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North Tarrant Express (NTE) 2E

Fugro Technical Memo No. 2

To: Jiri Filipovic, PE – AECOM
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From: Yanfeng Li, P.E. & Chula B. Ellepola, P.E.
Date: November 20, 2009
Fugro Project No.: 04-4009-1031
AECOM Contact No.: 112671 (114801.12.24)

Re: Preliminary Geotechnical Recommendations for MSE Retaining Walls – **Fill Sections**

This design memorandum presents geotechnical information for the design of mechanically stabilized earth retaining walls (MSE RW) proposed for the NTE Segment 2E project. This type of retaining wall is proposed for fill sections. Our recommendations are based on the following:

- Plan and profile drawings and cross sections provided by AECOM Technical Services, Inc.;
- Subsurface information obtained through the advancement of 21 borings (4 pavement borings, 8 bridge borings and 9 interchange borings) by Fugro Consultants, Inc. (Fugro); and
- A soil survey performed for TxDOT by CTL Thompson (2005) and provided to Fugro.

This information is preliminary and is aimed at providing the design team with adequate information to dimension the mechanically stabilized earth retaining walls to develop a bill of quantity (BOQ). Additional borings and analyses are required to develop final geotechnical design recommendations.

Discussion

The CTL Thompson study performed for TxDOT was a soil survey aimed at determining the potential vertical rise (PVR) of the pavement subgrade and, as such, the borings did not provide information about the stiffness of the subgrade. Therefore, our recommendations are based on the 21-widely spaced Fugro borings. Based on the provided cross sections, a total of 47 retaining walls are proposed within Segment 2E. Out of these 47 walls, 37 retaining walls are indentified as fill walls and 10 retaining walls are indentified as cut walls. The approximate locations (start and end stations) and maximum heights of these fill walls are estimated from the provided cross sections and are presented in Table 3. We divided the subgrade conditions for these retaining walls into three (3) groupings:

1. **Soft Subgrades:** These are areas where the surficial subgrade beneath the proposed retaining wall is soft. These areas can support a maximum wall height of 10 feet without experiencing bearing capacity and global stability failure. The subgrade beneath the proposed retaining wall has to be improved to a depth equal to 70 percent of the height of the proposed MSE RW (0.7H) for taller MSE retaining walls to be constructed in these areas or to the depths shown on Table No. 3. The soft soils have to be excavated and replaced with clays compacted to a greater density or with flexbase, granular aggregate, and/or stone columns. A more expensive alternative is to carry the vehicular traffic on a bridge;
2. **Very Stiff Subgrades:** These are areas where the surficial subgrade beneath the proposed retaining wall is very stiff. These areas can support a maximum wall height of 20 feet without experiencing bearing capacity and global stability failure. The subgrade beneath the proposed retaining wall has to be improved to a depth equal to 70 percent of the height of the proposed MSE RW (0.7H) for taller MSE retaining walls to be constructed in these areas or to the depths shown on Table No. 3. The very stiff soils have to be excavated and replaced with flexbase, granular aggregate, and/or stone columns. A more expensive alternative is to carry the vehicular traffic on a bridge; and
3. **Hard Subgrades:** These are areas where the surficial subgrade beneath the proposed retaining wall is hard. These areas can support a maximum wall height of 40 feet without experiencing bearing capacity and global stability failure. Based on the information available to us, our calculations indicate that this is the maximum height that the NTE Segment 2E project area can support. Even then, there may be differential settlement issues at the interface of the MSE select fill and clay retained fill of the embankments, at approach slabs, and at the abutments. ***We recommend using bridge structures in lieu of embankments exceeding 40 feet in height***.

Table 3 summarizes the information and provides preliminary quantifiable recommendations to perform the BOQ estimates.

Mechanically Stabilized Earth Retaining Walls

Mechanically stabilized earth retaining walls are constructed in fill conditions by placing alternate layers of granular material and reinforcing elements. This reinforced mass is used to retain clay and unreinforced granular soil embankments, which are called retained fill. The retained fill will exert lateral forces on the reinforced mass, which can cause it to slide on its base, rotate around the toe of the retaining wall, experience bearing capacity failure, and/or experience global stability failure. The resistance to these factors is produced by the frictional forces generated within the reinforced mass by the interaction of the weight of the select fill on the reinforcing elements. A non-erodable facing is used to provide an aesthetic appearance and prevent erosion of the MSE retaining wall face. Thus, the stability of a retaining wall is analyzed for the following conditions:

I. External Stability:

1. Determining the resistance against base sliding,
2. Determining the resistance against overturning,
3. Determining the resistance against bearing capacity failure,
4. Limiting the eccentricity of the resultant forces, and
5. Determining the global stability.

II. Internal Stability

1. Determination of the tensile strength of the reinforcement; and
2. Determination of the pullout resistance of the reinforcement.

Typically, the geotechnical engineer and the MSE RW structural engineer have to work together and feed each other design information to perform the stability analyses. We performed the external stability analyses for the three subgrade conditions discussed in this tech memo.

Material Properties

The properties of the materials used in our analyses are presented in Table 1.

Table 1. Material Properties

Material	Cohesion, C, psf		Angle of Internal Friction, °		Unit Weight, pcf	Coefficient of Lateral Pressure, Ka
	Effective Stress	Total Stress	Effective Stress	Total Stress		
MSE Select Fill	0	0	34	34	125	0.28
Retained Fill (Fat Clay)	150	800	21	0	125	0.47
Soft Subgrade	125	750	19	0	125	-
Very Stiff Subgrade	150	1,500	24	0	125	-
Hard	175	2,500	29	0	125	-

Results of the MSE Retaining Wall Stability Analyses

The sliding, overturning, bearing capacity, and eccentricity analyses were performed using the methodology shown on Attachment 1 of this memo. Global stability analyses were performed for the tallest wall section for long-term (effective stress) and short-term (total stress) conditions. For the purpose of expediting information to the wall designer, discussion of the results have been curtailed. The analyses results are summarized in Table 2 below.

Table 2. Results and Recommendations for the Preliminary Design of MSE Retaining Walls

Parameters	Soft Subgrade	Very Stiff Subgrade	Hard Subgrade
Max. Wall Height, H, ft.	10	20	40
Embedment, E, ft.	H/10 or 2 feet, whichever is more		
Max. Bearing Pressure, ksf	2.23	3.87	6.34
Max. Limiting Eccentricity, e, ft.	1.31	2.32	3.45
Safe for Global Bearing Capacity for Effective Stress (Long Term)	Yes	Yes	Yes
Safe for Global Bearing Capacity for Total Stress (Short Term)	Yes	Yes	Yes
Safe for Local Shear	Yes	Yes	Yes
Safe against Sliding	Yes	Yes	Yes
Safe against Overturning	Yes	Yes	Yes

Table 2. Results and Recommendations for the Preliminary Design of MSE Retaining Walls

Parameters	Soft Subgrade	Very Stiff Subgrade	Hard Subgrade
Meets the Eccentricity Criteria (< W/6)	Yes	Yes	Yes
Width of the Reinforced (Select Fill) Volume, W, ft.	0-10' - 0.7H (Minimum of 8 ft.)	0-10' – 0.7H 10-15' – 0.75H 15-20' – 0.8H	0-10' – 0.7H 10-20' – 0.8H 20-30' – 0.9H 30-40' – 1.0H
Global Stability Safety Factor for *Effective* Stress Conditions using *Circular* Failure Surfaces at *Maximum* Wall Height, FS	1.62	1.61	1.68
Global Stability Safety Factor for *Total* Stress Conditions using *Circular* Failure Surfaces at *Maximum* Wall Height, FS	2.97	2.58	1.66
Global Stability Safety Factor for *Effective* Stress Conditions using *Block* Failure Surfaces at *Maximum* Wall Height, FS	1.42	1.41	1.42
Global Stability Safety Factor for *Total* Stress Conditions using *Block* Failure Surfaces at *Maximum* Wall Height, FS	2.13	1.87	1.48

The demarcation of the soft, very stiff, and hard subgrade areas were determined using the results of the borings advanced by us and are presented in the following table along with our recommendations to improve the subgrade for BOQ purposes.

Table 3. Subgrade Consistency and Subgrade Improvement Recommendations

Boring No.	RW No.	Approximate EMX Station Nos.		Max. Height (ft.)	Subgrade Consistency	Subgrade Improvement Recommendations
		Start	End			
2E-1& 2E-2	RWW01	1296	1298	17.4	stiff	None required
	RWW02	1301	1309	20	stiff	None required
	RWW03	1301	1310	22.4	stiff (0-5 ft.)	Overexcavate and replace stiff clay with flexbase for wall section higher than 20 ft .
	RWW04	1304	1320	4.8	stiff	None required

	RWE01	1296	1307	28.8	stiff (0-5 ft)	Overexcavate and replace stiff clay with flexbase for wall section higher than 20 ft.
	RWE02	1296	1322	30.2	stiff (0-5 ft)	
2E2 & 2E3, 2E4	RWW05	1313	1324	8.4	soft	None required
	RWW06	1320	1325	4.0	soft	None required
	RWW07	1326	1330	21.9	soft (0-4 ft) stiff (4-8 ft)	Overexcavate soft soil and replace with well-compacted soil for wall section between 10 and 20 ft. Overexcavate and replace soft and stiff soil with flexbase for wall section higher than 20 ft.
	RWW08	1334	1340	22.7	soft (0-4 ft) stiff (4-8 ft)	
	RWE03	1319	1321	2.3	soft	None required
	RWE04	1321	1330	27	soft (0-4 ft) stiff (4-8 ft)	Overexcavate soft soil and replace with well-compacted soil for wall section between 10 and 20 ft. Overexcavate and replace soft and stiff soil with flexbase for wall section higher than 20 ft.
	RWE05	1334	1342	20	soft (0-4 ft)	Overexcavate soft soil and replace with well-compacted soil for wall section between 10 and 20 ft.
	RWE06	1334	1337	4.0	soft	None required
2E3, 2E4 & 2E5, 2E6	RWW09	1340	1355	29.5	soft (0-5 ft) stiff (5-10 ft)	Overexcavate soft soil and replace with well-compacted soil for wall section between 10 and 20 ft. Overexcavate and replace soft and stiff soil with flexbase for wall section higher than 20 ft.
	RWW10	1340	1358	33.5	soft (0-5 ft) stiff (5-10 ft)	
	RWW11	1348	1358	12.4	soft (0-5 ft)	Overexcavate soft soil and replace with well-compacted soil for wall section higher than 10 ft.
	RWE07	1343	1358	20.0	soft (0-5 ft)	
2E5, 2E6 & 2E7A, 8A	RWW12	1362	1374	26.5	soft (0-4 ft) stiff (4-8 ft)	Overexcavate soft soil and replace with well-compacted soil for wall section between 10 and 20 ft. Overexcavate and replace soft and stiff soil with flexbase for wall section higher than 20 ft.
	RWW12A	1362	1375	25	soft (0-4 ft) stiff (4-8 ft)	
	RWE08	1362	1376	30.5	soft (0-4 ft) stiff (4-8 ft)	
	RWE08A	1362	1375	25.9	soft (0-4 ft) stiff (4-8 ft)	
	RWE08B	1362	1375	5	soft	None required
	RWE09	1363	1365	5	soft	None required

2E7A, 2E8A & 2E9, 2E10	RWW14	1386	1394	9.5	soft	None required
	RWW19	1412	1424	24	soft (0-4 ft) stiff (4-8 ft)	Overexcavate soft soil and replace with well-compacted soil for wall section between 10 and 20 ft. Overexcavate and replace soft and stiff soil with flexbase for wall section higher than 20 ft.
	RWE11	1380	1385	7	soft	None required
	RWE13	1397	1403	3.2	soft	None required
	RWE15	1402	1409	4	soft	None required
	RWE17	1401	1408	28	soft (0-4 ft) stiff (4-8 ft)	Overexcavate soft soil and replace with well-compacted soil for wall section between 10 and 20 ft. Overexcavate and replace soft and stiff soil with flexbase for wall section higher than 20 ft.
	RWE18	1404	1408	19	soft (0-4 ft) stiff (4-8 ft)	Overexcavate soft soil and replace with well-compacted soil for wall section higher than 10 ft.
2E9, 2E10 & 2E11, 2e12	RWE19	1434	1442	9.6	soft	None required
2E11, 2E12 & 2E13, 2E14	RWE20	1467	1470	11.3	soft (0-3 ft)	Overexcavate soft soil and replace with well-compacted soil for wall section higher than 10 ft.
	RWE21	1467	1470	16.3	soft (0-3 ft)	
2E13, 14 & 2E15	RWE22	1471	1483	3.5	soft	None required
	RWE23	1481	1488	23.6	soft (0-3 ft) stiff (3-6 ft)	Overexcavate soft soil and replace with well-compacted soil for wall section between 10 and 20 ft. Overexcavate and replace soft and stiff soil with flexbase for wall section higher than 20 ft.
	RWE24	1481	1488	23.9	soft (0-3 ft) stiff (3-6 ft)	

Additional design recommendations concerning all preliminary aspects of the design and construction of the MSE retaining walls will be provided in our geotechnical report to be produced later. In preparation of this memorandum, we have strived to perform our services in a manner consistent with that level of care and skill ordinarily exercised by other members of our profession currently practicing in the same locality under similar conditions. No other representation, express or implied is included or intended in this report, any addendum report, opinion, document, or other instrument of service.

ATTACHMENTS

The following are attached to this memorandum:

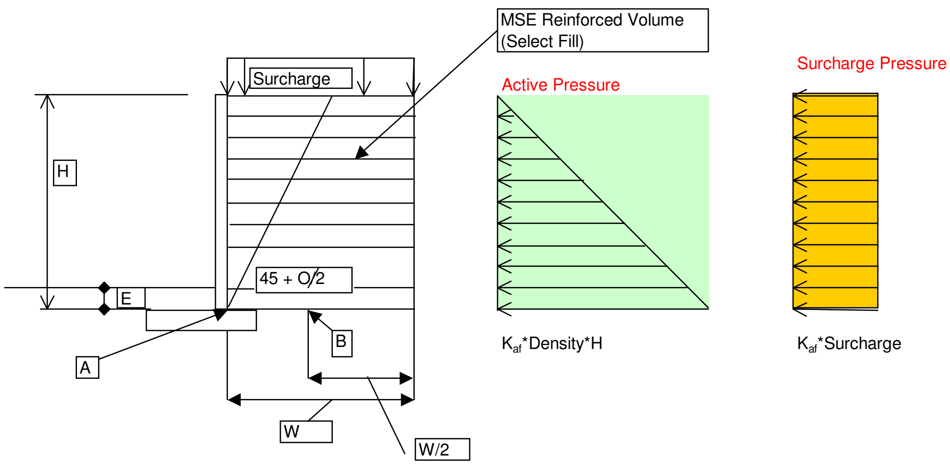
1. *The MSE analysis outputs for soft, stiff, and hard subgrade soils*
2. *Global stability analyses for soft, stiff, and hard subgrade soils*

Attachment 1

Project No.: 04-4009-1031
Project Name: North Tarrant Express (NTE) - Segment 2E
Location: Soft Subgrade Foundation Soils
City, State: Tarrant County, Texas

Date: 11/16/2009

Pertinent Borings:



Given

H (ft)		10	
W (ft)	0.8	8	W = 0.7H to 1.0H
Surcharge (ksf)		0.25	
SF Unit Weight (kcf)		0.125	
SF Friction Angle (degrees)		34	
Subgrade Density, kcf		0.125	
SF-Subgrade Friction Angle		34	
Embedment, E, ft.		2	
Friction Angle - Retained Fill, °		21	
Unit Weight - Retained Fill, kcf		0.125	

1) Active and Passive Pressure

Reinforced Volume-Select Fill

Ka	0.283	0.283
Kp	3.534	3.534

Retained Fill

Kaf	0.472	0.472
Kpf	2.119	2.119

2) Failure Plane

Reinforced Volume-Select Fill

Angle from vertical: (45-ϕ/2) 28

Retained Fill

Angle from vertical: (45-ϕ/2) 34.5

3) Stability calculations: (exclude vertical surcharge force - not always present - increases stability)

Moment about Point A: (neglect soil over toe)

Area		Sum Vertical Force kips	Sum Hor. Force kips	Arm ft.	Moment kip-ft.
MSE SF	H*W*Density	10		4	40.00
Active Pressure-retained fill	0.5*K$_{af}$*Density*H^2		2.95	3.33	9.83
Surcharge-retained fill	K$_{af}$*Surcharge		1.18	5.00	5.90

4) Bearing Pressure Calculation (include vertical surcharge pressure)

Area		Sum Vertical Force kips	Sum Hor. Force Kips	Arm ft.	Moment kip-ft.
Surcharge	surcharge*W	2		4	8.00
	Total	12	4.13		

5) Locate Resultant

eccentricity, e= sum of moments about Point B (midpoint of MSE SF) / sum of vertical forces

eccentricity, e= 15.73 / 12

eccentricity, e= 1.31 ft.

6) Use Meyerhoff's Pressure Distribution to Determine Max. Bearing Pressure

Max. Bearing Pressure: sum vertical forces / W-2*e

Max. Bearing Pressure: 12 / 5.38

Max. Bearing Pressure: 2.23 ksf

7) Check Ultimate Bearing Capacity - Strip with Width W - Subgrade Soils

$$q_u = C * N_c + \gamma * D_f * Nq + 0.5 * W * \gamma * N_\gamma$$

General Shear

$$q = \frac{2}{3} C * N_c + \gamma * D_f * N'q + 0.5 * W * \gamma * N'_\gamma$$

Local Shear - Das (assumes a 33% reduction in cohesion and tan Ø)

Pick values from the tables in the "*Bearing Capacity Factor*" sheet

Subgrade Soils **Soft**

Long Term (effective stress)

Cohesion, C: 125 ksf

Angle of internal friction: 19 degrees

General Shear

Df= 2 ft.
Nc= 23.36
Nq= 11.4
$N\gamma =$ 7.08

Local Shear

D'f= 2 ft.
N'c= 23.36
N'q= 3.61
$N'\gamma =$ 1.03

Short Term (total stress)

Cohesion, C: 0.75 ksf

Angle of internal friction: 0 degrees

General Shear

Df= 2 ft.
Nc= 5.7
Nq= 1
$N\gamma =$ 0

Local Shear

D'f= 2 ft.
N'c= 5.7
N'q= 1
$N'\gamma =$ 0

Shear Type	Long or Short Term	Ultimate Bearing Capacity, ksf	Max. Bearing Pressure, ksf	Factor of Safety	Min. Safety Factor	Condition
General	Long	2926.39	2.23	1312.28	2	Good
General	Short	4.53	2.23	2	2	Good
Local	Long	1948.08	2.23	873.58	2	Good
Local	Short	3.1	2.23	1.39	2	Inadequate safety factor by Das

Local Shear (FHWA Method)

To prevent large horizontal movements of the structure on weak soils, H< 3C/(Density of subgrade soil)

H < 18 ft.

8) Check Sliding

FS-sliding= Resisting Force / Driving Force = Friction / Active Pressure = Vertical Force * tan (Q) / Active Pressure

FS-sliding= 1.63 Min. FS-sliding= 1.5

FS-Sliding Condition: Safe against sliding

9) Check Overturning

Moments about Point A:

FS-overturning= Moments Resisting Overturning / Moments Driving Overturning = 40.00 / 15.73

FS-overturning= 2.54 Min. FS-Overturning= 2.0

FS-overturning Condition: Safe against overturning

10) Global Stability Analyses

Use GSTABL7 or UTEXAS4 for effective and total stress conditions

Summary

Retaining Wall Height 10 ft. **Subgrade Stiffness:** **Soft**

Footing Width, W 8 ft.

Max Bearing Pressure: 2.23 ksf

Eccentricity, e= 1.31 ft.

Embedment, E= 2 ft.

Shear Type	Long or Short Term	Ultimate Bearing Capacity, ksf	Max. Bearing Pressure, ksf	Factor of Safety	Min. Safety Factor	Condition
General	Long	2926.39	2.23	1312.28	2	Good
General	Short	4.53	2.23	2	2	Good
Local	Long	1948.08	2.23	873.58	2	Good
Local	Short	3.1	2.23	1.39	2	Inadequate safety factor by Das

Max. Height of Wall for Local Shear = 18 ft. Use this value instead of Das's values for local shear

FS-Sliding Condition: 1.63 Safe against sliding

FS-overturning Condition: 2.54 Safe against overturning

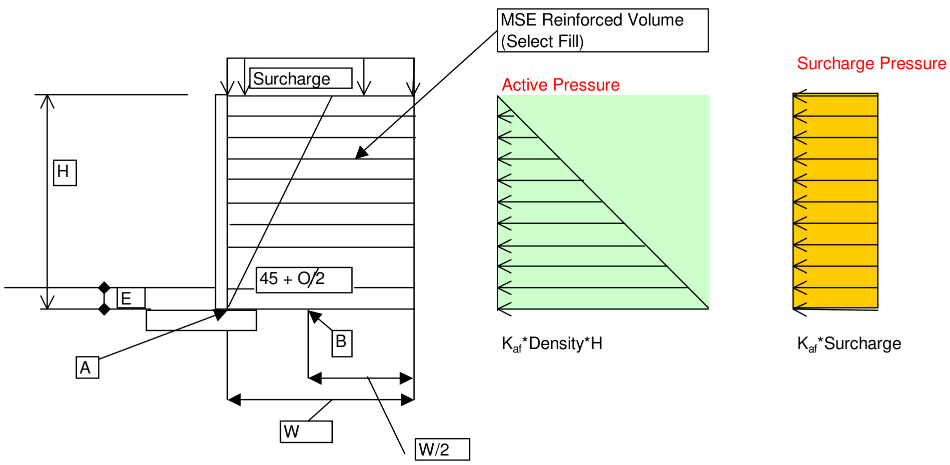
Eccentricity, e = 1.31 W/6-soil= 1.333 Good

W/4-rock=

Project No.: 04-4009-1031
Project Name: North Tarrant Express (NTE) - Segment 2E
Location: Stiff Subgrade Foundation Soils
City, State: Tarrant County, Texas

Date: 11/16/2009

Pertinent Borings:



Given

H (ft)		20
W (ft)	0.8	16
Surcharge (ksf)		0.25
SF Unit Weight (kcf)		0.125
SF Friction Angle (degrees)		34
Subgrade Density, kcf		0.125
SF-Subgrade Friction Angle		34
Embedment, E, ft.		2
Friction Angle - Retained Fill, °		21
Unit Weight - Retained Fill, kcf		0.125

W = 0.7H to 1.0H

1) Active and Passive Pressure

Reinforced Volume-Select Fill

Ka	0.283	0.283
Kp	3.534	3.534

Retained Fill

Kaf	0.472	0.472
Kpf	2.119	2.119

2) Failure Plane

Reinforced Volume-Select Fill

Angle from vertical: (45-Ø/2) 28

Retained Fill

Angle from vertical: (45-Ø/2) 34.5

3) Stability calculations: (exclude vertical surcharge force - not always present - increases stability)

Moment about Point A: (neglect soil over toe)

Area		Sum Vertical Force kips	Sum Hor. Force kips	Arm ft.	Moment kip-ft.
MSE SF	H*W*Density	40		8	320.00
Active Pressure-retained fill	0.5*K_{af}*Density*H^2		11.80	6.67	78.67
Surcharge-retained fill	K_{af}*Surcharge		2.36	10.00	23.60

4) Bearing Pressure Calculation (include vertical surcharge pressure)

Area		Sum Vertical Force kips	Sum Hor. Force Kips	Arm ft.	Moment kip-ft.
Surcharge	surcharge*W	4		8	32.00
	Total	44	14.16		

5) Locate Resultant

eccentricity, e= sum of moments about Point B (midpoint of MSE SF) / sum of vertical forces

eccentricity, e= 102.27 / 44

eccentricity, e= 2.32 ft.

6) Use Meyerhoff's Pressure Distribution to Determine Max. Bearing Pressure

Max. Bearing Pressure: sum vertical forces / W-2*e

Max. Bearing Pressure: 44 / 11.36

Max. Bearing Pressure: 3.87 ksf

7) Check Ultimate Bearing Capacity - Strip with Width W - Subgrade Soils

$$q_u = C * N_c + \gamma * D_f * Nq + 0.5 * W * \gamma * N_\gamma$$

General Shear

$$q = \frac{2}{3} C * N_c + \gamma * D_f * N'q + 0.5 * W * \gamma * N'_\gamma$$

Local Shear - Das (assumes a 33% reduction in cohesion and tan Ø)

Pick values from the tables in the "*Bearing Capacity Factor*" sheet

Subgrade Soils **Very Stiff**

Long Term (effective stress)

Cohesion, C: 0.15 ksf

Angle of internal friction: 24 degrees

General Shear

Df= 2 ft.

Nc= 23.36

Nq= 11.4

$N\gamma =$ 7.08

Local Shear

D'f= 2 ft.

N'c= 23.36

N'q= 3.61

$N'\gamma =$ 1.03

Short Term (total stress)

Cohesion, C: 1.5 ksf

Angle of internal friction: 0 degrees

General Shear

Df= 2 ft.

Nc= 5.7

Nq= 1

$N\gamma =$ 0

Local Shear

D'f= 2 ft.

N'c= 5.7

N'q= 1

$N'\gamma =$ 0

Shear Type	**Long or Short Term**	**Ultimate Bearing Capacity, ksf**	**Max. Bearing Pressure, ksf**	**Factor of Safety**	**Min. Safety Factor**	**Condition**
General	Long	13.43	3.87	3.47	2	Good
General	Short	8.8	3.87	2.27	2	Good
Local	Long	4.27	3.87	1.1	2	Inadequate safety factor by Das
Local	Short	5.95	3.87	1.54	2	Inadequate safety factor by Das

Local Shear (FHWA Method)

To prevent large horizontal movements of the structure on weak soils, H< 3C/(Density of subgrade soil)

H < 36 ft.

8) Check Sliding

FS-sliding= Resisting Force / Driving Force = Friction / Active Pressure = Vertical Force * tan (Φ) / Active Pressure

FS-sliding= 1.91 Min. FS-sliding= 1.5

FS-Sliding Condition: Safe against sliding

9) Check Overturning

Moments about Point A:

FS-overturning= Moments Resisting Overturning / Moments Driving Overturning = 320.00 / 102.27

FS-overturning= 3.13 Min. FS-Overturning= 2.0

FS-overturning Condition: Safe against overturning

10) Global Stability Analyses

Use GSTABL7 or UTEXAS4 for effective and total stress conditions

Summary

Retaining Wall Height 20 ft. **Subgrade Stiffness:** **Very Stiff**

Footing Width, W 16 ft.

Max Bearing Pressure: 3.87 ksf

Eccentricity, e= 2.32 ft.

Embedment, E= 2 ft.

Shear Type	Long or Short Term	Ultimate Bearing Capacity, ksf	Max. Bearing Pressure, ksf	Factor of Safety	Min. Safety Factor	Condition
General	Long	13.43	3.87	3.47	2	Good
General	Short	8.8	3.87	2.27	2	Good
Local	Long	4.27	3.87	1.1	2	Inadequate safety factor by Das
Local	Short	5.95	3.87	1.54	2	Inadequate safety factor by Das

Max. Height of Wall for Local Shear = 36 ft. Use this value instead of Das's values for local shear

FS-Sliding Condition: 1.91 Safe against sliding

FS-overturning Condition: 3.13 Safe against overturning

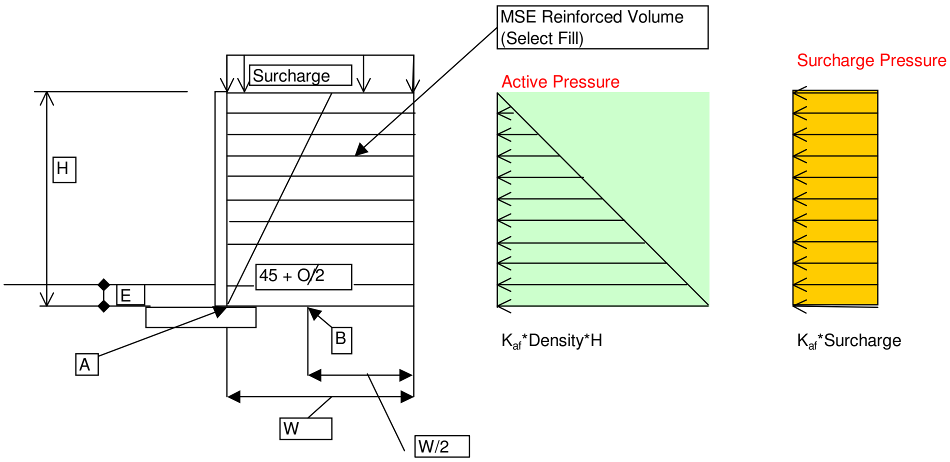
Eccentricity, e = 2.32 W/6-soil= 2.667 Good

W/4-rock=

Project No.: 04-4009-1031
Project Name: North Tarrant Express (NTE) - Segment 2E
Location: Hard Subgrade Foundation Soils
City, State: Tarrant County, Texas

Date: 11/16/2009

Pertinent Borings:



Given

H (ft)		40
W (ft)	1	40
Surcharge (ksf)		0.25
SF Unit Weight (kcf)		0.125
SF Friction Angle (degrees)		34
Subgrade Density, kcf		0.125
SF-Subgrade Friction Angle		34
Embedment, E, ft.		2
Friction Angle - Retained Fill, °		21
Unit Weight - Retained Fill, kcf		0.125

W = 0.7H to 1.0H

1) Active and Passive Pressure

Reinforced Volume-Select Fill

Ka	0.283	0.283
Kp	3.534	3.534

Retained Fill

Kaf	0.472	0.472
Kpf	2.119	2.119

2) Failure Plane

Reinforced Volume-Select Fill

Angle from vertical: (45-Ø/2) 28

Retained Fill

Angle from vertical: (45-Ø/2) 34.5

3) Stability calculations: (exclude vertical surcharge force - not always present - increases stability)

Moment about Point A: (neglect soil over toe)

Area		Sum Vertical Force kips	Sum Hor. Force kips	Arm ft.	Moment kip-ft.
MSE SF	H*W*Density	200		20	4,000.00
Active Pressure-retained fill	$0.5 \cdot K_{af} \cdot Density \cdot H^2$		47.20	13.33	629.33
Surcharge-retained fill	K_{af}*Surcharge		4.72	20.00	94.40

4) Bearing Pressure Calculation (include vertical surcharge pressure)

Area		Sum Vertical Force kips	Sum Hor. Force Kips	Arm ft.	Moment kip-ft.
Surcharge	surcharge*W	10		20	200.00
	Total	210	51.92		

5) Locate Resultant

eccentricity, e= sum of moments about Point B (midpoint of MSE SF) / sum of vertical forces

eccentricity, e= 723.73 / 210

eccentricity, e= 3.45 ft.

6) Use Meyerhoff's Pressure Distribution to Determine Max. Bearing Pressure

Max. Bearing Pressure: sum vertical forces / W-2*e

Max. Bearing Pressure: 210 / 33.1

Max. Bearing Pressure: 6.34 ksf

7) Check Ultimate Bearing Capacity - Strip with Width W - Subgrade Soils

$$q_u = C * N_c + \gamma * D_f * Nq + 0.5 * W * \gamma * N_\gamma$$

General Shear

$$q = \frac{2}{3} C * N_c + \gamma * D_f * N'q + 0.5 * W * \gamma * N'_\gamma$$

Local Shear - Das (assumes a 33% reduction in cohesion and tan Ø)

Pick values from the tables in the "*Bearing Capacity Factor*" sheet

Subgrade Soils **hard**

Long Term (effective stress)

Cohesion, C:	0.175 ksf	**General Shear** Df=	2 ft.	Nq=	11.4
Angle of internal friction:	29 degrees	Nc=	23.36	$N\gamma =$	7.08
		Local Shear D'f=	2 ft.	N'q=	3.61
		N'c=	23.36	$N'\gamma =$	1.03

Short Term (total stress)

Cohesion, C:	2.5 ksf	**General Shear** Df=	2 ft.	Nq=	1
Angle of internal friction:	0 degrees	Nc=	5.7	$N\gamma =$	0
		Local Shear D'f=	2 ft.	N'q=	1
		N'c=	5.7	$N'\gamma =$	0

Shear Type	Long or Short Term	Ultimate Bearing Capacity, ksf	Max. Bearing Pressure, ksf	Factor of Safety	Min. Safety Factor	Condition
General	Long	24.64	6.34	3.89	2	Good
General	Short	14.5	6.34	2.29	2	Good
Local	Long	6.2	6.34	0.98	2	Inadequate safety factor by Das
Local	Short	9.75	6.34	1.54	2	Inadequate safety factor by Das

Local Shear (FHWA Method)

To prevent large horizontal movements of the structure on weak soils, H< 3C/(Density of subgrade soil)

H < 60 ft.

8) Check Sliding

FS-sliding= Resisting Force / Driving Force = Friction / Active Pressure = Vertical Force * tan (Ǫ) / Active Pressure

FS-sliding= 2.6 Min. FS-sliding= 1.5

FS-Sliding Condition: Safe against sliding

9) Check Overturning

Moments about Point A:

FS-overturning= Moments Resisting Overturning / Moments Driving Overturning = 4,000.00 / 723.73

FS-overturning= 5.53 Min. FS-Overturning= 2.0

FS-overturning Condition: Safe against overturning

10) Global Stability Analyses

Use GSTABL7 or UTEXAS4 for effective and total stress conditions

Summary

Retaining Wall Height	40 ft.	**Subgrade Stiffness:**	**hard**
Footing Width, W	40 ft.		
Max Bearing Pressure:	6.34 ksf		
Eccentricity, e=	3.45 ft.		
Embedment, E=	2 ft.		

Shear Type	**Long or Short Term**	**Ultimate Bearing Capacity, ksf**	**Max. Bearing Pressure, ksf**	**Factor of Safety**	**Min. Safety Factor**	**Condition**
General	Long	24.64	6.34	3.89	2	Good
General	Short	14.5	6.34	2.29	2	Good
Local	Long	6.2	6.34	0.98	2	Inadequate safety factor by Das
Local	Short	9.75	6.34	1.54	2	Inadequate safety factor by Das

Max. Height of Wall for Local Shear = 60 ft. Use this value instead of Das's values for local shear

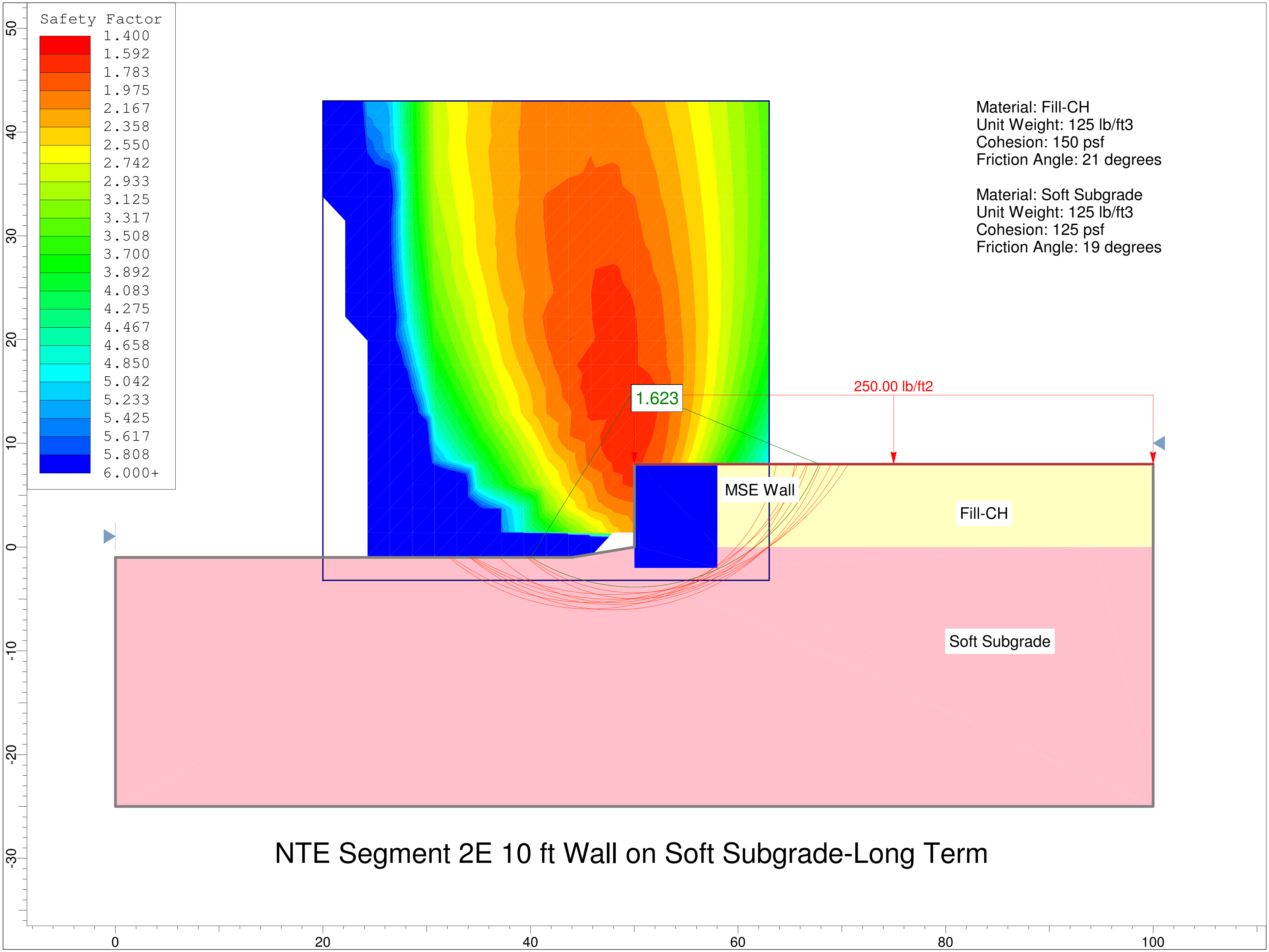
FS-Sliding Condition: 2.6 Safe against sliding

FS-overturning Condition: 5.53 Safe against overturning

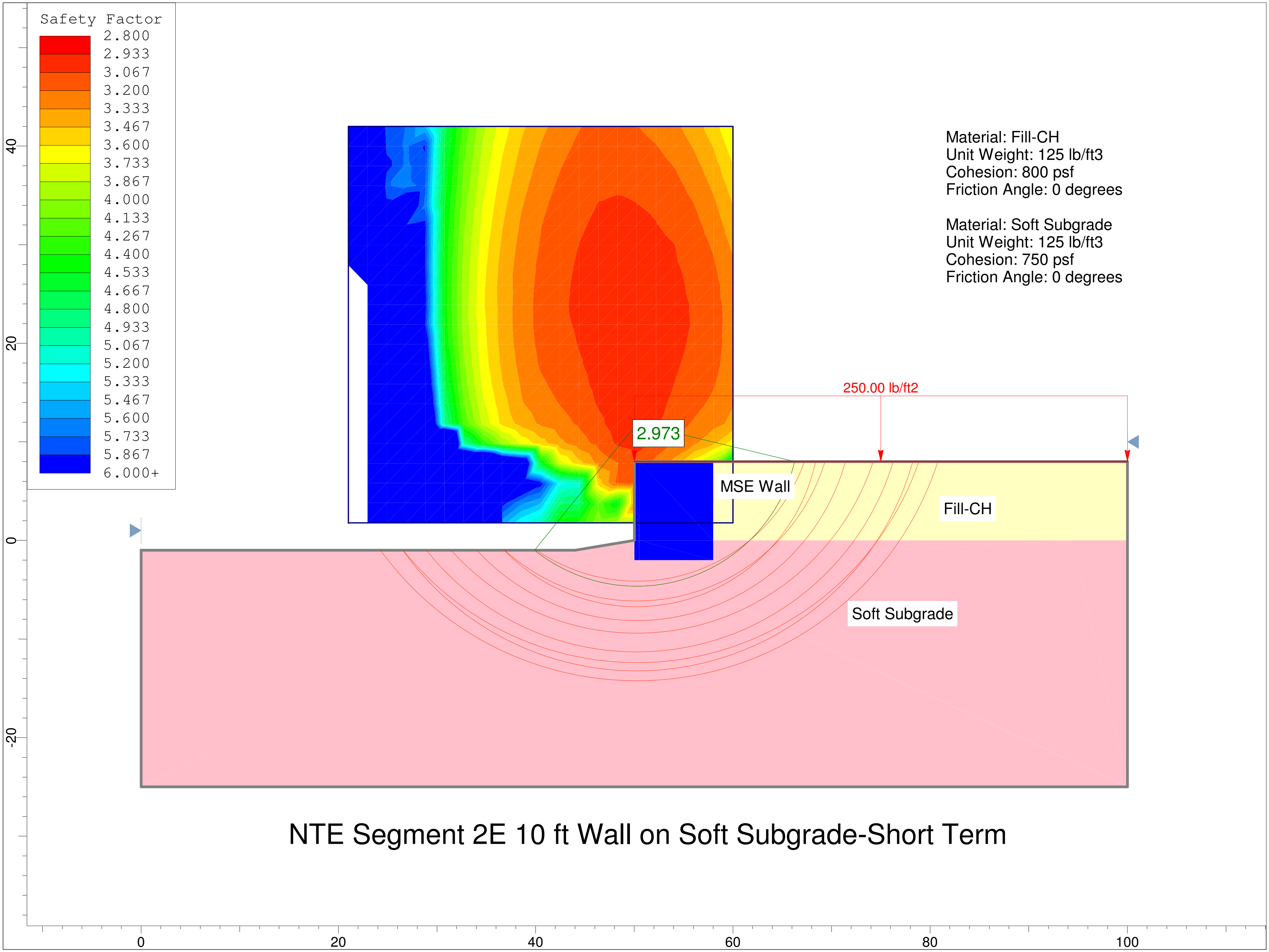
Eccentricity, e = 3.45 W/6-soil= 6.667 Good

W/4-rock=

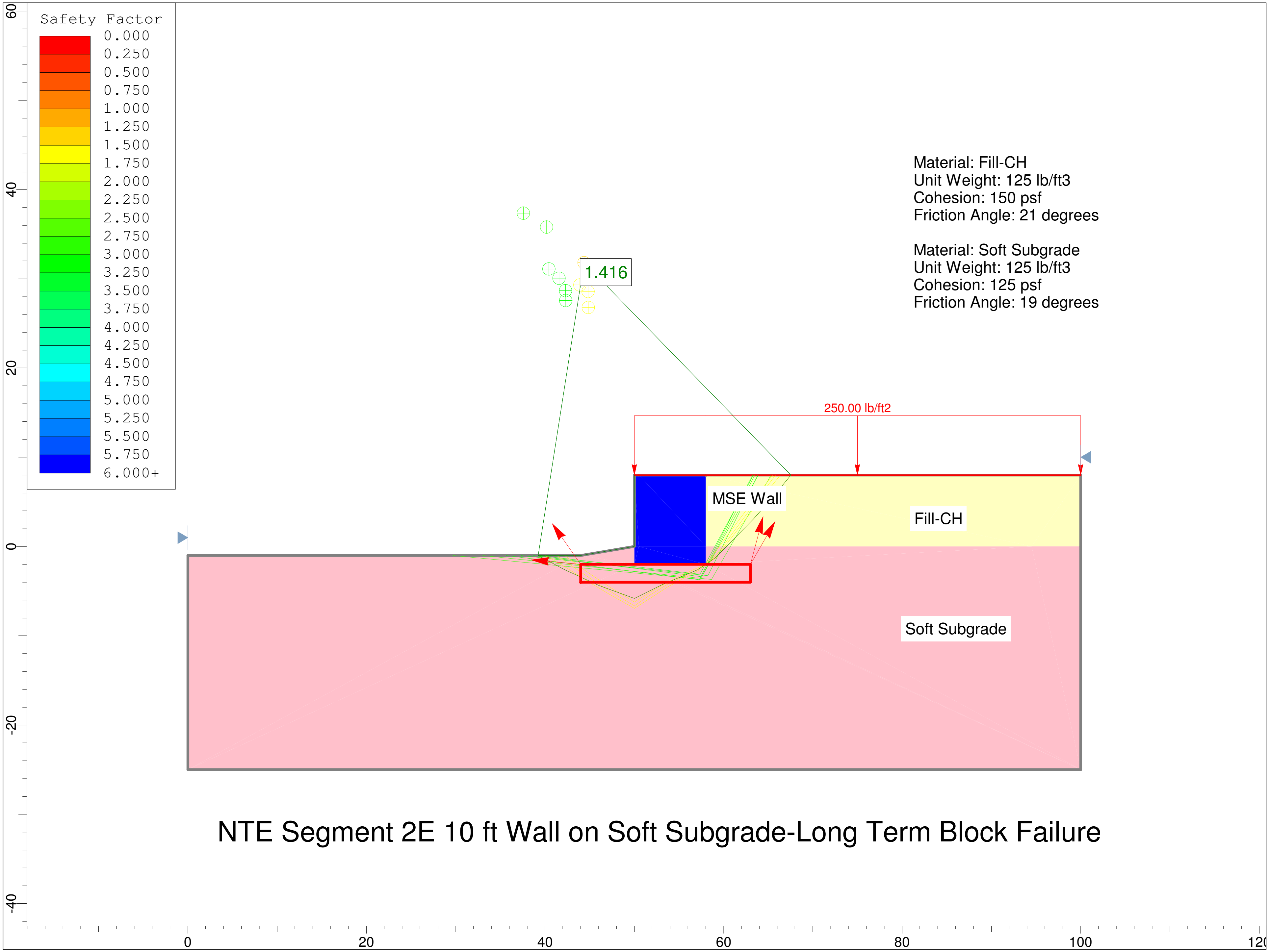
Attachment 2



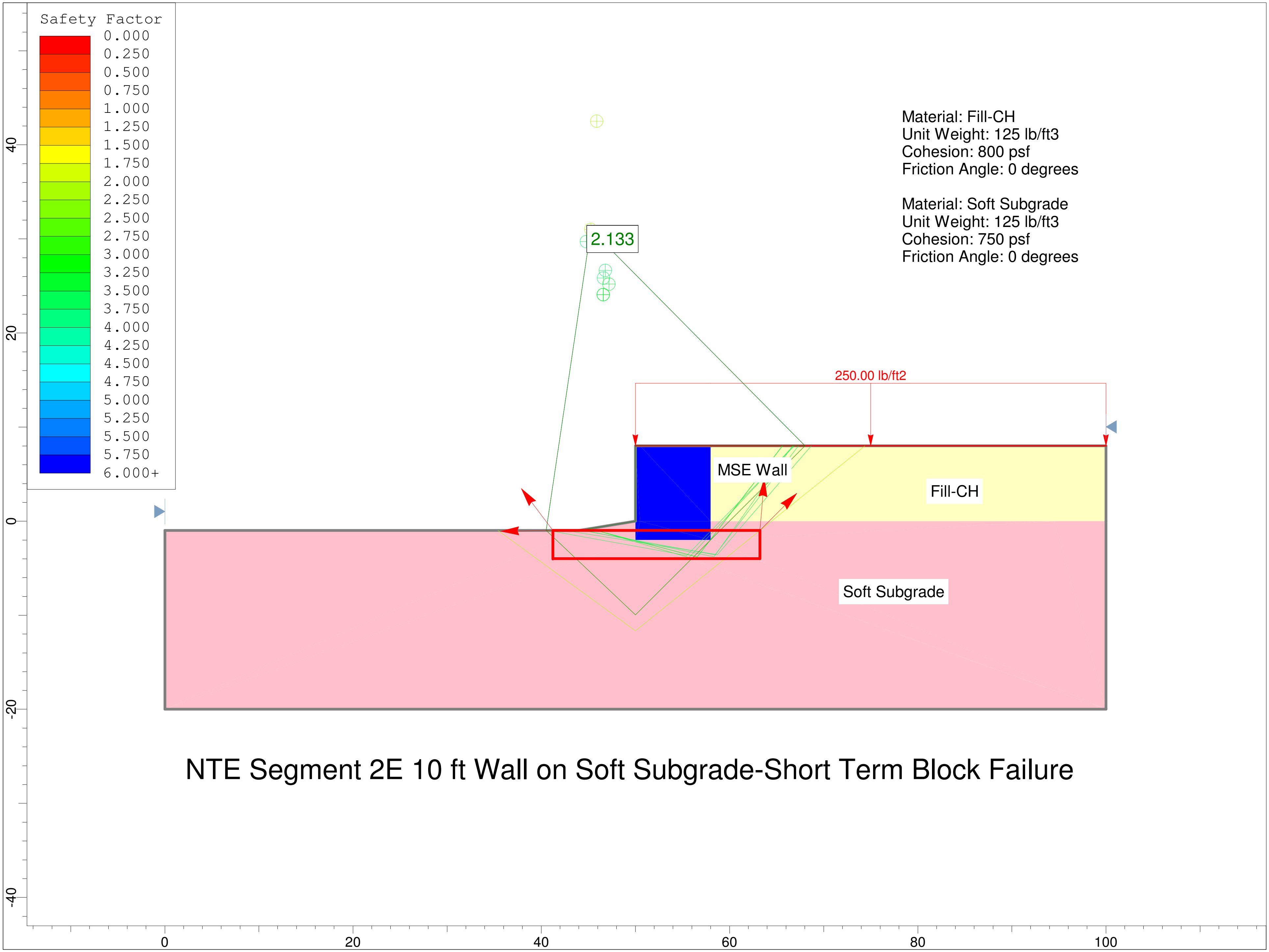
NTE Segment 2E 10 ft Wall on Soft Subgrade-Long Term



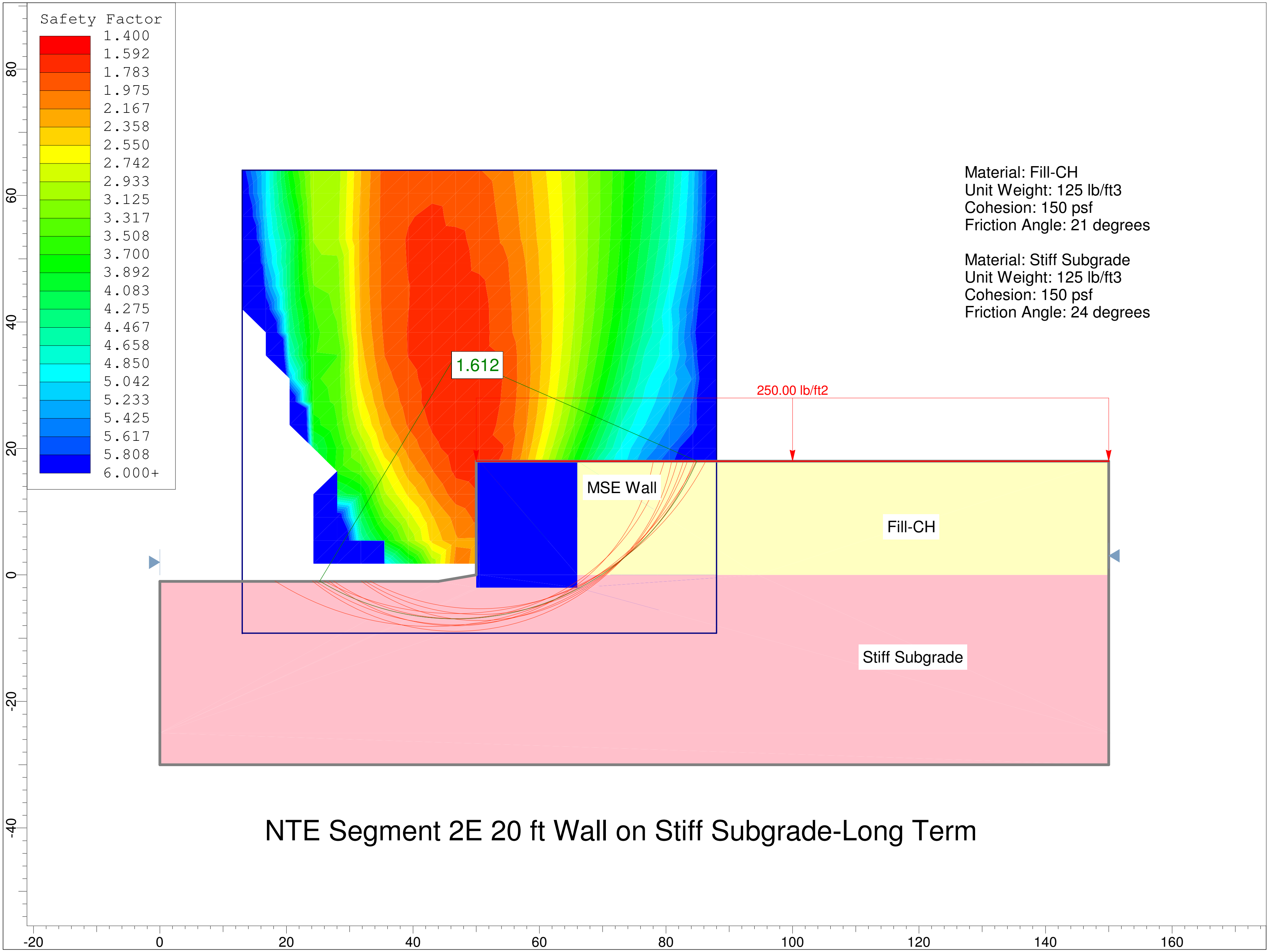
NTE Segment 2E 10 ft Wall on Soft Subgrade-Short Term



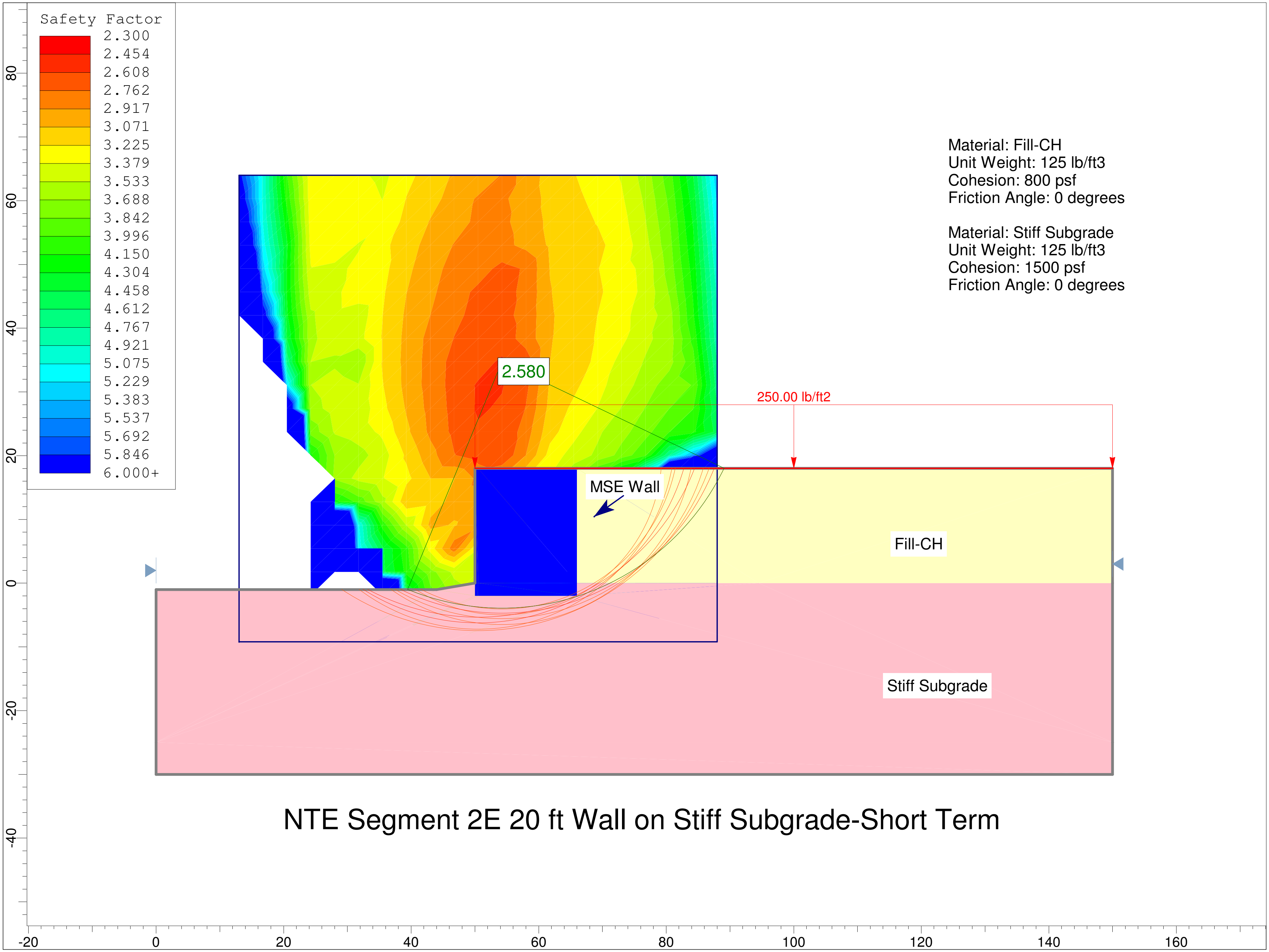
NTE Segment 2E 10 ft Wall on Soft Subgrade-Long Term Block Failure



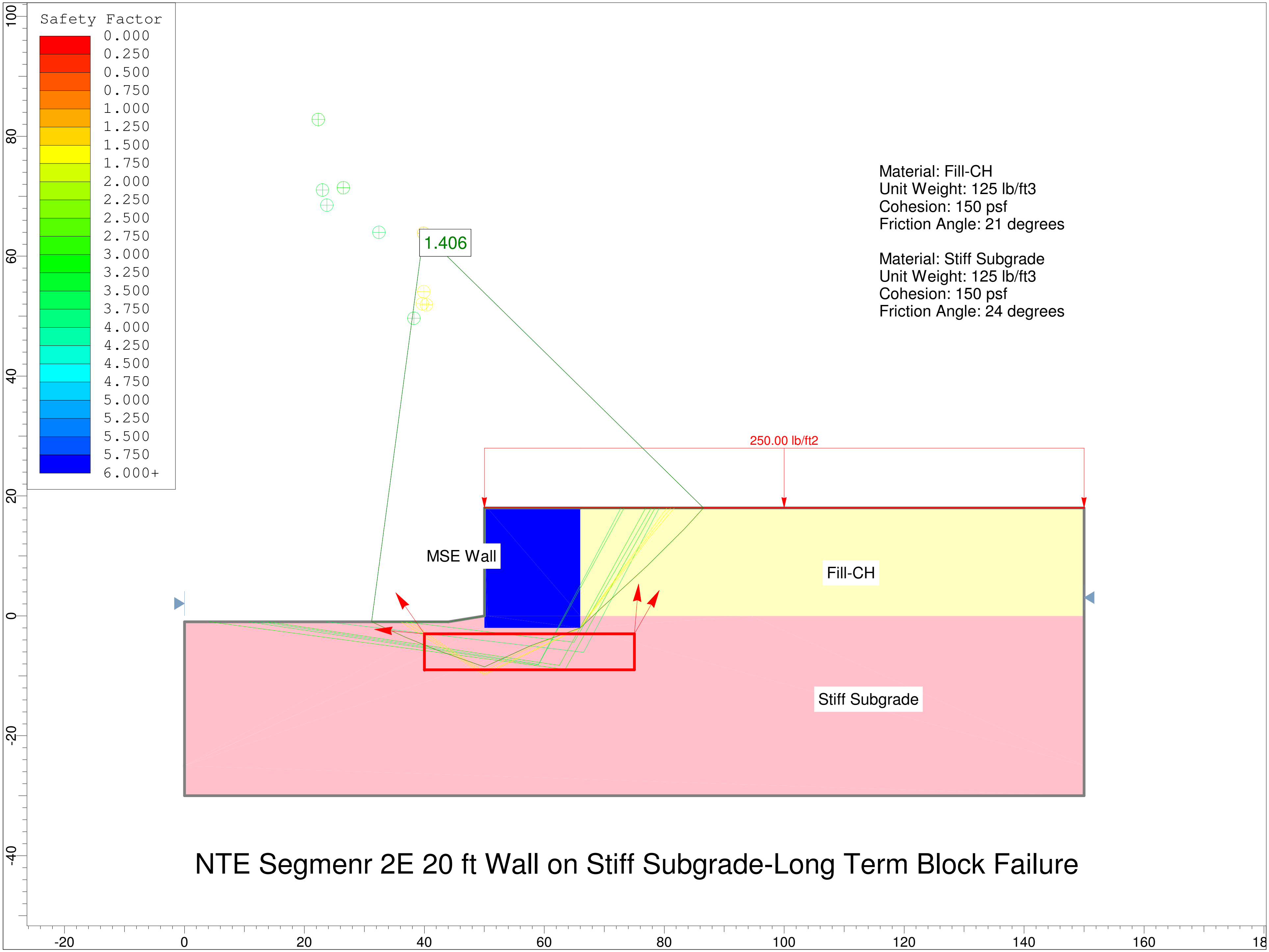
NTE Segment 2E 10 ft Wall on Soft Subgrade-Short Term Block Failure



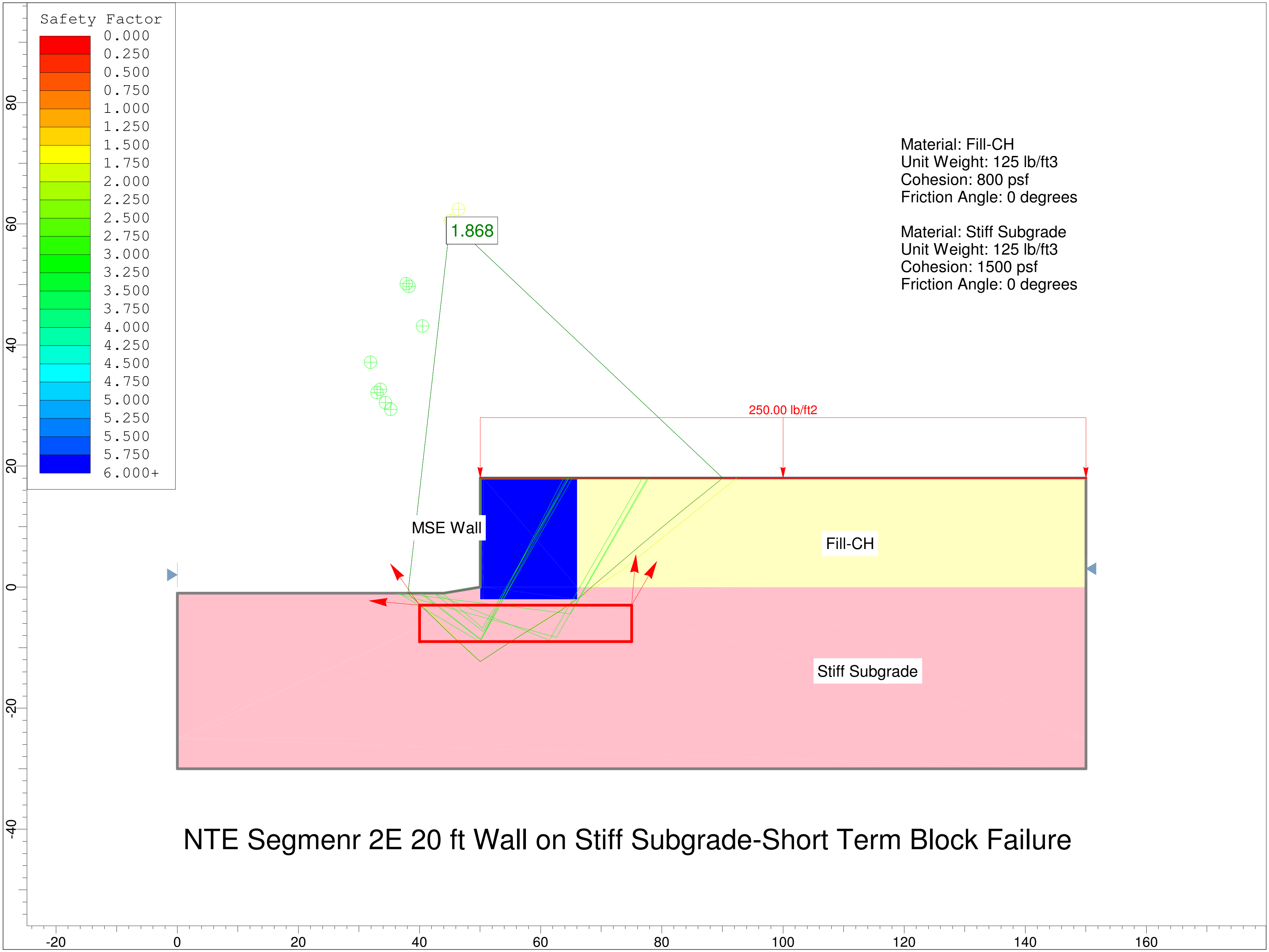
NTE Segment 2E 20 ft Wall on Stiff Subgrade-Long Term



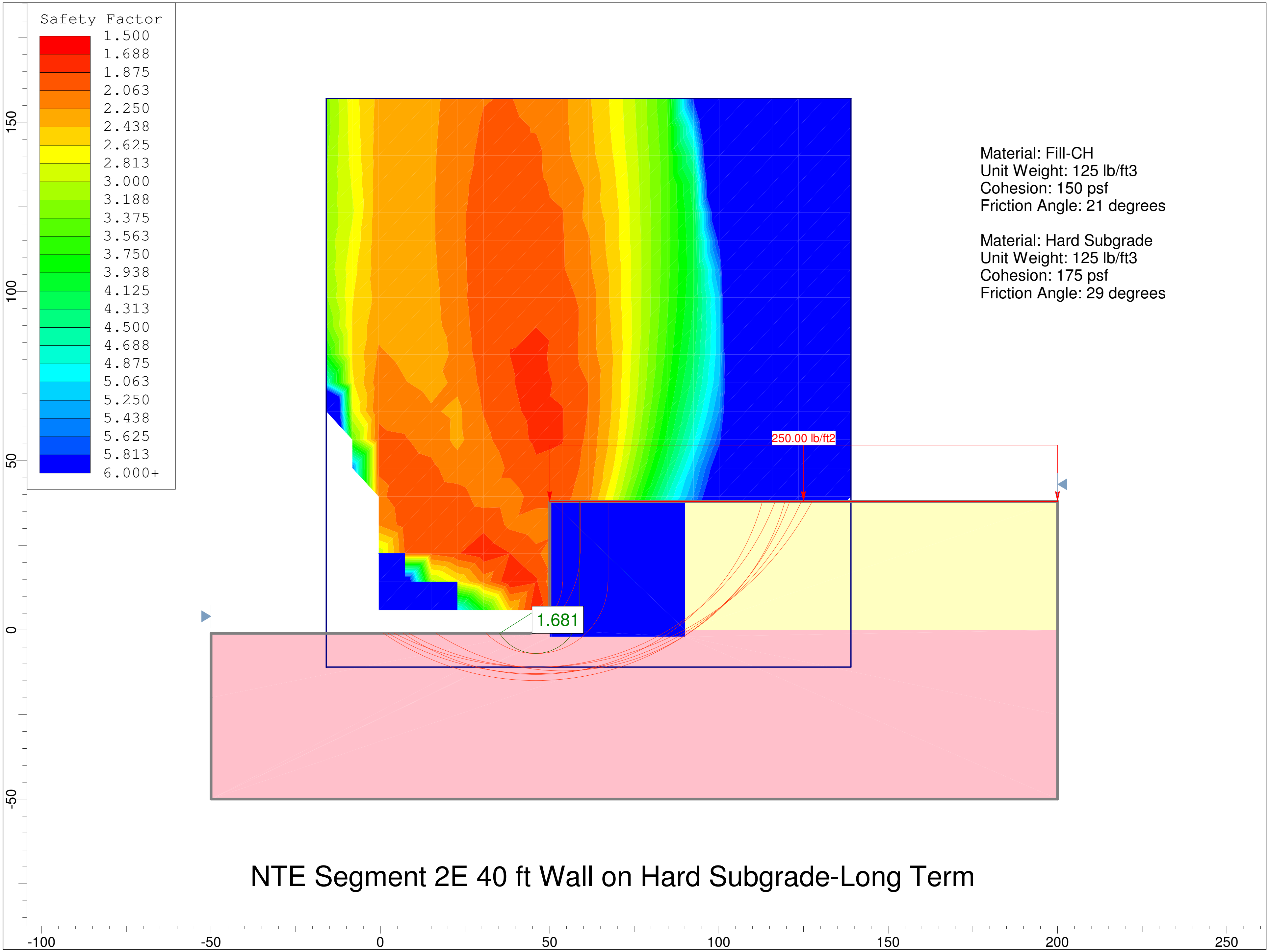
NTE Segment 2E 20 ft Wall on Stiff Subgrade-Short Term

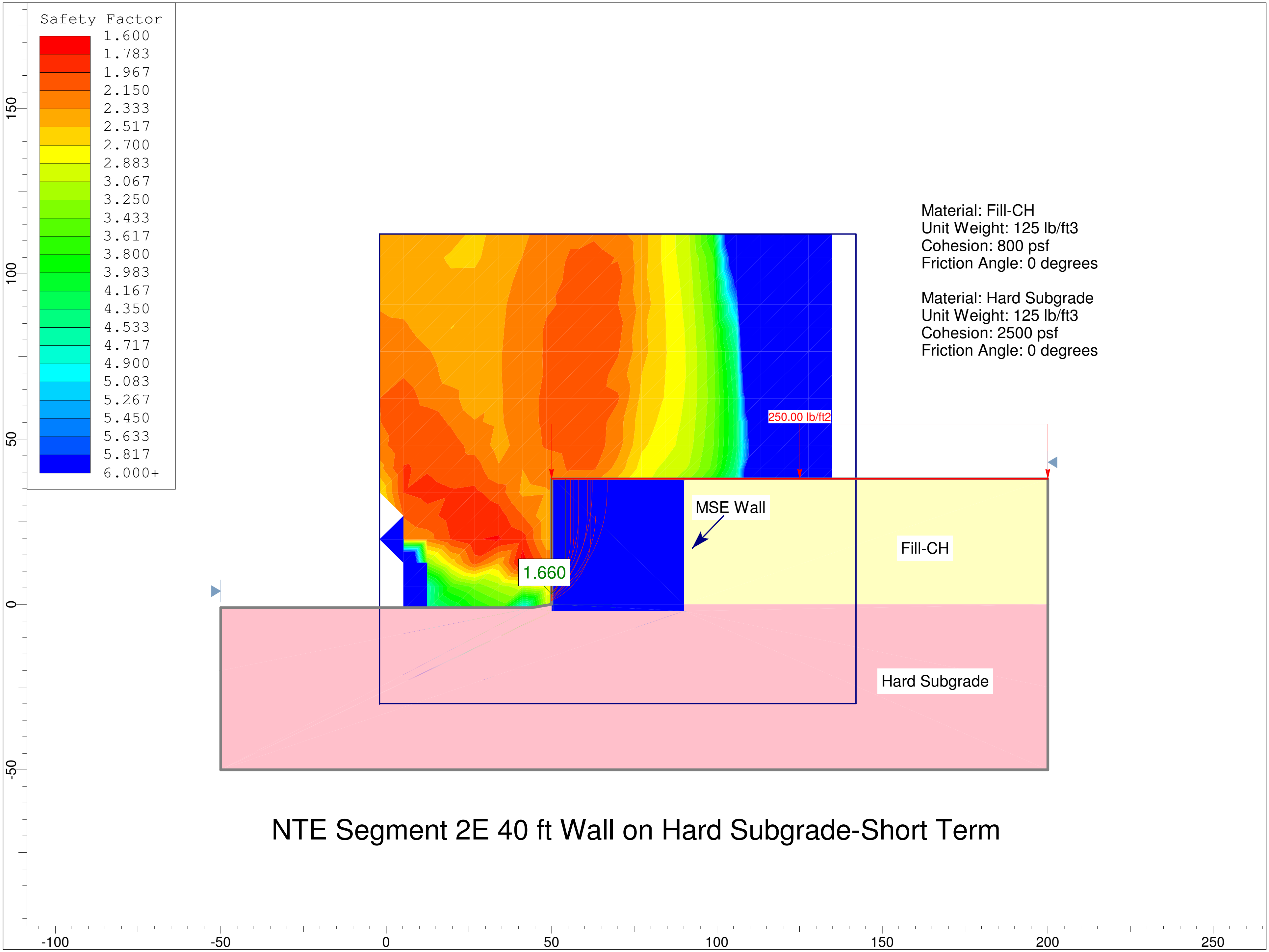


Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
1.406
Material: Fill-CH
Unit Weight: 125 lb/ft3
Cohesion: 150 psf
Friction Angle: 21 degrees
Material: Stiff Subgrade
Unit Weight: 125 lb/ft3
Cohesion: 150 psf
Friction Angle: 24 degrees
250.00 lb/ft2
MSE Wall
Fill-CH
Stiff Subgrade
NTE Segmenr 2E 20 ft Wall on Stiff Subgrade-Long Term Block Failure

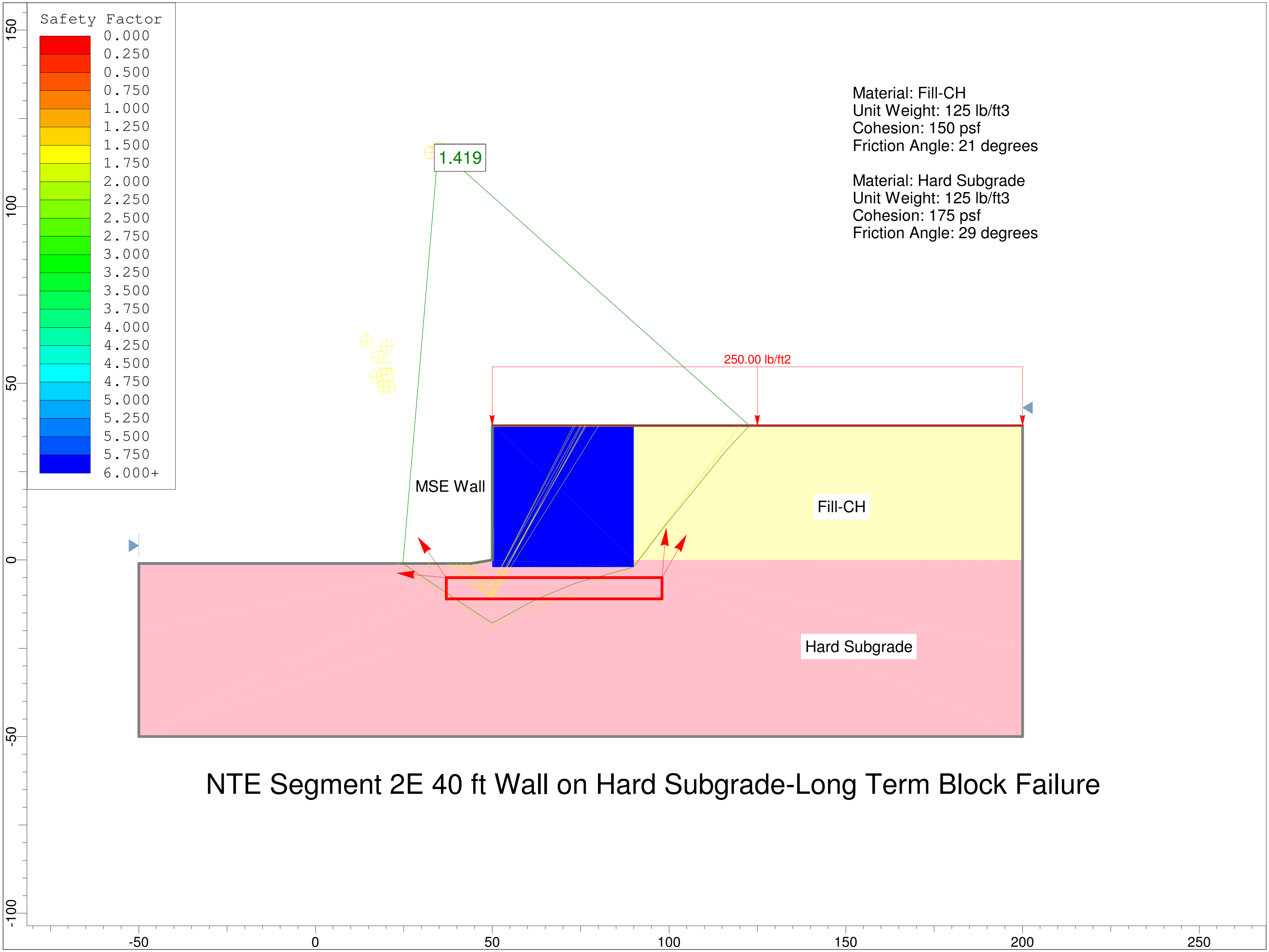


NTE Segmenr 2E 20 ft Wall on Stiff Subgrade-Short Term Block Failure

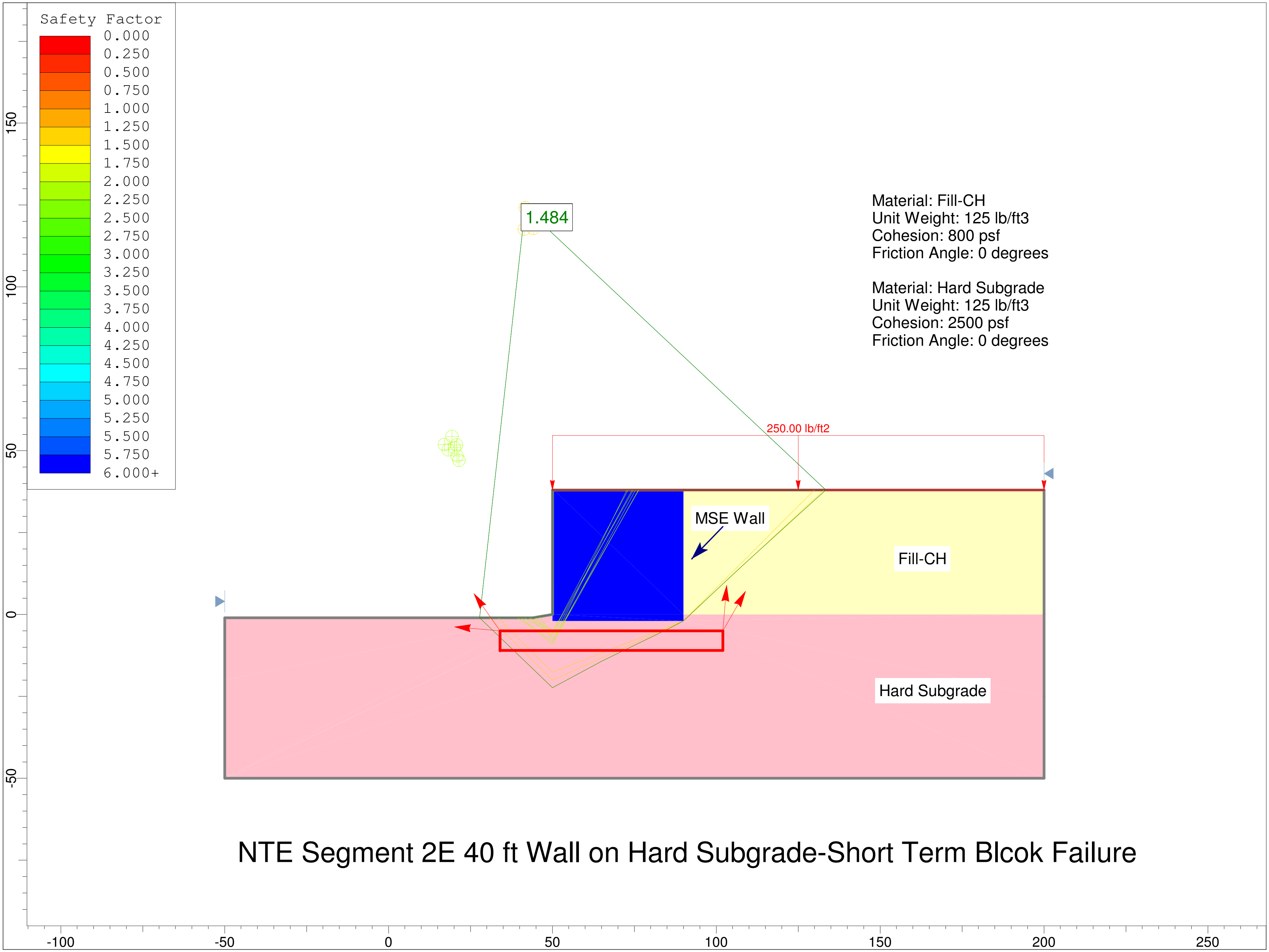

Safety Factor
1.500
1.688
1.875
2.063
2.250
2.438
2.625
2.813
3.000
3.188
3.375
3.563
3.750
3.938
4.125
4.313
4.500
4.688
4.875
5.063
5.250
5.438
5.625
5.813
6.000+
Material: Fill-CH
Unit Weight: 125 lb/ft3
Cohesion: 150 psf
Friction Angle: 21 degrees
Material: Hard Subgrade
Unit Weight: 125 lb/ft3
Cohesion: 175 psf
Friction Angle: 29 degrees
250.00 lb/ft2
1.681
150
100
50
0
-50
-100
-50
0
50
100
150
200
250
NTE Segment 2E 40 ft Wall on Hard Subgrade-Long Term



NTE Segment 2E 40 ft Wall on Hard Subgrade-Short Term



NTE Segment 2E 40 ft Wall on Hard Subgrade-Long Term Block Failure



NTE Segment 2E 40 ft Wall on Hard Subgrade-Short Term Blcok Failure