PRRWF20220381

THE APPROVED CONSTRUCTION PLANS AND ALL ENGINEERING DOCUMENTS MUST BE POSTED ON THE JOB AT ALL INSPECTIONS IN A VISIBLE AND READILY ACCESSIBLE LOCATION.

GravityStone Edge®

SO SIMPLE. IT'S ADVANCED

An Engineered Earth Retention Product

The 1-2-6 Advantage

- One product
- Two systems
- Six Structural Solutions

"In over 25 years of site remediation I have not found a more innovative and flexible system than GravityStone ® Edge"
- Ty Gillis, GradeSolutions

IMPROVING SRW SOLUTIONS:

- 33% more product and 15% less weight than traditional one square foot SRW's
- GravityStone® Edge is more economical and flexible than other SRW or machine-laid products

BELOW GRADE:

- Fills: Geogrid Reinforced (MSE)
- Cuts: Modular System
- Poor Soils: Slide Stop
- Sustainable Sites: Green Walls

ABOVE GRADE:

- Barriers/Parapets
- Columns
- Planters

AESTHETICS:

- Optional Textures and Geometry

ALIGNMENT:

- Reversible Alignment Plug (RAP)
- Concrete Alignment Nub (CAN)

WESTBLOCK SYSTEMS

GravityStone® Components

Trunk
24" x 8" x 4"

Anchor Junction
12" x 8" x 6"

GravityStone® Modular Assemblies

Edge: 24″ x 8″ x 10.5″

Mini Cell: 24″ Deep

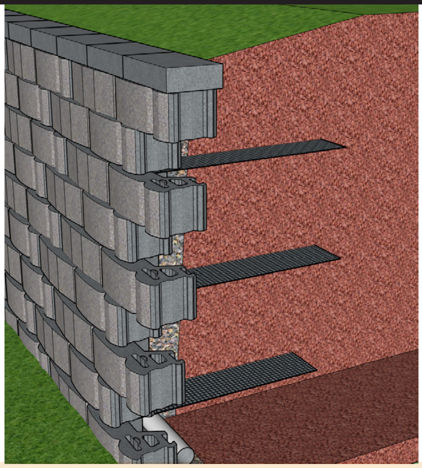
Single Cell: 37″ Deep
+27″ each additional Cell

Two Systems

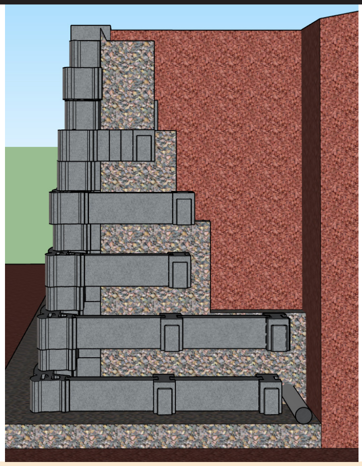
MSE: "Fill" sites typically are best served by Core combined with Geogrid reinforcement (MSE).

Modular: Assemble the components and place the aggregate, it's that easy. Modular's narrow footprint typically requires 30% less depth than MSE, allowing a fit on tight sites, minimizing excavation, and allowing for all weather construction.

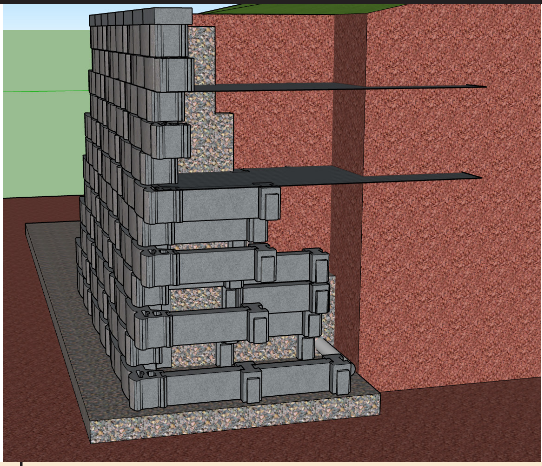
Structural Solutions



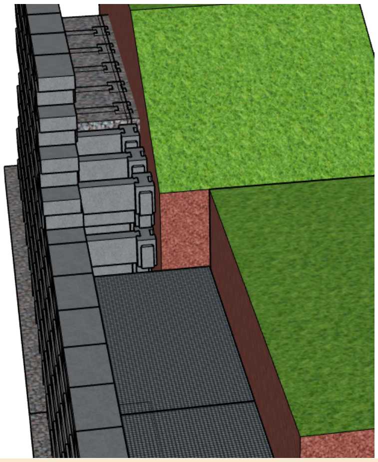
GravityStone® MSE
With Geogrid (MSE) reinforcement for use in "Fills"



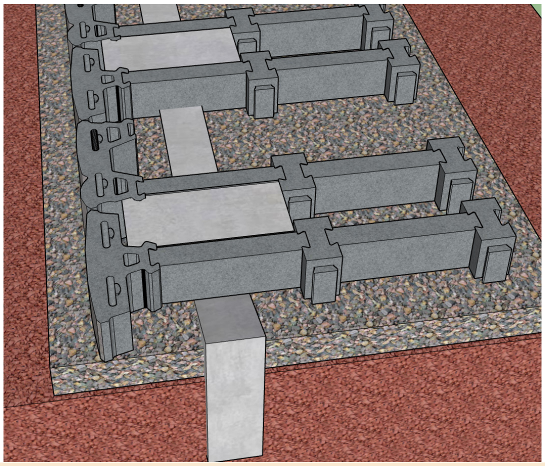
GravityStone® Modular
Components assembled into "Cells," form narrow walls ideal for "Cuts"



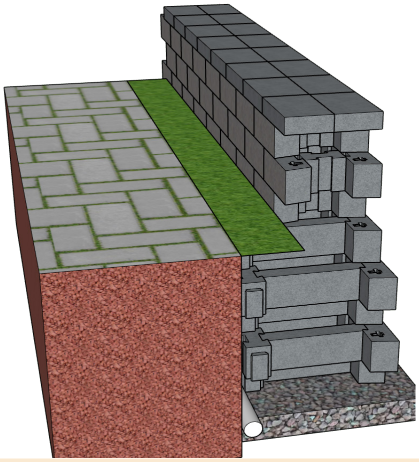
Vertical Hybrid
Combine the two systems above or below



Lateral Hybrid
Combine the two systems side by side



Slide Stop®
When soils are weak and the wall must be narrow



Barrier/Parapets/Columns
Create above grade features using Modular components

PRRWF20220381

Race Engineering & Assoc.

DESIGN CALCULATIONS

PUYALLUP CORPORATE PARK
PUYALLUP, WA

SUBMITTED BY:

Robert Race, P.E.

I HEREBY CERTIFY THAT THIS PLAN, SPECIFICATIONS, OR REPORT WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY LICENSED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF WASHINGTON.

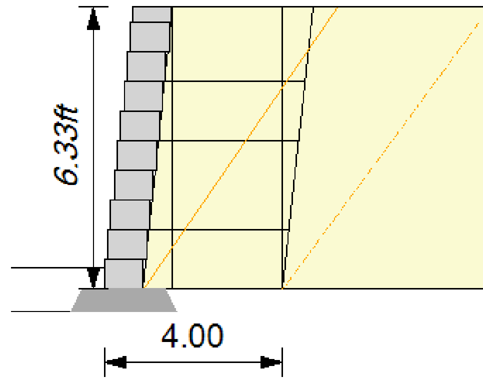
_______________________________________ DATE: 2/24/2021

ROBERT J. RACE, P.E. LICENSE NO. 26697

PRRWF20220381

REA Analysis

Project: PUYALLUP PARK
Location: PUYALLUP, WA
Designer: rjr
Date: 8/21/2020
Section: Wall 1, S_163.0_to_242.0
Design Method: NCMA_09_3rd_Ed, Ignore Vert. Force
Design Unit: GravityStone Edge (CAN)



Seismic Acc: 0.326

SOIL PARAMETERS	φ	coh	γ
Reinforced Soil:	33 deg	0psf	120pcf
Retained Soil:	32 deg	0psf	125pcf
Foundation Soil:	32 deg	50psf	125pcf

Leveling Pad: Crushed Stone

GEOMETRY

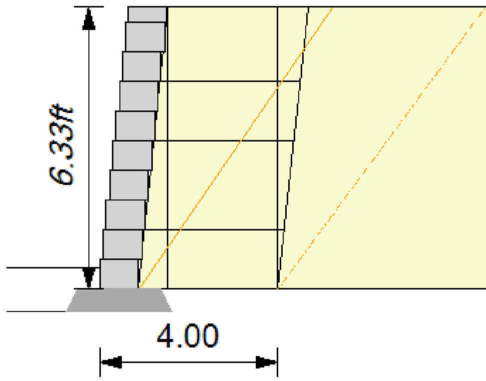
Design Height:	6.33ft (5.83ft Exp.)	Live Load:	0psf
Wall Batter/Tilt:	6.20/ 0.00 deg	Live Load Offset:	0.00ft
Embedment:	0.50ft	LL2 Width:	0ft
Leveling Pad Depth:	0.50ft	Dead Load:	0psf
Slope Angle:	0.0 deg	Dead Load Offset:	0.0ft
Slope Length:	0.0ft	Dead Load Width:	0ft
Slope Toe Offset:	0.0ft		

Vertical δ on Single Depth

FACTORS OF SAFETY (Static / Seismic)

Sliding:	1.50 / 1.13	Pullout:	1.50 / 1.13
Overturning:	2.00 / 1.50	Uncertainties:	1.50 / 1.13
Bearing:	2.00 / 1.50	Connection:	1.50 / 1.13
Shear:	1.50 / 1.13	Bending:	1.50 / 1.13

Note: Calculations and quantities are for PRELIMINARY ANALYTICAL USE ONLY and MUST NOT be used for final n or construction without the independent review, verification, and approval by a qualified professional engineer.



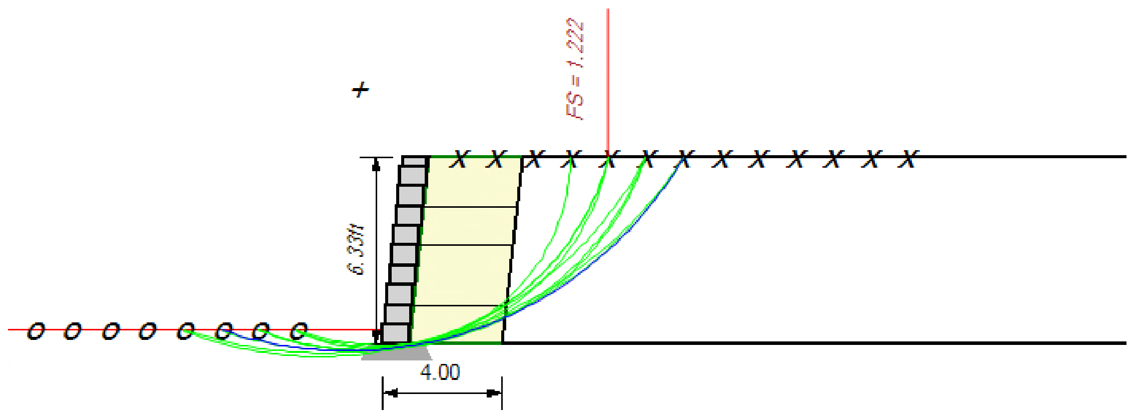
RESULTS (Static / Seismic)

FoS Sliding:	3.78 / [1.99]	FoS Overturning:	6.41 / [2.70]
Bearing	761 / [791]	FoS Bearing:	14.16 / [13.62]
Pullout	1.50		
Total Pullout	1,995	FoS Total Pullout	4.56
Total Pullout (S)	1,995	FoS Total Pullout (S)	4.56
Top FoSot:	5.93	FoS Connection:	6.82

ID	Ht	Lngth	Geogrid	Ta_tn [Ta_tns]	TMax [Tmd]	Tal/FS [seis]	FS Tal [seis]	PkCn [seis]	PkCn/FS [seis]	FS PO	FS Sldg
3	4.67	4.00	SG200	1836 [2846]	70 [71]	1224 [2530]	26.27 [20.14]	818 [1091]	17.56 [8.69]	1.23 [0.61]NG	46.20 [27.33]
2	3.33	4.00	SG200	1836 [2846]	136 [71]	1224 [2530]	13.53 [13.74]	868 [1157]	9.59 [6.28]	3.27 [2.14]	16.39 [10.16]
1	1.33	4.00	SG200	1836 [2846]	207 [71]	1224 [2530]	8.86 [10.21]	942 [1256]	6.82 [5.07]	7.07 [5.26]	7.13 [4.65]

Column Descriptions:

Ta: allowable geogrid strength
Rc %: percent coverage for geosynthetics
EP (Pa) internal active earth pressure
LL (Pql) earth pressure due to live load surcharge
DL (Pqd) earth pressure due to dead load surcharge
Tmax maximum earth pressure on geosynthetic layer
FSstr factor of safety on geogrid strength (Ta/Tmax)
Ta cn allowable tension on the connection
FS Pkcn, factor of safety on the connection (Ta cn/Tmax)
FS PO, factor of safety on pullout (Ta pullout/(Tmax - LL)
Grid Embedment, depth of embedment beyond the theorectical failure plane.


FS = 1.222
6.33ft
4.00

GLOBAL RESULTS

Global stability is a global analysis (Bishop) with the failure planes originating at the top of the slope / wall and exiting out below the wall in the area infront of the structure. For MSE walls, the resistance of the geogrid reinforcement is included in the resisting forces. The curve may go through the base of the wall and the wall shear would be included. In most cases the failure plane will pass below the structure.

ID	Enter Point X	Enter Point Y	Exit Point X	Exit Point Y	Center X	Center Y	Radius	FoS
1	7.58	6.33	-4.21	0.50	-0.85	8.55	8.73	1.222
2	7.58	6.33	-4.21	0.50	-0.85	8.54	8.71	1.224
1	8.85	6.33	-6.74	0.50	-2.16	12.02	12.39	1.256
1	7.58	6.33	-2.95	0.50	-0.06	7.71	7.77	1.256
2	6.32	6.33	-2.95	0.50	-0.17	6.37	6.49	1.278
1	10.12	6.33	-5.48	0.50	-1.29	13.08	13.25	1.285
1	8.85	6.33	-2.95	0.50	0.13	9.13	9.16	1.294
2	8.85	6.33	-4.21	0.50	-0.54	9.83	10.03	1.296
1	10.12	6.33	-6.74	0.50	-2.02	14.14	14.44	1.298
2	10.12	6.33	-5.48	0.50	-1.20	12.83	13.05	1.318

GEOGRID REINFORCING

STRUCTURAL PROPERTIES: Stratagrid

GEOGRID PROPERTIES

Name	Tult	RFcr	RFd	RFid	Ci	Cd	Alpha	Ltds
SG200	3600	1.55	1.10	1.15	0.80	0.80	0.80	1836

CONNECTION STRENGTHS

Geogrid	Slope 1	Intercept 1	Peak Break	Slope 2	Intercept 2	Max Normal	Rup Conn	Conn Creep	Tlot (%)	Tlot
SG200	28.00	1135	-1	0.00	0	1575	False	1.55	110	3960
SG350	26.00	1180	-1	0.00	0	2625	False	1.55	110	5500
SG550	26.00	1435	-1	0.00	0	3675	False	1.55	110	8965
SG600	26.00	1435	-1	0.00	0	3675	False	1.55	110	10010

SHEAR STRENGTHS

Slope 36 deg

Intercept 439psf

CALCULATION RESULTS

OVERVIEW

REA Wall calculates stability assuming the wall is a rigid body. Forces and moments are calculated about the base and the front toe of the wall. The base block width or bottom reinforcement length is used in the calculations. The concrete units, granular fill over the blocks or reinforced zone soils are used as resisting forces.

EARTH PRESSURES

The method of analysis uses the Coulomb Earth Pressure equation (below) to calculate active earth pressures. Wall friction is assumed to act at the back of the wall face. The component of earth pressure is assumed to act perpendicular to the boundary surface. The effective delta angle is delta minus the wall batter at the back face (assumed to be vertical). If the slope breaks within the failure zone, a trial wedge method of analysis is used.

INTERNAL EARTH PRESSURES

Effective internal Delta angle (2/3 phi)	delta =22.0 deg
Coefficient of active earth pressure	ka =0.223
Internal failure plane	ρ = 55.4 deg

EXTERNAL EARTH PRESSURES

Effective external Delta angle	delta =32.00 deg
Coefficient of active earth pressure	ka =0.232
External failure plane	ρ = 53.6 deg

FORCES AND MOMENTS

REA Wall resolves all the geometry into simple geometric shapes to make checking easier. All x and y coordinates are referenced to a zero point at the front toe. The wall image can be exported to CAD for a more detailed output.

Name	Factor γ	Force (V)	Force (H)	X-len	Y-len	Mo	Mr
Face Blocks(W1)	1.00	666	--	0.70	--	--	466
Soil(W2)	1.00	234	--	1.31	--	--	306
Soil(W3)	1.00	1883	--	2.76	--	--	5198
Soil(W4)	1.00	261	--	4.23	--	--	1105
Pa_h	1.00	--	523	--	2.11	1104	--
Sum (V, H)	1.00	3045	523		Sum Mom	1104	7075

W0: leveling pad
W1: facing units
W2: soil wedge behind the face
W3: rectangular area in MSE area
W4: the wedge at the back of the mass
W5: slope area over the mass
W6: Rectangle zone in broken back
W7: Live load over the mass
W8: Dead load over the mass
W9: Force Pa
W10: Surcharge load Paq
W11: Dead Load Surcharge Paqd
X-Len: is measured from the center of the base (+) Driving, (-) Resisting.

Pa_h: horizontal earth pressure
Pq_h: horizontal surcharge pressure
Pa_v: vertical earth pressure
Pq_v: vertical surcharge pressure

BASE SLIDING

Sliding at the base is checked at the soil-to-soil interface between the reinforced mass and the foundation soil.

Forces resisting sliding = (SumVr- W0 - W1 - W7)	
3,045 - 0 - 666 - 0	SumVr = 2,379ppf
Resisting force = SumVr x tan(32) + c x L + Base Shear	Rf1 =1,977
where L is the base width	
where Base Shear = N tan(40.0) * 0.8	447.15
Driving force is the horizontal component of Pah + Pqh+ Pdh	Df = 523
Factor of Safety = Rf/Df	FSsl =4.02

OVERTURNING ABOUT THE TOE

Overturning at the base is checked by assuming rotation about the front toe by the block mass, soil retained on the blocks or within the reinforced zone. Allowable overturning can be defined by eccentricity (e/L) or by the ratio of resisting moments divided by overturning moment (FSot).

Moments resisting overturning = Sum(M1 to M6) + MPav + MPqv	Mr =7,075ft-lbs
Moments causing overturning = MPah + MPqh	Mo =1,104ft-lbs
Factor of safety = Mr/Mo	FSot =6.41 OK

ECCENTRICITY AND BEARING

Eccentricity is the calculation of the distance of the resultant away from the centroid of mass. In wall ReinDesign the eccentricity is used to calculate an effective footing width, or in rigid structure, it is used to calculate the pressure distribution below the base.

Calculation of Eccentricity

e = (SumMr + M7 + SumMo)/SumV

Mr = -2,014.27

Mo = 2,132.74

e = (-2,014.272,132.74) /3,044.73) e =-1.362

Because 'e' is negative (leaning into the embankment), it is ignored to get the maximum bearing at the face of the wall.

Calculation of Bearing Pressures

Qult = c*Nc + q*Nq + 0.5*gamma*(B')*Ng

where:

Nc =35.49

Nq =23.18

Ng =30.21

c =50.00psf

q =62.50psf

B' =6.72ft

Calculate Ultimate Bearing, Qult Qult =10,776.72psf

Applied Bearing Pressures = (SumVert / B' + (2B + LP depth)/2 * LP depth *gamma)

sigma =761.18psf

Calculated Factors of Safety for Bearing Qult/sigma =14.16

TENSION CALCULATIONS

Tmax is the maximum tension in the reinforcing based on the earth pressure and surcharge loads applied. In the NCMA design method, earth pressures are calculated using the Coulomb Earth pressure equation. Infinite surcharge loads are applied as q x ka. In designs were there is a broken back slope, or the surcharge is not uniform over the area, a tie-back wedge analysis method is used.

FS = (Tal * FS_tn) / Tmax

TABLE OF RESULTS

Elevation[ft]	ka	z	sv	Name[ft]	Tult[ppf]	Ta[ppf]	Rc %	Tmax[ppf]	FS
4.67	0.223	1.17	2.33	SG200	3,600	1,224	100	70	26.27
3.33	0.223	3.16	1.67	SG200	3,600	1,224	100	136	13.53
1.33	0.223	4.83	1.67	SG200	3,600	1,224	100	207	8.86

PULLOUT CALCULATIONS

Pullout is the amount of resistance of the reinforcing has to a pullout failure based on the Tmax applied and the depth of embedment (resistance). In an NCMA design the failure place is defined as the Coulomb failure plane which varies with face batter, backslope angle, and surcharge loads applied. All failure planes begin at the tail. of the facing units.

For AASHTO calculations, the live load surcharge is not included in the Tmax value for pullout.

Failure Plane Angle (ρ) = 55.4 Deg

NOTE: The pullout capacity is limited by the Ultimate Strength of the reinforcing layer, not the ultimate pullout capacity calculated.

F* = 0.67 x tan(φ) = 0.67 x 0.65 = 0.44
Le = embedment length = Li - block depth - hi * Tan(90 - ρ)
La = Li - Le
sv = geogrid spacing
Rc = % coverage
α = scale effect correction
Pullout = 2 x Le x F* x sv x α x Rc

TABLE OF RESULTS

Elevation[ft]	Normal[lbf]	Ci	% Coverage	Tmax[ppf]	Le[ft]	La[ft]	Pullout_[Pr][ppf]	FS PO
4.67	82.76	0.80	100	70	0.41	3.59	86	1.23
3.33	427.58	0.80	100	136	1.19	2.81	444	3.27
1.33	1409.43	0.80	100	207	2.35	1.65	1464	7.07

CONNECTION CALCULATIONS

Connection is the amount of resistance of the reinforcing has to a pullout failure from the facing units based on the Tmax applied and the normal load on the units. In an AASHTO LRFD design, creep on the connection may be applied for frictional and mechanical connections. In NCMA or AASHTO 2002, a frictional failure is based on the peak connection capacity divided by a factor of safety. For a rupture connection the capacity is the peak load divided by a creep reduction factor and a factor of safety.

Frictional Connection

Peak Connection = N(ppf) tan(slope) + intercept

Rupture Connection

Connection Capacity = [N(ppf) tan(slope) + intercept] / RFcr

RFcr can be a value obtained from long-term testing or by default could be the creep reduction factor of the geogrid reinforcing.

Tal_cn = Allowable connection capacity = Tult_cn / FScn

Rc = % coverage

FS = Tal_cn * FScn/Tmax

TABLE OF RESULTS

Elev[ft]	Name[ft]	Tmax[ppf]	Ttotal[ppf]	Rc %	N[ppf]	Avail_CN[ppf]	FS cn	FS cns
4.67	SG200	70	71	100	173	818	11.71	11.46
3.33	SG200	136	71	100	313	868	6.39	12.15
1.33	SG200	207	71	100	523	942	4.55	13.20

SEISMIC CALCULATIONS

The loads considered under seismic loading are primarily inertial loadings. The wave passes the structure putting the mass into motion and then the mass will try to continue in the direction of the initial wave. In the calculations you see the one dynamic earth pressure from the wedge of the soil behind the reinforced mass, and then all the other forces come from inertia calculations of the face put into motion and then trying to be held in place.

Design Acceleration A = 0.326
Displacment (d) d = 2.0in

Design Acceleration Coefficient Displacment
Kh_d = 0.74 A (A/d)^0.25 = kh(int) = 0.153
Design Acceleration Coefficient Displacment Based (empirically)
Kh_d = 0.74 A (A/d)^0.25 = kh(ext) = 0.153
Vertical Acceleration kv =0.000

SEISMIC THRUST
INTERNAL Kae
Kae Kae =0.322
D_Kae = Kae - Ka = (0.322 - 0.223) D_Kae =0.099
EXTERNAL Kae
Kae Kae =0.342
D_Kae = Kae - Ka = (0.342 - 0.000) D_Kae =0.110
Pae = 0.5*gamma*(H)^2*D_Kae Pae =276ppf
Pae_h/2 = Pae*cos(delta)/2 Pae_h/2 =117ppf
Pae_v/2 = Pae*sin(delta)/2 Pae_v/2 =73ppf

INERTIA FORCES OF THE STRUCTURE
Face (Pif) = (W1)*kh(ext) = 666 * 0.153 Pif =102ppf
Mass (Pir) = (W)*kh(ext) = 1,729 * 0.153 Pir =265ppf
Slope (Pis) = (W)*kh(ext) = 0 * 0.153 Pis =0ppf
Dead Load(Pidl) = (DL)*kh(ext) = 0 * 0.153 Pidl =0ppf

TABLE OF RESULTS FOR SEISMIC REACTIONS

Name	Force (V)	Force (H)	X-len	Y-len	Mo	Mr
Face Blocks(W1)	666	--	0.70	--	--	466
Soil(W2)	234	--	1.31	--	--	306
Soil(W3)	1883	--	2.76	--	--	5198
Soil(W4)	261	--	4.23	--	--	1105
Pa_h	--	523	--	2.11	1104	--
Pir	--	265	--	3.16	839	--
Pif	--	102	--	3.16	323	--
Pae_h/2	--	248	--	3.16	370	--
Pae_v/2	120	--	0.44	--	--	53
Sum V / H	3104.76	1014.42		Sum Mom	2635.87	7127.56

TENSION CALCULATIONS, SEISMIC

Tmax is the maximum tension in the reinforcing based on the earth pressure and surcharge loads applied.

For walls with extensible reinforcing, the inertial force shall be distributed uniformly to the reinforcements on a load per unit width of wall bases as follows:

Tmd = (Pi/n)

where:

Tmd = incremental dynamic inertia force at Layer i

Pi = internal inertia force due to the weight of backfill within the active zone,

KhWa = where Wa is the weight of teh active zone and Kh is calculated as specified

n = total number of reinforcement layers in the wall

The total load applied to the reinforcement on a load per unit of wall width basis is determined as follows:

Total = Tmax + Tmd

where:

Tmax = the static load applied to the reinforcements.

In seismic design the mass is designed to resist the static and dynamic components of the load determined as:

Srs >= Tmax RF/ Rc

where the reinforcing must be able to resist the load at any time of it's design life. Design for static loads require the strength of the reinforcement be reduced for creep and other degradation mechanisms.The dynamic load is a transient load and does not cause strength loss due to creep. The dynamic component of load for seismic design is:

Srt >= Tmd RFid RFd/ Rc

The strength required for Tmax requires reduction for creep (Rc), where the strength for Tmd does not include the effects of creep.

Srs = ultimate reinforcement tensile resistance required to resist static load component (kip/ft)

Srt = ultimate reinforcement tensile resistance required to resist dynamic load component.

Rc = reinforcement coverage ratio

RF = combined strength reduction factor to account for potential long-term degradation due to installation damage, creep, and chemical aging

RFid = strength reduction factor to account for installation damage to reinforcement

RFd = strength reduction factor to prevent rupture of reinforcement due to chemical and biological degradation

The required ultimate tensile resistance of the geosynthetic reinforcement shall be determined as:

Tult = Srs + Srt

Table of Results, Seismic Tension

Elevation[ft]	Name	Ta[ppf]	Tas[ppf]	Coverage Ratio %	Tmax[ppf]	TSmax[ppf]	FS Str	FSs Str
4.67	SG200	1224	2530	100	70	71	17.52	36.20
3.33	SG200	1224	2530	100	136	71	9.02	18.64
1.33	SG200	1224	2530	100	207	71	5.91	12.21

PULLOUT CALCULATIONS, SEISMIC

Pullout is the amount of resistance of the reinforcing has to a pullout failure based on the Tmax applied and the depth of embedment (resistance). In an NCMA design the failure place is defined as the Coulomb failure plane which varies with face batter, backslope angle, and surcharge loads applied. All failure planes begin at the tail. of the facing units.

Failure Plane Angle (ρ) = 55.4 Deg

NOTE: The pullout capacity is limited by the Ultimate Strength of the reinforcing layer, not the ultimate pullout capacity calculated.

F* = 0.67 x tan(φ) = 0.67 x 0.65 = 0.44
Le = embedment length = Li - block depth - hi * Tan(90 - ρ)
La = Li - Le
sv = geogrid spacing
Rc = % coverage
α = scale effect correction
Pullout = 2 x Le x F* x sv x α x Rc

TABLE OF RESULTS

Elev[ft]	Rc %	Tmax[ppf]	Ttotal[ppf]	Le[ft]	La[ft]	TRpo[ppf]	TRpos[ppf]	FS PO	FS SeisPO
4.67	100	70	0	0.41	3.59	86	86	1.23	0.62
3.33	100	136	0	1.19	2.81	444	444	3.27	1.64
1.33	100	207	0	2.35	1.65	1464	1464	7.07	3.53

CONNECTION CALCULATIONS, SEISMIC

Facing elements shall be designed to resist the seismic loads, i.e., Ttotal.
The required ultimate tensile resistance of the geosynthetic reinforcement at the connection is:
Tult = Srs + Srt

In REA software, friction resistance at the base block is an option to reduce the tension on the bottom layer of reinforcement. Research has shown the tension in the bottom layer of reinforcement to be very low if not zero.

Base friction is used to reduce the tension in the bottom layer of reinforcing. The force in the bottom layer is the tension from half way to the reinforcing layer above to the halfway to the foundation level below.

Base Friction = 447.15 / 1.50 bs = 298ppf

Amount utilized to reduce bottom tension = 0ppf

TABLE OF RESULTS, Seismic Connection

Elev[ft]	Name[ft]	Tmax[ppf]	Ttotal[ppf]	Rc %	N[ppf]	Avail_CN[ppf]	FS cn	FS cns
4.67	SG200	70	71	100	173	818	11.71	11.46
3.33	SG200	136	71	100	313	868	6.39	12.15
1.33	SG200	207	71	100	523	942	4.55	13.20