ReCon Retaining Wall Structural Calculations

21 Eastman Road
Somerville, MA

Prepared by:

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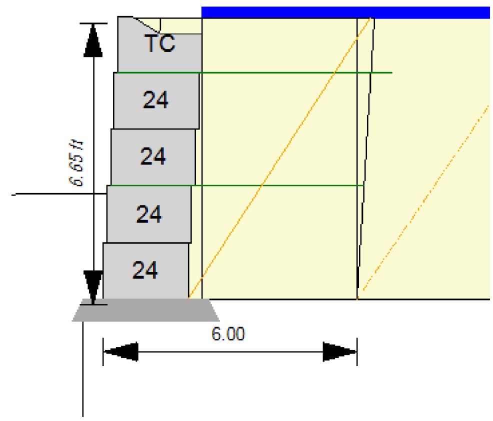
September 10, 2018

Retaining Wall Systems

ReCon Wall

Version: 4.0.17187.1304



Project: 21 Eastman, Somerville, MA
Location: 21 Eastman, Somerville, MA
Designer: CM Kirby Engineering, PLLC
Date: 9/10/2018
Section: Section 1
Design Method: NCMA_09_3rd_Ed, Ignore Vert. Force
Design Unit: ReCon Series 50 A-24

SOIL PARAMETERS	φ	coh	γ
Reinforced Soil:	34 deg	0 psf	125 pcf
Retained Soil:	34 deg	0 psf	125 pcf
Foundation Soil:	35 deg	0 psf	130 pcf
Leveling Pad: Crushed Stone			

GEOMETRY

Design Height:	6.65 ft	Live Load:	100 psf
Wall Batter/Tilt:	3.60/ 0.00 deg	Live Load Offset:	0.00 ft
Embedment:	2.50 ft	LL2 Width:	100 ft
Leveling Pad Depth:	0.50 ft	Dead Load:	0 psf
Slope Angle:	0.0 deg	Dead Load Offset:	0.0 ft
Slope Length:	0.0 ft	Dead Load Width:	100 ft
Slope Toe Offset:	0.0 ft		
Vertical δ on Single Depth		Toe Slope Angle:	15.00
		Toe Slope Length:	100.00
		Toe Slope Bench:	2.00

FACTORS OF SAFETY

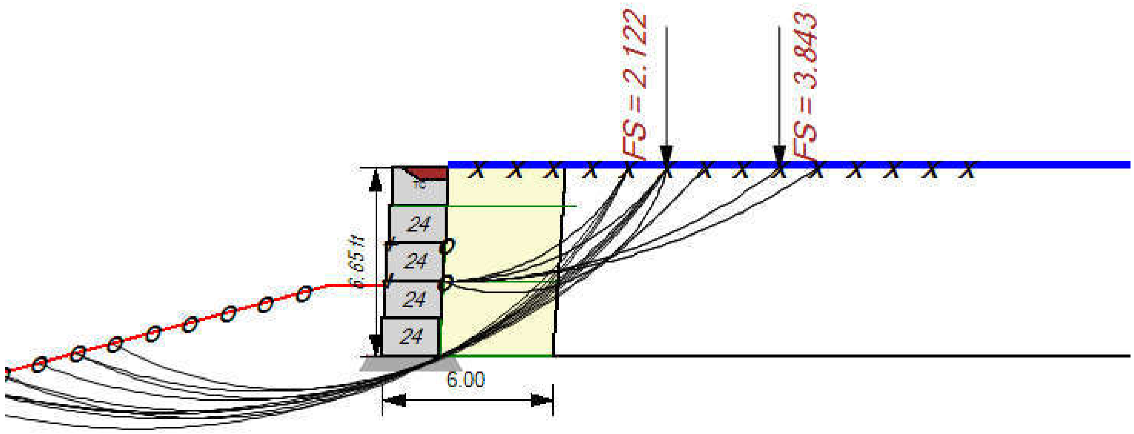
Sliding:	1.50	Pullout:	1.50
Overturning:	2.00	Uncertainties:	1.50
Bearing:	2.00	Connection:	1.50
Shear:	1.50	Bending:	1.50

RESULTS

FoS Sliding:	4.91	FoS Overturning:	9.74
Bearing	975	FoS Bearing:	8.84
Total Pullout	1747	FoS Total Pullout	3.88
Top FoSot:	14.14	FoS Connection:	4.43

ID	Height	Length	Geogrid.	Tallow	% Cvrg	EP (Pa)	LL (Pql)	DL (Pqd)	TMax	FS Str	Tal Cn	FS Pk Cn	FS PO/[Tmax]	FS Sldg [fndn]	Grid Embed
2	5.33	6.5	SF55	1827	100	95	58	0	153	17.93	702	6.89	1.79/[153]	100.00	1.37
1	2.67	6	SF55	1827	100	288	58	0	346	7.92	1022	4.43	4.25/[346]	32.87 [5.04]	2.44

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



COMPOUND RESULTS

Compound stability is a global analysis (Bishop) with the failure planes originating at the top of the slope / wall and exiting out through the face of the wall. For MSE walls, the resistance of the geogrid reinforcement is included in the analysis and the shear resistance of the face units is included.

ID	Enter Point X	Enter Point Y	Exit Point X	Exit Point Y	Center X	Center Y	Radius	FoS
2	13.98	6.65	2.17	2.67	2.03	22.58	19.91	3.843
2	13.98	6.65	2.17	2.67	2.03	22.58	19.91	3.843
2	15.31	6.65	2.17	2.67	2.05	26.72	24.06	4.067
2	15.31	6.65	2.17	2.67	2.05	26.72	24.06	4.067
2	8.66	6.65	2.17	2.67	1.88	10.41	7.74	4.568
2	8.66	6.65	2.17	2.67	1.88	10.41	7.74	4.568
3	9.99	6.65	2.17	2.67	4.35	8.05	5.81	4.583
3	9.99	6.65	2.17	2.67	4.35	8.05	5.81	4.583
2	9.99	6.65	2.17	2.67	1.93	12.79	10.12	4.587
2	9.99	6.65	2.17	2.67	1.93	12.79	10.12	4.587

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 analysis. 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	9.99	6.65	-14.81	-0.93	-7.52	19.55	21.74	2.122
1	9.99	6.65	-16.14	-1.29	-8.60	20.85	23.39	2.125
1	9.99	6.65	-13.48	-0.58	-6.43	18.24	20.10	2.129
1	9.99	6.65	-12.15	-0.22	-5.34	16.94	18.46	2.151
1	9.99	6.65	-10.82	0.14	-4.25	15.62	16.82	2.155
1	8.66	6.65	-10.82	0.14	-4.27	12.94	14.38	2.156
2	11.32	6.65	-14.81	-0.93	-7.64	23.15	25.13	2.160
1	8.66	6.65	-13.48	-0.58	-6.31	14.97	17.12	2.171
1	8.66	6.65	-9.49	0.49	-3.25	11.91	13.01	2.172
1	11.32	6.65	-14.81	-0.93	-7.74	23.49	25.43	2.177

NOTES ON DESIGN UNITS

The wall section is designed on a 'per unit width bases' (lb/ft/ft of wall or kN/m/meter of wall). In the calculations the software shows lb/ft or kN/m, neglecting the unit width factor for simplicity.

The weights for the wall unit are shown as lbs / ft3 (kN / m3). For SRW design a 1 sf unit is typically 1 ft deep, 1.5 ft wide and 8 inches tall (or 1 ft3). therefore a typical value of 120 pcf is shown. With larger units the unit weight will vary with the size of the unit. Say we have 4 ft wide unit, 1.5 ft tall and 24 inches deep with a tapered shape (sides narrow), built with 150 pcf concrete. We add up the concrete, the gravel fill and divide by the volume and and the results may come out to 140 pcf, as shown in the table. The units with more gravel may have lower effective unit weights based on the calculations.

Hollow Units
Hollow units with gravel fill are treated differently in AASHTO. If the fill can fall out as the unit is lifted, then AASHTO only allows 80% of the weight of the fill to be used for eccentricity (overturning calculations). In the properties page for the units the weight of the concrete may be as low as 75 pcf. This is the effective unit weight of the concrete only (e.g. the weight of the concrete divided by the volume of the unit). The density of the concrete maybe 150 pcf, but not the effective weight including the volume of the void spaces used for gravel fill.

Rounding Errors
When doing hand calculations the values may vary from the values shown in the software. The program is designed using double precision values (64 bit precision: 14 decimal places). Over several calculations the results may differ from the single calculation the user is making, probably inputting one or two already rounded values.

Result Rounding
As noted above the software is based on double precision values. For example, using an NCMA design method an allowable factor of safety of 1.5 the software may calculate a value of 1.49999999999999, since this is less than 1.5, it would be false (NG), even though the results shown is 1.50 (results are rounded to 2 places on the screen). In the design check we round to 2 decimal places to check against the suggested value (1.49999999999 rounds to 1.50). Given the precision of the calculation, this will provide a safe design even though the 'absolute' value is less than the minimum suggested.

DESIGN DATA

TARGET DESIGN VALUES (Factors of Safety)

Minimum Factor of Safety for the sliding along the base	FSsl = 1.5
Minimum Factor of Safety for overturning about the toe	FSot = 2.0
Minimum Factor of Safety for bearing (foundation shear failure)	FSbr = 2.0
	-Seismic requirements are 75% of

MINIMUM DESIGN REQUIREMENTS

Minimum embedment depth	Min_emb = 2.5 ft

INPUT DATA

Geometry

Wall Geometry

Design Height (top of leveling pad to finished grade at top of wall)	H =6.65 ft
Embedment (measured from top of leveling pad to finished grade at toe)	emb =2.50 ft
Leveling Pad Depth	LP =0.50 ft
Face Batter (measured from vertical)	i =3.6 deg

Slope Geometry

Slope Angle (back slope angle measured from horizontal)	β =0.0 deg
Slope toe offset (horiz. bench from wall to toe of slope)	STL_offset =0.0 ft
Slope Length (horiz. length from wall to top of slope)	SL_Length =0.0 ft

NOTE: If the slope toe is offset or the slope breaks within three times the wall height, a Coulomb Trial Wedge method of analysis is used.

Surcharge Loading

Live Load (assumed transient loading (e.g. traffic))	LL = 100 psf
Live Load Offset (measured from back face of wall)	LL_offset = 0.0 ft
Live Load Width (assumed strip loading)	LL_width = 100.0 ft

Soil Parameters

Reinforced Zone	
Angle of Internal Friction	φ = 34 deg
Cohesion	coh = 0.0 psf
Moist Unit Weight	gamma = 125 pcf
Retained Zone	
Angle of Internal Friction	φ = 34 deg
Cohesion	coh = 0.0 psf
Moist Unit Weight	gamma = 125 pcf
Foundation	
Angle of Internal Friction	φ = 35 deg
Cohesion	coh = 0.0 psf
Moist Unit Weight	gamma = 130 pcf

RETAINING WALL UNITS

STRUCTURAL PROPERTIES:

N is the normal force [or factored normal load] on the base unit
The default leveling pad to base unit shear is ATan(0.7), or 35 deg. or may be the manufacturer supplied data.

Table of Values:

Unit	Ht (in)	Width (in)	Depth (in)	Concr_Vol (cf/ft)	Concr_Density (pcf)	CG (in)
Cap 6.5	6.50	48.00	24.00	1.08	145.00	12.00, 3.25
Top Cap	16.00	48.00	24.00	2.01	145.00	10.68, 8.00
A-24	16.00	48.00	24.00	2.53	145.00	11.70, 8.00
B-39	16.00	48.00	39.00	3.88	145.00	18.60, 8.00
C-45	16.00	48.00	45.00	4.38	145.00	21.30, 8.00
D-60	16.00	48.00	60.00	5.53	145.00	27.60, 8.00
E-66	16.00	48.00	66.00	5.93	145.00	30.10, 8.00
F-72	16.00	48.00	72.00	6.35	145.00	32.70, 8.00
G-78	16.00	48.00	78.00	6.78	145.00	35.30, 8.00
H-84	16.00	48.00	84.00	7.20	145.00	38.00, 8.00

GEOGRID REINFORCING

STRUCTURAL PROPERTIES: Synteen

GEOGRID PROPERTIES

Name	Tult	RFcr	RFd	RFid	Ci	Cd	Alpha	LTDS
SF55	5000	1.58	1.10	1.05	0.90	0.90	0.80	2740

CONNECTION STRENGTHS

Geogrid	Grade	Tult [lb/ft]	Tult-cn Eqn	RFcr	Tlot	RFd
Synteen	SF55	5000	822 + 2 σ_n tan 32 deg	1.00	5000	1.10

SHEAR STRENGTHS

Slope 0 deg

Intercept 6775 psf

CALCULATION RESULTS

OVERVIEW

ReCon Wall Systems 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 =22.7 deg
Coefficient of active earth pressure	ka =0.230
Internal failure plane	ρ = 57.0 deg

EXTERNAL EARTH PRESSURES

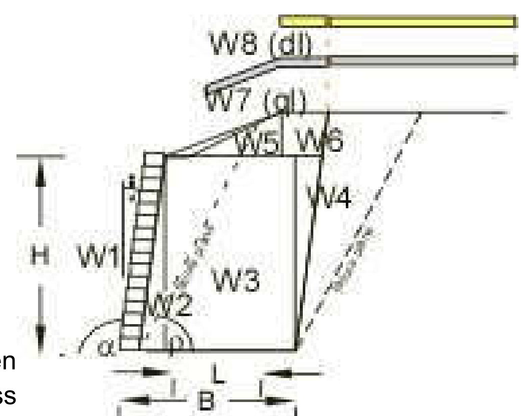
Effective external Delta angle	delta =34.00 deg
Coefficient of active earth pressure	ka =0.232
External failure plane	ρ = 55.7 deg

$$Ka := \frac{\cos(\phi_i + i)^2}{\cos(i)^2 \cdot \cos(\delta_i - i)\left(1 + \sqrt{\frac{\sin(\phi_i + \delta_i)\cdot\sin(\phi_i - \beta)}{\cos(\delta_i - i)\cdot\cos(i + \beta)}}\right)^2}$$

FORCES AND MOMENTS

ReCon Wall Systems 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	1755	--	1.12	--	--	1969
Soil Fill(W0)	1.00	151	--	1.62	--	--	246
Soil(W2)	1.00	111	--	2.22	--	--	247
Soil(W3)	1.00	3046	--	4.17	--	--	12695
Soil(W4)	1.00	174	--	6.14	--	--	1068
LL(W7)	1.00	408	--	4.38	--	--	1787
Pa_h	1.00	--	552	--	2.22	1224	--
Pq_h	1.00	--	133	--	3.33	442	--
Sum (V, H)	1.00	5646	685		Sum Mom	1666	16224



Note: live load forces and moments are not included in SumV or Mr as live loads are not included as resisting forces.

- 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: Rectang zone in broken
- W7: Live load over the mass
- W8: Dead load over the mass
- W9: Force Pa
- W10: Surcharge load Paq
- W11: Dead Load Surchage Paqd

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)	
5646 - 151 - 1755 - 408	SumVr = 3331 ppf
Resisting force = SumVr x tan(34) + c x L + Base Shear	Rf1 =3367
where L is the base width	
where Base Shear = N tan(40.0) * 0.8	1119.87
Driving force is the horizontal component of Pah + Pqh+ Pdh	Df = 685
Factor of Safety = Rf/Df	FSsl =5.04

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 =16224 ft-lbs
Moments causing overturning = MPah + MPqh	Mo =1666 ft-lbs
Factor of safety = Mr/Mo	FSot =9.74 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 = L/2 - (SumMr + M7 - SumMo)/SumV

e =6.00/2 - (16224.48 + 1787.04 - 1665.74) /5645.98) e =0.105

Calculation of Bearing Pressures

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

where:

Nc =46.12

Nq =33.30

Ng =48.03

c =0.00 psf

q =312.50 psf

B' =5.79 ft

Calculate Ultimate Bearing, Qult Qult =8000.00 psf

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

sigma =975.09 psf

Calculated Factors of Safety for Bearing Qult/sigma =8.84

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.

TABLE OF RESULTS

Elevation[ft]	Name[ft]	Ta[ppf]	Rc %	Tmax[ppf]	FS Str
5.33	SF55	1827	100	153	17.93
2.67	SF55	1827	100	346	7.92

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 embedement (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 liveload surcharge is not included in the Tmax value for pullout.

Failure Plane Angle = 57.0 Deg

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

F* = 0.67 x tan(phi) = 0.67 x 0.67 = 0.45
Pullout = 2 x Le x F* x sv x alpha x Coverage

TABLE OF RESULTSPeak Connection = N tan(slope) + intercept

Connection Capacity = [N tan(slope) + intercept] / RFcr
/tRFcr can be a value obtained from long-term testing or by default could be the creep reduction factor of the geogrid reinforcing.

TABLE OF RESULTS

Elevation[ft]	Ci	% Coverage	Tmax[ppf]	Le[ft]	La[ft]	Pullout_[Pr][ppf]	FS PO
5.33	0.90	100	153	1.37	5.13	274	1.79
2.67	0.90	100	346	2.44	3.56	1473	4.25

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 ConnectionRupture Connection

Elev[ft]	Name	Tmax[ppf]	Rc %	N[ppf]	CRcr	Ta_cn[ppf]	FS cn
5.33	SF55	153	100	370	1053	6.89	
2.67	SF55	346	100	1138	1533	4.43	

ReCon Wall

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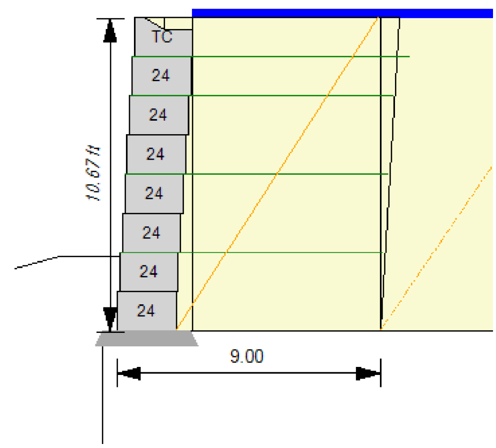

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Leveling Pad: Crushed Stone			

GEOMETRY

Design Height:	10.67 ft	Live Load:	100 psf
Wall Batter/Tilt:	3.60/ 0.00 deg	Live Load Offset:	0.00 ft
Embedment:	2.50 ft	LL2 Width:	100 ft
Leveling Pad Depth:	0.50 ft	Dead Load:	0 psf
Slope Angle:	0.0 deg	Dead Load Offset:	0.0 ft
Slope Length:	0.0 ft	Dead Load Width:	100 ft
Slope Toe Offset:	0.0 ft		
Vertical δ on Single Depth		Toe Slope Angle:	15.00
		Toe Slope Length:	100.00
		Toe Slope Bench:	2.00

FACTORS OF SAFETY

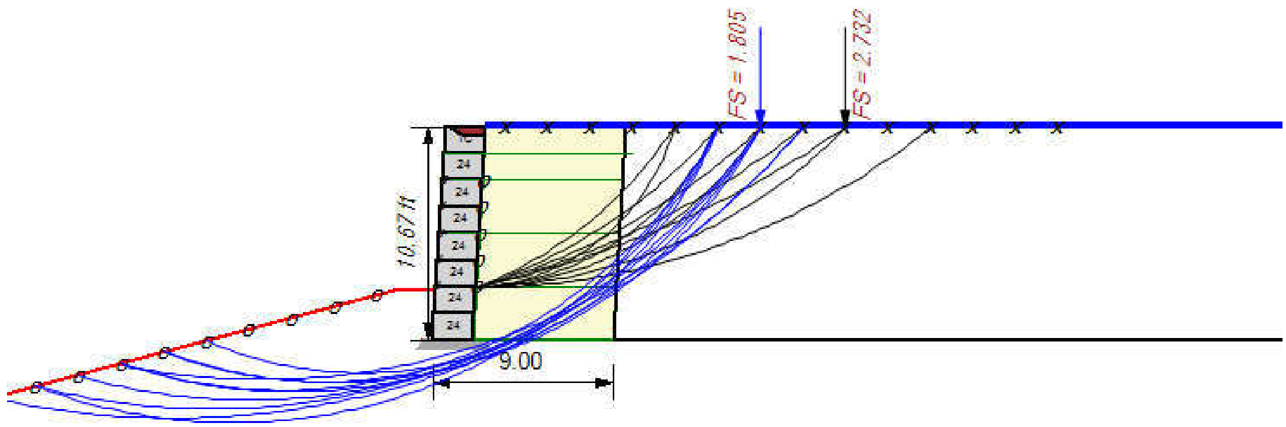
Sliding:	1.50	Pullout:	1.50
Overturning:	2.00	Uncertainties:	1.50
Bearing:	2.00	Connection:	1.50
Shear:	1.50	Bending:	1.50

RESULTS

FoS Sliding:	4.95	FoS Overturning:	9.44
Bearing	1519	FoS Bearing:	5.57
Total Pullout	9483	FoS Total Pullout	6.19
Top FoSot:	14.07	FoS Connection:	3.54

ID	Height	Length	Geogrid.	Tallow	% Cvrg	EP (Pa)	LL (Pql)	DL (Pqd)	TMax	FS Str	Tal Cn	FS Pk Cn	FS PO/[Tmax]	FS Sldg [fndn]	Grid Embed
4	9.33	9.5	SF55	1827	100	54	43	0	98	27.97	702	10.75	4.20/[98]	100.00	2.03
3	8	9	SF55	1827	100	163	43	0	206	13.27	862	6.27	4.53/[206]	69.75	2.31
2	5.33	9	SF55	1827	100	386	58	0	444	6.17	1182	3.99	7.06/[444]	24.76	3.87
1	2.67	9	SF55	1827	100	579	58	0	637	4.30	1502	3.54	7.85/[637]	13.60 [5.10]	5.44

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



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ID	Enter Point X	Enter Point Y	Exit Point X	Exit Point Y	Center X	Center Y	Radius	FoS
3	20.66	10.67	2.17	2.67	1.73	29.04	26.37	2.732
2	16.39	10.67	2.17	2.67	-6.80	35.25	33.79	2.825
2	14.26	10.67	2.17	2.67	-6.02	28.16	26.78	2.863
2	18.53	10.67	2.17	2.67	-7.65	43.45	41.95	2.926
2	12.12	10.67	2.17	2.67	-5.32	22.17	20.90	2.989
3	14.26	10.67	2.17	2.67	1.51	16.79	14.14	3.031
2	20.66	10.67	2.17	2.67	-8.55	52.78	51.25	3.107
3	24.93	10.67	2.17	2.67	1.81	40.04	37.38	3.118
3	12.12	10.67	2.17	2.67	1.38	13.84	11.20	3.120
3	16.39	10.67	2.17	2.67	1.61	20.31	17.65	3.134

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 analysis. 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
2	16.39	10.67	-19.91	-2.30	-11.17	30.52	33.97	1.805
2	16.39	10.67	-15.65	-1.16	-7.00	24.74	27.30	1.815
2	14.26	10.67	-13.51	-0.58	-5.53	19.60	21.70	1.819
2	18.53	10.67	-15.65	-1.16	-8.43	33.29	35.19	1.819
3	16.39	10.67	-13.51	-0.58	-5.00	22.14	24.27	1.835
2	14.26	10.67	-15.65	-1.16	-7.51	22.00	24.54	1.836
3	14.26	10.67	-19.91	-2.30	-10.05	23.22	27.36	1.849
2	14.26	10.67	-11.38	-0.01	-3.59	17.39	19.07	1.850
2	16.39	10.67	-17.78	-1.73	-9.06	27.53	30.53	1.856
3	18.53	10.67	-22.05	-2.87	-12.88	37.21	41.12	1.857

NOTES ON DESIGN UNITS

The wall section is designed on a 'per unit width bases' (lb/ft/ft of wall or kN/m/meter of wall). In the calculations the software shows lb/ft or kN/m, neglecting the unit width factor for simplicity.

The weights for the wall unit are shown as lbs / ft3 (kN / m3). For SRW design a 1 sf unit is typically 1 ft deep, 1.5 ft wide and 8 inches tall (or 1 ft3). therefore a typical value of 120 pcf is shown. With larger units the unit weight will vary with the size of the unit. Say we have 4 ft wide unit, 1.5 ft tall and 24 inches deep with a tapered shape (sides narrow), built with 150 pcf concrete. We add up the concrete, the gravel fill and divide by the volume and and the results may come out to 140 pcf, as shown in the table. The units with more gravel may have lower effective unit weights based on the calculations.

Hollow Units

Hollow units with gravel fill are treated differently in AASHTO. If the fill can fall out as the unit is lifted, then AASHTO only allows 80% of the weight of the fill to be used for eccentricity (overturning calculations). In the properties page for the units the weight of the concrete may be as low as 75 pcf. This is the effective unit weight of the concrete only (e.g. the weight of the concrete divided by the volume of the unit). The density of the concrete maybe 150 pcf, but not the effective weight including the volume of the void spaces used for gravel fill.

Rounding Errors

When doing hand calculations the values may vary from the values shown in the software. The program is designed using double precision values (64 bit precision: 14 decimal places). Over several calculations the results may differ from the single calculation the user is making, probably inputting one or two already rounded values.

Result Rounding

As noted above the software is based on double precision values. For example, using an NCMA design method an allowable factor of safety of 1.5 the software may calculate a value of 1.49999999999999, since this is less than 1.5, it would be false (NG), even though the results shown is 1.50 (results are rounded to 2 places on the screen). In the design check we round to 2 decimal places to check against the suggested value (1.49999999999 rounds to 1.50). Given the precision of the calculation, this will provide a safe design even though the 'absolute' value is less than the minimum suggested.

DESIGN DATA

TARGET DESIGN VALUES (Factors of Safety)

Minimum Factor of Safety for the sliding along the base	FSsl = 1.5
Minimum Factor of Safety for overturning about the toe	FSot = 2.0
Minimum Factor of Safety for bearing (foundation shear failure)	FSbr = 2.0
	-Seismic requirements are 75% of

MINIMUM DESIGN REQUIREMENTS

Minimum embedment depth	Min_emb = 2.5 ft

INPUT DATA

Geometry

Wall Geometry

Design Height (top of leveling pad to finished grade at top of wall)	H =10.67 ft
Embedment (measured from top of leveling pad to finished grade at toe)	emb =2.50 ft
Leveling Pad Depth	LP =0.50 ft
Face Batter (measured from vertical)	i =3.6 deg

Slope Geometry

Slope Angle (back slope angle measured from horizontal)	β =0.0 deg
Slope toe offset (horiz. bench from wall to toe of slope)	STL_offset =0.0 ft
Slope Length (horiz. length from wall to top of slope)	SL_Length =0.0 ft

NOTE: If the slope toe is offset or the slope breaks within three times the wall height, a Coulomb Trial Wedge method of analysis is used.

Surcharge Loading

Live Load (assumed transient loading (e.g. traffic))	LL = 100 psf
Live Load Offset (measured from back face of wall)	LL_offset = 0.0 ft
Live Load Width (assumed strip loading)	LL_width = 100.0 ft

Soil Parameters

Reinforced Zone	
Angle of Internal Friction	φ = 34 deg
Cohesion	coh = 0.0 psf
Moist Unit Weight	gamma = 125 pcf
Retained Zone	
Angle of Internal Friction	φ = 34 deg
Cohesion	coh = 0.0 psf
Moist Unit Weight	gamma = 125 pcf
Foundation	
Angle of Internal Friction	φ = 35 deg
Cohesion	coh = 0.0 psf
Moist Unit Weight	gamma = 130 pcf

RETAINING WALL UNITS

STRUCTURAL PROPERTIES:

N is the normal force [or factored normal load] on the base unit
The default leveling pad to base unit shear is ATan(0.7), or 35 deg. or may be the manufacturer supplied data.

Table of Values:

Unit	Ht (in)	Width (in)	Depth (in)	Concr_Vol (cf/ft)	Concr_Density (pcf)	CG (in)
Cap 6.5	6.50	48.00	24.00	1.08	145.00	12.00, 3.25
Top Cap	16.00	48.00	24.00	2.01	145.00	10.68, 8.00
A-24	16.00	48.00	24.00	2.53	145.00	11.70, 8.00
B-39	16.00	48.00	39.00	3.88	145.00	18.60, 8.00
C-45	16.00	48.00	45.00	4.38	145.00	21.30, 8.00
D-60	16.00	48.00	60.00	5.53	145.00	27.60, 8.00
E-66	16.00	48.00	66.00	5.93	145.00	30.10, 8.00
F-72	16.00	48.00	72.00	6.35	145.00	32.70, 8.00
G-78	16.00	48.00	78.00	6.78	145.00	35.30, 8.00
H-84	16.00	48.00	84.00	7.20	145.00	38.00, 8.00

GEOGRID REINFORCING

STRUCTURAL PROPERTIES: Synteen

GEOGRID PROPERTIES

Name	Tult	RFcr	RFd	RFid	Ci	Cd	Alpha	LTDS
SF55	5000	1.58	1.10	1.05	0.90	0.90	0.80	2740

CONNECTION STRENGTHS

Geogrid	Grade	Tult [lb/ft]	Tult-cn Eqn	RFcr	Tlot	RFd
Synteen	SF55	5000	822 + 2 σ_n tan 32 deg	1.00	5000	1.10

SHEAR STRENGTHS

Slope 0 deg

Intercept 6775 psf

CALCULATION RESULTS

OVERVIEW

ReCon Wall Systems 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 =22.7 deg
Coefficient of active earth pressure	ka =0.230
Internal failure plane	ρ = 57.0 deg

EXTERNAL EARTH PRESSURES

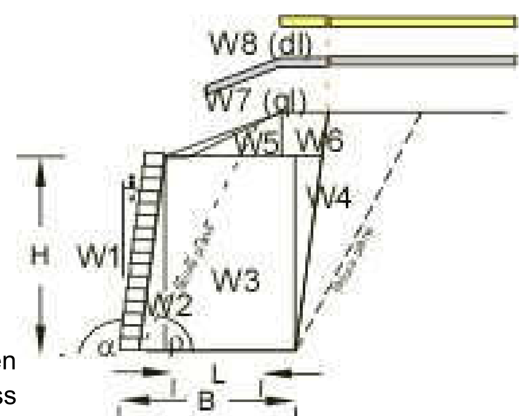
Effective external Delta angle	delta =34.00 deg
Coefficient of active earth pressure	ka =0.232
External failure plane	ρ = 55.7 deg

$$Ka := \frac{\cos(\phi_i + i)^2}{\cos(i)^2 \cdot \cos(\delta_i - i)\left(1 + \sqrt{\frac{\sin(\phi_i + \delta_i)\cdot\sin(\phi_i - \beta)}{\cos(\delta_i - i)\cdot\cos(i + \beta)}}\right)^2}$$

FORCES AND MOMENTS

ReCon Wall Systems 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	2854	--	1.25	--	--	3573
Soil Fill(W0)	1.00	205	--	1.79	--	--	367
Soil(W2)	1.00	343	--	2.39	--	--	820
Soil(W3)	1.00	8553	--	5.79	--	--	49553
Soil(W4)	1.00	448	--	9.22	--	--	4129
LL(W7)	1.00	708	--	6.13	--	--	4342
Pa_h	1.00	--	1422	--	3.56	5056	--
Pq_h	1.00	--	213	--	5.34	1137	--
Sum (V, H)	1.00	13111	1635		Sum Mom	6193	58442



Note: live load forces and moments are not included in SumV or Mr as live loads are not included as resisting forces.

- 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: Rectang zone in broken
- W7: Live load over the mass
- W8: Dead load over the mass
- W9: Force Pa
- W10: Surcharge load Paq
- W11: Dead Load Surchage Paqd

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

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)	
13111 - 205 - 2854 - 708	SumVr = 9344 ppf
Resisting force = SumVr x tan(34) + c x L + Base Shear	Rf1 =8099
where L is the base width	
where Base Shear = N tan(40.0) * 0.8	1796.74
Driving force is the horizontal component of Pah + Pqh+ Pdh	Df = 1635
Factor of Safety = Rf/Df	FSsl =5.10

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 =58442 ft-lbs
Moments causing overturning = MPah + MPqh	Mo =6193 ft-lbs
Factor of safety = Mr/Mo	FSot =9.44 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 = L/2 - (SumMr + M7 - SumMo)/SumV

e =9.00/2 - (58442.10 + 4342.02 - 6193.25) /13110.89) e =0.184

Calculation of Bearing Pressures

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

where:

Nc =46.12

Nq =33.30

Ng =48.03

c =0.00 psf

q =312.50 psf

B' =8.63 ft

Calculate Ultimate Bearing, Qult Qult =8000.00 psf

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

sigma =1518.76 psf

Calculated Factors of Safety for Bearing Qult/sigma =5.57

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.

TABLE OF RESULTS

Elevation[ft]	Name[ft]	Ta[ppf]	Rc %	Tmax[ppf]	FS Str
9.33	SF55	1827	100	98	27.97
8.00	SF55	1827	100	206	13.27
5.33	SF55	1827	100	444	6.17
2.67	SF55	1827	100	637	4.30

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 embedement (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 liveload surcharge is not included in the Tmax value for pullout.

Failure Plane Angle = 57.0 Deg

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

F* = 0.67 x tan(phi) = 0.67 x 0.67 = 0.45
Pullout = 2 x Le x F* x sv x alpha x Coverage

TABLE OF RESULTSPeak Connection = N tan(slope) + intercept

Connection Capacity = [N tan(slope) + intercept] / RFcr
/tRFcr can be a value obtained from long-term testing or by default could be the creep reduction factor of the geogrid reinforcing.

TABLE OF RESULTS

Elevation[ft]	Ci	% Coverage	Tmax[ppf]	Le[ft]	La[ft]	Pullout_[Pr][ppf]	FS PO
9.33	0.90	100	98	2.03	7.47	411	4.20
8.00	0.90	100	206	2.31	6.69	936	4.53
5.33	0.90	100	444	3.87	5.13	3136	7.06
2.67	0.90	100	637	5.44	3.56	5000	7.85

CONNECTION CALCULATIONS

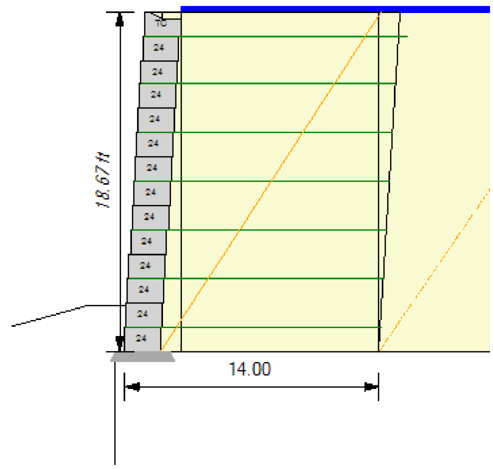
Connection is the amount of resistance of the reinforcing has to a pullout failure from the facing units based on the Tmax applied and the normal load on the units. In an AASHTO LRFD design, creep on the connection may be applied for frictional and mechanical connections. In NCMA or AASHTO 2002, a frictional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

Elev[ft]	Name	Tmax[ppf]	Rc %	N[ppf]	CRcr	Ta_cn[ppf]	FS cn
9.33	SF55	98	100	370	1053	10.75	
8.00	SF55	206	100	754	1293	6.27	
5.33	SF55	444	100	1522	1773	3.99	
2.67	SF55	637	100	2291	2253	3.54	

ReCon Wall

Version: 4.0.17187.1304



Project: 21 Eastman, Somerville, MA
Location: 21 Eastman, Somerville, MA
Designer: CM Kirby Engineering, PLLC
Date: 9/10/2018
Section: Section 3
Design Method: NCMA_09_3rd_Ed, Ignore Vert. Force
Design Unit: ReCon Series 50 A-24

SOIL PARAMETERS	φ	coh	γ
Reinforced Soil:	34 deg	0 psf	125 pcf
Retained Soil:	34 deg	0 psf	125 pcf
Foundation Soil:	35 deg	0 psf	130 pcf

Leveling Pad: Crushed Stone

GEOMETRY

Design Height:	18.67 ft	Live Load:	100 psf
Wall Batter/Tilt:	3.60/ 0.00 deg	Live Load Offset:	0.00 ft
Embedment:	2.50 ft	LL2 Width:	100 ft
Leveling Pad Depth:	0.50 ft	Dead Load:	0 psf
Slope Angle:	0.0 deg	Dead Load Offset:	0.0 ft
Slope Length:	0.0 ft	Dead Load Width:	100 ft
Slope Toe Offset:	0.0 ft		
Vertical δ on Single Depth		Toe Slope Angle:	15.00
		Toe Slope Length:	100.00
		Toe Slope Bench:	2.00

FACTORS OF SAFETY

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

RESULTS

FoS Sliding:	4.67	FoS Overturning:	8.14
Bearing	2609	FoS Bearing:	3.18
Total Pullout	27539	FoS Total Pullout	5.72
Top FoSot:	14.82	FoS Connection:	2.78

ID	Height	Length	Geogrid.	Tallow	% Cvrg	EP (Pa)	LL (Pql)	DL (Pqd)	TMax	FS Str	Tal Cn	FS Pk Cn	FS PO/[Tmax]	FS Sldg [fndn]	Grid Embed
7	17.33	14.5	SF55	1827	100	97	58	0	155	17.71	702	6.81	3.06/[155]	100.00	2.34
6	14.67	14	SF55	1827	100	290	58	0	348	7.88	1022	4.41	5.94/[348]	48.02	3.40
5	12	14	SF55	1827	100	483	58	0	541	5.07	1342	3.72	9.25/[541]	23.19	4.96
4	9.33	14	SF55	1827	100	676	58	0	734	3.74	1662	3.40	6.82/[734]	14.58	6.53
3	6.67	14	SF55	1827	100	869	58	0	927	2.96	1770	2.87	5.40/[927]	10.45	8.09
2	4	14	SF55	1827	100	1062	58	0	1120	2.45	1779	2.38	4.47/[1120]	8.09	9.65
1	1.33	14	SF55	1827	100	923	43	0	966	2.84	1788	2.78	5.17/[966]	6.60 [4.82]	11.22

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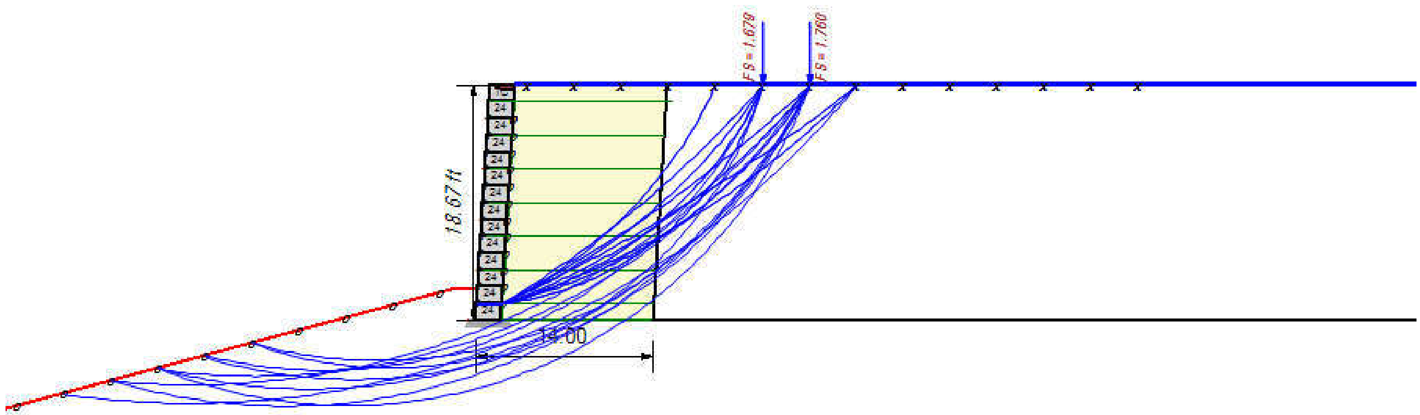
ID	Height	Length	Geogrid.	Tallow	% Cvrg	EP (Pa)	LL (Pql)	DL (Pqd)	TMax	FS Str	Tal Cn	FS Pk Cn	FS PO/[Tmax]	FS Sldg [fndn]	Grid Embed



COMPOUND RESULTS

Compound stability is a global analysis (Bishop) with the failure planes originating at the top of the slope / wall and exiting out through the face of the wall. For MSE walls, the resistance of the geogrid reinforcement is included in the analysis and the shear resistance of the face units is included.

ID	Enter Point X	Enter Point Y	Exit Point X	Exit Point Y	Center X	Center Y	Radius	FoS
2	26.49	18.67	2.08	1.33	-50.31	100.95	112.56	1.760
3	22.76	18.67	2.08	1.33	-16.17	44.11	46.51	1.762
2	22.76	18.67	2.08	1.33	-45.73	79.36	91.51	1.771
3	26.49	18.67	2.08	1.33	-17.57	54.87	57.03	1.772
4	26.49	18.67	2.08	1.33	-6.47	39.23	38.85	1.782
3	30.23	18.67	2.08	1.33	-19.14	67.30	69.29	1.805
4	22.76	18.67	2.08	1.33	-6.11	32.10	31.84	1.820
3	19.03	18.67	2.08	1.33	-15.00	34.97	37.73	1.825
2	30.23	18.67	2.08	1.33	-55.22	125.87	137.09	1.841
5	22.76	18.67	2.08	1.33	-0.91	25.90	24.75	1.855

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 analysis. 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
3	22.76	18.67	-21.51	-2.73	-12.03	34.16	38.08	1.679
4	26.49	18.67	-25.25	-3.73	-13.18	39.35	44.74	1.690
3	30.23	18.67	-32.71	-5.73	-22.49	61.29	67.79	1.693
3	26.49	18.67	-17.78	-1.73	-7.57	34.36	37.50	1.699
6	26.49	18.67	-25.25	-3.73	-10.15	32.35	39.11	1.702
5	26.49	18.67	-28.98	-4.73	-15.12	39.86	46.69	1.703
2	26.49	18.67	-25.25	-3.73	-17.52	49.38	53.67	1.704
4	22.76	18.67	-17.78	-1.73	-6.83	27.00	30.74	1.707
1	26.49	18.67	-28.98	-4.73	-22.67	57.77	62.82	1.709
4	26.49	18.67	-21.51	-2.73	-9.53	34.94	39.53	1.710

NOTES ON DESIGN UNITS

The wall section is designed on a 'per unit width bases' (lb/ft/ft of wall or kN/m/meter of wall). In the calculations the software shows lb/ft or kN/m, neglecting the unit width factor for simplicity.

The weights for the wall unit are shown as lbs / ft3 (kN / m3). For SRW design a 1 sf unit is typically 1 ft deep, 1.5 ft wide and 8 inches tall (or 1 ft3). therefore a typical value of 120 pcf is shown. With larger units the unit weight will vary with the size of the unit. Say we have 4 ft wide unit, 1.5 ft tall and 24 inches deep with a tapered shape (sides narrow), built with 150 pcf concrete. We add up the concrete, the gravel fill and divide by the volume and and the results may come out to 140 pcf, as shown in the table. The units with more gravel may have lower effective unit weights based on the calculations.

Hollow Units

Hollow units with gravel fill are treated differently in AASHTO. If the fill can fall out as the unit is lifted, then AASHTO only allows 80% of the weight of the fill to be used for eccentricity (overturning calculations). In the properties page for the units the weight of the concrete may be as low as 75 pcf. This is the effective unit weight of the concrete only (e.g. the weight of the concrete divided by the volume of the unit). The density of the concrete maybe 150 pcf, but not the effective weight including the volume of the void spaces used for gravel fill.

Rounding Errors

When doing hand calculations the values may vary from the values shown in the software. The program is designed using double precision values (64 bit precision: 14 decimal places). Over several calculations the results may differ from the single calculation the user is making, probably inputting one or two already rounded values.

Result Rounding

As noted above the software is based on double precision values. For example, using an NCMA design method an allowable factor of safety of 1.5 the software may calculate a value of 1.49999999999999, since this is less than 1.5, it would be false (NG), even though the results shown is 1.50 (results are rounded to 2 places on the screen). In the design check we round to 2 decimal places to check against the suggested value (1.49999999999 rounds to 1.50). Given the precision of the calculation, this will provide a safe design even though the 'absolute' value is less than the minimum suggested.

DESIGN DATA

TARGET DESIGN VALUES (Factors of Safety)

Minimum Factor of Safety for the sliding along the base	FSsl = 1.5
Minimum Factor of Safety for overturning about the toe	FSot = 2.0
Minimum Factor of Safety for bearing (foundation shear failure)	FSbr = 2.0
	-Seismic requirements are 75% of

MINIMUM DESIGN REQUIREMENTS

Minimum embedment depth	Min_emb = 2.5 ft

INPUT DATA

Geometry

Wall Geometry

Design Height (top of leveling pad to finished grade at top of wall)	H =18.67 ft
Embedment (measured from top of leveling pad to finished grade at toe)	emb =2.50 ft
Leveling Pad Depth	LP =0.50 ft
Face Batter (measured from vertical)	i =3.6 deg

Slope Geometry

Slope Angle (back slope angle measured from horizontal)	β =0.0 deg
Slope toe offset (horiz. bench from wall to toe of slope)	STL_offset =0.0 ft
Slope Length (horiz. length from wall to top of slope)	SL_Length =0.0 ft

NOTE: If the slope toe is offset or the slope breaks within three times the wall height, a Coulomb Trial Wedge method of analysis is used.

Surcharge Loading

Live Load (assumed transient loading (e.g. traffic))	LL = 100 psf
Live Load Offset (measured from back face of wall)	LL_offset = 0.0 ft
Live Load Width (assumed strip loading)	LL_width = 100.0 ft

Soil Parameters

Reinforced Zone

Angle of Internal Friction	φ = 34 deg
Cohesion	coh = 0.0 psf
Moist Unit Weight	gamma = 125 pcf

Retained Zone

Angle of Internal Friction	φ = 34 deg
Cohesion	coh = 0.0 psf
Moist Unit Weight	gamma = 125 pcf

Foundation

Angle of Internal Friction	φ = 35 deg
Cohesion	coh = 0.0 psf
Moist Unit Weight	gamma = 130 pcf

RETAINING WALL UNITS

STRUCTURAL PROPERTIES:

N is the normal force [or factored normal load] on the base unit
The default leveling pad to base unit shear is ATan(0.7), or 35 deg. or may be the manufacturer supplied data.

Table of Values:

Unit	Ht (in)	Width (in)	Depth (in)	Concr_Vol (cf/ft)	Concr_Density (pcf)	CG (in)
Cap 6.5	6.50	48.00	24.00	1.08	145.00	12.00, 3.25
Top Cap	16.00	48.00	24.00	2.01	145.00	10.68, 8.00
A-24	16.00	48.00	24.00	2.53	145.00	11.70, 8.00
B-39	16.00	48.00	39.00	3.88	145.00	18.60, 8.00
C-45	16.00	48.00	45.00	4.38	145.00	21.30, 8.00
D-60	16.00	48.00	60.00	5.53	145.00	27.60, 8.00
E-66	16.00	48.00	66.00	5.93	145.00	30.10, 8.00
F-72	16.00	48.00	72.00	6.35	145.00	32.70, 8.00
G-78	16.00	48.00	78.00	6.78	145.00	35.30, 8.00
H-84	16.00	48.00	84.00	7.20	145.00	38.00, 8.00

GEOGRID REINFORCING

STRUCTURAL PROPERTIES: Synteen

GEOGRID PROPERTIES

Name	Tult	RFcr	RFd	RFid	Ci	Cd	Alpha	LTDS
SF55	5000	1.58	1.10	1.05	0.90	0.90	0.80	2740

CONNECTION STRENGTHS

Geogrid	Grade	Tult [lb/ft]	Tult-cn Eqn	RFcr	Tlot	RFd
Synteen	SF55	5000	822 + 2 σ_n tan 32 deg	1.00	5000	1.10

SHEAR STRENGTHS

Slope 0 deg

Intercept 6775 psf

CALCULATION RESULTS

OVERVIEW

ReCon Wall Systems 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 =22.7 deg
Coefficient of active earth pressure	ka =0.230
Internal failure plane	ρ = 57.0 deg

EXTERNAL EARTH PRESSURES

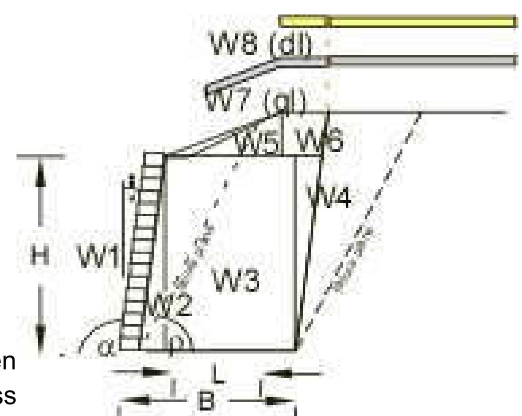
Effective external Delta angle	delta =34.00 deg
Coefficient of active earth pressure	ka =0.232
External failure plane	ρ = 55.7 deg

$$Ka := \frac{\cos(\phi_i + i)^2}{\cos(i)^2 \cdot \cos(\delta_i - i)\left(1 + \sqrt{\frac{\sin(\phi_i + \delta_i)\cdot\sin(\phi_i - \beta)}{\cos(\delta_i - i)\cdot\cos(i + \beta)}}\right)^2}$$

FORCES AND MOMENTS

ReCon Wall Systems 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	5051	--	1.51	--	--	7612
Soil Fill(W0)	1.00	313	--	2.07	--	--	649
Soil(W2)	1.00	1182	--	2.73	--	--	3223
Soil(W3)	1.00	25460	--	8.55	--	--	217562
Soil(W4)	1.00	1371	--	14.39	--	--	19725
LL(W7)	1.00	1208	--	9.13	--	--	11036
Pa_h	1.00	--	4352	--	6.22	27086	--
Pq_h	1.00	--	373	--	9.34	3482	--
Sum (V, H)	1.00	34585	4725		Sum Mom	30568	248772



Note: live load forces and moments are not included in SumV or Mr as live loads are not included as resisting forces.

- 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: Rectang zone in broken
- W7: Live load over the mass
- W8: Dead load over the mass
- W9: Force Pa
- W10: Surcharge load Paq
- W11: Dead Load Surchage Paqd

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)	
34585 - 313 - 5051 - 1208	SumVr = 28012 ppf
Resisting force = SumVr x tan(34) + c x L + Base Shear	Rf1 =22045
where L is the base width	
where Base Shear = N tan(40.0) * 0.8	3150.48
Driving force is the horizontal component of Pah + Pqh+ Pdh	Df = 4725
Factor of Safety = Rf/Df	FSsl =4.82

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 =248772 ft-lbs
Moments causing overturning = MPah + MPqh	Mo =30568 ft-lbs
Factor of safety = Mr/Mo	FSot =8.14 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 = L/2 - (SumMr + M7 - SumMo)/SumV

e =14.00/2 - (248772.16 + 11035.88 - 30568.05) /34584.60) e =0.372

Calculation of Bearing Pressures

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

where:

Nc =46.12

Nq =33.30

Ng =48.03

c =0.00 psf

q =312.50 psf

B' =13.26 ft

Calculate Ultimate Bearing, Qult Qult =8000.00 psf

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

sigma =2608.83 psf

Calculated Factors of Safety for Bearing Qult/sigma =3.18

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.

TABLE OF RESULTS

Elevation[ft]	Name[ft]	Ta[ppf]	Rc %	Tmax[ppf]	FS Str
17.33	SF55	1827	100	155	17.71
14.67	SF55	1827	100	348	7.88
12.00	SF55	1827	100	541	5.07
9.33	SF55	1827	100	734	3.74
6.67	SF55	1827	100	927	2.96
4.00	SF55	1827	100	1120	2.45
1.33	SF55	1827	100	966	2.84

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 embedement (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 liveload surcharge is not included in the Tmax value for pullout.

Failure Plane Angle = 57.0 Deg

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

F* = 0.67 x tan(phi) = 0.67 x 0.67 = 0.45
Pullout = 2 x Le x F* x sv x alpha x Coverage

TABLE OF RESULTSPeak Connection = N tan(slope) + intercept

Connection Capacity = [N tan(slope) + intercept] / RFcr
/tRFcr can be a value obtained from long-term testing or by default could be the creep reduction factor of the geogrid reinforcing.

TABLE OF RESULTS

Elevation[ft]	Ci	% Coverage	Tmax[ppf]	Le[ft]	La[ft]	Pullout_[Pr][ppf]	FS PO
17.33	0.90	100	155	2.34	12.16	474	3.06
14.67	0.90	100	348	3.40	10.60	2065	5.94
12.00	0.90	100	541	4.96	9.04	5000	9.25
9.33	0.90	100	734	6.53	7.47	5000	6.82
6.67	0.90	100	927	8.09	5.91	5000	5.40
4.00	0.90	100	1120	9.65	4.35	5000	4.47
1.33	0.90	100	966	11.22	2.78	5000	5.17

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 ConnectionRupture Connection

Elev[ft]	Name	Tmax[ppf]	Rc %	N[ppf]	CRcr	Ta_cn[ppf]	FS cn
17.33	SF55	155	100	370	1053	6.81	
14.67	SF55	348	100	1138	1533	4.41	
12.00	SF55	541	100	1907	2013	3.72	
9.33	SF55	734	100	2675	2493	3.40	
6.67	SF55	927	100	3443	2655	2.87	
4.00	SF55	1120	100	4211	2669	2.38	
1.33	SF55	966	100	4980	2682	2.78	