GROUND
ENGINEERING

December 19, 2022

Subject: Engineering Design, Proposed Lock + Load Retaining Wall, **2119 NW Killarney Lane**, Lee's Summit, Missouri

Job No. 22-3664

Mr. Tim Jordan
Raintree Landscaping, LLC
4072 SW Normandy Dr
Lee's Summit, MO 64082

Dear Mr. Jordan,

This report presents engineering design for the proposed Lock + Load (L+L) wall to be constructed for the residence located at 2119 NW Killarney Lane, Lee's Summit, Missouri. To complete our design work, GROUND was provided with the following documents:

(1) PDF copy of the Construction Stake Plot Plan, prepared by Henley Survey Co., and provided on August 22, 2022.

(2) Apex Engineers, Inc. foundation and recommendations report dated September 20, 2021.

Proposed Construction and Design Assumptions

The proposed project will consist of the construction of one (1) L+L wall in single-tier configuration to support the back yard. The L+L wall will have a maximum exposed wall height of approximately 13 feet. We understand that the proposed L+L walls will be constructed with L+L concrete panel units and counterforts, TenCate Miragrid reinforcement, select granular backfill in the reinforced zone and on-site soil retained zone.

Anticipated Subsurface Condition

Geotechnical information was not available at the time of our design. We anticipate that the wall subgrade and on-site backfill materials will typically consist of lean clay soils. We also assume that groundwater will not impact wall construction or the long-term stability of the wall. The assumed soil parameters used in the retaining wall design are summarized below, **must** be verified prior to and during the wall construction.

The assumed soil parameters below and the assumed groundwater conditions shall be evaluated by the Geotechnical Engineer and shall provide alternate values, if applicable.

Material Type	Unit Weight *(pcf)*	Friction Angle *(degree)*	Cohesion *(psf)*
On-Site Soil (Lean Clay)	120	26	100
Select Granular Fill	135	34	0

Cohesion values above were used in the global stability analysis only. It should be noted that soil strength could be significantly reduced, if the soils become wet. Therefore, surface drainage should be properly constructed and the wall drain should be properly installed in the retaining walls.

Lock+Load Retaining Wall Design

L+L retaining wall design was performed for various design wall heights (including exposed wall height and required toe embedment) of the proposed retaining walls. The design calculations were performed in general accordance with AASHTO ASD 2002 design procedures by using the MSEW+® computer program. Surcharges, representing pedestrian live loads, were included in the calculations.

The L+L wall design calculations evaluated the external stability (including base sliding, overturning, bearing capacity, and base eccentricity), internal stability (including geogrid length, over stress, pullout resistance, and internal sliding), and facing stability (including facing overturning, shear, and connection stress) to determine the required geogrid strengths, number of layers, and reinforcement lengths. Results of the L+L wall design calculations are presented in Appendix A.

Global Stability and Temporary Slope Stability Analyses

Global stability analysis was performed on one (1) critical wall section. The Global stability analysis was performed by using the Slope-W® computer program. The Morgenstern-Price Method was used to calculate the factor of safety. The lowest factor of safety is above the typically accepted minimum value of 1.3. The result of the global stability analysis is presented in Appendix B.

Additional Retaining Wall Recommendations

A properly constructed wall drain system should be included in the retaining wall. Drainage systems in retaining walls are intended to collect and divert water infiltration or natural seepage. Wall drain systems are not intended to handle surface runoff or concentrated water at the top of walls, which should be collected and diverted by properly designed and constructed storm drainage features. The areas surrounding the retaining wall should be carefully graded to provide positive surface drainage away from the wall. Landscape irrigation around retaining wall should be reduced to a minimum throughout

the life of the retaining wall. The wall systems and the surrounding areas must be kept relatively dry at all times during and after the construction to prevent water from infiltrating into the wall systems. In no case shall surface runoff be allowed to enter the wall construction areas, or water be allowed to pond above the wall. Temporary and permanent slopes and other stripped areas shall be adequately protected against erosion. Erosion along the wall and slopes will result in sloughing and could lead to a wall failure.

L+L walls are flexible retention systems, and should be anticipated to move both laterally and vertically after construction. If surface improvements, such as flatworks, sidewalks, curbs and gutters, pavements, fences, guardrails, utility pads, storm features, and manholes are installed near the wall, the anticipated wall movement often results in movement of the nearby surface improvements. Surface runoff infiltrating through joints of these surface improvements into wall backfill can aggravate movements of these surface improvements and the wall. Therefore, surface improvements and storm features should be located away from the wall systems. All of the joints of surface improvements must be properly sealed and maintained throughout the life of the wall systems.

Underground wet utility lines, such as waterlines, storm sewers, sanitary sewers, irrigation lines, and water features installed within or near retaining wall backfill are susceptible to leak due to potential wall movements. Utility line leaks can also induce retaining wall movements and result in wall failures. Therefore, we strongly recommend that wet utility lines be installed away from retaining wall systems. In the event that wet utility lines or water features are installed within or near retaining wall backfill, the bottom of utility trenches or water features shall be properly lined to prevent water from infiltrating into the wall systems.

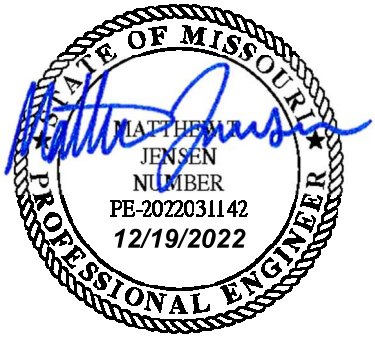
Closure

Based on the provided information, necessary assumptions, results of the retaining wall design calculations, and the nature of the proposed construction, the Drawings including Cover Sheet (Sheet 1), General Notes (Sheets 2), Wall Site Plan (Sheet 3), Wall Elevation (Sheet 4), and Typical Wall Section and Details (Sheets 5 and 6) are included in this submittal. The proposed retaining walls must also be constructed in accordance with the geogrid and panel manufacturers' guidelines, unless otherwise noted on the Drawings.

Retaining wall design provided herein was developed based on the provided information, available geotechnical data, and other necessary assumptions. Actual conditions exposed during construction may be anticipated to differ, somewhat, from those described above. If during construction, surface, soil, bedrock, or groundwater conditions appear to be at variance with those described above, GROUND should be advised at once, so that re-evaluation of the wall design may be made in a timely manner.

The retaining wall design provided herein was prepared exclusively for Raintree Landscaping LLC. The engineering design and Drawings may only be used by Raintree Landscaping LLC and authorized contractors. This wall design and report was prepared in a manner consistent with that degree of care and skill ordinarily exercised by members of the same profession currently practicing under the same or similar circumstances with the same or similar scope of services. No warranty is expressed or implied, and no outcome is guaranteed. GROUND is not responsible for the variations in the actual surface conditions, subsurface conditions, and grades at the site. If you have any questions, please contact our office.

Sincerely,
GROUND Engineering Consultants, Inc.



Matthew Jensen, P.E.

Reviewed by Carl Henderson, P.E.

APPENDIX A

LOCK+LOAD RETAINING WALL DESIGN CALCULATIONS

AASHTO 2002 ASD DESIGN METHOD
2119 NW Killarney Ln

MSEW+: Update # 2022.03

PROJECT IDENTIFICATION

Title: 2119 NW Killarney Ln
Project Number:
Client: Raintree Landscaping LLC
Designer: GROUND
Station Number:

Description:

DH=14.67'

Company's information:

Name: GROUND Engineering Consultants, Inc.
Street: 41 Inverness Drive East

Englewood , CO 80112
Telephone #: 303-289-1989
Fax #:
E-Mail:

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Original date and time of creating this file: Sept 2022

PROGRAM MODE: ANALYSIS
of a SIMPLE STRUCTURE
using GEOGRID as reinforcing material.

SOIL DATA

REINFORCED SOIL

Unit weight,	γ	135.0 lb/ft ^{3}
Design value of internal angle of friction,	ϕ	34.0 °

RETAINED SOIL

Unit weight,	γ	120.0 lb/ft ^{3}
Design value of internal angle of friction,	ϕ	26.0 °

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight,	$\gamma_{equiv.}$	120.0 lb/ft ^{3}
Equivalent internal angle of friction,	$\phi_{equiv.}$	26.0 °
Equivalent cohesion,	$c_{equiv.}$	0.0 lb/ft ^{2}

Water table does not affect bearing capacity

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Inclination of internal slip plane, ψ = 62.00° (see Fig. 28 in DEMO 82).
Ka (external stability) = 0.3905 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

BEARING CAPACITY

Bearing capacity is controlled by general shear.
Bearing capacity factors (calculated by MSEW): Nc = 22.25 N γ= 12.54

SEISMICITY

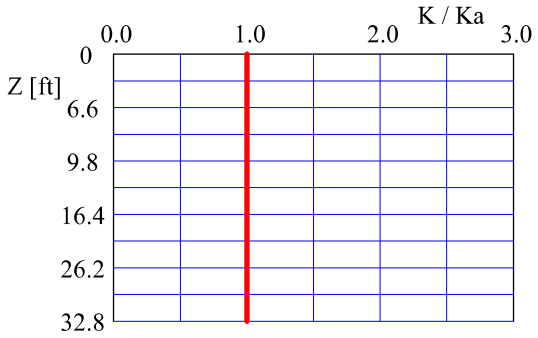
Not Applicable

INPUT DATA: Geogrids (Analysis)

D A T A	Geogrid type #1	Geogrid type #2	Geogrid type #3	Geogrid type #4	Geogrid type #5
Tult [lb/ft]	4700.0				
Durability reduction factor, RFd	1.15				
Installation-damage reduction factor, RFid	1.15				
Creep reduction factor, RFc	1.45	N/A	N/A	N/A	N/A
Fs-overall for strength	N/A				
Coverage ratio, Rc	1.000				
Friction angle along geogrid-soil interface, ρ	24.22				
Pullout resistance factor, F*	0.67·tanϕ	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	0.8				

Variation of Lateral Earth Pressure Coefficient With Depth

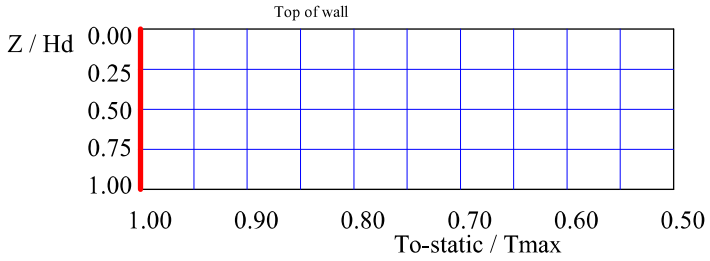
Z	K / Ka
0 ft	1.00
3.3 ft	1.00
6.6 ft	1.00
9.8 ft	1.00
13.1 ft	1.00
16.4 ft	1.00
19.7 ft	1.00



INPUT DATA: Facia and Connection (according to revised Demo 82) (Analysis)

FACIA type: Facing enabling frictional connection of reinforcement (e.g., modular concrete blocks, gabions)
Depth/height of block is 2.50/1.30 ft. Horizontal distance to Center of Gravity of block is: 1.25 ft.
Average unit weight of block is: γ_f = 135.00 lb/ft ^{3}

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



Geogrid Type #1 σ (1)	CRult (2)	Geogrid Type #2 σ	CRult	Geogrid Type #3 σ	CRult	Geogrid Type #4 σ	CRult	Geogrid Type #5 σ	CRult
100.0	0.31								
133.6	0.60	N/A		N/A		N/A		N/A	
217.2	0.76								
275.6	0.90								

Geogrid Type #1 3) σ	CRcr	Geogrid Type #2 σ	CRcr	Geogrid Type #3 σ	CRcr	Geogrid Type #4 σ	CRcr	Geogrid Type #5 σ	CRcr
0.0	0.00								
750.0	0.63	N/A		N/A		N/A		N/A	

(1) σ = Confining stress in between stacked blocks [lb/ft ^{2}]
(2) CRult = Tc-ult / Tult
(3) CRcr = Tcre / Tult

D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	Mira5XT	N/A	N/A	N/A	N/A
Connection strength reduction factor, RFd	1.15	N/A	N/A	N/A	N/A
Creep reduction factor, RFc	N/A	N/A	N/A	N/A	N/A

INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd 14.67 [ft] { Embedded depth is E = 0.00 ft, and height above top of finished bottom grade is H = 14.67 ft }

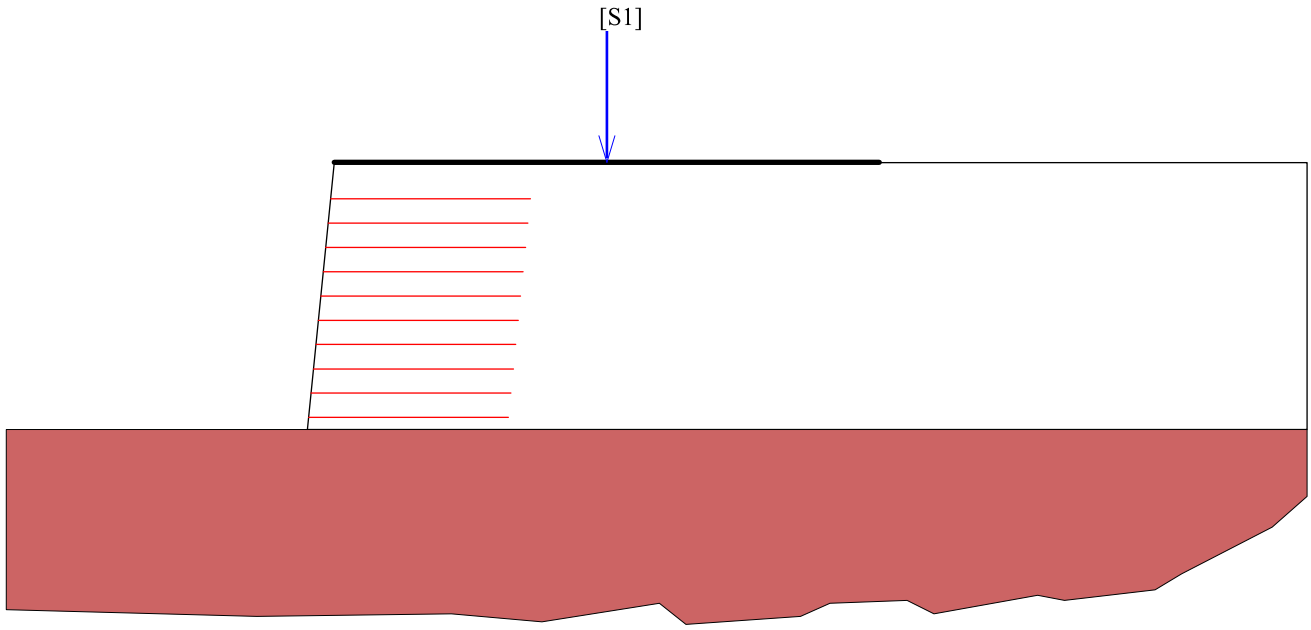
Soil in front of wall is Horizontal.

Batter, ω 5.8 [deg]
Backslope, β 0.0 [deg]
Backslope rise 0.0 [ft] Broken back equivalent angle, I = 0.00° (see Fig. 25 in DEMO 82)

U N I F O R M S U R C H A R G E
Uniformly distributed dead load is 0.0 [lb/ft ²]

OTHER EXTERNAL LOAD(S)
[S1] Strip Load, Qv-d = 0.0 and Qv-l = 100.0 [lb/ft ²].
Footing width, b=30.0 [ft]. Distance of center of footing from wall face, d = 15.0 [ft] @ depth of 0.0 [ft] below soil surface.

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

0 2 4 6 8 10 [ft]

ANALYSIS: CALCULATED FACTORS (Static conditions)

Bearing capacity, Fs = 2.89, Meyerhof stress = 2352 lb/ft².

Foundation Interface: Direct sliding, Fs = 1.789, Eccentricity, e/L = 0.0963, Fs-overturning = 4.13

GEOGRID				CONNECTION						
#	Elevation [ft]	Length [ft]	Type #	Fs-overall [connection strength]	Fs-overall [geogrid strength]	Geogrid strength Fs	Pullout resistance Fs	Direct sliding Fs	Eccentricity e/L	Product name
1	0.67	11.00	1	3.47	3.30	3.299	18.794	1.727	0.0867	Mira5XT
2	2.00	11.00	1	3.83	3.64	3.641	18.416	1.900	0.0693	Mira5XT
3	3.33	11.00	1	4.23	4.03	4.028	17.321	2.108	0.0539	Mira5XT
4	4.67	11.00	1	4.76	4.53	4.530	16.137	2.365	0.0404	Mira5XT
5	6.00	11.00	1	5.45	5.19	5.191	15.012	2.687	0.0290	Mira5XT
6	7.33	11.00	1	6.33	6.03	6.025	13.746	3.103	0.0195	Mira5XT
7	8.67	11.00	1	7.58	7.22	7.218	12.470	3.667	0.0118	Mira5XT
8	10.00	11.00	1	7.97	9.03	9.029	11.182	4.463	0.0061	Mira5XT
9	11.33	11.00	1	7.53	11.93	11.930	9.662	5.678	0.0021	Mira5XT
10	12.67	11.00	1	4.42	11.69	11.693	5.135	7.786	-0.0000	Mira5XT

AASHTO 2002 ASD DESIGN METHOD
2119 NW Killarney Ln

MSEW+: Update # 2022.03

PROJECT IDENTIFICATION

Title: 2119 NW Killarney Ln
Project Number:
Client: Raintree Landscaping LLC
Designer: GROUND
Station Number:

Description:

DH=10.67'

Company's information:

Name: GROUND Engineering Consultants, Inc.
Street: 41 Inverness Drive East

Englewood , CO 80112
Telephone #: 303-289-1989
Fax #:
E-Mail:

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PROGRAM MODE: ANALYSIS
of a SIMPLE STRUCTURE
using GEOGRID as reinforcing material.

SOIL DATA

REINFORCED SOIL

Unit weight,	γ	135.0 lb/ft ^{3}
Design value of internal angle of friction,	ϕ	34.0 °

RETAINED SOIL

Unit weight,	γ	120.0 lb/ft ^{3}
Design value of internal angle of friction,	ϕ	26.0 °

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight,	$\gamma_{equiv.}$	120.0 lb/ft ^{3}
Equivalent internal angle of friction,	$\phi_{equiv.}$	26.0 °
Equivalent cohesion,	$c_{equiv.}$	0.0 lb/ft ^{2}

Water table does not affect bearing capacity

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Inclination of internal slip plane, ψ = 62.00° (see Fig. 28 in DEMO 82).
Ka (external stability) = 0.3905 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

BEARING CAPACITY

Bearing capacity is controlled by general shear.
Bearing capacity factors (calculated by MSEW): Nc = 22.25 N γ= 12.54

SEISMICITY

Not Applicable

INPUT DATA: Geogrids (Analysis)

D A T A	Geogrid type #1	Geogrid type #2	Geogrid type #3	Geogrid type #4	Geogrid type #5
Tult [lb/ft]	4700.0				
Durability reduction factor, RFd	1.15				
Installation-damage reduction factor, RFid	1.15				
Creep reduction factor, RFc	1.45	N/A	N/A	N/A	N/A
Fs-overall for strength	N/A				
Coverage ratio, Rc	1.000				
Friction angle along geogrid-soil interface, ρ	24.22				
Pullout resistance factor, F*	0.67·tanϕ	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	0.8				

Variation of Lateral Earth Pressure Coefficient With Depth

Z	K / Ka
0 ft	1.00
3.3 ft	1.00
6.6 ft	1.00
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13.1 ft	1.00
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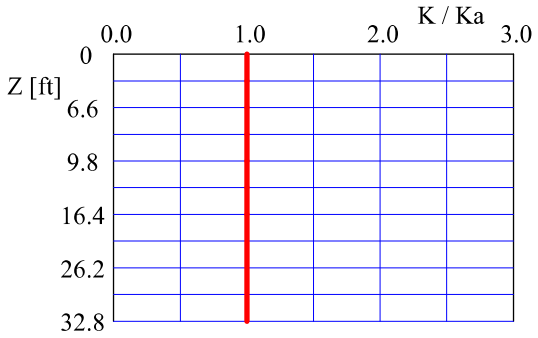

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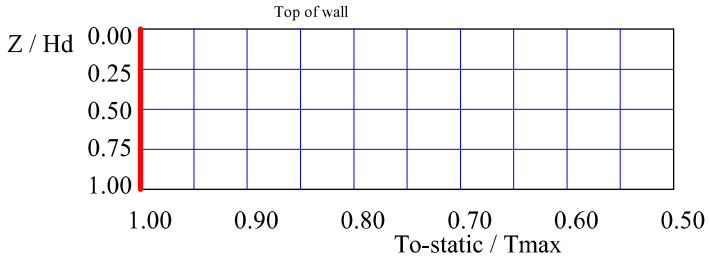
FACIA type: Facing enabling frictional connection of reinforcement (e.g., modular concrete blocks, gabions)
Depth/height of block is 2.50/1.30 ft. Horizontal distance to Center of Gravity of block is: 1.25 ft.
Average unit weight of block is: γ_f = 135.00 lb/ft ^{3}

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



Geogrid Type #1 σ (1)	CRult (2)	Geogrid Type #2 σ	CRult	Geogrid Type #3 σ	CRult	Geogrid Type #4 σ	CRult	Geogrid Type #5 σ	CRult
100.0	0.31								
133.6	0.60	N/A		N/A		N/A		N/A	
217.2	0.76								
275.6	0.90								

Geogrid Type #1 3) σ	CRcr	Geogrid Type #2 σ	CRcr	Geogrid Type #3 σ	CRcr	Geogrid Type #4 σ	CRcr	Geogrid Type #5 σ	CRcr
0.0	0.00								
750.0	0.63	N/A		N/A		N/A		N/A	

(1) σ = Confining stress in between stacked blocks [lb/ft ^{2}]
(2) CRult = Tc-ult / Tult
(3) CRcr = Tcre / Tult

D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	Mira5XT	N/A	N/A	N/A	N/A
Connection strength reduction factor, RFd	1.15	N/A	N/A	N/A	N/A
Creep reduction factor, RFc	N/A	N/A	N/A	N/A	N/A

INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd 10.67 [ft] { Embedded depth is E = 0.00 ft, and height above top of finished bottom grade is H = 10.67 ft }

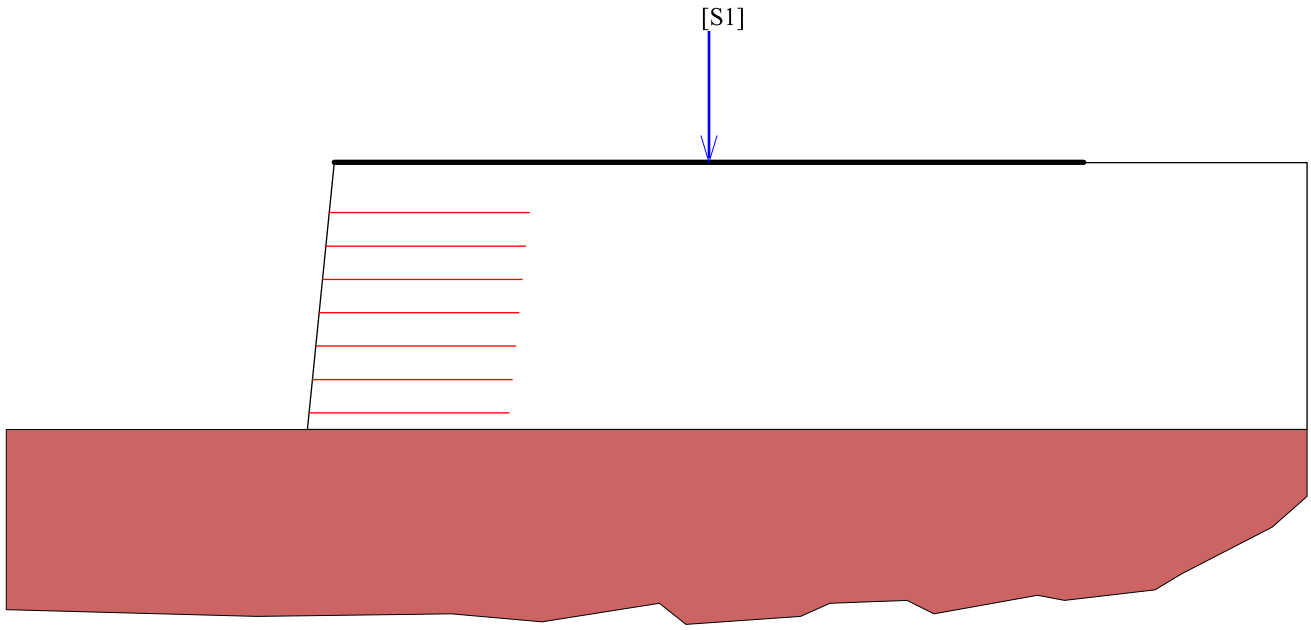
Soil in front of wall is Horizontal.

Batter, ω 5.8 [deg]
Backslope, β 0.0 [deg]
Backslope rise 0.0 [ft] Broken back equivalent angle, I = 0.00° (see Fig. 25 in DEMO 82)

U N I F O R M S U R C H A R G E
Uniformly distributed dead load is 0.0 [lb/ft ²]

OTHER EXTERNAL LOAD(S)
[S1] Strip Load, Qv-d = 0.0 and Qv-l = 100.0 [lb/ft ²].
Footing width, b=30.0 [ft]. Distance of center of footing from wall face, d = 15.0 [ft] @ depth of 0.0 [ft] below soil surface.

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

0 2 4 6 8 10 [ft]

ANALYSIS: CALCULATED FACTORS (Static conditions)

Bearing capacity, Fs = 2.78, Meyerhof stress = 1760 lb/ft².

Foundation Interface: Direct sliding, Fs = 1.721, Eccentricity, e/L = 0.1042, Fs-overturning = 3.89

GEOGRID				CONNECTION						
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2	2.00	8.00	1	5.45	5.19	5.191	12.733	1.920	0.0667	Mira5XT
3	3.33	8.00	1	6.33	6.03	6.025	11.507	2.223	0.0466	Mira5XT
4	4.67	8.00	1	7.58	7.22	7.218	10.278	2.634	0.0301	Mira5XT
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6	7.33	8.00	1	7.53	11.93	11.930	7.649	4.099	0.0081	Mira5XT
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AASHTO 2002 ASD DESIGN METHOD
2119 NW Killarney Ln

MSEW+: Update # 2022.03

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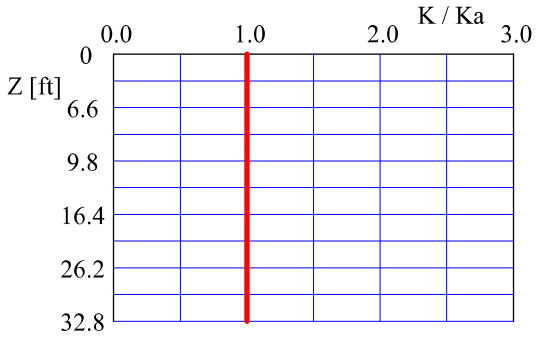
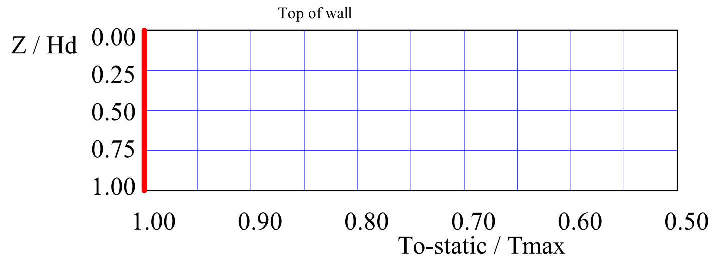


INPUT DATA: Facia and Connection (according to revised Demo 82)
(Analysis)

FACIA type: Facing enabling frictional connection of reinforcement (e.g., modular concrete blocks, gabions)
Depth/height of block is 2.50/1.30 ft. Horizontal distance to Center of Gravity of block is: 1.25 ft.
Average unit weight of block is: γ_f = 135.00 lb/ft ³

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



Geogrid Type #1 σ [1]	CRult [2]	Geogrid Type #2 σ	CRult	Geogrid Type #3 σ	CRult	Geogrid Type #4 σ	CRult	Geogrid Type #5 σ	CRult
100.0	0.31								
133.6	0.60	N/A		N/A		N/A		N/A	
217.2	0.76								
275.6	0.90								

Geogrid Type #1[3)] σ	CRcr	Geogrid Type #2 σ	CRcr	Geogrid Type #3 σ	CRcr	Geogrid Type #4 σ	CRcr	Geogrid Type #5 σ	CRcr
0.0	0.00								
750.0	0.63	N/A		N/A		N/A		N/A	

(1) σ = Confining stress in between stacked blocks [lb/ft ²]
(2) CRult = Tc-ult / Tult
(3) CRcr = Tcre / Tult

D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	Mira5XT	N/A	N/A	N/A	N/A
Connection strength reduction factor, RFd	1.15	N/A	N/A	N/A	N/A
Creep reduction factor, RFc	N/A	N/A	N/A	N/A	N/A

INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd 6.67 [ft] { Embedded depth is E = 0.00 ft, and height above top of finished bottom grade is H = 6.67 ft }

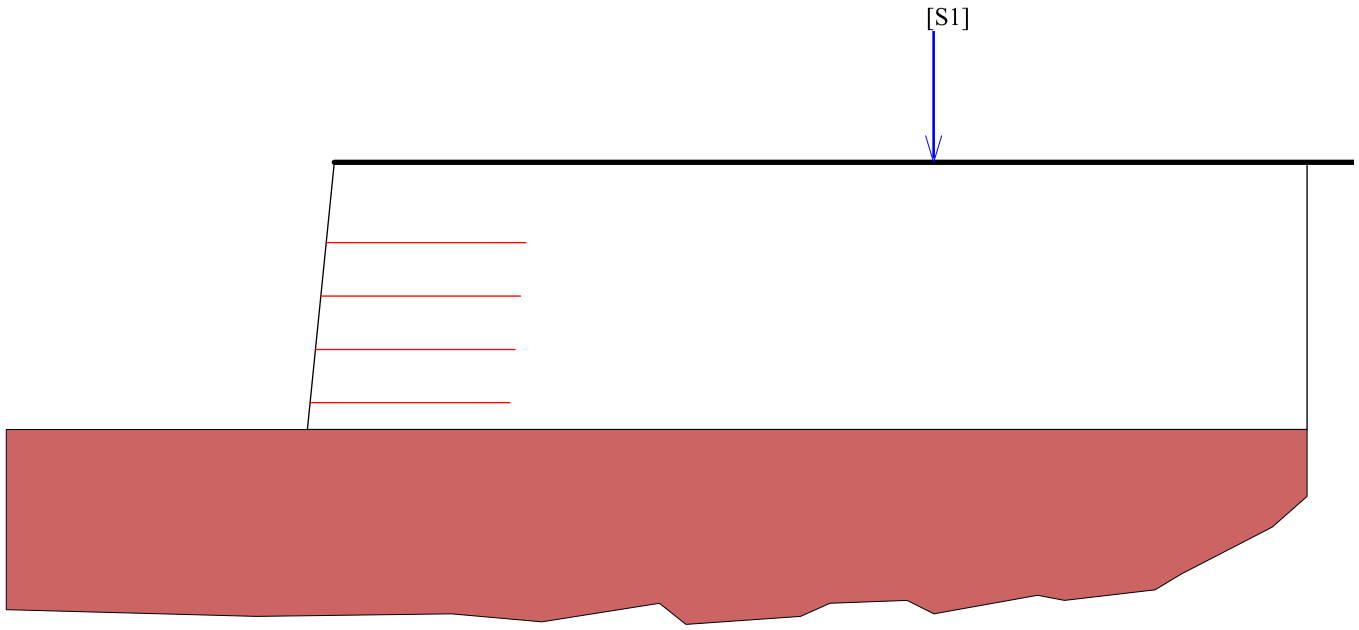
Soil in front of wall is Horizontal.

Batter, ω 5.8 [deg]
Backslope, β 0.0 [deg]
Backslope rise 0.0 [ft] Broken back equivalent angle, I = 0.00° (see Fig. 25 in DEMO 82)

U N I F O R M S U R C H A R G E
Uniformly distributed dead load is 0.0 [lb/ft ²]

OTHER EXTERNAL LOAD(S)
[S1] Strip Load, Qv-d = 0.0 and Qv-l = 100.0 [lb/ft ²].
Footing width, b=30.0 [ft]. Distance of center of footing from wall face, d = 15.0 [ft] @ depth of 0.0 [ft] below soil surface.

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

0 2 4 6 [ft]

ANALYSIS: CALCULATED FACTORS (Static conditions)

Bearing capacity, Fs = 2.55, Meyerhof stress = 1169 lb/ft².

Foundation Interface: Direct sliding, Fs = 1.589, Eccentricity, e/L = 0.1214, Fs-overturning = 3.46

GEOGRID				CONNECTION						
#	Elevation [ft]	Length [ft]	Type #	Fs-overall [connection strength]	Fs-overall [geogrid strength]	Geogrid strength Fs	Pullout resistance Fs	Direct sliding Fs	Eccentricity e/L	Product name
1	0.67	5.00	1	7.58	7.22	7.218	7.948	1.606	0.0983	Mira5XT
2	2.00	5.00	1	7.97	9.03	9.029	6.917	1.969	0.0602	Mira5XT
3	3.33	5.00	1	7.53	11.93	11.930	5.631	2.526	0.0316	Mira5XT
4	4.67	5.00	1	4.42	11.69	11.693	2.770	3.492	0.0123	Mira5XT

APPENDIX B

RESULTS OF GLOBAL STABILITY ANALYSIS

2119 NW Killarney Lane