Hand Calculation

Problem Statement:

Design a cantilevered retaining wall and footing are adequate for the following conditions:

Governing Code : IBC 2024
Referenced Design Standard(s) : ACI 318-19

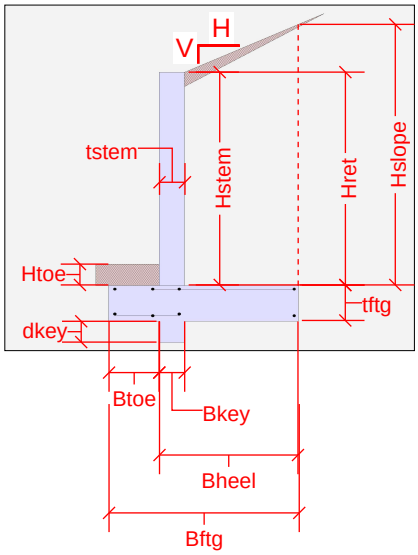
Criteria

Retained Height, H_{ret}	=	10.00 ft
~~Wall height above soil~~	=	~~0.00 ft~~
Slope Behind Wall, H:V	=	2:1
Height of Soil over Toe, H_{toe}	=	12.00 in
~~Water table above bottom of footing~~	=	~~0.0 ft~~

H_{slope} = 12.25 ft

Soil Data

Allow Soil Bearing, q_{allow}	=	3,000.0 psf
~~Equivalent Fluid Pressure Method~~		
Active Heel Pressure, P_a	=	45.0 psf/ft
	=	
Passive Pressure, P_p	=	389.0 psf/ft
Soil Density, Heel, γ_{heel}	=	110.00 pcf
Soil Density, Toe, γ_{toe}	=	110.00 pcf
Footing||Soil Friction, μ	=	0.400
Soil height to ignore for passive pressure, H_{ignore}	=	12.00 in



Footing & Stem Dimensions:

Footing Thickness, t_{ftg} = 1.67 ft
Footing Width, B_{ftg} = 7.50 ft
Toe Width, B_{toe} = 2.00 ft
Heel Width, B_{heel} = 5.50 ft
Key Width, B_{key} = 1.00 ft
Key Depth, d_{key} = 1.00 ft

Stem Height, H_{stem} = 10.00 ft
Stem Thickness, t_{stem} = 1.00 ft

Concrete Data:

Concrete Compressive Strength, f'c = 2,500 psi
Rebar Yield Strength, fy = 60 ksi
Concrete Density, γ_{conc} = 150 pcf

Service Level Load Factors
(Used for overturning, sliding, and soil pressure calculations):

Dead Load "D" = 1.0
Live Load "L" = 1.0
Earth Load "H" = 1.0
Wind Load "W" = 0.6
Seismic Load "E" = 0.7

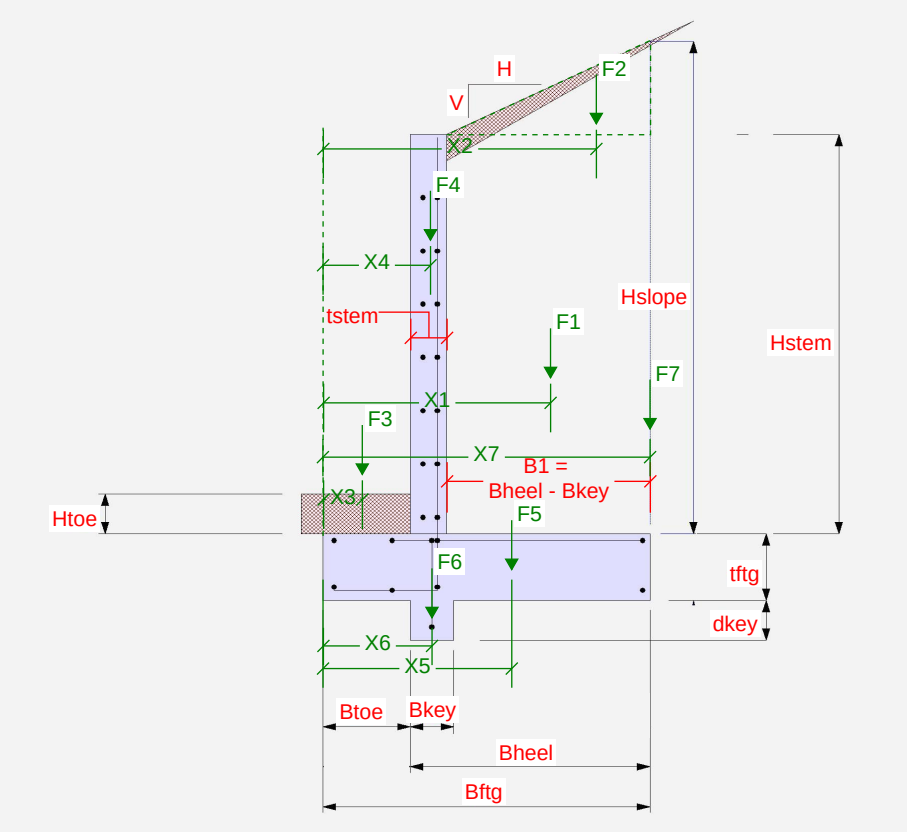
Strength Level Load Factors
(Used for concrete stem and footing calculations):

Dead Load "D" = 1.2
Live Load "L" = 1.6
Earth Load "H" = 1.6
Wind Load "W" = 1.0
Seismic Load "E" = 1.0

Hand Calculation

Solution:

Step 1: Check Soil Bearing Pressure



Resisting Moments

Item	Force (lbs)	Distance (ft)	Moment (lb-ft)
Soil Over Heel	F1 = Hstem * (B1) * γheel = 4950	x1 = Btoe + Bkey + (1/2*B1) = 5.25	F1*x1 = 25,987.5
Sloped Soil Over Heel	F2 = 1/2 * B1 * (Hslope - Hstem)* γheel = 556.9	x2 = Btoe + Bkey + (2/3*B1) = 6.0	F2*x2 = 3,341.3
Soil Over Toe	F3 = Htoe * Btoe * γtoe = 220	x3 = 1/2*Btoe	F3*x3 = 220
Stem Weight	F4 = tstem * Hstem * γconc = 1500	x4 = Btoe + (1/2*tstem) = 2.5	F4*x4 = 3750
Footing Weight	F5 = Bftg * tftg * γconc = 1875	x5 = 1/2*Bftg = 3.75	F5*x5 = 7031.25
Key Weight	F6 = Bkey * dkey * γconc = 150	x6 = Btoe + (1/2*Bkey) = 2.5	F6*x6 = 375
Vertical Component	F7	x7	F7*x7

*exclude vertical component of active lateral soil pressure from soil bearing pressure calculation

need

Overturning Moments

Item	Force (lbs)	Distance (ft)	Moment (lb-ft)
Active Pressure	Pactive = 1/2 * Pa * (Hslope + tftg) ^2 = 4357.66	ha = 1/3 * (Hslope + tftg) = 4.64	Pa*ha = 20214.68

Hand Calculation

Step 2: Stability Checks - Check Sliding

Step 3: Stability Checks - Check Overturning

Step 4: Check Stem

Step 5: Check Footing

Project Title:
Engineer:
Project ID:
Project Descr:

Cantilevered Retaining Wall

Project File: Ticket 136481_CRW - OH Prep.ec6

DESCRIPTION: CRW Verification Calculation

Code References

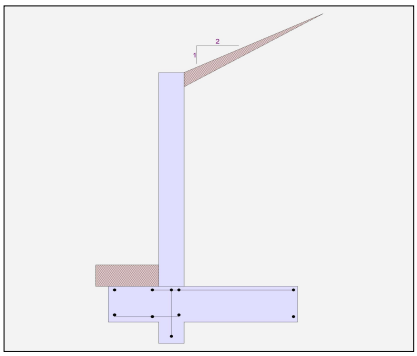
Governing Code : IBC 2024
Referenced Design Standard(s) : ACI 318-19

Criteria

Retained Height	=	10.00 ft
Wall height above soil	=	0.00 ft
Slope Behind Wall	=	2.00
Height of Soil over Toe	=	12.00 in
Water table above bottom of footing	=	0.0 ft

Soil Data

Allow Soil Bearing	=	3,000.0 psf
Equivalent Fluid Pressure Method		
Active Heel Pressure	=	45.0 psf/ft
	=	
Passive Pressure	=	389.0 psf/ft
Soil Density, Heel	=	110.00 pcf
Soil Density, Toe	=	110.00 pcf
Footing||Soil Friction	=	0.400
Soil height to ignore for passive pressure	=	12.00 in



Surcharge Loads

Surcharge Over Heel	=	0.0 psf
Used To Resist Sliding & Overturning		
Surcharge Over Toe	=	0.0
Used for Sliding & Overturning		

Axial Load Applied to Stem

Axial Dead Load	=	0.0 lbs
Axial Live Load	=	0.0 lbs
Axial Load Eccentricity	=	0.0 in

Lateral Load Applied to Stem

Lateral Load	=	0.0 #/ft
...Height to Top	=	0.00 ft
...Height to Bottom	=	0.00 ft
Load Type	=	Wind (W) (Service Level)
Wind on Exposed Stem (Strength Level)	=	0.0 psf

Adjacent Footing Load

Adjacent Footing Load	=	0.0 lbs
Footing Width	=	0.00 ft
Eccentricity	=	0.00 in
Wall to Ftg CL Dist	=	0.00 ft
Footing Type		Line Load
Base Above/Below Soil at Back of Wall	=	0.000 ft
Poisson's Ratio	=	0.300

Design Summary

Wall Stability Ratios

Overturning	=	2.78	OK
Sliding	=	1.59	OK
Global Stability	=	2.00	

Total Bearing Load	=	11,308 lbs	
...resultant ecc.	=	18.42 in	
Eccentricity outside middle third			
Soil Pressure @ Toe	=	2,785 psf	OK
Soil Pressure @ Heel	=	0 psf	OK
Allowable	=	3,000 psf	
Soil Pressure Less Than Allowable			
ACI Factored @ Toe	=	3,899 psf	
ACI Factored @ Heel	=	0 psf	
Footing Shear @ Toe	=	10.2 psi	OK
Footing Shear @ Heel	=	19.3 psi	OK
Allowable	=	75.0 psi	

Sliding Calcs

Lateral Sliding Force	=	4,357.7 lbs

Vertical component of active lateral soil pressure IS NOT considered in the calculation of soil bearing pressures.

Load Factors

Building Code	
Dead Load	1.200
Live Load	1.600
Earth, H	1.600
Wind, W	1.000
Seismic, E	1.000

Stem Construction

		Bottom		
		Stem OK		
Design Height Above Ftg	ft =	0.00		
Wall Material Above "Ht"	=	Concrete		
Design Method	=	SD	SD	SD
Thickness	=	12.00		
Rebar Size	=	# 6		
Rebar Spacing	=	12.00		
Rebar Placed at	=	Edge		
Design Data				
fb/FB + fa/Fa	=	**0.665**		
Total Force @ Section				
Service Level	lbs =			
Strength Level	lbs =	3,600.0		
Moment....Actual				
Service Level	ft-# =			
Strength Level	ft-# =	12,000.0		
Moment.....Allowable	=	18,029.5		
Shear.....Actual				
Service Level	psi =			
Strength Level	psi =	31.2		
Shear.....Allowable	psi =	46.9		
Anet (Masonry)	in2 =			
Wall Weight	psf =	150.0		
Rebar Depth 'd'	in =	9.63		
Masonry Data				
f'm	psi =			
Fs	psi =			
Solid Grouting	=			
Modular Ratio 'n'	=			
Equiv. Solid Thick.	=			
Masonry Block Type	=	Normal Weight		
Masonry Design Method	=	ASD		
Concrete Data				
f'c	psi =	2,500.0		
Fy	psi =	60,000.0		

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DESCRIPTION: CRW Verification Calculation

Summary of Sliding Forces

	FS = 1.0	FS = 1.5
Lateral Force @ Base of Footing	4,357.66 lbs	6,536.48 lbs
less 100% Passive Force	- 2,420.44 lbs	- 2,420.44 lbs
less 100% Friction Force	- 4,523.08 lbs	- 4,523.08 lbs
Added Resisting Force Required	0.0 lbs	
Added Resisting Force Required for 1.5 Factor of Safety		0.00 lbs

Sliding Factor of Safety = 1.593: 1.00

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DESCRIPTION: CRW Verification Calculation

Concrete Stem Rebar Area Details

Bottom Stem	Vertical Reinforcing	Horizontal Reinforcing	
As (based on applied moment) :	0.2865 in2/ft		
0.0018bh : 0.0018(12)(12) :	0.2592 in2/ft	Horizontal Reinforcing Options :	
	==========	One layer of :	Two layers of :
Required Area :	0.2865 in2/ft	#4@ 9.26 in	#4@ 18.52 in
Provided Area :	0.44 in2/ft	#5@ 14.35 in	#5@ 28.70 in
Maximum Area :	1.3039 in2/ft	#6@ 20.37 in	#6@ 40.74 in

Footing Data

Toe Width	=	2.00 ft
Heel Width	=	5.50
Total Footing Width	=	7.50
Footing Thickness	=	20.00 in
Key Width	=	12.00 in
Key Depth	=	12.00 in
Key Distance from Toe	=	2.00 ft

f'c = 2,500 psi Fy = 60,000 psi
Footing Concrete Density = 150.00 pcf
Min. As % = 0.0018
Cover @ Top 2.00 @ Btm.= 3.00 in

Footing Design Results

		Toe	Heel	Key	
Factored Pressure	=	3,899	0		psf
Mu' : Upward	=	7,015	4,733		ft-#
Mu' : Downward	=	864	18,407		ft-#
Mu: Design	=	6,151	13,674	1,775	ft-#

Toe Reinforcing = # 6 @ 12.00 in
Heel Reinforcing = # 6 @ 12.00 in
Key Reinforcing = # 5 @ 12.00 in

Mu:Design @ Toe	6,151.47 ft-#	OK
phiMn Toe	31,893 ft-#	
As min req'd 0.0018bh : 0.0018(12)(20) :	0.432 in2/ft	OK
As provided #6@12.0 in o.c.	0.44 in2/ft	
As Max :	2.2352 in2/ft	OK
Mu:Design @ Heel	13,674.11 ft-#	OK
phiMn Heel	33,873 ft-#	
As min req'd 0.0018bh : 0.0018(12)(20) :	0.432 in2/ft	OK
As provided #6@12.0 in o.c.	0.44 in2/ft	
As Max :	2.3707 in2/ft	OK
Mu:Design @ Key	1,774.96 ft-#	OK
phiMn Key	7,861 ft-#	
As min req'd 0.0018bh : 0.0018(12)(12) :	0.2592 in2/ft	OK
As provided #5@12.0 in o.c.	0.31 in2/ft	
As Max :	0.8128 in2/ft	OK

Footing Torsion, Tu = 0.00 ft-lbs
Footing Allow. Torsion, φ Tn = 0.00 ft-lbs

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

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DESCRIPTION: CRW Verification Calculation

Summary of Overturning & Resisting Forces & Moments

Item		.....OVERTURNING..... Force lbs	Distance ft	Moment ft-#		.....RESISTING..... Force lbs	Distance ft	Moment ft-#
HL Act Pres (ab water tbl)		4,357.7	4.64	20,214.7	Soil Over HL (ab. water tbl)	4,950.0	5.25	25,987.5
HL Act Pres (be water tbl)					Soil Over HL (bel. water tbl)		5.25	
Hydrostatic Force					Water Table			
Buoyant Force	=				Sloped Soil Over Heel	= 556.9	6.00	3,341.3
Surcharge over Heel	=				Surcharge Over Heel	=		
Surcharge Over Toe	=				Adjacent Footing Load	=		
Adjacent Footing Load	=				Axial Dead Load on Stem	=		
Added Lateral Load	=				* Axial Live Load on Stem	=		
Load @ Stem Above Soil	=				Soil Over Toe	= 220.0	1.00	220.0
	=				Surcharge Over Toe	=		
					Stem Weight(s)	= 1,500.0	2.50	3,750.0
					Earth @ Stem Transitions	=		
Total	=	4,357.7	**O.T.M.** =	20,214.7	Footing Weight	= 1,875.0	3.75	7,031.3
					Key Weight	= 150.0	2.50	375.0
					Vert. Component	= 2,055.8	7.50	15,418.8
					Total =	11,307.7 lbs	**R.M.=**	56,123.8

Resisting/Overturning Ratio = **2.78**

Vertical Loads used for Soil Pressure = 11,307.7 lbs

* Axial live load NOT included in total displayed, or used for overturning resistance, but is included for soil pressure calculation.

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

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

Tilt

Horizontal Deflection at Top of Wall due to settlement of soil

(Deflection due to wall bending not considered)

Soil Spring Reaction Modulus	250.0	pci
Horizontal Defl @ Top of Wall (approximate only)	0.103	in

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

Cantilevered Retaining Wall

DESCRIPTION: CRW Verification Calculation

Rebar Lap & Embedment Lengths Information

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

Stem Design Segment: Bottom

Lap Splice length for #6 bar specified in this stem design segment (25.4.2.4a) =	28.08 in
Development length for #6 bar specified in this stem design segment =	21.60 in
Hooked embedment length into footing for #6 bar specified in this stem design segment =	10.86 in
As Provided =	0.4400 in2/ft
As Required =	0.3821 in2/ft
Ψ r: Confining Reinforcement Factor =	1.00
Ψ o: Location Factor =	1.00
Ψ c: Concrete Strength Factor =	0.77

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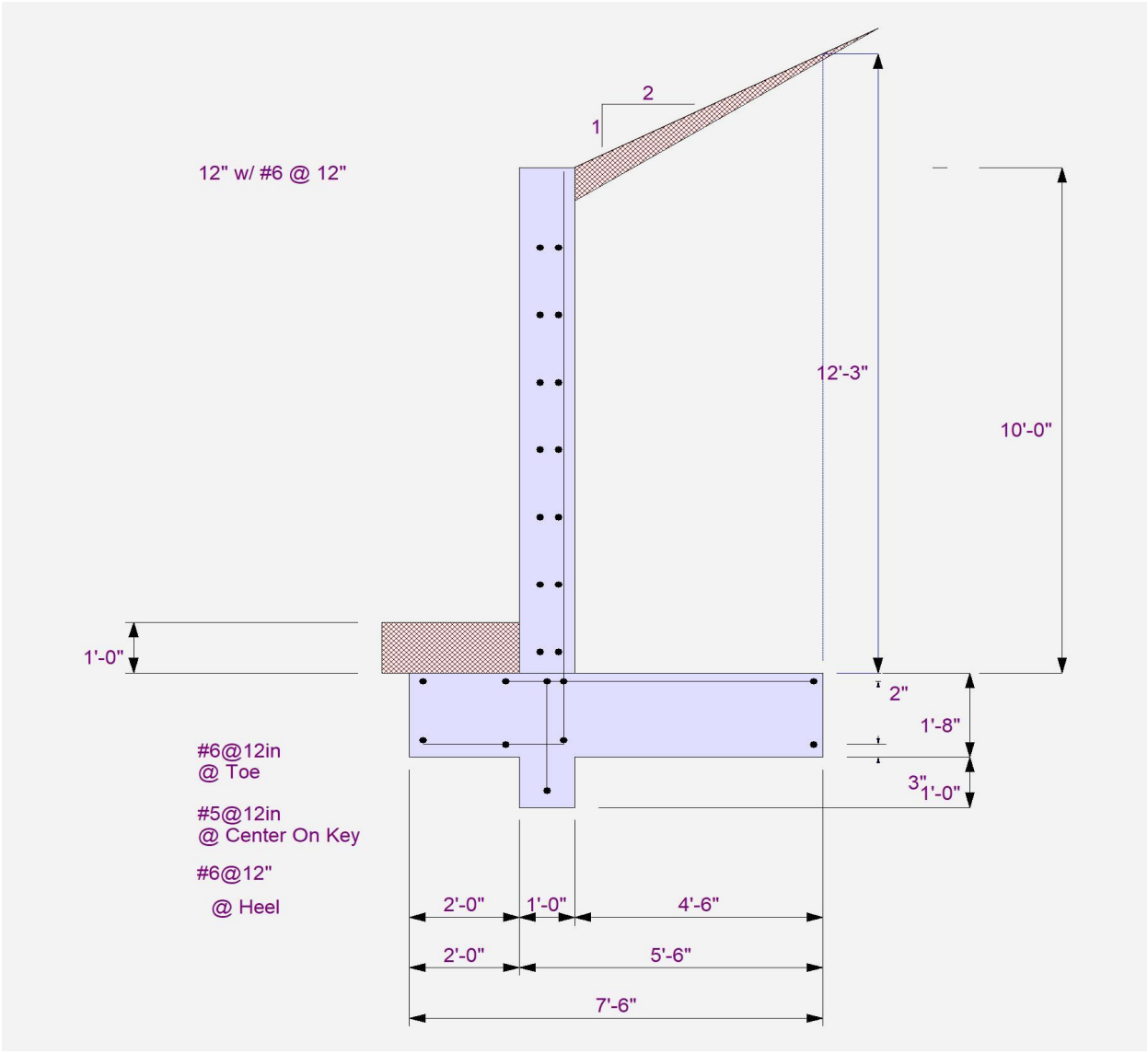

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