\ RF_D = RF$	1.12 x 1.5 x 1.3 = 2.18
Coverage ratio, R_c	1.0
Facing unit weight, γ_{block} (pcf)	120
Facing block height (ft)	0.67
Facing block width, W_u (ft)	1.0
Connection strength as fraction of T_{ult}, CR_u	0.75

Baseline Solution: Stage I

Objective: Find $\mathbf{T_{max}} \rightarrow T_{ult}=1.5\ LTDS = 1.5\ RF_{id}\ RF_d\ RF_{cr}\ \mathbf{T_{max}}$



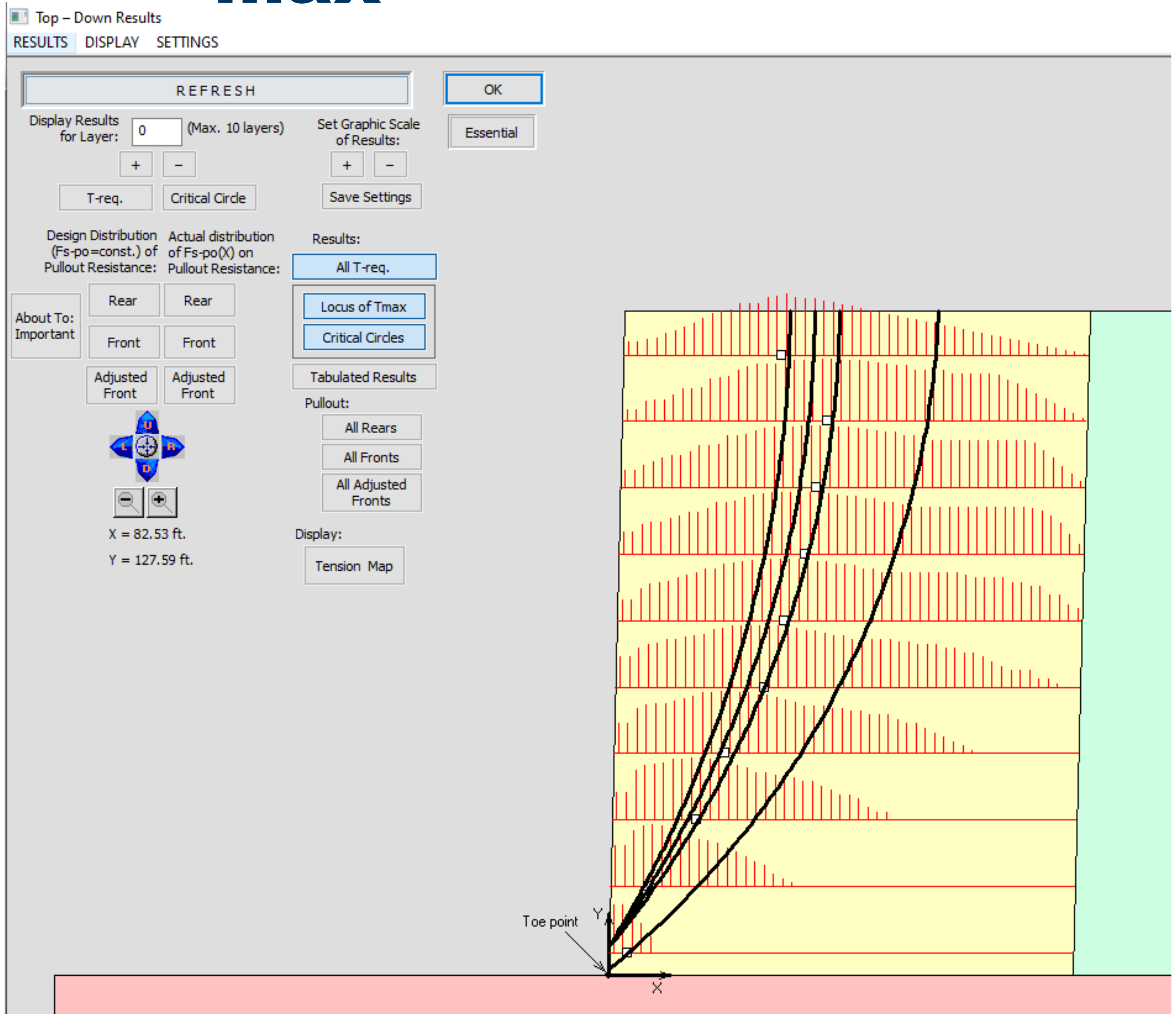
Define Search Domain to Determine T_{max} and T_o



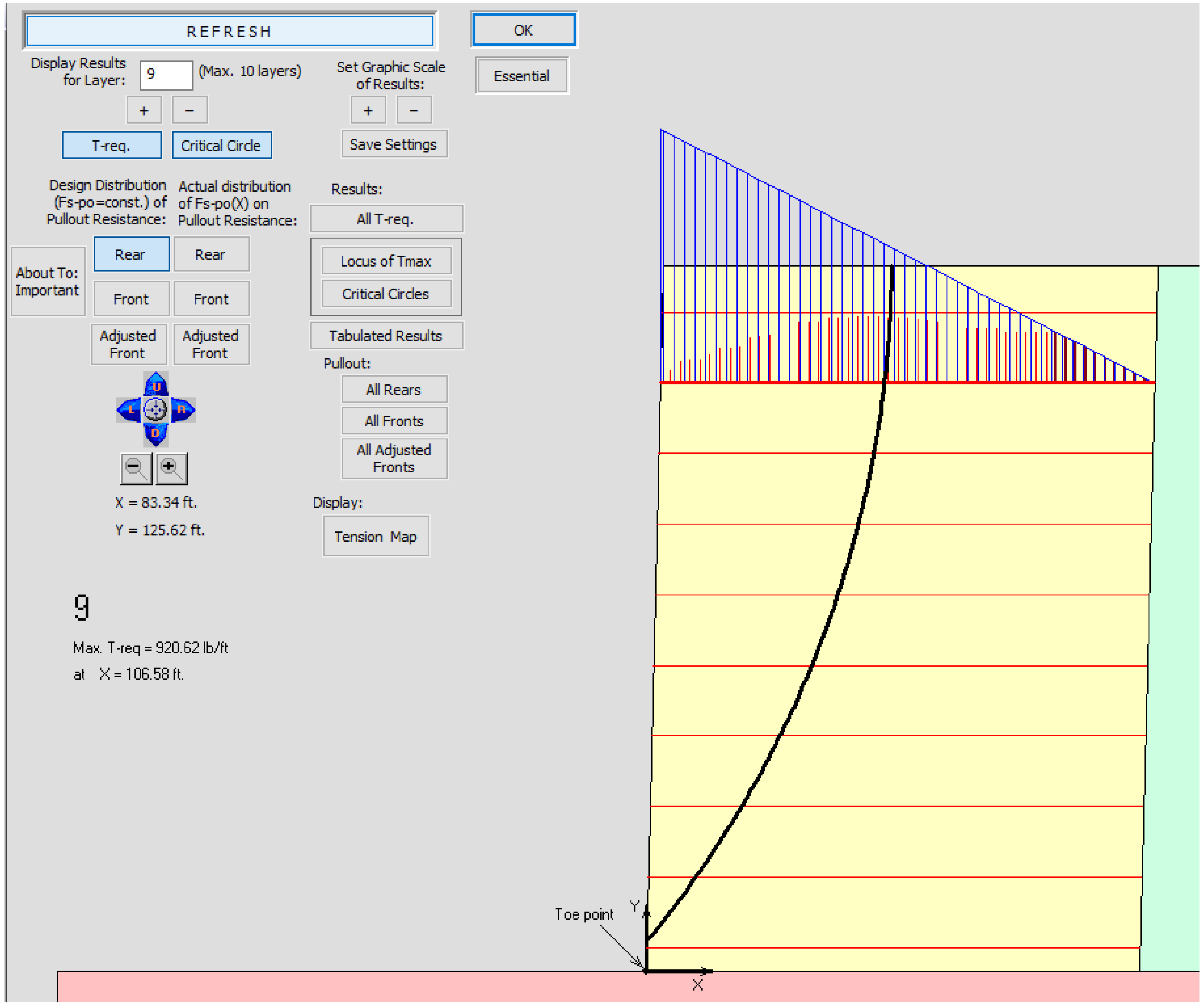
Run and Get $T_{req}(x)$, Locus of T_{max}, Circles Defining T_{max}

If reinforcement strength is same as Treq(x), any circle through layers will have the same Fs=1.0 ➔ All circles are equally critical ➔ Therefore, baseline results are rendered based on which we have to select reinforcement with adequate Tult ensuring sufficient margins of safety

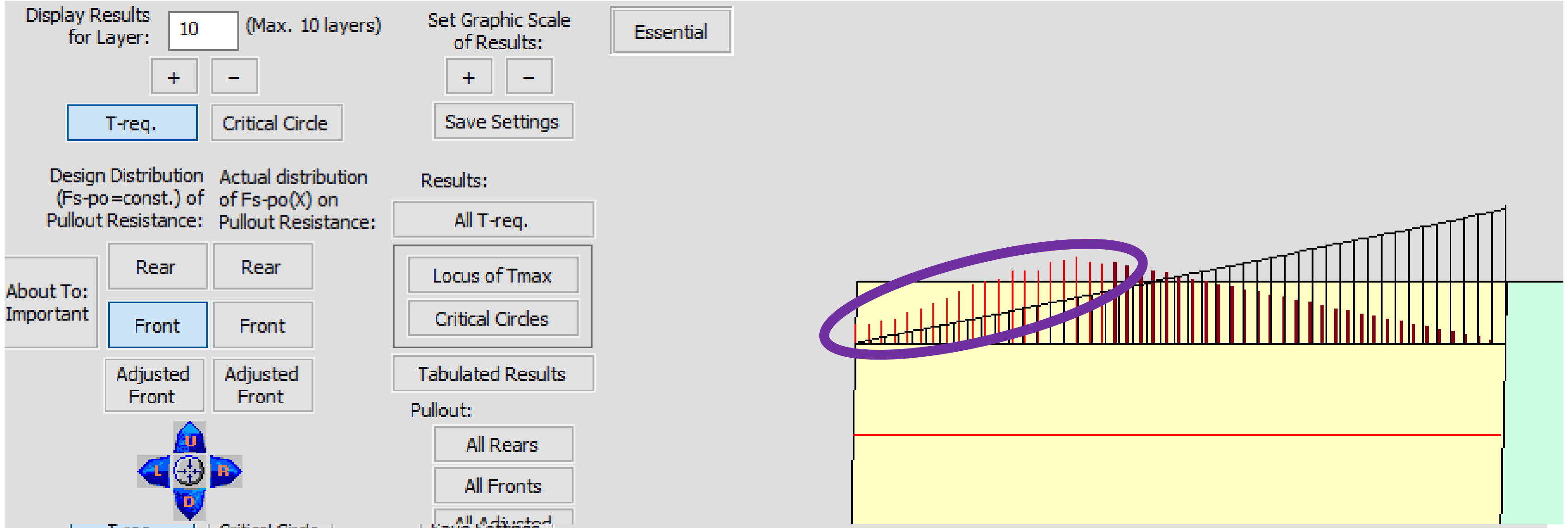
Note: There is well-defined Active Wedge as postulated in most simplified designs

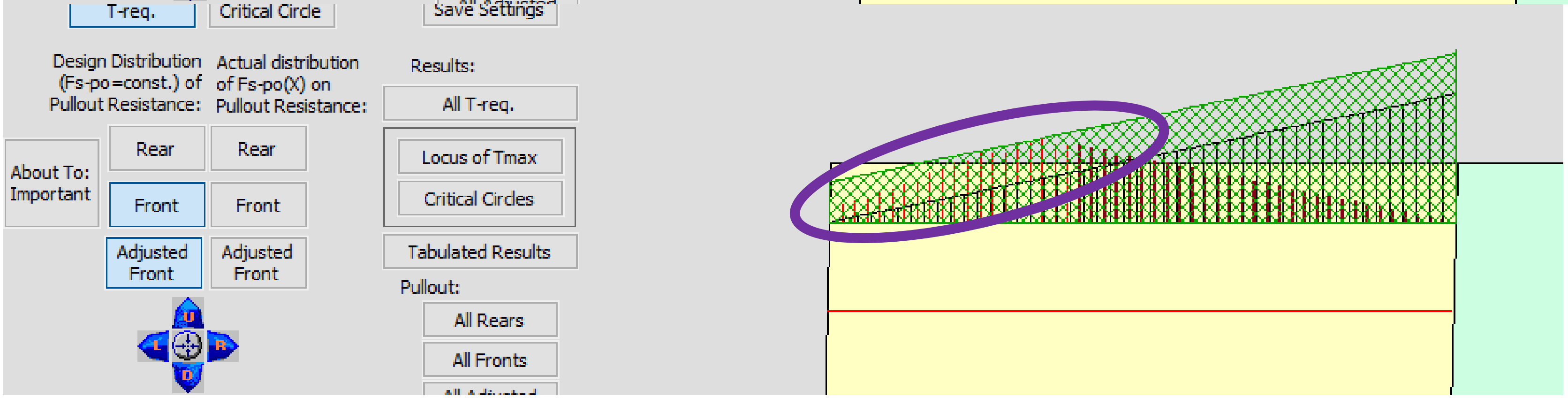


Circle for Layer 9 Determining T_{max}. Note that Treq is limited by Pullout Resistance thus Shedding load to layers below

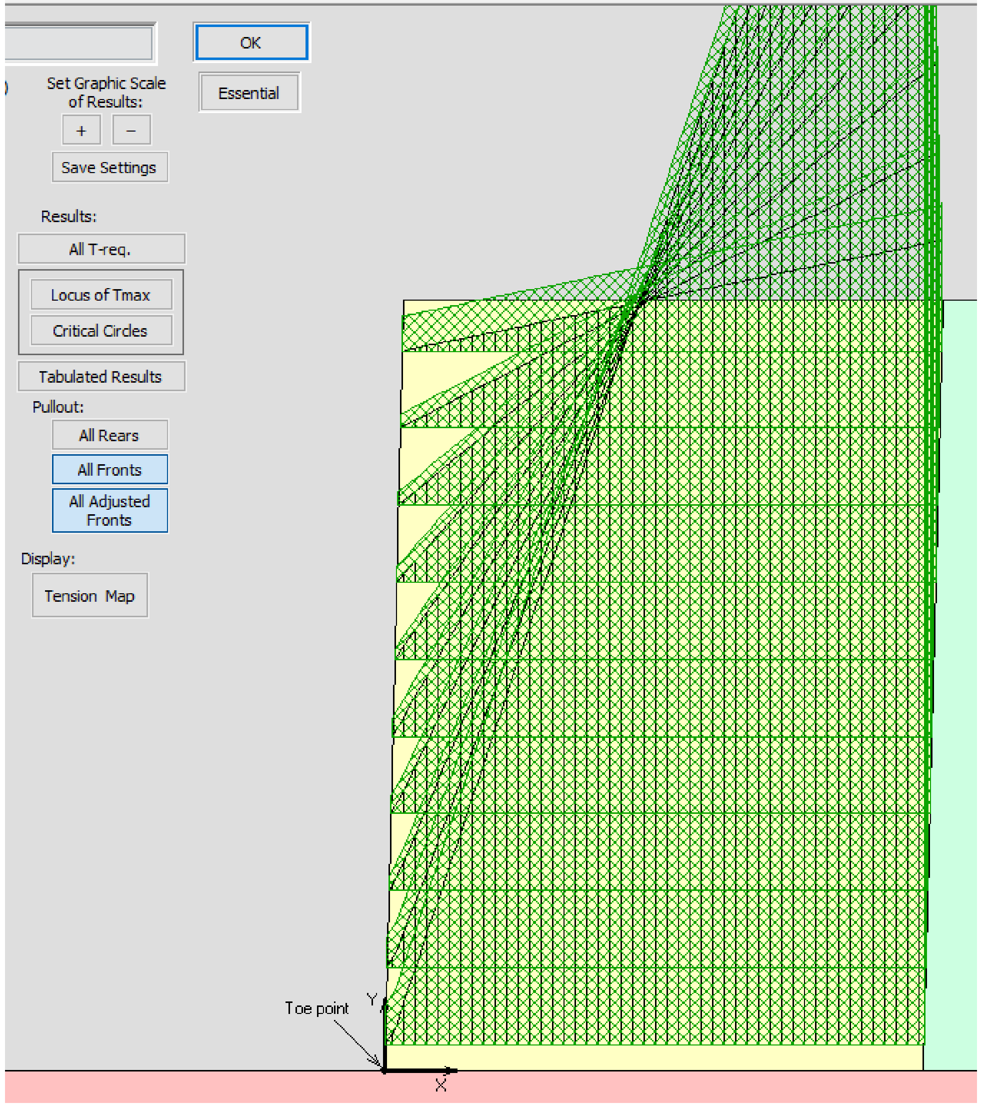


Determining To: For Treq, frontend pullout resistance must be satisfied

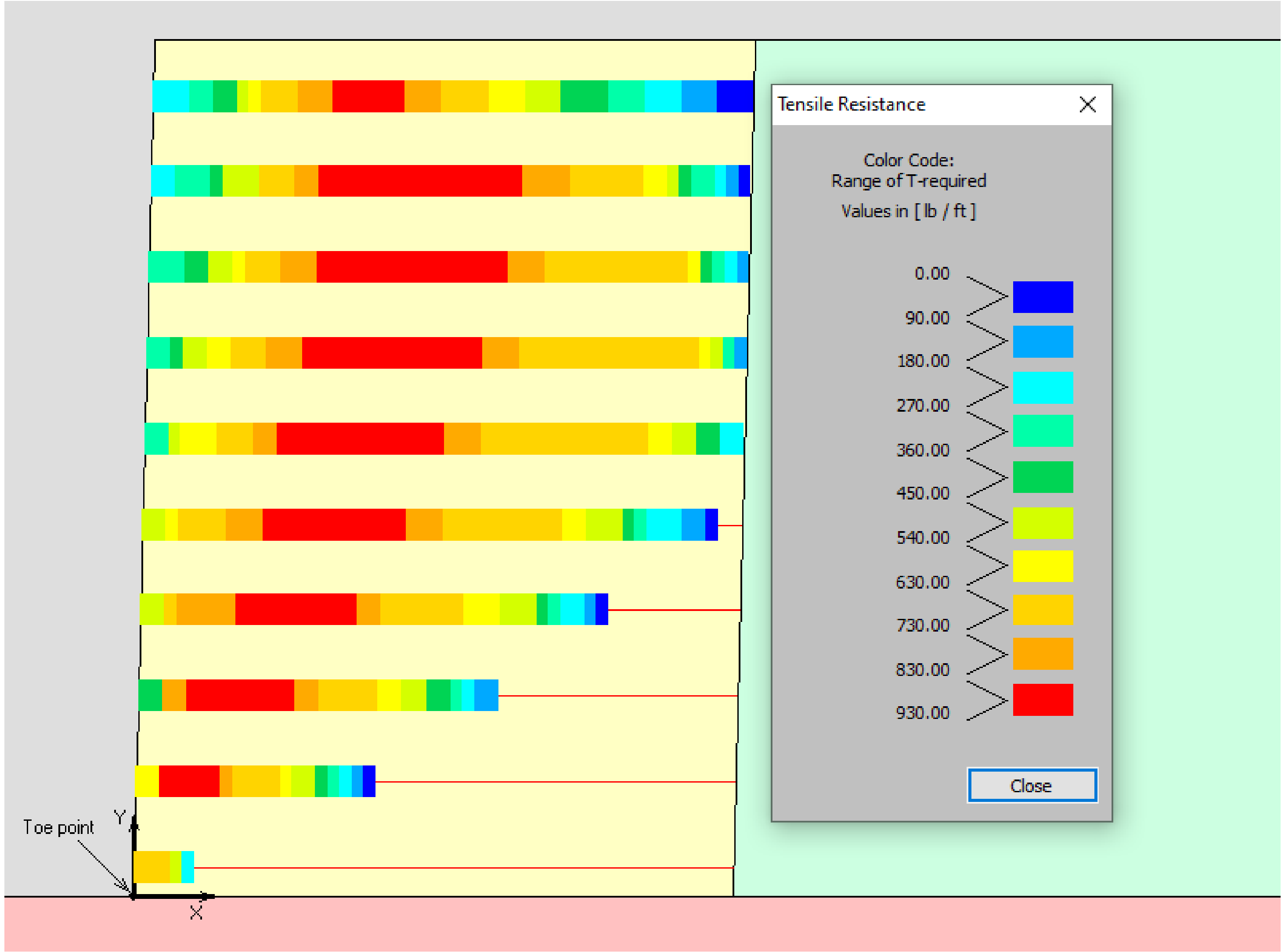




All Adjusted Front Pullouts



Tension Map: Color Coded Visual of Treq

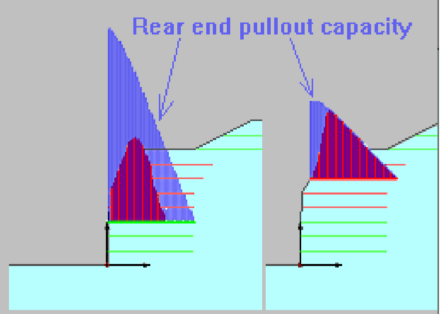


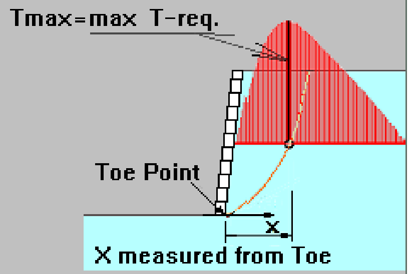
Tabulated Results

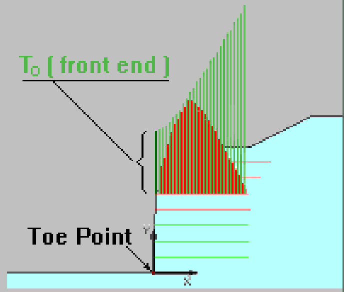
Tabulated Results – Stage I ("Internal Stability")

Layer No.	Height from Toe [ft]	Current input of LTDS * [lb/ft]	Fs-reinf.= LTDS / Tmax	T-required: T max [lb/ft]	T-required: Located at X from Toe [ft]	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
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 = Tult / (RFid * RFd * RFcr * RFa) where Tult 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.

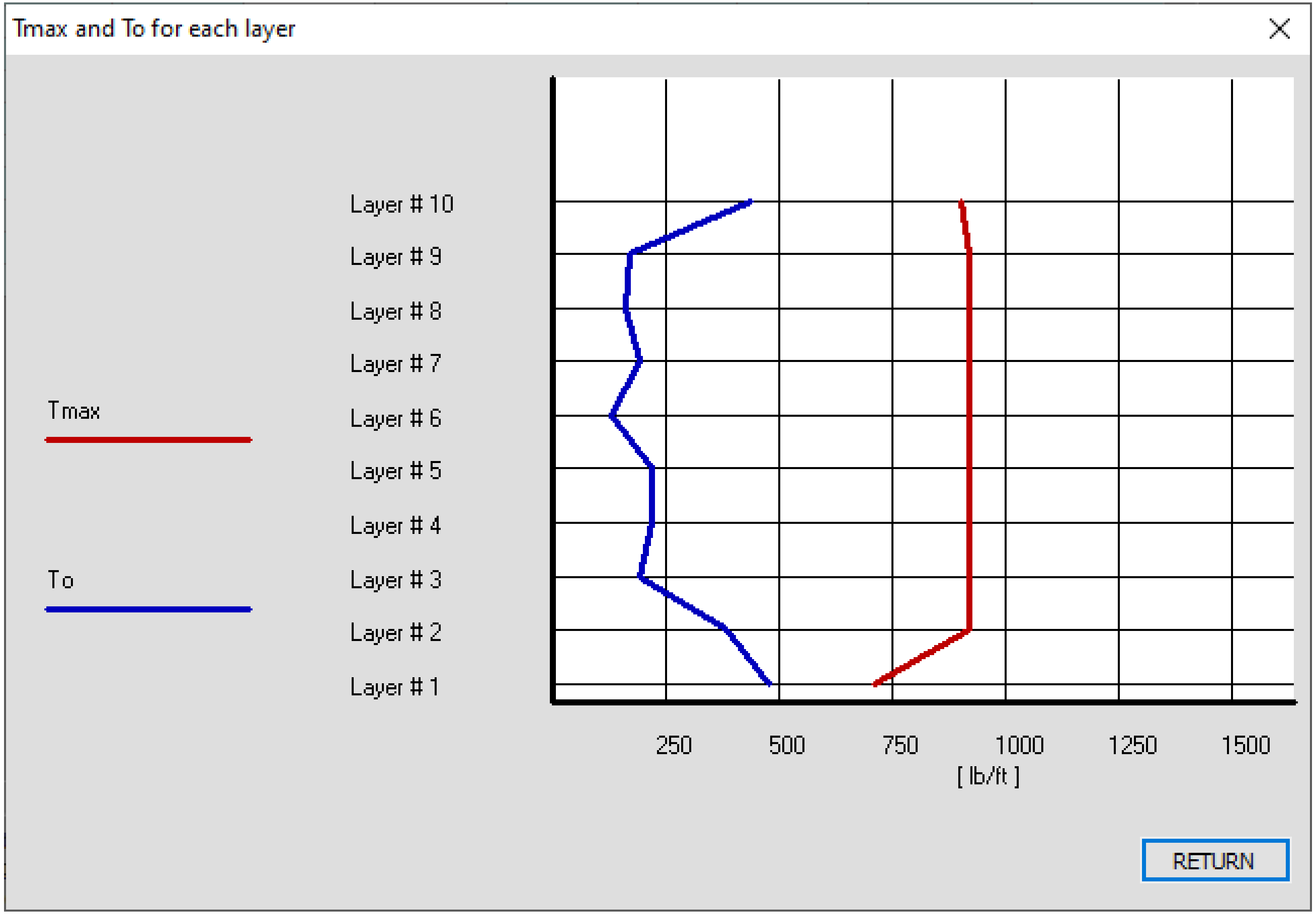
** CoSt = Connection Strength = % of LTDS available at front-end as currently specified in input of Reinforcement in Global Stability.
Fs-conn. = "Factor of safety" on connection strength considering the strength specified in Global stability and the calculated connection load in Baseline Solution.

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

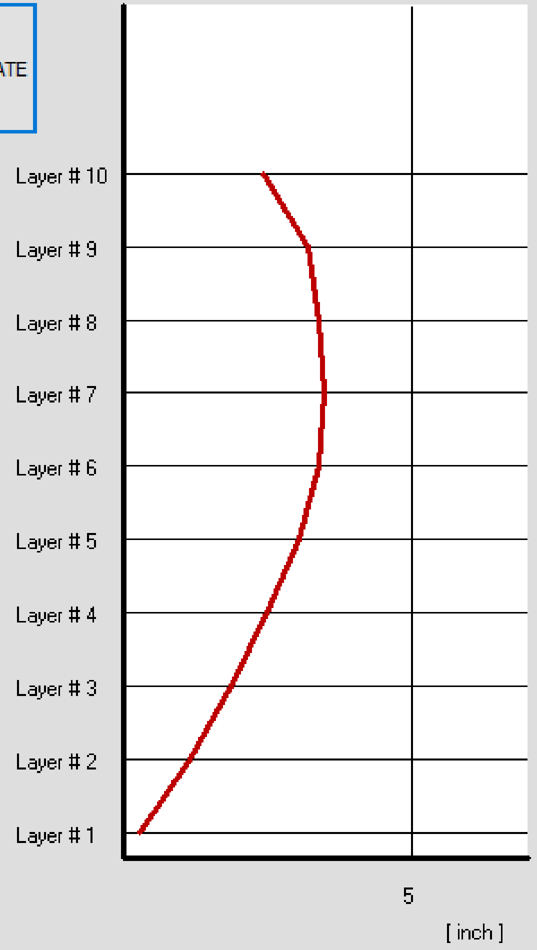


Estimate Horizontal Displacement

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

Layer No.	Height from Toe	Current input of LTDS	Tensile Modulus of Geosynthetics, J, at 2% strain	Horizontal Displacement at Face of Slope, d
	[ft]	[lb/ft]	[lb/ft]	[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



NOTES:

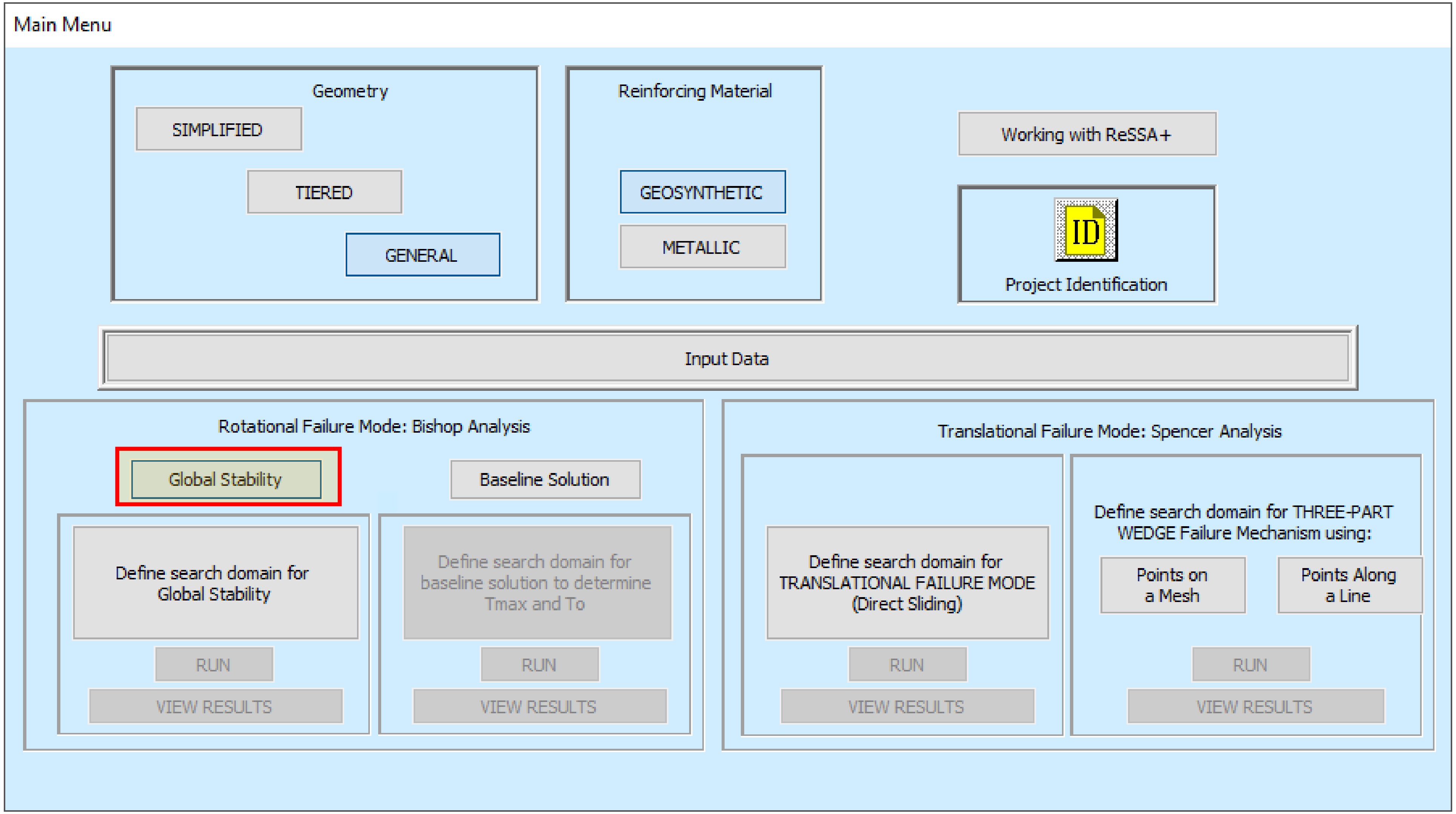
1. The approximated horizontal displacement at the face of the slope is appropriate for limit state; i.e., when your specified Fs=1.0 in top-down approach leading to full mobilization of the soil strength considering rotational slip surfaces.
2. The approximated horizontal displacement, d, is calculated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

$$d=\sum_{i=1}^{n}\left(\frac{T_i}{J}\right)\Delta X_i$$

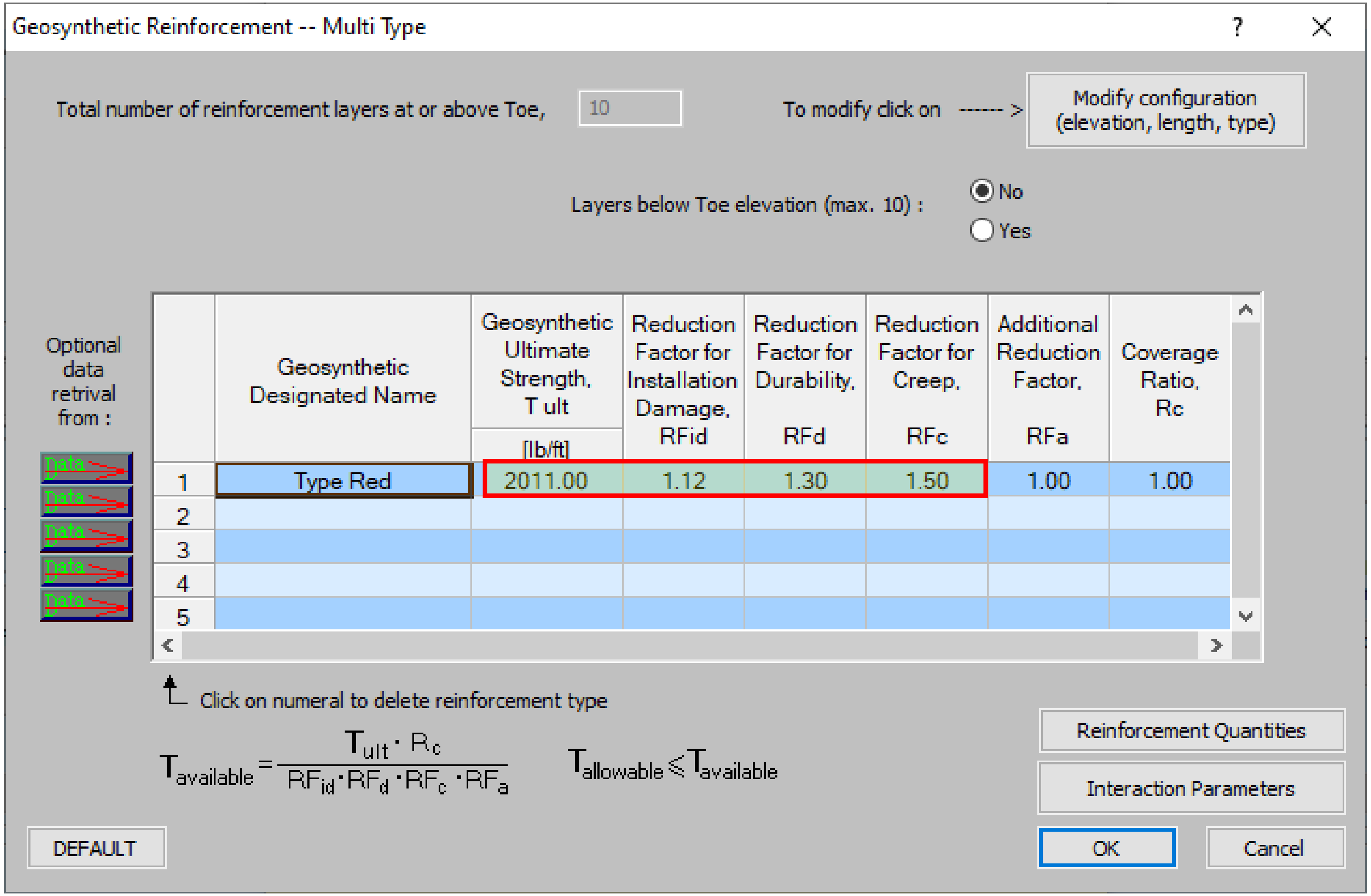
Where: Ti is the force calculated at segment i and ΔX_i is the length of segment i.
That is, $\Delta X_i = L / n$ where L is length of the considered reinforcement layer and n is the number of segments along a layer specified in your data (between 50 and 200). J is the tensile modulus of the reinforcement having unit of [Force/Length].
Typically, J is determined at 2% geosynthetic strain.
3. 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 Fs is adequate, typically >1.3 .

DEFAULT | OK | Cancel

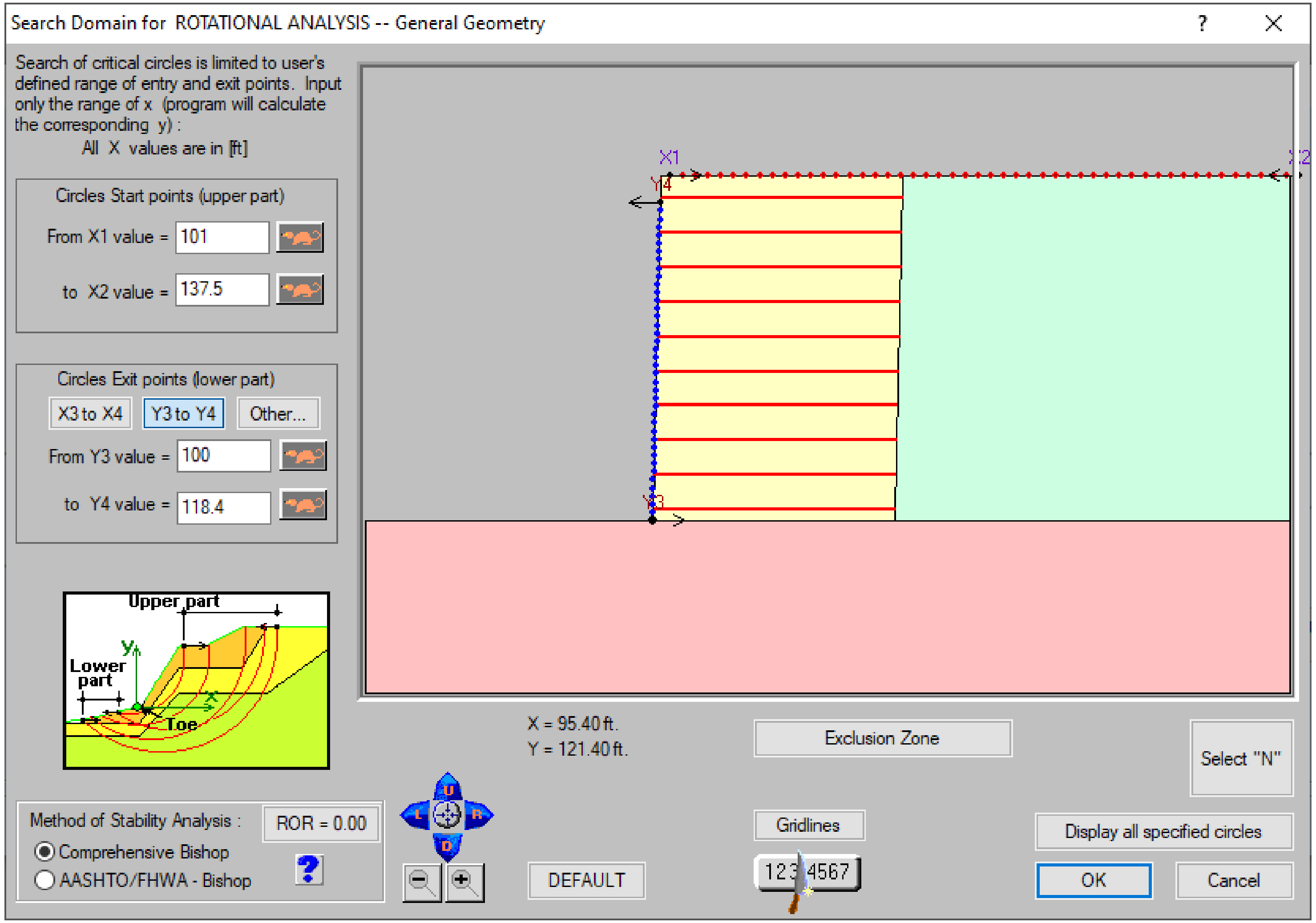
Back to Main Menu - Global Stability – Stage II Design



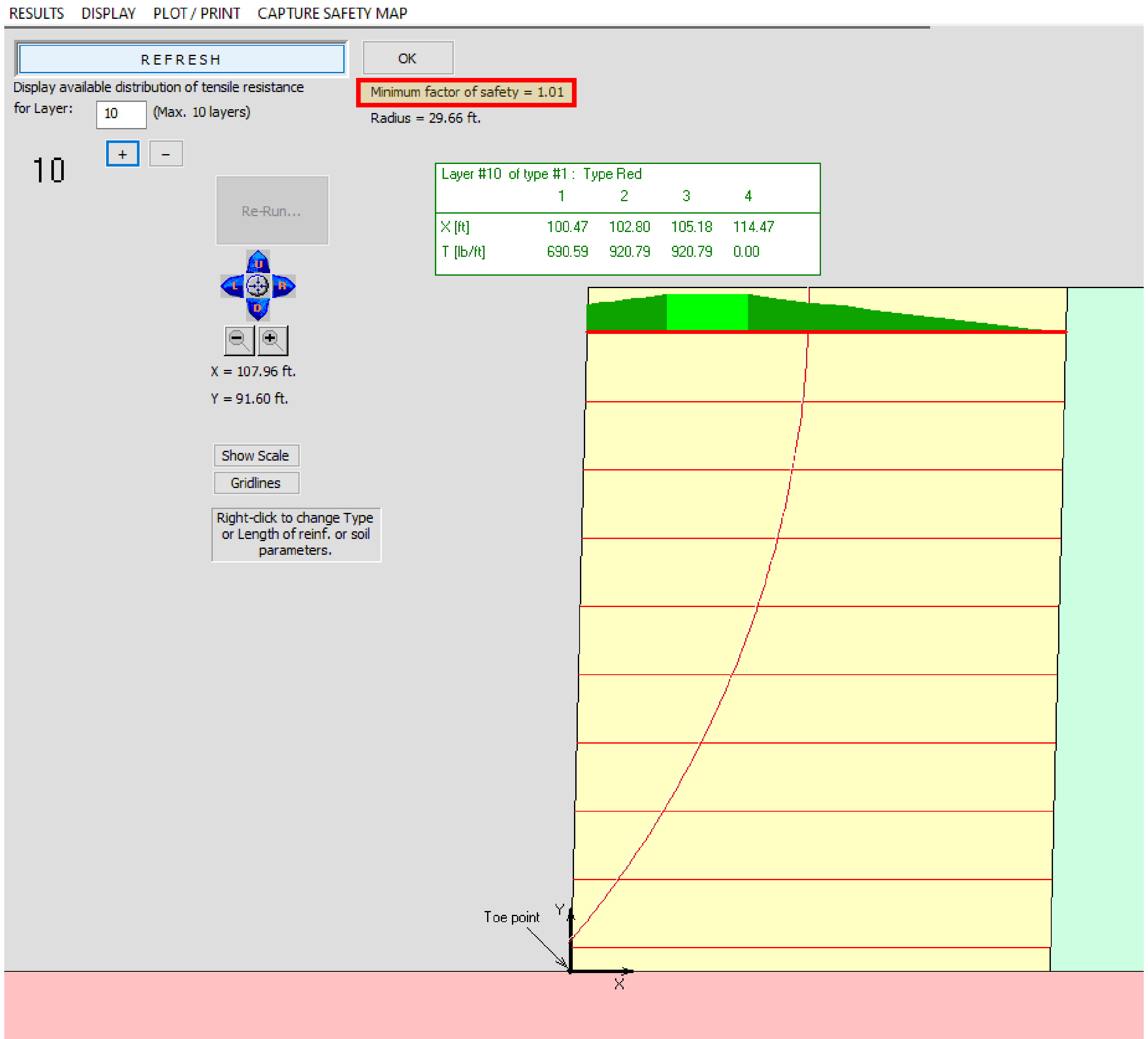
Specified T_{ult}/RF Renders Fs=1.0 – Recall Internal Stability



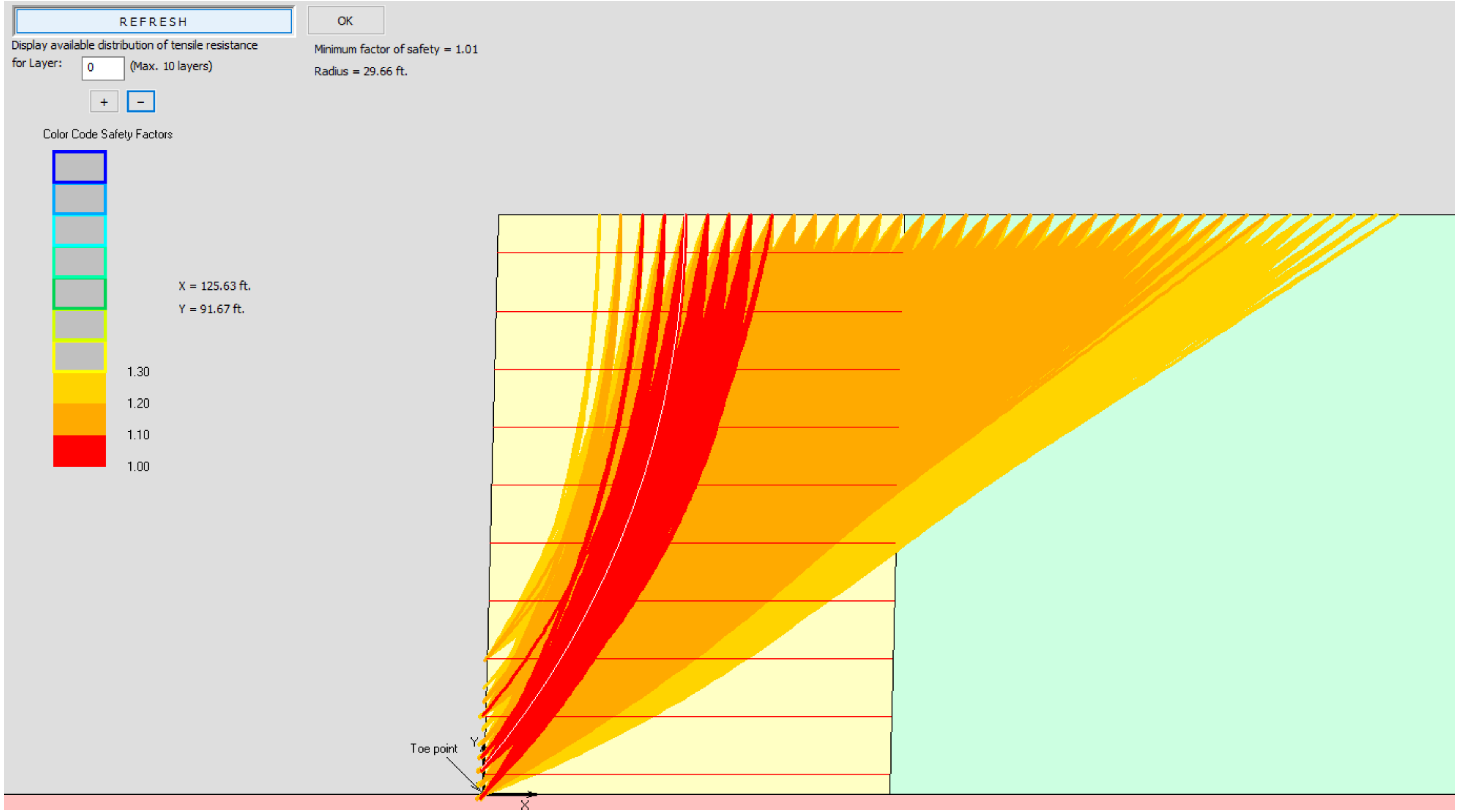
To Ascertain Results in Internal Stability, Run Global – Define Search



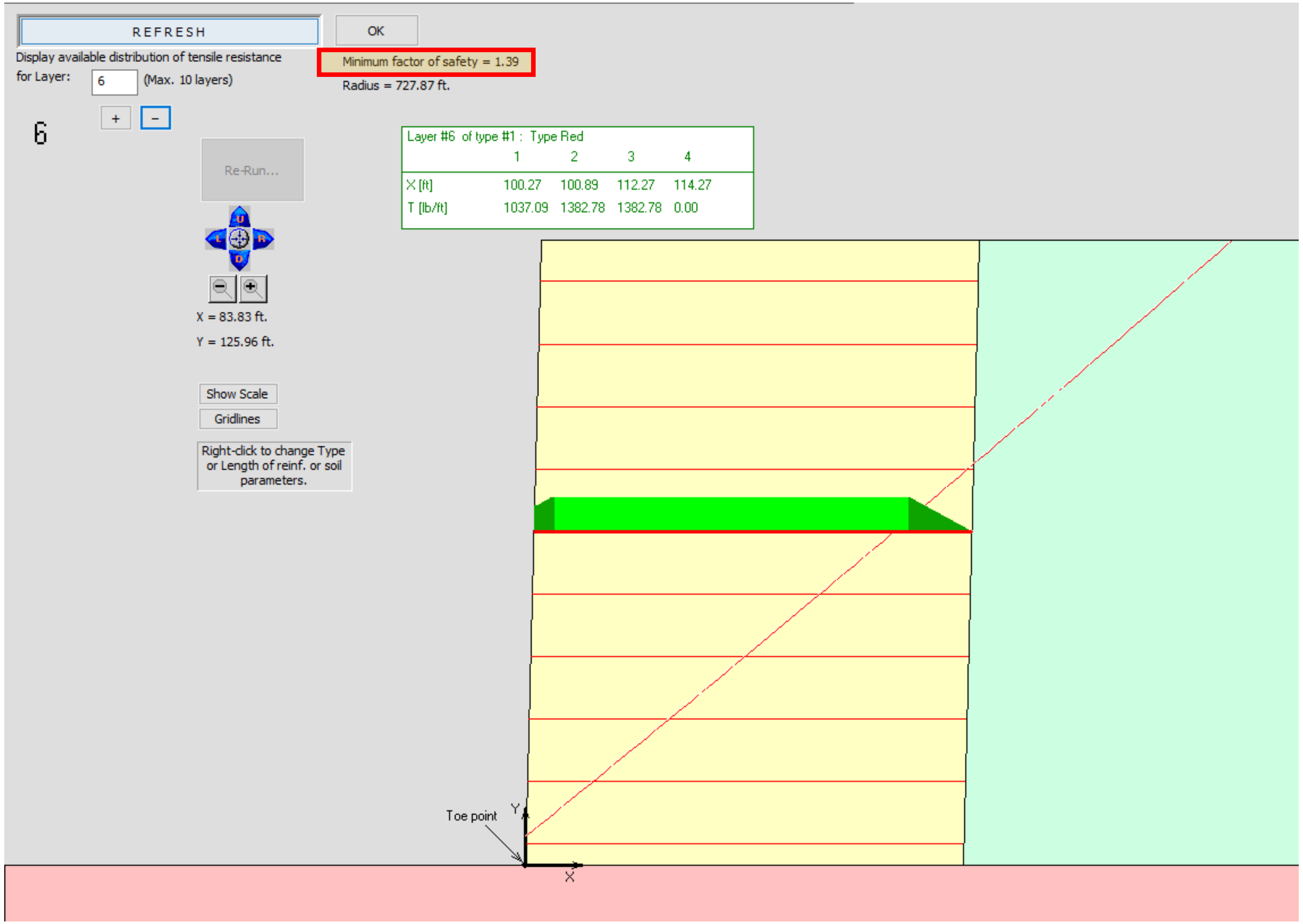
Run and Get Fs=1.01 OK



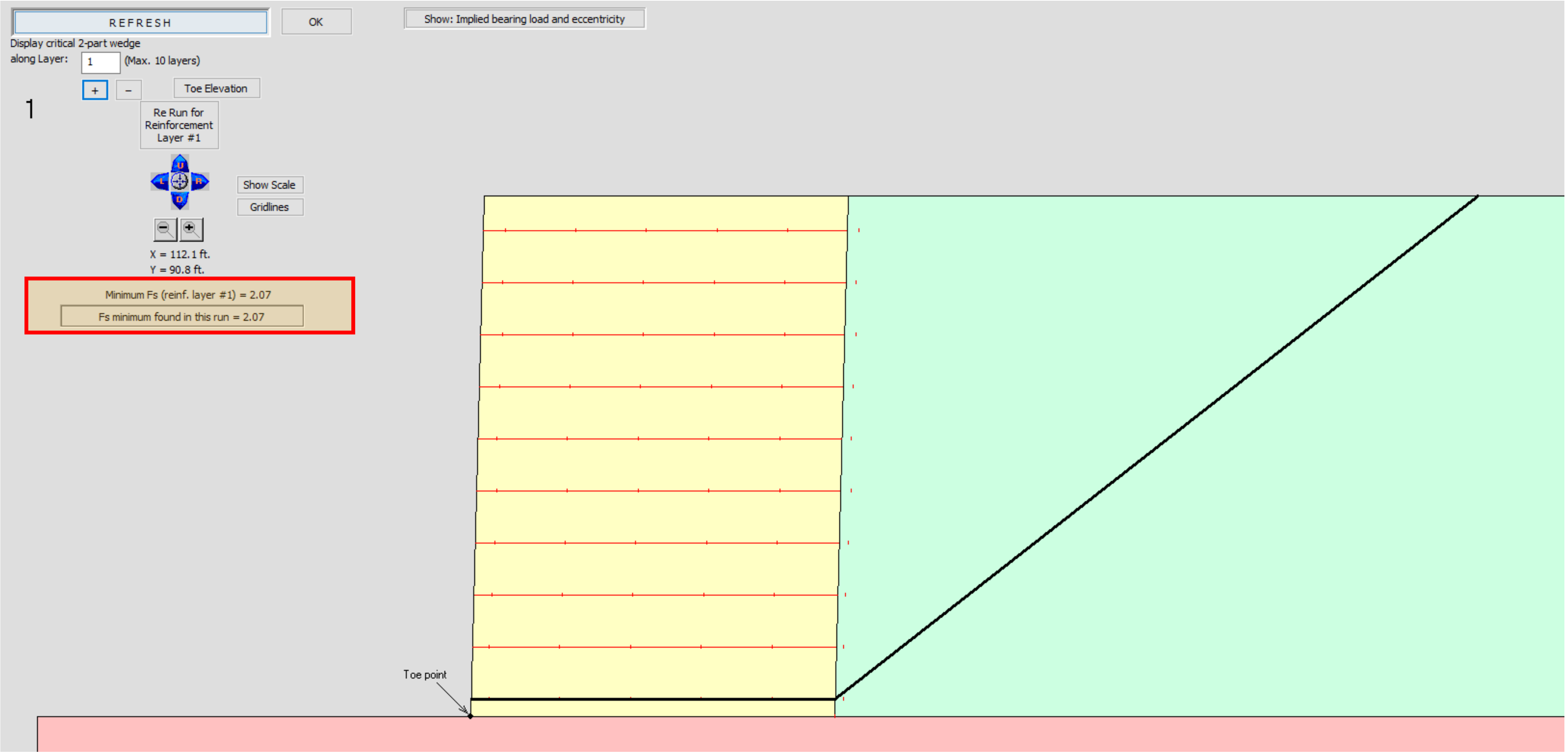
Safety Map Showing the Spatial Distribution of Fs on Soil Strength



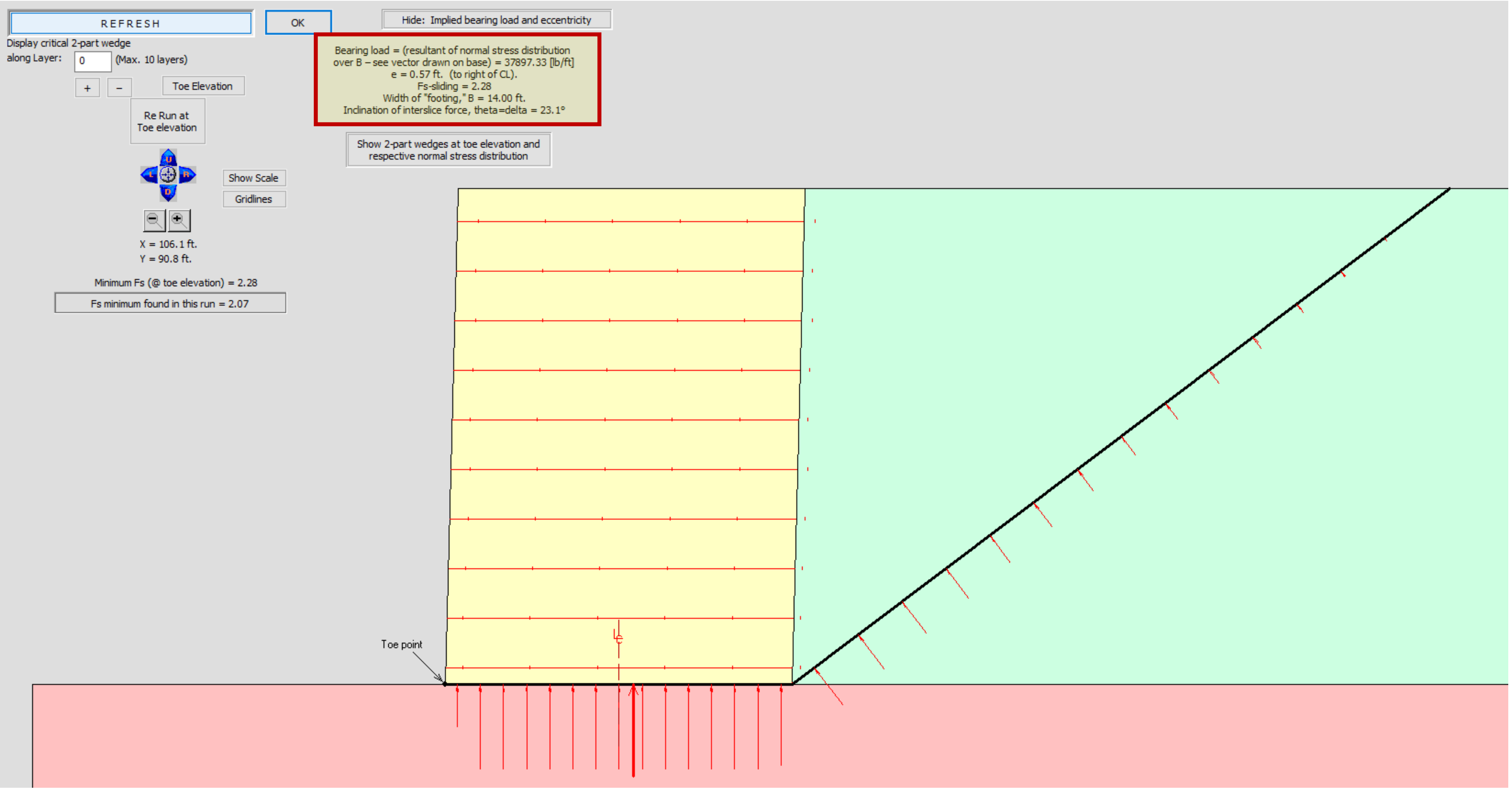
Stage II: T_{ult}=1.5 RF T_{max} = 3020 lb/ft
Run Global Stab.: Fs=1.39>1.30 OK



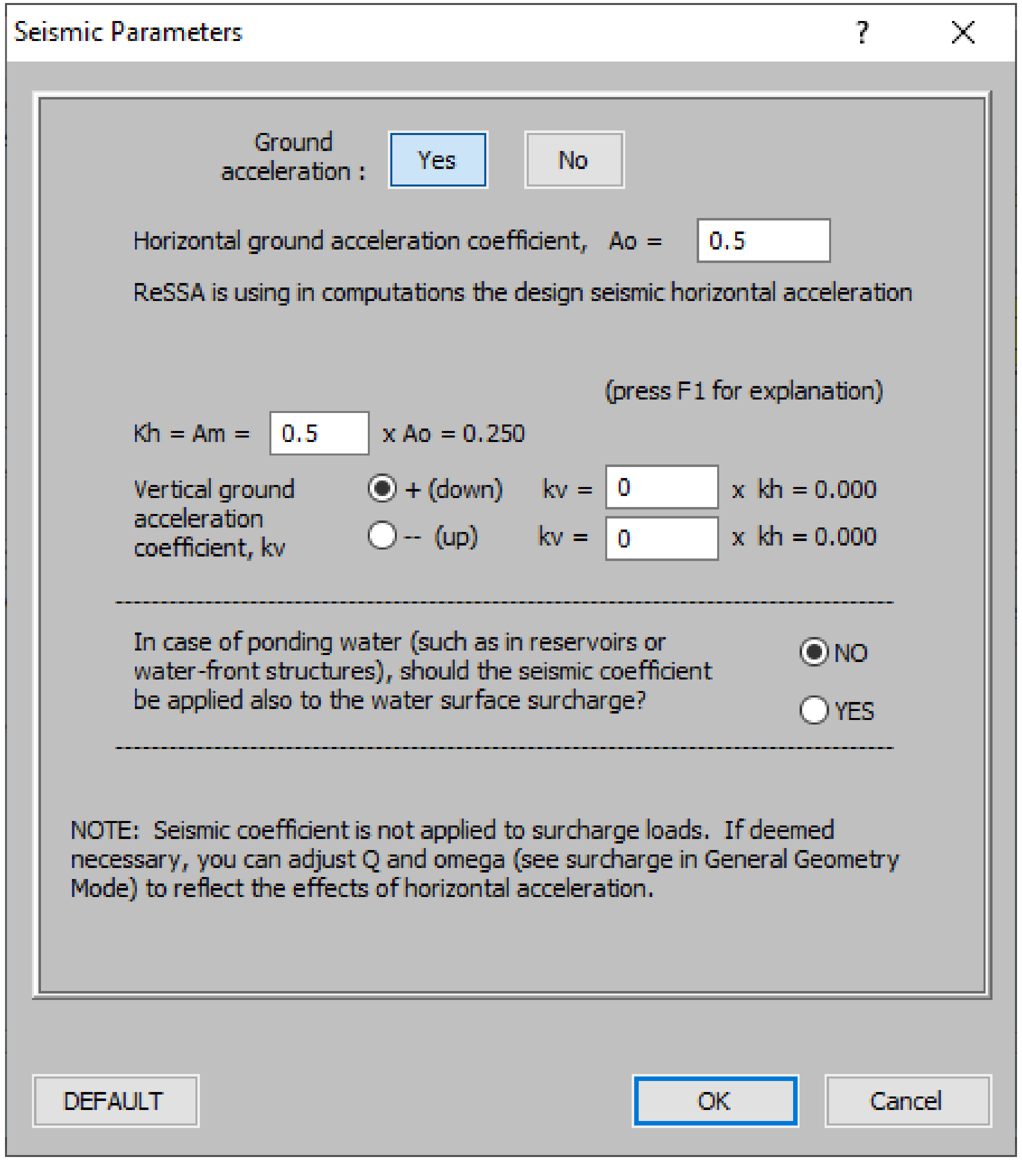
Run 2 Part Wedge Sliding using Spencer – Fs=2.07 OK



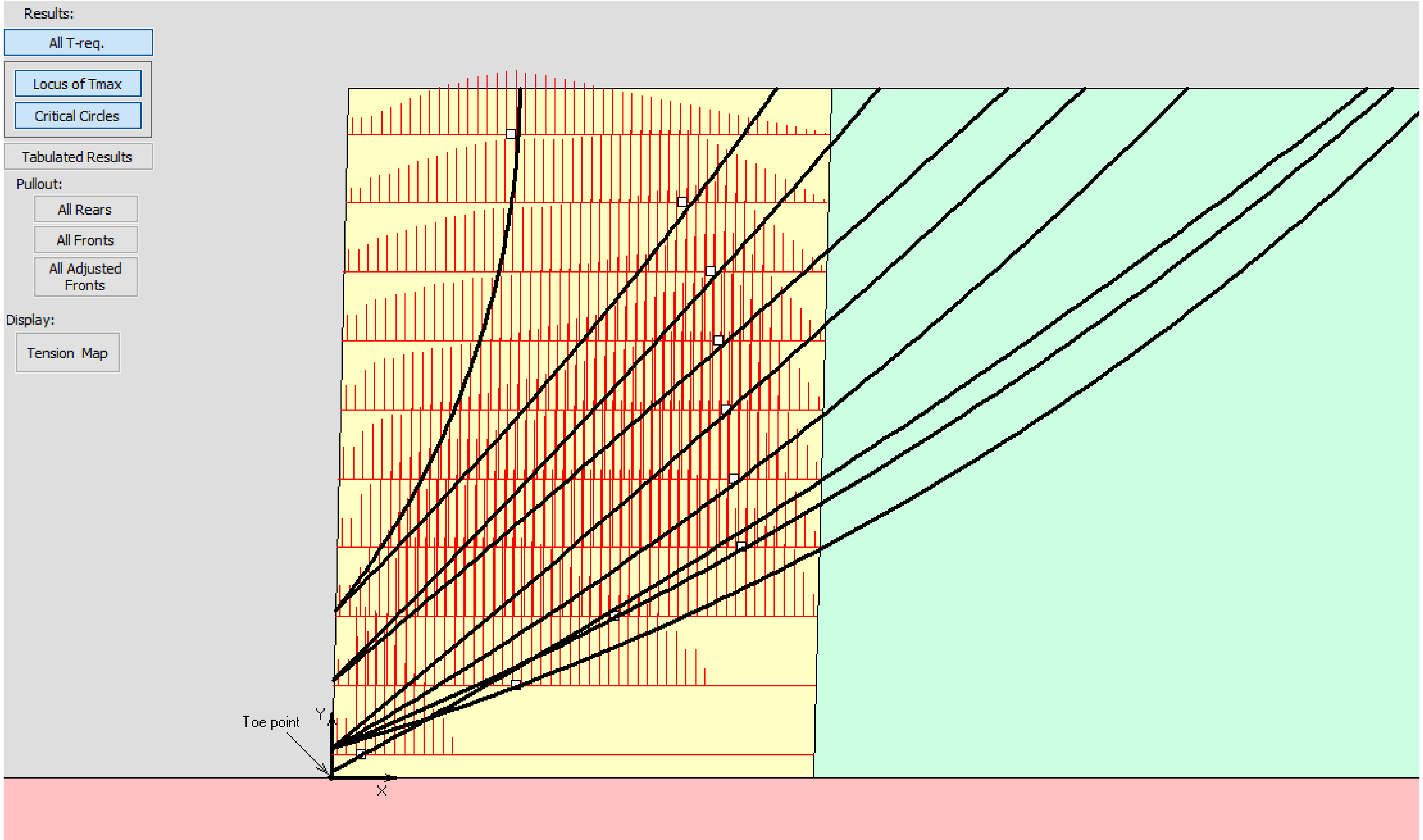
Using Spencer: Get Normal Stress → e, R and Meyerhof σ_v=R/(L-2e)



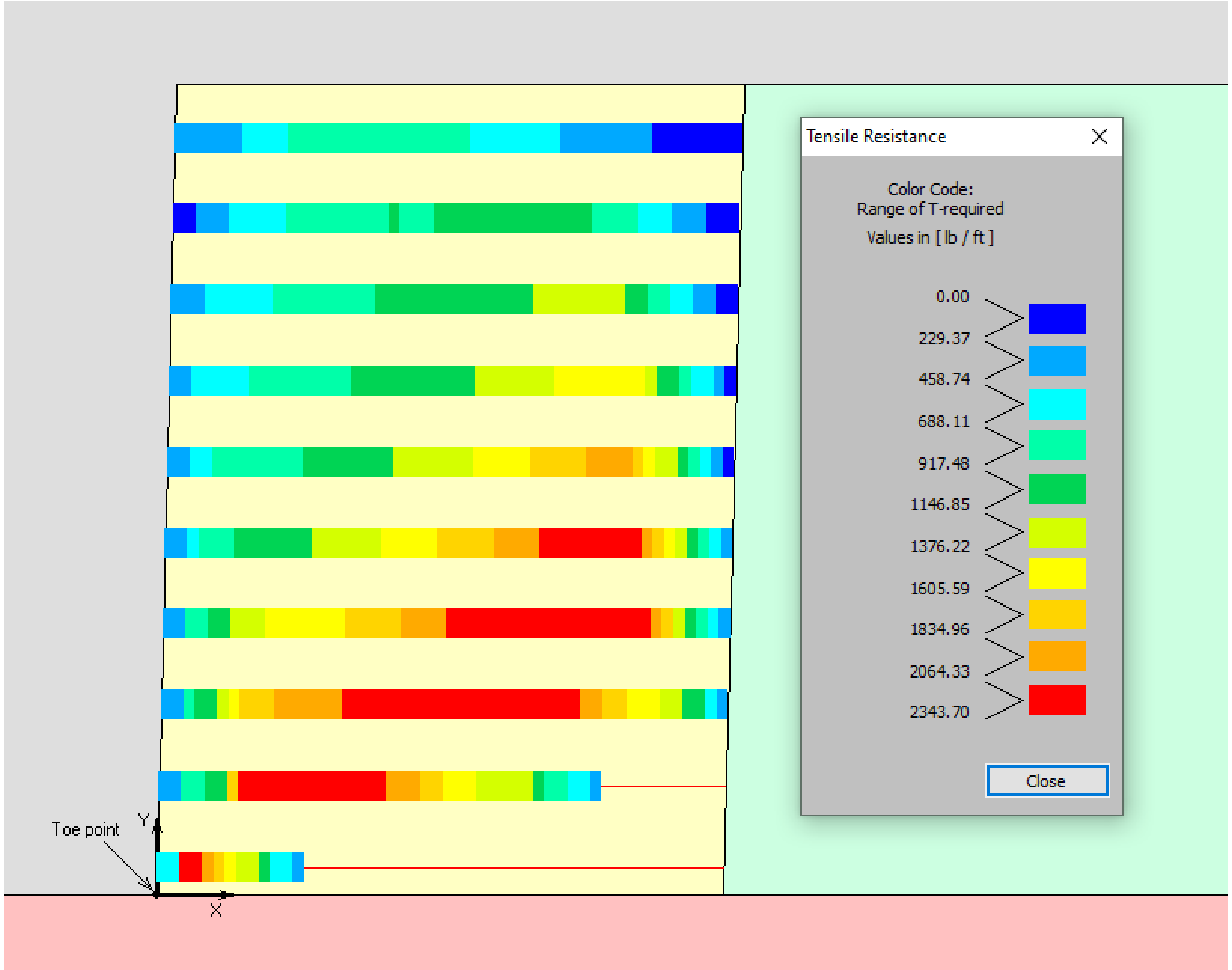
Let's get some seismic excitation



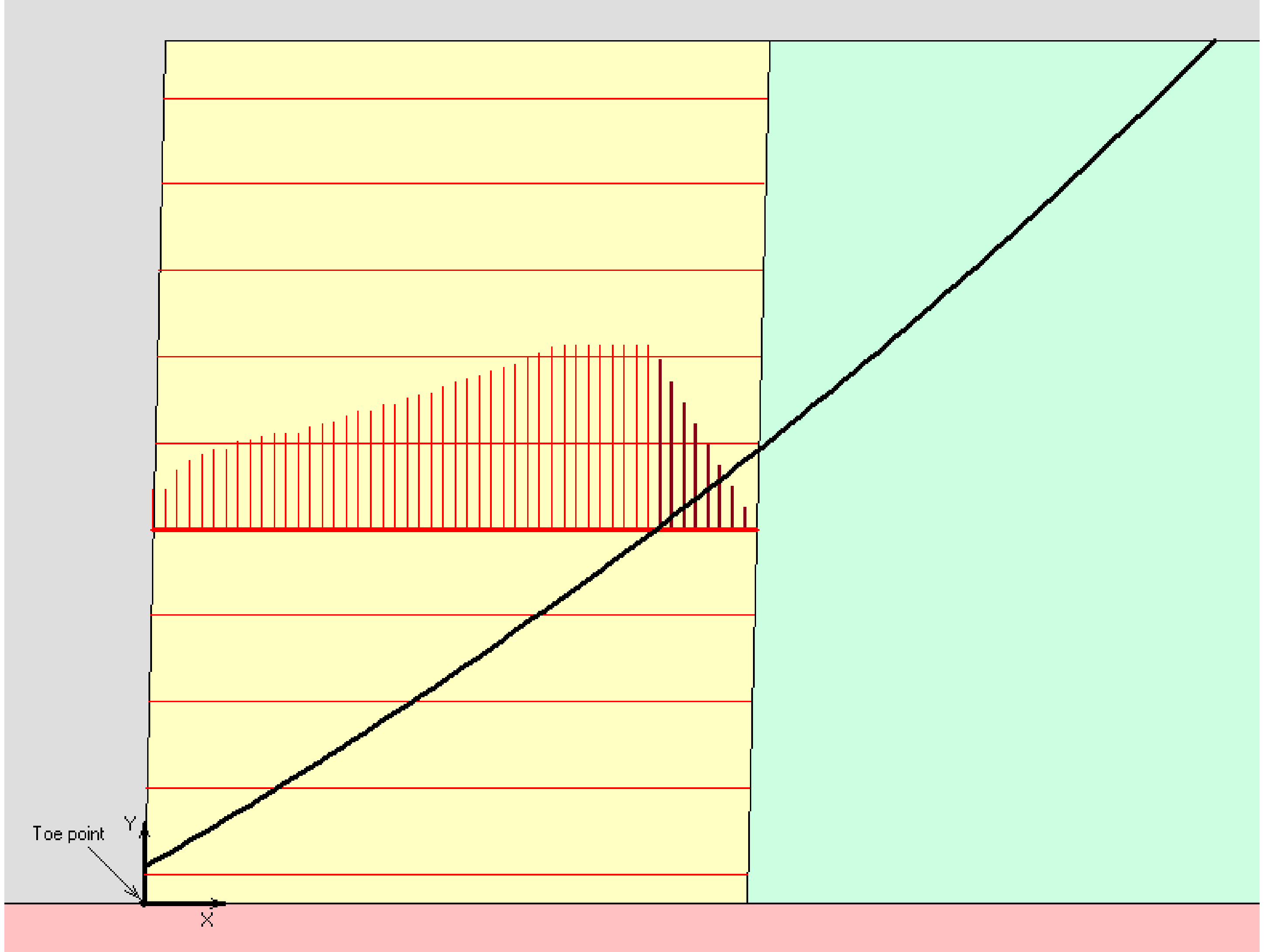
Change RFcr=1.0 and Run Baseline



Tension Map Indicates the Impact of Compound Stability



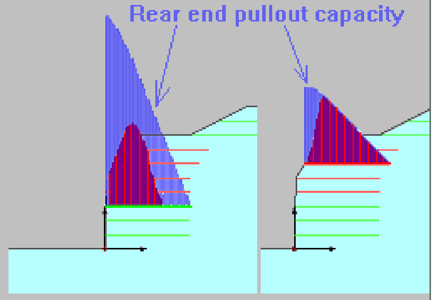
Under Seismic Loading Pullout May Play Significant Role

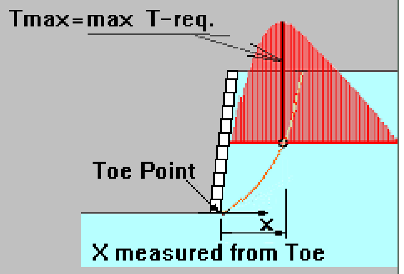


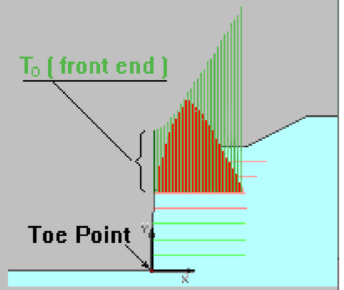
While Tmax increases, taking RFcr=1.0 Renders Adequate Reinforcement Strength → System is stable

Tabulated Results – Stage I ("Internal Stability")

Layer No.	Height from Toe [ft]	Current input of LTDS * [lb/ft]	Fs-reinf.= LTDS / Tmax	T-required: T max [lb/ft]	T-required: Located at X from Toe [ft]	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
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 = Tult / (RFid * RFd * RFcr * RFa) where Tult 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.
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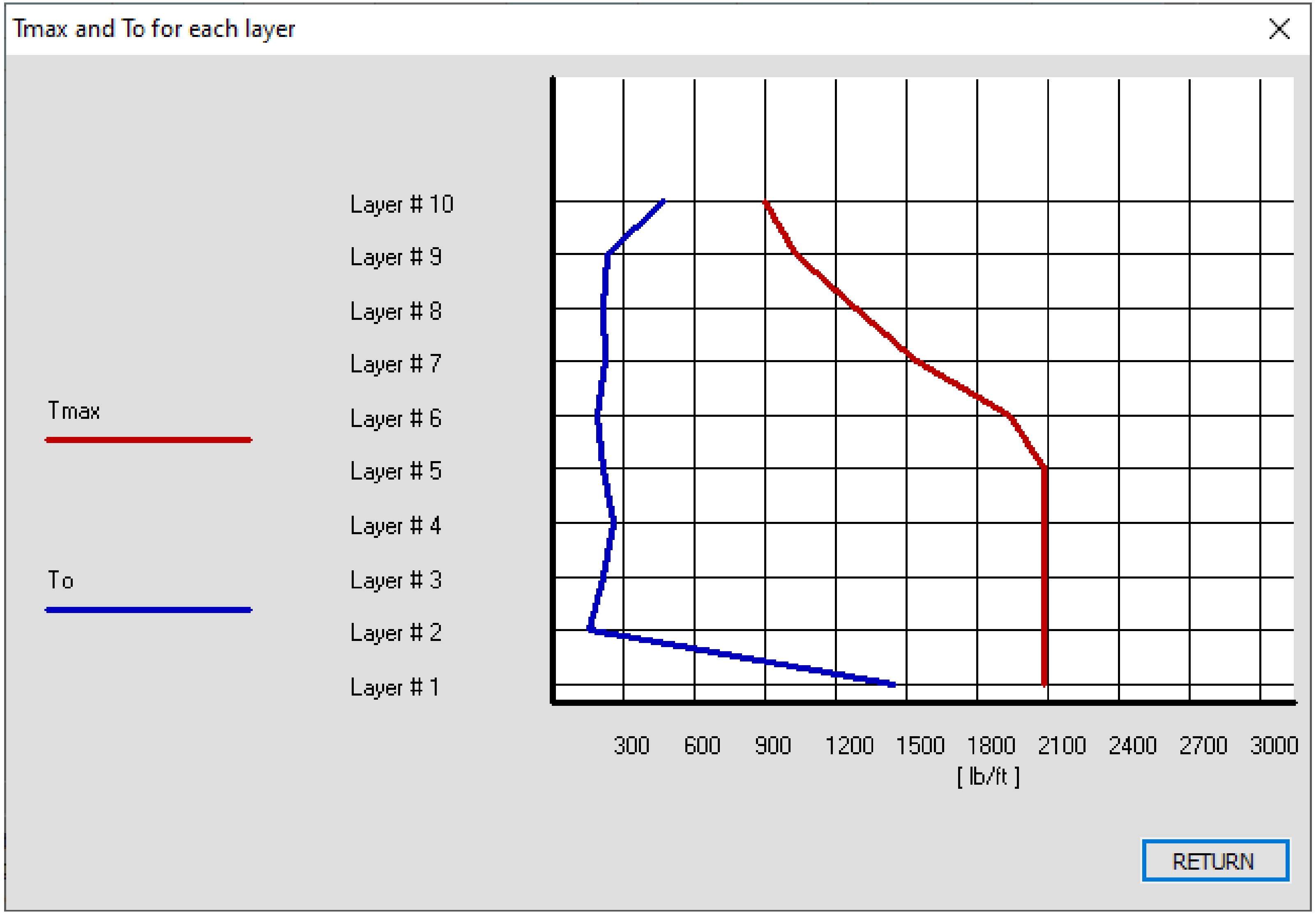
It is suggested that you read and understand the commentary in FHWA-HIF-17-004, Section 10.5, pp. 105-108, including Fig 10-37.

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

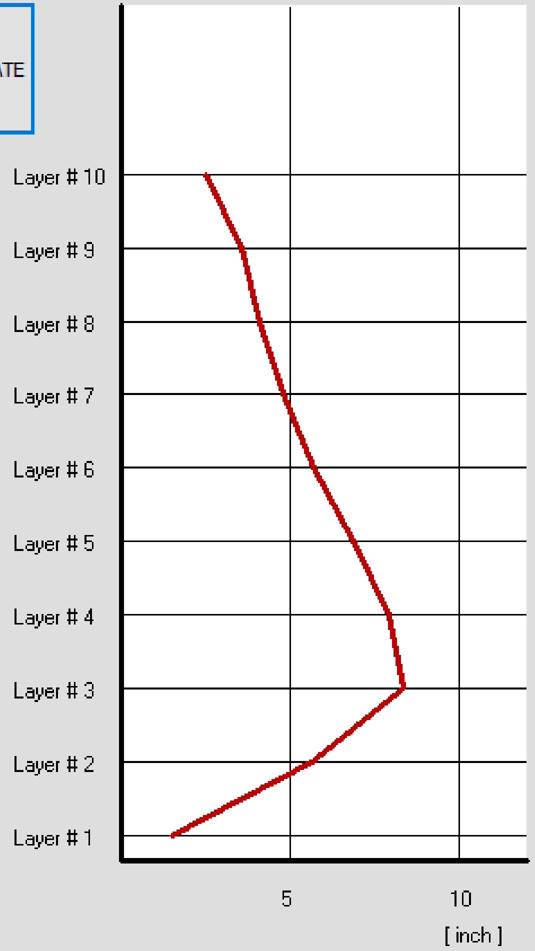


Also Displacement is large at Bottom Layers

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	2074.18	34000	1.53
2	2.67	2074.18	34000	5.67
3	4.67	2074.18	34000	8.34
4	6.67	2074.18	34000	7.96
5	8.67	2074.18	34000	6.90
6	10.67	2074.18	34000	5.72
7	12.67	2074.18	34000	4.80
8	14.67	2074.18	34000	4.14
9	16.67	2074.18	34000	3.56
10	18.67	2074.18	34000	2.53

CALCULATE



NOTES:

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

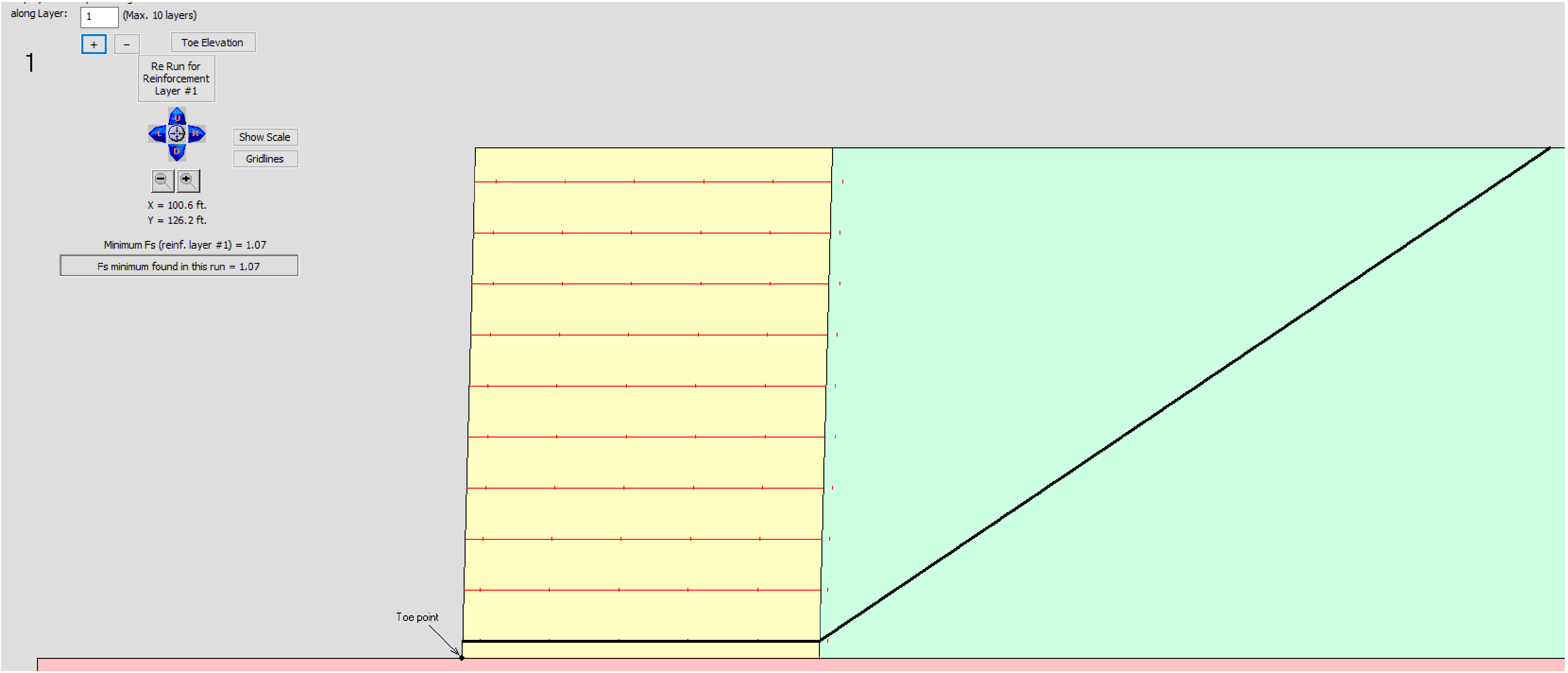
$$d=\sum_{i=1}^{n}\left(\frac{T_i}{J}\right)\Delta X_i$$

Where: Ti 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.

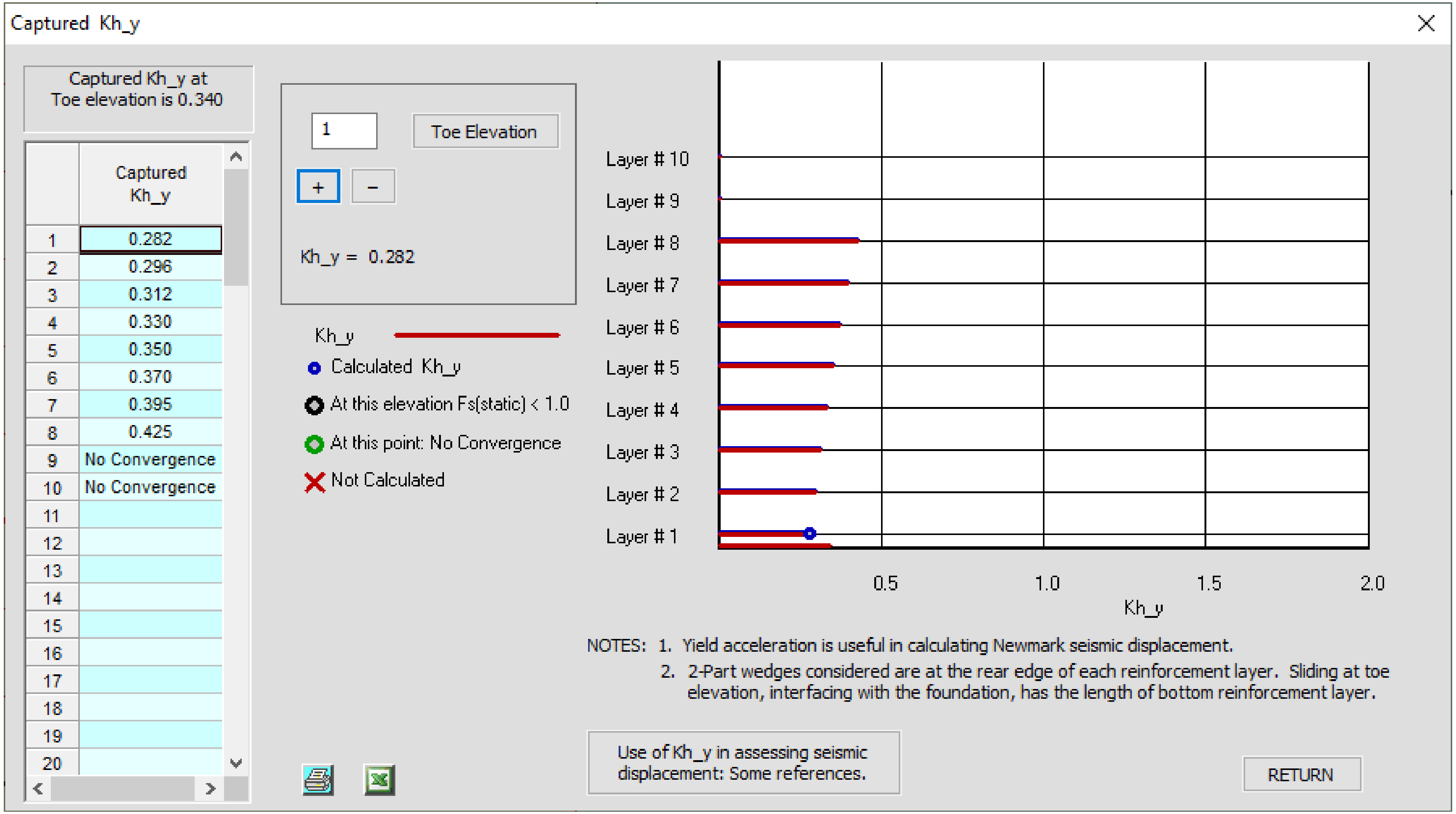
3. The displacement d is solely due to estimated cumulative elongation of the reinforcement. It does not reflect possible translational movement of the reinforced mass. To avoid translational movement, conduct 2-part wedge global stability analysis (in Global Stability mode) verifying that for the selected layout of reinforcement the global Fs is adequate, typically >1.3 .

DEFAULT OK Cancel

Global Stability Sliding: Fs=1.07 OK



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



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