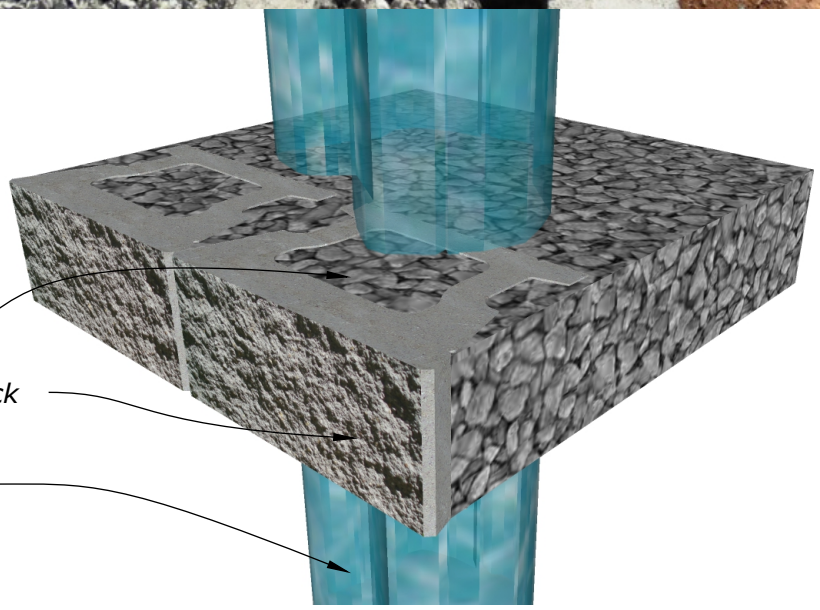
CornerStone100™
by CORNERSTONE®

CornerStone 100 Permeable Concrete



Permeable Concrete

No Fines concrete was developed as an alternative to standard Concrete Masonry Units (CMU) and geogrid reinforced retaining walls. With No-fines permeable concrete the retaining wall blocks and concrete become one porous mass eliminating the need for costly rebar and geogrids which can demand a lot of excavation and backfilling.
The No-Fines concrete by itself is a permeable concrete that is made by removing the fine aggregates in concrete. Removing the fines adds significant voids within the concrete giving it a permeable structure.
No-fines concrete can reduces the amount of excavation by nearly 30%

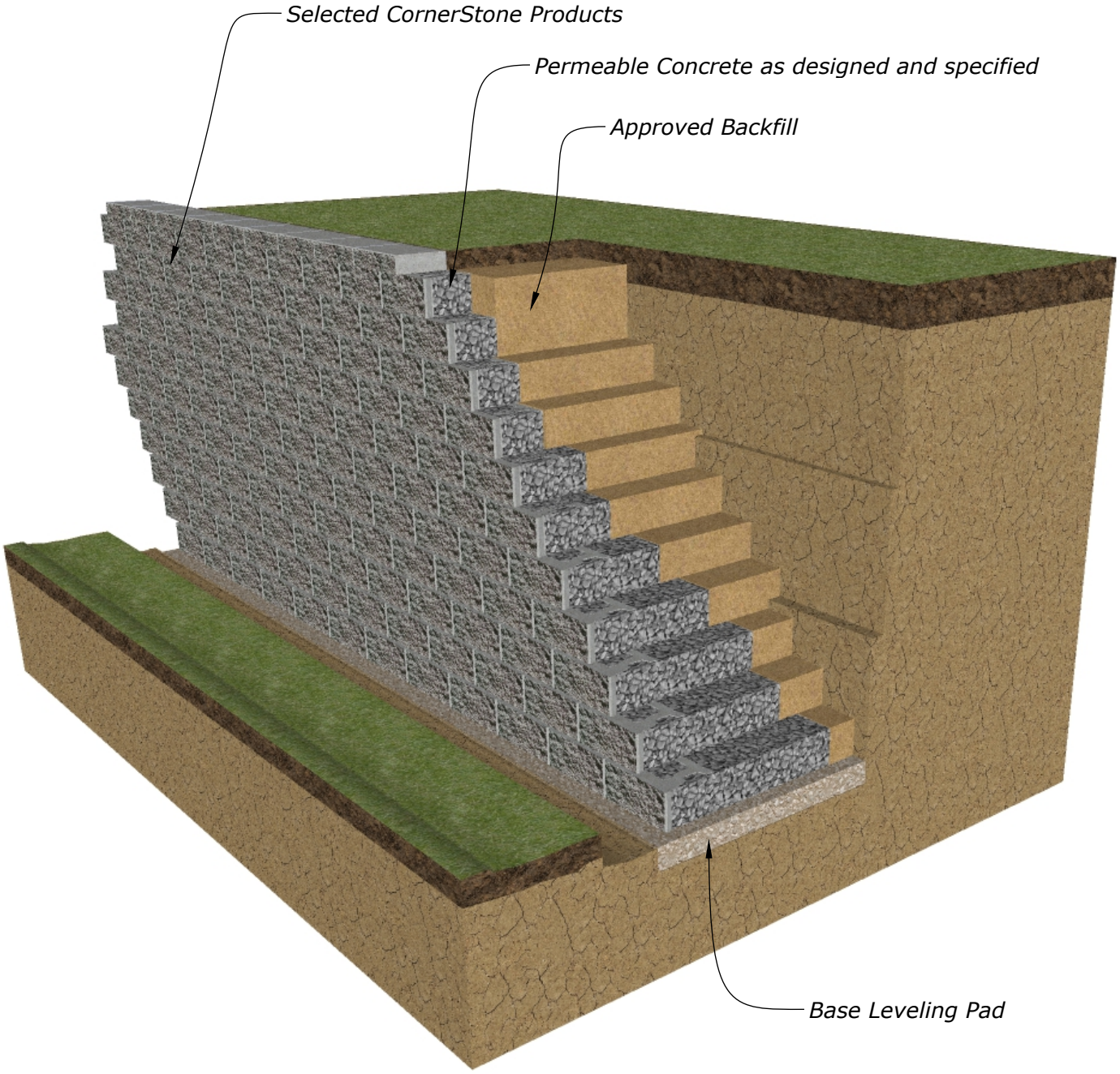
Advantages

- Less excavation required by contractor saving time and money
- No compaction or testing for backfilling the retaining wall
- Eliminating the drainage layer
- Your retaining wall acts as one mass
- The whole wall will be permeable never allowing water to settle into the backfill
- Increase your property as it is the most valuable investment
- The concrete is light weight
- No geogrids required

Typical Mix Design

- Portland Cement, Type 1 or II, ASTM C150
- No. 57 or No. 6 stone or equivalent, ASTM C33
- Aggregate/Cement Ratio: Approx 6:1 by weight
- Water/Cement Ratio: 0.35 to 0.45 by weight
- In-place Void Ratio : 20% - 30%
- In-place Unit Weight: 110 to 130 lbs/cf
- Compressive Strength: 2,000 psi nominally @ 28 days

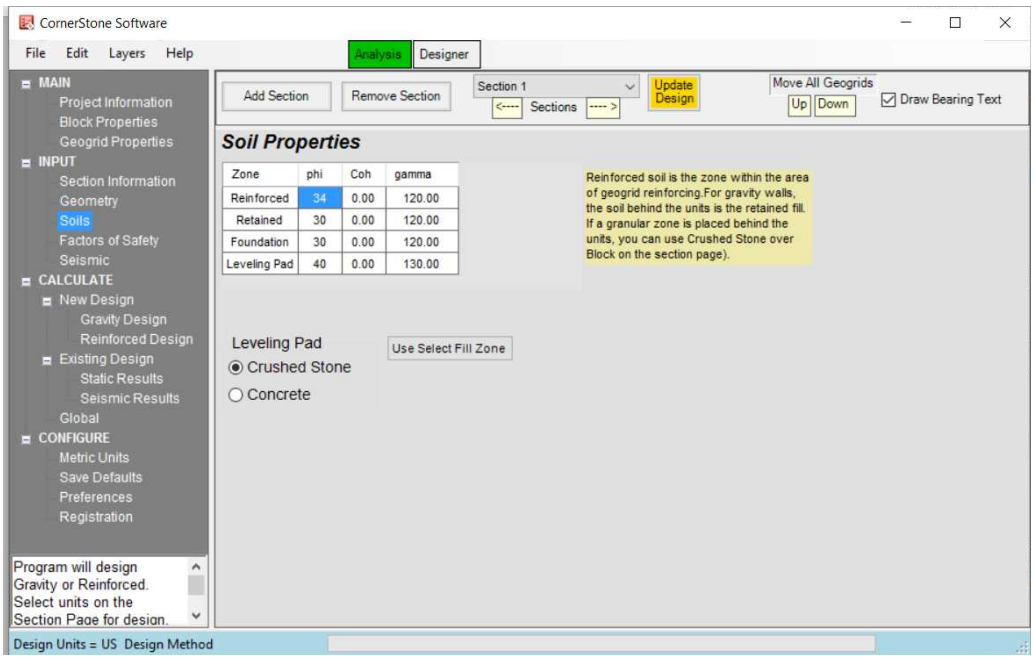
This mix design is given as a guide. A local concrete ready mix supplier should be consulted based on local materials and strengths.



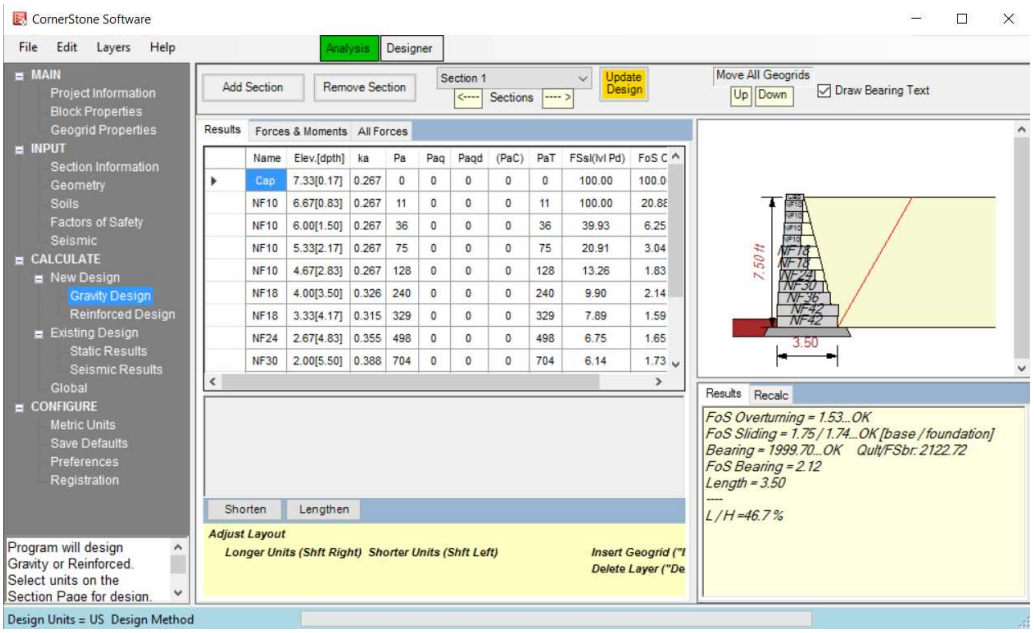
CornerStone Wall Designer

In the following pages we have completed a sample design analysis using CornerStone Wall Designer engineering program.

For preliminary design purposes we have used certain design assumptions



Soils information used for Analysis



Gravity Analysis using no fines concrete

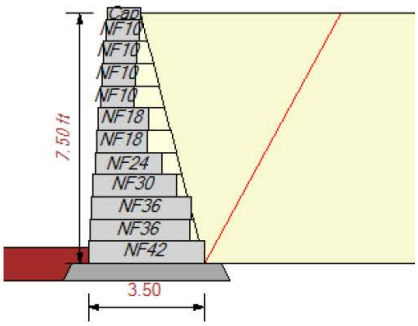
Gravity Analysis using permeable concrete - Output

CORNERSTONE WALLDESIGNER

REAWall

Version: 4.0.16099

Project:	No Fines Concrete Sample Section
Location:	Site Location
Designer:	xxx
Date:	5/13/2016
Section:	Section 1
Design Method:	NCMA_09_3rd_Ed
Design Unit:	CornerStone_NF



SOIL PARAMETERS	φ	coh	γ
Retained Soil:	32 deg	0 psf	120 pcf
Foundation Soil:	32 deg	0 psf	120 pcf
Leveling Pad:	40 deg	0 psf	130 pcf
	Crushed Stone		

GEOMETRY

Design Height:	7.50 ft	Live Load:	0 psf
Wall Batter/Tilt:	4.47/ 0.00 deg	Live Load Offset:	0.00 ft
Embedment:	0.50 ft	Live Load 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	Leveling Pad Width:	4.50 ft
Vertical δ on Single Depth			

FACTORS OF SAFETY

Sliding:	1.50	Overturning:	1.50
Bearing:	2.00		

RESULTS

FoS Sliding:	1.85 (lvlpd)	FoS Overturning:	1.56
Bearing:	1813.82	FoS Bearing:	3.19

Name	Elev.[dpth]	ka	Pa	Paq	Paqd	(PaC)	PaT	FSsl(lvl Pd)	FoS OT	%D/H
Cap	7.33[0.17]	0.245	0	0	0	0	0	100.00	100.00	300%
NF10	6.67[0.83]	0.245	10	0	0	0	10	100.00	22.92	120%
NF10	6.00[1.50]	0.245	33	0	0	0	33	43.84	6.86	67%
NF10	5.33[2.17]	0.245	69	0	0	0	69	22.96	3.34	46%
NF10	4.67[2.83]	0.245	118	0	0	0	118	14.56	2.00	35%
NF18	4.00[3.50]	0.304	224	0	0	0	224	10.73	2.32	43%
NF18	3.33[4.17]	0.294	306	0	0	0	306	8.57	1.72	36%
NF24	2.67[4.83]	0.333	467	0	0	0	467	7.28	1.78	41%
NF30	2.00[5.50]	0.366	665	0	0	0	665	6.59	1.85	45%
NF36	1.33[6.17]	0.394	899	0	0	0	899	6.18	1.91	49%
NF36	0.67[6.83]	0.377	1055	0	0	0	1055	5.62	1.56	44%
NF42	0.00[7.50]	0.399	1346	0	0	0	1346	1.85 (2.01)	1.64	47%

Gravity Analysis using permeable concrete - Output

CORNERSTONE WALLDESIGNER

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 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.

Gravity Analysis using permeable concrete - Output

CORNERSTONE WALLDESIGNER

DESIGN DATA

TARGET DESIGN VALUES (Factors of Safety)

Minimum Factor of Safety for the sliding along the base	FSsl =1.50
Minimum Factor of Safety for overturning about the toe	FSot =1.50
Minimum Factor of Safety for bearing (foundation shear failure)	FSbr =2.00

MINIMUM DESIGN REQUIREMENTS

Minimum embedment depth	Min_emb =0.50 ft

INPUT DATA

Geometry

Wall Geometry

Design Height, top of leveling pad to finished grade at top of wall	H =7.50 ft
Embedment, measured from top of leveling pad to finished grade	emb =0.50 ft
Leveling Pad Depth	LP Thickeness =0.50 ft
Face Batter, measured from vertical	i =4.47 deg

Slope Geometry

Slope Angle, measured from horizontal	β =0.00 deg
Slope toe offset, measured from back of the face unit	STL_offset =0.00 ft
Slope Length, measured from back of wall facing	SL_Length =0.00 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 = 0.00 psf
Live Load Offset, measured from back face of wall	LL_offset =0.00 ft
Live Load Width, assumed strip loading	LL_width = 100.00 ft
Dead Load, assumed permanent loading (e.g. buildings)	DL = 0.00 psf
Dead Load Offset, measured from back face of wall	DL_offset =0.00 ft
Dead Load Width, assumed strip loading	DL_width = 100.00 ft

Soil Parameters

Retained Zone

Angle of Internal Friction	φ = 32.00 deg
Cohesion	coh =0.00 psf
Moist Unit Weight	gamma =120.00 pcf

Foundation

Angle of Internal Friction	φ = 32.00 deg
Cohesion	coh =0.00 psf
Moist Unit Weight	gamma =120.00 pcf

Gravity Analysis using permeable concrete - Output

CORNERSTONE WALLDESIGNER

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 0.8 tan(φ) or
may be the manufacturer supplied data. φ is assumed to be 40 degrees for a stone leveling pad.

Table of Values:

Unit	Ht (in)	Width (in)	Depth (in)	Equiv_Density (pcf)	Equiv_CG (in)
Cap	4.00	18.00	12.00	120.00	6.00
CS_100	8.00	18.00	12.00	120.00	6.00
CS_118	8.00	18.00	18.00	120.00	6.00
CS_124	8.00	18.00	24.00	120.00	6.00
CS_130	8.00	18.00	30.00	120.00	6.00
CS_136	8.00	18.00	36.00	120.00	6.00
CS_142	8.00	18.00	42.00	120.00	6.00

Gravity Analysis using permeable concrete - Output

CORNERSTONE WALLDESIGNER

FORCE DETAILS

The details below shown how the forces and moments are calculated for each force component. The values shown are not factored. All loads are based on a unit width (ppf / kNpm).

Layer	Block Wt	X-Arm	Moment	Soil Wt	X-Arm	Moment
1	40.00	1.07	42.93	0.43	1.59	0.68
2	80.00	1.02	81.69	14.45	1.62	23.38
3	80.00	0.97	77.52	32.32	1.67	54.10
4	80.00	0.92	73.35	50.19	1.73	86.95
5	80.00	0.86	69.19	68.06	1.79	121.93
6	120.00	0.81	97.52	45.93	2.10	96.53
7	120.00	0.76	91.27	63.80	2.16	137.86
8	160.00	0.71	113.35	41.67	2.47	102.97
9	200.00	0.66	131.27	19.54	2.78	54.38
10	240.00	0.60	145.02	0.66	3.12	2.07
11	240.00	0.55	132.51	15.28	3.15	48.19
12	280.00	0.50	140.00			

Block Weight (Force v) = block: 1720 X-Arm = 0.70 ft
Soils Block Weight (Force v) = 352 ppf X-Arm = 2.07 ft

Active Earth Pressure Pa = 1346 ppf
Pa_h (Force H) = Pa cos(batter + δ) = 1346 x cos(14.4 + 24.0) = 1054 ppf
Y-Arm = 2.50 ft
Pa_v (Force V) = Pa sin(batter + δ) = 1346 x sin(14.4 + 24.0) = 836 ppf
X-Arm = 2.86 ft

Passive Earth Pressures
Passive earth pressures are used for resistance of the Leveling Pad, but may be extended upward to assist with the resistance of the wall facing for walls that have deep embedments.

Passive Earth Pressure:
kp = 3.25
Pp = 146.46 ppf

Gravity Analysis using permeable concrete - Output

CORNERSTONE WALLDESIGNER

CALCULATION RESULTS

OVERVIEW

CornerStone 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 is used in the calculations. The concrete units and granular fill over the blocks 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 δ angle is δ minus the wall batter at the back face. If the slope breaks within the failure zone, a trial wedge method of analysis is used.

EXTERNAL EARTH PRESSURES

Effective δ angle (3/4 retained phi)	δ =24.0 deg
Coefficient of active earth pressure	ka =0.399
External failure plane	ρ = 61 deg
Effective Angle from horizontal	Eff. Angle =75.59 deg
Coefficient of passive earth pressure: kp = (1 + sin(φ)) / (1 - sin(φ))	kp =3.25

W0: stone within units
W1: facing units
W2: stone over the tails
W9: Driving force Pa
W10: Driving Surcharge load Paq
W11: Driving Dead Load Surchage Paqd

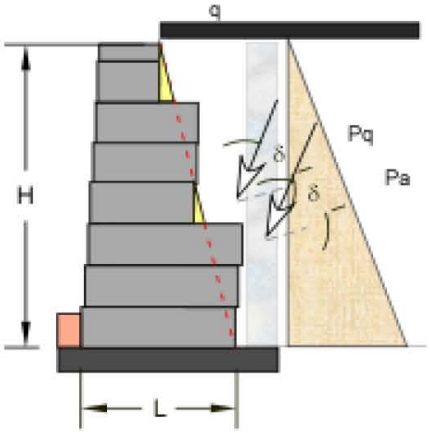
FORCES AND MOMENTS

The program 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 of the base block.

UNFACTORED LOADS

Name	Factor γ	Force (V)	Force (H)	X-len	Y-len	Mo	Mr
Face Blocks(W1)	1.00	1720	--	0.70	--	--	1196
Soil Wedge(W2)	1.00	352	--	2.07	--	--	729
LvlPad(W18)	1.00	244	--	--	--	--	--
Pa_h	1.00	--	1054	--	2.50	2636	--
Pa_v	1.00	836	--	2.86	--	--	2389
Sum V / H	1.00	3152	1054		Sum Mom	2636	4314

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



Gravity Analysis using permeable concrete - Output

CORNERSTONE WALLDESIGNER

BASE SLIDING

Sliding at the base is checked at the block to leveling pad interface between the base block and the leveling pad. Sliding is also checked between the leveling pad and the foundation soils.

Forces Resisting sliding = W1 + W2 + Pav	
1720 + 352 + 836	N =2908 ppf
Resisting force at pad = N tan(slope) + intercept x L	
2908 x tan(33.9) + 0.0 x 3.5	Rf1 =1952
where L is the base block width	
Friction angle is the lesser of the leveling pad and Fnd	φ =32.00 deg
N1 includes N (the leveling pad) + leveling pad (LP)	
2908 + 244	N1 = 3152 ppf
Passive resistance is calculated using kp = (1 + sin(32))/(1 - sin(32))	kp = 3.25
Pressure at top of resisting trapezoid, d1 = 0.50	Fp1 = 195.28
Pressure at base of resisting trapezoid, d2 = 0.50	Fp2 = 195.28
Depth of trapezoid	depth = 0.00
Pp = (Fp1 + Fp2) / 2 * depth	146.46
Resisting force at fnd = (N1 tan(phi) + c L) + Pp	
3152 x tan(32) + 0 x 3.8 + 146	Rf2 = 2116
where LP = lvl pad thickness * 130pcf * (L + lvl pad thickness/2)	
Driving force is the horizontal component of Pah	
1054	Df =1054
FSsl = Rf / Df	FSsl =1.85 / 2.01

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Gravity Analysis using permeable concrete - Output

CORNERSTONE WALLDESIGNER

OVERTURNING ABOUT THE TOE

Overturning at the base is checked by assuming rotation about the front toe by the block mass and the soil retained on the blocks. Allowable overturning can be defined by eccentricity (e/L). For concrete leveling pads eccentricity is checked at the base of the pad.

Moments resisting eccentricity = M1 + M2 + MLvlPad + MPav
1196 + 729 + 2389 — Mr =4314 ft-lbs

Moments causing eccentricity = MPah + MPq
2636 — Mo =2636 ft-lbs

e = L/2 - (Mr - Mo)/ N1
e =3.50/2 - (4314 - 2636) /3152 — e =1.17
e/L = 0.34

FSot = Mr / Mo
FSot =4314 / 2636 — FSot =1.64

Gravity Analysis using permeable concrete - Output

CORNERSTONE WALLDESIGNER

ECCENTRICITY AND BEARING

Eccentricity is the calculation of the distance of the resultant away from the centroid of mass. In wall design the eccentricity is used to calculate an effective footing width.

Calculation of Eccentricity

SumV = (W1 + W2 + Pa_v)

e = L/2 - (SumMr - SumMo)/(SumV)

e =3.50/2 - (1678 /2908.22) e =1.173 ft

Calculation of Bearing Pressures

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

where:

Nc =35.49

Nq =23.18

Ng =30.21

c =0.00 psf

q = 120.00 psf

B' = B - 2e + lvlpad = 1.65 ft

Gamma(LP) =130 pcf

Calculate Ultimate Bearing, Qult	Qult =5779 psf
Bearing Pressure = (SumVert / B') + ((2B + LP depth)/2 * LP depth * gamma)	sigma =1813.82 psf
Calculated Factors of Safety for Bearing	Qult/sigma =3.19