Your Project Calculations

Project Name: Ken Branam rev3

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=Ken%20Branam%20rev3&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/8_2023

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=RXZK6JJSfbdCUAMPnctTpnFLqjasmEiNf1vDAIxZ2fDhPXCfvv8eEK2VI7YBwGJJ

Array Specification

Product:	Beam
Unique ID:	2P-22.5-10TOP-XD-45-L-5Hx6W-5IKA
Duty Classification:	XD
Module Width:	44.60 in
Module Length:	74.90in
Number of Rows:	5
Number of Columns:	6
Total Number of Modules:	30
Desired Tilt Angle:	46
Front Edge Clearance:	5
Total Array Height at Tilt:	18.44 ft
Total Frame Length:	37.50 ft
Frame Weight:	2398 lbs
Array Dimensions N/S:	18.79 ft
Array Dimensions E/W:	37.95 ft
Rail Length:	225.50 in
Rail Spacing:	3.12 ft
Rail Check:	Not Checked

Support Specifications

Pole Size:	10in Pipe Sch 40
Pole Length above Grade:	11.76 ft
Number of Poles:	2
Pole Spacing:	22.5 ft

Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 8.00 ft Pile 2: 8.00 ft
Foundation Volume:	9.481 y^3
Foundation Result:	PASSED
Mount Twist:	2.193306 kip

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	15510 Cuerno Verde View, Colorado Springs, CO 80926, USA
Wind Speed:	130 mph
Snow Load:	40 psf
Design Uplift Pressure:	0.030795 ksf
Design Downforce Pressure:	-0.030795 ksf
Design Snow Pressure:	0.010557 ksf

Design Disclaimer

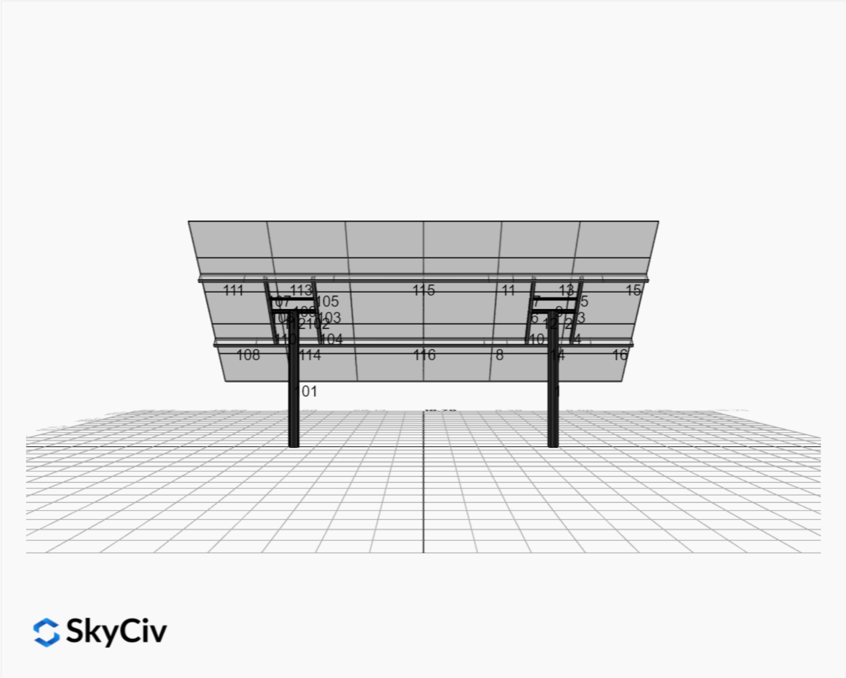
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

AutoDesigner Input

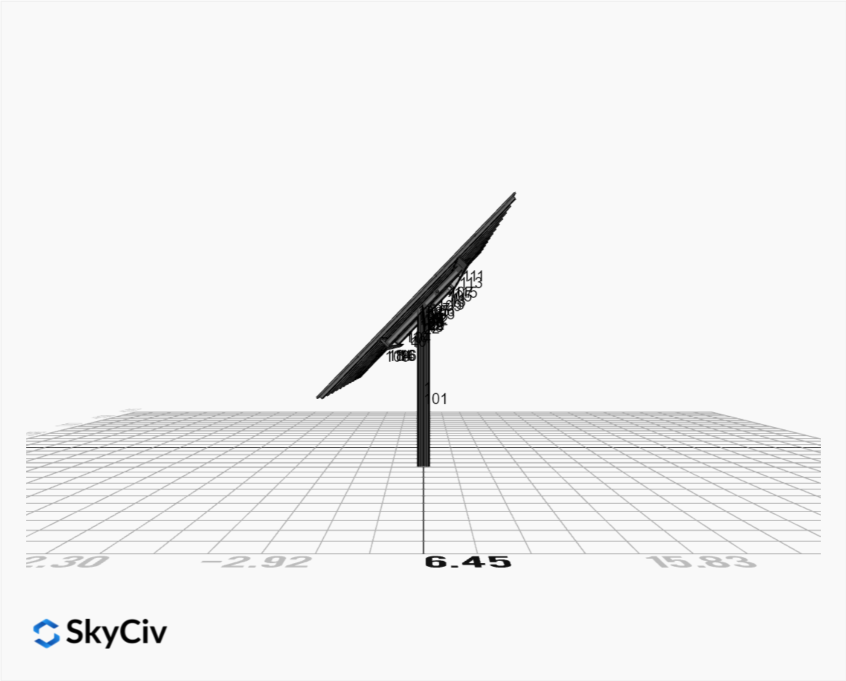
{"product_type":"Beam","project_id":"Ken Branam rev3","site_address":"15510 Cuerno Verde View, Colorado Springs, CO 80926, USA","module_width":44.6,"module_length":74.9,"number_rows":"5","number_columns":6,"pole_mount_section":"4_40","core_pipe_width":65,"core_pipe_section":"2_40","adjuster_section":"2_40","core_beam_height":65,"core_beam_section":"HSS3x2x1/8","main_pipe_section":"2_12GA","pole_spacing":"15","tilt_angle":46,"ground_clearance":5,"risk_category":"I","exposure_category":"C","frame_duty_override":"auto","pole_override":"auto","soil_type":"sand","customer_foundation_override":"48_Square","foundation_type":"Square","foundation_size":48,"check_rails":false,"wind_speed_override":130,"snow_load_override":40,"direct_snow_load":false}

Design Notes:

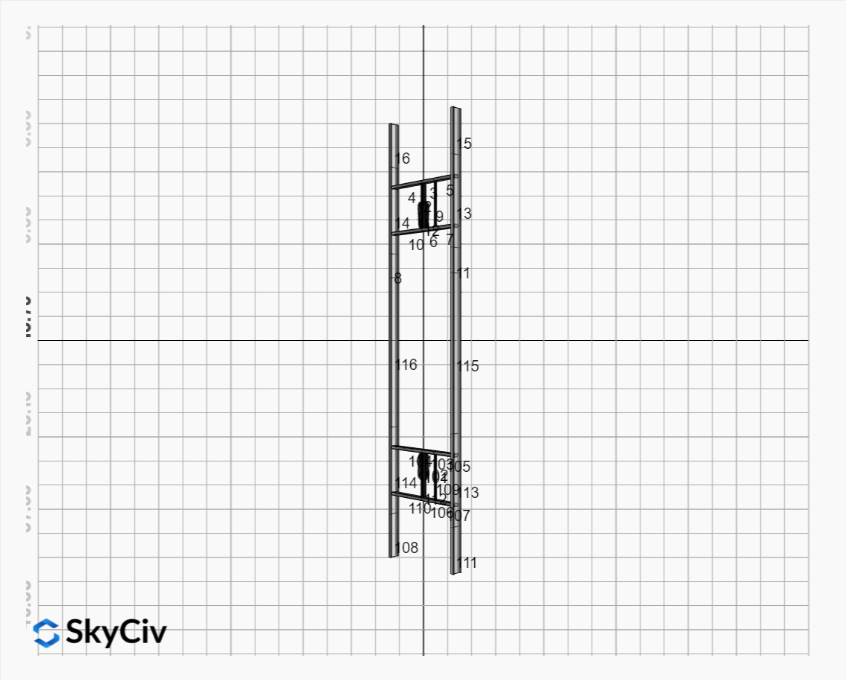
- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Design and Sizing is approximate only



SkyCiv



6.45
15.83
SkyCiv



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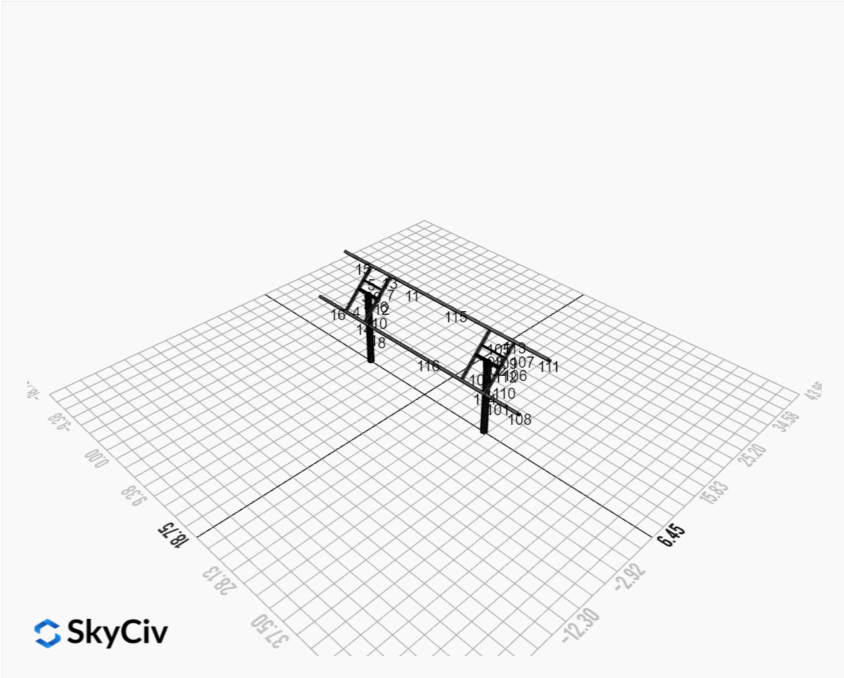
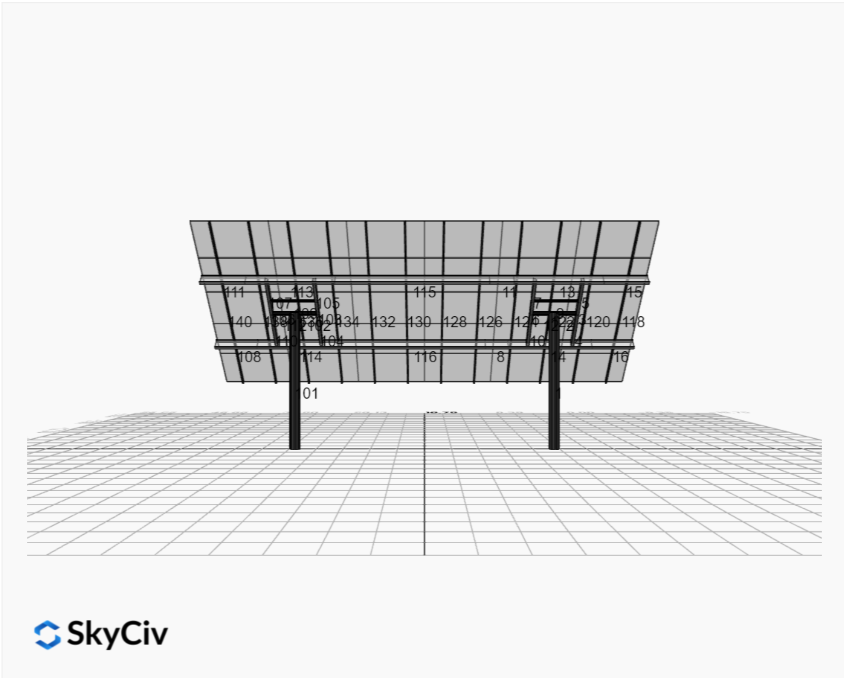
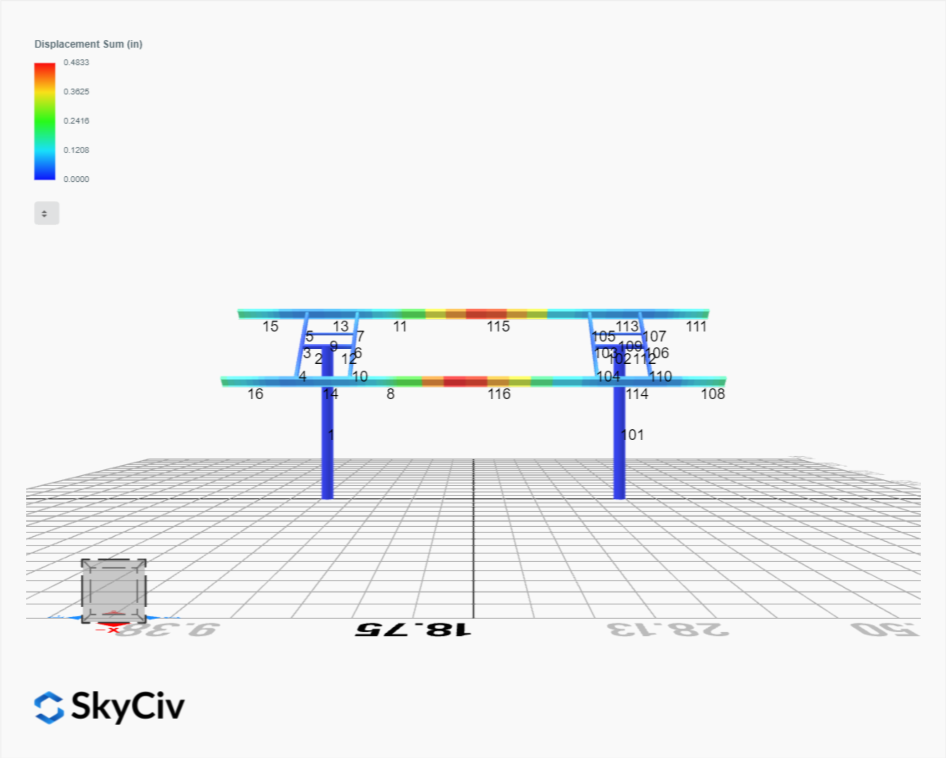
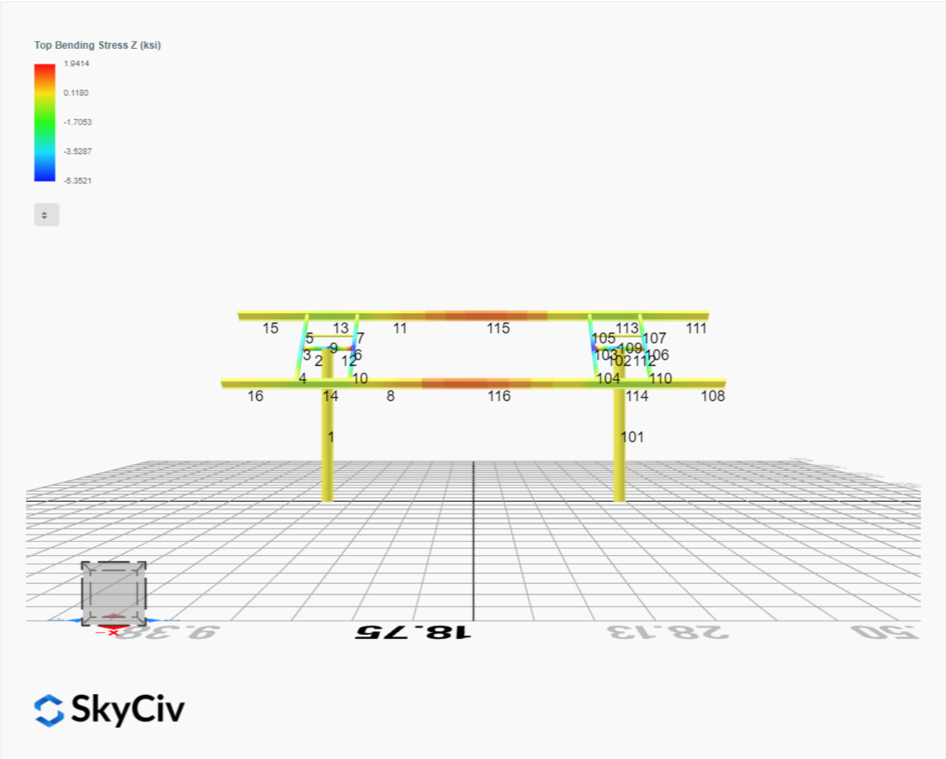
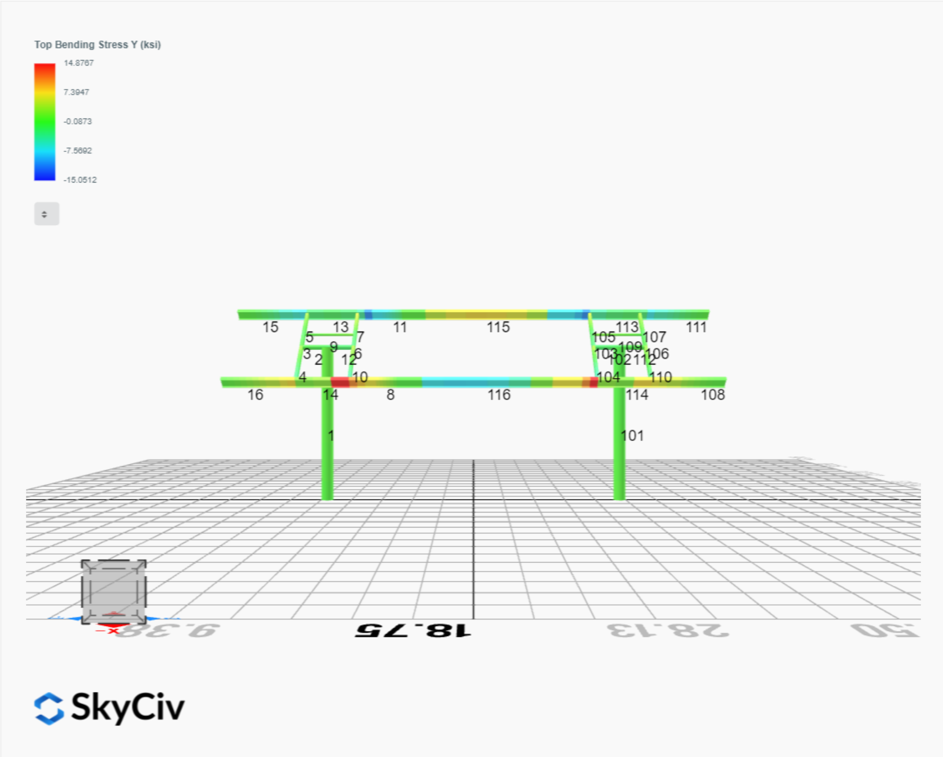

0.00
9.38
18.75
28.13
37.50
6.45
-2.92
-12.30
15.83
25.20
34.58
11
115
116
111
110
108

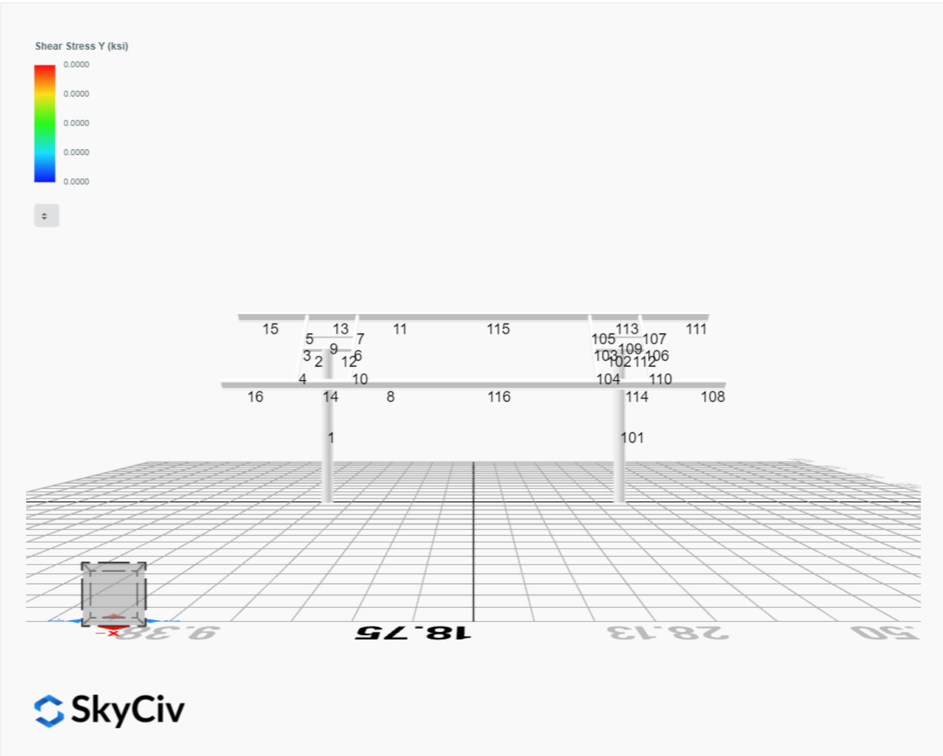

111
115
105
140
134
132
130
128
126
120
118
104
108
114
116

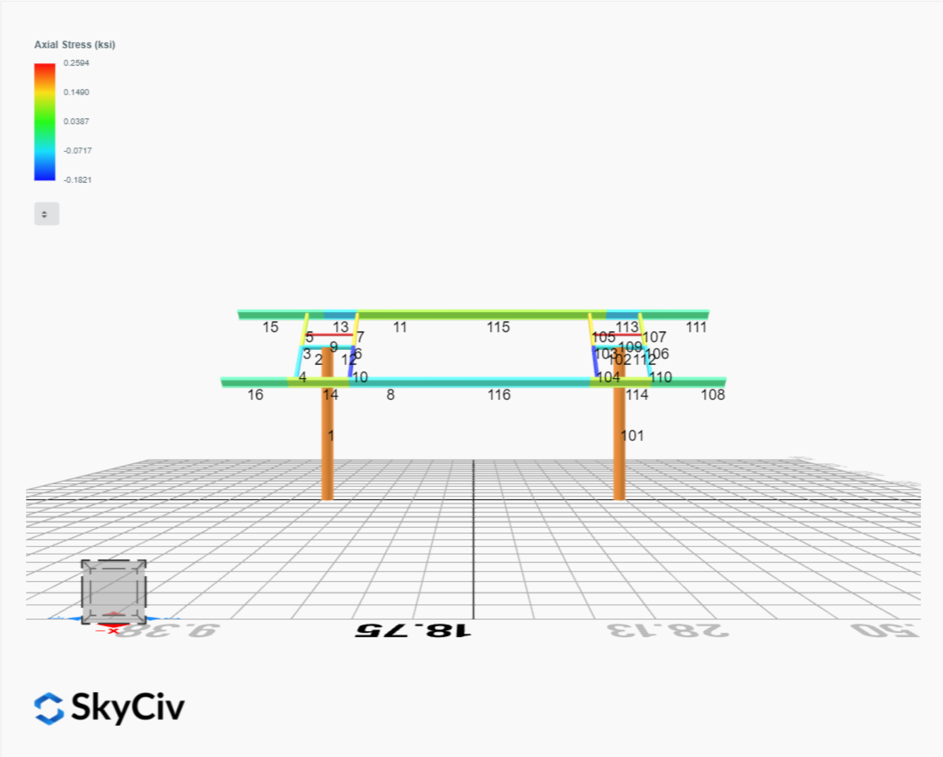
FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
14.8767
7.3947
-0.0873
-7.5692
-15.0512
15
13
11
115
113
111
5
7
105
107
9
109
3
2
12
6
103
102
112
106
4
10
104
110
16
14
8
116
114
108
1
101
18.75
28.13
SkyCiv


Shear Stress Y (ksi)
0.0000
0.0000
0.0000
0.0000
0.0000
15
13
11
115
113
111
5
7
105
107
9
109
3
2
12
6
103
102
112
106
4
10
104
110
16
14
8
116
114
108
1
101
18.75
28.13
SkyCiv


Axial Stress (ksi)
0.2594
0.1490
0.0387
-0.0717
-0.1821
15
13
11
115
113
111
16
14
8
116
114
108
1
101
18.75
SkyCiv

Reaction Forces for Foundation 1 (Node ID#1), (kip, kip-ft)

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	0.0000	2.8051	0.0754	0.2428	-0.0937	0.0254
ULS: 2. D + L	0.0000	2.8051	0.0754	0.2428	-0.0937	0.0254
ULS: 3. D + (S or Lr or R)	0.0000	5.3889	0.1705	0.5496	-0.2121	0.0325
ULS: 3. D + (S or Lr or R)	0.0000	2.8051	0.0754	0.2428	-0.0937	0.0254
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0000	4.7430	0.1467	0.4729	-0.1825	0.0307
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0000	2.8051	0.0754	0.2428	-0.0937	0.0254
ULS: 5b. D + 0.7E	0.0000	2.8051	0.0754	0.2428	-0.0937	0.0254
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0000	4.7430	0.1467	0.4729	-0.1825	0.0307
ULS: 8. 0.6D + 0.7E	0.0000	1.6831	0.0453	0.1457	-0.0562	0.0152
ULS: 5a. D + 0.6W_Wind downforce Case A only	-4.7393	7.3818	0.2909	0.8718	-1.3082	56.3674
ULS: 5a. D + 0.6W_Wind downforce Case B only	0.0000	2.8051	0.0754	0.2428	-0.0937	0.0254
ULS: 5a. D + 0.6W_Wind uplift Case A only	4.7393	-1.7715	-0.1390	-0.3823	1.1186	-55.1051
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0000	2.8051	0.0754	0.2428	-0.0937	0.0254
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.5545	8.1755	0.3083	0.9447	-1.0934	42.2872
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0000	4.7430	0.1467	0.4729	-0.1825	0.0307
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.5545	1.3105	-0.0141	0.0041	0.7267	-41.3172
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0000	4.7430	0.1467	0.4729	-0.1825	0.0307
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.5545	6.2376	0.2371	0.7146	-1.0045	42.2819
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0000	2.8051	0.0754	0.2428	-0.0937	0.0254
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.5545	-0.6274	-0.0854	-0.2260	0.8155	-41.3225
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0000	2.8051	0.0754	0.2428	-0.0937	0.0254
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-4.7393	6.2598	0.2608	0.7747	-1.2707	56.3572
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	0.0000	1.6831	0.0453	0.1457	-0.0562	0.0152
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	4.7393	-2.8936	-0.1692	-0.4794	1.1561	-55.1153
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0000	1.6831	0.0453	0.1457	-0.0562	0.0152

Worst Case Reactions LRFD

These calculations are taken directly from the FEA via SkyCiv and are used in the Concrete Checks of the Foundatino Module. Note: Worst case values are assumed as downforce wind load cases.

Result	Value (kip, kip-ft)
Axial	12.2859
Shear X	-7.8988
Shear Z	0.4975
Moment X	1.4948
Moment Y (Twist)	2.1924
Moment Z	94.6504

Worst Case Reactions ASD

These results are taken from the worst case values in the above table and are used in the Soil Checks in the Foundation Module. Note: Worst case values are assumed as downforce wind load cases.

Result	Value (kip, kip-ft)
Axial	8.1755
Shear X	-4.7393
Shear Z	0.3083
Moment X	0.9447
Moment Y (Twist)	1.3082
Moment Z	56.3674

Reaction Forces for Foundation 2 (Node ID#101), (kip, kip-ft)

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	-0.0000	2.8051	-0.0754	-0.2429	0.0938	0.0255
ULS: 2. D + L	-0.0000	2.8051	-0.0754	-0.2429	0.0938	0.0255
ULS: 3. D + (S or Lr or R)	-0.0000	5.3889	-0.1705	-0.5498	0.2123	0.0326
ULS: 3. D + (S or Lr or R)	-0.0000	2.8051	-0.0754	-0.2429	0.0938	0.0255
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0000	4.7430	-0.1467	-0.4731	0.1827	0.0308
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0000	2.8051	-0.0754	-0.2429	0.0938	0.0255
ULS: 5b. D + 0.7E	-0.0000	2.8051	-0.0754	-0.2429	0.0938	0.0255

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0000	4.7430	-0.1467	-0.4731	0.1827	0.0308
ULS: 8. 0.6D + 0.7E	-0.0000	1.6831	-0.0453	-0.1457	0.0563	0.0153
ULS: 5a. D + 0.6W_Wind downforce Case A only	-4.7393	7.3818	-0.2909	-0.8719	1.3082	56.3674
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0000	2.8051	-0.0754	-0.2429	0.0938	0.0255
ULS: 5a. D + 0.6W_Wind uplift Case A only	4.7393	-1.7715	0.1390	0.3822	-1.1186	-55.1051
ULS: 5a. D + 0.6W_Wind uplift Case B only	-0.0000	2.8051	-0.0754	-0.2429	0.0938	0.0255
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.5545	8.1755	-0.3083	-0.9448	1.0935	42.2873
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0000	4.7430	-0.1467	-0.4731	0.1827	0.0308
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.5545	1.3105	0.0141	-0.0042	-0.7266	-41.3171
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0000	4.7430	-0.1467	-0.4731	0.1827	0.0308
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.5545	6.2376	-0.2371	-0.7146	1.0046	42.2819
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0000	2.8051	-0.0754	-0.2429	0.0938	0.0255
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.5545	-0.6274	0.0854	0.2259	-0.8155	-41.3224
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0000	2.8051	-0.0754	-0.2429	0.0938	0.0255
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-4.7393	6.2598	-0.2608	-0.7747	1.2707	56.3572
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0000	1.6831	-0.0453	-0.1457	0.0563	0.0153
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	4.7393	-2.8936	0.1692	0.4794	-1.1561	-55.1153
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	-0.0000	1.6831	-0.0453	-0.1457	0.0563	0.0153

Worst Case Reactions LRFD

These calculations are taken directly from the FEA via SkyCiv and are used in the Concrete Checks of the Foundatino Module. Note: Worst case values are assumed as downforce wind load cases.

Result	Value (kip, kip-ft)
Axial	12.2858
Shear X	-7.8989
Shear Z	-0.4975
Moment X	-1.4957
Moment Y (Twist)	2.1933
Moment Z	94.6524

Worst Case Reactions ASD

These results are taken from the worst case values in the above table and are used in the Soil Checks in the Foundation Module. Note: Worst case values are assumed as downforce wind load cases.

Result	Value (kip, kip-ft)
Axial	8.1755
Shear X	-4.7393
Shear Z	-0.3083
Moment X	-0.9448
Moment Y (Twist)	1.3082
Moment Z	56.3674

Project Details

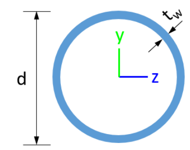
Design Code:	AISC 360-16 LRFD
Provision:	LRFD
Country:	United States
User Name:	sales@mtsolar.us
Unit System:	imperial

Design Input Information

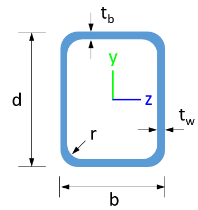
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

Design Materials			
ID	E (ksi)	F_y (ksi)	F_u (ksi)
1	29000	50	65

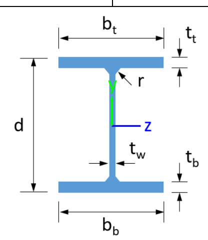
Section Dimensions



ID	Name	d (in)	t_w (in)					
3	2in Pipe Sch 120	2.38	0.25					
6	4in Pipe Sch 120	4.50	0.44					
11	10in Pipe Sch 40	10.75	0.36					



ID	Name	d (in)	b (in)	t_w (in)	t_b (in)	r (in)		
17	HSS5x3x1/4	5.00	3.00	0.23	0.23	0.23		



ID	Name	d (in)	t_w (in)	b_t (in)	b_b (in)	t_t (in)	t_b (in)	r (in)
20	W10x12	9.87	0.19	3.96	3.96	0.21	0.21	0.30

Section Properties								
ID	Name	A (in^2)	J (in^4)	I_{yp} (in^4)	I_{zp} (in^4)	I_w (in^6)	S_{yp} (in^3)	S_{zp} (in^3)
3	2in Pipe Sch 120	1.67	1.91	0.96	0.96	0.00	1.13	1.13
6	4in Pipe Sch 120	5.58	23.29	11.64	11.64	0.00	7.24	7.24
11	10in Pipe Sch 40	11.91	321.47	160.73	160.73	0.00	39.38	39.38

17	HSS5x3x1/4	3.37	11.00	4.81	10.70	62.42	3.77	5.38
20	W10x12	3.54	0.05	2.18	53.80	50.90	1.74	12.60

Member Properties								
Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	11	24.69	24.69	11.76	-	300	200	1
2	6	1.30	1.30	2.00	-	300	200	1
3	17	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.15,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18	300	200	1
4	17	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.68,1.69,1.67,1.68,1.66,1.68,1.67,1.69,1.66,1.69,1.67,1.68,1.63,1.68,1.67,1.69,1.66,1.69,1.67,1.69,1.66,1.69	300	200	1
5	17	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.64,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68	300	200	1
6	17	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.18,1.16,1.18,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19	300	200	1
7	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.65,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.67,1.68	300	200	1
8	20	1.33	1.33	2.05	1.57,1.57,1.57,1.57,1.57,1.57,1.54,1.57,1.53,1.57,1.54,1.57,1.53,1.57,1.55,1.57,1.41,1.57,1.55,1.57,1.53,1.57,1.54,1.57,1.54,1.57	300	200	1
9	3	2.60	2.60	4.00	-	300	200	1
10	17	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.63,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68	300	200	1
11	20	1.33	1.33	2.05	1.58,1.58,1.58,1.58,1.58,1.58,1.55,1.58,1.54,1.58,1.55,1.58,1.54,1.58,1.56,1.58,1.42,1.58,1.55,1.58,1.53,1.58,1.55,1.58,1.54,1.58	300	200	1
12	6	1.30	1.30	2.00	-	300	200	1
13	20	4.88	4.00	7.50	1.10,1.10,1.10,1.10,1.10,1.10,1.11,1.10,1.12,1.10,1.11,1.10,1.12,1.10,1.11,1.10,1.19,1.10,1.11,1.10,1.12,1.10,1.11,1.10,1.12,1.10	300	200	1
14	20	4.88	4.00	7.50	1.10,1.10,1.10,1.10,1.10,1.10,1.11,1.10,1.11,1.10,1.11,1.10,1.11,1.10,1.11,1.10,1.18,1.10,1.11,1.10,1.12,1.10,1.11,1.10,1.11,1.10	300	200	1
15	20	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
16	20	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
101	11	24.69	24.69	11.76	-	300	200	1
102	6	1.30	1.30	2.00	-	300	200	1
103	17	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.18,1.16,1.18,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19	300	200	1
104	17	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.63,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68	300	200	1
105	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.65,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.67,1.68	300	200	1
106	17	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.15,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18	300	200	1
107	17	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.64,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68	300	200	1

108	20	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
109	3	2.60	2.60	4.00	-	300	200	1
110	17	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.68,1.69,1.67,1.68,1.66,1.68,1.67,1.69,1.66,1.69,1.67,1.68,1.63,1.68,1.67,1.69,1.66,1.69,1.67,1.69,1.66,1.69	300	200	1
111	20	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
112	6	1.30	1.30	2.00	-	300	200	1
113	20	4.88	4.00	7.50	1.10,1.10,1.10,1.10,1.10,1.10,1.11,1.10,1.12,1.10,1.11,1.10,1.12,1.10,1.11,1.10,1.18,1.10,1.11,1.10,1.12,1.10,1.11,1.10,1.12,1.10	300	200	1
114	20	4.88	4.00	7.50	1.10,1.10,1.10,1.10,1.10,1.10,1.11,1.10,1.12,1.10,1.11,1.10,1.11,1.10,1.11,1.10,1.18,1.10,1.11,1.10,1.12,1.10,1.11,1.10,1.11,1.10	300	200	1
115	20	8.42	8.42	12.95	1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.10,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11	300	200	1
116	20	8.42	8.42	12.95	1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.10,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11	300	200	1

Member Design Capacity

Member ID	$\Phi_t P_n$ (kip)	$\Phi_c P_n$ (kip)	$\Phi_b M_{zn}$ (k-ft)	$\Phi_b M_{yn}$ (k-ft)	$\Phi_v V_{yn}$ (kip)	$\Phi_v V_{zn}$ (kip)
1	535.87	333.03	147.68	147.68	160.76	160.76
2	251.01	248.88	27.16	27.16	75.30	75.30
3	151.65	150.70	20.17	14.14	54.12	28.95
4	151.65	145.15	20.17	14.14	54.12	28.95
5	151.65	149.10	20.17	14.14	54.12	28.95
6	151.65	150.70	20.17	14.14	54.12	28.95
7	151.65	149.10	20.17	14.14	54.12	28.95
8	159.30	142.47	46.90	6.46	56.26	44.91
9	75.10	66.32	4.25	4.25	22.53	22.53
10	151.65	145.15	20.17	14.14	54.12	28.95
11	159.30	142.47	46.90	6.46	56.26	44.91
12	251.01	248.88	27.16	27.16	75.30	75.30
13	159.30	116.35	33.62	6.46	56.26	44.91
14	159.30	116.35	33.62	6.46	56.26	44.91
15	159.30	55.15	46.90	6.46	56.26	44.91
16	159.30	55.15	46.90	6.46	56.26	44.91
101	535.87	333.03	147.68	147.68	160.76	160.76
102	251.01	248.88	27.16	27.16	75.30	75.30
103	151.65	150.70	20.17	14.14	54.12	28.95
104	151.65	145.15	20.17	14.14	54.12	28.95
105	151.65	149.10	20.17	14.14	54.12	28.95
106	151.65	150.70	20.17	14.14	54.12	28.95
107	151.65	149.10	20.17	14.14	54.12	28.95
108	159.30	55.15	46.90	6.46	56.26	44.91
109	75.10	66.32	4.25	4.25	22.53	22.53
110	151.65	145.15	20.17	14.14	54.12	28.95
111	159.30	55.15	46.90	6.46	56.26	44.91
112	251.01	248.88	27.16	27.16	75.30	75.30
113	159.30	116.35	33.62	6.46	56.26	44.91
114	159.30	116.35	33.62	6.46	56.26	44.91
115	159.30	48.27	14.61	6.46	56.26	44.91

115	159.30	48.27	14.61	6.46	56.26	44.91
116	159.30	48.27	14.61	6.46	56.26	44.91

Design Ratio

Member ID	P	M_z	M_y	V_y	V_z	(P,M_z,M_y)	Worst LC	KL/r	δ	Status
1	0.037	0.641	0.029	0.049	0.003	0.669	#13	0.403	Not Required	Pass
2	0.004	0.274	0.234	0.065	0.048	0.510	#13	0.036	Not Required	Pass
3	0.006	0.560	0.038	0.055	0.008	0.564	#13	0.046	Not Required	Pass
4	0.006	0.557	0.122	0.056	0.028	0.628	#13	0.082	Not Required	Pass
5	0.006	0.348	0.112	0.056	0.030	0.363	#13	0.076	Not Required	Pass
6	0.010	0.718	0.079	0.073	0.015	0.773	#13	0.046	Not Required	Pass
7	0.010	0.445	0.203	0.071	0.052	0.477	#13	0.076	Not Required	Pass
8	0.003	0.109	0.252	0.048	0.021	0.257	#21	0.102	Not Required	Pass
9	0.016	0.054	0.082	0.003	0.003	0.141	#13	0.206	Not Required	Pass
10	0.011	0.715	0.193	0.071	0.041	0.760	#13	0.082	Not Required	Pass
11	0.005	0.108	0.261	0.048	0.021	0.267	#21	0.102	Not Required	Pass
12	0.003	0.434	0.315	0.091	0.060	0.749	#13	0.036	Not Required	Pass
13	0.006	0.193	0.550	0.060	0.026	0.665	#21	0.306	Not Required	Pass
14	0.007	0.195	0.539	0.060	0.026	0.651	#21	0.204	Not Required	Pass
15	0.000	0.054	0.138	0.024	0.011	0.178	#21	Not Required	Not Required	Pass
16	0.000	0.054	0.138	0.024	0.011	0.178	#21	Not Required	Not Required	Pass
101	0.037	0.641	0.029	0.049	0.003	0.670	#13	0.403	Not Required	Pass
102	0.003	0.434	0.315	0.091	0.060	0.749	#13	0.036	Not Required	Pass
103	0.010	0.718	0.079	0.073	0.015	0.773	#13	0.046	Not Required	Pass
104	0.011	0.715	0.193	0.071	0.041	0.760	#13	0.082	Not Required	Pass
105	0.010	0.445	0.203	0.071	0.052	0.477	#13	0.076	Not Required	Pass
106	0.006	0.560	0.038	0.055	0.008	0.564	#13	0.046	Not Required	Pass
107	0.006	0.348	0.112	0.056	0.030	0.363	#13	0.076	Not Required	Pass
108	0.000	0.054	0.138	0.024	0.011	0.178	#21	Not Required	Not Required	Pass
109	0.016	0.054	0.082	0.003	0.003	0.141	#13	0.206	Not Required	Pass
110	0.006	0.557	0.123	0.056	0.028	0.628	#13	0.082	Not Required	Pass
111	0.000	0.054	0.138	0.024	0.011	0.178	#21	Not Required	Not Required	Pass
112	0.004	0.274	0.234	0.065	0.048	0.510	#13	0.036	Not Required	Pass
113	0.006	0.193	0.550	0.060	0.026	0.665	#21	0.204	Not Required	Pass
114	0.007	0.195	0.539	0.060	0.026	0.651	#21	0.306	Not Required	Pass
115	0.014	0.703	0.297	0.048	0.021	0.874	#13	0.644	Not Required	Pass
116	0.004	0.707	0.293	0.048	0.021	0.876	#13	0.644	Not Required	Pass

Definitions

Φ_t	Safety factor for tensile
Φ_c	Safety factor for compression
Φ_b	Safety factor for flexure
Φ_v	Safety factor for shear
E	Modulus of elasticity
F_y	Specified minimum yield stress
F_u	Specified minimum tensile strength
A	Cross-sectional area
J	Torsional constant
I_{yp}	Moment of inertia about the Y axes
I_{zp}	Moment of inertia about the Z axes
I_w	Warping constant
S_{yp}	Plastic section modulus about the Y axis
S_{zp}	Plastic section modulus about the Z axis
KL	Effective length
C_b	Buckling modification factor (from all load combinations)
L_b	Length between braced points

L_b	Length between braced points
LST	Limited slenderness for tension
LSC	Limited slenderness for compression
LD	Limited deflection
P_n	Nominal axial strength (tension/comresssion)
M_n	Nominal flexural strength (about Z/Y axis)
V_n	Nominal shear strength (along Z/Y axis)
P	Design ratio in case of axial force
M_z	Design ratio in case of bending about Z axis
M_y	Design ratio in case of bending about Y axis
V_y	Design ratio in case of shear along Y axis
V_z	Design ratio in case of shear along Z axis
(P,M_z,M_y)	Design ratio in case of axial force and bending action
KL/r	Design ratio in case of section slenderness
δ	Design ratio in case of member deflection
OK	Capacity is provided
NG	Capacity is not provided

REFERENCES	CALCULATIONS	RESULTS

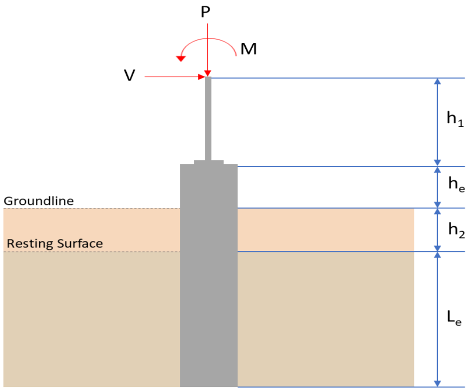
SkyCiv Foundation Design

Pile Foundation

Design Information :

Design code : IBC 2021 (International Building Code)
Unit System : Imperial

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 8\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

Layer	Label	Allowable Bearing Pressure (q_a) (psf)	Allowable Lateral Pressure (R) (psf/ft)
1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	8.176	12.286
V_x (kip)	-4.739	-7.899
V_z (kip)	0.308	0.498
M_x (kipft)	0.945	1.495
M_z (kipft)	56.367	94.650

Material Properties

$f'_{ck} = 2.5\ \mathrm{ksi}$ - Concrete strength,

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

$$H = (0\ \mathrm{ft}) + (0\ \mathrm{ft}) + (0\ \mathrm{ft})$$

$$H = 0\ \mathrm{ft}$$

Considering x-direction:

H_o - Lateral force per length of pile,

$$H_o = \frac{V_x}{1.57\,D}$$

$$H_o = \frac{(-4.739\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.75462\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

$$M_o = \frac{M_z + (V_x\,H)}{1.57\,D}$$

$$M_o = \frac{(56.367\ \mathrm{kipft}) + ((-4.739\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 8.9756\ \mathrm{kipft/ft}$$

Required depth of embedment in earth:

$$L_x^3 - \left(14.14 \times \frac{H_o \times L_x}{R}\right) - \left(18.85 \times \frac{M_o}{R}\right) = 0$$

Solving the cubic equation:
$L_{e,x} = 7.2927\ \mathrm{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{1.57\, b}$$

$$H_o = \frac{(0.308\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = 0.049045\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

$$M_o = \frac{M_x + (V_z\, H)}{1.57\, b}$$

$$M_o = \frac{(0.945\ \mathrm{kipft}) + ((0.308\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.15048\ \mathrm{kipft/ft}$$

Required depth of embedment in earth:

$$L_z^3 - \left(14.14 \times \frac{H_o \times L_z}{R}\right) - \left(18.85 \times \frac{M_o}{R}\right) = 0$$

Solving the cubic equation:
$L_{e,z} = 2.7157\ \mathrm{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

$L_{e,req}$ - Depth of pile required,

$$L_{e,req} = MAX[L_{e,x}, L_{e,z}]$$

$$L_{e,req} = MAX[(7.2927\ \mathrm{ft}), (2.7157\ \mathrm{ft})]$$

$$L_{e,req} = 7.293\ \mathrm{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8\ \mathrm{ft}) - (0\ \mathrm{ft}) - (0\ \mathrm{ft})$$

$$L_e = 8\ \mathrm{ft}$$

$Ratio$ - Embedded depth

$$Ratio = \frac{L_{e,req}}{L_e}$$

$$Ratio = \frac{(7.293\ \mathrm{ft})}{(8\ \mathrm{ft})}$$

$$Ratio = 0.91163$$

Status: **PASS**
Ratio: **0.910**

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

$$A = (48\ \mathrm{in}) \times (48\ \mathrm{in})$$

$$A = 16\ \mathrm{ft}^2$$

q - End-bearing pressure

$$q = \frac{P_v}{A}$$

$$q = \frac{(8.176\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.511\ \mathrm{kip/ft}^2$$

$q = 0.511\ \mathrm{kip/ft}$

Check bearing capacity ratio:

$Ratio$ - Capacity

$$Ratio = \frac{q}{q_a}$$

$$Ratio = \frac{\left(0.511\ \mathrm{kip/ft^2}\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.2555$$

Status: **PASS**
Ratio: **0.260**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

$$L/D = \frac{L}{D}$$

$$L/D = \frac{(8\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 2$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.75462\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 8.9756\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

$$a = \frac{(4\,M_o\,L_e) + \left(3\,H_o\,L_e^2\right)}{(6\,M_o) + (4\,H_o\,L_e)}$$

$$a = \frac{(4 \times (8.9756\ \mathrm{kipft/ft}) \times (8\ \mathrm{ft})) + \left(3 \times (-0.75462\ \mathrm{kip/ft}) \times (8\ \mathrm{ft})^2\right)}{(6 \times (8.9756\ \mathrm{kipft/ft})) + (4 \times (-0.75462\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))}$$

$$a = 5.5397\ \mathrm{ft}$$

p - Earth pressure against the pile at distance a/2 from resting surface,

$$p = \frac{0.75\,[(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\,[(3\,M_o) + (2\,H_o\,L_e)]}$$

$$p = \frac{0.75 \times [(4 \times (8.9756\ \mathrm{kipft/ft})) + (3 \times (-0.75462\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]^{\ 2}}{(8\ \mathrm{ft})^2 \times [(3 \times (8.9756\ \mathrm{kipft/ft})) + (2 \times (-0.75462\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]}$$

$$p = 0.24975\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{6\,[(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$

$$s = \frac{6 \times [(2 \times (8.9756\ \mathrm{kipft/ft})) + ((-0.75462\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]}{(8\ \mathrm{ft})^2}$$

$$s = 1.117\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

p_a - Allowable lateral soil pressure at depth a/2,

$$p_a = R\,\frac{a}{2}$$

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.5397\ \mathrm{ft})}{2}$$

$$p_a = 0.41548\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

$$Ratio = \frac{p}{p_a}$$

$$Ratio = \frac{\left(0.24975\ \mathrm{kip/ft^2}\right)}{\left(0.41548\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.60111$$

Status: **PASS**
Ratio: **0.600**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8\ \mathrm{ft})$$

$$p_s = 1.2\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{\left(1.117\ \mathrm{kip/ft^2}\right)}{\left(1.2\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.93081$$

Status: PASS
Ratio: 0.930

Considering z-direction:

$H_o = 0.049045\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.15048\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

$$a = \frac{(4\,M_o\,L_e) + \left(3\,H_o\,L_e^2\right)}{(6\,M_o) + (4\,H_o\,L_e)}$$

$$a = \frac{(4 \times (0.15048\ \mathrm{kipft/ft}) \times (8\ \mathrm{ft})) + \left(3 \times (0.049045\ \mathrm{kip/ft}) \times (8\ \mathrm{ft})^2\right)}{(6 \times (0.15048\ \mathrm{kipft/ft})) + (4 \times (0.049045\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))}$$

$$a = 5.7565\ \mathrm{ft}$$

p - Earth pressure against the pile at distance a/2 from resting surface,

$$p = \frac{0.75\,[(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\,[(3\,M_o) + (2\,H_o\,L_e)]}$$

$$p = \frac{0.75 \times [(4 \times (0.15048\ \mathrm{kipft/ft})) + (3 \times (0.049045\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]^{\ 2}}{(8\ \mathrm{ft})^2 \times [(3 \times (0.15048\ \mathrm{kipft/ft})) + (2 \times (0.049045\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]}$$

$$p = 0.030002\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{6\,[(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$

$$s = \frac{6 \times [(2 \times (0.15048\ \mathrm{kipft/ft})) + ((0.049045\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]}{(8\ \mathrm{ft})^2}$$

$$s = 0.064998\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

p_a - Allowable lateral soil pressure at depth a/2,

$$p_a = R\,\frac{a}{2}$$

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.7565\ \mathrm{ft})}{2}$$

$$p_a = 0.43174\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

$$Ratio = \frac{p}{p_a}$$

$$Ratio = \frac{\left(0.030002\ \mathrm{kip/ft^2}\right)}{\left(0.43174\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.069491$$

Status: PASS
Ratio: 0.070

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8\ \mathrm{ft})$$

$$p_s = 1.2\ \mathrm{kip/ft^2}$$

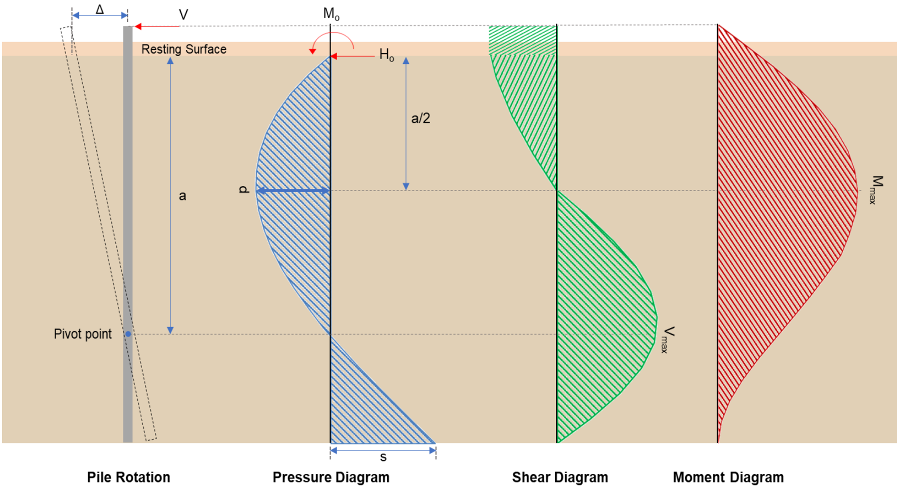
$Ratio$ - Lateral soil capacity

$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{(0.064998\ \text{kip/ft}^2)}{(1.2\ \text{kip/ft}^2)}$$

$$Ratio = 0.054165$$

Status: **PASS**
Ratio: **0.050**



Shear force and Bending moment (x-direction, LRFD)

H_o - Lateral force per length of pile,

$$H_o = \frac{V_x}{1.57\,D}$$

$$H_o = \frac{(-7.899\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -1.2578\ \text{kip/ft}$$

M_o - Moment per length of pile,

$$M_o = \frac{M_z + (V_x\,H)}{1.57\,D}$$

$$M_o = \frac{(94.65\ \text{kipft}) + ((-7.899\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 15.072\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

$$E = \frac{M_o}{H_o}$$

$$E = \frac{(15.072\ \text{kipft/ft})}{(-1.2578\ \text{kip/ft})}$$

$$E = 11.983\ \text{ft}$$

a - Distance from resting surface to pivot point,

$$a = \frac{(4\,M_o\,L_e) + \left(3\,H_o\,L_e^2\right)}{(6\,M_o) + (4\,H_o\,L_e)}$$

$$a = \frac{(4 \times (15.072\ \text{kipft/ft}) \times (8\ \text{ft})) + \left(3 \times (-1.2578\ \text{kip/ft}) \times (8\ \text{ft})^2\right)}{(6 \times (15.072\ \text{kipft/ft})) + (4 \times (-1.2578\ \text{kip/ft}) \times (8\ \text{ft}))}$$

$$a = 5.5387\ \text{ft}$$

V_{max} - Max shear force located at depth a,

$$V_{max} = (H_o\,D)\left[1 - \left[3\left(\frac{4\,E}{L_e} + 3\right)\left(\frac{a}{L_e}\right)^2\right] + \left[4\left(\frac{3\,E}{L_e} + 2\right)\left(\frac{a}{L_e}\right)^3\right]\right]$$

$$V_{max} = ((-1.2578\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (11.983\ \text{ft})}{(8\ \text{ft})} + 3\right) \times \left(\frac{(5.5387\ \text{ft})}{(8\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (11.983\ \text{ft})}{(8\ \text{ft})} + 2\right) \times \left(\frac{(5.5387\ \text{ft})}{(8\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 16.652\ \text{kip}$$

M_{max} - Max bending moment located at depth a/2,

$$M_{max} = (H_o\, D\, L_e) \left[\left(\frac{E}{L_e} + \frac{a}{2\, L_e} \right) - \left[\left(\frac{4\, E}{L_e} + 3 \right) \left(\frac{a}{2\, L_e} \right)^3 \right] + \left[\left(\frac{3\, E}{L_e} + 2 \right) \left(\frac{a}{2\, L_e} \right)^4 \right] \right]$$

$$M_{max} = ((-1.2578 \text{ kip/ft}) \times (48 \text{ in}) \times (8 \text{ ft})) \times \left[\left(\frac{(11.983 \text{ ft})}{(8 \text{ ft})} + \frac{(5.5387 \text{ ft})}{2 \times (8 \text{ ft})} \right) - \left[\left(\frac{4 \times (11.983 \text{ ft})}{(8 \text{ ft})} + 3 \right) \times \left(\frac{(5.5387 \text{ ft})}{2 \times (8 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (11.983 \text{ ft})}{(8 \text{ ft})} + 2 \right) \times \left(\frac{(5.5387 \text{ ft})}{2 \times (8 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 62.961 \text{ kipft}$$

Shear force and Bending moment (z-direction, LRFD)

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{1.57\, b}$$

$$H_o = \frac{(0.498 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0793 \text{ kip/ft}$$

M_o - Moment per length of pile,

$$M_o = \frac{M_x + (V_z\, H)}{1.57\, b}$$

$$M_o = \frac{(1.495 \text{ kipft}) + ((0.498 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.23806 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

$$E = \frac{M_o}{H_o}$$

$$E = \frac{(0.23806 \text{ kipft/ft})}{(0.0793 \text{ kip/ft})}$$

$$E = 3.002 \text{ ft}$$

a - Distance from resting surface to pivot point,

$$a = \frac{(4\, M_o\, L_e) + \left(3\, H_o\, L_e^2\right)}{(6\, M_o) + (4\, H_o\, L_e)}$$

$$a = \frac{(4 \times (0.23806 \text{ kipft/ft}) \times (8 \text{ ft})) + \left(3 \times (0.0793 \text{ kip/ft}) \times (8 \text{ ft})^2\right)}{(6 \times (0.23806 \text{ kipft/ft})) + (4 \times (0.0793 \text{ kip/ft}) \times (8 \text{ ft}))}$$

$$a = 5.7599 \text{ ft}$$

V_{max} - Max shear force located at depth a,

$$V_{max} = (H_o\, b) \left[1 - \left[3 \left(\frac{4\, E}{L_e} + 3 \right) \left(\frac{a}{L_e} \right)^2 \right] + \left[4 \left(\frac{3\, E}{L_e} + 2 \right) \left(\frac{a}{L_e} \right)^3 \right] \right]$$

$$V_{max} = ((0.0793 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.002 \text{ ft})}{(8 \text{ ft})} + 3 \right) \times \left(\frac{(5.7599 \text{ ft})}{(8 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (3.002 \text{ ft})}{(8 \text{ ft})} + 2 \right) \times \left(\frac{(5.7599 \text{ ft})}{(8 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.4229 \text{ kip}$$

M_{max} - Max bending moment located at depth a/2,

$$M_{max} = (H_o\, b\, L_e) \left[\left(\frac{E}{L_e} + \frac{a}{2\, L_e} \right) - \left[\left(\frac{4\, E}{L_e} + 3 \right) \left(\frac{a}{2\, L_e} \right)^3 \right] + \left[\left(\frac{3\, E}{L_e} + 2 \right) \left(\frac{a}{2\, L_e} \right)^4 \right] \right]$$

$$M_{max} = ((0.0793 \text{ kip/ft}) \times (48 \text{ in}) \times (8 \text{ ft})) \times \left[\left(\frac{(3.002 \text{ ft})}{(8 \text{ ft})} + \frac{(5.7599 \text{ ft})}{2 \times (8 \text{ ft})} \right) - \left[\left(\frac{4 \times (3.002 \text{ ft})}{(8 \text{ ft})} + 3 \right) \times \left(\frac{(5.7599 \text{ ft})}{2 \times (8 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (3.002 \text{ ft})}{(8 \text{ ft})} + 2 \right) \times \left(\frac{(5.7599 \text{ ft})}{2 \times (8 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 1.4661 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 2.5 \text{ ksi}$ - Concrete strength,
$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
Table 22.4.2.1 $\alpha = 0.8$ - Alpha factor for axial strength,
$A_g = 2304 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

Required reinforcement due to axial load, $A_{st,required}$
22.4.2.2, 10.6.1.1 $A_{st,required}$

$$A_{st,required} = Min\left[\frac{\frac{P}{\phi\ \alpha} - (0.85\ f'_{ck}\ A_g)}{f_{yk} - (0.85\ f'_{ck})}, (0.08\ A_g)\right]$$

$$A_{st,required} = Min\left[\frac{\frac{(12.286 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.188 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

$$A_{min} = Max\left[A_{st,required}, (0.0018\ A_g)\right]$$

$$A_{min} = Max\left[\left(-84.188 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{min} = 4.1472 \text{ in}^2$$

n_{rebar} - Required number of reinforcement,

$$n_{rebar} = \frac{A_{min}}{A_{rebar}}$$

$$n_{rebar} = \frac{\left(4.1472 \text{ in}^2\right)}{\left(0.3068 \text{ in}^2\right)}$$

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

$$A_{st} = n_{rebar}\ \frac{\pi\ d_{bar}^2}{4}$$

$$A_{st} = (14) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 4.2951 \text{ in}^2$$

$Ratio$ - Capacity

$$Ratio = \frac{A_{min}}{A_{st}}$$

$$Ratio = \frac{\left(4.1472 \text{ in}^2\right)}{\left(4.2951 \text{ in}^2\right)}$$

$$Ratio = 0.96556$$

Status: **PASS**
Ratio: **0.970**

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

$$s_{rebar} = Max\left[1.5, (1.5\ d_{bar})\right]$$

$$s_{rebar} = Max\left[1.5, (1.5 \times (0.625 \text{ in}))\right]$$

$$s_{rebar} = 1.5 \text{ in}$$

Ties:

25.7.2.2 Since longitudinal reinforcement is $\leq$ No. 10ø: Use #3(0.375 in)
25.7.2.1 s_{ties} - Maximum spacing of ties,

$$s_{ties} = Min\left[(16\ d_{bar}), (48\ d_{ties}), Min\,(D, b)\right]$$

$$s_{ties} = Min\left[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), Min\,((48 \text{ in}), (48 \text{ in}))\right]$$

$$s_{ties} = 10 \text{ in}$$

Summary:

Main reinforcement: **14 - #5 (0.625 in)**

	Ties: **#3(0.375 in) - 10 in**	

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

$$\phi P_N = \phi\, 0.80\, \left[\left(0.85\, f'_{ck}\, \left[A_g - A_{st}\right]\right) + \left(f_{yk}\, A_{st}\right)\right]$$

$$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(2304\ \text{in}^2\right) - \left(4.2951\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(4.2951\ \text{in}^2\right)\right)\right]$$

$$\phi P_N = 2675.2\ \text{kip}$$

$Ratio$ - Capacity

$$Ratio = \frac{P}{\phi P_N}$$

$$Ratio = \frac{(12.286\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0045926$$

Status: **PASS**
Ratio: **0.000**

Shear Strength (ACI 318-19, LRFD)

Parameters:

$b_w = 48\ \text{in}$ - Effective width,

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

$$d = 0.80 \times (48\ \text{in})$$

$$d = 38.4\ \text{in}$$

22.5.5.1.3 λ_s - size effect modification factor

$$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1\right]$$

$$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(38.4\ \text{in})}{10}}}, 1\right]$$

$$\lambda_s = 0.64282$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,

22.5.5.1.1 $V_{c,max}$ - Max shear strength of concrete

$$V_{c,max} = 5\, \lambda_s\, \sqrt{f'_{ck}}\, b_w\, d$$

$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,max} = 296.21\ \text{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 12.286\ \text{kip} \rightarrow 12286\ \text{lbf}$,

22.5.5.1.1(a) $V_{c,a}$ - Shear strength of concrete (a)

$$V_{c,a} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \frac{P}{6\, A_g}\right]\, b_w\, d$$

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(12286\ \text{lbf})}{6 \times \left(2304\ \text{in}^2\right)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 120.12\ \text{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,

22.5.5.1.2 $V_{c,b}$ - Shear strength of concrete (b)

$$V_{c,b} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \left(0.05\, f'_{ck}\right)\right]\, b_w\, d$$

$$V_{c,b} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + (0.05 \times (2500\ \text{psi}))\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,b} = 348.89\ \text{kip}$$

V_c - Governing shear strength of concrete

$$V_c = Min\left[V_{c,max}, V_{c,a}, V_{c,b}\right]$$

$$V_c = Min\left[(296.21\ \text{kip}), (120.12\ \text{kip}), (348.89\ \text{kip})\right]$$

$$V_c = 120.12\ \text{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,

22.5.1.2 $V_{s,a}$ - Shear strength of steel (a)

$$V_{s,a} = 8\sqrt{f'_{ck}}\, b_w\, d$$

$$V_{s,a} = 8 \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{s,a} = 737.28\ \text{kip}$$

A_v - Ties rebar area,

$$A_v = \frac{\pi\, d_{ties}^2}{4}$$

$$A_v = \frac{\pi \times (0.375\ \text{in})^2}{4}$$

$$A_v = 0.11045\ \text{in}^2$$

22.5.8.5.3 $V_{s,b}$ - Shear strength of steel (b)

$$V_{s,b} = \frac{2\, A_v\, f_{ywk}\, d}{s_{ties}}$$

$$V_{s,b} = \frac{2 \times \left(0.11045\ \text{in}^2\right) \times (60\ \text{ksi}) \times (38.4\ \text{in})}{(10\ \text{in})}$$

$$V_{s,b} = 50.894\ \text{kip}$$

V_s - Governing shear strength of steel

$$V_s = MIN\left[V_{s,a}, V_{s,b}\right]$$

$$V_s = MIN\left[(737.28\ \text{kip}), (50.894\ \text{kip})\right]$$

$$V_s = 50.894\ \text{kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

$$\phi V_n = \phi\ (V_c + V_s)$$

$$\phi V_n = (0.65) \times ((120.12\ \text{kip}) + (50.894\ \text{kip}))$$

$$\phi V_n = 111.16\ \text{kip}$$

Considering x-direction:

$V_{max} = 16.652\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

$$Ratio = \frac{V_{max}}{\phi V_n}$$

$$Ratio = \frac{(16.652\ \text{kip})}{(111.16\ \text{kip})}$$

$$Ratio = 0.1498$$

Status: **PASS**
Ratio: **0.150**

Considering z-direction:

$V_{max} = 0.4229\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

$$Ratio = \frac{V_{max}}{\phi V_n}$$

$$Ratio = \frac{(0.4229\ \text{kip})}{(111.16\ \text{kip})}$$

$$Ratio = 0.0038044$$

Status: **PASS**
Ratio: **0.000**

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{b\, D^2}{6}$$

$$S_m = \frac{(48\ \text{in}) \times (48\ \text{in})^2}{6}$$

$$S_m = 18432\ \text{in}^3$$

	$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6 \text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$ $$\phi M_n = 249.6 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 62.961 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(62.961 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.25225$$	Status: **PASS** Ratio: **0.250**
	Considering z-direction: $M_{max} = 1.4661 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(1.4661 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.0058738$$	Status: **PASS** Ratio: **0.010**

REFERENCES	CALCULATIONS	RESULTS

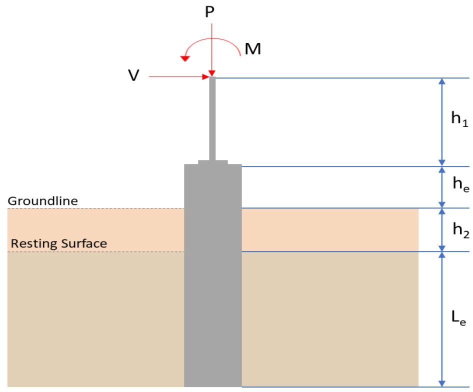
SkyCiv Foundation Design

Pile Foundation

Design Information :

Design code : IBC 2021 (International Building Code)
Unit System : Imperial

Pile Input



Geometry

Pile shape: rectangular

$b = 48\ \mathrm{in}$ - Pile width

$D = 48\ \mathrm{in}$ - Pile depth

$L = 8\ \mathrm{ft}$ - Total pile length

$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,

$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface

$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

Layer	Label	Allowable Bearing Pressure (q_a) (psf)	Allowable Lateral Pressure (R) (psf/ft)
1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	8.175	12.286
V_x (kip)	-4.739	-7.899
V_z (kip)	-0.308	-0.498
M_x (kipft)	-0.945	-1.496
M_z (kipft)	56.367	94.652

Material Properties

$f'_{ck} = 2.5\ \mathrm{ksi}$ - Concrete strength,

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

$$H = (0\ \mathrm{ft}) + (0\ \mathrm{ft}) + (0\ \mathrm{ft})$$

$$H = 0\ \mathrm{ft}$$

Considering x-direction:

H_o - Lateral force per length of pile,

$$H_o = \frac{V_x}{1.57\ D}$$

$$H_o = \frac{(-4.739\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.75462\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

$$M_o = \frac{M_z + (V_x\ H)}{1.57\ D}$$

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$$M_o = \frac{(56.367\ \mathrm{kipft}) + ((-4.739\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 8.9756\ \mathrm{kipft/ft}$$

Required depth of embedment in earth:

$$L_x^3 - \left(14.14 \times \frac{H_o \times L_x}{R}\right) - \left(18.85 \times \frac{M_o}{R}\right) = 0$$

Solving the cubic equation:
$L_{e,x} = 7.2927\ \mathrm{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{1.57\, b}$$

$$H_o = \frac{(-0.308\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.049045\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

$$M_o = \frac{M_x + (V_z\, H)}{1.57\, b}$$

$$M_o = \frac{(0.945\ \mathrm{kipft}) + ((-0.308\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.15048\ \mathrm{kipft/ft}$$

Required depth of embedment in earth:

$$L_z^3 - \left(14.14 \times \frac{H_o \times L_z}{R}\right) - \left(18.85 \times \frac{M_o}{R}\right) = 0$$

Solving the cubic equation:
$L_{e,z} = 1.8698\ \mathrm{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

$L_{e,req}$ - Depth of pile required,

$$L_{e,req} = MAX[L_{e,x}, L_{e,z}]$$

$$L_{e,req} = MAX[(7.2927\ \mathrm{ft}), (1.8698\ \mathrm{ft})]$$

$$L_{e,req} = 7.293\ \mathrm{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8\ \mathrm{ft}) - (0\ \mathrm{ft}) - (0\ \mathrm{ft})$$

$$L_e = 8\ \mathrm{ft}$$

$Ratio$ - Embedded depth

$$Ratio = \frac{L_{e,req}}{L_e}$$

$$Ratio = \frac{(7.293\ \mathrm{ft})}{(8\ \mathrm{ft})}$$

$$Ratio = 0.91163$$

Status: **PASS**
Ratio: **0.910**

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

$$A = (48\ \mathrm{in}) \times (48\ \mathrm{in})$$

$$A = 16\ \mathrm{ft}^2$$

q - End-bearing pressure

$$q = \frac{P_v}{A}$$

$$q = \frac{(8.175\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.51094\ \mathrm{kip/ft}^2$$

$q = 0.51094\ \text{kip/ft}$

Check bearing capacity ratio:

$Ratio$ - Capacity

$$Ratio = \frac{q}{q_a}$$

$$Ratio = \frac{\left(0.51094\ \text{kip/ft}^2\right)}{(2000\ \text{psf})}$$

$$Ratio = 0.25547$$

Status: **PASS**
Ratio: **0.260**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

$$L/D = \frac{L}{D}$$

$$L/D = \frac{(8\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 2$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.75462\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 8.9756\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

$$a = \frac{(4\, M_o\, L_e) + \left(3\, H_o\, L_e^2\right)}{(6\, M_o) + (4\, H_o\, L_e)}$$

$$a = \frac{(4 \times (8.9756\ \text{kipft/ft}) \times (8\ \text{ft})) + \left(3 \times (-0.75462\ \text{kip/ft}) \times (8\ \text{ft})^2\right)}{(6 \times (8.9756\ \text{kipft/ft})) + (4 \times (-0.75462\ \text{kip/ft}) \times (8\ \text{ft}))}$$

$$a = 5.5397\ \text{ft}$$

p - Earth pressure against the pile at distance a/2 from resting surface,

$$p = \frac{0.75\ [(4\, M_o) + (3\, H_o\, L_e)]^2}{L_e^2\ [(3\, M_o) + (2\, H_o\, L_e)]}$$

$$p = \frac{0.75 \times [(4 \times (8.9756\ \text{kipft/ft})) + (3 \times (-0.75462\ \text{kip/ft}) \times (8\ \text{ft}))]^{\ 2}}{(8\ \text{ft})^2 \times [(3 \times (8.9756\ \text{kipft/ft})) + (2 \times (-0.75462\ \text{kip/ft}) \times (8\ \text{ft}))]}$$

$$p = 0.24975\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{6\ [(2\, M_o) + (H_o\, L_e)]}{L_e^2}$$

$$s = \frac{6 \times [(2 \times (8.9756\ \text{kipft/ft})) + ((-0.75462\ \text{kip/ft}) \times (8\ \text{ft}))]}{(8\ \text{ft})^2}$$

$$s = 1.117\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

p_a - Allowable lateral soil pressure at depth a/2,

$$p_a = R\, \frac{a}{2}$$

$$p_a = (150\ \text{psf/ft}) \times \frac{(5.5397\ \text{ft})}{2}$$

$$p_a = 0.41548\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

$$Ratio = \frac{p}{p_a}$$

$$Ratio = \frac{\left(0.24975\ \text{kip/ft}^2\right)}{\left(0.41548\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.60111$$

Status: **PASS**
Ratio: **0.600**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8\ \mathrm{ft})$$

$$p_s = 1.2\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{\left(1.117\ \mathrm{kip/ft^2}\right)}{\left(1.2\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.93081$$

Status: **PASS**
Ratio: **0.930**

Considering z-direction:

$H_o = -0.049045\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.15048\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

$$a = \frac{(4\,M_o\,L_e) + \left(3\,H_o\,L_e^2\right)}{(6\,M_o) + (4\,H_o\,L_e)}$$

$$a = \frac{(4 \times (0.15048\ \mathrm{kipft/ft}) \times (8\ \mathrm{ft})) + \left(3 \times (-0.049045\ \mathrm{kip/ft}) \times (8\ \mathrm{ft})^2\right)}{(6 \times (0.15048\ \mathrm{kipft/ft})) + (4 \times (-0.049045\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))}$$

$$a = 5.7565\ \mathrm{ft}$$

p - Earth pressure against the pile at distance a/2 from resting surface,

$$p = \frac{0.75\,[(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\,[(3\,M_o) + (2\,H_o\,L_e)]}$$

$$p = \frac{0.75 \times [(4 \times (0.15048\ \mathrm{kipft/ft})) + (3 \times (-0.049045\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]^{\ 2}}{(8\ \mathrm{ft})^2 \times [(3 \times (0.15048\ \mathrm{kipft/ft})) + (2 \times (-0.049045\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]}$$

$$p = -0.011632\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{6\,[(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$

$$s = \frac{6 \times [(2 \times (0.15048\ \mathrm{kipft/ft})) + ((-0.049045\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]}{(8\ \mathrm{ft})^2}$$

$$s = -0.0085689\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

p_a - Allowable lateral soil pressure at depth a/2,

$$p_a = R\,\frac{a}{2}$$

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.7565\ \mathrm{ft})}{2}$$

$$p_a = 0.43174\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

$$Ratio = \frac{p}{p_a}$$

$$Ratio = \frac{\left(-0.011632\ \mathrm{kip/ft^2}\right)}{\left(0.43174\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.026942$$

Status: **PASS**
Ratio: **-0.030**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8\ \mathrm{ft})$$

$$p_s = 1.2\ \mathrm{kip/ft^2}$$

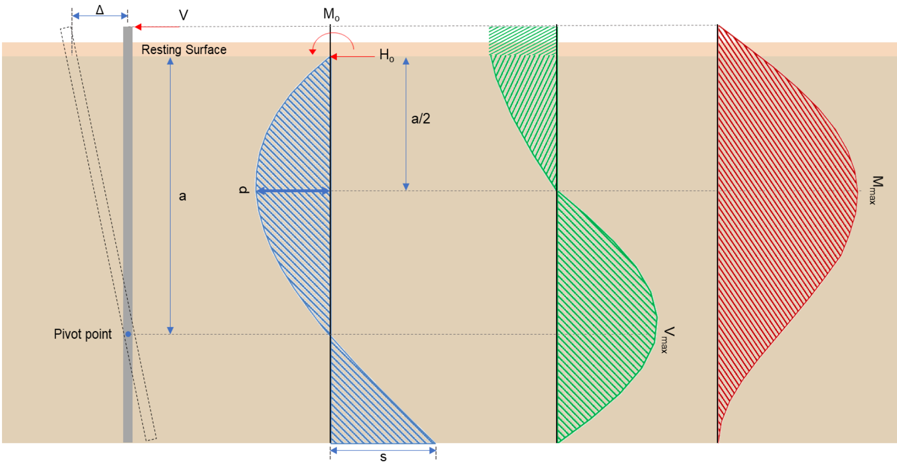
$Ratio$ - Lateral soil capacity

$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{\left(-0.0085689 \text{ kip/ft}^2\right)}{\left(1.2 \text{ kip/ft}^2\right)}$$

$$Ratio = -0.0071407$$

Status: **PASS**
Ratio: **-0.010**



Pile Rotation Pressure Diagram Shear Diagram Moment Diagram

Shear force and Bending moment (x-direction, LRFD)

H_o - Lateral force per length of pile,

$$H_o = \frac{V_x}{1.57\, D}$$

$$H_o = \frac{(-7.899 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -1.2578 \text{ kip/ft}$$

M_o - Moment per length of pile,

$$M_o = \frac{M_z + (V_x\, H)}{1.57\, D}$$

$$M_o = \frac{(94.652 \text{ kipft}) + ((-7.899 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 15.072 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

$$E = \frac{M_o}{H_o}$$

$$E = \frac{(15.072 \text{ kipft/ft})}{(-1.2578 \text{ kip/ft})}$$

$$E = 11.983 \text{ ft}$$

a - Distance from resting surface to pivot point,

$$a = \frac{(4\, M_o\, L_e) + \left(3\, H_o\, L_e^2\right)}{(6\, M_o) + (4\, H_o\, L_e)}$$

$$a = \frac{(4 \times (15.072 \text{ kipft/ft}) \times (8 \text{ ft})) + \left(3 \times (-1.2578 \text{ kip/ft}) \times (8 \text{ ft})^2\right)}{(6 \times (15.072 \text{ kipft/ft})) + (4 \times (-1.2578 \text{ kip/ft}) \times (8 \text{ ft}))}$$

$$a = 5.5387 \text{ ft}$$

V_{max} - Max shear force located at depth a,

$$V_{max} = (H_o\, D) \left[1 - \left[3 \left(\frac{4\, E}{L_e} + 3\right) \left(\frac{a}{L_e}\right)^2\right] + \left[4 \left(\frac{3\, E}{L_e} + 2\right) \left(\frac{a}{L_e}\right)^3\right]\right]$$

$$V_{max} = ((-1.2578 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (11.983 \text{ ft})}{(8 \text{ ft})} + 3\right) \times \left(\frac{(5.5387 \text{ ft})}{(8 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (11.983 \text{ ft})}{(8 \text{ ft})} + 2\right) \times \left(\frac{(5.5387 \text{ ft})}{(8 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 16.652 \text{ kip}$$

M_{max} - Max bending moment located at depth a/2,

$$M_{max} = (H_o\, D\, L_e) \left[\left(\frac{E}{L_e} + \frac{a}{2\, L_e}\right) - \left[\left(\frac{4\, E}{L_e} + 3\right) \left(\frac{a}{2\, L_e}\right)^3\right] + \left[\left(\frac{3\, E}{L_e} + 2\right) \left(\frac{a}{2\, L_e}\right)^4\right]\right]$$

$$M_{max} = ((-1.2578 \text{ kip/ft}) \times (48 \text{ in}) \times (8 \text{ ft})) \times \left[\left(\frac{(11.983 \text{ ft})}{(8 \text{ ft})} + \frac{(5.5387 \text{ ft})}{2 \times (8 \text{ ft})}\right) - \left[\left(\frac{4 \times (11.983 \text{ ft})}{(8 \text{ ft})} + 3\right) \times \left(\frac{(5.5387 \text{ ft})}{2 \times (8 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (11.983 \text{ ft})}{(8 \text{ ft})} + 2\right) \times \left(\frac{(5.5387 \text{ ft})}{2 \times (8 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 62.962 \text{ kipft}$$

Shear force and Bending moment (z-direction, LRFD)

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{1.57\, b}$$

$$H_o = \frac{(-0.498 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0793 \text{ kip/ft}$$

M_o - Moment per length of pile,

$$M_o = \frac{M_x + (V_z\, H)}{1.57\, b}$$

$$M_o = \frac{(1.496 \text{ kipft}) + ((-0.498 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.23822 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

$$E = \frac{M_o}{H_o}$$

$$E = \frac{(0.23822 \text{ kipft/ft})}{(-0.0793 \text{ kip/ft})}$$

$$E = 3.004 \text{ ft}$$

a - Distance from resting surface to pivot point,

$$a = \frac{(4\, M_o\, L_e) + \left(3\, H_o\, L_e^2\right)}{(6\, M_o) + (4\, H_o\, L_e)}$$

$$a = \frac{(4 \times (0.23822 \text{ kipft/ft}) \times (8 \text{ ft})) + \left(3 \times (-0.0793 \text{ kip/ft}) \times (8 \text{ ft})^2\right)}{(6 \times (0.23822 \text{ kipft/ft})) + (4 \times (-0.0793 \text{ kip/ft}) \times (8 \text{ ft}))}$$

$$a = 5.7598 \text{ ft}$$

V_{max} - Max shear force located at depth a,

$$V_{max} = (H_o\, b) \left[1 - \left[3 \left(\frac{4\, E}{L_e} + 3\right) \left(\frac{a}{L_e}\right)^2\right] + \left[4 \left(\frac{3\, E}{L_e} + 2\right) \left(\frac{a}{L_e}\right)^3\right]\right]$$

$$V_{max} = ((-0.0793 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.004 \text{ ft})}{(8 \text{ ft})} + 3\right) \times \left(\frac{(5.7598 \text{ ft})}{(8 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.004 \text{ ft})}{(8 \text{ ft})} + 2\right) \times \left(\frac{(5.7598 \text{ ft})}{(8 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.42304 \text{ kip}$$

M_{max} - Max bending moment located at depth a/2,

$$M_{max} = (H_o\, b\, L_e) \left[\left(\frac{E}{L_e} + \frac{a}{2\, L_e}\right) - \left[\left(\frac{4\, E}{L_e} + 3\right) \left(\frac{a}{2\, L_e}\right)^3\right] + \left[\left(\frac{3\, E}{L_e} + 2\right) \left(\frac{a}{2\, L_e}\right)^4\right]\right]$$

$$M_{max} = ((-0.0793 \text{ kip/ft}) \times (48 \text{ in}) \times (8 \text{ ft})) \times \left[\left(\frac{(3.004 \text{ ft})}{(8 \text{ ft})} + \frac{(5.7598 \text{ ft})}{2 \times (8 \text{ ft})}\right) - \left[\left(\frac{4 \times (3.004 \text{ ft})}{(8 \text{ ft})} + 3\right) \times \left(\frac{(5.7598 \text{ ft})}{2 \times (8 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.004 \text{ ft})}{(8 \text{ ft})} + 2\right) \times \left(\frac{(5.7598 \text{ ft})}{2 \times (8 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 1.4666 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 2.5 \text{ ksi}$ - Concrete strength,
$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
Table 22.4.2.1 $\alpha = 0.8$ - Alpha factor for axial strength,
$A_g = 2304 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

Required reinforcement due to axial load, $A_{st,required}$
22.4.2.2, 10.6.1.1 $A_{st,required}$

$$A_{st,required} = Min\left[\frac{\frac{P}{\phi\ \alpha} - (0.85\ f'_{ck}\ A_g)}{f_{yk} - (0.85\ f'_{ck})}, (0.08\ A_g)\right]$$

$$A_{st,required} = Min\left[\frac{\frac{(12.286 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.188 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

$$A_{min} = Max\left[A_{st,required}, (0.0018\ A_g)\right]$$

$$A_{min} = Max\left[\left(-84.188 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{min} = 4.1472 \text{ in}^2$$

n_{rebar} - Required number of reinforcement,

$$n_{rebar} = \frac{A_{min}}{A_{rebar}}$$

$$n_{rebar} = \frac{\left(4.1472 \text{ in}^2\right)}{\left(0.3068 \text{ in}^2\right)}$$

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

$$A_{st} = n_{rebar}\ \frac{\pi\ d_{bar}^2}{4}$$

$$A_{st} = (14) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 4.2951 \text{ in}^2$$

$Ratio$ - Capacity

$$Ratio = \frac{A_{min}}{A_{st}}$$

$$Ratio = \frac{\left(4.1472 \text{ in}^2\right)}{\left(4.2951 \text{ in}^2\right)}$$

$$Ratio = 0.96556$$

Status: **PASS**
Ratio: **0.970**

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

$$s_{rebar} = Max\left[1.5, (1.5\ d_{bar})\right]$$

$$s_{rebar} = Max\left[1.5, (1.5 \times (0.625 \text{ in}))\right]$$

$$s_{rebar} = 1.5 \text{ in}$$

Ties:

25.7.2.2 Since longitudinal reinforcement is $\leq$ No. 10ø: Use #3(0.375 in)
25.7.2.1 s_{ties} - Maximum spacing of ties,

$$s_{ties} = Min\left[(16\ d_{bar}), (48\ d_{ties}), Min\,(D, b)\right]$$

$$s_{ties} = Min\left[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), Min\,((48 \text{ in}), (48 \text{ in}))\right]$$

$$s_{ties} = 10 \text{ in}$$

Summary:

Main reinforcement: **14 - #5 (0.625 in)**

	Ties: **#3(0.375 in) - 10 in**		

	Axial Compression Strength (ACI 318-19, LRFD)	
22.4.2.2	ϕP_N - Allowable axial compressive strength $$\phi P_N = \phi\, 0.80\, \left[\left(0.85\, f'_{ck}\, \left[A_g - A_{st}\right]\right) + \left(f_{yk}\, A_{st}\right)\right]$$ $$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \mathrm{ksi}) \times \left[\left(2304\ \mathrm{in}^2\right) - \left(4.2951\ \mathrm{in}^2\right)\right]\right) + \left((60\ \mathrm{ksi}) \times \left(4.2951\ \mathrm{in}^2\right)\right)\right]$$ $$\phi P_N = 2675.2\ \mathrm{kip}$$	
	$Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(12.286\ \mathrm{kip})}{(2675.2\ \mathrm{kip})}$$ $$Ratio = 0.0045926$$	Status: **PASS** Ratio: **0.000**
	Shear Strength (ACI 318-19, LRFD) **Parameters:** $b_w = 48\ \mathrm{in}$ - Effective width,	
22.5.2.2	d - Effective depth $$d = 0.80\, D$$ $$d = 0.80 \times (48\ \mathrm{in})$$ $$d = 38.4\ \mathrm{in}$$	
22.5.5.1.3	λ_s - size effect modification factor $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1\right]$$ $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(38.4\ \mathrm{in})}{10}}}, 1\right]$$ $$\lambda_s = 0.64282$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$,	
22.5.5.1.1	$V_{c,max}$ - Max shear strength of concrete $$V_{c,max} = 5\, \lambda_s\, \sqrt{f'_{ck}}\, b_w\, d$$ $$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\ \mathrm{psi})} \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$ $$V_{c,max} = 296.21\ \mathrm{kip}$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$, $P = 12.286\ \mathrm{kip} \rightarrow 12286\ \mathrm{lbf}$,	
22.5.5.1.1(a)	$V_{c,a}$ - Shear strength of concrete (a) $$V_{c,a} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \frac{P}{6\, A_g}\right]\, b_w\, d$$ $$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \mathrm{psi})} + \frac{(12286\ \mathrm{lbf})}{6 \times \left(2304\ \mathrm{in}^2\right)}\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$ $$V_{c,a} = 120.12\ \mathrm{kip}$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$,	
22.5.5.1.2	$V_{c,b}$ - Shear strength of concrete (b) $$V_{c,b} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \left(0.05\, f'_{ck}\right)\right]\, b_w\, d$$ $$V_{c,b} = \left[2 \times (0.64282) \times \sqrt{(2500\ \mathrm{psi})} + (0.05 \times (2500\ \mathrm{psi}))\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$ $$V_{c,b} = 348.89\ \mathrm{kip}$$	
	V_c - Governing shear strength of concrete $$V_c = Min\left[V_{c,max}, V_{c,a}, V_{c,b}\right]$$ $$V_c = Min\left[(296.21\ \mathrm{kip}), (120.12\ \mathrm{kip}), (348.89\ \mathrm{kip})\right]$$ $$V_c = 120.12\ \mathrm{kip}$$	

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,

22.5.1.2 $V_{s,a}$ - Shear strength of steel (a)

$$V_{s,a} = 8 \sqrt{f'_{ck}}\, b_w\, d$$

$$V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{s,a} = 737.28 \text{ kip}$$

A_v - Ties rebar area,

$$A_v = \frac{\pi\, d_{ties}^2}{4}$$

$$A_v = \frac{\pi \times (0.375 \text{ in})^2}{4}$$

$$A_v = 0.11045 \text{ in}^2$$

22.5.8.5.3 $V_{s,b}$ - Shear strength of steel (b)

$$V_{s,b} = \frac{2\, A_v\, f_{ywk}\, d}{s_{ties}}$$

$$V_{s,b} = \frac{2 \times \left(0.11045 \text{ in}^2\right) \times (60 \text{ ksi}) \times (38.4 \text{ in})}{(10 \text{ in})}$$

$$V_{s,b} = 50.894 \text{ kip}$$

V_s - Governing shear strength of steel

$$V_s = MIN\left[V_{s,a}, V_{s,b}\right]$$

$$V_s = MIN\left[(737.28 \text{ kip}), (50.894 \text{ kip})\right]$$

$$V_s = 50.894 \text{ kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

$$\phi V_n = \phi\, (V_c + V_s)$$

$$\phi V_n = (0.65) \times ((120.12 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.16 \text{ kip}$$

Considering x-direction:

$V_{max} = 16.652 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

$$Ratio = \frac{V_{max}}{\phi V_n}$$

$$Ratio = \frac{(16.652 \text{ kip})}{(111.16 \text{ kip})}$$

$$Ratio = 0.1498$$

Status: **PASS**
Ratio: **0.150**

Considering z-direction:

$V_{max} = 0.42304 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

$$Ratio = \frac{V_{max}}{\phi V_n}$$

$$Ratio = \frac{(0.42304 \text{ kip})}{(111.16 \text{ kip})}$$

$$Ratio = 0.0038056$$

Status: **PASS**
Ratio: **0.000**

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{b\, D^2}{6}$$

$$S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$$

$$S_m = 18432 \text{ in}^3$$

$\lambda = 1$ - Concrete modification factor (Normal concrete),
Allowable flexural strength:
M_n shall be the lesser of:
$\phi M_{n,1}$

$$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$

$$\phi M_{n,1} = 249.600kipft$$

14.5.2.1b $\phi M_{n,2}$

$$\phi M_{n,2} = \phi \, 0.85 \, f_{ck}' \, S_m$$

$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$

$$\phi M_{n,2} = 2121.6 \text{ kipft}$$

Therefore,
ϕM_n - Allowable flexural strength,

$$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$

$$\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$

$$\phi M_n = 249.6 \text{ kipft}$$

Considering x-direction:

$M_{max} = 62.962 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

$$Ratio = \frac{M_{max}}{\phi M_n}$$

$$Ratio = \frac{(62.962 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.25225$$

Status: **PASS**
Ratio: **0.250**

Considering z-direction:

$M_{max} = 1.4666 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

$$Ratio = \frac{M_{max}}{\phi M_n}$$

$$Ratio = \frac{(1.4666 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.005876$$

Status: **PASS**
Ratio: **0.010**