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DESIGN MEMORANDUM

Date: January 30, 2025

To: Mr. Zack Deems, AECOM

From: Brendan P. Andrews P.E., NEAS Inc.

RE: **Geotechnical Design Memorandum**
Project CUY-14-6.93, PID 104132
Retaining Wall 2 – Temporary MSE Wall
Cuyahoga County, Ohio

INTRODUCTION

This memorandum presents foundation design information for the proposed temporary Retaining Wall 2 (RW-2) as part of the overall Ohio Department of Transportation (ODOT) CUY-14-6.93 (PID 104132) project located in Cuyahoga County, Ohio. A summary of the proposed structure and our recommendations for retaining wall foundation design is presented below.

This document is a supplement to our Structure Foundation Exploration Report dated February 29, 2024 for the Project Retaining Walls associated with the CUY-14-6.93 project. Information regarding geology, site observations, the geotechnical exploration performed and subsequent findings can be found in the referenced report.

PROPOSED/EXISTING SITE CONDITIONS

Proposed Construction

It is our understanding that ODOT plans to replace the existing bridge CUY-14-0693 with a new shortened structure on a new alignment as well as remove the existing bridge CUY-CR24-0062. To facilitate the proposed bridge replacement, bridge removal, and realignment, the construction of five (5) permanent and two (2) temporary retaining walls are required.

Two (2) permanent retaining walls, designated as Retaining Walls 1 and 5 (RW-1 & RW-5), are proposed at the western end of the existing CUY-14-0693 bridge structure (Bent No. 1) and extend east to the rear abutment of the newly realigned bridge CUY 14 0693. RW-1 and RW-5 will replace the indicated portion of the existing CUY 14-0693 by supporting the proposed SR-14 embankment soils and providing grade separation between SR-14 and both Chaincraft Rd (RW-1) and Garfield Parkway (RW-5). Temporary RW- 2 is also proposed at this location to facilitate the construction phasing and maintenance of traffic (MOT) scheme by temporarily supporting the proposed SR-14 embankment soils in order to maintain at least one lane of SR-14 during construction. Temporary RW-2 will be a temporary wire-faced MSE wall that will likely be a back to-back wall with RW-1 for the entirety of its length and will be approximately 470 ft in length with a maximum wall height of approximately 42 ft

ANALYSES AND RECOMMENDATIONS

Based on design information for temporary RW-2 within the project plan set dated August 5, 2024 produced by AECOM, it is our understanding that the temporary wall will consist of temporary wire face MSE wall type. Geotechnical analyses consisting of external stability (i.e., bearing resistance, eccentricity, and sliding resistance), global stability, and settlement were performed for the proposed RW-2. The analyses performed are based on the information presented in the Structure Foundation Exploration Report dated February 29, 2024 for the Project Retaining Walls in addition to: 1) the soil characteristics gathered during the subsurface exploration (i.e., SPT results, laboratory test results, etc.); 2) the above indicated proposed design information for the referenced retaining wall provided by AECOM; and, 3) other design assumptions presented in subsequent sections of this memo.

The geotechnical engineering analyses were performed in accordance with AASHTO's Publication LRFD BDS (AASHTO, 2020) and ODOT's 2021 BDM (ODOT, 2021). Based on the results of the analysis, it is our opinion that the subsurface conditions encountered are generally satisfactory and will provide adequate resistance to bearing, sliding and overturning assuming the proposed retaining walls are constructed in accordance with the recommendations provided within this memo, as well as all applicable standards and specifications (i.e., ODOT, manufacture, etc.) for MSE wall construction.

Soil Profile for Analysis

For retaining wall foundation analyses purposes, each boring drilled for temporary RW-2 was reviewed and a generalized material profile was developed. Utilizing the generalized soil profile, engineering properties for each soil stratum were estimated based on their field (i.e., SPT N_{60} Values, hand penetrometer values, etc.) and laboratory test (i.e., Atterberg Limits, grain size, etc.) results using correlations provided in published engineering manuals, research reports and guidance documents. Soil layers from each boring with similar behavior (i.e., cohesive or non-cohesive/granular) and characteristics (i.e., relative compactness/consistency, moisture content, etc.) were grouped into generalized soil units (i.e., Soil Types) and weighted average values of the estimated engineering soil properties were assigned to each Soil Type to develop a generalized soil profile for analysis. For temporary RW-2, borings B-001-0-21, B-002-1-21, B-004-0-21 and B-006-0-21 were reviewed for analysis purposes. A summary of the generalized soil profile at these borings locations, including designated Soil Types, elevations, average engineering soil properties are presented the referenced project retaining wall SFE report.

Retaining Wall Design Assumptions

As the proposed project retaining walls are planned as MSE type, ODOT's BDM and AASHTO's LRFD BDS dictate analysis parameters and design minimums/constraints to be used in the analysis and design process. The referenced parameters and design minimums/constraints that were significant to our analyses consist of the following:

- Minimum reinforcement strap lengths of proposed MSE walls are to be 70% of the total wall height (as measured from proposed profile grade at the face of the wall to the top of the leveling pad) or 8 ft, whichever is greater, at the section of wall being analyzed, per ODOT's BDM section 307.4-A;
- Minimum MSE wall embedment depths (as measured from top of the leveling pad to the lowest point on the ground surface within 4-ft of the face of the wall) are to conform to Figure 201-5 presented in ODOT's BDM and be the larger of 3 ft or the local frost depth;

- Soils below the bottom of leveling pad will be undercut a minimum of 1 ft and replaced Granular Material Type C according to the requirements of ODOT Construction & Materials Specifications Section 204.07 (CMS 204.07);
- Maximum allowable differential settlement in the longitudinal direction is 1%. (BDM Section 307.1.6); and,
- Reinforced Zone and Retained Fill soils will meet the minimum design soil parameters per Table 840.04-1 of the ODOT Supplemental Specification 840 (SS-840) as shown in Table 5 below.

Table 1: Design Soil Parameters for Fill Materials

Fill Zone	Type of Soil	Soil Unit Weight (pcf)	Friction Angle (°)	Cohesion (psf)
Reinforced Zone	Select Granular Backfill	120	34	0
Retained Soil	On-site soil varying from sandy lean clay to silty sand	120	30	0

Notes:
1. Table reproduced from Section 840.04 - A-1 of ODOT's SS 840.

With respect to design constraints and assumptions specific to the proposed retaining walls, the geometry of the proposed walls (i.e., exposed wall heights, existing ground elevations, proposed final grade behind/at the toe of the wall, etc.) is assumed to be consistent with that shown within the project plan set dated August 5, 2024 produced by AECOM.

External Stability Analysis

Based on our estimated engineering soil properties, the developed generalized profile and the retaining wall design assumptions provided above, external stability analyses of the proposed temporary RW-2 were performed. External stability was evaluated along the proposed temporary RW-2 alignment. One (1) cross-section for RW-2 at Station 14+69.73 was estimated to be most "critical" with the critical cross-section consisting of the cross-section with the maximum total wall height. This cross-section was evaluated for resistance to bearing pressure, sliding forces and overturning at the Strength Limit State in accordance with Section 11.10.5 of the AASHTO's LRFD BDS. Bearing resistances were calculated in accordance with LRFD BDS Sections 10.6.3.1.2a.

The capacity to demand ratios (CDRs) calculated for the referenced cross-section with respect to bearing, sliding and overturning, as well as the calculated factored bearing resistance are presented in Table 1 below. (External Stability and Bearing Resistance Calculation Results are attached).

Table 1: Retaining Wall 2 External Stability Analysis

Dimensions	
Retaining Wall 2	
Design Wall Height (feet)	42.1
Exposed Wall Height (feet)	38.6
Length of Reinforecement (feet)	29.5
Length of Reinf. To Height Ratio	0.7
Approximate Station(1)	14+69.73
Capactiy Demand Ratio (CDR)	
Sliding	1.4
Overturning / Eccentricity	1.7
Bearing Capacity	1.2
Factored Bearing Resistance (ksf)(2)	12.0

Notes:
1. *Stationing in reference to baseline of proposed retaining wall.*
2. *Bearing Resistance calculated in accordance to Section 11.10.5.4 of LRFD BDS and factored using Resistance Factor provided in Table 11.5.7-1 of LRFD BDS.*

Global Stability

For purposes of evaluating the stability of the proposed temporary RW-2, NEAS reviewed multiple cross-sections within the wall's limits that were interpreted to represent conditions that posed the greatest potential for slope instability. In general, cross-sections along the proposed wall alignment were reviewed to determine if the section would represent a combination of existing subsurface conditions and planned site grading that would be most critical to slope stability (i.e., maximum total wall height, maximum embankment height measured from toe of slope to top of wall, proposed cut into existing embankment slopes, weak soil layer, etc.). Based on our review of the available information at the referenced location and the associated soil properties, the cross-section estimated to be most "critical" was analyzed for global stability. One (1) cross-section for RW-2 at Station 14+69.73 was estimated to be most "critical" with the critical cross-section consisting of the cross-section with the maximum total wall height.

For this cross-section, NEAS developed a representative cross-sectional model to use as the basis for global stability analyses. The model was developed from NEAS's interpretation of the available information which included: 1) the project plan set dated August 5, 2024 produced by AECOM; 2) a live load surcharge of 250 psf, accounting for traffic induced loads; and, 3) test borings and laboratory data developed as part of this our Structure Foundation Exploration Report dated February 29, 2024 for the Project Retaining Walls. With respect to the soil's engineering properties, the provided Soil Profile and Estimated Engineering Properties presented in our SFE report dated February 29, 2024 for the Project Retaining Walls were used in our analysis. The estimated engineering soil properties determined for borings B-004-0-21 and B-006-0-21 were utilized in the development of the cross-sectional model for RW-2.

The above referenced slope stability model was analyzed for long-term (Effective Stress) and short-term (Total Stress) slope stability utilizing the software entitled *Slide2* by Rocscience, Inc. Specifically, the Modified Bishop and Spencer analysis methods were used to calculate a factor of safety (FOS) for circular type slope failures. The FOS is the ratio of the resisting forces and the driving forces, with the desired safety factor being more than about 1.33 which equates to an AASHTO resistance factor less than 0.75 (per AASHTO's LRFD BDS the specified resistance factors are essentially the inverse of the FOS that should be targeted in slope stability programs). For this analysis, a resistance factor of 0.75 or lower is targeted as the slope does not contain or support a structural element.

Based on our slope stability analyses for the referenced retaining wall sections, the minimum slope stability safety factor is about 2.54 (0.39 resistance factor). The graphical outputs of the slope stability program (cross-sectional model, calculated safety factor, and critical failure plane) are attached.

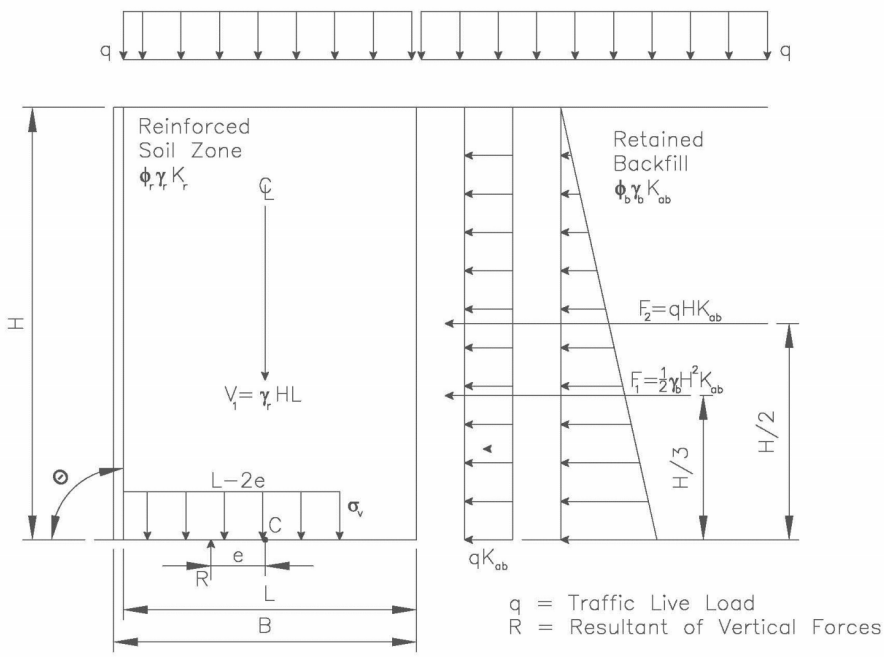
Settlement Analysis

As RW-2 is planned to be a temporary wire-faced MSE wall that: 1) supports SR-14 embankment during the phased construction of the project; and, 2) is located between RW-1 and RW-5 which are planned to support final grades of SR-14, the settlement analysis performed and reported for RW-1, RW-5 and the associated SR-14 embankment within the referenced project retaining wall SFE report applies.

EXTERNAL ANALYSIS

Objective: **To evaluate the external stability of MSE wall design with vertical wall face and horizontal backfill.**
Method: **In accordance with ODOT Bridge Design Manual, 2013 [Sect. 307] LRFD Bridge Design Specifications, 8th Ed., 2018, [Sect. 11.10.5].**
Assumptions:

- **Horizontal backfill behind MSE wall.**
- **For battered or vertical walls with a back face of wall angle of θ to horizontal.**
- **Not for sheet type reinforcement. If so, use different assessment for Sliding parameter ϕ_μ.**
- **MSE wall not acting as abutment, if so must meet minimum embedment depth of H/10 if no slope in front of wall**
- **Load combinations and wall configuration are as shown below:**



Givens:

Wall Geometry:

$H_e := 851.56 \cdot ft - 809.5 \cdot ft - 3.5 \cdot ft = 38.6\ ft$ — Exposed wall height

$\theta := 90 \cdot deg$ — Angle of back face of wall to horizontal: 90 deg for vertical or near vertical walls (per Berg et al., 2009; near vertical = 80 deg < θ < 100 deg)

Reinforced Backfill Soil Design Parameters:

$\phi'_r := 34 \cdot deg$ — Effective angle of internal friction (Per BDM [Table 307-1])

$\gamma_r := 120 \cdot \frac{lbf}{ft^3}$ — Unit weight (Per BDM [Table 307-1])

$c'_r := 0 \cdot \frac{lbf}{ft^2}$ — Effective Cohesion

Retained Backfill Soil Design Parameters:

$\phi'_b := 30 \cdot deg$ — Effective angle of internal friction (Per BDM [Table 307-1])

$\gamma_b := 120 \cdot \frac{lbf}{ft^3}$ — Unit weight (Per BDM [Table 307-1])

$c'_b := 0 \cdot \frac{lbf}{ft^2}$ — Effective Cohesion

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Foundation Soil Design Parameters:

Drained Conditions (Effective Stress):

$\phi'_f := 29 \cdot deg$ — Effective angle of internal friction

$\gamma_f := 110 \cdot \frac{lbf}{ft^3}$ — Unit weight

$c'_f := 0 \cdot \frac{lbf}{ft^2}$ — Cohesion

Undrained Conditions (Total Stress):

$\phi_f := 29 \cdot deg$ — Angle of internal friction (Same as Drained Conditions if Sand)

$\gamma_f = 110 \ \frac{lbf}{ft^3}$ — Unit weight

$c_f := 0 \cdot \frac{lbf}{ft^2}$ — Cohesion (Use Su if Angle of internal friction = 0 deg)

Foundation Surcharge Soil Parameters:

$\gamma_q := 120 \cdot \frac{lbf}{ft^3}$ — Unit weight of Soil above bearing depth (Used in Bearing Resistance of Soil Calculation LRFD 10.6.3.1.2a-1)

Depth of Embedment Check:

$d_{frost} := 3.5 \ ft$ $\quad d_{user} := 0 \ ft$ — Local Frost Depth

$Slope_{fw} := 0 \ deg$ — Inclination of ground slope in front of wall :

- Horizontal: **0**
- 3H:1V: **18.435**
- 2H:1V: **26.565**
- 1.5H:1V: **33.690**

$d_{est} := \max(d_{frost}, 3 \ ft, d_{user})$ $\quad d_{est} = 3.5 \ ft$

$H_{est} := d_{est} + (4 \ ft \cdot \tan(Slope_{fw})) + H_e$ $\quad H_{est} = 42.1 \ ft$

$$d_{eSlope} := \text{if}\left(Slope_{fw} < 1 \ deg, \frac{H_{est}}{20}, \text{if}\left(Slope_{fw} < 26.565 \ deg, \frac{H_{est}}{10}, \text{if}\left(Slope_{fw} < 33.69 \ deg, \frac{H_{est}}{7}, \frac{H_{est}}{5}\right)\right)\right)$$

$d_{eSlope} = 2.1 \ ft$ — Minimum Embedment Depth per Table C11.10.2.2-1 of LRFD BDS

$d_e := \max(d_{est}, d_{eSlope})$ $\quad d_e = 3.5 \ ft$ — Minimum Required Embedment Depth used in analysis.

$H := d_e + (4 \ ft \cdot \tan(Slope_{fw})) + H_e$ $\quad H = 42.1 \ ft$ — Design Wall Height

Estimate Length of Reinforcement:

$L_{user} := 0 \cdot ft$ — User inputted value (if changes need to be made to satisfy other requirements)

$L := \max(8 \cdot ft, 0.7 \cdot H, L_{user})$ $\quad L = 29.4 \ ft$ — Length of Reinforcement

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Live Load Surcharge Parameters:

$SUR := 250 \cdot \frac{lbf}{ft^2}$

Live load surcharge (per LRFD BDS [3.11.6.4] & BDM [307.1.1])
Note: When traffic vehicular live loads are not present within 0.5*H from the back of the reinforced zone let SUR equal 100 psf to account for construction loads.

Calculations:

Active Earth Pressure:

$\beta := 0 \qquad \delta := \beta$

Inclination of ground slope behind face of wall and angle of friction between retained backfill and reinforced soil

$$\Gamma := \left(1 + \sqrt{\frac{\left(\sin\left(\phi'_b + \delta\right) \cdot \sin\left(\phi'_b - \beta\right)\right)}{\left(\sin\left(\theta - \delta\right) \cdot \sin\left(\theta + \beta\right)\right)}}\right)^2$$

$$k_{af} := \left(\frac{\left(\sin\left(\theta + \phi'_b\right)\right)^2}{\left(\Gamma \cdot \left(\sin\left(\theta\right)\right)^2 \cdot \sin\left(\theta - \delta\right)\right)}\right) \qquad k_{af} = 0.3333$$

Active Earth Pressure Coefficient

$F_T := \frac{1}{2} \cdot \gamma_b \cdot H^2 \cdot k_{af} \qquad F_T = 35380.9 \frac{lbf}{ft}$ Active Earth Force Resultant (EH)

$F_{SUR} := SUR \cdot H \cdot k_{af} \qquad F_{SUR} = 3505 \frac{lbf}{ft}$ Live Load Surcharge (LS)

Vertical Loads:

$V_1 := \gamma_r \cdot H \cdot L \qquad V_1 = 148599.7 \frac{lbf}{ft}$ Soil backfill - reinforced soil (EV)

$V_2 := SUR \cdot L \qquad V_2 = 7360.5 \frac{lbf}{ft}$ Live Load Surcharge - (LS)

Moment Arm:		Moment:	
$d_{v1} := 0 \cdot ft$	$d_{v1} = 0\ ft$	$MV_1 := V_1 \cdot d_{v1}$	$MV_1 = 0 \frac{lbf \cdot ft}{ft}$
$d_{v2} := 0\ ft$	$d_{v2} = 0\ ft$	$MV_2 := V_2 \cdot d_{v2}$	$MV_2 = 0 \frac{lbf \cdot ft}{ft}$

Horizontal Loads:

$H_1 := F_T = 35380.9 \frac{lbf}{ft}$ Active Earth Force Resultant (horizontal comp. - EH)

$H_2 := F_{SUR} = 3505 \frac{lbf}{ft}$ Live Load Surcharge Resultant (horizontal comp. - LS)

Moment Arm:		Moment:	
$d_{h1} := \frac{H}{3}$	$d_{h1} = 14\ ft$	$MH_1 := H_1 \cdot d_{h1}$	$MH_1 = 496039.8 \frac{lbf \cdot ft}{ft}$
$d_{h2} := \frac{H}{2}$	$d_{h2} = 21\ ft$	$MH_2 := H_2 \cdot d_{h2}$	$MH_2 = 73710.1 \frac{lbf \cdot ft}{ft}$

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Unfactored Loads by Load Type

$V_{EV} := V_1$ $\quad V_{EV} = 148599.7 \frac{lbf}{ft}$

$V_{LS} := V_2$ $\quad V_{LS} = 7360.5 \frac{lbf}{ft}$

$H_{EH} := H_1$ $\quad H_{EH} = 35380.9 \frac{lbf}{ft}$

$H_{LS} := H_2$ $\quad H_{LS} = 3505 \frac{lbf}{ft}$

Unfactored Moments by Load Type

$M_{EV} := MV_1$ $\quad M_{EV} = 0 \frac{lbf \cdot ft}{ft}$

$M_{LS} := MV_2$ $\quad M_{LS} = 0 \frac{lbf \cdot ft}{ft}$

$M_{EH2} := MH_1$ $\quad M_{EH2} = 496039.8 \frac{lbf \cdot ft}{ft}$

$M_{LS2} := MH_2$ $\quad M_{LS2} = 73710.1 \frac{lbf \cdot ft}{ft}$

Load Combination Limit States:

$\eta := 1$ LRFD Load Modifier

Strength Limit State I: EV(min) = 1.00 EV(max) = 1.35
EH(min) = 0.90 EH(max) = 1.50
LS = 1.75

Strength Limit State Ia: (Sliding and Eccentricity)	$Ia_{EV} := 1$	$Ia_{EH} := 1.5$	$Ia_{LS} := 1.75$
Strength Limit State Ib: (Bearing Capacity)	$Ib_{EV} := 1.35$	$Ib_{EH} := 1.5$	$Ib_{LS} := 1.75$

Factored Vertical Loads by Limit State:

$V_{Ia} := \eta \cdot (Ia_{EV} \cdot V_{EV})$ $\quad V_{Ia} = 148599.7 \frac{lbf}{ft}$

$V_{Ib} := \eta \cdot ((Ib_{EV} \cdot V_{EV}) + (Ib_{LS} \cdot V_{LS}))$ $\quad V_{Ib} = 213490.4 \frac{lbf}{ft}$

Factored Horizontal Loads by Limit State:

$H_{Ia} := \eta \cdot ((Ia_{LS} \cdot H_{LS}) + (Ia_{EH} \cdot H_{EH}))$ $\quad H_{Ia} = 59205.1 \frac{lbf}{ft}$

$H_{Ib} := \eta \cdot ((Ib_{LS} \cdot H_{LS}) + (Ib_{EH} \cdot H_{EH}))$ $\quad H_{Ib} = 59205.1 \frac{lbf}{ft}$

Factored Moments Produced by Vertical Loads by Limit State:

$MV_{Ia} := \eta \cdot (Ia_{EV} \cdot M_{EV})$ $\quad MV_{Ia} = 0 \frac{lbf \cdot ft}{ft}$

$MV_{Ib} := \eta \cdot ((Ib_{EV} \cdot M_{EV}) + (Ib_{LS} \cdot M_{LS}))$ $\quad MV_{Ib} = 0 \frac{lbf \cdot ft}{ft}$

Factored Moments Produced by Horizontal Loads by Limit State:

$MH_{Ia} := \eta \cdot ((Ia_{LS} \cdot M_{LS2}) + (Ia_{EH} \cdot M_{EH2}))$ $\quad MH_{Ia} = 873052.5 \frac{lbf \cdot ft}{ft}$

$MH_{Ib} := \eta \cdot ((Ib_{LS} \cdot M_{LS2}) + (Ib_{EH} \cdot M_{EH2}))$ $\quad MH_{Ib} = 873052.5 \frac{lbf \cdot ft}{ft}$

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Compute Bearing Resistance:

Compute the Effective Bearing Length (Strength Ib):

$\Sigma M_R := MV_{Ib}$ $\quad \Sigma M_R = 0 \ \frac{lbf \cdot ft}{ft}$ Sum of Resisting Moments (Strength Ib)

$\Sigma M_O := MH_{Ib}$ $\quad \Sigma M_O = 873052.5 \ \frac{lbf \cdot ft}{ft}$ Sum of Overturning Moments (Strength Ib)

$\Sigma V := V_{Ib}$ $\quad \Sigma V = 213490.4 \ \frac{lbf}{ft}$ Sum of Vertical Loads (Strength Ib)

$e_{wall} := \frac{(\Sigma M_O - \Sigma M_R)}{\Sigma V}$ $\quad e_{wall} = 4.1 \ ft$ Wall Eccentricity

$B' := \text{if}(e_{wall} > 0, L - 2 \cdot e_{wall}, L)$ $\quad B' = 21.3 \ ft$ Effective Bearing Width

Foundation Layout:

$L_{Wall} := 200 \cdot ft$ Assumed Footing Length (Wall Section Length)

$H' := H_{Ib}$ $\quad H' = 59205.1 \ \frac{lbf}{ft}$ Summation of Horizontal Loads (Strength Ib)

$V' := V_{Ib}$ $\quad V' = 213490.4 \ \frac{lbf}{ft}$ Summation of Vertical Loads (Strength Ib)

$D_f := d_e$ $\quad D_f = 3.5 \ ft$ Footing embedment

$d_w := 0 \cdot ft$ Depth of Groundwater below Bearing Grade

$\theta' := 90 \cdot deg$ Direction of H' and V' resultant measured from wall back face **LRFD [Figure C10.6.3.1.2a-1]**

Drained Conditions (Effective Stress):

$N_q := \text{if}\left(\phi'_f > 0, e^{\pi \cdot \tan(\phi'_f)} \cdot \tan\left(45 \ deg + \frac{\phi'_f}{2}\right)^2, 1.0\right)$ $\quad N_q = 16.44$

$N_c := \text{if}\left(\phi'_f > 0, \frac{N_q - 1}{\tan(\phi'_f)}, 5.14\right)$ $\quad N_c = 27.86$

$N_\gamma := 2 \cdot (N_q + 1) \cdot \tan(\phi'_f)$ $\quad N_\gamma = 19.3$

Compute shape correction factors per **LRFD [Table 10.6.3.1.2a-3]**:

$s_c := \text{if}\left(\phi'_f > 0, 1 + \left(\frac{B'}{L_{Wall}}\right) \cdot \left(\frac{N_q}{N_c}\right), 1 + \left(\frac{B'}{5 \cdot L_{Wall}}\right)\right)$ $\quad s_c = 1.063$

$s_q := \text{if}\left(\phi'_f > 0, 1 + \left(\frac{B'}{L_{Wall}} \cdot \tan(\phi'_f)\right), 1\right)$ $\quad s_q = 1.059$

$s_\gamma := \text{if}\left(\phi'_f > 0, 1 - 0.4 \cdot \left(\frac{B'}{L_{Wall}}\right), 1\right)$ $\quad s_\gamma = 0.957$

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Load inclination factors using **LRFD [10.6.3.1.2a-5] thru [10.6.3.1.2a-9]:**

$i_q := 1$ $\qquad i_q = 1$

$i_\gamma := 1$ $\qquad i_\gamma = 1$

$i_c := 1$ $\qquad i_c = 1$

Compute groundwater depth correction factors per **LRFD [Table 10.6.3.1.2a-2]**:

$C_{wq} := \text{if}\left(d_w \geq 0, 1, 0.5\right)$ $\qquad C_{wq} = 1$

$C_{w\gamma} := \text{if}\left(d_w > 1.5 \cdot B', 1, 0.5\right)$ $\qquad C_{w\gamma} = 0.5$

Depth Correction Factor per Hanson (1970):

$$d_q := \text{if}\left(\frac{D_f}{B'} \leq 1, 1 + 2 \cdot \tan\left(\phi'_f\right) \cdot \left(1 - \sin\left(\phi'_f\right)\right)^2 \cdot \frac{D_f}{B'}, 1 + 2 \cdot \tan\left(\phi'_f\right) \cdot \left(1 - \sin\left(\phi'_f\right)\right)^2 \cdot \text{atan}\left(\frac{D_f}{B'}\right)\right)$$

$d_q = 1.05$

Compute modified bearing capacity factors **LRFD [Equation 10.6.3.1.2a-2 to 10.6.3.1.2a-4]:**

$N_{cm} := N_c \cdot s_c \cdot i_c$ $\qquad N_{cm} = 29.609$

$N_{qm} := N_q \cdot s_q \cdot i_q$ $\qquad N_{qm} = 17.412$

$N_{\gamma m} := N_\gamma \cdot s_\gamma \cdot i_\gamma$ $\qquad N_{\gamma m} = 18.516$

Compute nominal bearing resistance, **LRFD [Eq 10.6.3.1.2a-1]:**

$q_{nd} := c'_f \cdot N_{cm} + \gamma_q \cdot D_f \cdot N_{qm} \cdot d_q \cdot C_{wq} + 0.5 \cdot \gamma_f \cdot B' \cdot N_{\gamma m} \cdot C_{w\gamma}$ $\qquad q_{nd} = 18494.1 \ \frac{lbf}{ft^2}$

Compute factored bearing resistance, **LRFD [Eq 10.6.3.1.1]:**

$\phi_b := 0.65$ $\qquad$ Bearing resistance factor **LRFD Table 11.5.7-1.**

$q_{Rd} := \phi_b \cdot q_{nd}$ $\qquad q_{Rd} = 12 \ ksf$ $\qquad$ Factored bearing resistance Drained Conditions

Undrained Conditions (Effective Stress):

$$N_q := \text{if}\left(\phi_f > 0, e^{\pi \cdot \tan\left(\phi_f\right)} \cdot \tan\left(45\ deg + \frac{\phi_f}{2}\right)^2, 1.0\right)$$ $\qquad N_q = 16.44$

$$N_c := \text{if}\left(\phi_f > 0, \frac{N_q - 1}{\tan\left(\phi_f\right)}, 5.14\right)$$ $\qquad N_c = 27.86$

$N_\gamma := 2 \cdot \left(N_q + 1\right) \cdot \tan\left(\phi_f\right)$ $\qquad N_\gamma = 19.3$

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Compute shape correction factors per **LRFD [Table 10.6.3.1.2a-3]**:

$$s_c := \text{if}\left(\phi_f > 0, 1 + \left(\frac{B'}{L_{Wall}}\right) \cdot \left(\frac{N_q}{N_c}\right), 1 + \left(\frac{B'}{5 \cdot L_{Wall}}\right)\right) \qquad s_c = 1.063$$

$$s_q := \text{if}\left(\phi_f > 0, 1 + \left(\frac{B'}{L_{Wall}} \cdot \tan(\phi_f)\right), 1\right) \qquad s_q = 1.059$$

$$s_\gamma := \text{if}\left(\phi_f > 0, 1 - 0.4 \cdot \left(\frac{B'}{L_{Wall}}\right), 1\right) \qquad s_\gamma = 0.957$$

Load inclination factors using **LRFD [10.6.3.1.2a-5] thru [10.6.3.1.2a-9]:**

$i_q := 1$ $\qquad i_q = 1$

$i_\gamma := 1$ $\qquad i_\gamma = 1$

$i_c := 1$ $\qquad i_c = 1$

Compute modified bearing capacity factors **LRFD [Equation 10.6.3.1.2a-2 to 10.6.3.1.2a-4]:**

$N_{cm} := N_c \cdot s_c \cdot i_c$ $\qquad N_{cm} = 29.609$

$N_{qm} := N_q \cdot s_q \cdot i_q$ $\qquad N_{qm} = 17.412$

$N_{\gamma m} := N_\gamma \cdot s_\gamma \cdot i_\gamma$ $\qquad N_{\gamma m} = 18.516$

Compute nominal bearing resistance, **LRFD [Eq 10.6.3.1.2a-1:**

$$q_{nu} := c_f \cdot N_{cm} + \gamma_q \cdot D_f \cdot N_{qm} \cdot d_q \cdot C_{wq} + 0.5 \cdot \gamma_f \cdot B' \cdot N_{\gamma m} \cdot C_{w\gamma} \qquad q_{nu} = 18494.1 \ \frac{lbf}{ft^2}$$

Compute factored bearing resistance, **LRFD [Eq 10.6.3.1.1]:**

$\phi_b := 0.65$ $\qquad$ Bearing resistance factor **LRFD Table 11.5.7-1.**

$q_{Ru} := \phi_b \cdot q_{nu}$ $\qquad q_{Ru} = 12 \ ksf$ $\qquad$ Factored bearing resistance Undrained Conditions

Factored Bearing Resistance Drained vs. Undrained Conditions:

Drained Conditions: $q_{Rd} = 12 \ ksf$

Undrained Conditions: $q_{Ru} = 12 \ ksf$

Factored Bearing Resistance to be used in CDR Calculations: $q_R := q_{Ru}$

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Evaluate External Stability of Wall:

Bearing Resistance at Base of the Wall:

Compute the resultant location (distance from Point 'O'):

$\Sigma M_R := MV_{Ib}$ $\quad \Sigma M_R = 0 \ \frac{lbf \cdot ft}{ft}$ Sum of Resisting Moments (Strength Ib)

$\Sigma M_O := MH_{Ib}$ $\quad \Sigma M_O = 873052.5 \ \frac{lbf \cdot ft}{ft}$ Sum of Overturning Moments (Strength Ib)

$\Sigma V := V_{Ib}$ $\quad \Sigma V = 213490.4 \ \frac{lbf}{ft}$ Sum of Vertical Loads (Strength Ib)

$e_{wall} := \frac{(\Sigma M_O - \Sigma M_R)}{\Sigma V}$ $\quad e_{wall} = 4.1 \ ft$ Wall Eccentricity

$B' := \text{if}\left(e_{wall} > 0, L - 2 \cdot e_{wall}, L\right)$ $\quad B' = 21.3 \ ft$ Effective Bearing Width

Compute the ultimate bearing stress:

$\sigma_v := \frac{\Sigma V}{B'}$ $\quad \sigma_v = 10040.4 \ \frac{lbf}{ft^2}$ Ultimate Bearing Stress

Bearing Capacity:Demand Ratio (CDR)

$CDR_{Bearing} := \frac{q_R}{\sigma_v}$ Is the CDR > or = to 1.0? $CDR_{Bearing} = 1.20$

Limiting Eccentricity at Base of MSE Wall (Strength Ia):

$e_{max} := \frac{L}{3}$ $\quad e_{max} = 9.8 \ ft$ Maximum Eccentricity **LRFD [C11.6.3.3.]**

$\Sigma M_R := MV_{Ia}$ $\quad \Sigma M_R = 0 \ \frac{lbf \cdot ft}{ft}$ Sum of Resisting Moments (Strength Ia)

$\Sigma M_O := MH_{Ia}$ $\quad \Sigma M_O = 873052.5 \ \frac{lbf \cdot ft}{ft}$ Sum of Overturning Moments (Strength Ia)

$\Sigma V := V_{Ia}$ $\quad \Sigma V = 148599.7 \ \frac{lbf}{ft}$ Sum of Vertical Loads (Strength Ia)

$e_{wall} := \frac{(\Sigma M_O - \Sigma M_R)}{\Sigma V}$ $\quad e_{wall} = 5.9 \ ft$

Eccentricity Capacity:Demand Ratio (CDR)

$CDR_{Eccentricity} := \frac{e_{max}}{e_{wall}}$ Is the CDR > or = to 1.0? $CDR_{Eccentricity} = 1.67$

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Sliding Resistance at Base of Wall LRFD [10.6.3.4]:

Factored Sliding Force (Strength Ia):

$F_\tau := H_{Ia}$ $\qquad F_\tau = 59205.1 \ \frac{lbf}{ft}$

Compute sliding resistance between soil and foundation:

Drained Conditions:

$\Sigma V := V_{Ia}$ $\qquad \Sigma V = 148599.7 \ \frac{lbf}{ft}$ $\qquad$ Sum of Vertical Loads (Strength Ia)

$R_{\tau d} := \Sigma V \cdot \tan(\phi'_f)$ $\qquad R_{\tau d} = 82370.1 \ \frac{lbf}{ft}$ $\qquad$ Nominal sliding resistance Drained Conditions

Undrained Conditions:

$\Sigma V := V_{Ia}$ $\qquad \Sigma V = 148599.7 \ \frac{lbf}{ft}$ $\qquad$ Sum of Vertical Loads (Strength Ia)

$R_{\tau u} := min(0.5 \cdot V_{Ia}, c_f \cdot L)$ $\qquad R_{\tau u} = 0 \ \frac{lbf}{ft}$ $\qquad$ Nominal sliding resistance Undrained Conditions

Nominal Sliding Resistance Drained vs. Undrained Conditions:

Drained Conditions: $R_{\tau d} = 82.37 \ \frac{kip}{ft}$

Undrained Conditions: $R_{\tau u} = 0 \ \frac{kip}{ft}$

Nominal Sliding Resistance to be used in CDR Calculations: $R_\tau := R_{\tau d}$

Compute factored resistance against failure by sliding **LRFD [10.6.3.4]**:

$\phi_\tau := 1.0$ $\qquad$ Resistance factor for sliding resistance specified in **LRFD Table 11.5.7-1.**

$\phi R_n := \phi_\tau \cdot R_\tau$ $\qquad R_R := \phi R_n$

$R_R = 82.4 \ \frac{kip}{ft}$

Sliding Capacity:Demand Ratio (CDR)

$CDR_{Sliding} := \frac{R_R}{F_\tau}$ $\qquad$ Is the CDR > or = to 1.0? $\qquad CDR_{Sliding} = 1.39$

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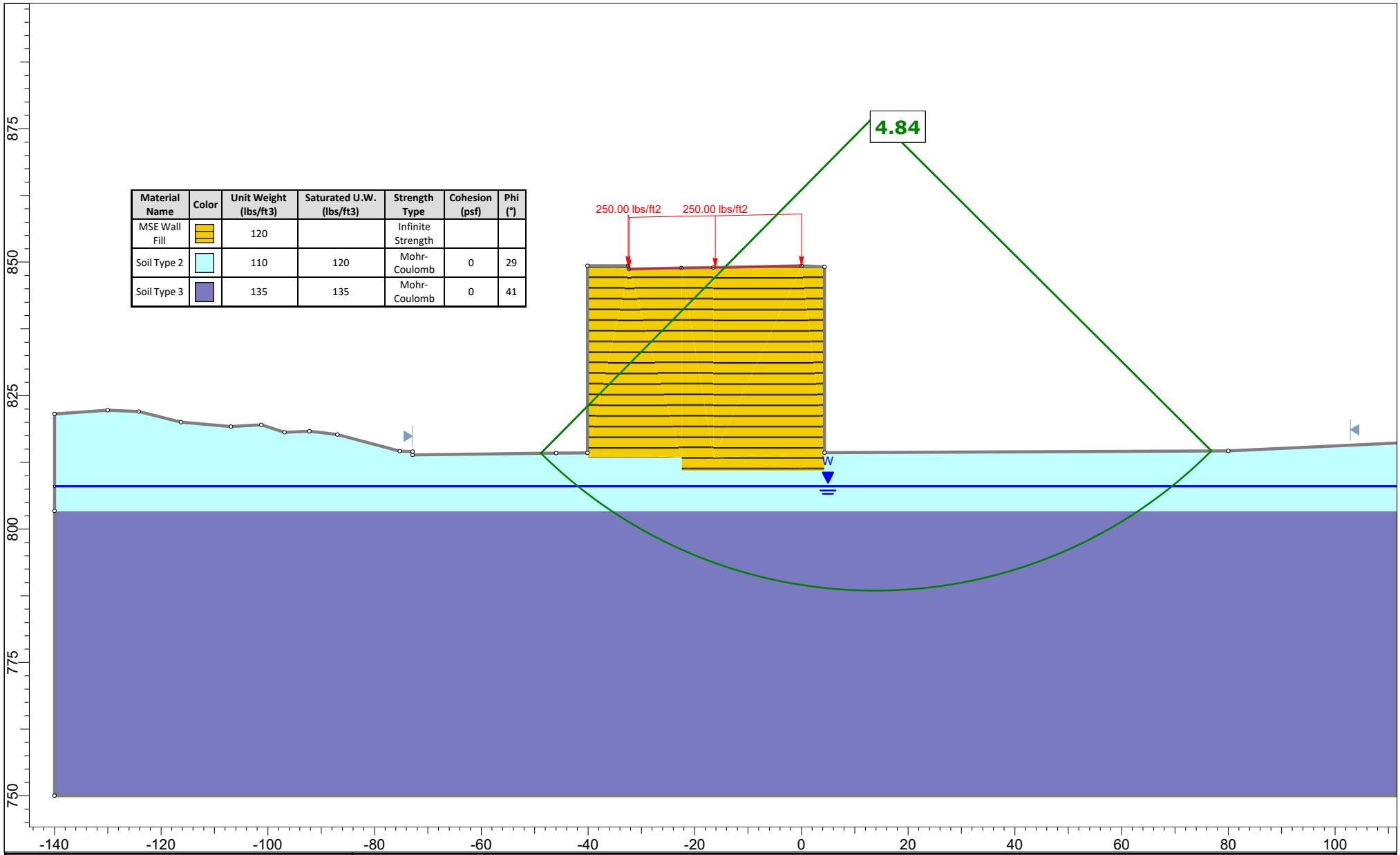
GLOBAL STABILITY



Material Name	Color	Unit Weight (lbs/ft3)	Saturated U.W. (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (°)
MSE Wall Fill		120		Infinite Strength		
Soil Type 2		110	120	Mohr-Coulomb	0	29
Soil Type 3		135	135	Mohr-Coulomb	0	41

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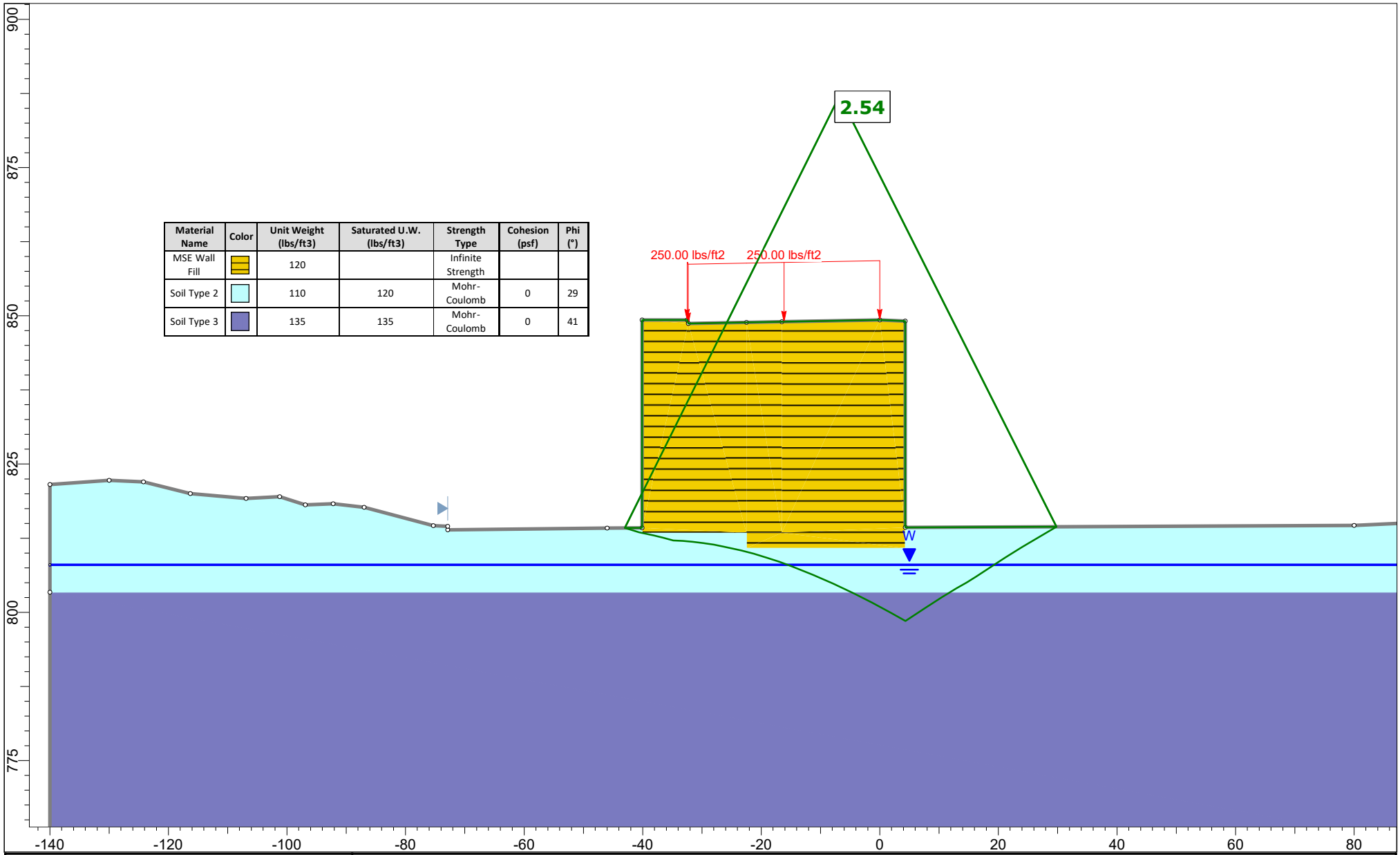
SLIDEINTERPRET 9.037

Project	CUY-14-6.93, PID 104132		
Analysis Description	Retaining Wall 2 - STA. 14+69 - Total and Effective Stress		
Drawn By	BPA	*Company*	NEAS Inc.
Date		*File Name*	Wall2_STA14+69_021325.slmd



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