Structural Design Calculations
Tualatin Garden Corner Curves
Tualatin, OR

Client Information
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Project Site
Tualatin Garden Corner Curves
SW 105th Ave., Blake St., SW 108th Ave.
Tualatin, OR 97062
45.3644, -122.7863

Prepared By:
Peterson Structural Engineers
March 27, 2020
Job No. 1801-0336

Endorsement
Expires 12/31/20
**Scope**

To provide structural calculations for the Tualatin Garden Curves roadway improvement project at the location given on the cover page. Elements under review include Mechanically Stabilized Earth (MSE) walls supporting the roadway and Cantilever Cast-in-Place (CIP) walls retaining soil. Any other elements not specifically referenced in these calculations are outside the purview of these calculations and are designed by others.

**References**

1. American Association of State Highway and Transportation Officials LRFD Bridge Design Specifications, 8th Edition (AASHTO)
2. 2018 Oregon Department of Transportation Standard Specifications for Construction (ODOT)
3. 2018 Oregon Department of Transportation Geotechnical Design Manual (ODOT GDM)
4. 2014 Building Code Requirements for Structural Concrete, ACI 318-14, and Commentary (ACI)
7. Geotechnical Report prepared by GRI dated February 20, 2019
8. 90% Civil Drawings provide by client dated July 10, 2019, issued September 16, 2019

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Project Information

- Project Site: SW 105th Ave., Blake St., SW 108th Ave in Tualatin, OR 97062
- Below is a graphic of the structural elements included in PSE’s scope:

Figure 1: Roadway Plan
Retaining Wall Information:

- MSE Walls:
  - Wall 1
    - Max Height = 6.0’
    - Supports Roadway
  - Wall 2
    - Max Height = 4.0’
    - Supports Roadway
  - Wall 3:
    - Max Height = 10.5’
    - Supports Bicycle lane/roadway
    - Culvert interrupts, MSE wall portion above culvert
    - Located near stream
  - Wall 4:
    - Max Height = 7’-0”
    - Supports bicycle lane
    - Culvert interrupts, MSE wall portion above culvert

- CIP Cantilever Walls
  - Wall 5:
    - Max Height = 6’-0”
    - Retains soil on roadway side
Design Loads: Per AASHTO, ODOT, and Geotech Report

**Lateral Loads**

Soil Lateral Loads (per Geotech)
- Active Earth Pressure:
  - CIP Cantilever Wall = 35pcf (yielding wall)
  - MSE Wall: Coulomb theory used with the following parameters:
    - Soil density of 130pcf
    - Soil internal friction angle = 34-36°
    - Soil-Structure friction angle = 34°
- Passive Earth Pressure: conservatively ignore

**Seismic Loads**
- Concrete Retaining Walls: 0H @ top of wall, 8H @ bottom (yielding wall) – Triangular load distribution per Geotech
- MSE Walls: Per ODOT Geotechnical Design Manual, calculate pseudo-static acceleration coefficients:
  - Horizontal Pseudo Seismic Load, $k_h = 0.5A_s$ [ODOT GDM, Section 6.5.3.1]
    - $A_s = F_{pga} \times PGA$ [AASHTO 3.10.4.2-2]
    - 1000yr PGA = 0.27 [Per ODOT Seismic Maps]
    - $F_{pga} = 1.2$ [Per ASHTO 3.10.3.2]
    - $k_h = 0.162g$ ← Used as pseudo-static horizontal seismic acceleration in analysis software for analyzing MSE walls
  - Vertical Pseudo Seismic Load, $k_v = 0.00g$ [ODOT GDM, Section 6.5.3.1]

**Gravity Loads**

Surcharge Loads (per Geotech)
- Concrete Retaining Walls: No surcharge loads
- MSE Walls:
  - Uniform Vertical Surcharge = 200psf (accounts for traffic and construction loads)
MSE Wall Design

By inspection, Walls 3 controls for the design of Wall 1, 2, 3, and 4 as it retains the greatest soil height under equivalent load parameters and conditions. Design for Wall heights ranging from 0’-0” to 10’-6” at increments of 1’-6” (equivalent to block height).
Wall Information:
- Max Height = 10.5'
- Max Number of Courses = 7
- Curved wall sections around the road curves. Varies in height along length.
- Supports roadway in some regions (Wall 1, 2, and 4) and bike path in others (Wall 3). All MSE wall segments designed to resist roadway surcharge loading.
- Design for Wall heights ranging from 0'-0" to 10'-6" at increments of 1'-6" (equivalent to unit block height).
Design Criteria:
- Evaluated per AASHTO Chapter 11.10, Requirements per Geotechnical Engineer, and NCMA Design Manual for Segmental Retaining Walls
- Active Earth Pressure Calculation Method: Coulomb
- Passive Earth Pressure conservatively ignored
- Seismic Analysis Method: Mononobe-Okabe (Per AASHTO)
- Min. Required Reinforcement Length = 0.7*Height of Wall (Per AASHTO 11.10.2.1)
- Block and geogrid internal stability and strength evaluated using Safety Factors
- Verification Methodology: Safety Factors (Per NCMA Table 5-2)

<table>
<thead>
<tr>
<th>Case</th>
<th>Transient/Variable</th>
<th>Seismic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overturning FS</td>
<td>1.50</td>
<td>1.10</td>
</tr>
<tr>
<td>Sliding FS</td>
<td>1.50</td>
<td>1.10</td>
</tr>
<tr>
<td>Soil Bearing FS*</td>
<td>1.33 (1500psf)</td>
<td>1.00 (2000psf)</td>
</tr>
<tr>
<td>Sliding Along Geo-Reinforcement FS</td>
<td>1.50</td>
<td>1.10</td>
</tr>
<tr>
<td>Geo-Reinforcement Strength FS</td>
<td>1.50</td>
<td>1.10</td>
</tr>
<tr>
<td>Geo-Reinforcement Pull Out FS</td>
<td>1.50</td>
<td>1.10</td>
</tr>
<tr>
<td>Geo-Reinforcement Connection FS</td>
<td>1.50</td>
<td>1.10</td>
</tr>
</tbody>
</table>

*Allowable soil bearing pressures were prescribed by the Geotechnical engineer (1500 psf for static and 2000psf for seismic). As such, an additional factor of safety was not applied in the structural calculations for soil bearing pressure, as PSE understands that it was already accounted for in the recommended allowable pressure prescribed by the Geotechnical engineer.

Design Loads:
- Active Earth Pressure = 35pcf (yielding wall)
- Uniform Vertical Surcharge atop wall = 200psf
- Horizontal Seismic Loads: \( k_h = 0.162g \)
- Vertical Seismic Loads: \( k_v = 0.00g \)

Per MSE wall analysis software (See Appendix A), the following design outcomes are acceptable for varying heights of MSE walls:

![MSE retaining wall schedule](image-url)
Design the CIP Concrete Retaining Walls per AASHTO Chapter 11.6.
CIP Cantilever Wall Design – Wall 5

Wall Information:
- Max Height = 6.0’
- Retains soil from roadway
- Concrete Strength, $f'_c = 4,000$psi
- Wall Stem = 8” thick. Reinforced with #5 bars @ 12” o.c., each way, both faces
  - The stem has been conservatively evaluated in RetainPro as a singly reinforced section with #5 bars @ 12” o.c. at the tension face.
- Wall Footing:
  - Depth = 1’-0”
  - Toe Width = 2’-0”
  - Heel Width = 4’-6” max, 2’-6” min (varies with wall height)
  - Reinforced with #5 bars @ 12” o.c., each way, both faces
- Wall Key: No wall key present
Design Criteria

- Evaluated per AASHTO and Requirements per Geotechnical Engineer
  - Load Factors input for Strength Level I state:
    - Dead Load, DC = 1.25
    - Surcharge Load (live), ES = 1.50 (Note: surcharge = 0psf)
    - Earth Active Pressure, EH = 1.50
    - Seismic, EQ = N/A
  - Load Factors input for Extreme Event I state: By inspection, Controls
    - Dead Load, DC = 1.25
    - Surcharge Load (live), ES = γEQ = 0.75 (Note: surcharge = 0psf)
    - Earth Active Pressure, EH = 1.50
    - Seismic, EQ = 1.00

- External Stability:
  - Overturning FS = 1.5
  - Sliding FS = 1.5

- Allowable Bearing Pressure = 2000psf (allowed 1/3 increase for short term loads per Geotech report)
- Stem wall and Footing Design: Per AASHTO & ACI LRFD Criteria

Design Loads:

- Active Earth Pressure = 35pcf (yielding wall)
- Passive Earth Pressure conservatively ignored
- Uniform Vertical Surcharge = 0psf (doesn’t support roadway)
- Seismic Loads: 0H @ top of wall, 8H at bottom of wall

Per RetainPro (see Appendix), the following table is acceptable for varying heights of CIP walls:

<table>
<thead>
<tr>
<th>WALL HEIGHT, “H_{top}”</th>
<th>STEM THICKNESS</th>
<th>STEM REINFORCEMENT</th>
<th>FOOTING HEEL WIDTH, “f”</th>
<th>FOOTING TOE WIDTH</th>
<th>FOOTING DEPTH</th>
<th>FOOTING REINFORCEMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>0’–0” TO 3’– 0”</td>
<td>0’–8”</td>
<td>#5 BARS @ 12” O.C., BOTH FACERS, EACH WAY</td>
<td>2’–6”</td>
<td>2’–0”</td>
<td>1’–0”</td>
<td>#5 BARS @ 12” O.C., TOP AND BOTTOM, EACH WAY</td>
</tr>
<tr>
<td>3’–0” TO 4’– 6”</td>
<td>0’–8”</td>
<td>#5 BARS @ 12” O.C., BOTH FACERS, EACH WAY</td>
<td>3’–6”</td>
<td>2’–0”</td>
<td>1’–0”</td>
<td>#5 BARS @ 12” O.C., TOP AND BOTTOM, EACH WAY</td>
</tr>
<tr>
<td>4’–6” TO 6’– 0”</td>
<td>0’–8”</td>
<td>#5 BARS @ 12” O.C., BOTH FACERS, EACH WAY</td>
<td>4’–6”</td>
<td>2’–0”</td>
<td>1’–0”</td>
<td>#5 BARS @ 12” O.C., TOP AND BOTTOM, EACH WAY</td>
</tr>
</tbody>
</table>

CIP CANTILEVER RETAINING WALL NOTES
1. ALL CIP CANTILEVER WALLS OF VARYING HEIGHT SHALL CONFORM TO THE REQUIREMENTS OUTLINED IN THE CIP CANTILEVER WALL SCHEDULE.
2. POST INSTALLED FENCES AT TOP WALLS SHALL BE INSTALLED PER ODOT ANCHORAGE REQUIREMENTS. E.O.R. SHALL BE NOTIFIED PRIOR TO ANCHORING TO WALLS.
3. TABULATED FOOTING WIDTHS MAY BE INCREASED AT CONTRACTOR’S OPTION.
4. WALL FOOTINGS SHALL NOT BE MULTIPURPOSED FOR ROADWAY/CURB FOOTINGS.
5. E.O.R. SHALL BE NOTIFIED IF TREE ROOTS CONFLICT WITH RETAINING WALLS/WALL FOOTINGS.

Note: By inspection, the MSE Retaining walls are designed for greater loading than the CIP Cantilever wall since the MSE walls are responsible for supporting the roadway and surcharge loads. As such, the MSE wall designs control. At contractor/owner’s option, MSE walls may be constructed in lieu of CIP cantilever walls. Finish grade elevations behind and in front of the walls shall not change. MSE walls must be constructed in conformance with MSE wall construction details and schedule.
Appendix A – MSE Wall Design
10'-6” Tall Wall – Seismic Case
Analysis of Redi Rock wall

Input data
Project
Date: 11/25/2019

Settings
(input for current task)

Materials and standards
AASHTO - reduce parameters of friction soil/soil by 2/3 φ

Wall analysis
Active earth pressure calculation: Coulomb
Passive earth pressure calculation: Mazinrani (Rankine)
Earthquake analysis: Mononobe-Okabe
Shape of earth wedge: Calculate as skew
Allowable eccentricity: 0.333
Internal stability: Standard - straight slip surface
Reduction coeff. of contact first block - base: 1.00
Verification methodology: Safety factors (ASD)

| Safety factors for overturning: SF₀ = 1.10 [-] |
| Safety factor for sliding resistance: SFᵣ = 1.10 [-] |
| Safety factor for bearing capacity: SFₑ = 1.00 [-] |
| Safety factor for sliding along geo-reinforcement: SFₑᵣ = 1.10 [-] |
| Safety factor for geo-reinforcement strength: SFᵣᵣ = 1.10 [-] |
| Safety factor for pull out resistance of geo-reinf.: SFᵦᵣ = 1.10 [-] |
| Safety factor for connection strength: SFₑᵣᵢ = 1.10 [-] |

Geometry

<table>
<thead>
<tr>
<th>No. group</th>
<th>Description</th>
<th>Count</th>
<th>Setback [s in]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Block 28 PC</td>
<td>6</td>
<td>1.62</td>
</tr>
<tr>
<td>2</td>
<td>Top block 28</td>
<td>1</td>
<td>-</td>
</tr>
</tbody>
</table>

Base

Geometry
Upper setback a₁ = 0.50 ft
Lower setback a₂ = 0.50 ft
Height h = 0.50 ft
Width b = 3.50 ft

Material
Unreinforced Footing
Concrete self-weight γ = 150.00 pcf
Shear cub (key) capacity = 0.00 lb/ft
Friction angle concrete-concrete = 30.00°
### Types of reinforcements

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Type of reinforcement</th>
<th>Line type</th>
<th>$T_{ult}$ [lb/ft]</th>
<th>$R_L$ [lb/ft]</th>
<th>$R_{Con}$ [lb/ft]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Miragrid 5XT</td>
<td>Miragrid 5XT</td>
<td></td>
<td>4700.00</td>
<td>2069.35</td>
<td>2174.26</td>
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<tr>
<td>2</td>
<td>Miragrid 8XT</td>
<td>Miragrid 8XT</td>
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<td>7400.00</td>
<td>3393.87</td>
<td>3423.30</td>
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<tr>
<td>3</td>
<td>Miragrid 10XT</td>
<td>Miragrid 10XT</td>
<td></td>
<td>9500.00</td>
<td>4357.00</td>
<td>4287.39</td>
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<tr>
<td>4</td>
<td>Miragrid 20XT</td>
<td>Miragrid 20XT</td>
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<td>13705.00</td>
<td>6558.83</td>
<td>6030.20</td>
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<tr>
<td>5</td>
<td>Miragrid 24XT</td>
<td>Miragrid 24XT</td>
<td></td>
<td>27415.00</td>
<td>13716.42</td>
<td>10560.73</td>
</tr>
</tbody>
</table>

### Reinforcement details

1. **Miragrid 5XT**
   - Short-term char. strength
   - Creep red. factor
   - Durability red. factor
   - Installation damage red. factor
   - Long-term design strength $R_L = 2069.35$ [lb/ft]
   - Coefficient of direct slip along reinforcement $C_{ds} = 0.67$
   - Coefficient of interaction of soil and geo-reinforcement $C_i = 0.67$
   - Scale correction factor $SC = 0.8$
   - Long-term strength reduction factor $CR_{LR} = 0.532$
   - Analysis of long-term strength $R_{Con} = 2174.26$ [lb/ft]

2. **Miragrid 8XT**
   - Short-term char. strength
   - Creep red. factor
   - Durability red. factor
   - Installation damage red. factor
   - Long-term design strength $R_L = 3393.87$ [lb/ft]
   - Coefficient of direct slip along reinforcement $C_{ds} = 0.67$
   - Coefficient of interaction of soil and geo-reinforcement $C_i = 0.67$
   - Scale correction factor $SC = 0.8$
   - Long-term strength reduction factor $CR_{LR} = 0.532$
   - Analysis of long-term strength $R_{Con} = 3423.30$ [lb/ft]

3. **Miragrid 10XT**
   - Short-term char. strength
   - Creep red. factor
   - Durability red. factor
   - Installation damage red. factor
   - Long-term design strength $R_L = 4357.00$ [lb/ft]
   - Coefficient of direct slip along reinforcement $C_{ds} = 0.67$
   - Coefficient of interaction of soil and geo-reinforcement $C_i = 0.67$
   - Scale correction factor $SC = 0.8$
   - Long-term strength reduction factor $CR_{LR} = 0.519$
   - Analysis of long-term strength $R_{Con} = 4287.39$ [lb/ft]

4. **Miragrid 20XT**
   - Short-term char. strength
   - Creep red. factor
   - Durability red. factor
   - Installation damage red. factor
   - Long-term design strength $R_L = 6558.83$ [lb/ft]
   - Coefficient of direct slip along reinforcement $C_{ds} = 0.67$
   - Coefficient of interaction of soil and geo-reinforcement $C_i = 0.67$
   - Scale correction factor $SC = 0.8$
   - Long-term strength reduction factor $CR_{LR} = 0.532$
   - Analysis of long-term strength $R_{Con} = 6030.20$ [lb/ft]
Creep red. factor \[ RF_{CR} = 1.58 \]
Durability red. factor \[ RF_{D} = 1.15 \]
Installation damage red. factor \[ RF_{ID} = 1.15 \]
Long-term design strength \[ R_{L} = 6558.83 \text{ lb/ft} \]
Coefficient of direct slip along reinforcement \[ C_{di} = 0.67 \]
Coefficient of interaction of soil and geo-reinforcement \[ C_{i} = 0.67 \]
Scale correction factor \[ \alpha = 0.8 \]
Long-term strength reduction factor \[ CR_{cr} = 0.506 \]
Analysis of long-term strength \[ R_{con} = 6030.20 \text{ lb/ft} \]

5. Miragrid 24XT

Short-term char. strength \[ T_{ult} = 27415.00 \text{ lb/ft} \]
Creep red. factor \[ RF_{CR} = 1.58 \]
Durability red. factor \[ RF_{D} = 1.15 \]
Installation damage red. factor \[ RF_{ID} = 1.10 \]
Long-term design strength \[ R_{L} = 13716.42 \text{ lb/ft} \]
Coefficient of direct slip along reinforcement \[ C_{di} = 0.67 \]
Coefficient of interaction of soil and geo-reinforcement \[ C_{i} = 0.67 \]
Scale correction factor \[ \alpha = 0.8 \]
Long-term strength reduction factor \[ CR_{cr} = 0.443 \]
Analysis of long-term strength \[ R_{con} = 10560.73 \text{ lb/ft} \]

Reinforcements

Input mode: 1 reinforcement type
Reinf. installation: in every row of blocks (50%)
Type of reinforcement: Miragrid 5XT
Top reinforcement: straight (25%)
Reinforcement geometry: identical length of reinforcements
Length of reinforcement \[ l = 7.50 \text{ ft} \]

<table>
<thead>
<tr>
<th>No.</th>
<th>Consider</th>
<th>Name</th>
<th>Length of reinforcement [ l ] [ft]</th>
<th>End pt. coordinate [ l_k ] [ft]</th>
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<tbody>
<tr>
<td>1</td>
<td>Yes</td>
<td>Miragrid 5XT</td>
<td>7.50</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Yes</td>
<td>Miragrid 5XT</td>
<td>7.50</td>
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<tr>
<td>3</td>
<td>Yes</td>
<td>Miragrid 5XT</td>
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<td>4</td>
<td>Yes</td>
<td>Miragrid 5XT</td>
<td>7.50</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Yes</td>
<td>Miragrid 5XT</td>
<td>7.50</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Yes</td>
<td>Miragrid 5XT</td>
<td>7.50</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>No</td>
<td></td>
<td>7.50</td>
<td></td>
</tr>
</tbody>
</table>
Soil parameters

Gravel Backfill
Unit weight: $\gamma = 130.0 \text{ pcf}$
Stress-state: effective
Angle of internal friction: $\varphi_{ef} = 35.50^\circ$
Cohesion of soil: $c_{ef} = 0.0 \text{ psf}$
Angle of friction struc.-soil: $\delta = 34.00^\circ$
Saturated unit weight: $\gamma_{sat} = 130.0 \text{ pcf}$

Input surface surcharges

<table>
<thead>
<tr>
<th>No.</th>
<th>Surcharge</th>
<th>Action</th>
<th>Mag.1</th>
<th>Mag.2</th>
<th>Ord.x</th>
<th>Length</th>
<th>Depth</th>
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<tbody>
<tr>
<td>1</td>
<td>Yes</td>
<td>variable</td>
<td>200.0</td>
<td></td>
<td></td>
<td></td>
<td>on terrain</td>
</tr>
</tbody>
</table>

Resistance on front face of the structure
Resistance on front face of the structure is not considered.

Earthquake
Factor of horizontal acceleration $K_h = 0.1620$
Factor of vertical acceleration $K_v = 0.0000$
Water below the GWT is free.
Specific gravity of soil particles $G_s = 2.08$. 
Settings of the stage of construction
Design situation: seismic

Verification No. 1
Forces acting on construction

<table>
<thead>
<tr>
<th>Name</th>
<th>F_{\text{hor}}</th>
<th>App. Pt. z [ft]</th>
<th>F_{\text{vert}}</th>
<th>App. Pt. x [ft]</th>
<th>Design coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight - reinforced soil</td>
<td>0.0</td>
<td>-5.28</td>
<td>10380.9</td>
<td>6.46</td>
<td>1.000</td>
</tr>
<tr>
<td>Earthquake - soil wedge</td>
<td>1681.7</td>
<td>-5.28</td>
<td>0.0</td>
<td>6.46</td>
<td>1.000</td>
</tr>
<tr>
<td>Active pressure</td>
<td>1572.7</td>
<td>-3.50</td>
<td>689.3</td>
<td>10.51</td>
<td>1.000</td>
</tr>
<tr>
<td>Earthq.- act. pressure</td>
<td>700.5</td>
<td>-7.00</td>
<td>307.0</td>
<td>10.51</td>
<td>1.000</td>
</tr>
<tr>
<td>Roadway Surcharge</td>
<td>460.9</td>
<td>-5.25</td>
<td>202.0</td>
<td>10.51</td>
<td>1.000</td>
</tr>
<tr>
<td>Weight - wall</td>
<td>0.0</td>
<td>-6.08</td>
<td>2844.2</td>
<td>1.55</td>
<td>1.000</td>
</tr>
<tr>
<td>Earthq. - constr.</td>
<td>460.8</td>
<td>-6.08</td>
<td>0.0</td>
<td>1.55</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Verification of complete wall
Place of verification: bottom of blocks

Check for overturning stability
Resisting moment \( M_{\text{res}} = 84064.0 \text{ lbf/ft} \)
Overturning moment \( M_{\text{curt}} = 24049.4 \text{ lbf/ft} \)

Safety factor = 3.50 > 1.10
Wall for overturning is SATISFACTORY

Check for slip
Resisting horizontal force \( H_{\text{res}} = 9439.32 \text{ lbf/ft} \)
Active horizontal force \( H_{\text{act}} = 4876.53 \text{ lbf/ft} \)

Safety factor = 1.94 > 1.10
Wall for slip is SATISFACTORY

Overall check - WALL is SATISFACTORY
Bearing capacity of foundation soil

Design load acting at the center of footing bottom

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-17234.3</td>
<td>5745.70</td>
<td>-2468.01</td>
<td>0.000</td>
<td>1641.6</td>
</tr>
</tbody>
</table>

Service load acting at the center of footing bottom

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-17234.3</td>
<td>5745.70</td>
<td>-2468.01</td>
</tr>
</tbody>
</table>

Verification of foundation soil

Place of verification: bottom of leveling pad
Stress in the footing bottom: trapezoid

Eccentricity verification

Max. eccentricity of normal force $e = 0.000$
Maximum allowable eccentricity $e_{aw} = 0.333$

Eccentricity of the normal force is SATISFACTORY

Verification of bearing capacity

Max. stress at footing bottom $\sigma = 1641.6$ psf
Bearing capacity of foundation soil $R_d = 2000.0$ psf
Safety factor $= 1.22 > 1.00$

Bearing capacity of foundation soil is SATISFACTORY

Overall verification - bearing capacity of found. soil is SATISFACTORY
Verification of slip on georeinforcement No. 1

Forces acting on construction (verification of reinforcement No.: 1)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight - wall</td>
<td>0.0</td>
<td>-5.08</td>
<td>2891.6</td>
<td>-3.78</td>
<td>1.000</td>
</tr>
<tr>
<td>Earthq. constr.</td>
<td>468.4</td>
<td>-5.08</td>
<td>0.0</td>
<td>-3.78</td>
<td>1.000</td>
</tr>
<tr>
<td>Active pressure</td>
<td>1572.7</td>
<td>-3.50</td>
<td>689.3</td>
<td>7.50</td>
<td>1.000</td>
</tr>
<tr>
<td>Earthq. - act.pressure</td>
<td>700.5</td>
<td>-7.00</td>
<td>307.0</td>
<td>7.50</td>
<td>1.000</td>
</tr>
<tr>
<td>Roadway Surcharge</td>
<td>460.9</td>
<td>-5.25</td>
<td>202.0</td>
<td>7.50</td>
<td>1.000</td>
</tr>
<tr>
<td>Weight - reinforced soil</td>
<td>0.0</td>
<td>-5.14</td>
<td>9760.4</td>
<td>3.95</td>
<td>1.000</td>
</tr>
<tr>
<td>Earthquake - soil wedge</td>
<td>1568.6</td>
<td>-5.14</td>
<td>0.0</td>
<td>3.95</td>
<td>1.000</td>
</tr>
<tr>
<td>Roadway Surcharge</td>
<td>0.0</td>
<td>-10.50</td>
<td>1720.8</td>
<td>0.20</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Verification against slip along geotextile No.: 1

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inclination of slip surface</td>
<td>90.00 °</td>
</tr>
<tr>
<td>Overall normal force acting on reinforcement</td>
<td>12679.49 lbf/ft</td>
</tr>
<tr>
<td>Coefficient of reduction of slip along geo-textile</td>
<td>0.92</td>
</tr>
<tr>
<td>Resistance along geo-reinforcement</td>
<td>8298.05 lbf/ft</td>
</tr>
<tr>
<td>Wall resistance</td>
<td>0.00 lbf/ft</td>
</tr>
<tr>
<td>Overall bearing capacity of reinforcements</td>
<td>0.00 lbf/ft</td>
</tr>
</tbody>
</table>

Check for slip:

- Resisting horizontal force $H_{res} = 8298.05$ lbf/ft
- Active horiz. force $H_{act} = 2734.06$ lbf/ft
- Factor of safety $= 3.04 > 1.10$
Slip along geotextile is SATISFACTORY

Calculation of internal stability No. 1

Calculated forces and strength of reinforcements

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Miragrid 5XT</td>
<td>-233.67</td>
<td>10.50</td>
<td>517.34</td>
<td>49.68</td>
<td>1957.03</td>
<td>13.13</td>
<td>543.57</td>
<td>47.29</td>
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<tr>
<td>2</td>
<td>Miragrid 5XT</td>
<td>-423.11</td>
<td>9.00</td>
<td>1034.67</td>
<td>44.98</td>
<td>3030.75</td>
<td>15.36</td>
<td>1087.13</td>
<td>42.81</td>
</tr>
<tr>
<td>3</td>
<td>Miragrid 5XT</td>
<td>-375.37</td>
<td>7.50</td>
<td>1034.67</td>
<td>39.91</td>
<td>2265.49</td>
<td>18.31</td>
<td>1087.13</td>
<td>37.96</td>
</tr>
<tr>
<td>4</td>
<td>Miragrid 5XT</td>
<td>-350.42</td>
<td>6.00</td>
<td>1034.67</td>
<td>37.25</td>
<td>1588.29</td>
<td>24.27</td>
<td>1087.13</td>
<td>35.46</td>
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<tr>
<td>5</td>
<td>Miragrid 5XT</td>
<td>-325.48</td>
<td>4.50</td>
<td>1034.67</td>
<td>34.60</td>
<td>1029.14</td>
<td>34.79</td>
<td>1087.13</td>
<td>32.93</td>
</tr>
<tr>
<td>6</td>
<td>Miragrid 5XT</td>
<td>-300.53</td>
<td>3.00</td>
<td>1034.67</td>
<td>31.95</td>
<td>578.04</td>
<td>57.19</td>
<td>1087.13</td>
<td>30.41</td>
</tr>
</tbody>
</table>

Check for tensile strength (reinforcement No.1)
Tension strength $R_t = 517.34$ lb/ft
Force in reinforcement $F_x = 233.67$ lb/ft
Safety factor $= 2.21 > 1.10$

Reinforcement for tensile strength is SATISFACTORY

Check for pull out resistance (reinforcement No.6)
Pull out resistance $T_p = 578.04$ lb/ft
Force in reinforcement $F_x = 300.53$ lb/ft
Safety factor $= 1.92 > 1.10$

Reinforcement for pull out resistance is SATISFACTORY

Verification of connection strength (reinforcement No.1)
Connection strength $R_{con} = 543.57$ lb/ft
Force in reinforcement $F_x = 233.67$ lb/ft
Safety factor $= 2.33 > 1.10$

Connection strength is SATISFACTORY

Overall verification - reinforcement is SATISFACTORY
<table>
<thead>
<tr>
<th>Name</th>
<th>Stage - analysis : 1 - 1</th>
</tr>
</thead>
</table>

**Diagram:**

- Name: Internal stability
- Stage - analysis: 1 - 1

- Dimensions: 1050 x 9.83
- Measurements:
  - 233.67
  - 7.50
  - 375.37
  - 375.48
  - 350.42
  - 300.59

**Additional Information:**

- Project: 1801-0336
- Date: 3/27/2020
- Designer: NRW
- Sheet: A11
10’-6” Tall Wall – Transient Case
**Analysis of Redi Rock wall**

**Input data**

**Project**
Date: 11/25/2019

**Settings**
(input for current task)

**Materials and standards**
AASHTO - reduce parameters of friction soil/soil by 2/3 \( \phi \)

**Wall analysis**
- Active earth pressure calculation: Coulomb
- Passive earth pressure calculation: Mazhindani (Rankine)
- Earthquake analysis: Mononobe-Okabe
- Shape of earth wedge: Calculate as skew
- Allowable eccentricity: 0.333
- Internal stability: Standard – straight slip surface
- Reduction coeff. of contact first block - base: 1.00
- Verification methodology: Safety factors (ASD)

<table>
<thead>
<tr>
<th>Safety factors</th>
<th>Transient design situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF(_0) for overturning</td>
<td>1.50 [-]</td>
</tr>
<tr>
<td>SF(_s) for sliding resistance</td>
<td>1.50 [-]</td>
</tr>
<tr>
<td>SF(_b) for bearing capacity</td>
<td>1.33 [-]</td>
</tr>
<tr>
<td>SF(_s) for sliding along geo-reinforcement</td>
<td>1.50 [-]</td>
</tr>
<tr>
<td>SF(_st) for geo-reinforcement strength</td>
<td>1.50 [-]</td>
</tr>
<tr>
<td>SF(_po) for pull out resistance of geo-reinf.</td>
<td>1.50 [-]</td>
</tr>
<tr>
<td>SF(_con) for connection strength</td>
<td>1.50 [-]</td>
</tr>
</tbody>
</table>

**Geometry**

<table>
<thead>
<tr>
<th>No. group</th>
<th>Description</th>
<th>Count</th>
<th>Setback s [in]</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Block 28 PC</td>
<td>6</td>
<td>1.62</td>
</tr>
<tr>
<td>2</td>
<td>Top block 28</td>
<td>1</td>
<td>-</td>
</tr>
</tbody>
</table>

**Base**
- Geometry
  - Upper setback: \( a_1 = 0.50 \) ft
  - Lower setback: \( a_2 = 0.50 \) ft
  - Height: \( h = 0.50 \) ft
  - Width: \( b = 3.50 \) ft
- Material
  - Unreinforced Footing
  - Concrete self-weight: \( \gamma = 150.00 \) pcf
  - Shear cub (key) capacity: \( 0.00 \) lb/ft
  - Friction angle concrete-concrete: \( 30.00^\circ \)
Types of reinforcements

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Type of reinforcement</th>
<th>Line type</th>
<th>T_{ult} [lb/ft]</th>
<th>R_{L} [lb/ft]</th>
<th>R_{Con} [lb/ft]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Miragrid 5XT</td>
<td>Miragrid 5XT</td>
<td></td>
<td>4700.00</td>
<td>2069.35</td>
<td>2174.26</td>
</tr>
<tr>
<td>2</td>
<td>Miragrid 8XT</td>
<td>Miragrid 8XT</td>
<td></td>
<td>7400.00</td>
<td>3393.87</td>
<td>3423.30</td>
</tr>
<tr>
<td>3</td>
<td>Miragrid 10XT</td>
<td>Miragrid 10XT</td>
<td></td>
<td>9500.00</td>
<td>4357.00</td>
<td>4287.39</td>
</tr>
<tr>
<td>4</td>
<td>Miragrid 20XT</td>
<td>Miragrid 20XT</td>
<td></td>
<td>13705.00</td>
<td>6558.83</td>
<td>6030.20</td>
</tr>
<tr>
<td>5</td>
<td>Miragrid 24XT</td>
<td>Miragrid 24XT</td>
<td></td>
<td>27415.00</td>
<td>13716.42</td>
<td>10560.73</td>
</tr>
</tbody>
</table>

Reinforcement details

1. **Miragrid 5XT**
   - Short-term char. strength: $T_{ult} = 4700.00\ lbf/ft$
   - Creep red. factor: $RF_{CR} = 1.58$
   - Durability red. factor: $RF_{D} = 1.15$
   - Installation damage red. factor: $RF_{ID} = 1.25$
   - Long-term design strength: $R_{L} = 2069.35\ lbf/ft$
   - Coefficient of direct slip along reinforcement: $C_{ds} = 0.67$
   - Coefficient of interaction of soil and geo-reinforcement: $C_{I} = 0.67$
   - Scale correction factor: $\alpha = 0.8$
   - Long-term strength reduction factor: $CR_{L} = 0.532$
   - Analysis of long-term strength: $R_{Con} = 2174.26\ lbf/ft$

2. **Miragrid 8XT**
   - Short-term char. strength: $T_{ult} = 7400.00\ lbf/ft$
   - Creep red. factor: $RF_{CR} = 1.58$
   - Durability red. factor: $RF_{D} = 1.15$
   - Installation damage red. factor: $RF_{ID} = 1.20$
   - Long-term design strength: $R_{L} = 3393.87\ lbf/ft$
   - Coefficient of direct slip along reinforcement: $C_{ds} = 0.67$
   - Coefficient of interaction of soil and geo-reinforcement: $C_{I} = 0.67$
   - Scale correction factor: $\alpha = 0.8$
   - Long-term strength reduction factor: $CR_{L} = 0.532$
   - Analysis of long-term strength: $R_{Con} = 3423.30\ lbf/ft$

3. **Miragrid 10XT**
   - Short-term char. strength: $T_{ult} = 9500.00\ lbf/ft$
   - Creep red. factor: $RF_{CR} = 1.58$
   - Durability red. factor: $RF_{D} = 1.15$
   - Installation damage red. factor: $RF_{ID} = 1.20$
   - Long-term design strength: $R_{L} = 4357.00\ lbf/ft$
   - Coefficient of direct slip along reinforcement: $C_{ds} = 0.67$
   - Coefficient of interaction of soil and geo-reinforcement: $C_{I} = 0.67$
   - Scale correction factor: $\alpha = 0.8$
   - Long-term strength reduction factor: $CR_{L} = 0.519$
   - Analysis of long-term strength: $R_{Con} = 4287.39\ lbf/ft$

4. **Miragrid 20XT**
Short-term char. strength


Creep red. factor


Durability red. factor


Installation damage red. factor


Long-term design strength


Coefficient of direct slip along reinforcement


Coefficient of interaction of soil and geo-reinforcement


Scale correction factor


Long-term strength reduction factor


Analysis of long-term strength


5. Miragrid 24XT


Short-term char. strength


Creep red. factor


Durability red. factor


Installation damage red. factor


Long-term design strength


Coefficient of direct slip along reinforcement


Coefficient of interaction of soil and geo-reinforcement


Scale correction factor


Long-term strength reduction factor


Analysis of long-term strength


Reinforcements

Input mode : 1 reinforcement type
Reinf. installation : in every row of blocks (50%)
Type of reinforcement : Miragrid 5XT
Top reinforcement : straight (25%)
Reinforcement geometry : identical length of reinforcements
Length of reinforcement \( l = 7.50 \) ft

Reinforcements:

<table>
<thead>
<tr>
<th>No.</th>
<th>Consider</th>
<th>Name</th>
<th>Length of reinforcement ( l ) [ft]</th>
<th>End pt. coordinate ( l_k ) [ft]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yes</td>
<td>Miragrid 5XT</td>
<td>7.50</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Yes</td>
<td>Miragrid 5XT</td>
<td>7.50</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Yes</td>
<td>Miragrid 5XT</td>
<td>7.50</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Yes</td>
<td>Miragrid 5XT</td>
<td>7.50</td>
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<tr>
<td>5</td>
<td>Yes</td>
<td>Miragrid 5XT</td>
<td>7.50</td>
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<tr>
<td>6</td>
<td>Yes</td>
<td>Miragrid 5XT</td>
<td>7.50</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Soil parameters

Gravel Backfill
Unit weight: \( \gamma = 130.0 \text{ pcf} \)
Stress-state: effective
Angle of internal friction: \( \varphi_{ef} = 35.50^\circ \)
Cohesion of soil: \( c_{ef} = 0.0 \text{ psf} \)
Angle of friction struct.-soil: \( \delta = 34.00^\circ \)
Saturated unit weight: \( \gamma_{sat} = 130.0 \text{ pcf} \)

Input surface surcharges

<table>
<thead>
<tr>
<th>No.</th>
<th>Surcharge</th>
<th>Change</th>
<th>Action</th>
<th>Mag. 1 ( \text{[lb/ft}^2)</th>
<th>Mag. 2 ( \text{[lb/ft}^2)</th>
<th>Ord. x ( \text{[ft]})</th>
<th>Length ( \text{[ft]})</th>
<th>Depth ( \text{[ft]})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yes</td>
<td></td>
<td>variable</td>
<td>200.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

No. Name

1 Roadway Surcharge

Resistance on front face of the structure
Resistance on front face of the structure is not considered.

Settings of the stage of construction
Design situation: transient
Verification No. 1

Forces acting on construction

<table>
<thead>
<tr>
<th>Name</th>
<th>( F_\text{hor} ) [lbf/ft]</th>
<th>( \text{App. Pt.} ) ( z ) [ft]</th>
<th>( F_\text{vert} ) [lbf/ft]</th>
<th>( \text{App. Pt.} ) ( x ) [ft]</th>
<th>Design coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight - reinforced soil</td>
<td>0.0</td>
<td>-6.28</td>
<td>10380.9</td>
<td>6.46</td>
<td>1.00</td>
</tr>
<tr>
<td>Active pressure</td>
<td>1572.7</td>
<td>-3.50</td>
<td>689.3</td>
<td>10.51</td>
<td>1.00</td>
</tr>
<tr>
<td>Roadway Surcharge</td>
<td>460.9</td>
<td>-5.25</td>
<td>202.0</td>
<td>10.51</td>
<td>1.00</td>
</tr>
<tr>
<td>Weight - wall</td>
<td>0.0</td>
<td>-5.08</td>
<td>2844.2</td>
<td>1.55</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Verification of complete wall

Place of verification: bottom of blocks

Check for overturning stability
Resisting moment \( M_\text{res} = 80837.1 \text{ lbf}\cdot\text{ft} \)
Overturning moment \( M_\text{over} = 7923.9 \text{ lbf}\cdot\text{ft} \)

Safety factor = 10.20 > 1.50
Wall for overturning is SATISFACTORY

Check for slip
Resisting horizontal force \( H_\text{res} = 9238.39 \text{ lbf/ft} \)
Active horizontal force \( H_\text{act} = 2033.55 \text{ lbf/ft} \)

Safety factor = 4.54 > 1.50
Wall for slip is SATISFACTORY

Overall check - WALL is SATISFACTORY
Bearing capacity of foundation soil

Design load acting at the center of footing bottom

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-2484.3</td>
<td>5170.87</td>
<td>-3778.51</td>
<td>0.000</td>
<td>1477.4</td>
</tr>
</tbody>
</table>

Service load acting at the center of footing bottom

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-2484.3</td>
<td>5170.87</td>
<td>-3778.51</td>
</tr>
</tbody>
</table>

Verification of foundation soil

Place of verification: bottom of leveling pad
Stress in the footing bottom: trapezoid

Eccentricity verification

Max. eccentricity of normal force \( e_n = 0.000 \)
Maximum allowable eccentricity \( e_{aw} = 0.333 \)

Eccentricity of the normal force is SATISFACTORY

Verification of bearing capacity

Max. stress at footing bottom \( \sigma = 1477.4 \text{ psf} \)
Bearing capacity of foundation soil \( R_d = 2000.0 \text{ psf} \)
Safety factor = 1.35 > 1.33

Bearing capacity of foundation soil is SATISFACTORY
Overall verification - bearing capacity of found. soil is SATISFACTORY

Verification of slip on georeinforcement No. 1
Forces acting on construction (verification of reinforcement No.: 1)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight - wall</td>
<td>0.0</td>
<td>-5.08</td>
<td>2891.6</td>
<td>-3.78</td>
<td>1.00</td>
</tr>
<tr>
<td>Active pressure</td>
<td>1572.7</td>
<td>-3.60</td>
<td>689.3</td>
<td>7.50</td>
<td>1.00</td>
</tr>
<tr>
<td>Roadway Surcharge</td>
<td>460.9</td>
<td>-5.25</td>
<td>202.0</td>
<td>7.50</td>
<td>1.00</td>
</tr>
<tr>
<td>Weight - reinforced soil</td>
<td>0.0</td>
<td>-5.14</td>
<td>9760.4</td>
<td>3.95</td>
<td>1.00</td>
</tr>
<tr>
<td>Roadway Surcharge</td>
<td>0.0</td>
<td>-10.50</td>
<td>1720.8</td>
<td>0.20</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Verification against slip along geotextile No.: 1
Inclination of slip surface = 90.00°
Overall normal force acting on reinforcement = 12372.47 lbf/ft
Coefficient of reduction of slip along geo-textile = 0.92
Resistance along geo-reinforcement = 8097.12 lbf/ft
Wall resistance = 1869.45 lbf/ft
Overall bearing capacity of reinforcements = 0.00 lbf/ft

Check for slip:
Resisting horizontal force $H_{res} = 9768.57$ lbf/ft
Active horiz. force $H_{act} = 2033.55$ lbf/ft
Factor of safety = 4.80 > 1.50
Slip along geotextile is SATISFACTORY
Calculation of internal stability No. 1

Calculated forces and strength of reinforcements

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>( F_x ) [lbf/ft]</th>
<th>Depth z [ft]</th>
<th>( R_t ) [lbf/ft]</th>
<th>Utiliz. [%]</th>
<th>( T_p ) [lbf/ft]</th>
<th>Utiliz. [%]</th>
<th>( R_{con} ) [lbf/ft]</th>
<th>Utiliz. [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Miragrid 5XT</td>
<td>-230.06</td>
<td>10.50</td>
<td>517.34</td>
<td>66.71</td>
<td>1957.03</td>
<td>17.63</td>
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<td>46.29</td>
<td>2255.49</td>
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<td>44.05</td>
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<td>-266.29</td>
<td>6.00</td>
<td>1034.67</td>
<td>38.61</td>
<td>1588.29</td>
<td>25.15</td>
<td>1087.13</td>
<td>36.74</td>
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<td>5</td>
<td>Miragrid 5XT</td>
<td>-213.31</td>
<td>4.50</td>
<td>1034.67</td>
<td>30.92</td>
<td>1029.14</td>
<td>31.09</td>
<td>1087.13</td>
<td>29.43</td>
</tr>
<tr>
<td>6</td>
<td>Miragrid 5XT</td>
<td>-160.32</td>
<td>3.00</td>
<td>1034.67</td>
<td>23.24</td>
<td>578.04</td>
<td>41.60</td>
<td>1087.13</td>
<td>22.12</td>
</tr>
</tbody>
</table>

Check for tensile strength (reinforcement No.1)
Tension strength \( R_t = 517.34 \) lbf/ft
Force in reinforcement \( F_x = 230.06 \) lbf/ft
Safety factor = 2.25 > 1.50
Reinforcement for tensile strength is SATISFACTORY

Check for pull out resistance (reinforcement No.6)
Pull out resistance \( T_p = 578.04 \) lbf/ft
Force in reinforcement \( F_x = 160.32 \) lbf/ft
Safety factor = 3.61 > 1.50
Reinforcement for pull out resistance is SATISFACTORY

Verification of connection strength (reinforcement No.1)
Connection strength \( R_{con} = 543.57 \) lbf/ft
Force in reinforcement \( F_x = 230.06 \) lbf/ft
Safety factor = 2.36 > 1.50
Connection strength is SATISFACTORY

Overall verification - reinforcement is SATISFACTORY
9'-0" Tall Wall – Seismic Case
Analysis of Redi Rock wall

Input data

Project
Task : MSE Wall Design
Part : 9.0' MSE Wall - Seismic Case
Author : NRW
Date : 11/25/2019
Project number : 1801-0336

Settings
(Input for current task)

Materials and standards
AASHTO - reduce parameters of friction soil/soil by 2/3 φ

Wall analysis
Active earth pressure calculation : Coulomb
Passive earth pressure calculation : Mazinandi (Rankine)
Earthquake analysis : Mononobe-Okabe
Shape of earth wedge : Calculate as skew
Allowable eccentricity : 0.333
Internal stability : Standard - straight slip surface
Reduction coeff. of contact first block - base : 1.00
Verification methodology : Safety factors (ASD)

| Safety factors for overturning: | SF₀ = 1.10 [-] |
| Safety factor for sliding resistance: | SFₛ = 1.10 [-] |
| Safety factor for bearing capacity: | SFₓ = 1.00 [-] |
| Safety factor for sliding along geo-reinforcement: | SFₑ = 1.10 [-] |
| Safety factor for geo-reinforcement strength: | SFₓₑ = 1.10 [-] |
| Safety factor for pull out resistance of geo-reinf.: | SFₑₒ = 1.10 [-] |
| Safety factor for connection strength: | SFₑₒₑ = 1.10 [-] |

Geometry

<table>
<thead>
<tr>
<th>No. group</th>
<th>Description</th>
<th>Count</th>
<th>Setback s [in]</th>
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<tbody>
<tr>
<td>1</td>
<td>Block 28 PC</td>
<td>5</td>
<td>1.62</td>
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<tr>
<td>2</td>
<td>Top block 28</td>
<td>1</td>
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</tbody>
</table>

Base

Geometry
Upper setback a₁ = 0.50 ft
Lower setback a₂ = 0.50 ft
Height h = 0.50 ft
Width b = 3.50 ft

Material
Unreinforced Footing
Concrete self-weight γ = 150.00 pcf
Shear cub (key) capacity = 0.00 lbf/ft
Friction angle concrete-concrete = 30.00°
## Types of reinforcements

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Type of reinforcement</th>
<th>Line type</th>
<th>$T_{ult}$ [lb/ft]</th>
<th>$R_t$ [lb/ft]</th>
<th>$R_{con}$ [lb/ft]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Miragrid 5XT</td>
<td>Miragrid 5XT</td>
<td>----------</td>
<td>4700.00</td>
<td>2069.35</td>
<td>2174.26</td>
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<tr>
<td>2</td>
<td>Miragrid 8XT</td>
<td>Miragrid 8XT</td>
<td>----------</td>
<td>7400.00</td>
<td>3393.87</td>
<td>3423.30</td>
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<tr>
<td>3</td>
<td>Miragrid 10XT</td>
<td>Miragrid 10XT</td>
<td>----------</td>
<td>9500.00</td>
<td>4357.00</td>
<td>4287.39</td>
</tr>
<tr>
<td>4</td>
<td>Miragrid 20XT</td>
<td>Miragrid 20XT</td>
<td>----------</td>
<td>13705.00</td>
<td>6558.83</td>
<td>6030.20</td>
</tr>
<tr>
<td>5</td>
<td>Miragrid 24XT</td>
<td>Miragrid 24XT</td>
<td>----------</td>
<td>27415.00</td>
<td>13716.42</td>
<td>10560.73</td>
</tr>
</tbody>
</table>

## Reinforcement details

1. **Miragrid 5XT**
   - Short-term char. strength: $T_{ult} = 4700.00$ lb/ft
   - Creep red. factor: $RF_{CR} = 1.58$
   - Durability red. factor: $RF_{D} = 1.15$
   - Installation damage red. factor: $RF_{ID} = 1.25$
   - Long-term design strength: $R_t = 2069.35$ lb/ft
   - Coefficient of direct slip along reinforcement: $C_{ds} = 0.67$
   - Coefficient of interaction of soil and geo-reinforcement: $C_t = 0.67$
   - Scale correction factor: $\alpha = 0.8$
   - Long-term strength reduction factor: $CR_{cf} = 0.532$
   - Analysis of long-term strength: $R_{con} = 2174.26$ lb/ft

2. **Miragrid 8XT**
   - Short-term char. strength: $T_{ult} = 7400.00$ lb/ft
   - Creep red. factor: $RF_{CR} = 1.58$
   - Durability red. factor: $RF_{D} = 1.15$
   - Installation damage red. factor: $RF_{ID} = 1.20$
   - Long-term design strength: $R_t = 3393.87$ lb/ft
   - Coefficient of direct slip along reinforcement: $C_{ds} = 0.67$
   - Coefficient of interaction of soil and geo-reinforcement: $C_t = 0.67$
   - Scale correction factor: $\alpha = 0.8$
   - Long-term strength reduction factor: $CR_{cf} = 0.532$
   - Analysis of long-term strength: $R_{con} = 3423.30$ lb/ft

3. **Miragrid 10XT**
   - Short-term char. strength: $T_{ult} = 9500.00$ lb/ft
   - Creep red. factor: $RF_{CR} = 1.58$
   - Durability red. factor: $RF_{D} = 1.15$
   - Installation damage red. factor: $RF_{ID} = 1.20$
   - Long-term design strength: $R_t = 4357.00$ lb/ft
   - Coefficient of direct slip along reinforcement: $C_{ds} = 0.67$
   - Coefficient of interaction of soil and geo-reinforcement: $C_t = 0.67$
   - Scale correction factor: $\alpha = 0.8$
   - Long-term strength reduction factor: $CR_{cf} = 0.519$
   - Analysis of long-term strength: $R_{con} = 4287.39$ lb/ft
4. Miragrid 20XT

Short-term char. strength \( T_{ult} = 13705.00 \text{ lb/ft} \)
Creep red. factor \( R_{FCR} = 1.58 \)
Durability red. factor \( R_{FD} = 1.15 \)
Installation damage red. factor \( R_{FID} = 1.15 \)
Long-term design strength \( R_{LT} = 6558.83 \text{ lb/ft} \)
Coefficient of direct slip along reinforcement \( C_{ds} = 0.67 \)
Coefficient of interaction of soil and geo-reinforcement \( C_{I} = 0.67 \)
Scale correction factor \( \alpha = 0.8 \)
Long-term strength reduction factor \( CR_{ct} = 0.506 \)
Analysis of long-term strength \( R_{con} = 6030.20 \text{ lb/ft} \)

5. Miragrid 24XT

Short-term char. strength \( T_{ult} = 27415.00 \text{ lb/ft} \)
Creep red. factor \( R_{FCR} = 1.58 \)
Durability red. factor \( R_{FD} = 1.15 \)
Installation damage red. factor \( R_{FID} = 1.10 \)
Long-term design strength \( R_{LT} = 13716.42 \text{ lb/ft} \)
Coefficient of direct slip along reinforcement \( C_{ds} = 0.67 \)
Coefficient of interaction of soil and geo-reinforcement \( C_{I} = 0.67 \)
Scale correction factor \( \alpha = 0.8 \)
Long-term strength reduction factor \( CR_{ct} = 0.443 \)
Analysis of long-term strength \( R_{con} = 10560.73 \text{ lb/ft} \)

Reinforcements

Input mode: 1 reinforcement type
Reinf. installation: in every row of blocks (50%)
Type of reinforcement: Miragrid 5XT
Top reinforcement: straight (25%)
Reinforcement geometry: identical length of reinforcements
Length of reinforcement \( l = 6.50 \text{ ft} \)

<table>
<thead>
<tr>
<th>No.</th>
<th>Consider</th>
<th>Name</th>
<th>Length of reinforcement ( l ) [ft]</th>
<th>End pt. coordinate ( l_k ) [ft]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yes</td>
<td>Miragrid 5XT</td>
<td>6.50</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Yes</td>
<td>Miragrid 5XT</td>
<td>6.50</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Yes</td>
<td>Miragrid 5XT</td>
<td>6.50</td>
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<td>4</td>
<td>Yes</td>
<td>Miragrid 5XT</td>
<td>6.50</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Yes</td>
<td>Miragrid 5XT</td>
<td>6.50</td>
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</tr>
<tr>
<td>6</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
MSE Wall Design
9.0' MSE Wall - Seismic Case

Name: Reinforcements
Stage - analysis: 1 - 0

Basic soil parameters

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Pattern</th>
<th>$\Phi_{ef}$ [°]</th>
<th>$C_{ef}$ [psf]</th>
<th>$\gamma$ [pcf]</th>
<th>$\gamma_{su}$ [pcf]</th>
<th>$\delta$ [°]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Gravel Backfill</td>
<td></td>
<td>35.50</td>
<td>0.0</td>
<td>130.0</td>
<td>67.50</td>
<td>34.00</td>
</tr>
</tbody>
</table>

All soils are considered as cohesionless for at rest pressure analysis.

Soil parameters

Gravel Backfill

- Unit weight: $\gamma = 130.0$ pcf
- Stress-state: effective
- Angle of internal friction: $\Phi_{ef} = 35.50$ °
- Cohesion of soil: $C_{ef} = 0.0$ psf
- Angle of friction struct.-soil: $\delta = 34.00$ °
- Saturated unit weight: $\gamma_{sat} = 130.0$ pcf

Input surface surcharges

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yes</td>
<td>variable</td>
<td>200.0</td>
<td></td>
<td></td>
<td></td>
<td>on terrain</td>
</tr>
</tbody>
</table>

No.

1 Roadway Surcharge
Resistance on front face of the structure
Resistance on front face of the structure is not considered.

Earthquake
Factor of horizontal acceleration $K_h = 0.1620$
Factor of vertical acceleration $K_v = 0.0000$
Water below the GWT is free.
Specific gravity of soil particles $G_s = 2.08$.

Settings of the stage of construction
Design situation: seismic

Verification No. 1
Forces acting on construction

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight - reinforced soil</td>
<td>0.0</td>
<td>-4.54</td>
<td>7735.2</td>
<td>5.88</td>
<td>1.000</td>
</tr>
<tr>
<td>Earthquake - soil wedge</td>
<td>1253.1</td>
<td>-4.54</td>
<td>0.0</td>
<td>5.88</td>
<td>1.000</td>
</tr>
<tr>
<td>Active pressure</td>
<td>1155.4</td>
<td>-3.00</td>
<td>506.4</td>
<td>9.38</td>
<td>1.000</td>
</tr>
<tr>
<td>Earthq. - act. pressure</td>
<td>514.7</td>
<td>-6.00</td>
<td>225.6</td>
<td>9.38</td>
<td>1.000</td>
</tr>
<tr>
<td>Roadway Surcharge</td>
<td>395.0</td>
<td>-4.50</td>
<td>173.1</td>
<td>9.38</td>
<td>1.000</td>
</tr>
<tr>
<td>Weight - wall</td>
<td>0.0</td>
<td>-4.33</td>
<td>2424.2</td>
<td>1.48</td>
<td>1.000</td>
</tr>
<tr>
<td>Earthq. - constr.</td>
<td>392.7</td>
<td>-4.33</td>
<td>0.0</td>
<td>1.48</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Verification of complete wall
Place of verification: bottom of blocks

Check for overturning stability
Resisting moment $M_{res} = 57560.9$ lb-ft/ft
Overturning moment $M_{turn} = 15716.9$ lb-ft/ft

Safety factor $= 3.66 > 1.10$
Wall for overturning is SATISFACTORY

Check for slip
Resisting horizontal force $H_{res} = 7241.11$ lb/ft
Active horizontal force $H_{act} = 3710.95$ lb/ft

Safety factor $= 1.95 > 1.10$
Wall for slip is SATISFACTORY

Overall check - WALL is SATISFACTORY
Bearing capacity of foundation soil

Design load acting at the center of footing bottom

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-11905.0</td>
<td>4805.98</td>
<td>-2079.23</td>
<td>0.000</td>
<td>1373.1</td>
</tr>
</tbody>
</table>

Service load acting at the center of footing bottom

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-11905.0</td>
<td>4805.98</td>
<td>-2079.23</td>
</tr>
</tbody>
</table>

Verification of foundation soil

Place of verification: bottom of leveling pad
Stress in the footing bottom: trapezoid

Eccentricity verification

Max. eccentricity of normal force $e = 0.000$
Maximum allowable eccentricity $e_{aw} = 0.333$

**Eccentricity of the normal force is SATISFACTORY**

Verification of bearing capacity

Max. stress at footing bottom $\sigma = 1373.1$ psf
Bearing capacity of foundation soil $R_d = 2000.0$ psf
Safety factor $= 1.46 > 1.00$

**Bearing capacity of foundation soil is SATISFACTORY**
Overall verification - bearing capacity of found. soil is SATISFACTORY

Name: Bearing cap.  Stage - analysis: 1 - 1

Verification of slip on geotextile No. 1

Forces acting on construction (verification of reinforcement No.: 1)

<table>
<thead>
<tr>
<th></th>
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<th></th>
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</thead>
<tbody>
<tr>
<td>Weight - wall</td>
<td>0.0</td>
<td>-4.33</td>
<td>2470.8</td>
<td>-3.85</td>
<td>1.00</td>
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<td>Earthq. - constr.</td>
<td>400.3</td>
<td>-4.33</td>
<td>0.0</td>
<td>-3.85</td>
<td>1.00</td>
</tr>
<tr>
<td>Active pressure</td>
<td>1155.4</td>
<td>-3.00</td>
<td>506.4</td>
<td>6.50</td>
<td>1.00</td>
</tr>
<tr>
<td>Earthq. - act pressure</td>
<td>514.7</td>
<td>-6.00</td>
<td>225.6</td>
<td>6.50</td>
<td>1.00</td>
</tr>
<tr>
<td>Roadway Surcharge</td>
<td>395.6</td>
<td>-4.50</td>
<td>173.1</td>
<td>6.50</td>
<td>1.00</td>
</tr>
<tr>
<td>Weight - reinforced soil</td>
<td>0.0</td>
<td>-4.40</td>
<td>7286.3</td>
<td>3.41</td>
<td>1.00</td>
</tr>
<tr>
<td>Earthquake - soil wedge</td>
<td>1167.8</td>
<td>-4.40</td>
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<td>3.41</td>
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<tr>
<td>Roadway Surcharge</td>
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<td>-9.00</td>
<td>1547.9</td>
<td>-0.37</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Verification against slip along geotextile No. 1

- Inclination of slip surface = 90.00°
- Overall normal force acting on reinforcement = 9739.33 lb/ft
- Coefficient of reduction of slip along geo-textile = 0.92
- Resistance along geo-reinforcement = 6373.87 lb/ft
- Wall resistance = 0.00 lb/ft
- Overall bearing capacity of reinforcements = 0.00 lb/ft

Check for slip:
Resisting horizontal force $H_{res} = 6373.87$ lb/ft
Active horiz. force  \( H_{act} = 2065.13 \ \text{lbf/ft} \)

Factor of safety  = 3.09 > 1.10

Slip along geotextile is SATISFACTORY

Calculation of internal stability No. 1

Calculated forces and strength of reinforcements

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>( F_x ) [lbf/ft]</th>
<th>Depth [ft]</th>
<th>( R_t ) [lbf/ft]</th>
<th>Utiliz. [%]</th>
<th>( T_p ) [lbf/ft]</th>
<th>Utiliz. [%]</th>
<th>( R_{con} ) [lbf/ft]</th>
<th>Utiliz. [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Miragrid 5XT</td>
<td>-204.08</td>
<td>9.00</td>
<td>517.34</td>
<td>43.39</td>
<td>1453.79</td>
<td>15.44</td>
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<td>2</td>
<td>Miragrid 5XT</td>
<td>-367.03</td>
<td>7.50</td>
<td>1034.67</td>
<td>39.02</td>
<td>2152.86</td>
<td>18.75</td>
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<td>Miragrid 5XT</td>
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<td>6.00</td>
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<td>34.27</td>
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<td>967.56</td>
<td>33.81</td>
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<td>30.10</td>
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<td>5</td>
<td>Miragrid 5XT</td>
<td>-272.49</td>
<td>3.00</td>
<td>1034.67</td>
<td>28.97</td>
<td>536.99</td>
<td>55.82</td>
<td>1087.13</td>
<td>27.57</td>
</tr>
</tbody>
</table>

Check for tensile strength (reinforcement No.1)

Tension strength  \( R_t = 517.34 \ \text{lbf/ft} \)

Force in reinforcement  \( F_x = 204.08 \ \text{lbf/ft} \)

Safety factor  = 2.54 > 1.10

Reinforcement for tensile strength is SATISFACTORY

Check for pull out resistance (reinforcement No.5)

Pull out resistance  \( T_p = 536.99 \ \text{lbf/ft} \)

Force in reinforcement  \( F_x = 272.49 \ \text{lbf/ft} \)

Safety factor  = 1.97 > 1.10

Reinforcement for pull out resistance is SATISFACTORY

Verification of connection strength (reinforcement No.1)

Connection strength  \( R_{con} = 543.57 \ \text{lbf/ft} \)

Force in reinforcement  \( F_x = 204.08 \ \text{lbf/ft} \)

Safety factor  = 2.66 > 1.10

Connection strength is SATISFACTORY

Overall verification - reinforcement is SATISFACTORY
**Name:** Internal stability  
**Stage - analysis:** 1 - 1

<table>
<thead>
<tr>
<th>Layer</th>
<th>Height (ft)</th>
<th>Contribution (kips)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8.83</td>
<td>204.08</td>
</tr>
<tr>
<td>2</td>
<td>6.50</td>
<td>367.01</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>322.38</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>297.44</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>272.49</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>8.83</td>
</tr>
</tbody>
</table>

*Seismic Case*
9'-0" Tall Wall – Transient Case
Analysis of Redi Rock wall

Input data

<table>
<thead>
<tr>
<th>Part</th>
<th>9.0' MSE Wall - Transient Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Author</td>
<td>NRW</td>
</tr>
<tr>
<td>Date</td>
<td>11/25/2019</td>
</tr>
<tr>
<td>Project number</td>
<td>1801-0336</td>
</tr>
</tbody>
</table>

Settings

(input for current task)

Materials and standards

AASHTO - reduce parameters of friction soil/soil by 2/3

Wall analysis

<table>
<thead>
<tr>
<th>Active earth pressure calculation</th>
<th>Coulomb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive earth pressure calculation</td>
<td>Mazinadri (Rankine)</td>
</tr>
<tr>
<td>Earthquake analysis</td>
<td>Mononobe-Okrabe</td>
</tr>
<tr>
<td>Shape of earth wedge</td>
<td>Calculate as skew</td>
</tr>
<tr>
<td>Allowable eccentricity</td>
<td>0.333</td>
</tr>
<tr>
<td>Internal stability</td>
<td>Standard - straight slip surface</td>
</tr>
<tr>
<td>Reduction coeff. of contact first block - base</td>
<td>1.00</td>
</tr>
<tr>
<td>Verification methodology</td>
<td>Safety factors (ASD)</td>
</tr>
</tbody>
</table>

### Safety factors

| Safety factor for overturning    | SF<sub>0</sub> | 1.50 |
| Safety factor for sliding resistance | SF<sub>r</sub> | 1.50 |
| Safety factor for bearing capacity | SF<sub>b</sub> | 1.33 |
| Safety factor for sliding along geo-reinforcement | SF<sub>sr</sub> | 1.50 |
| Safety factor for geo-reinforcement strength | SF<sub>sr</sub> | 1.50 |
| Safety factor for pull out resistance of geo-reinf. | SF<sub>po</sub> | 1.50 |
| Safety factor for connection strength | SF<sub>con</sub> | 1.50 |

### Blocks

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
<th>Height h [in]</th>
<th>Width w [in]</th>
<th>Unit weight γ [pcf]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Top block 24 straight</td>
<td>18.00</td>
<td>24.00</td>
<td>108.00</td>
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<tr>
<td>2</td>
<td>Block 28 PC</td>
<td>18.00</td>
<td>28.00</td>
<td>120.00</td>
</tr>
<tr>
<td>3</td>
<td>Block 41 PC</td>
<td>18.00</td>
<td>40.50</td>
<td>120.00</td>
</tr>
<tr>
<td>4</td>
<td>Top block 28</td>
<td>18.00</td>
<td>28.00</td>
<td>120.00</td>
</tr>
<tr>
<td>5</td>
<td>Top block 41</td>
<td>18.00</td>
<td>40.50</td>
<td>120.00</td>
</tr>
<tr>
<td>6</td>
<td>Top block 24 straight garden</td>
<td>18.00</td>
<td>24.00</td>
<td>80.00</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
<th>Min. shear strength F&lt;sub&gt;min&lt;/sub&gt; [lb/ft]</th>
<th>Max. shear strength F&lt;sub&gt;max&lt;/sub&gt; [lb/ft]</th>
<th>Friction f [°]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Top block 24 straight</td>
<td>6061.00</td>
<td>11276.00</td>
<td>44.00</td>
</tr>
<tr>
<td>2</td>
<td>Block 28 PC</td>
<td>6061.00</td>
<td>11276.00</td>
<td>44.00</td>
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<tr>
<td>3</td>
<td>Block 41 PC</td>
<td>6061.00</td>
<td>11276.00</td>
<td>44.00</td>
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<tr>
<td>4</td>
<td>Top block 28</td>
<td>6061.00</td>
<td>11276.00</td>
<td>44.00</td>
</tr>
</tbody>
</table>
PSE
NRW
1801-0336
9.0' MSE Wall - Transient Case

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
<th>Min. shear strength $F_{\text{min}}$ [lb/ft]</th>
<th>Max. shear strength $F_{\text{max}}$ [lb/ft]</th>
<th>Friction $f$ [°]</th>
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</thead>
<tbody>
<tr>
<td>5</td>
<td>Top block 41</td>
<td>6061.00</td>
<td>11276.00</td>
<td>44.00</td>
</tr>
<tr>
<td>6</td>
<td>Top block 24 straight garden</td>
<td>6061.00</td>
<td>11276.00</td>
<td>44.00</td>
</tr>
</tbody>
</table>

Setbacks

<table>
<thead>
<tr>
<th>No.</th>
<th>Setback $s$ [in]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.010</td>
</tr>
<tr>
<td>2</td>
<td>0.375</td>
</tr>
<tr>
<td>3</td>
<td>1.625</td>
</tr>
<tr>
<td>6</td>
<td>3.250</td>
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</table>

Geometry

<table>
<thead>
<tr>
<th>No. group</th>
<th>Description</th>
<th>Count</th>
<th>Setback $s$ [in]</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Block 28 PC</td>
<td>5</td>
<td>1.62</td>
</tr>
<tr>
<td>2</td>
<td>Top block 28</td>
<td>1</td>
<td>-</td>
</tr>
</tbody>
</table>

Base Geometry

Upper setback $a_1 = 0.50$ ft
Lower setback $a_2 = 0.50$ ft
Height $h = 0.50$ ft
Width $b = 3.50$ ft

Material

Unreinforced Footing
Concrete self-weight $\gamma = 150.00$ pcf
Shear cub (key) capacity $= 0.00$ lb/ft
Friction angle concrete-concrete $= 30.00$ °

Types of reinforcements

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Type of reinforcement</th>
<th>Line type</th>
<th>$T_{\text{ult}}$ [lb/ft]</th>
<th>$R_i$ [lb/ft]</th>
<th>$R_{\text{con}}$ [lb/ft]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Miragrid 5XT</td>
<td>Miragrid 5XT</td>
<td>---</td>
<td>4700.00</td>
<td>2069.35</td>
<td>2174.26</td>
</tr>
<tr>
<td>2</td>
<td>Miragrid 8XT</td>
<td>Miragrid 8XT</td>
<td>---</td>
<td>7400.00</td>
<td>3393.87</td>
<td>3423.30</td>
</tr>
<tr>
<td>3</td>
<td>Miragrid 10XT</td>
<td>Miragrid 10XT</td>
<td>---</td>
<td>9500.00</td>
<td>4357.00</td>
<td>4287.39</td>
</tr>
<tr>
<td>4</td>
<td>Miragrid 20XT</td>
<td>Miragrid 20XT</td>
<td>~~~~~~~~~~</td>
<td>13705.00</td>
<td>6558.83</td>
<td>6030.20</td>
</tr>
<tr>
<td>5</td>
<td>Miragrid 24XT</td>
<td>Miragrid 24XT</td>
<td>~~~~~~~~~~~~~~~~~~</td>
<td>27415.00</td>
<td>13716.42</td>
<td>10560.73</td>
</tr>
</tbody>
</table>

Reinforcement details

1. Miragrid 5XT
   Short-term char. strength
   Creep red. factor $T_{\text{ult}} = 4700.00$ lb/ft
   $R_{\text{CR}} = 1.58$
<table>
<thead>
<tr>
<th>Component</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durability red. factor</td>
<td>1.15</td>
</tr>
<tr>
<td>Installation damage red. factor</td>
<td>1.25</td>
</tr>
<tr>
<td>Long-term design strength</td>
<td>2069.35 lbf/ft</td>
</tr>
<tr>
<td>Coefficient of direct slip along reinforcement</td>
<td>0.67</td>
</tr>
<tr>
<td>Coefficient of interaction of soil and geo-reinforcement</td>
<td>0.67</td>
</tr>
<tr>
<td>Scale correction factor</td>
<td>0.8</td>
</tr>
<tr>
<td>Long-term strength reduction factor</td>
<td>0.532</td>
</tr>
<tr>
<td>Analysis of long-term strength</td>
<td>2174.26 lbf/ft</td>
</tr>
</tbody>
</table>

2. Miragrid 8XT

<table>
<thead>
<tr>
<th>Component</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short-term char. strength</td>
<td>7400.00 lbf/ft</td>
</tr>
<tr>
<td>Creep red. factor</td>
<td>1.58</td>
</tr>
<tr>
<td>Durability red. factor</td>
<td>1.15</td>
</tr>
<tr>
<td>Installation damage red. factor</td>
<td>1.20</td>
</tr>
<tr>
<td>Long-term design strength</td>
<td>3393.87 lbf/ft</td>
</tr>
<tr>
<td>Coefficient of direct slip along reinforcement</td>
<td>0.67</td>
</tr>
<tr>
<td>Coefficient of interaction of soil and geo-reinforcement</td>
<td>0.67</td>
</tr>
<tr>
<td>Scale correction factor</td>
<td>0.8</td>
</tr>
<tr>
<td>Long-term strength reduction factor</td>
<td>0.532</td>
</tr>
<tr>
<td>Analysis of long-term strength</td>
<td>3423.30 lbf/ft</td>
</tr>
</tbody>
</table>

3. Miragrid 10XT

<table>
<thead>
<tr>
<th>Component</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short-term char. strength</td>
<td>9500.00 lbf/ft</td>
</tr>
<tr>
<td>Creep red. factor</td>
<td>1.58</td>
</tr>
<tr>
<td>Durability red. factor</td>
<td>1.15</td>
</tr>
<tr>
<td>Installation damage red. factor</td>
<td>1.20</td>
</tr>
<tr>
<td>Long-term design strength</td>
<td>4357.00 lbf/ft</td>
</tr>
<tr>
<td>Coefficient of direct slip along reinforcement</td>
<td>0.67</td>
</tr>
<tr>
<td>Coefficient of interaction of soil and geo-reinforcement</td>
<td>0.67</td>
</tr>
<tr>
<td>Scale correction factor</td>
<td>0.8</td>
</tr>
<tr>
<td>Long-term strength reduction factor</td>
<td>0.519</td>
</tr>
<tr>
<td>Analysis of long-term strength</td>
<td>4287.39 lbf/ft</td>
</tr>
</tbody>
</table>

4. Miragrid 20XT

<table>
<thead>
<tr>
<th>Component</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short-term char. strength</td>
<td>13705.00 lbf/ft</td>
</tr>
<tr>
<td>Creep red. factor</td>
<td>1.58</td>
</tr>
<tr>
<td>Durability red. factor</td>
<td>1.15</td>
</tr>
<tr>
<td>Installation damage red. factor</td>
<td>1.15</td>
</tr>
<tr>
<td>Long-term design strength</td>
<td>6558.83 lbf/ft</td>
</tr>
<tr>
<td>Coefficient of direct slip along reinforcement</td>
<td>0.67</td>
</tr>
<tr>
<td>Coefficient of interaction of soil and geo-reinforcement</td>
<td>0.67</td>
</tr>
<tr>
<td>Scale correction factor</td>
<td>0.8</td>
</tr>
<tr>
<td>Long-term strength reduction factor</td>
<td>0.506</td>
</tr>
<tr>
<td>Analysis of long-term strength</td>
<td>6030.20 lbf/ft</td>
</tr>
</tbody>
</table>

5. Miragrid 24XT

<table>
<thead>
<tr>
<th>Component</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short-term char. strength</td>
<td>27415.00 lbf/ft</td>
</tr>
<tr>
<td>Creep red. factor</td>
<td>1.58</td>
</tr>
<tr>
<td>Durability red. factor</td>
<td>1.15</td>
</tr>
<tr>
<td>Installation damage red. factor</td>
<td>1.10</td>
</tr>
<tr>
<td>Long-term design strength</td>
<td>13716.42 lbf/ft</td>
</tr>
<tr>
<td>Coefficient of direct slip along reinforcement</td>
<td>0.67</td>
</tr>
</tbody>
</table>
Peterson Structural Engineers, Inc.
www.psengineers.com

Coefficient of interaction of soil and geo-reinforcement $C_1 = 0.67$
Scale correction factor $\alpha = 0.8$
Long-term strength reduction factor $CR_{cr} = 0.443$
Analysis of long-term strength $R_{con} = 10560.73$ lb/ft

**Reinforcements**
Input mode: 1 reinforcement type
Reinf. installation: in every row of blocks (50%)
Type of reinforcement: Miragrid 5XT
Top reinforcement: straight (25%)
Reinforcement geometry: identical length of reinforcements
Length of reinforcement $l = 6.50$ ft

<table>
<thead>
<tr>
<th>No.</th>
<th>Consider</th>
<th>Name</th>
<th>Length of reinforcement $l$ [ft]</th>
<th>End pt. coordinate $l_k$ [ft]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yes</td>
<td>Miragrid 5XT</td>
<td>6.50</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Yes</td>
<td>Miragrid 5XT</td>
<td>6.50</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Yes</td>
<td>Miragrid 5XT</td>
<td>6.50</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Yes</td>
<td>Miragrid 5XT</td>
<td>6.50</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Yes</td>
<td>Miragrid 5XT</td>
<td>6.50</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>No</td>
<td></td>
<td></td>
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</table>
Basic soil parameters

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Pattern</th>
<th>$\theta_{ef}$ [°]</th>
<th>$c_{ef}$ [psf]</th>
<th>$\gamma$ [pcf]</th>
<th>$\gamma_{su}$ [pcf]</th>
<th>$\delta$ [°]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Gravel Backfill</td>
<td></td>
<td>35.50</td>
<td>0.0</td>
<td>130.00</td>
<td>67.50</td>
<td>34.00</td>
</tr>
</tbody>
</table>

All soils are considered as cohesionless for at rest pressure analysis.

Soil parameters

Gravel Backfill

- Unit weight: $\gamma = 130.0$ pcf
- Effective stress state
- Angle of internal friction: $\phi_{ef} = 35.50^\circ$
- Cohesion of soil: $c_{ef} = 0.0$ psf
- Angle of friction struct-soil: $\delta = 34.00^\circ$
- Saturated unit weight: $\gamma_{sat} = 130.0$ pcf

Geological profile and assigned soils

<table>
<thead>
<tr>
<th>No.</th>
<th>Thickness of layer [ft]</th>
<th>Depth z [ft]</th>
<th>Assigned soil</th>
<th>Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-</td>
<td>0.00 ... $\infty$</td>
<td>Gravel Backfill</td>
<td></td>
</tr>
</tbody>
</table>

Terrain profile

Terrain behind the structure is flat.

Water influence

Ground water table is located below the structure.

Input surface surcharges

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yes</td>
<td>variable</td>
<td>200.0</td>
<td></td>
<td></td>
<td></td>
<td>on terrain</td>
</tr>
<tr>
<td></td>
<td>roadway surcharge</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Resistance on front face of the structure

Resistance on front face of the structure is not considered.

Settings of the stage of construction

Design situation: transient

Verification No. 1

Forces acting on construction

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight - reinforced soil</td>
<td>0.0</td>
<td>-4.54</td>
<td>7735.2</td>
<td>5.88</td>
<td>1.000</td>
</tr>
<tr>
<td>Active pressure</td>
<td>1155.4</td>
<td>-3.00</td>
<td>506.4</td>
<td>9.38</td>
<td>1.000</td>
</tr>
</tbody>
</table>
**Verification of complete wall**

Place of verification: bottom of blocks

**Check for overturning stability**

Resisting moment \( M_{\text{res}} = 55446.3 \text{ lbf/ft} \)

Overturning moment \( M_{\text{out}} = 5243.9 \text{ lbf/ft} \)

Safety factor = \( 10.57 > 1.50 \)

**Wall for overturning is SATISFACTORY**

**Check for slip**

Resisting horizontal force \( H_{\text{res}} = 7093.49 \text{ lbf/ft} \)

Active horizontal force \( H_{\text{act}} = 1550.47 \text{ lbf/ft} \)

Safety factor = \( 4.58 > 1.50 \)

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

---

**Table:**

<table>
<thead>
<tr>
<th>Name</th>
<th>( F_{\text{hor}} ) [lbf/ft]</th>
<th>( z ) [ft]</th>
<th>( F_{\text{vert}} ) [lbf/ft]</th>
<th>( x ) [ft]</th>
<th>Design coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roadway Surcharge</td>
<td>395.0</td>
<td>-4.50</td>
<td>173.1</td>
<td>9.38</td>
<td>1.000</td>
</tr>
<tr>
<td>Weight - wall</td>
<td>0.0</td>
<td>-4.33</td>
<td>2424.2</td>
<td>1.48</td>
<td>1.000</td>
</tr>
</tbody>
</table>
Bearing capacity of foundation soil

Design load acting at the center of footing bottom

<table>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-17038.2</td>
<td>4369.40</td>
<td>-3123.97</td>
<td>0.000</td>
<td>1248.4</td>
</tr>
</tbody>
</table>

Service load acting at the center of footing bottom

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-17038.2</td>
<td>4369.40</td>
<td>-3123.97</td>
</tr>
</tbody>
</table>

Verification of foundation soil

Place of verification: bottom of leveling pad
Stress in the footing bottom: trapezoid

Eccentricity verification
Max. eccentricity of normal force $e_n = 0.000$
Maximum allowable eccentricity $e_{aw} = 0.333$

Eccentricity of the normal force is SATISFACTORY

Verification of bearing capacity
Max. stress at footing bottom $\sigma = 1248.4$ psf
Bearing capacity of foundation soil $R_d = 2000.0$ psf
Safety factor = 1.60 > 1.33

Bearing capacity of foundation soil is SATISFACTORY

Overall verification - bearing capacity of found. soil is SATISFACTORY
Verification of slip on geotextile No. 1

Forces acting on construction (verification of reinforcement No.: 1)

<table>
<thead>
<tr>
<th>Name</th>
<th>( F_{\text{hor}} ) [lbf/ft]</th>
<th>App. Pt. ( z ) [ft]</th>
<th>( F_{\text{vert}} ) [lbf/ft]</th>
<th>App. Pt. ( x ) [ft]</th>
<th>Design coefficient</th>
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<tbody>
<tr>
<td>Weight - wall</td>
<td>0.0</td>
<td>-4.33</td>
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</tr>
<tr>
<td>Active pressure</td>
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<td>-3.00</td>
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<td>6.50</td>
<td>1.000</td>
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<tr>
<td>Roadway Surcharge</td>
<td>395.0</td>
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<td>173.1</td>
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<td>1.000</td>
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<td>-9.00</td>
<td>1547.9</td>
<td>-0.37</td>
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</tr>
</tbody>
</table>

Verification against slip along geotextile No.: 1

Inclination of slip surface \( = 90.00 \) \(^\circ\)
Overall normal force acting on reinforcement \( = 9613.77 \) lbf/ft
Coefficient of reduction of slip along geo-textile \( = 0.92 \)
Resistance along geo-reinforcement \( = 6226.25 \) lbf/ft
Wall resistance \( = 1426.51 \) lbf/ft
Overall bearing capacity of reinforcements \( = 0.00 \) lbf/ft

Check for slip:
Resisting horizontal force \( H_{\text{res}} = 7652.76 \) lbf/ft
Active horizon. force \( H_{\text{act}} = 1550.47 \) lbf/ft
Factor of safety \( = 4.94 > 1.50 \)
Slip along geotextile is SATISFACTORY
Calculation of internal stability No. 1

Calculated forces and strength of reinforcements

<table>
<thead>
<tr>
<th></th>
<th></th>
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<tbody>
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<td>33.07</td>
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<td>-160.32</td>
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<td>23.24</td>
<td>536.99</td>
<td>44.78</td>
<td>1087.13</td>
<td>22.12</td>
</tr>
</tbody>
</table>

Check for tensile strength (reinforcement No.1)

Tension strength $R_t = 517.34$ lbf/ft.
Force in reinforcement $F_x = 200.48$ lbf/ft.
Safety factor $= 2.58 > 1.50$

Reinforcement for tensile strength is SATISFACTORY

Check for pull out resistance (reinforcement No.5)

Pull out resistance $T_p = 536.99$ lbf/ft.
Force in reinforcement $F_x = 160.32$ lbf/ft.
Safety factor $= 3.35 > 1.50$

Reinforcement for pull out resistance is SATISFACTORY

Verification of connection strength (reinforcement No.1)

Connection strength $R_{con} = 543.57$ lbf/ft.
Force in reinforcement $F_x = 200.48$ lbf/ft.
Safety factor $= 2.71 > 1.50$

Connection strength is SATISFACTORY

Overall verification - reinforcement is SATISFACTORY
7’-6” Tall Wall – Seismic Case
Analysis of Redi Rock wall

Input data

Project
Task : MSE Wall Design
Part : 7.5' MSE Wall - Seismic Case
Author : NRW
Date : 11/25/2019
Project number : 1801-0336

Settings
(Input for current task)

Materials and standards
AASHTO - reduce parameters of friction soil/soil by 2/3 φ

Wall analysis
Active earth pressure calculation : Coulomb
Passive earth pressure calculation : Mazinrani (Rankine)
Earthquake analysis : Mononobe-Okabe
Shape of earth wedge : Calculate as skew
Allowable eccentricity : 0.333
Internal stability : Standard - straight slip surface
Reduction coeff. of contact first block - base : 1.00
Verification methodology : Safety factors (ASD)

| Safety factors for overturning : | SF₀ = 1.10 [-] |
| Safety factor for sliding resistance : | SFₛ = 1.10 [-] |
| Safety factor for bearing capacity : | SFᵦ = 1.00 [-] |
| Safety factor for sliding along geo-reinforcement : | SFₛᵦ = 1.10 [-] |
| Safety factor for geo-reinforcement strength : | SFᵦᵦ = 1.10 [-] |
| Safety factor for pull out resistance of geo-reinf. : | SFᵦᵦᵦ = 1.10 [-] |
| Safety factor for connection strength : | SFᵦᵦᵦᵦ = 1.10 [-] |

Geometry

<table>
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<tr>
<th>No. group</th>
<th>Description</th>
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<tr>
<td>1</td>
<td>Block 28 PC</td>
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<tr>
<td>2</td>
<td>Top block 28</td>
<td>1</td>
<td>-</td>
</tr>
</tbody>
</table>

Base

Geometry
Upper setback a₁ = 0.50 ft.
Lower setback a₂ = 0.50 ft.
Height h = 0.50 ft.
Width b = 3.50 ft.

Material
Unreinforced Footing
Concrete self-weight γ = 150.00 pcf
Shear cub (key) capacity τ = 0.00 lb/ft
Friction angle concrete-concrete = 30.00°
# Types of reinforcements

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Type of reinforcement</th>
<th>Line type</th>
<th>$T_{ult}$ [lbf/ft]</th>
<th>$R_t$ [lbf/ft]</th>
<th>$R_{con}$ [lbf/ft]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Miragrid 5XT</td>
<td>Miragrid 5XT</td>
<td>----------</td>
<td>4700.00</td>
<td>2069.35</td>
<td>2174.26</td>
</tr>
<tr>
<td>2</td>
<td>Miragrid 8XT</td>
<td>Miragrid 8XT</td>
<td>----------</td>
<td>7400.00</td>
<td>3393.87</td>
<td>3423.30</td>
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<tr>
<td>3</td>
<td>Miragrid 10XT</td>
<td>Miragrid 10XT</td>
<td>----------</td>
<td>9500.00</td>
<td>4357.00</td>
<td>4287.39</td>
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<tr>
<td>4</td>
<td>Miragrid 20XT</td>
<td>Miragrid 20XT</td>
<td>~~~~~~~~~</td>
<td>13705.00</td>
<td>6558.83</td>
<td>6030.20</td>
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<tr>
<td>5</td>
<td>Miragrid 24XT</td>
<td>Miragrid 24XT</td>
<td>~~~~~~~~~</td>
<td>27415.00</td>
<td>13716.42</td>
<td>10560.73</td>
</tr>
</tbody>
</table>

## Reinforcement details

1. **Miragrid 5XT**
   - Short-term char. strength: $T_{ult} = 4700.00$ lbf/ft
   - Creep red. factor: $RF_{CR} = 1.58$
   - Durability red. factor: $RF_{D} = 1.15$
   - Installation damage red. factor: $RF_{ID} = 1.25$
   - Long-term design strength: $R_t = 2069.35$ lbf/ft
   - Coefficient of direct slip along reinforcement: $C_{ds} = 0.67$
   - Coefficient of interaction of soil and geo-reinforcement: $C_{i} = 0.67$
   - Scale correction factor: $\alpha = 0.8$
   - Long-term strength reduction factor: $CR_{cr} = 0.532$
   - Analysis of long-term strength: $R_{con} = 2174.26$ lbf/ft

2. **Miragrid 8XT**
   - Short-term char. strength: $T_{ult} = 7400.00$ lbf/ft
   - Creep red. factor: $RF_{CR} = 1.58$
   - Durability red. factor: $RF_{D} = 1.15$
   - Installation damage red. factor: $RF_{ID} = 1.20$
   - Long-term design strength: $R_t = 3393.87$ lbf/ft
   - Coefficient of direct slip along reinforcement: $C_{ds} = 0.67$
   - Coefficient of interaction of soil and geo-reinforcement: $C_{i} = 0.67$
   - Scale correction factor: $\alpha = 0.8$
   - Long-term strength reduction factor: $CR_{cr} = 0.532$
   - Analysis of long-term strength: $R_{con} = 3423.30$ lbf/ft

3. **Miragrid 10XT**
   - Short-term char. strength: $T_{ult} = 9500.00$ lbf/ft
   - Creep red. factor: $RF_{CR} = 1.58$
   - Durability red. factor: $RF_{D} = 1.15$
   - Installation damage red. factor: $RF_{ID} = 1.20$
   - Long-term design strength: $R_t = 4357.00$ lbf/ft
   - Coefficient of direct slip along reinforcement: $C_{ds} = 0.67$
   - Coefficient of interaction of soil and geo-reinforcement: $C_{i} = 0.67$
   - Scale correction factor: $\alpha = 0.8$
   - Long-term strength reduction factor: $CR_{cr} = 0.519$
   - Analysis of long-term strength: $R_{con} = 4287.39$ lbf/ft
4. Miragrid 20XT
Short-term char. strength \( T_{\text{ult}} = 13705.00 \text{ lb/ft} \)
Creep red. factor \( R_{\text{fcr}} = 1.58 \)
Durability red. factor \( R_{\text{frd}} = 1.15 \)
Installation damage red. factor \( R_{\text{fid}} = 1.15 \)
Long-term design strength \( R_{\text{f}} = 6558.83 \text{ lb/ft} \)
Coefficient of direct slip along reinforcement \( C_{\text{ds}} = 0.67 \)
Coefficient of interaction of soil and geo-reinforcement \( C_{\text{i}} = 0.67 \)
Scale correction factor \( \alpha = 0.8 \)
Long-term strength reduction factor \( C_{\text{Rf}} = 0.506 \)
Analysis of long-term strength \( R_{\text{con}} = 6030.20 \text{ lb/ft} \)

5. Miragrid 24XT
Short-term char. strength \( T_{\text{ult}} = 27415.00 \text{ lb/ft} \)
Creep red. factor \( R_{\text{fcr}} = 1.58 \)
Durability red. factor \( R_{\text{frd}} = 1.15 \)
Installation damage red. factor \( R_{\text{fid}} = 1.10 \)
Long-term design strength \( R_{\text{f}} = 13716.42 \text{ lb/ft} \)
Coefficient of direct slip along reinforcement \( C_{\text{ds}} = 0.67 \)
Coefficient of interaction of soil and geo-reinforcement \( C_{\text{i}} = 0.67 \)
Scale correction factor \( \alpha = 0.8 \)
Long-term strength reduction factor \( C_{\text{Rf}} = 0.443 \)
Analysis of long-term strength \( R_{\text{con}} = 10560.73 \text{ lb/ft} \)

Reinforcements
Input mode : 1 reinforcement type
Reinf. installation : in every row of blocks (50%)
Type of reinforcement : Miragrid 5XT
Top reinforcement : straight (25%)
Reinforcement geometry : identical length of reinforcements
Length of reinforcement \( l = 5.50 \text{ ft} \)

<table>
<thead>
<tr>
<th>No.</th>
<th>Consider</th>
<th>Name</th>
<th>Length of reinforcement ( l [\text{ft}] )</th>
<th>End pt. coordinate ( l_{k} [\text{ft}] )</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Yes</td>
<td>Miragrid 5XT</td>
<td>5.50</td>
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<td>2</td>
<td>Yes</td>
<td>Miragrid 5XT</td>
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<td>3</td>
<td>Yes</td>
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<td>5.50</td>
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</table>
**Basic soil parameters**

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Pattern</th>
<th>( \varphi_{ef} )</th>
<th>( c_{ef} )</th>
<th>( \gamma )</th>
<th>( \gamma_{su} )</th>
<th>( \delta )</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Gravel Backfill</td>
<td></td>
<td>35.50</td>
<td>0.0</td>
<td>130.0</td>
<td>67.50</td>
<td>34.00</td>
</tr>
</tbody>
</table>

All soils are considered as cohesionless for at rest pressure analysis.

**Soil parameters**

**Gravel Backfill**
- Unit weight: \( \gamma = 130.0 \text{ pcf} \)
- Effective stress-state: effective
- Angle of internal friction: \( \varphi_{ef} = 35.50^\circ \)
- Cohesion of soil: \( c_{eff} = 0.0 \text{ psf} \)
- Angle of friction struct.-soil: \( \delta = 34.00^\circ \)
- Saturated unit weight: \( \gamma_{sat} = 130.0 \text{ pcf} \)

**Input surface surcharges**

<table>
<thead>
<tr>
<th>No.</th>
<th>Surcharge change</th>
<th>Action</th>
<th>Mag.1</th>
<th>Mag.2</th>
<th>Ord.x</th>
<th>Length</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yes</td>
<td>variable</td>
<td>200.0</td>
<td></td>
<td></td>
<td></td>
<td>off terrain</td>
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</table>

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>new change</th>
<th>Action</th>
<th>Mag.1</th>
<th>Mag.2</th>
<th>Ord.x</th>
<th>Length</th>
<th>Depth</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Roadway Surcharge</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Resistance on front face of the structure
Resistance on front face of the structure is not considered.

Earthquake
Factor of horizontal acceleration $K_h = 0.1620$
Factor of vertical acceleration $K_v = 0.0000$
Water below the GWT is free.
Specific gravity of soil particles $G_s = 2.08$.

Settings of the stage of construction
Design situation: seismic

Verification No. 1
Forces acting on construction

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<thead>
<tr>
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<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight - reinforced soil</td>
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<td>5479.5</td>
<td>5.29</td>
<td>1.000</td>
</tr>
<tr>
<td>Earthquake - soil wedge</td>
<td>887.7</td>
<td>-3.79</td>
<td>0.0</td>
<td>5.29</td>
<td>1.000</td>
</tr>
<tr>
<td>Active pressure</td>
<td>802.4</td>
<td>-2.50</td>
<td>351.7</td>
<td>8.24</td>
<td>1.000</td>
</tr>
<tr>
<td>Earthq. - act.pressure</td>
<td>357.4</td>
<td>-5.00</td>
<td>156.6</td>
<td>8.24</td>
<td>1.000</td>
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<tr>
<td>Roadway Surcharge</td>
<td>329.2</td>
<td>-3.75</td>
<td>144.3</td>
<td>8.24</td>
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<td>1.41</td>
<td>1.000</td>
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<tr>
<td>Earthq. - constr.</td>
<td>324.7</td>
<td>-3.58</td>
<td>0.0</td>
<td>1.41</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Verification of complete wall
Place of verification: bottom of blocks

Check for overturning stability
Resisting moment $M_{res} = 37220.9$ lbf/ft
Overturning moment $M_{ov} = 9557.5$ lbf/ft

Safety factor = 3.89 > 1.10
Wall for overturning is SATISFACTORY

Check for slip
Resisting horizontal force $H_{res} = 5324.76$ lbf/ft
Active horizontal force $H_{act} = 2701.34$ lbf/ft

Safety factor = 1.97 > 1.10
Wall for slip is SATISFACTORY

Overall check - WALL is SATISFACTORY
Bearing capacity of foundation soil

Design load acting at the center of footing bottom

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-7344.7</td>
<td>3825.51</td>
<td>-1599.26</td>
<td>0.000</td>
<td>1121.6</td>
</tr>
</tbody>
</table>

Service load acting at the center of footing bottom

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-7344.7</td>
<td>3825.51</td>
<td>-1599.26</td>
</tr>
</tbody>
</table>

Verification of foundation soil

Place of verification: bottom of leveling pad
Stress in the footing bottom: trapezoid

Eccentricity verification

Max. eccentricity of normal force $e = 0.000$  
Maximum allowable eccentricity $e_{aw} = 0.333$

Eccentricity of the normal force is SATISFACTORY

Verification of bearing capacity

Max. stress at footing bottom $\sigma = 1121.6$ psf
Bearing capacity of foundation soil $R_d = 2000.0$ psf
Safety factor $= 1.78 > 1.00$

Bearing capacity of foundation soil is SATISFACTORY
Overall verification - bearing capacity of found. soil is SATISFACTORY

Name: Bearing cap.  Stage - analysis: 1 - 1

<table>
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<tr>
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</thead>
<tbody>
<tr>
<td>Weight - wall</td>
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<td>-3.58</td>
<td>2049.7</td>
<td>-3.92</td>
<td>1.000</td>
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<tr>
<td>Earthq. - constr.</td>
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<td>-3.58</td>
<td>0.0</td>
<td>-3.92</td>
<td>1.000</td>
</tr>
<tr>
<td>Active pressure</td>
<td>802.4</td>
<td>-2.50</td>
<td>351.7</td>
<td>5.50</td>
<td>1.000</td>
</tr>
<tr>
<td>Earthq. - act pressure</td>
<td>357.4</td>
<td>-5.00</td>
<td>156.6</td>
<td>5.50</td>
<td>1.000</td>
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<tr>
<td>Roadway Surcharge</td>
<td>329.2</td>
<td>-3.75</td>
<td>144.3</td>
<td>5.50</td>
<td>1.000</td>
</tr>
<tr>
<td>Weight - reinforced soil</td>
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<td>-3.67</td>
<td>5175.9</td>
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<td>1.000</td>
</tr>
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<td>Earthquake - soil wedge</td>
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<td>1.000</td>
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<tr>
<td>Roadway Surcharge</td>
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<td>-7.50</td>
<td>1375.0</td>
<td>-0.94</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Verification against slip along geotextile No.: 1

- Inclination of slip surface = $90.00^\circ$
- Overall normal force acting on reinforcement = 7203.44 lbf/ft
- Coefficient of reduction of slip along geo-textile = 0.92
- Resistance along geo-reinforcement = 4714.26 lbf/ft
- Wall resistance = 0.00 lbf/ft
- Overall bearing capacity of reinforcements = 0.00 lbf/ft

Check for slip:
Resisting horizontal force $H_{res} = 4714.26$ lbf/ft
Active horiz. force  \( H_{act} = 1488.98 \text{ lbf/ft} \)

Factor of safety = 3.17 > 1.10

Slip along geotextile is SATISFACTORY

Calculation of internal stability No. 1

Calculated forces and strength of reinforcements

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>( F_x ) [lbf/ft]</th>
<th>Depth ( z ) [ft]</th>
<th>( R_t ) [lbf/ft]</th>
<th>Utiliz. [%]</th>
<th>( T_p ) [lbf/ft]</th>
<th>Utiliz. [%]</th>
<th>( R_{con} ) [lbf/ft]</th>
<th>Utiliz. [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Miragrid 5XT</td>
<td>-174.49</td>
<td>7.50</td>
<td>517.34</td>
<td>37.10</td>
<td>1025.11</td>
<td>18.72</td>
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<td>35.31</td>
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<td>2</td>
<td>Miragrid 5XT</td>
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<td>6.00</td>
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<td>24.02</td>
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<td>27.26</td>
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<td>-244.45</td>
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<td>25.99</td>
<td>496.93</td>
<td>54.22</td>
<td>1087.13</td>
<td>24.73</td>
</tr>
</tbody>
</table>

Check for tensile strength (reinforcement No.1)

Tension strength  \( R_t = 517.34 \text{ lbf/ft} \)

Force in reinforcement \( F_x = 174.49 \text{ lbf/ft} \)

Safety factor = 2.96 > 1.10

Reinforcement for tensile strength is SATISFACTORY

Check for pull out resistance (reinforcement No.4)

Pull out resistance  \( T_p = 495.93 \text{ lbf/ft} \)

Force in reinforcement \( F_x = 244.45 \text{ lbf/ft} \)

Safety factor = 2.03 > 1.10

Reinforcement for pull out resistance is SATISFACTORY

Verification of connection strength (reinforcement No.1)

Connection strength  \( R_{con} = 543.57 \text{ lbf/ft} \)

Force in reinforcement \( F_x = 174.49 \text{ lbf/ft} \)

Safety factor = 3.12 > 1.10

Connection strength is SATISFACTORY

Overall verification - reinforcement is SATISFACTORY
7'-6" Tall Wall – Transient Case
### Analysis of Redi Rock wall

#### Input data

**Project**
- Part: 7.5’ MSE Wall - Transient Case
- Author: NRW
- Date: 12/6/2019
- Project number: 1801-0336

**Settings**
- (input for current task)

**Materials and standards**
- AASHTO - reduce parameters of friction soil/soil by 2/3

**Wall analysis**
- Active earth pressure calculation: Coulomb
- Passive earth pressure calculation: Mazinadri (Rankine)
- Earthquake analysis: Mononobe-Okabe
- Shape of earth wedge: Calculate as skew
- Allowable eccentricity: 0.333
- Internal stability: Standard - straight slip surface
- Reduction coeff. of contact first block - base: 1.00
- Verification methodology: Safety factors (ASD)

#### Safety factors

<table>
<thead>
<tr>
<th>Safety factor</th>
<th>Transient design situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety factor for overturning</td>
<td>SF₀ = 1.50 [-]</td>
</tr>
<tr>
<td>Safety factor for sliding resistance</td>
<td>SF₆ = 1.50 [-]</td>
</tr>
<tr>
<td>Safety factor for bearing capacity</td>
<td>SF₇ = 1.33 [-]</td>
</tr>
<tr>
<td>Safety factor for sliding along geo-reinforcement</td>
<td>SF₄ = 1.50 [-]</td>
</tr>
<tr>
<td>Safety factor for geo-reinforcement strength</td>
<td>SF₅ = 1.50 [-]</td>
</tr>
<tr>
<td>Safety factor for pull out resistance of geo-reinforcement</td>
<td>SF₆ = 1.50 [-]</td>
</tr>
<tr>
<td>Safety factor for connection strength</td>
<td>SF₁ = 1.50 [-]</td>
</tr>
</tbody>
</table>

#### Geometry

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
<th>Count</th>
<th>Setback s [in]</th>
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<tbody>
<tr>
<td>1</td>
<td>Block 28 PC</td>
<td>4</td>
<td>1.62</td>
</tr>
<tr>
<td>2</td>
<td>Top block 28</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

**Base**
- Geometry
- Upper setback a₁ = 0.50 ft
- Lower setback a₂ = 0.50 ft
- Height h = 0.50 ft
- Width b = 3.50 ft

**Material**
- Unreinforced Footing
  - Concrete self-weight γ = 150.00 pcf
  - Shear cub (key) capacity = 0.00 lbf/ft
  - Friction angle concrete-concrete = 30.00°
### Types of Reinforcements

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Type of reinforcement</th>
<th>Line type</th>
<th>$T_{\text{ult}}$ [lb/ft]</th>
<th>$R_{L}$ [lb/ft]</th>
<th>$R_{\text{con}}$ [lb/ft]</th>
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</thead>
<tbody>
<tr>
<td>1</td>
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<td>Miragrid 5XT</td>
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<td>4700.00</td>
<td>2069.35</td>
<td>2174.26</td>
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<tr>
<td>2</td>
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<td>Miragrid 8XT</td>
<td></td>
<td>7400.00</td>
<td>3393.87</td>
<td>3423.30</td>
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<tr>
<td>3</td>
<td>Miragrid 10XT</td>
<td>Miragrid 10XT</td>
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<td>9600.00</td>
<td>4357.00</td>
<td>4287.39</td>
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<tr>
<td>4</td>
<td>Miragrid 20XT</td>
<td>Miragrid 20XT</td>
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<td>13705.00</td>
<td>6558.83</td>
<td>6030.20</td>
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<td>5</td>
<td>Miragrid 24XT</td>
<td>Miragrid 24XT</td>
<td></td>
<td>27415.00</td>
<td>13716.42</td>
<td>10560.73</td>
</tr>
</tbody>
</table>

#### Reinforcement Details

1. **Miragrid 5XT**
   - Short-term char. strength $T_{\text{ult}} = 4700.00$ lb/ft
   - Creep red. factor $R_{\text{cr}} = 1.58$
   - Durability red. factor $R_{\text{df}} = 1.15$
   - Installation damage red. factor $R_{\text{id}} = 1.20$
   - Long-term design strength $R_{L} = 2069.35$ lb/ft
   - Coefficient of direct slip along reinforcement $C_{ds} = 0.67$
   - Coefficient of interaction of soil and geo-reinforcement $C_{i} = 0.67$
   - Scale correction factor $\alpha = 0.8$
   - Long-term strength reduction factor $CR_{\text{cr}} = 0.532$
   - Analysis of long-term strength $R_{\text{con}} = 2174.26$ lb/ft

2. **Miragrid 8XT**
   - Short-term char. strength $T_{\text{ult}} = 7400.00$ lb/ft
   - Creep red. factor $R_{\text{cr}} = 1.58$
   - Durability red. factor $R_{\text{df}} = 1.15$
   - Installation damage red. factor $R_{\text{id}} = 1.20$
   - Long-term design strength $R_{L} = 3393.87$ lb/ft
   - Coefficient of direct slip along reinforcement $C_{ds} = 0.67$
   - Coefficient of interaction of soil and geo-reinforcement $C_{i} = 0.67$
   - Scale correction factor $\alpha = 0.8$
   - Long-term strength reduction factor $CR_{\text{cr}} = 0.532$
   - Analysis of long-term strength $R_{\text{con}} = 3423.30$ lb/ft

3. **Miragrid 10XT**
   - Short-term char. strength $T_{\text{ult}} = 9600.00$ lb/ft
   - Creep red. factor $R_{\text{cr}} = 1.58$
   - Durability red. factor $R_{\text{df}} = 1.15$
   - Installation damage red. factor $R_{\text{id}} = 1.20$
   - Long-term design strength $R_{L} = 4357.00$ lb/ft
   - Coefficient of direct slip along reinforcement $C_{ds} = 0.67$
   - Coefficient of interaction of soil and geo-reinforcement $C_{i} = 0.67$
   - Scale correction factor $\alpha = 0.8$
   - Long-term strength reduction factor $CR_{\text{cr}} = 0.519$
   - Analysis of long-term strength $R_{\text{con}} = 4287.39$ lb/ft

4. **Miragrid 20XT**

---

**PSE**
Peterson Structural Engineers, Inc.
www.psengineers.com

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**project** 1801-0336 **date** 3/27/2020
**designer** NRW **sheet** A55
5. Miragrid 24XT
Short-term char. strength

Design parameters:

- T_{ult} = 13705.00 lb/ft
- RF_{CR} = 1.58
- RF_{D} = 1.15
- RF_{ID} = 1.15
- R_{c} = 6558.83 lb/ft
- C_{p} = 0.67
- C_{I} = 0.67
- \alpha = 0.8
- CR_{cr} = 0.506
- R_{con} = 6030.20 lb/ft

Analysis of long-term strength:

- R_{con} = 10560.73 lb/ft

Reinforcements:

- Input mode: 1 reinforcement type
- Reinforcement type: Miragrid 5XT
- Top reinforcement: straight (25%)
- Reinforcement geometry: identical length of reinforcements
- Length of reinforcement l = 5.50 ft

<table>
<thead>
<tr>
<th>No.</th>
<th>Consider</th>
<th>Name</th>
<th>Length of reinforcement l [ft]</th>
<th>End pt. coordinate l_k [ft]</th>
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<tbody>
<tr>
<td>1</td>
<td>Yes</td>
<td>Miragrid 5XT</td>
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<td>2</td>
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</tr>
<tr>
<td>3</td>
<td>Yes</td>
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<td></td>
</tr>
<tr>
<td>4</td>
<td>Yes</td>
<td>Miragrid 5XT</td>
<td>5.50</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Soil parameters

**Gravel Backfill**
- Unit weight: \( \gamma = 130.0 \text{ pcf} \)
- Stress-state: effective
- Angle of internal friction: \( \phi_{ef} = 35.50^\circ \)
- Cohesion of soil: \( c_{ef} = 0.0 \text{ psf} \)
- Angle of friction struct.-soil: \( \delta = 34.00^\circ \)
- Saturated unit weight: \( \gamma_{sat} = 130.0 \text{ pcf} \)

**Input surface surcharges**

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<tr>
<th></th>
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<tr>
<td>1</td>
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<td>variable</td>
<td>200.0</td>
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</table>

**Resistance on front face of the structure**
Resistance on front face of the structure is not considered.

**Settings of the stage of construction**
Design situation: transient
Verification No. 1
Forces acting on construction

<table>
<thead>
<tr>
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<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Weight - reinforced soil</td>
<td>0.0</td>
<td>-3.79</td>
<td>5479.6</td>
<td>5.29</td>
<td>1.000</td>
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<tr>
<td>Active pressure</td>
<td>802.4</td>
<td>-2.50</td>
<td>351.7</td>
<td>8.24</td>
<td>1.000</td>
</tr>
<tr>
<td>Roadway Surcharge</td>
<td>329.2</td>
<td>-3.75</td>
<td>144.3</td>
<td>8.24</td>
<td>1.000</td>
</tr>
<tr>
<td>Weight - wall</td>
<td>0.0</td>
<td>-3.58</td>
<td>2004.2</td>
<td>1.41</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Verification of complete wall
Place of verification: bottom of blocks

Check for overturning stability
Resisting moment $M_{res} = 35930.2$ lb-ft/ft
Overturning moment $M_{ovr} = 3240.4$ lb-ft/ft

Safety factor $= 11.09 > 1.50$
**Wall for overturning is SATISFACTORY**

Check for slip
Resisting horizontal force $H_{res} = 5222.24$ lb/ft
Active horizontal force $H_{act} = 1131.58$ lb/ft

Safety factor $= 4.62 > 1.50$
**Wall for slip is SATISFACTORY**

Overall check - WALL is SATISFACTORY
**Bearing capacity of foundation soil**

**Design load acting at the center of footing bottom**

<table>
<thead>
<tr>
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<td>3607.75</td>
<td>-2407.02</td>
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<td>1030.0</td>
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</table>

**Service load acting at the center of footing bottom**

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</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-10599.5</td>
<td>3607.75</td>
<td>-2407.02</td>
</tr>
</tbody>
</table>

**Verification of foundation soil**

Place of verification: bottom of leveling pad
Stress in the footing bottom: trapezoid

**Eccentricity verification**

Max. eccentricity of normal force \( e = 0.000 \)
Maximum allowable eccentricity \( e_{aw} = 0.333 \)

**Eccentricity of the normal force is SATISFACTORY**

**Verification of bearing capacity**

Max. stress at footing bottom \( \sigma = 1030.8 \text{ psf} \)
Bearing capacity of foundation soil \( R_d = 2000.0 \text{ psf} \)
Safety factor \( = 1.94 > 1.33 \)

**Bearing capacity of foundation soil is SATISFACTORY**
Overall verification - bearing capacity of found. soil is SATISFACTORY

Verification of slip on georeinforcement No. 1

Forces acting on construction (verification of reinforcement No.: 1)

<table>
<thead>
<tr>
<th>Name</th>
<th>$F_{\text{hor}}$</th>
<th>App. Pt. z [ft]</th>
<th>$F_{\text{vert}}$</th>
<th>App. Pt. x [ft]</th>
<th>Design coefficient</th>
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</thead>
<tbody>
<tr>
<td>Weight - wall</td>
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<td>-3.58</td>
<td>2049.7</td>
<td>-3.92</td>
<td>1.000</td>
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<tr>
<td>Active pressure</td>
<td>802.4</td>
<td>-2.50</td>
<td>351.7</td>
<td>5.50</td>
<td>1.000</td>
</tr>
<tr>
<td>Roadway Surcharge</td>
<td>329.2</td>
<td>-3.75</td>
<td>144.3</td>
<td>5.50</td>
<td>1.000</td>
</tr>
<tr>
<td>Weight - reinforced soil</td>
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<td>-3.67</td>
<td>5175.9</td>
<td>2.88</td>
<td>1.000</td>
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<tr>
<td>Roadway Surcharge</td>
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<td>-7.50</td>
<td>1375.0</td>
<td>-0.94</td>
<td>1.000</td>
</tr>
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</table>

Verification against slip along geotextile No.: 1

Inclination of slip surface = 90.00°
Overall normal force acting on reinforcement = 7046.79 lb/ft
Coefficient of reduction of slip along geo-textile = 0.92
Resistance along geo-reinforcement = 4611.75 lb/ft
Wall resistance = 1183.40 lb/ft
Overall bearing capacity of reinforcements = 0.00 lb/ft

Check for slip:
Resisting horizontal force $H_{\text{res}} = 5795.15$ lb/ft
Active horiz. force $H_{\text{act}} = 1131.58$ lb/ft
Factor of safety = 5.12 > 1.50
Slip along geotextile is SATISFACTORY
Calculation of internal stability No. 1

Calculated forces and strength of reinforcements

<table>
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<tr>
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<th></th>
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<td>49.55</td>
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<td>1034.67</td>
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<td>1424.07</td>
<td>29.77</td>
<td>1087.13</td>
<td>38.99</td>
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<td>Miragrid 5XT</td>
<td>-213.31</td>
<td>4.50</td>
<td>1034.67</td>
<td>30.92</td>
<td>905.98</td>
<td>35.32</td>
<td>1087.13</td>
<td>29.43</td>
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<td>4</td>
<td>Miragrid 5XT</td>
<td>-160.32</td>
<td>3.00</td>
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<td>23.24</td>
<td>495.93</td>
<td>48.49</td>
<td>1087.13</td>
<td>22.12</td>
</tr>
</tbody>
</table>

Check for tensile strength (reinforcement No. 1)

Tension strength $R_t = 517.34$ lbf/ft

Force in reinforcement $F_x = 170.89$ lbf/ft

Safety factor = 3.03 > 1.50

Reinforcement for tensile strength is SATISFACTORY

Check for pull out resistance (reinforcement No. 4)

Pull out resistance $T_p = 495.93$ lbf/ft

Force in reinforcement $F_x = 180.32$ lbf/ft

Safety factor = 3.09 > 1.50

Reinforcement for pull out resistance is SATISFACTORY

Verification of connection strength (reinforcement No. 1)

Connection strength $R_{con} = 543.57$ lbf/ft

Force in reinforcement $F_x = 170.89$ lbf/ft

Safety factor = 3.18 > 1.50

Connection strength is SATISFACTORY

Overall verification - reinforcement is SATISFACTORY
6'-0” Tall Wall – Seismic Case
Analysis of Redi Rock wall

Input data

Project
Task: MSE Wall Design
Part: 6.0' MSE Wall - Seismic Case
Author: NRW
Date: 11/25/2019
Project number: 1801-0336

Settings
(Input for current task)

Materials and standards
AASHTO - reduce parameters of friction soil/soil by 2/3 φ

Wall analysis
Active earth pressure calculation: Coulomb
Passive earth pressure calculation: Mazinadri (Rankine)
Earthquake analysis: Mononobe-Okabe
Shape of earth wedge: Calculate as skew
Allowable eccentricity: 0.333
Internal stability: Standard - straight slip surface
Reduction coeff. of contact first block - base: 1.00
Verification methodology: Safety factors (ASD)

| Safety factors for overturning: | SF₀ = 1.10 [-] |
| Safety factor for sliding resistance: | SF₆ = 1.10 [-] |
| Safety factor for bearing capacity: | SF₆ = 1.00 [-] |
| Safety factor for sliding along geo-reinforcement: | SF₆ = 1.10 [-] |
| Safety factor for geo-reinforcement strength: | SF₆ = 1.10 [-] |
| Safety factor for pull out resistance of geo-reinf.: | SF₆ = 1.10 [-] |
| Safety factor for connection strength: | SF₆ = 1.10 [-] |

Geometry

<table>
<thead>
<tr>
<th>No. group</th>
<th>Description</th>
<th>Count</th>
<th>Setback s [ft]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Block 28 PC</td>
<td>3</td>
<td>1.62</td>
</tr>
<tr>
<td>2</td>
<td>Top block 28</td>
<td>1</td>
<td>-</td>
</tr>
</tbody>
</table>

Base

Geometry
Upper setback a₁ = 0.50 ft
Lower setback a₂ = 0.50 ft
Height h = 0.50 ft
Width b = 3.50 ft

Material
Unreinforced Footing
Concrete self-weight γ = 150.00pcf
Shear cub (key) capacity = 0.00 lbf/ft
Friction angle concrete-concrete = 30.00°
### Types of reinforcements

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Type of reinforcement</th>
<th>Line type</th>
<th>T_{ult} [lbf/ft]</th>
<th>R_{t} [lbf/ft]</th>
<th>R_{con} [lbf/ft]</th>
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<tbody>
<tr>
<td>1</td>
<td>Miragrid 5XT</td>
<td>Miragrid 5XT</td>
<td>-</td>
<td>4700.00</td>
<td>2069.35</td>
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<td>Miragrid 8XT</td>
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<td>Miragrid 10XT</td>
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<td>-</td>
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<tr>
<td>4</td>
<td>Miragrid 20XT</td>
<td>Miragrid 20XT</td>
<td>~</td>
<td>13705.00</td>
<td>6558.83</td>
<td>6030.20</td>
</tr>
<tr>
<td>5</td>
<td>Miragrid 24XT</td>
<td>Miragrid 24XT</td>
<td>~</td>
<td>27415.00</td>
<td>13716.42</td>
<td>10560.73</td>
</tr>
</tbody>
</table>

### Reinforcement details

1. **Miragrid 5XT**
   - Short-term char. strength: $T_{ult} = 4700.00$ lbf/ft
   - Creep red. factor: $RF_{CR} = 1.58$
   - Durability red. factor: $RF_{D} = 1.15$
   - Installation damage red. factor: $RF_{ID} = 1.25$
   - Long-term design strength: $R_{t} = 2069.35$ lbf/ft
   - Coefficient of direct slip along reinforcement: $C_{D} = 0.67$
   - Coefficient of interaction of soil and geo-reinforcement: $C_{t} = 0.67$
   - Scale correction factor: $\alpha = 0.8$
   - Long-term strength reduction factor: $CR_{CR} = 0.532$
   - Analysis of long-term strength: $R_{con} = 2174.26$ lbf/ft

2. **Miragrid 8XT**
   - Short-term char. strength: $T_{ult} = 7400.00$ lbf/ft
   - Creep red. factor: $RF_{CR} = 1.58$
   - Durability red. factor: $RF_{D} = 1.15$
   - Installation damage red. factor: $RF_{ID} = 1.20$
   - Long-term design strength: $R_{t} = 3393.87$ lbf/ft
   - Coefficient of direct slip along reinforcement: $C_{D} = 0.67$
   - Coefficient of interaction of soil and geo-reinforcement: $C_{t} = 0.67$
   - Scale correction factor: $\alpha = 0.8$
   - Long-term strength reduction factor: $CR_{CR} = 0.532$
   - Analysis of long-term strength: $R_{con} = 3423.30$ lbf/ft

3. **Miragrid 10XT**
   - Short-term char. strength: $T_{ult} = 9500.00$ lbf/ft
   - Creep red. factor: $RF_{CR} = 1.58$
   - Durability red. factor: $RF_{D} = 1.15$
   - Installation damage red. factor: $RF_{ID} = 1.20$
   - Long-term design strength: $R_{t} = 4357.00$ lbf/ft
   - Coefficient of direct slip along reinforcement: $C_{D} = 0.67$
   - Coefficient of interaction of soil and geo-reinforcement: $C_{t} = 0.67$
   - Scale correction factor: $\alpha = 0.8$
   - Long-term strength reduction factor: $CR_{CR} = 0.519$
   - Analysis of long-term strength: $R_{con} = 4287.39$ lbf/ft
4. Miragrid 20XT
- Short-term char. strength: $T_{UL} = 13705.00$ lb/ft
- Creep red. factor: $RF_{CR} = 1.58$
- Durability red. factor: $RF_D = 1.15$
- Installation damage red. factor: $RF_{ID} = 1.15$
- Long-term design strength: $R_L = 6558.83$ lb/ft
- Coefficient of direct slip along reinforcement: $C_{ds} = 0.67$
- Coefficient of interaction of soil and geo-reinforcement: $C_i = 0.67$
- Scale correction factor: $\alpha = 0.8$
- Long-term strength reduction factor: $CR_{cr} = 0.506$
- Analysis of long-term strength: $R_{con} = 6030.20$ lb/ft

5. Miragrid 24XT
- Short-term char. strength: $T_{UL} = 27415.00$ lb/ft
- Creep red. factor: $RF_{CR} = 1.58$
- Durability red. factor: $RF_D = 1.15$
- Installation damage red. factor: $RF_{ID} = 1.10$
- Long-term design strength: $R_L = 13716.42$ lb/ft
- Coefficient of direct slip along reinforcement: $C_{ds} = 0.67$
- Coefficient of interaction of soil and geo-reinforcement: $C_i = 0.67$
- Scale correction factor: $\alpha = 0.8$
- Long-term strength reduction factor: $CR_{cr} = 0.443$
- Analysis of long-term strength: $R_{con} = 10560.73$ lb/ft

**Reinforcements**
- Input mode: 1 reinforcement type
- Reinf. installation: in every row of blocks (50%)
- Type of reinforcement: Miragrid 5XT
- Top reinforcement: straight (25%)
- Reinforcement geometry: identical length of reinforcements
- Length of reinforcement $l = 4.50$ ft

<table>
<thead>
<tr>
<th>No.</th>
<th>Consider</th>
<th>Name</th>
<th>Length of reinforcement $l$ [ft]</th>
<th>End pt. coordinate $l_R$ [ft]</th>
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<tbody>
<tr>
<td>1</td>
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<td>3</td>
<td>Yes</td>
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<td>4.50</td>
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</tr>
<tr>
<td>4</td>
<td>No</td>
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</table>
Basic soil parameters

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Pattern</th>
<th>$\varphi_{ef}$ [°]</th>
<th>$c_{ef}$ [psf]</th>
<th>$\gamma$ [pcf]</th>
<th>$\gamma_{su}$ [pcf]</th>
<th>$\delta$ [°]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Gravel Backfill</td>
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<td>35.50</td>
<td>0.0</td>
<td>130.00</td>
<td>67.50</td>
<td>34.00</td>
</tr>
</tbody>
</table>

All soils are considered as cohesionless for a rest pressure analysis.

Soil parameters

Gravel Backfill
- Unit weight: $\gamma = 130.0$ pcf
- Stress-state: effective
- Angle of internal friction: $\varphi_{ef} = 35.50$ °
- Cohesion of soil: $c_{ef} = 0.0$ psf
- Angle of friction struct-soil: $\delta = 34.00$ °
- Saturated unit weight: $\gamma_{sat} = 130.0$ pcf

Input surface surcharges

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
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<td>variable</td>
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</tbody>
</table>

No. 1 Roadway Surcharge

...
Resistance on front face of the structure
Resistance on front face of the structure is not considered.

Earthquake
Factor of horizontal acceleration $K_h = 0.1620$
Factor of vertical acceleration $K_v = 0.0000$
Water below the GWT is free.
Specific gravity of soil particles $G_s = 2.08$.

Settings of the stage of construction
Design situation: seismic

Verification No. 1
Forces acting on construction

<table>
<thead>
<tr>
<th>Name</th>
<th>$F_{hor}$ [lbf/ft]</th>
<th>$F_{vert}$ [lbf/ft]</th>
<th>$z$ [ft]</th>
<th>$x$ [ft]</th>
<th>Design coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight - reinforced soil</td>
<td>0.0</td>
<td>3613.8</td>
<td>-3.05</td>
<td>4.70</td>
<td>1.000</td>
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<tr>
<td>Earthquake - soil wedge</td>
<td>585.4</td>
<td>0.0</td>
<td>-3.05</td>
<td>4.70</td>
<td>1.000</td>
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<tr>
<td>Active pressure</td>
<td>513.5</td>
<td>225.1</td>
<td>-2.00</td>
<td>7.10</td>
<td>1.000</td>
</tr>
<tr>
<td>Earthq.- act.pressure</td>
<td>228.7</td>
<td>100.3</td>
<td>-4.00</td>
<td>7.10</td>
<td>1.000</td>
</tr>
<tr>
<td>Roadway Surcharge</td>
<td>263.3</td>
<td>115.4</td>
<td>-3.00</td>
<td>7.10</td>
<td>1.000</td>
</tr>
<tr>
<td>Weight - wall</td>
<td>0.0</td>
<td>1584.2</td>
<td>-2.83</td>
<td>1.34</td>
<td>1.000</td>
</tr>
<tr>
<td>Earthq.- constr.</td>
<td>256.6</td>
<td>0.0</td>
<td>-2.83</td>
<td>1.34</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Verification of complete wall
Place of verification: bottom of blocks

Check for overturning stability
Resisting moment $M_{res} = 22411.1$ lbf/ft
Overturning moment $M_{olv} = 5246.9$ lbf/ft
Safety factor $= 4.24 > 1.10$
Wall for overturning is SATISFACTORY

Check for slip
Resisting horizontal force $H_{res} = 3690.24$ lbf/ft
Active horizontal force $H_{act} = 1847.69$ lbf/ft
Safety factor $= 2.00 > 1.10$
Wall for slip is SATISFACTORY

Overall check - WALL is SATISFACTORY
Bearing capacity of foundation soil

Design load acting at the center of footing bottom

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-3725.5</td>
<td>3104.24</td>
<td>-1026.26</td>
<td>0.000</td>
<td>886.9</td>
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</table>

Service load acting at the center of footing bottom

<table>
<thead>
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<th></th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>-3725.5</td>
<td>3104.24</td>
<td>-1026.26</td>
</tr>
</tbody>
</table>

Verification of foundation soil

Place of verification: bottom of leveling pad
Stress in the footing bottom: trapezoid

Eccentricity verification

Max. eccentricity of normal force $e = 0.000$
Maximum allowable eccentricity $e_{alw} = 0.333$

Eccentricity of the normal force is SATISFACTORY

Verification of bearing capacity

Max. stress at footing bottom $\sigma = 886.9$ psf
Bearing capacity of foundation soil $R_d = 2000.0$ psf
Safety factor $= 2.25 > 1.00$

Bearing capacity of foundation soil is SATISFACTORY
Overall verification - bearing capacity of found. soil is SATISFACTORY

Verification of slip on georeinforcement No. 1
Forces acting on construction (verification of reinforcement No.: 1)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Weight - wall</td>
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<td>1628.2</td>
<td>-3.99</td>
<td>1.00</td>
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<td>Earthq. - constr.</td>
<td>263.8</td>
<td>-2.83</td>
<td>0.0</td>
<td>-3.99</td>
<td>1.00</td>
</tr>
<tr>
<td>Active pressure</td>
<td>513.5</td>
<td>-2.00</td>
<td>225.1</td>
<td>4.50</td>
<td>1.00</td>
</tr>
<tr>
<td>Earthq. - act pressure</td>
<td>228.7</td>
<td>-4.00</td>
<td>100.3</td>
<td>4.50</td>
<td>1.00</td>
</tr>
<tr>
<td>Roadway Surcharge</td>
<td>263.3</td>
<td>-3.00</td>
<td>115.4</td>
<td>4.50</td>
<td>1.00</td>
</tr>
<tr>
<td>Weight - reinforced soil</td>
<td>0.0</td>
<td>-2.94</td>
<td>3429.0</td>
<td>2.35</td>
<td>1.00</td>
</tr>
<tr>
<td>Earthquake - soil wedge</td>
<td>543.0</td>
<td>-2.94</td>
<td>0.0</td>
<td>2.35</td>
<td>1.00</td>
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<tr>
<td>Roadway Surcharge</td>
<td>0.0</td>
<td>-6.00</td>
<td>1202.1</td>
<td>-1.51</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Verification against slip along geotextile No. 1
- Inclination of slip surface = 90.00°
- Overall normal force acting on reinforcement = 5071.80 lbf/ft
- Coefficient of reduction of slip along geo-textile = 0.92
- Resistance along geo-reinforcement = 3319.22 lbf/ft
- Wall resistance = 0.00 lbf/ft
- Overall bearing capacity of reinforcements = 0.00 lbf/ft

Check for slip:
- Resisting horizontal force $H_{res} = 3319.22$ lbf/ft

Project: 1801-0336  Date: 3/27/2020  Designer: NRW  Sheet: A70
Active horiz. force \( H_{act} = 1005.62 \text{ lbf/ft} \)

Factor of safety = 3.30 > 1.10

Slip along geotextile is SATISFACTORY

**Calculation of internal stability No. 1**

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>( F_x ) [lbf/ft]</th>
<th>Depth ( z ) [ft]</th>
<th>( R_t ) [lbf/ft]</th>
<th>Utiliz. [%]</th>
<th>( T_p ) [lbf/ft]</th>
<th>Utiliz. [%]</th>
<th>( R_{con} ) [lbf/ft]</th>
<th>Utiliz. [%]</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Miragrid 5XT</td>
<td>-144.90</td>
<td>6.00</td>
<td>517.34</td>
<td>30.81</td>
<td>670.98</td>
<td>23.76</td>
<td>543.57</td>
<td>29.32</td>
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<tr>
<td>2</td>
<td>Miragrid 5XT</td>
<td>-254.87</td>
<td>4.50</td>
<td>1034.67</td>
<td>27.10</td>
<td>844.39</td>
<td>33.20</td>
<td>1087.13</td>
<td>25.79</td>
</tr>
<tr>
<td>3</td>
<td>Miragrid 5XT</td>
<td>-216.41</td>
<td>3.00</td>
<td>1034.67</td>
<td>23.01</td>
<td>454.88</td>
<td>52.33</td>
<td>1087.13</td>
<td>21.90</td>
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</table>

**Check for tensile strength (reinforcement No.1)**

Tension strength \( R_t = 517.34 \text{ lbf/ft} \)

Force in reinforcement \( F_x = 144.90 \text{ lbf/ft} \)

Safety factor = 3.57 > 1.10

**Reinforcement for tensile strength is SATISFACTORY**

**Check for pull out resistance (reinforcement No.3)**

Pull out resistance \( T_p = 454.88 \text{ lbf/ft} \)

Force in reinforcement \( F_x = 216.41 \text{ lbf/ft} \)

Safety factor = 2.10 > 1.10

**Reinforcement for pull out resistance is SATISFACTORY**

**Verification of connection strength (reinforcement No.1)**

Connection strength \( R_{con} = 543.57 \text{ lbf/ft} \)

Force in reinforcement \( F_x = 144.90 \text{ lbf/ft} \)

Safety factor = 3.75 > 1.10

**Connection strength is SATISFACTORY**

**Overall verification - reinforcement is SATISFACTORY**
6’-0” Tall Wall – Transient Case
### Analysis of Redi Rock wall

#### Input data

**Project**
- Part: 6.0' MSE Wall - Transient Case
- Author: NRW
- Date: 12/6/2019
- Project number: 1801-0336

**Settings**

* (input for current task)

**Materials and standards**

AASHTO - reduce parameters of friction soil/soil by 2/3 ϕ

**Wall analysis**

- Active earth pressure calculation: Coulomb
- Passive earth pressure calculation: Mazinardi (Rankine)
- Earthquake analysis: Mononobe-Okabe
- Shape of earth wedge: Calculate as skew
- Allowable eccentricity: 0.333
- Internal stability: Standard - straight slip surface
- Reduction coeff. of contact first block - base: 1.00
- Verification methodology: Safety factors (ASD)

### Safety factors

| Safety factor for overturning: | SF <sub>o</sub> | 1.50 [-] |
| Safety factor for sliding resistance: | SF <sub>r</sub> | 1.50 [-] |
| Safety factor for bearing capacity: | SF <sub>b</sub> | 1.33 [-] |
| Safety factor for sliding along geo-reinforcement: | SF <sub>sr</sub> | 1.50 [-] |
| Safety factor for geo-reinforcement strength: | SF <sub>st</sub> | 1.50 [-] |
| Safety factor for pull out resistance of geo-reinf.: | SF <sub>po</sub> | 1.50 [-] |
| Safety factor for connection strength: | SF <sub>con</sub> | 1.50 [-] |

### Geometry

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<tr>
<th>No. group</th>
<th>Description</th>
<th>Count</th>
<th>Setback s [ft]</th>
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<td>1</td>
<td>Block 26 PC</td>
<td>3</td>
<td>1.62</td>
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<tr>
<td>2</td>
<td>Top block 26</td>
<td>1</td>
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</tbody>
</table>

#### Base

**Geometry**

- Upper setback: a₁ = 0.50 ft
- Lower setback: a₂ = 0.50 ft
- Height: h = 0.50 ft
- Width: b = 3.50 ft

**Material**

- Unreinforced Footing
- Concrete self-weight: γ = 150.00 pcf
- Shear cub (key) capacity: 0.00 lbf/ft
- Friction angle concrete-concrete: 30.00 °
Types of reinforcements

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Type of reinforcement</th>
<th>Line type</th>
<th>T_{ult} [lb/ft]</th>
<th>R_{L} [lb/ft]</th>
<th>R_{con} [lb/ft]</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Miragrid 5XT</td>
<td>Miragrid 5XT</td>
<td>----------</td>
<td>4700.00</td>
<td>2069.35</td>
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<td>Miragrid 8XT</td>
<td>Miragrid 8XT</td>
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<td>7400.00</td>
<td>3393.87</td>
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<tr>
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<td>Miragrid 10XT</td>
<td>Miragrid 10XT</td>
<td>----------</td>
<td>9500.00</td>
<td>4357.00</td>
<td>4287.39</td>
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<tr>
<td>4</td>
<td>Miragrid 20XT</td>
<td>Miragrid 20XT</td>
<td>~~~~~~~~~~</td>
<td>13705.00</td>
<td>6558.83</td>
<td>6030.20</td>
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<tr>
<td>5</td>
<td>Miragrid 24XT</td>
<td>Miragrid 24XT</td>
<td>~~~~~~~~~~</td>
<td>27415.00</td>
<td>13716.42</td>
<td>10560.73</td>
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</tbody>
</table>

Reinforcement details

1. Miragrid 5XT
   - Short-term char. strength: \( T_{ult} = 4700.00 \) lb/ft
   - Creep red. factor: \( R_{FCR} = 1.58 \)
   - Durability red. factor: \( R_{FD} = 1.15 \)
   - Installation damage red. factor: \( R_{FDI} = 1.25 \)
   - Long-term design strength: \( R_{L} = 2069.35 \) lb/ft
   - Coefficient of direct slip along reinforcement: \( C_{ds} = 0.67 \)
   - Coefficient of interaction of soil and geo-reinforcement: \( C_{I} = 0.67 \)
   - Scale correction factor: \( \alpha = 0.8 \)
   - Long-term strength reduction factor: \( CR_{cr} = 0.532 \)
   - Analysis of long-term strength: \( R_{con} = 2174.26 \) lb/ft

2. Miragrid 8XT
   - Short-term char. strength: \( T_{ult} = 7400.00 \) lb/ft
   - Creep red. factor: \( R_{FCR} = 1.58 \)
   - Durability red. factor: \( R_{FD} = 1.15 \)
   - Installation damage red. factor: \( R_{FDI} = 1.20 \)
   - Long-term design strength: \( R_{L} = 3393.87 \) lb/ft
   - Coefficient of direct slip along reinforcement: \( C_{ds} = 0.67 \)
   - Coefficient of interaction of soil and geo-reinforcement: \( C_{I} = 0.67 \)
   - Scale correction factor: \( \alpha = 0.8 \)
   - Long-term strength reduction factor: \( CR_{cr} = 0.532 \)
   - Analysis of long-term strength: \( R_{con} = 3423.30 \) lb/ft

3. Miragrid 10XT
   - Short-term char. strength: \( T_{ult} = 9500.00 \) lb/ft
   - Creep red. factor: \( R_{FCR} = 1.58 \)
   - Durability red. factor: \( R_{FD} = 1.15 \)
   - Installation damage red. factor: \( R_{FDI} = 1.20 \)
   - Long-term design strength: \( R_{L} = 4357.00 \) lb/ft
   - Coefficient of direct slip along reinforcement: \( C_{ds} = 0.67 \)
   - Coefficient of interaction of soil and geo-reinforcement: \( C_{I} = 0.67 \)
   - Scale correction factor: \( \alpha = 0.8 \)
   - Long-term strength reduction factor: \( CR_{cr} = 0.519 \)
   - Analysis of long-term strength: \( R_{con} = 4287.39 \) lb/ft

4. Miragrid 20XT
Short-term char. strength
Creep red. factor
Durability red. factor
Installation damage red. factor
Long-term design strength
Coefficient of direct slip along reinforcement
Coefficient of interaction of soil and geo-reinforcement
Scale correction factor
Long-term strength reduction factor
Analysis of long-term strength

5. Miragrid 24XT
Short-term char. strength
Creep red. factor
Durability red. factor
Installation damage red. factor
Long-term design strength
Coefficient of direct slip along reinforcement
Coefficient of interaction of soil and geo-reinforcement
Scale correction factor
Long-term strength reduction factor
Analysis of long-term strength

Reinforcements
Input mode : 1 reinforcement type
Reinf. installation : in every row of blocks (50%)
Type of reinforcement : Miragrid 5XT
Top reinforcement : straight (25%)
Reinforcement geometry : identical length of reinforcements
Length of reinforcement $l = 4.50$ ft

<table>
<thead>
<tr>
<th>No.</th>
<th>Consider</th>
<th>Name</th>
<th>Length of reinforcement $l$ [ft]</th>
<th>End pt. coordinate $l_k$ [ft]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yes</td>
<td>Miragrid 5XT</td>
<td>4.50</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Yes</td>
<td>Miragrid 5XT</td>
<td>4.50</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Yes</td>
<td>Miragrid 5XT</td>
<td>4.50</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>No</td>
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</tbody>
</table>
Soil parameters

Gravel Backfill

- Unit weight: $\gamma = 130.0$ pcf
- Stress-state: effective
- Angle of internal friction: $\phi_{ef} = 35.50^\circ$
- Cohesion of soil: $c_{ef} = 0.0$ psf
- Angle of friction struc.-soil: $\delta = 34.00^\circ$
- Saturated unit weight: $\gamma_{sat} = 130.0$ pcf

Input surface surcharges

<table>
<thead>
<tr>
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</tr>
</tbody>
</table>

Roadway Surcharge

Resistance on front face of the structure

Resistance on front face of the structure is not considered.

Settings of the stage of construction

Design situation: transient
Verification No. 1
Forces acting on construction

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight - reinforced soil</td>
<td>0.0</td>
<td>-3.05</td>
<td>3613.8</td>
<td>4.70</td>
<td>1.00</td>
</tr>
<tr>
<td>Active pressure</td>
<td>513.5</td>
<td>-2.00</td>
<td>225.1</td>
<td>7.10</td>
<td>1.00</td>
</tr>
<tr>
<td>Roadway Surcharge</td>
<td>263.3</td>
<td>-3.00</td>
<td>115.4</td>
<td>7.10</td>
<td>1.00</td>
</tr>
<tr>
<td>Weight - wall</td>
<td>0.0</td>
<td>-2.83</td>
<td>1584.2</td>
<td>1.34</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Verification of complete wall
Place of verification: bottom of blocks

Check for overturning stability
Resisting moment \( M_{res} = 21528.9 \text{ lbf} \cdot \text{ft} \)
Overturning moment \( M_{out} = 1817.1 \text{ lbf} \cdot \text{ft} \)

Safety factor = 11.85 > 1.50
Wall for overturning is SATISFACTORY

Check for slip
Resisting horizontal force \( H_{res} = 3624.63 \text{ lbf} \)
Active horizontal force \( H_{act} = 776.88 \text{ lbf} \)

Safety factor = 4.67 > 1.50
Wall for slip is SATISFACTORY

Overall check - WALL is SATISFACTORY
Bearing capacity of foundation soil

Design load acting at the center of footing bottom

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-5618.8</td>
<td>2685.87</td>
<td>-1625.84</td>
<td>0.000</td>
<td>824.5</td>
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</table>

Service load acting at the center of footing bottom

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-5618.8</td>
<td>2685.87</td>
<td>-1625.84</td>
</tr>
</tbody>
</table>

Verification of foundation soil

Place of verification: bottom of leveling pad
Stress in the footing bottom: trapezoid

Eccentricity verification

Max. eccentricity of normal force $e = 0.000$
Maximum allowable eccentricity $e_{aw} = 0.333$

Eccentricity of the normal force is SATISFACTORY

Verification of bearing capacity

Max. stress at footing bottom $\sigma = 824.5 \text{ psf}$
Bearing capacity of foundation soil $R_d = 2000.0 \text{ psf}$
Safety factor $= 2.43 > 1.33$

Bearing capacity of foundation soil is SATISFACTORY
Overall verification - bearing capacity of found. soil is SATISFACTORY

Verification of slip on geosynthetic reinforcement No. 1

Forces acting on construction (verification of reinforcement No.: 1)

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Weight - wall</td>
<td>0.0</td>
<td>-2.83</td>
<td>1628.2</td>
<td>-3.99</td>
<td>1.000</td>
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<tr>
<td>Active pressure</td>
<td>513.5</td>
<td>-2.00</td>
<td>225.1</td>
<td>4.50</td>
<td>1.000</td>
</tr>
<tr>
<td>Roadway Surcharge</td>
<td>263.3</td>
<td>-3.00</td>
<td>115.4</td>
<td>4.50</td>
<td>1.000</td>
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<tr>
<td>Weight - reinforced soil</td>
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<tr>
<td>Roadway Surcharge</td>
<td>0.0</td>
<td>-6.00</td>
<td>1202.1</td>
<td>-1.51</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Verification against slip along geotextile No.: 1

- Inclination of slip surface $\theta = 90.00^\circ$
- Overall normal force acting on reinforcement $F_{nor} = 4971.55$ lbf/ft
- Coefficient of reduction of slip along geo-textile $\mu = 0.92$
- Resistance along geo-reinforcement $R = 3253.61$ lbf/ft
- Wall resistance $W = 940.03$ lbf/ft
- Overall bearing capacity of reinforcements $B = 0.00$ lbf/ft

Check for slip:
- Resisting horizontal force $H_{res} = 4193.64$ lbf/ft
- Active horizontal force $H_{act} = 776.88$ lbf/ft

Factor of safety $k = 5.40 > 1.50$

Slip along geotextile is SATISFACTORY
### Calculation of internal stability No. 1

#### Calculated forces and strength of reinforcements

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<tr>
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<tbody>
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<td>517.34</td>
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<td>Miragrid 5XT</td>
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<td>844.39</td>
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<td>1087.13</td>
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<td>Miragrid 5XT</td>
<td>-160.32</td>
<td>3.00</td>
<td>1034.67</td>
<td>23.24</td>
<td>454.88</td>
<td>52.87</td>
<td>1087.13</td>
<td>22.12</td>
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</tbody>
</table>

#### Check for tensile strength (reinforcement No.1)
- Tension strength $R_t = 517.34$ lbf/ft
- Force in reinforcement $F_x = 141.30$ lbf/ft
- Safety factor $= 3.66 > 1.50$
- **Reinforcement for tensile strength is SATISFACTORY**

#### Check for pull out resistance (reinforcement No.3)
- Pull out resistance $T_p = 454.88$ lbf/ft
- Force in reinforcement $F_x = 180.32$ lbf/ft
- Safety factor $= 2.84 > 1.50$
- **Reinforcement for pull out resistance is SATISFACTORY**

#### Verification of connection strength (reinforcement No.1)
- Connection strength $R_{con} = 543.57$ lbf/ft
- Force in reinforcement $F_x = 141.30$ lbf/ft
- Safety factor $= 3.85 > 1.50$
- **Connection strength is SATISFACTORY**

**Overall verification - reinforcement is SATISFACTORY**
4’-6” Tall Wall – Seismic Case
Analysis of Redi Rock wall

Input data

Project
Task: MSE Wall Design
Part: 4.5' MSE Wall - Seismic Case
Author: NRW
Date: 11/25/2019
Project number: 1801-0336

Settings
(Input for current task)

Materials and standards
AASHTO - reduce parameters of friction soil/soil by 2/3 φ

Wall analysis
Active earth pressure calculation: Coulomb
Passive earth pressure calculation: Mazin (Rankine)
Earthquake analysis: Mononobe-Okabe
Shape of earth wedge: Calculate as skew
Allowable eccentricity: 0.333
Internal stability: Standard - straight slip surface
Reduction coeff. of contact first block - base: 1.00
Verification methodology: Safety factors (ASD)

<table>
<thead>
<tr>
<th>Safety factor for overturning: SF₀</th>
<th>Safety factors</th>
<th>Seismic design situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF₀ = 1.10 [-]</td>
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</table>

<table>
<thead>
<tr>
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<th>Seismic design situation</th>
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<tbody>
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<tr>
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<th>Safety factors</th>
<th>Seismic design situation</th>
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</thead>
<tbody>
<tr>
<td>SFₚ = 1.00 [-]</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Safety factor for sliding along geo-reinforcement: SFₘ</th>
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<th>Seismic design situation</th>
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<tbody>
<tr>
<td>SFₘ = 1.10 [-]</td>
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</table>

<table>
<thead>
<tr>
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<th>Safety factors</th>
<th>Seismic design situation</th>
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<tbody>
<tr>
<td>SFₛᵣ = 1.10 [-]</td>
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<table>
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<tr>
<th>Safety factor for pull out resistance of geo-reinf.: SFₚᵣ</th>
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<th>Seismic design situation</th>
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<tbody>
<tr>
<td>SFₚᵣ = 1.10 [-]</td>
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<table>
<thead>
<tr>
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<th>Safety factors</th>
<th>Seismic design situation</th>
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<tbody>
<tr>
<td>SFₚₑᵣ = 1.10 [-]</td>
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</table>

Geometry

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
<th>Count</th>
<th>Setback s [in]</th>
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<tbody>
<tr>
<td>1</td>
<td>Block 28 PC</td>
<td>2</td>
<td>1.62</td>
</tr>
<tr>
<td>2</td>
<td>Top block 28</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Base

Geometry
Upper setback: \( a₁ = 0.50 \) ft
Lower setback: \( a₂ = 0.50 \) ft
Height: \( h = 0.50 \) ft
Width: \( b = 3.50 \) ft

Material
Unreinforced Footing
Concrete self-weight: \( \gamma = 150.00 \)pcf
Shear cub (key) capacity: \( 0.00 \) lbf/ft
Friction angle concrete-concrete: \( 30.00 \)°
## Types of reinforcements

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Type of reinforcement</th>
<th>Line type</th>
<th>$T_{ult}$ [lbf/ft]</th>
<th>$R_l$ [lbf/ft]</th>
<th>$R_{con}$ [lbf/ft]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Miragrid 5XT</td>
<td>Miragrid 5XT</td>
<td></td>
<td>4700.00</td>
<td>2069.35</td>
<td>2174.26</td>
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<tr>
<td>2</td>
<td>Miragrid 8XT</td>
<td>Miragrid 8XT</td>
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<td>7400.00</td>
<td>3393.87</td>
<td>3423.30</td>
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<tr>
<td>3</td>
<td>Miragrid 10XT</td>
<td>Miragrid 10XT</td>
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<td>9500.00</td>
<td>4357.00</td>
<td>4287.39</td>
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<tr>
<td>4</td>
<td>Miragrid 20XT</td>
<td>Miragrid 20XT</td>
<td>11</td>
<td>13705.00</td>
<td>6568.83</td>
<td>6030.20</td>
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<tr>
<td>5</td>
<td>Miragrid 24XT</td>
<td>Miragrid 24XT</td>
<td>11</td>
<td>27415.00</td>
<td>13716.42</td>
<td>10560.73</td>
</tr>
</tbody>
</table>

### Reinforcement details

1. **Miragrid 5XT**
   - Short-term char. strength
   - Creep red. factor $R_{FC}$ = 1.58
   - Durability red. factor $R_{FD}$ = 1.15
   - Installation damage red. factor $R_{FID}$ = 1.25
   - Long-term design strength $R_l$ = 2069.35 lbf/ft
   - Coefficient of direct slip along reinforcement $C_{dsr}$ = 0.67
   - Coefficient of interaction of soil and geo-reinforcement $C_l$ = 0.67
   - Scale correction factor $\alpha$ = 0.8
   - Long-term strength reduction factor $CR_{Cr}$ = 0.532
   - Analysis of long-term strength $R_{con}$ = 2174.26 lbf/ft

2. **Miragrid 8XT**
   - Short-term char. strength
   - Creep red. factor $R_{FC}$ = 1.58
   - Durability red. factor $R_{FD}$ = 1.15
   - Installation damage red. factor $R_{FID}$ = 1.20
   - Long-term design strength $R_l$ = 3393.87 lbf/ft
   - Coefficient of direct slip along reinforcement $C_{dsr}$ = 0.67
   - Coefficient of interaction of soil and geo-reinforcement $C_l$ = 0.67
   - Scale correction factor $\alpha$ = 0.8
   - Long-term strength reduction factor $CR_{Cr}$ = 0.532
   - Analysis of long-term strength $R_{con}$ = 3423.30 lbf/ft

3. **Miragrid 10XT**
   - Short-term char. strength
   - Creep red. factor $R_{FC}$ = 1.58
   - Durability red. factor $R_{FD}$ = 1.15
   - Installation damage red. factor $R_{FID}$ = 1.20
   - Long-term design strength $R_l$ = 4357.00 lbf/ft
   - Coefficient of direct slip along reinforcement $C_{dsr}$ = 0.67
   - Coefficient of interaction of soil and geo-reinforcement $C_l$ = 0.67
   - Scale correction factor $\alpha$ = 0.8
   - Long-term strength reduction factor $CR_{Cr}$ = 0.519
   - Analysis of long-term strength $R_{con}$ = 4287.39 lbf/ft
4. Miragrid 20XT
Short-term char. strength \( T_{UL} = 13705.00 \text{ lb/ft} \)
Creep red. factor \( R_{FCR} = 1.58 \)
Durability red. factor \( R_{FD} = 1.15 \)
Installation damage red. factor \( R_{FID} = 1.15 \)
Long-term design strength \( R_{L} = 6558.83 \text{ lb/ft} \)
Coefficient of direct slip along reinforcement \( C_{ds} = 0.67 \)
Coefficient of interaction of soil and geo-reinforcement \( C_{I} = 0.67 \)
Scale correction factor \( \alpha = 0.8 \)
Long-term strength reduction factor \( CR_{cr} = 0.506 \)
Analysis of long-term strength \( R_{con} = 6030.20 \text{ lb/ft} \)

5. Miragrid 24XT
Short-term char. strength \( T_{UL} = 27415.00 \text{ lb/ft} \)
Creep red. factor \( R_{FCR} = 1.58 \)
Durability red. factor \( R_{FD} = 1.15 \)
Installation damage red. factor \( R_{FID} = 1.10 \)
Long-term design strength \( R_{L} = 13716.42 \text{ lb/ft} \)
Coefficient of direct slip along reinforcement \( C_{ds} = 0.67 \)
Coefficient of interaction of soil and geo-reinforcement \( C_{I} = 0.67 \)
Scale correction factor \( \alpha = 0.8 \)
Long-term strength reduction factor \( CR_{cr} = 0.443 \)
Analysis of long-term strength \( R_{con} = 10560.73 \text{ lb/ft} \)

Reinforcements
Input mode: 1 reinforcement type
Reinf. installation: in every row of blocks (50%)
Type of reinforcement: Miragrid 5XT
Top reinforcement: straight (25%)
Reinforcement geometry: identical length of reinforcements
Length of reinforcement \( l = 3.50 \text{ ft} \)

<table>
<thead>
<tr>
<th>No.</th>
<th>Consider</th>
<th>Name</th>
<th>Length of reinforcement ( l ) [ft]</th>
<th>End pt. coordinate ( l_k ) [ft]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yes</td>
<td>Miragrid 5XT</td>
<td>3.50</td>
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</tr>
<tr>
<td>2</td>
<td>Yes</td>
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<td>3.50</td>
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</tr>
<tr>
<td>3</td>
<td>No</td>
<td>Miragrid 5XT</td>
<td>3.50</td>
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</table>
Name: Reinforcements
Stage: analysis : 1 - 0

Basic soil parameters

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Pattern</th>
<th>$\phi_{ef}$ $^\circ$</th>
<th>$c_{ef}$ [psf]</th>
<th>$\gamma$ [pcf]</th>
<th>$\gamma_{su}$ [pcf]</th>
<th>$\delta$ $^\circ$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Gravel Backfill</td>
<td></td>
<td>35.50</td>
<td>0.0</td>
<td>130.00</td>
<td>67.50</td>
<td>34.00</td>
</tr>
</tbody>
</table>

All soils are considered as cohesionless for at rest pressure analysis.

Soil parameters

Gravel Backfill
Unit weight: $\gamma = 130.0$ pcf
Stress-state: effective
Angle of internal friction: $\phi_{ef} = 35.50^\circ$
Cohesion of soil: $c_{ef} = 0.0$ psf
Angle of friction struct.-soil: $\delta = 34.00^\circ$
Saturated unit weight: $\gamma_{sat} = 130.0$ pcf

Input surface surcharges

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<tbody>
<tr>
<td>1</td>
<td>Yes</td>
<td>variable</td>
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<td>200.0</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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</table>

No. Roadway Surcharge

---
Resistance on front face of the structure
Resistance on front face of the structure is not considered.

Earthquake
Factor of horizontal acceleration $K_h = 0.1620$
Factor of vertical acceleration $K_v = 0.0000$
Water below the GWT is free.
Specific gravity of soil particles $G_s = 2.08$.

Settings of the stage of construction
Design situation: seismic

Verification No. 1
Forces acting on construction

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<thead>
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<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Weight - reinforced soil</td>
<td>0.0</td>
<td>-2.32</td>
<td>2138.1</td>
<td>4.08</td>
<td>1.000</td>
</tr>
<tr>
<td>Earthquake - soil wedge</td>
<td>346.4</td>
<td>-2.32</td>
<td>0.0</td>
<td>4.08</td>
<td>1.000</td>
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<tr>
<td>Active pressure</td>
<td>288.9</td>
<td>-1.50</td>
<td>126.6</td>
<td>5.97</td>
<td>1.000</td>
</tr>
<tr>
<td>Earthq.-act.pressure</td>
<td>128.7</td>
<td>-3.00</td>
<td>56.4</td>
<td>5.97</td>
<td>1.000</td>
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<tr>
<td>Roadway Surcharge</td>
<td>197.5</td>
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<td>86.6</td>
<td>5.97</td>
<td>1.000</td>
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<tr>
<td>Weight - wall</td>
<td>0.0</td>
<td>-2.08</td>
<td>1164.2</td>
<td>1.27</td>
<td>1.000</td>
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<tr>
<td>Earthq.-constr.</td>
<td>188.6</td>
<td>-2.08</td>
<td>0.0</td>
<td>1.27</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Verification of complete wall
Place of verification: bottom of blocks

Check for overturning stability
Resisting moment $M_{res} = 11818.8$ lb/ft
Overturning moment $M_{turn} = 2460.9$ lb/ft
Safety factor = 4.80 > 1.10
Wall for overturning is SATISFACTORY

Check for slip
Resisting horizontal force $H_{res} = 2337.58$ lb/ft
Active horizontal force $H_{act} = 1150.01$ lb/ft
Safety factor = 2.03 > 1.10
Wall for slip is SATISFACTORY

Overall check - WALL is SATISFACTORY
Bearing capacity of foundation soil

**Design load acting at the center of footing bottom**

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-1224.4</td>
<td>2342.04</td>
<td>-355.86</td>
<td>0.000</td>
<td>669.2</td>
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</tbody>
</table>

**Service load acting at the center of footing bottom**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-1224.4</td>
<td>2342.04</td>
<td>-355.86</td>
</tr>
</tbody>
</table>

**Verification of foundation soil**

- Place of verification: bottom of leveling pad
- Stress in the footing bottom: trapezoid

**Eccentricity verification**

Max. eccentricity of normal force \( e \) = 0.000
Maximum allowable eccentricity \( e_{\text{aw}} \) = 0.333

**Eccentricity of the normal force is SATISFACTORY**

**Verification of bearing capacity**

Max. stress at footing bottom \( \sigma \) = 669.2 psf
Bearing capacity of foundation soil \( R_d \) = 2000.0 psf
Safety factor = 2.99 > 1.00

**Bearing capacity of foundation soil is SATISFACTORY**
Overall verification - bearing capacity of found. soil is SATISFACTORY

Verification of slip on georeinforcement No. 1
Forces acting on construction (verification of reinforcement No.: 1)

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight - wall</td>
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<td>-2.08</td>
<td>1205.7</td>
<td>-4.06</td>
<td>1.000</td>
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<td>Earthq. - constr.</td>
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<td>-2.08</td>
<td>0.0</td>
<td>-4.06</td>
<td>1.000</td>
</tr>
<tr>
<td>Active pressure</td>
<td>288.9</td>
<td>-1.50</td>
<td>126.6</td>
<td>3.50</td>
<td>1.000</td>
</tr>
<tr>
<td>Earthq. - act pressure</td>
<td>128.7</td>
<td>-3.00</td>
<td>56.4</td>
<td>3.50</td>
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<td>Roadway Surcharge</td>
<td>197.5</td>
<td>-2.25</td>
<td>86.6</td>
<td>3.50</td>
<td>1.000</td>
</tr>
<tr>
<td>Weight - reinforced soil</td>
<td>0.0</td>
<td>-2.21</td>
<td>2045.7</td>
<td>1.82</td>
<td>1.000</td>
</tr>
<tr>
<td>Earthquake - soil wedge</td>
<td>318.9</td>
<td>-2.21</td>
<td>0.0</td>
<td>1.82</td>
<td>1.000</td>
</tr>
<tr>
<td>Roadway Surcharge</td>
<td>0.0</td>
<td>-4.50</td>
<td>1029.2</td>
<td>-2.07</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Verification against slip along geotextile No.: 1

| Inclination of slip surface | 90.00 $^\circ$ |
| Overall normal force acting on reinforcement | 3344.42 lbf/ft |
| Coefficient of reduction of slip along geo-textile | 0.92 |
| Resistance along geo-reinforcement | 2188.74 lbf/ft |
| Wall resistance | 0.00 lbf/ft |
| Overall bearing capacity of reinforcements | 0.00 lbf/ft |

Check for slip:
Resisting horizontal force $H_{res} = 2188.74$ lbf/ft
Calculation of internal stability No. 1

Calculated forces and strength of reinforcements

<table>
<thead>
<tr>
<th></th>
<th></th>
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<td>24.52</td>
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<td>32.41</td>
<td>543.57</td>
<td>23.34</td>
</tr>
<tr>
<td>2</td>
<td>Miragrid 5XT</td>
<td>-198.79</td>
<td>3.00</td>
<td>1034.67</td>
<td>21.13</td>
<td>413.82</td>
<td>52.84</td>
<td>1087.13</td>
<td>20.11</td>
</tr>
</tbody>
</table>

Check for tensile strength (reinforcement No.1)
Tension strength $R_t = 517.34$ lbf/ft
Force in reinforcement $F_x = 115.31$ lbf/ft
Safety factor $= 4.49 > 1.10$

Reinforcement for tensile strength is SATISFACTORY

Check for pull out resistance (reinforcement No.2)
Pull out resistance $T_p = 413.82$ lbf/ft
Force in reinforcement $F_x = 198.79$ lbf/ft
Safety factor $= 2.08 > 1.10$

Reinforcement for pull out resistance is SATISFACTORY

Verification of connection strength (reinforcement No.1)
Connection strength $R_{com} = 543.57$ lbf/ft
Force in reinforcement $F_x = 115.31$ lbf/ft
Safety factor $= 4.71 > 1.10$

Connection strength is SATISFACTORY

Overall verification - reinforcement is SATISFACTORY
4’-6” Tall Wall – Transient Case
Analysis of Redi Rock wall

Input data

Project
Part: 4.5' MSE Wall - Transient Case
Author: NRW
Date: 12/6/2019
Project number: 1801-0336

Settings
(input for current task)

Materials and standards
AASHTO - reduce parameters of friction soil/soil by 2/3 (q)

Wall analysis
Active earth pressure calculation: Coulomb
Passive earth pressure calculation: Mazinabi (Rankine)
Earthquake analysis: Monone-Okaibe
Shape of earth wedge: Calculate as skew
Allowable eccentricity: 0.333
Internal stability: Standard - straight slip surface
Reduction coeff. of contact first block - base: 1.00
Verification methodology: Safety factors (ASD)

Safety factors

<table>
<thead>
<tr>
<th>Safety factor for overturning:</th>
<th>SF_o = 1.50 [-]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety factor for sliding resistance:</td>
<td>SF_r = 1.50 [-]</td>
</tr>
<tr>
<td>Safety factor for bearing capacity:</td>
<td>SF_b = 1.33 [-]</td>
</tr>
<tr>
<td>Safety factor for sliding along geo-reinforcement:</td>
<td>SF sr = 1.50 [-]</td>
</tr>
<tr>
<td>Safety factor for geo-reinforcement strength:</td>
<td>SF st = 1.50 [-]</td>
</tr>
<tr>
<td>Safety factor for pull out resistance of geo-reinf.:</td>
<td>SF po = 1.50 [-]</td>
</tr>
<tr>
<td>Safety factor for connection strength:</td>
<td>SF con = 1.50 [-]</td>
</tr>
</tbody>
</table>

Geometry

<table>
<thead>
<tr>
<th>No. group</th>
<th>Description</th>
<th>Count</th>
<th>Setback s [in]</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Block 26 PC</td>
<td>2</td>
<td>1.62</td>
</tr>
<tr>
<td>2</td>
<td>Top block 28</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Base

Geometry
Upper setback a1 = 0.50 ft
Lower setback a2 = 0.50 ft
Height h = 0.50 ft
Width b = 3.50 ft

Material
Unreinforced Footing
Concrete self-weight γ = 150.00 pcf
Shear cub (key) capacity = 0.00 lb/ft
Friction angle concrete-concrete = 30.00 °
### Types of reinforcements

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Type of reinforcement</th>
<th>Line type</th>
<th>T&lt;sub&gt;ult&lt;/sub&gt; [lb/ft]</th>
<th>R&lt;sub&gt;L&lt;/sub&gt; [lb/ft]</th>
<th>R&lt;sub&gt;Con&lt;/sub&gt; [lb/ft]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Miragrid 5XT</td>
<td>Miragrid 5XT</td>
<td>-</td>
<td>4700.00</td>
<td>2069.35</td>
<td>2174.26</td>
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<tr>
<td>2</td>
<td>Miragrid 8XT</td>
<td>Miragrid 8XT</td>
<td>-</td>
<td>7400.00</td>
<td>3393.87</td>
<td>3423.30</td>
</tr>
<tr>
<td>3</td>
<td>Miragrid 10XT</td>
<td>Miragrid 10XT</td>
<td>-</td>
<td>9500.00</td>
<td>4357.00</td>
<td>4287.39</td>
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<tr>
<td>4</td>
<td>Miragrid 20XT</td>
<td>Miragrid 20XT</td>
<td>~~~~~~~~~</td>
<td>13705.00</td>
<td>6558.83</td>
<td>6030.20</td>
</tr>
<tr>
<td>5</td>
<td>Miragrid 24XT</td>
<td>Miragrid 24XT</td>
<td>~~~~~~~~~</td>
<td>27415.00</td>
<td>13716.42</td>
<td>10560.73</td>
</tr>
</tbody>
</table>

#### Reinforcement details

1. **Miragrid 5XT**
   - Short-term char. strength: T<sub>ult</sub> = 4700.00 lb/ft
   - Creep red. factor: RFCR = 1.58
   - Durability red. factor: RDFD = 1.15
   - Installation damage red. factor: RFID = 1.25
   - Long-term design strength: RL = 2089.35 lb/ft
   - Coefficient of direct slip along reinforcement: C<sub>dR</sub> = 0.67
   - Coefficient of interaction of soil and geo-reinforcement: C<sub>l</sub> = 0.67
   - Scale correction factor: α = 0.8
   - Long-term strength reduction factor: CR<sub>lt</sub> = 0.532
   - Analysis of long-term strength: R<sub>Con</sub> = 2174.26 lb/ft

2. **Miragrid 8XT**
   - Short-term char. strength: T<sub>ult</sub> = 7400.00 lb/ft
   - Creep red. factor: RFCR = 1.58
   - Durability red. factor: RDFD = 1.15
   - Installation damage red. factor: RFID = 1.20
   - Long-term design strength: RL = 3393.87 lb/ft
   - Coefficient of direct slip along reinforcement: C<sub>dR</sub> = 0.67
   - Coefficient of interaction of soil and geo-reinforcement: C<sub>l</sub> = 0.67
   - Scale correction factor: α = 0.8
   - Long-term strength reduction factor: CR<sub>lt</sub> = 0.532
   - Analysis of long-term strength: R<sub>Con</sub> = 3423.30 lb/ft

3. **Miragrid 10XT**
   - Short-term char. strength: T<sub>ult</sub> = 9500.00 lb/ft
   - Creep red. factor: RFCR = 1.58
   - Durability red. factor: RDFD = 1.15
   - Installation damage red. factor: RFID = 1.20
   - Long-term design strength: RL = 4357.00 lb/ft
   - Coefficient of direct slip along reinforcement: C<sub>dR</sub> = 0.67
   - Coefficient of interaction of soil and geo-reinforcement: C<sub>l</sub> = 0.67
   - Scale correction factor: α = 0.8
   - Long-term strength reduction factor: CR<sub>lt</sub> = 0.519
   - Analysis of long-term strength: R<sub>Con</sub> = 4287.39 lb/ft

4. **Miragrid 20XT**

---

**project** 1801-0336  **date** 3/27/2020  **designer** NRW  **sheet** A95
5. Miragrid 24XT

Reinforcements

Input mode : 1 reinforcement type
Reinf. installation : in every row of blocks (50%)
Type of reinforcement : Miragrid 24XT
Top reinforcement : straight (25%)
Reinforcement geometry : identical length of reinforcements
Length of reinforcement $l = 3.50$ ft

<table>
<thead>
<tr>
<th>No.</th>
<th>Consider</th>
<th>Name</th>
<th>Length of reinforcement $l$ [ft]</th>
<th>End pt. coordinate $l_k$ [ft]</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Yes</td>
<td>Miragrid 5XT</td>
<td>3.50</td>
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<tr>
<td>2</td>
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<td>Miragrid 5XT</td>
<td>3.50</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>No</td>
<td>Miragrid 5XT</td>
<td>3.50</td>
<td></td>
</tr>
</tbody>
</table>
Soil parameters

Gravel Backfill

- Unit weight: $\gamma = 130.0$ pcf
- Stress-state: effective
- Angle of internal friction: $\phi_{ef} = 35.50^\circ$
- Cohesion of soil: $c_{ef} = 0.0$ psf
- Angle of friction struct.-soil: $\delta = 34.00^\circ$
- Saturated unit weight: $\gamma_{sat} = 130.0$ pcf

Input surface surcharges

<table>
<thead>
<tr>
<th></th>
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<th></th>
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<tr>
<td>1</td>
<td>Yes</td>
<td></td>
<td>variable</td>
<td>200.0</td>
<td></td>
<td></td>
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<td></td>
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</tbody>
</table>

1 Roadway Surcharge

Resistance on front face of the structure

Resistance on front face of the structure is not considered.

Settings of the stage of construction

Design situation: transient
Verification No. 1
Forces acting on construction

<table>
<thead>
<tr>
<th>Name</th>
<th>$F_{\text{hor}}$ (lb/ft)</th>
<th>App. Pt. $z$ [ft]</th>
<th>$F_{\text{vert}}$ (lb/ft)</th>
<th>App. Pt. $x$ [ft]</th>
<th>Design coefficient</th>
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<tbody>
<tr>
<td>Weight - reinforced soil</td>
<td>0.0</td>
<td>-2.32</td>
<td>2138.1</td>
<td>4.08</td>
<td>1.00</td>
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<tr>
<td>Active pressure</td>
<td>288.9</td>
<td>-1.50</td>
<td>126.6</td>
<td>5.97</td>
<td>1.00</td>
</tr>
<tr>
<td>Roadway Surcharge</td>
<td>197.5</td>
<td>-2.25</td>
<td>86.6</td>
<td>5.97</td>
<td>1.00</td>
</tr>
<tr>
<td>Weight - wall</td>
<td>0.0</td>
<td>-2.08</td>
<td>1164.2</td>
<td>1.27</td>
<td>1.00</td>
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</tbody>
</table>

Verification of complete wall
Place of verification: bottom of blocks

Check for overturning stability
Resisting moment $M_{\text{res}} = 11482.2$ lb*ft/ft
Overturning moment $M_{\text{ov}} = 877.7$ lb*ft/ft

Safety factor $= 13.08 > 1.50$
Wall for overturning is SATISFACTORY

Check for slip
Resisting horizontal force $H_{\text{res}} = 2300.67$ lb/ft
Active horizontal force $H_{\text{act}} = 486.37$ lb/ft

Safety factor $= 4.73 > 1.50$
Wall for slip is SATISFACTORY

Overall check - WALL is SATISFACTORY
### Bearing capacity of foundation soil

#### Design load acting at the center of footing bottom

<table>
<thead>
<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-2192.2</td>
<td>2203.63</td>
<td>-776.02</td>
<td>0.000</td>
<td>629.6</td>
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</tbody>
</table>

#### Service load acting at the center of footing bottom

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-2192.2</td>
<td>2203.63</td>
<td>-776.02</td>
</tr>
</tbody>
</table>

### Verification of foundation soil

Place of verification: bottom of leveling pad
Stress in the footing bottom: trapezoid

#### Eccentricity verification

Max. eccentricity of normal force $e = 0.000$
Maximum allowable eccentricity $e_{aw} = 0.333$

**Eccentricity of the normal force is SATISFACTORY**

#### Verification of bearing capacity

Max. stress at footing bottom $\sigma = 629.6$ psf
Bearing capacity of foundation soil $R_d = 2000.0$ psf
Safety factor $= 3.18 > 1.33$

**Bearing capacity of foundation soil is SATISFACTORY**
Overall verification - bearing capacity of found. soil is SATISFACTORY

Verification of slip on georeinforcement No. 1

Forces acting on construction (verification of reinforcement No.: 1)

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Weight - wall</td>
<td>0.0</td>
<td>-2.08</td>
<td>1205.7</td>
<td>-4.06</td>
<td>1.00</td>
</tr>
<tr>
<td>Active pressure</td>
<td>288.9</td>
<td>-1.50</td>
<td>126.6</td>
<td>3.50</td>
<td>1.00</td>
</tr>
<tr>
<td>Roadway Surcharge</td>
<td>197.5</td>
<td>-2.25</td>
<td>86.6</td>
<td>3.50</td>
<td>1.00</td>
</tr>
<tr>
<td>Weight - reinforced soil</td>
<td>0.0</td>
<td>-2.21</td>
<td>2045.7</td>
<td>1.82</td>
<td>1.00</td>
</tr>
<tr>
<td>Roadway Surcharge</td>
<td>0.0</td>
<td>-4.50</td>
<td>1029.2</td>
<td>-2.07</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Verification against slip along geotextile No.: 1

Inclination of slip surface $\theta = 90.00^\circ$
Overall normal force acting on reinforcement $= 3288.03$ lb/ft
Coefficient of reduction of slip along geo-textile $= 0.92$
Resistance along geo-reinforcement $= 2151.84$ lb/ft
Wall resistance $= 696.14$ lb/ft
Overall bearing capacity of reinforcements $= 0.00$ lb/ft

Check for slip:
Resisting horizontal force $H_{\text{res}} = 2847.97$ lb/ft
Active horiz. force $H_{\text{act}} = 486.37$ lb/ft
Factor of safety $= 5.86 > 1.50$

Slip along geotextile is SATISFACTORY
Calculation of internal stability No. 1

Calculated forces and strength of reinforcements

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>$F_x$</th>
<th>Depth</th>
<th>$R_t$</th>
<th>Utiliz.</th>
<th>$T_p$</th>
<th>Utiliz.</th>
<th>$R_{con}$</th>
<th>Utiliz.</th>
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</thead>
<tbody>
<tr>
<td>1</td>
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<td>517.34</td>
<td>32.39</td>
<td>391.41</td>
<td>42.81</td>
<td>543.57</td>
<td>30.83</td>
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<td>Miragrid 5XT</td>
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<td>3.00</td>
<td>1034.67</td>
<td>24.71</td>
<td>413.82</td>
<td>61.79</td>
<td>1087.13</td>
<td>23.52</td>
</tr>
</tbody>
</table>

Check for tensile strength (reinforcement No.1)

Tension strength $R_t = 517.34$ lbf/ft

Force in reinforcement $F_x = 111.71$ lbf/ft

Safety factor $= 4.63 > 1.50$

Reinforcement for tensile strength is SATISFACTORY

Check for pull out resistance (reinforcement No.2)

Pull out resistance $T_p = 413.82$ lbf/ft

Force in reinforcement $F_x = 170.46$ lbf/ft

Safety factor $= 2.43 > 1.50$

Reinforcement for pull out resistance is SATISFACTORY

Verification of connection strength (reinforcement No.1)

Connection strength $R_{con} = 543.57$ lbf/ft

Force in reinforcement $F_x = 111.71$ lbf/ft

Safety factor $= 4.87 > 1.50$

Connection strength is SATISFACTORY

Overall verification - reinforcement is SATISFACTORY
3’-0” Tall Wall – Seismic Case
Analysis of Redi Rock wall

Input data

Project
Task: MSE Wall Design
Part: 3.0’ MSE Wall - Seismic Case - Unreinforced Soil
Author: NRW
Date: 11/25/2019
Project number: 1801-0336

Settings
(Input for current task)

Materials and standards
AASHTO - reduce parameters of friction soil/soil by 2/3 φ

Wall analysis
Active earth pressure calculation: Coulomb
Passive earth pressure calculation: Mazinndani (Rankine)
Earthquake analysis: Mononobe-Okabe
Shape of earth wedge: Calculate as skew
Allowable eccentricity: 0.333
Internal stability: Standard - straight slip surface
Reduction coeff. of contact first block - base: 1.00
Verification methodology: Safety factors (ASD)

<table>
<thead>
<tr>
<th>Safety factors</th>
<th>Seismic design situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety factor for overturning:</td>
<td>SF₀ = 1.10 [-]</td>
</tr>
<tr>
<td>Safety factor for sliding resistance:</td>
<td>SFₛ = 1.10 [-]</td>
</tr>
<tr>
<td>Safety factor for bearing capacity:</td>
<td>SFᵦ = 1.00 [-]</td>
</tr>
<tr>
<td>Safety factor for sliding along geo-reinforcement:</td>
<td>SFₛᵦ = 1.10 [-]</td>
</tr>
<tr>
<td>Safety factor for geo-reinforcement strength:</td>
<td>SFₛᵦ₊ = 1.10 [-]</td>
</tr>
<tr>
<td>Safety factor for pull out resistance of geo-reinf.:</td>
<td>SFₛᵦₑ = 1.10 [-]</td>
</tr>
<tr>
<td>Safety factor for connection strength:</td>
<td>SFᵦₑᵦ = 1.10 [-]</td>
</tr>
</tbody>
</table>

Geometry

<table>
<thead>
<tr>
<th>No. group, Description</th>
<th>Count</th>
<th>Setback s [ft]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Block 28</td>
<td>1</td>
<td>1.62</td>
</tr>
<tr>
<td>2 Top block 28</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Base

Geometry
Upper setback \( a₁ = 0.50 \) ft
Lower setback \( a₂ = 0.50 \) ft
Height \( h = 0.50 \) ft
Width \( b = 3.50 \) ft

Material
Unreinforced Footing
Concrete self-weight \( \gamma = 150.00 \) pcf
Shear cub (key) capacity = 0.00 lb/ft
Friction angle concrete-concrete = 30.00 °
Basic soil parameters

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Pattern</th>
<th>$\Phi_{ef}$ [°]</th>
<th>$C_{ef}$ [psf]</th>
<th>$\gamma$ [pcf]</th>
<th>$\gamma_{sat}$ [pcf]</th>
<th>$\delta$ [°]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Gravel Backfill</td>
<td></td>
<td>35.50</td>
<td>0.0</td>
<td>130.0</td>
<td>67.50</td>
<td>34.00</td>
</tr>
</tbody>
</table>

All soils are considered as cohesionless for at rest pressure analysis.

Soil parameters

Gravel Backfill
- Unit weight: $\gamma = 130.0$ pcf
- Stress-state: effective
- Angle of internal friction: $\Phi_{ef} = 35.50$ °
- Cohesion of soil: $C_{ef} = 0.0$ psf
- Angle of friction struct.-soil: $\delta = 34.00$ °
- Saturated unit weight: $\gamma_{sat} = 130.0$ pcf

Backfill
Backfill is not considered.

Input surface surcharges

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
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<td>1</td>
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<td>variable</td>
<td>200.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>on terrain</td>
</tr>
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</table>

Resistance on front face of the structure
Resistance on front face of the structure is not considered.

Earthquake
- Factor of horizontal acceleration $K_h = 0.1620$
- Factor of vertical acceleration $K_v = 0.0000$

Water below the GWT is free.
Specific gravity of soil particles $G_s = 2.08$.

Settings of the stage of construction
Design situation: seismic

Verification No. 1
Forces acting on construction

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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<tbody>
<tr>
<td>Weight - wall</td>
<td>0.0</td>
<td>-1.48</td>
<td>10.106</td>
<td>1.73</td>
<td>1.000</td>
</tr>
<tr>
<td>Earthq. constr.</td>
<td>164.4</td>
<td>-1.49</td>
<td>0.0</td>
<td>1.72</td>
<td>1.000</td>
</tr>
<tr>
<td>Weight - earth wedge</td>
<td>0.0</td>
<td>-0.87</td>
<td>47.7</td>
<td>3.09</td>
<td>1.000</td>
</tr>
<tr>
<td>Earthq. - soil wedge</td>
<td>120.5</td>
<td>-0.87</td>
<td>0.0</td>
<td>3.09</td>
<td>1.000</td>
</tr>
</tbody>
</table>
MSE Wall Design
3.0' MSE Wall - Seismic Case - Unreinforced Soil

<table>
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</tr>
</thead>
<tbody>
<tr>
<td>Weight - earth wedge</td>
<td>0.0</td>
<td>-3.29</td>
<td>96.0</td>
<td>1.96</td>
<td>1.000</td>
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<tr>
<td>Earthquake - soil wedge</td>
<td>15.9</td>
<td>-3.29</td>
<td>0.0</td>
<td>1.96</td>
<td>1.000</td>
</tr>
<tr>
<td>Active pressure</td>
<td>204.8</td>
<td>-1.14</td>
<td>202.3</td>
<td>3.23</td>
<td>1.000</td>
</tr>
<tr>
<td>Earthq. - act pressure</td>
<td>81.5</td>
<td>-2.33</td>
<td>73.7</td>
<td>2.99</td>
<td>1.000</td>
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<tr>
<td>Roadway Surcharge</td>
<td>178.1</td>
<td>-1.73</td>
<td>173.8</td>
<td>3.12</td>
<td>1.000</td>
</tr>
</tbody>
</table>

**Verification of complete wall**

**Check for overturning stability**
- Resisting moment $M_{res} = 3505.9$ lb/ft\(3\)
- Overturning moment $M_{out} = 1035.5$ lb/ft\(3\)

Safety factor = $3.39 > 1.10$

Wall for overturning is SATISFACTORY

**Check for slip**
- Resisting horizontal force $H_{res} = 1145.72$ lb/ft\(3\)
- Active horizontal force $H_{act} = 652.43$ lb/ft\(3\)

Safety factor = $1.76 > 1.10$

Wall for slip is SATISFACTORY

**Overall check - WALL is SATISFACTORY**
Dimensioning No. 1
Forces acting on construction

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Weight - wall</td>
<td>0.0</td>
<td>-1.41</td>
<td>748.1</td>
<td>1.23</td>
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<tr>
<td>Earthq. - constr.</td>
<td>128.7</td>
<td>-1.33</td>
<td>98.0</td>
<td>1.46</td>
<td>1.000</td>
</tr>
<tr>
<td>Weight - earth wedge</td>
<td>0.0</td>
<td>-2.79</td>
<td>98.0</td>
<td>1.46</td>
<td>1.000</td>
</tr>
<tr>
<td>Earthquake - soil wedge</td>
<td>15.9</td>
<td>-2.79</td>
<td>98.0</td>
<td>1.46</td>
<td>1.000</td>
</tr>
<tr>
<td>Active pressure</td>
<td>110.5</td>
<td>-1.05</td>
<td>66.7</td>
<td>2.41</td>
<td>1.000</td>
</tr>
<tr>
<td>Earthq. - act. pressure</td>
<td>58.8</td>
<td>-2.03</td>
<td>47.0</td>
<td>2.41</td>
<td>1.000</td>
</tr>
<tr>
<td>Roadway Surcharge</td>
<td>125.5</td>
<td>-1.65</td>
<td>93.2</td>
<td>2.41</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Verification of block No. 1
Check for overturning stability
Resisting moment \( M_{\text{res}} \) = 1559.2 lbf-ft
Overturning moment \( M_{\text{dry}} \) = 656.9 lbf-ft
Safety factor = 2.37 > 1.10
Joint for overturning stability is SATISFACTORY

Check for slip
Resisting horizontal force \( H_{\text{res}} \) = 608.01 lbf-ft
Active horizontal force \( H_{\text{act}} \) = 439.32 lbf-ft
Safety factor = 1.38 > 1.10
Joint for verification is SATISFACTORY

Bearing capacity of foundation soil
Design load acting at the center of footing bottom

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>340.5</td>
<td>1606.24</td>
<td>652.43</td>
<td>0.061</td>
<td>522.2</td>
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</table>

Service load acting at the center of footing bottom

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>340.5</td>
<td>1606.24</td>
<td>652.43</td>
</tr>
</tbody>
</table>

Verification of foundation soil
Stress in the footing bottom: trapezoid

Eccentricity verification
Max. eccentricity of normal force \( e \) = 0.061
Maximum allowable eccentricity \( e_{\text{allow}} \) = 0.333
Eccentricity of the normal force is SATISFACTORY

Verification of bearing capacity
Max. stress at footing bottom \( \sigma \) = 625.7 psf
Bearing capacity of foundation soil $R_d = 2000.0$ psf

Safety factor = 3.20 > 1.00

Bearing capacity of foundation soil is SATISFACTORY

Overall verification - bearing capacity of found. soil is SATISFACTORY
3'-0" Tall Wall – Transient Case
Analysis of Redi Rock wall

Input data

Project:
Task: MSE Wall Design
Part: 3.0' MSE Wall - Transient Case - Unreinforced Soil
Author: NRW
Date: 11/25/2019
Project number: 1801-0336

Settings
(Input for current task)

Materials and standards
AASHTO - reduce parameters of friction soil/soil by 2/3 φ

Wall analysis
Active earth pressure calculation: Coulomb
Passive earth pressure calculation: Mazinrad (Rankine)
Earthquake analysis: Mononobe-Okabe
Shape of earth wedge: Calculate as skew
Allowable eccentricity: 0.333
Internal stability: Standard - straight slip surface
Reduction coeff. of contact first block - base: 1.00
Verification methodology: Safety factors (ASD)

<table>
<thead>
<tr>
<th>Safety factors</th>
<th>SFα</th>
<th>SFφ</th>
<th>SFβ</th>
<th>SFγ</th>
<th>SFσ</th>
<th>SFφr</th>
<th>SFσr</th>
<th>SFσo</th>
<th>SFσn</th>
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</thead>
<tbody>
<tr>
<td>Safety factor for overturning:</td>
<td>SFo = 1.50 [-]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safety factor for sliding resistance:</td>
<td>SFs = 1.50 [-]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safety factor for bearing capacity:</td>
<td>SFβ = 1.33 [-]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safety factor for sliding along geo-reinforcement:</td>
<td>SFφr = 1.50 [-]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safety factor for geo-reinforcement strength:</td>
<td>SFσr = 1.50 [-]</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Safety factor for pull out resistance of geo-reinforcement:</td>
<td>SFσo = 1.50 [-]</td>
<td></td>
<td></td>
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<tr>
<td>Safety factor for connection strength:</td>
<td>SFσn = 1.50 [-]</td>
<td></td>
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</tbody>
</table>

Geometry

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
<th>Count</th>
<th>Setback s [ft]</th>
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<tbody>
<tr>
<td>1</td>
<td>Block 28</td>
<td>1</td>
<td>1.62</td>
</tr>
<tr>
<td>2</td>
<td>Top block 28</td>
<td>1</td>
<td>-</td>
</tr>
</tbody>
</table>

Base

Geometry
Upper setback a1 = 0.50 ft
Lower setback a2 = 0.50 ft
Height h = 0.50 ft
Width b = 3.50 ft

Material
Unreinforced footing
Concrete self-weight γ = 150.00 pcf
Shear cub (key) capacity c = 0.00 lb/ft
Friction angle concrete-concrete = 30.00°
## Basic soil parameters

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Pattern</th>
<th>( \varphi_{ef} ) (^{\circ})</th>
<th>( c_{ef} ) [psf]</th>
<th>( \gamma ) [pcf]</th>
<th>( \gamma_{su} ) [pcf]</th>
<th>( \delta ) (^{\circ})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Gravel Backfill</td>
<td><img src="image" alt="Pattern" /></td>
<td>35.50</td>
<td>0.0</td>
<td>130.00</td>
<td>67.50</td>
<td>34.00</td>
</tr>
</tbody>
</table>

All soils are considered as cohesionless for at rest pressure analysis.

## Soil parameters

### Gravel Backfill
- Unit weight: \( \gamma = 130.0 \text{ pcf} \)
- Stress-state: effective
- Angle of internal friction: \( \varphi_{ef} = 35.50 \, ^{\circ} \)
- Cohesion of soil: \( c_{ef} = 0.0 \text{ psf} \)
- Angle of friction struct.-soil: \( \delta = 34.00 \, ^{\circ} \)
- Saturated unit weight: \( \gamma_{sat} = 130.0 \text{ pcf} \)

### Backfill
Backfill is not considered.

## Input surface surcharges

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yes</td>
<td>variable</td>
<td>200.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>on terrain</td>
</tr>
</tbody>
</table>

### Resistance on front face of the structure
Resistance on front face of the structure is not considered.

## Settings of the stage of construction
Design situation: transient

### Verification No. 1

#### Forces acting on construction

<table>
<thead>
<tr>
<th>Name</th>
<th>( F_{hor} ) [lbf/ft]</th>
<th>( App.Pt. z ) [ft]</th>
<th>( F_{vert} ) [lbf/ft]</th>
<th>( App.Pt. x ) [ft]</th>
<th>Design coefficient</th>
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</thead>
<tbody>
<tr>
<td>Weight - wall</td>
<td>0.0</td>
<td>-1.48</td>
<td>1010.6</td>
<td>1.73</td>
<td>1.000</td>
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<tr>
<td>Weight - earth wedge</td>
<td>0.0</td>
<td>-0.87</td>
<td>47.7</td>
<td>3.09</td>
<td>1.000</td>
</tr>
<tr>
<td>Weight - earth wedge</td>
<td>0.0</td>
<td>-3.29</td>
<td>98.0</td>
<td>1.96</td>
<td>1.000</td>
</tr>
<tr>
<td>Active pressure</td>
<td>204.8</td>
<td>-1.14</td>
<td>202.3</td>
<td>3.32</td>
<td>1.000</td>
</tr>
<tr>
<td>Roadway Surcharge</td>
<td>178.1</td>
<td>-1.73</td>
<td>173.8</td>
<td>3.12</td>
<td>1.000</td>
</tr>
</tbody>
</table>

### Verification of complete wall

#### Check for overturning stability
- Resisting moment: \( M_{res} = 3285.1 \text{ lbf/ft} \)
- Overturning moment: \( M_{out} = 542.2 \text{ lbf/ft} \)
Safety factor = 6.06 > 1.50
Wall for overturning is SATISFACTORY

Check for slip
Resisting horizontal force $H_{res} = 1093.12$ lb/ft
Active horizontal force $H_{act} = 382.83$ lb/ft

Safety factor = 2.85 > 1.50
Wall for slip is SATISFACTORY

Overall check - WALL is SATISFACTORY

Dimensioning No. 1

<table>
<thead>
<tr>
<th></th>
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<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight - wall</td>
<td>0.00</td>
<td>-1.41</td>
<td>748.1</td>
<td>1.23</td>
<td>1.000</td>
</tr>
<tr>
<td>Weight - earth wedge</td>
<td>0.00</td>
<td>-2.79</td>
<td>98.0</td>
<td>1.46</td>
<td>1.000</td>
</tr>
<tr>
<td>Active pressure</td>
<td>110.5</td>
<td>-1.05</td>
<td>66.7</td>
<td>2.41</td>
<td>1.000</td>
</tr>
<tr>
<td>Roadway Surcharge</td>
<td>125.5</td>
<td>-1.65</td>
<td>93.2</td>
<td>2.41</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Verification of block No. 1

Check for overturning stability
Resisting moment $M_{res} = 1445.7$ lbf/ft
Overturning moment \( M_{\text{ovf}} = 322.6 \ \text{lbft/ft} \)

Safety factor = 4.48 > 1.50

**Joint for overturning stability is SATISFACTORY**

**Check for slip**

Resisting horizontal force \( H_{\text{res}} = 580.85 \ \text{lbft/ft} \)
Active horizontal force \( H_{\text{act}} = 236.02 \ \text{lbft/ft} \)

Safety factor = 2.46 > 1.50

**Joint for verification is SATISFACTORY**

**Bearing capacity of foundation soil**

**Design load acting at the center of footing bottom**

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>-61.0</td>
<td>1532.50</td>
<td>382.93</td>
<td>0.000</td>
<td>437.9</td>
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</tbody>
</table>

**Service load acting at the center of footing bottom**

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-61.0</td>
<td>1532.50</td>
<td>382.93</td>
</tr>
</tbody>
</table>

**Verification of foundation soil**

Stress in the footing bottom: trapezoid

**Eccentricity verification**

Max. eccentricity of normal force \( e = 0.000 \)
Maximum allowable eccentricity \( e_{\text{allow}} = 0.333 \)

**Eccentricity of the normal force is SATISFACTORY**

**Verification of bearing capacity**

Max. stress at footing bottom \( \sigma = 437.9 \ \text{psf} \)
Bearing capacity of foundation soil \( R_d = 2000.0 \ \text{psf} \)

Safety factor = 4.57 > 1.33

**Bearing capacity of foundation soil is SATISFACTORY**

**Overall verification - bearing capacity of found. soil is SATISFACTORY**
Appendix B – CIP Cantilever Wall Design
6'-0” Tall Wall
Peterson Structural Engineers, Inc.
www.psengineers.com

Project Name/Number : 1801-0336-02
Title : Garden Curves
Design : NRW
Sheet : B3

Soil Data
- Allow Soil Bearing = 2,000.0 psf
- Equivalent Fluid Pressure Method =
  - Active Heel Pressure = 35.0 psf/ft
- Passive Pressure = 0.0 psf/ft
- Soil Density, Heel = 130.00 psf
- Soil Density, Toe = 110.00 psf
- Footing/Soil Friction = 0.40
- Soil height to ignore for passive pressure = 0.00 in

Surcharge Loads
- Surcharge Over Heel = 0.0 psf
- Used To Resist Sliding & Overturning =
- Surcharge Over Toe = 0.0
- Used For Sliding & Overturning =

Axial Load Applied to Stem
- Axial Dead Load = 0.0 lbs
- Axial Live Load = 0.0 lbs
- Axial Load Eccentricity = 0.0 in

Earth Pressure Seismic Load
- Method : Triangular
- Load at bottom of Triangular Distribution = 48,000 psf
- Total Strength-Level Seismic Load = 156,000 lbs
- Total Service-Level Seismic Load = 117,000 lbs

Design Summary
- Wall Stability Ratios
  - Overturning = 4.71 OK
  - Sliding = 1.56 OK
- Total Bearing Load = 5,893 lbs
- ...resultant ecc.
- Soil Pressure @ Toe = 907 psf
- Soil Pressure @ Heel = 907 psf
- Allowable = 2,000 psf
- Soil Pressure Less Than Allowable
- ACI Factored @ Toe = 1,086 psf
- ACI Factored @ Heel = 1,086 psf
- Footing Shear @ Toe = 9.6 psi
- Footing Shear @ Heel = 5.7 psi
- Allowable = 9.4 psi
- Sliding Calc
- Lateral Sliding Force = 1,509.0 lbs
- less 100% Passive Force = 0.0 lbs
- less 100% Friction Force = 2,357.3 lbs
- Added Force Req'd = 0.0 lbs
- ...for 1.5 Stability = 0.0 lbs

Vertical component of active lateral soil pressure is considered in the calculation of soil bearing pressures.

Load Factors
- Building Code = IBC 2015, ACI
- Dead Load = 1.200
- Live Load = 1.600
- Earth, H = 1.600
- Wind, W = 1.200
- Seismic, E = 1.000

Concrete Data
- f'c = psi = 4,000.0
- f' = psi = 60,000.0

Masonry Data
- f'm = psi = 3,200
- f's = psi = 3,200
- Solid Grouting
- Modular Ratio 'n' =
- Wall Weight = psf = 100.0
- Short Term Factor =
- Eqv. Solid Thick =
- Masonry Block Type = Medium Weight
- Masonry Design Method = ASD

Stem Construction
- Design Height Above Fg = 1.00
- Wall Material Above "H" = Concrete
- Design Method = LRFD
- Thickness = 6.00
- Rebar Size = # 5
- Rebar Spacing = 12.00
- Rebar Placed at = 6 in
- Design Data
  - f's/f' = 0.260
  - Total Force @ Section
    - Service Level = lbs = 1,131.4
  - Moment...Actual
    - Service Level = ft-lb = 2,262.9
    - Moment...Allowable = 8,051.1
  - Shear...Actual
    - Service Level = psi = 15.7
    - Shear...Allowable = 94.9
  - Axial (Masonry) = in
    - Rebar Depth 'd' = 6.00
  - Concrete Data
    - f'c = psi = 4,000.0
    - f' = psi = 60,000.0

Adjacent Footing Load
- Adjacent Footing Load = 0.0 lbs
- Footing Width = 0.0 ft
- Eccentricity = 0.0 in
- Wall to Fg CL Dist = 0.0 ft
- Forcing Type = Line Load
- Base Above/Below Soil = 0.0 ft
- At Back of Wall
- Poisson's Ratio = 0.300

Cantilevered Retaining Wall

Code: IBC 2015, ACI 318-14, ACI 530-13

Concrete Stem Rebar Area Details

<table>
<thead>
<tr>
<th>Concrete Stem Rebar Area Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical Reinforcing</td>
</tr>
<tr>
<td>As (based on applied moment)</td>
</tr>
<tr>
<td>(4/3) * As</td>
</tr>
<tr>
<td>2000 * Ax * 16000</td>
</tr>
<tr>
<td>0.0018 * Ax * 0.0018 * 12 * 8</td>
</tr>
<tr>
<td>#4 @ 12.50 in</td>
</tr>
<tr>
<td>#5 @ 19.38 in</td>
</tr>
<tr>
<td>#6 @ 27.50 in</td>
</tr>
</tbody>
</table>

Horizontal Reinforcing

| Required Area:                  | 0.1728 in²/ft |
| Provided Area:                  | 0.31 in²/ft |
| Maximum Area:                   | 1.3005 in²/ft |

Footing Data

<table>
<thead>
<tr>
<th>Footing Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toe Width</td>
</tr>
<tr>
<td>Heel Width</td>
</tr>
<tr>
<td>Total Footing Width</td>
</tr>
<tr>
<td>Footing Thickness</td>
</tr>
<tr>
<td>Key Width</td>
</tr>
<tr>
<td>Key Depth</td>
</tr>
<tr>
<td>Key Distance from Toe</td>
</tr>
<tr>
<td>Fc</td>
</tr>
<tr>
<td>Fy</td>
</tr>
<tr>
<td>Factored Pressure</td>
</tr>
<tr>
<td>Mu: Upward</td>
</tr>
<tr>
<td>Mu: Downward</td>
</tr>
<tr>
<td>Mu: Design</td>
</tr>
<tr>
<td>Actual 1-Way Shear</td>
</tr>
<tr>
<td>Allow 1-Way Shear</td>
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<tr>
<td>Toe Reinforcing</td>
</tr>
<tr>
<td>Heel Reinforcing</td>
</tr>
<tr>
<td>Min. As %</td>
</tr>
<tr>
<td>Cover @ Top</td>
</tr>
<tr>
<td>Cover @ Btm.</td>
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Footing Design Results

<table>
<thead>
<tr>
<th>Footing Design Results</th>
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<tbody>
<tr>
<td>Toe Heel</td>
</tr>
<tr>
<td>Factored Pressure</td>
</tr>
<tr>
<td>Mu: Upward</td>
</tr>
<tr>
<td>Mu: Downward</td>
</tr>
<tr>
<td>Mu: Design</td>
</tr>
<tr>
<td>Actual 1-Way Shear</td>
</tr>
<tr>
<td>Allow 1-Way Shear</td>
</tr>
<tr>
<td>Toe Reinforcing</td>
</tr>
<tr>
<td>Heel Reinforcing</td>
</tr>
<tr>
<td>Min. As %</td>
</tr>
<tr>
<td>Cover @ Top</td>
</tr>
<tr>
<td>Cover @ Btm.</td>
</tr>
</tbody>
</table>

If tension exceeds allowable, provide supplemental design for footing tension.

Other Acceptable Sites & Spacings

| Toe: #4 @ 9.25 in, #5 @ 14.34 in, #6 @ 20.36 in, #7 @ 27.77 in, #8 @ 36.56 in, #9 @ 46 in |
| Heel: Not req'd: Mu < phi * 5 * lambda * sqrt(f'c') * Sm |
| Min footing T&S rein Area 1.68 in² |
| Min footing T&S rein Area per foot 0.26 in²/ft |
| If one layer of horizontal bars: #4 @ 9.26 in, #5 @ 14.35 in, #6 @ 20.37 in |
| If two layers of horizontal bars: #4 @ 9.26 in, #4 @ 18.52 in, #5 @ 14.35 in, #6 @ 20.37 in |
**Summary of Overturning & Resisting Forces & Moments**

<table>
<thead>
<tr>
<th>Item</th>
<th>Force</th>
<th>Distance</th>
<th>Moment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrostatic Force</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Base Yard Force</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surcharge Over Heel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surcharge Over Toe</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjacent Footing Load</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Load @ Stem Above Soil</td>
<td>117.6</td>
<td>2.33</td>
<td>274.4</td>
</tr>
<tr>
<td>Seismic Earth Load</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1,509.0</td>
<td>0.1 T.M.</td>
<td>4,409.9</td>
</tr>
</tbody>
</table>

Resisting/Overturning Ratio = 4.71
Vertical Loads used for Soil Pressure = 5,893.2 lbs

If seismic is included, the OTM and sliding ratios be 1.1 per section 1807.2.3 of IBC 2009 or IBC 201
Vertical component of active lateral soil pressure IS considered in the calculation of Sliding Resistance.
Vertical component of active lateral soil pressure IS NOT considered in the calculation of Overturning Resistance.

**Horizontal Deflection at Top of Wall due to settlement of soil**

<table>
<thead>
<tr>
<th>Deflection due to wall bending not considered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Spring Reaction Modulus</td>
</tr>
<tr>
<td>Horizontal Def @ Top of Wall (approximate only)</td>
</tr>
</tbody>
</table>

The above calculation is not valid if the heel soil bearing pressure exceeds that of the toe, because the wall would then tend to rotate into the retained soil.
Rebar Lap & Embedment Lengths Information

Stem Design Segment: Bottom
Stem Design Height: 0.00 ft above top of footing

Lap Splice length for #5 bar specified in this stem design segment = 18.50 in
Development length for #5 bar specified in this stem design segment = 14.23 in
Hooked embedment length into footing for #5 bar specified in this stem design segment = 6.00 in
As Provided = 0.3100 in/2/ft
As Required = 0.1728 in/2/ft
4’-6” Tall Wall
Cantilevered Retaining Wall

Criteria
- Retained Height = 4.50 ft
- Wall height above soil = 0.00 ft
- Slope Behind Wall = 2.00
- Height of Soil over Toe = 0.00 in
- Water height over heel = 0.0 ft

Surcharge Loads
- Surcharge Over Heel = 0.0 psf
- Used To Resist Sliding & Overflowing
- Surcharge Over Toe = 0.0

Axial Load Applied to Stem
- Axial Dead Load = 0.0 lbs
- Axial Live Load = 0.0 lbs
- Axial Load Eccentricity = 0.0 in

Earth Pressure Seismic Load
- Method: Triangular
- Load at bottom of Triangular Distribution = 48,000 psf
- Total Strength-Level Seismic Load = 132,000 lbs
- Total Service-Level Seismic Load = 92,400 lbs

Soil Data
- Allow Soil Bearing = 2,000.0 psf
- Equivalent Fluid Pressure Method
- Active Heel Pressure = 35.0 psf/ft
- Passive Pressure = 0.0 psf/ft
- Soil Density, Heel = 130.00pcf
- Soil Density, Toe = 110.00pcf
- Footing/Soil Friction = 0.400
- Soil height to ignore for passive pressure = 0.0 in

Lateral Load Applied to Stem
- Lateral Load = 0.0 kips
- ...Height to Top = 8.00 ft
- ...Height to Bottom = 0.00 ft
- Load Type = Earth (H)
- (Service Level)
- Wind on Exposed Stem = 0.0 psf
- (Strength Level)

Adjacent Footing Load
- Adjacent Footing Load = 0.0 lbs
- Footing Width = 0.0 ft
- Eccentricity = 0.0 in
- Wall to Ftq CL Dist = 0.0 ft
- Foiling Type = Line Load
- Base Above/Below Soil at Back of Wall = 0.0 ft
- Poisson's Ratio = 0.300

Design Summary
- Wall Stability Ratios
  - Overturning = 5.37 OK
  - Sliding = 1.59 OK
- Total Bearing Load = 3,705 lbs
- ...resultant ecc. = 0.00 in
- Soil Pressure @ Toe = 674 psf OK
- Soil Pressure @ Heel = 674 psf OK
- Allowable = 2,000 psf
- Soil Pressure Less Than Allowable
- ACI Factored @ Toe = 813 psf
- ACI Factored @ Heel = 813 psf
- Foiling Shear @ Toe = 6.8 psi OK
- Foiling Shear @ Heel = 4.2 psi OK
- Allowable = 75.0 psi
- Sliding Calc
  - Lateral Sliding Force = 929.6 lbs
  - less 100% Passive Force = 0.0 lbs
  - less 100% Friction Force = 1,482.1 lbs
  - Added Force Req'd = 0.0 lbs OK
  - ...for 1.5 Stability = 0.0 lbs OK

Vertical component of active lateral soil pressure is considered in calculation of soil bearing pressures.

Load Factors
- Building Code = IBC 2015,ACI
- Dead Load = 1.200
- Live Load = 1.600
- Earth, H = 1.600
- Wind, W = 1.000
- Seismic, E = 1.000

Design Construction
- Design Height Above Ftq
- Wall Material Above "H" = Concrete
- Design Method = LRFD
- Thickness = 6.00
- Rebar Spacing = 12.00
- Rebar Placed at = 8 in
- Shear = 124
- Masonry Data
  - fm = 600 psi
  - Fc = 2500 psi
  - fy = 60000 psi

Concrete Data
- Fc = 6000 psi
- fy = 60000 psi

PSE Peterson Structural Engineers, Inc.
www.pseengineers.com

---

Project Name/Number : 1801-0336-02
Project Location: RetainPro (c) 1997-2019, Build 11.18.57.17
Licenses : K84-03569123
License To : PETERSON STRUCTURAL ENGINEERS

---

NRW  3/27/2020

---

B12
### Cantilevered Retaining Wall

**Concrete Stem Rebar Area Details**

<table>
<thead>
<tr>
<th>Bottom Stem</th>
<th>Vertical Reinforcing</th>
<th>Horizontal Reinforcing</th>
</tr>
</thead>
<tbody>
<tr>
<td>As (based on applied moment)</td>
<td>0.0365 in²/ft</td>
<td></td>
</tr>
<tr>
<td>(4/3) * As</td>
<td>0.0513 in²/ft</td>
<td>Min Stem T&amp;S Reinf Area 0.964 in²</td>
</tr>
<tr>
<td>2000 × fy</td>
<td>200(12)(6)/60000</td>
<td>0.24 in²/ft</td>
</tr>
<tr>
<td>0.0018sh</td>
<td>0.0018(12)(8)</td>
<td>0.1728 in²/ft</td>
</tr>
<tr>
<td>Required Area</td>
<td>0.1728 in²</td>
<td>#4@ 12.50 in</td>
</tr>
<tr>
<td>Provided Area</td>
<td>0.31 in²</td>
<td>#5@ 25.00 in</td>
</tr>
<tr>
<td>Maximum Area</td>
<td>0.6126 in²</td>
<td>#6@ 55.00 in</td>
</tr>
</tbody>
</table>

**Footings Data**

| Toe Width | 2.00 ft |
| Heel Width | 3.50 ft |
| Total Footing Width | 5.50 ft |
| Footing Thickness | 12.00 in |
| Key Width | 12.00 in |
| Key Depth | 0.00 in |
| Key Distance from Toe | 2.00 ft |
| Fc | 2,500 psi |
| Fy | 60,000 psi |
| Footing Concrete Density | 150.00 pcf |
| Min. As % | 0.0016 |
| Cover @ Top | 3.00 @ Btm.| 3.00 in |

**Footings Design Results**

<table>
<thead>
<tr>
<th>Toe</th>
<th>Heel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factored Pressure</td>
<td>813</td>
</tr>
<tr>
<td>Mu*: Upward</td>
<td>1,626</td>
</tr>
<tr>
<td>Mu*: Downward</td>
<td>360</td>
</tr>
<tr>
<td>Mu: Design</td>
<td>1,266</td>
</tr>
<tr>
<td>Actual 1-Way Shear</td>
<td>6.81</td>
</tr>
<tr>
<td>Allow 1-Way Shear</td>
<td>40.00</td>
</tr>
<tr>
<td>Toe Reinforcing</td>
<td>#5@ 12.00 in</td>
</tr>
<tr>
<td>Head Reinforcing</td>
<td>#5@ 12.00 in</td>
</tr>
<tr>
<td>Key Reinforcing</td>
<td>#5@ 12.00 in</td>
</tr>
<tr>
<td>Footing Torsion, Tu</td>
<td>0.00 ft-lbs</td>
</tr>
<tr>
<td>Footing Allow. Torsion, phi Tu</td>
<td>0.00 ft-lbs</td>
</tr>
</tbody>
</table>

If torsion exceeds allowable, provide supplemental design for footing torsion.

**Other Acceptable Sites & Spacings**

- Toe: #4@ 9.25 in, #5@ 14.34 in, #6@ 20.36 in, #7@ 27.77 in, #8@ 36.56 in, #9@ 46 in
- Heel: Not req'd: Mu < phi*S*lambda*sqrt(fy/30)*D
- Key: Not req'd: Mu < phi*S*lambda*sqrt(fy/30)*D

Min footing T&S reinf Area: 1.43 in²

- Min footing T&S reinf Area per foot: 0.26 in²/ft
- If one layer of horizontal bars: #4@ 18.52 in
- If two layers of horizontal bars: #5@ 28.70 in
- #6@ 40.74 in
Cantilevered Retaining Wall

Summary of Overturning & Resisting Forces & Moments

<table>
<thead>
<tr>
<th>Item</th>
<th>Force</th>
<th>Distance</th>
<th>Moment</th>
</tr>
</thead>
<tbody>
<tr>
<td>HL Act Pres (ab water tbl)</td>
<td>423.0</td>
<td>1.33</td>
<td>1,930.2</td>
</tr>
<tr>
<td>HL Act Pres (be water tbl)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrostatic Force</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buoyant Force</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surcharge over Heel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surcharge Over Toe</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjacent Footing Load</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Added Lateral Load</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Load @ Stem Above Soil</td>
<td>92.4</td>
<td>1.83</td>
<td>169.4</td>
</tr>
<tr>
<td>Seismic Earth Load</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>929.6</td>
<td><strong>O.T.M.</strong></td>
<td>2,099.6</td>
</tr>
</tbody>
</table>

Resisting/Overturning Ratio = 5.37
Vertical Loads used for Soil Pressure = 3,705.3 lbs

If seismic is included, the O.T.M and sliding ratios
be 1.1 per section 1807.2.3 of IBC 2009 or IBC 201
Vertical component of active lateral soil pressure IS considered in the
calculation of Sliding Resistance.
Vertical component of active lateral soil pressure IS NOT considered in
the calculation of Overturning Resistance.

Tilt

Horizontal Deflection at Top of Wall due to settlement of soil

[Deflection due to wall bending not considered]

Soil Spring Reaction Modulus = 250.0 psi
Horizontal Def @ Top of Wall (approximate only) = 0.000 in

The above calculation is not valid if the heel soil bearing pressure exceeds that of the toe,
because the wall would then tend to rotate into the retained soil.
### Rebar Lap & Embedment Lengths Information

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Stem Design Segment</td>
<td>Bottom</td>
</tr>
<tr>
<td>Stem Design Height</td>
<td>0.00 ft above top of footing</td>
</tr>
<tr>
<td>Lap Splice length for #5 bar specified in this stem design segment</td>
<td>23.40 in</td>
</tr>
<tr>
<td>Development length for #5 bar specified in this stem design segment</td>
<td>18.00 in</td>
</tr>
<tr>
<td>Hooked embedment length into footing for #5 bar specified in this stem design segment</td>
<td>6.00 in</td>
</tr>
<tr>
<td>As Provided</td>
<td>0.3100 in²/ft</td>
</tr>
<tr>
<td>As Required</td>
<td>0.1728 in²/ft</td>
</tr>
</tbody>
</table>
Cantilevered Retaining Wall

- **Hydrostatic Force**
- **Lateral earth pressure due to the soil BELOW water table**
- **Seismic lateral earth pressure**

---

**Project Name/Number:** 1801-0336-02  
**Title:** Garden Curves  
**Design:** NRW  
**Date:** 3/27/2020  
**Sheet:** B17
Cantilevered Retaining Wall

- Designer to determine bar cutoff locations
- Applied Shear Diagram
Cantilevered Retaining Wall

Allowable Moment Lines:

- Concrete
- Masonry

Top of Soil

- 2,610.0 ft-lb
- 3,480.0 ft-lb
- 5,220.0 ft-lb
- 6,960.0 ft-lb
- 7,830.0 ft-lb

Applied Moment Diagram:

- Mu = 0.35 ft-lb
- MnPd = 7,830.0 ft-lb

Project Name/Number: 1801-0336-02
Title: Garden Curves
Date: 12 JUL 2019
Designer: NRW
Sheet: B19
3’-0” Tall Wall
Soil Data
- Allow Soil Bearing = 2,000.0 psf
- Equivalent Fluid Pressure Method =
- Active Heel Pressure = 35.0 psf
- Passive Pressure = 0.0 psf
- Soil Density, Heel = 130.00pcf
- Soil Density, Toe = 110.00pcf
- Footing/Soil Friction = 0.400
- Soil height to ignore for passive pressure = 0.00 in

Lateral Load Applied to Stem
- Lateral Load = 0.0 ft
- Height to Top = 8.00 ft
- Height to Bottom = 8.00 ft
- Load Type = Earth (H)
  - (Service Level)
- Wind on Exposed Stem = 0.0 psf
  - (Strength Level)

Surcharge Loads
- Surcharge Over Heel = 0.0 psf
- Used To Resist Sliding & Overturning =
- Surcharge Over Toe =
- Used For Sliding & Overturning =

Axial Load Applied to Stem
- Axial Dead Load = 0.0 lbs
- Axial Live Load = 0.0 lbs
- Axial Load Eccentricity = 0.0 in

Earth Pressure Seismic Load
- Method: Triangular
- Load at bottom of Triangular Distribution
  - (Strength) = 48,000 psf
- Total Strength-Level Seismic Load = 96,000 lbs
- Total Service-Level Seismic Load = 67,200 lbs

Design Summary
- Wall Stability Ratios
  - Overturning = 7.96 OK
  - Sliding = 1.68 OK
- Total Bearing Load = 2,058 lbs
  - ...resultant ecc. = 11.12 in
- Soil Pressure @ Toe = 907 psf OK
- Soil Pressure @ Heel = 0 psf OK
- Allowable = 2,000 psf
- Soil Pressure Less Than Allowable
  - ACI Factored @ Toe = 1,219 psf
  - ACI Factored @ Heel = 0 psf
- Footing Shear @ Toe = 8.5 psf OK
- Footing Shear @ Heel = 0.0 psf
- Allowable = 75.0 psi
- Sliding Calc
  - Lateral Sliding Force = 490.2 lbs
  - less 100% Passive Force = 0.0 lbs
  - less 100% Friction Force = 823.1 lbs
- Added Force Req'd = 0.0 lbs OK
  - ...for 1.5 Stability = 0.0 lbs OK

Stem Construction
- Design Height Above Flx =
- Wall Material Above "H" = Concrete
- Design Method = LRFD
- Thickness = 6.00
- Rebar Size = # 5
- Rebar Spacing = 12.00
- Rebar Placed at = 8 in
- Design Data
  - fsub/F =
  - Total Force @ Section
    - Service Level lbs =
    - Strength Level lbs = 306.0
    - Moment...Actual
      - Service Level ft-lb =
      - Strength Level ft-lb = 304.0
      - Moment...Allowable = 7,859.7
    - Shear...Actual
      - Service Level psi =
      - Shear...Allowable = 4.3
    - Axial (Masonry) in² =
    - Rebar Depth 'd' in = 6.00
- Masonry Data
  - f'm = psi =
  - FS = psi =
  - Solid Grouting =
  - Modular Ratio 'n' =
- Wall Weight psf = 100.0
- Short Term Factor =
- Equiv. Solid Thick =
- Masonry Block Type = Medium Weight
- Masonry Design Method = ASD
- Concrete Data
  - fs = psi = 2,500.0
  - fy = psi = 60,000.0

Load Factors
- Building Code = IBC 2015,ACI
- Dead Load = 1.20
- Live Load = 1.60
- Earth, H = 1.60
- Wind, W = 1.00
- Seismic, E = 1.00
## Concrete Stem Rebar Area Details

<table>
<thead>
<tr>
<th>As (based on applied moment)</th>
<th>Vertical Reinforcing</th>
<th>Horizontal Reinforcing</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.012 in²/ft</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.016 in²/ft</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.24 in²/ft</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.1728 in²/ft</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Required Area: 0.1728 in²/ft  
Provided Area: 0.31 in²/ft  
Maximum Area: 0.6128 in²/ft

### Footing Data

<table>
<thead>
<tr>
<th>Toe Width</th>
<th>2.00 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heel Width</td>
<td>2.00 ft</td>
</tr>
<tr>
<td>Total Footing Width</td>
<td>4.00 ft</td>
</tr>
<tr>
<td>Footing Thickness</td>
<td>12.00 in</td>
</tr>
<tr>
<td>Key Width</td>
<td>12.00 in</td>
</tr>
<tr>
<td>Key Depth</td>
<td>0.00 in</td>
</tr>
<tr>
<td>Key Distance from Toe</td>
<td>2.00 ft</td>
</tr>
</tbody>
</table>

Ft = 2.500 psi  
Fy = 60,000 psi  
Footing Concrete Density = 150.00pcf  
Min. As % = 0.0018  
Cover @ Top = 3.00  
@ Btm. = 3.00 in

### Footing Design Results

<table>
<thead>
<tr>
<th>Toe</th>
<th>Heel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factored Pressure = 1,269 psi</td>
<td>1,414 ft-lb</td>
</tr>
<tr>
<td>Mu*: Upward = 25,344</td>
<td>14,515 ft-lb</td>
</tr>
<tr>
<td>Mu*: Downward = 4,320</td>
<td>309 ft-lb</td>
</tr>
<tr>
<td>Mu: Design = 760</td>
<td>973 psi</td>
</tr>
<tr>
<td>Actual 1-Way Shear = 40.00</td>
<td>40.00 psi</td>
</tr>
<tr>
<td>Allow 1-Way Shear = 40.00</td>
<td>40.00 psi</td>
</tr>
<tr>
<td>Toe Reinforcing = 5 @ 12.00 in</td>
<td>5 @ 12.00 in</td>
</tr>
<tr>
<td>Head Reinforcing = 5 @ 12.00 in</td>
<td>5 @ 12.00 in</td>
</tr>
<tr>
<td>Key Reinforcing = 5 @ 12.00 in</td>
<td>5 @ 12.00 in</td>
</tr>
<tr>
<td>Footing Torsion, Tu</td>
<td>0.00 ft-lbs</td>
</tr>
<tr>
<td>Footing Allow. Torsion, phi Tu</td>
<td>0.00 ft-lbs</td>
</tr>
</tbody>
</table>

If torsion exceeds allowable, provide supplemental design for footing torsion.

### Other Acceptable Sizes & Spacings

| Toe: Not req'd: Mu < p*5/lambda*sqrt(c)*Sm  |
| Heel: Not req'd: Mu < p*5/lambda*sqrt(c)*Sm  |
| Key: No key defined  |

Min footing T&S rein Area = 1.17 in²  
Min footing T&S rein Area per foot = 0.26 in²/ft  
If one layer of horizontal bars: |  
If two layers of horizontal bars: |
| #4 @ 9.26 in | #4 @ 18.52 in |
| #6 @ 14.35 in | #5 @ 28.70 in |
| #6 @ 20.37 in | #6 @ 40.74 in |
### Cantilevered Retaining Wall

**Code:** IBC 2015, ACI 318-14, ACI 530-13

**Summary of Overturning & Resisting Forces & Moments**

<table>
<thead>
<tr>
<th>Item</th>
<th>Force</th>
<th>Distance</th>
<th>Moment</th>
</tr>
</thead>
<tbody>
<tr>
<td>HL Act Pres (ab water tbl)</td>
<td>423.0</td>
<td>1.33</td>
<td>593.3</td>
</tr>
<tr>
<td>HL Act Pres (be water tbl)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrostatic Force</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buoyant Force</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surcharge over Heel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surcharge Over Toe</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjacent Footing Load</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Added Lateral Load</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Load @ Stem Above Soil</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seismic Earth Load</td>
<td>67.2</td>
<td>1.33</td>
<td>89.6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>490.2</td>
<td><strong>O.T.M.</strong></td>
<td>653.7</td>
</tr>
</tbody>
</table>

**Resisting/Overturning Ratio** = **7.96**

Vertical Loads used for Soil Pressure = 2,057.9 lbs

If seismic is included, the O.T.M. and sliding ratios be 1.1 per section 1807.2.3 of IBC 2009 or IBC 2013

Vertical component of active lateral soil pressure IS considered in the calculation of Sliding Resistance.

Vertical component of active lateral soil pressure IS NOT considered in the calculation of Overturning Resistance.

---

**Tilt**

**Horizontal Deflection at Top of Wall due to settlement of soil**

(Deflection due to wall bending not considered)

- Soil Spring Reaction Modulus: 280.0 pci
- Horizontal Def @ Top of Wall (approximate only): 0.000 in

The above calculation is not valid if the net soil bearing pressure exceeds that of the top, because the wall would then tend to rotate into the retained soil.
Project Name/Number: 1801-0336-02
Title: Garden Curves
Design: NRW
Date: 12 JUL 2019

Wall 5 - CIP Cantilever Wall (3'-0" Tall Segment)

Rebar Lap & Embedment Lengths Information

<table>
<thead>
<tr>
<th>Stem Design Segment: Bottom</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Stem Design Height: 0.00 ft above top of footing</td>
<td>[ \text{Lap Splice length for #5 bar specified in this stem design segment} = 23.40 \text{ in} ]</td>
<td>[ \text{Development length for #5 bar specified in this stem design segment} = 18.00 \text{ in} ]</td>
<td>[ \text{Hooked embedment length into footing for #5 bar specified in this stem design segment} = 6.00 \text{ in} ]</td>
</tr>
<tr>
<td>As Provided</td>
<td>0.3100 in/2/ft</td>
<td>0.00 in</td>
<td></td>
</tr>
<tr>
<td>As Required</td>
<td>0.1728 in/2/ft</td>
<td>0.00 in</td>
<td></td>
</tr>
</tbody>
</table>
Cantilevered Retaining Wall

8" w/ #5 @ 12"

#5@12 in @ Toe
#5@12" @ Heel

2'-0" 2'-6"

3'-10" 3'-0"

3" 3"
Cantilevered Retaining Wall

Code: IBC 2015, ACI 318-14, ACI 530-13

Project Name/Number: 1801-0336-02
Title: Garden Curves
Design: NRW
Date: 12 JUL 2019

This diagram illustrates the forces acting on a cantilevered retaining wall. The following forces are indicated:
- Hydrostatic Force
- Lateral earth pressure due to the soil BELOW water table
- Seismic lateral earth pressure

The diagram shows:
- A retaining wall segment labeled 1 and 2
- Loads applied: Pp= 0.00#, 423#, 67#
- Soil pressure calculations: 900, 520 p.s.i.
Cantilevered Retaining Wall

Wall 1
Concrete
Masonry
Top of Soil

3.00 ft

0.0 ft
30.0 lbs
60.0 lbs
90.0 lbs
120.0 lbs
150.0 lbs
180.0 lbs
210.0 lbs
240.0 lbs
270.0 lbs

Designer to determine bar cutoff locations

Applied Shear Diagram

Project Name/Number: 1801-0336-02
Title: Garden Curves
Design: NRW
Date: 12 JUL 2019

Groundwater Considerations:

- Water table elevation:
- Water table pressure:
- Water table slope:

Assumptions:

- Soils:
- Loadings:
- Material properties:

Calculation:

- Shear forces:
- Bending moments:
- Rebar requirements:

Conclusion:

- Design verification:
- Recommendations: