Your Project Calculations

Project Name: Tester_rev1

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=Tester_rev1&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/9_2023

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=BPSjVE62XotcKCoZfcjGG8hrO0EP7mMvgxVgv4thqpprR7tPsi05uDQHlFpFaukP

Array Specification

Product:	Beam
Unique ID:	2P-15-8TOP-HD-12-L-5Hx4W-005F
Duty Classification:	HD
Module Width:	41.10 in
Module Length:	74.00in
Number of Rows:	5
Number of Columns:	4
Total Number of Modules:	20
Desired Tilt Angle:	45
Front Edge Clearance:	6
Total Array Height at Tilt:	18.18 ft
Total Frame Length:	24.50 ft
Frame Weight:	1971 lbs
Array Dimensions N/S:	17.33 ft
Array Dimensions E/W:	25.00 ft
Rail Length:	208.00 in
Rail Spacing:	3.08 ft
Rail Check:	Not Checked

Support Specifications

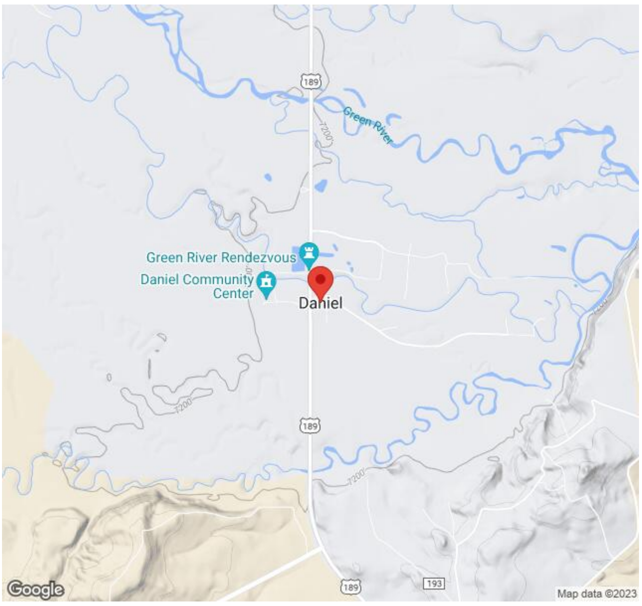
Pole Size:	8in Pipe Sch 80
Pole Length above Grade:	12.13 ft
Number of Poles:	2
Pole Spacing:	15 ft

Foundation Specifications

Foundation Type:	Round
Foundation Dimensions:	Ø36 in
Foundation Depth (below grade):	Pile 1: 15.00 ft Pile 2: 15.00 ft
Foundation Volume:	7.854 y^3
Foundation Result:	FAILED Try increasing foundation size and/or type and re-running foundation design check on right panel.
Mount Twist:	1.179017 kip

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	Daniel, WY, USA
Wind Speed:	115 mph
Snow Load:	85 psf
Design Uplift Pressure:	Multiple pressures
Design Downforce Pressure:	Multiple pressures
Design Snow Pressure:	0.023367 ksf

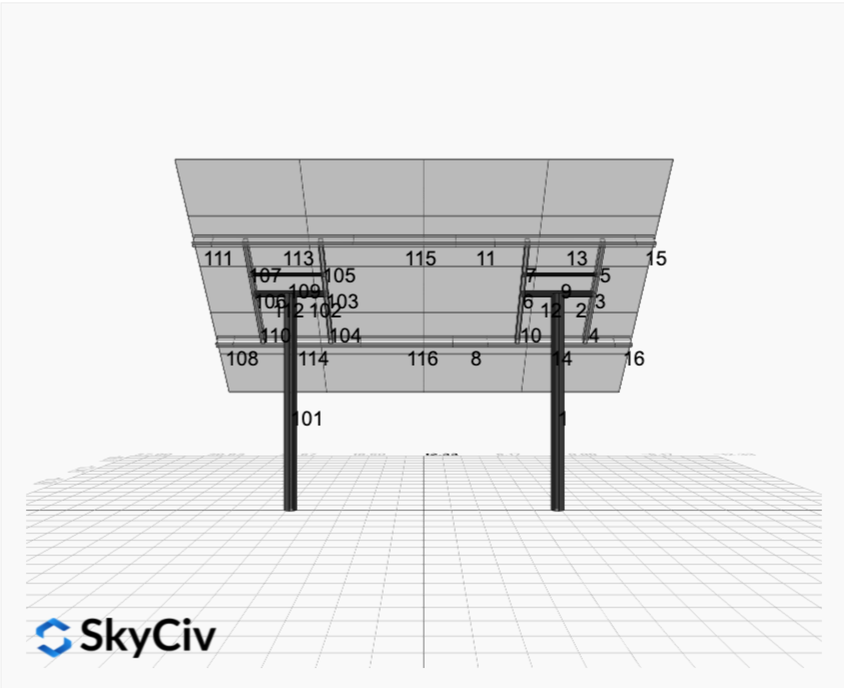


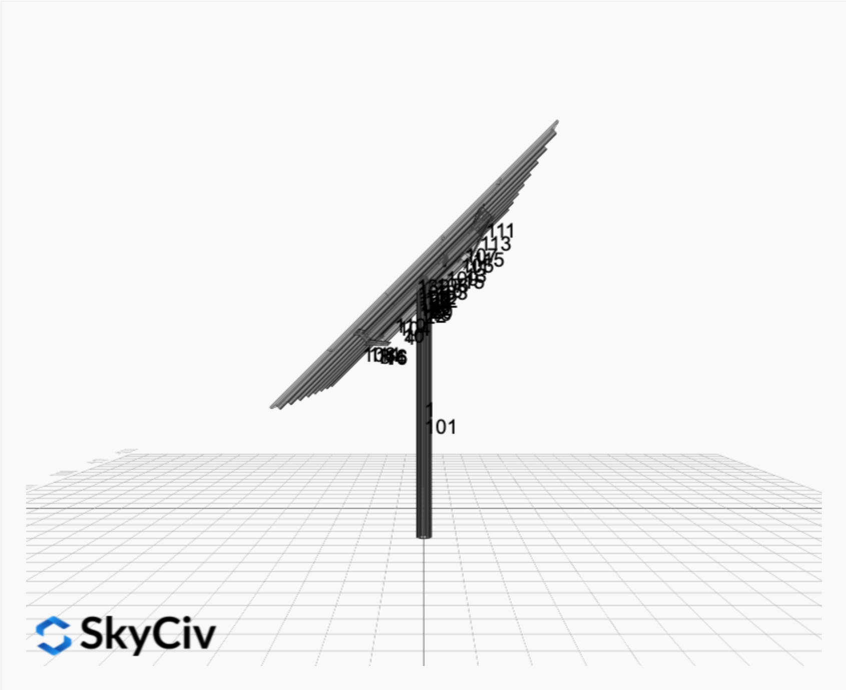
AutoDesigner Input

{"product_type":"Beam","project_id":"Tester_rev1","site_address":"Daniel, WY, USA","module_width":41.1,"module_length":74,"number_rows":"5","number_columns":4,"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":45,"ground_clearance":6,"risk_category":"I","exposure_category":"C","frame_duty_override":"auto","pole_override":"auto","soil_type":"sand","customer_foundation_override":"36_Round","foundation_type":"Round","foundation_size":36,"check_rails":false,"wind_speed_override":115,"snow_load_override":85,"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

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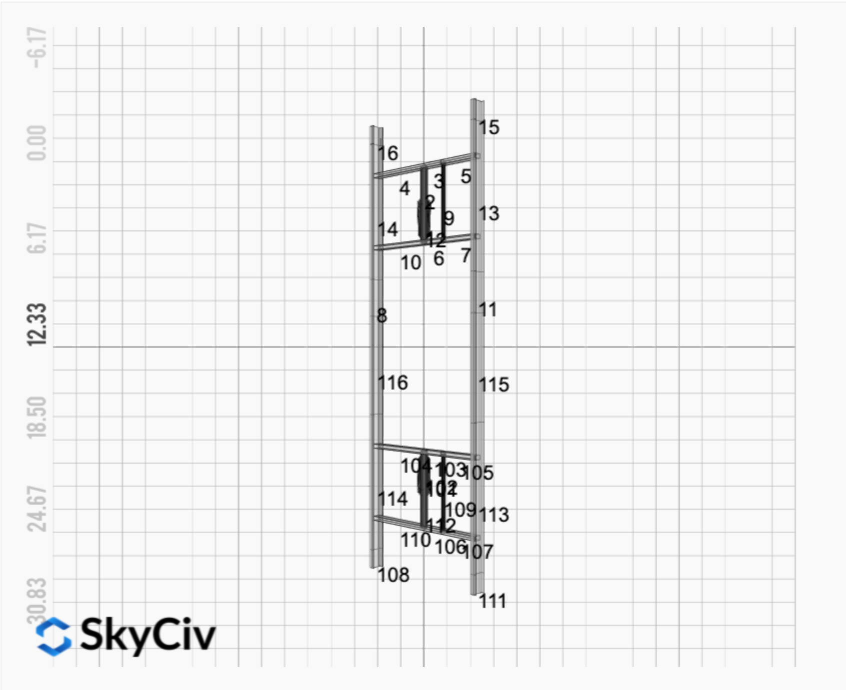
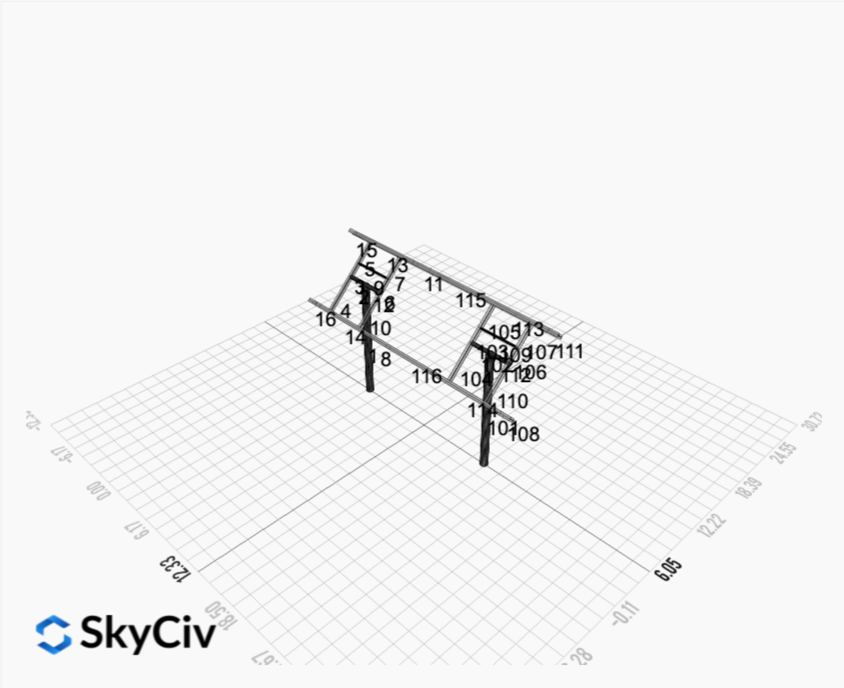
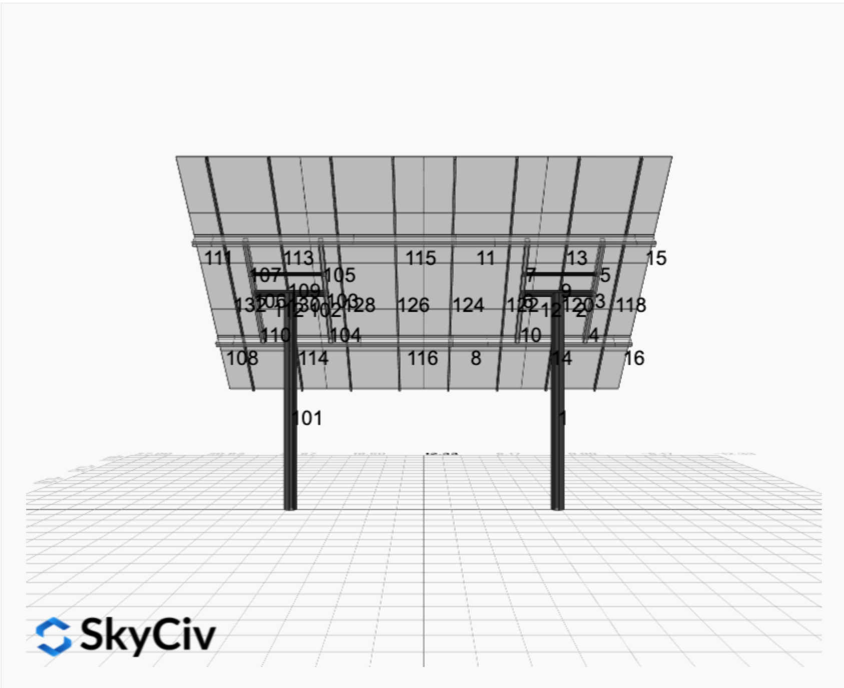
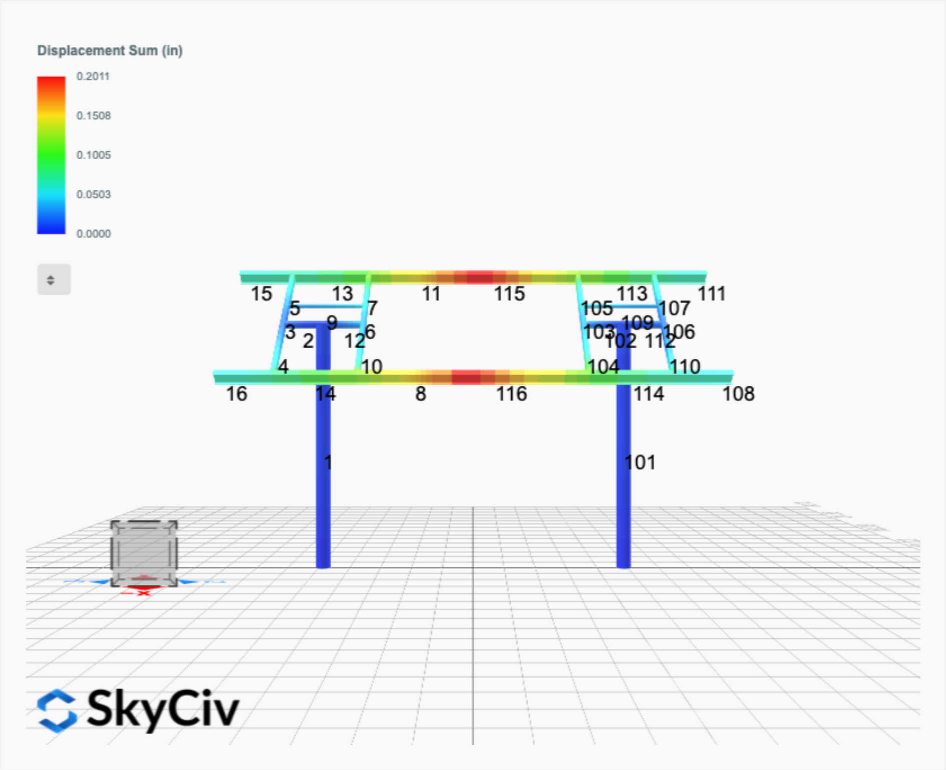
113
101
SkyCiv

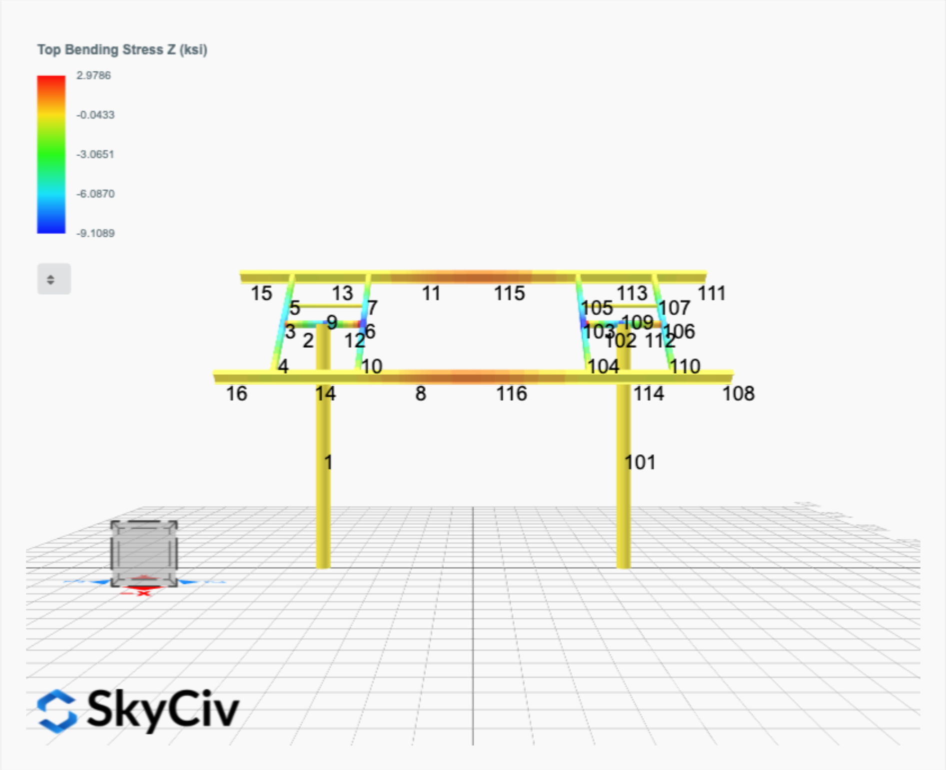

-6.17
0.00
6.17
12.33
18.50
24.67
30.83
15
16
4
3
5
2
9
13
14
12
10
6
7
8
11
116
115
104
103
105
114
109
113
112
110
106
107
108
111
SkyCiv

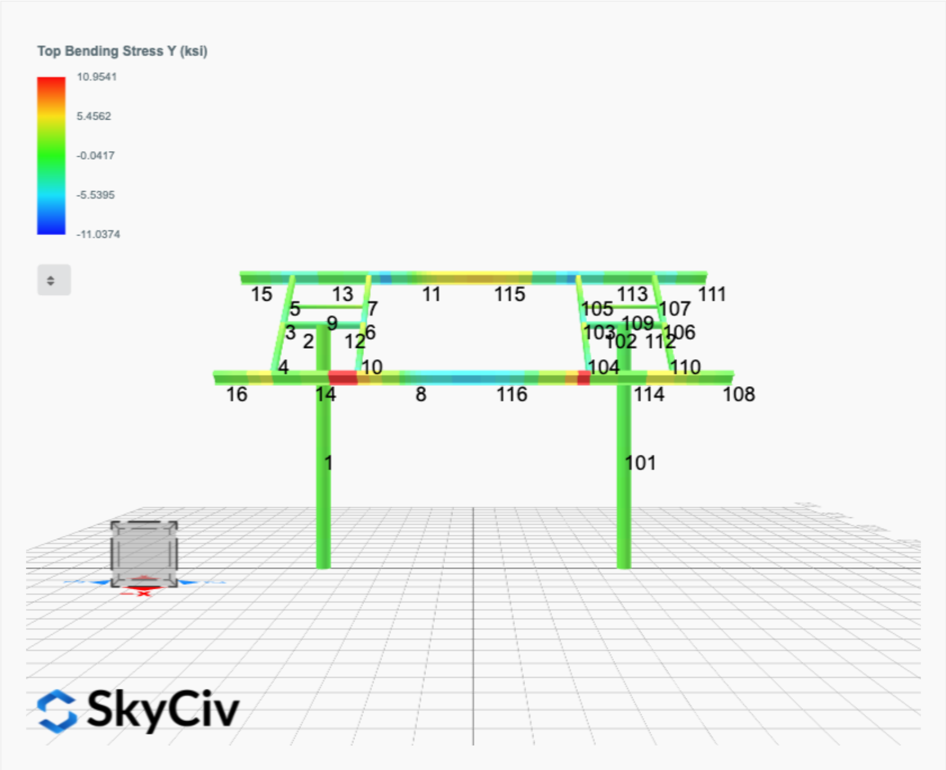


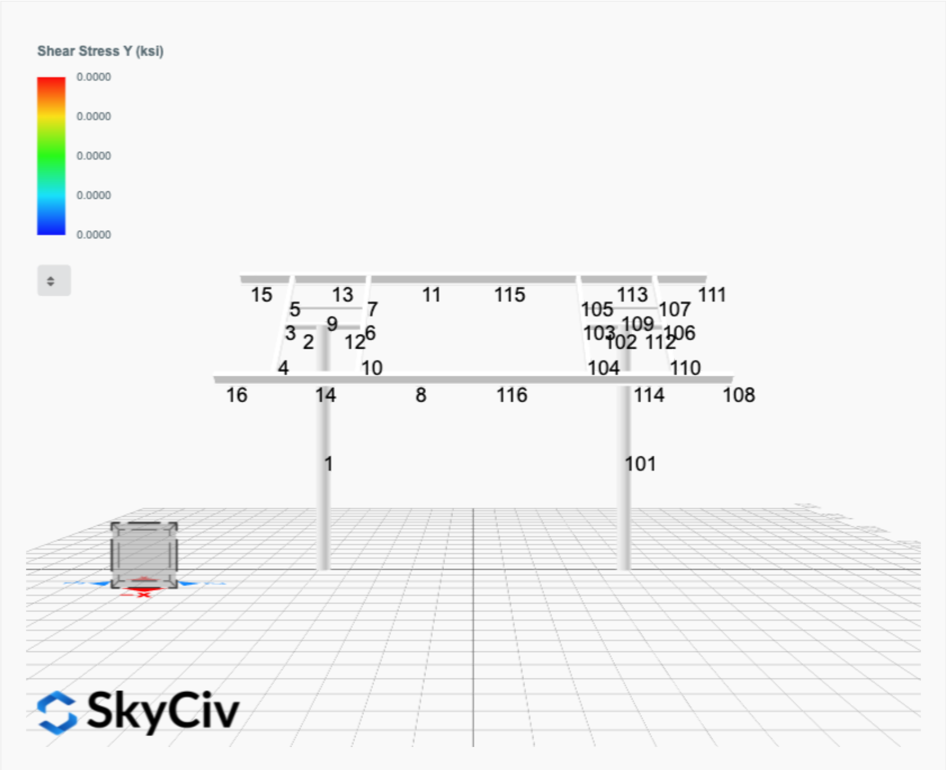


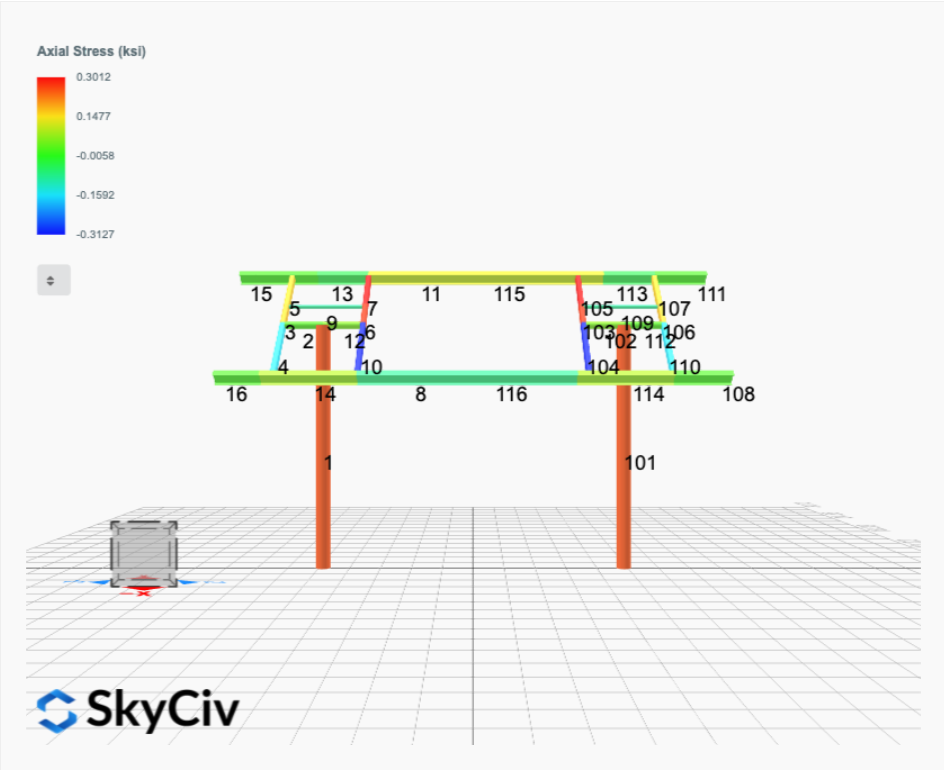
FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
10.9541
5.4562
-0.0417
-5.5395
-11.0374
15
13
11
115
113
111
5
7
105
107
3
9
6
103
109
106
2
12
102
112
4
10
104
110
16
14
8
116
114
108
1
101
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
3
9
6
103
109
106
2
12
102
112
4
10
104
110
16
14
8
116
114
108
1
101
SkyCiv


Axial Stress (ksi)
0.3012
0.1477
-0.0058
-0.1592
-0.3127
15
13
11
115
113
111
5
7
105
107
109
3
9
6
103
102
112
106
2
12
4
10
104
110
16
14
8
116
114
108
1
101
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	1.9719	0.0397	0.1411	-0.0288	0.0216
ULS: 2. D + L	0.0000	1.9719	0.0397	0.1411	-0.0288	0.0216
ULS: 3. D + (S or Lr or R)	0.0000	5.4804	0.1531	0.5454	-0.1125	0.0380
ULS: 3. D + (S or Lr or R)	0.0000	1.9719	0.0397	0.1411	-0.0288	0.0216
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0000	4.6032	0.1248	0.4443	-0.0916	0.0339
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0000	1.9719	0.0397	0.1411	-0.0288	0.0216
ULS: 5b. D + 0.7E	0.0000	1.9719	0.0397	0.1411	-0.0288	0.0216
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0000	4.6032	0.1248	0.4443	-0.0916	0.0339
ULS: 8. 0.6D + 0.7E	0.0000	1.1832	0.0238	0.0847	-0.0173	0.0130
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.4579	5.4298	0.1762	0.5940	-0.6925	43.7195
ULS: 5a. D + 0.6W_Wind downforce Case B only	-3.4579	5.4298	0.1762	0.5940	-0.6925	43.7195
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.5014	-0.5295	-0.0586	-0.1845	0.4505	-29.2591
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.2071	-0.2352	-0.0478	-0.1485	0.3975	-32.6870
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.5934	7.1966	0.2272	0.7839	-0.5894	32.8073
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.5934	7.1966	0.2272	0.7839	-0.5894	32.8073
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.8761	2.7272	0.0510	0.2001	0.2678	-21.9266
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.6554	2.9479	0.0592	0.2271	0.2281	-24.4975
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.5934	4.5653	0.1421	0.4808	-0.5266	32.7950
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.5934	4.5653	0.1421	0.4808	-0.5266	32.7950
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.8761	0.0959	-0.0341	-0.1031	0.3307	-21.9389
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.6554	0.3166	-0.0259	-0.0761	0.2909	-24.5098
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.4579	4.6410	0.1603	0.5375	-0.6810	43.7108
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-3.4579	4.6410	0.1603	0.5375	-0.6810	43.7108
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.5014	-1.3183	-0.0745	-0.2409	0.4620	-29.2677
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.2071	-1.0240	-0.0637	-0.2050	0.4090	-32.6956

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	10.8613
Shear X	-5.7631
Shear Z	0.3428
Moment X	1.1954
Moment Y (Twist)	1.1792
Moment Z	73.6440

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	7.1966
Shear X	-3.4579
Shear Z	0.2272
Moment X	0.7839
Moment Y (Twist)	0.6925
Moment Z	43.7195

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	1.9719	-0.0397	-0.1411	0.0288	0.0216
ULS: 2. D + L	-0.0000	1.9719	-0.0397	-0.1411	0.0288	0.0216
ULS: 3. D + (S or Lr or R)	-0.0000	5.4804	-0.1531	-0.5454	0.1126	0.0380
ULS: 3. D + (S or Lr or R)	-0.0000	1.9719	-0.0397	-0.1411	0.0288	0.0216
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0000	4.6032	-0.1248	-0.4443	0.0916	0.0339
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0000	1.9719	-0.0397	-0.1411	0.0288	0.0216
ULS: 5b. D + 0.7E	-0.0000	1.9719	-0.0397	-0.1411	0.0288	0.0216

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0000	4.6032	-0.1248	-0.4443	0.0916	0.0339
ULS: 8. 0.6D + 0.7E	-0.0000	1.1832	-0.0238	-0.0847	0.0173	0.0130
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.4579	5.4298	-0.1762	-0.5940	0.6925	43.7195
ULS: 5a. D + 0.6W_Wind downforce Case B only	-3.4579	5.4298	-0.1762	-0.5940	0.6925	43.7195
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.5014	-0.5295	0.0586	0.1845	-0.4505	-29.2591
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.2071	-0.2352	0.0478	0.1485	-0.3975	-32.6870
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.5934	7.1966	-0.2272	-0.7839	0.5894	32.8073
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.5934	7.1966	-0.2272	-0.7839	0.5894	32.8073
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.8761	2.7272	-0.0510	-0.2001	-0.2678	-21.9266
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.6554	2.9479	-0.0592	-0.2271	-0.2281	-24.4975
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.5934	4.5653	-0.1421	-0.4808	0.5266	32.7950
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.5934	4.5653	-0.1421	-0.4808	0.5266	32.7950
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.8761	0.0959	0.0341	0.1031	-0.3307	-21.9389
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.6554	0.3166	0.0259	0.0761	-0.2909	-24.5098
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.4579	4.6410	-0.1603	-0.5375	0.6810	43.7108
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-3.4579	4.6410	-0.1603	-0.5375	0.6810	43.7108
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.5014	-1.3183	0.0745	0.2409	-0.4620	-29.2677
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.2071	-1.0240	0.0637	0.2050	-0.4090	-32.6956

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	10.8613
Shear X	-5.7631
Shear Z	-0.3428
Moment X	-1.1953
Moment Y (Twist)	1.1790
Moment Z	73.6450

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	7.1966
Shear X	-3.4579
Shear Z	-0.2272
Moment X	-0.7839
Moment Y (Twist)	0.6925
Moment Z	43.7195

Project Details

Design Code: AISC 360-16 LRFD
Provision: LRFD
Country: United States

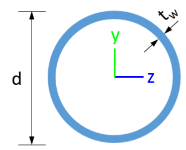
User Name: sales@mtsolar.us
Unit System: imperial

Design Input Information

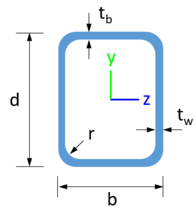
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

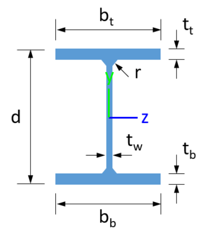
Section Dimensions



ID	Name	d (in)	t_w (in)					
2	2in Pipe Sch 80	2.38	0.22					
5	4in Pipe Sch 80	4.50	0.34					
10	8in Pipe Sch 80	8.63	0.50					



ID	Name	d (in)	b (in)	t_w (in)	t_b (in)	r (in)		
16	HSS5x3x3/16	5.00	3.00	0.17	0.17	0.17		



ID	Name	d (in)	t_w (in)	b_t (in)	b_b (in)	t_t (in)	t_b (in)	r (in)
19	W8x10	7.89	0.17	3.94	3.94	0.20	0.20	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)
2	2in Pipe Sch 80	1.48	1.74	0.87	0.87	0.00	1.02	1.02
5	4in Pipe Sch 80	4.41	19.22	9.61	9.61	0.00	5.85	5.85
10	8in Pipe Sch 80	12.76	211.43	105.72	105.72	0.00	33.05	33.05

16	HSS5x3x3/16	2.58	8.64	3.85	8.53	92.39	2.96	4.21
19	W8x10	2.96	0.04	2.09	30.80	30.90	1.66	8.87

Member Properties								
Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	10	25.47	25.47	12.13	-	300	200	1
2	5	1.30	1.30	2.00	-	300	200	1
3	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17	300	200	1
4	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.69,1.69,1.67,1.67,1.66,1.12,1.67,1.67,1.66,1.64,1.67,1.67,1.68,1.68,1.67,1.67,1.65,1.26,1.67,1.67,1.66,1.65	300	200	1
5	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.69,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66	300	200	1
6	16	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
7	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
8	19	1.33	1.33	2.05	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.18,1.07,1.18,1.18,1.18,1.16,1.19,1.19,1.20,1.20,1.18,1.18,1.18,1.12,1.18,1.18,1.18,1.17	300	200	1
9	2	2.60	2.60	4.00	-	300	200	1
10	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.58,1.67,1.67,1.66,1.65,1.67,1.67,1.68,1.67,1.67,1.67,1.66,1.54,1.67,1.67,1.66,1.66	300	200	1
11	19	1.33	1.33	2.05	1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.19,1.19,1.19,1.18,1.19,1.19,1.19,1.20,1.21,1.19,1.19,1.18,1.19,1.19,1.19,1.18,1.19	300	200	1
12	5	1.30	1.30	2.00	-	300	200	1
13	19	4.88	4.00	7.50	1.50,1.52,1.50,1.54,1.51,1.50,1.65,1.65,1.74,1.94,1.67,1.67,1.68,1.85,1.61,1.61,1.41,1.12,1.65,1.65,1.74,1.93,1.67,1.67,1.67,1.84	300	200	1
14	19	4.88	4.00	7.50	1.46,1.49,1.47,1.50,1.48,1.47,1.59,1.59,1.77,1.25,1.60,1.60,1.70,1.24,1.55,1.55,1.33,1.58,1.58,1.58,1.77,1.21,1.60,1.60,1.69,1.27	300	200	1
15	19	2.10	2.10	1.00	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	19	2.10	2.10	1.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
101	10	25.47	25.47	12.13	-	300	200	1
102	5	1.30	1.30	2.00	-	300	200	1
103	16	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
104	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.58,1.67,1.67,1.66,1.65,1.67,1.67,1.68,1.67,1.67,1.67,1.66,1.54,1.67,1.67,1.66,1.66	300	200	1
105	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
106	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17	300	200	1
107	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.69,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66	300	200	1

108	19	2.10	2.10	1.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
109	2	2.60	2.60	4.00	-	300	200	1
110	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.69,1.69,1.67,1.67,1.66,1.12,1.67,1.67,1.66,1.64,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.26,1.67,1.67,1.66,1.65	300	200	1
111	19	2.10	2.10	1.00	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	5	1.30	1.30	2.00	-	300	200	1
113	19	4.88	4.00	7.50	1.50,1.52,1.50,1.53,1.51,1.50,1.65,1.65,1.74,1.94,1.67,1.67,1.68,1.85,1.61,1.61,1.41,1.12,1.65,1.65,1.74,1.93,1.67,1.67,1.67,1.84	300	200	1
114	19	4.88	4.00	7.50	1.46,1.49,1.46,1.50,1.48,1.47,1.59,1.59,1.77,1.25,1.60,1.60,1.70,1.25,1.55,1.55,1.33,1.58,1.58,1.58,1.77,1.21,1.60,1.60,1.69,1.27	300	200	1
115	19	3.54	3.54	5.45	1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.06,1.07,1.07,1.07,1.06,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.06,1.07,1.07,1.07,1.06,1.07	300	200	1
116	19	3.54	3.54	5.45	1.07,1.07,1.07,1.07,1.07,1.07,1.06,1.06,1.06,1.03,1.06,1.06,1.06,1.06,1.07,1.07,1.07,1.07,1.06,1.06,1.06,1.04,1.06,1.06,1.06,1.06	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	574.32	251.80	123.94	123.94	172.30	172.30
2	198.33	196.72	21.95	21.95	59.50	59.50
3	116.10	115.41	15.79	11.10	42.08	23.28
4	116.10	111.33	15.79	11.10	42.08	23.28
5	116.10	114.23	15.79	11.10	42.08	23.28
6	116.10	115.41	15.79	11.10	42.08	23.28
7	116.10	114.23	15.79	11.10	42.08	23.28
8	133.20	126.01	32.87	6.12	40.24	43.62
9	66.48	58.89	3.82	3.82	19.94	19.94
10	116.10	111.33	15.79	11.10	42.08	23.28
11	133.20	126.01	32.87	6.12	40.24	43.62
12	198.33	196.72	21.95	21.95	59.50	59.50
13	133.20	104.94	25.67	6.12	40.24	43.62
14	133.20	104.94	27.73	6.12	40.24	43.62
15	133.20	121.82	32.87	6.12	40.24	43.62
16	133.20	121.82	32.87	6.12	40.24	43.62
101	574.32	251.80	123.94	123.94	172.30	172.30
102	198.33	196.72	21.95	21.95	59.50	59.50
103	116.10	115.41	15.79	11.10	42.08	23.28
104	116.10	111.33	15.79	11.10	42.08	23.28
105	116.10	114.23	15.79	11.10	42.08	23.28
106	116.10	115.41	15.79	11.10	42.08	23.28
107	116.10	114.23	15.79	11.10	42.08	23.28
108	133.20	121.82	32.87	6.12	40.24	43.62
109	66.48	58.89	3.82	3.82	19.94	19.94
110	116.10	111.33	15.79	11.10	42.08	23.28
111	133.20	121.82	32.87	6.12	40.24	43.62
112	198.33	196.72	21.95	21.95	59.50	59.50
113	133.20	104.94	25.67	6.12	40.24	43.62
114	133.20	104.94	27.73	6.12	40.24	43.62
115	133.20	109.71	29.25	6.12	40.24	43.62

115	133.20	109.71	29.25	6.12	40.24	43.62
116	133.20	109.71	28.42	6.12	40.24	43.62

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	0.043	0.594	0.024	0.033	0.002	0.623	#13	0.531	Not Required	Pass
2	0.001	0.294	0.218	0.072	0.046	0.497	#13	0.053	Not Required	Pass
3	0.009	0.593	0.060	0.059	0.017	0.619	#13	0.045	Not Required	Pass
4	0.008	0.532	0.068	0.053	0.016	0.580	#13	0.080	Not Required	Pass
5	0.008	0.369	0.035	0.059	0.007	0.374	#13	0.074	Not Required	Pass
6	0.013	0.725	0.133	0.073	0.042	0.794	#13	0.045	Not Required	Pass
7	0.014	0.449	0.131	0.072	0.031	0.465	#13	0.074	Not Required	Pass
8	0.003	0.149	0.137	0.038	0.018	0.269	#21	0.095	Not Required	Pass
9	0.004	0.045	0.077	0.003	0.004	0.112	#13	0.136	Not Required	Pass
10	0.015	0.657	0.125	0.066	0.029	0.688	#13	0.080	Not Required	Pass
11	0.005	0.163	0.137	0.042	0.018	0.276	#21	0.095	Not Required	Pass
12	0.002	0.429	0.272	0.100	0.052	0.683	#13	0.053	Not Required	Pass
13	0.006	0.087	0.324	0.061	0.026	0.348	#21	0.286	Not Required	Pass
14	0.003	0.080	0.320	0.055	0.026	0.339	#21	0.190	Not Required	Pass
15	0.000	0.007	0.017	0.011	0.005	0.023	#21	Not Required	Not Required	Pass
16	0.000	0.006	0.017	0.010	0.005	0.022	#21	Not Required	Not Required	Pass
101	0.043	0.594	0.024	0.033	0.002	0.623	#13	0.531	Not Required	Pass
102	0.002	0.429	0.272	0.100	0.052	0.683	#13	0.053	Not Required	Pass
103	0.013	0.725	0.133	0.073	0.042	0.794	#13	0.045	Not Required	Pass
104	0.015	0.657	0.125	0.066	0.029	0.688	#13	0.080	Not Required	Pass
105	0.014	0.449	0.131	0.072	0.031	0.465	#13	0.074	Not Required	Pass
106	0.009	0.593	0.060	0.059	0.017	0.619	#13	0.045	Not Required	Pass
107	0.008	0.369	0.035	0.059	0.007	0.374	#13	0.074	Not Required	Pass
108	0.000	0.006	0.017	0.010	0.005	0.022	#21	Not Required	Not Required	Pass
109	0.004	0.045	0.077	0.003	0.004	0.112	#13	0.136	Not Required	Pass
110	0.008	0.532	0.068	0.053	0.016	0.580	#13	0.080	Not Required	Pass
111	0.000	0.007	0.017	0.011	0.005	0.023	#21	Not Required	Not Required	Pass
112	0.001	0.294	0.218	0.072	0.046	0.497	#13	0.053	Not Required	Pass
113	0.006	0.087	0.324	0.061	0.026	0.348	#21	0.190	Not Required	Pass
114	0.003	0.080	0.320	0.055	0.026	0.339	#21	0.286	Not Required	Pass
115	0.005	0.202	0.184	0.042	0.018	0.356	#21	0.253	Not Required	Pass
116	0.003	0.185	0.184	0.038	0.018	0.347	#21	0.253	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/comression)
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

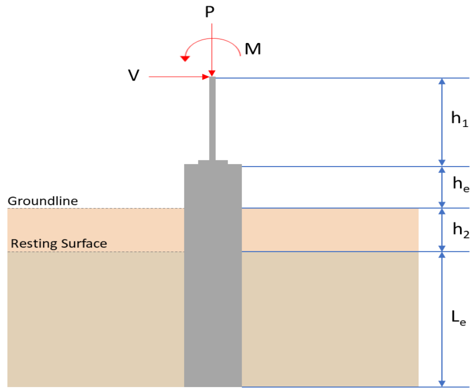
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36\ \text{in}$ - Pile diameter
$L = 15\ \text{ft}$ - Total pile length
$h_1 = 0\ \text{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \text{ft}$ - Depth to resisting surface
$h_e = 0\ \text{ft}$ - 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)	7.197	10.861
V_x (kip)	-3.458	-5.763
V_z (kip)	0.227	0.343
M_x (kipft)	0.784	1.195
M_z (kipft)	43.719	73.644

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.458\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -1.1527\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(43.719\ \text{kipft}) + ((-3.458\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 14.573\ \text{kipft/ft}$$

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:
$L_{e,x} = 9.3446\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(0.227\ \text{kip})}{(36\ \text{in})}$$

$$H_o = 0.075667\ \text{kip/ft}$$

M_o - Moment per length of pile,

$$M_o = \frac{M_x + (V_z\ H)}{D}$$

$$M_o = \frac{(0.784\ \text{kipft}) + ((0.227\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.26133\ \text{kipft/ft}$$

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:
$L_{e,z} = 3.9345\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(9.3446\ \text{ft}), (3.9345\ \text{ft})]$$

$$L_{e,req} = 9.345\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (15\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 15\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(9.345\ \text{ft})}{(15\ \text{ft})}$$

$$Ratio = 0.623$$

Status: **PASS**
Ratio: **0.620**

End-bearing Capacity (ASD)

A - Pile cros-section area

$$A = \pi \left(\frac{D}{2}\right)^2$$

$$A = \pi \times \left(\frac{(36\ \text{in})}{2}\right)^2$$

$$A = 7.0686\ \text{ft}^2$$

q - End-bearing pressure

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

$$q = \frac{(7.197\ \text{kip})}{(7.0686\ \text{ft}^2)}$$

$$q = 1.0182\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(1.0182\ \text{kip/ft}^2\right)}{(2000\ \text{psf})}$$

$$Ratio = 0.50908$$

Status: **PASS**
Ratio: **0.510**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(15\ \text{ft})}{(36\ \text{in})}$$

$$L/D = 5$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -1.1527\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 14.573\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (14.573\ \text{kipft/ft}) \times (15\ \text{ft})) + \left(3 \times (-1.1527\ \text{kip/ft}) \times (15\ \text{ft})^2\right)}{(6 \times (14.573\ \text{kipft/ft})) + (4 \times (-1.1527\ \text{kip/ft}) \times (15\ \text{ft}))}$$

$$a = 10.552\ \text{ft}$$

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

$$p = \frac{1.178\ [(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\ [(3\,M_o) + (2\,H_o\,L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (14.573\ \text{kipft/ft})) + (3 \times (-1.1527\ \text{kip/ft}) \times (15\ \text{ft}))]^{\ 2}}{(15\ \text{ft})^2 \times [(3 \times (14.573\ \text{kipft/ft})) + (2 \times (-1.1527\ \text{kip/ft}) \times (15\ \text{ft}))]}$$

$$p = 0.023627\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\ [(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (14.573\ \text{kipft/ft})) + ((-1.1527\ \text{kip/ft}) \times (15\ \text{ft}))]}{(15\ \text{ft})^2}$$

$$s = 0.49663\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(10.552\ \text{ft})}{2}$$

$$p_a = 0.7914\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.023627\ \text{kip/ft}^2\right)}{\left(0.7914\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.029854$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150 \text{ psf/ft}) \times (15 \text{ ft})$$

$$p_s = 2.25 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.49663 \text{ kip/ft}^2\right)}{\left(2.25 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.22073$$

Status: **PASS**
Ratio: **0.220**

Considering z-direction:

$H_o = 0.075667 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 0.26133 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.26133 \text{ kipft/ft}) \times (15 \text{ ft})) + \left(3 \times (0.075667 \text{ kip/ft}) \times (15 \text{ ft})^2\right)}{(6 \times (0.26133 \text{ kipft/ft})) + (4 \times (0.075667 \text{ kip/ft}) \times (15 \text{ ft}))}$$

$$a = 10.929 \text{ ft}$$

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

$$p = \frac{1.178\, [(4\, M_o) + (3\, H_o\, L_e)]^2}{L_e^2\, [(3\, M_o) + (2\, H_o\, L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (0.26133 \text{ kipft/ft})) + (3 \times (0.075667 \text{ kip/ft}) \times (15 \text{ ft}))]^{\,2}}{(15 \text{ ft})^2 \times [(3 \times (0.26133 \text{ kipft/ft})) + (2 \times (0.075667 \text{ kip/ft}) \times (15 \text{ ft}))]}$$

$$p = 0.033953 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\, [(2\, M_o) + (H_o\, L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (0.26133 \text{ kipft/ft})) + ((0.075667 \text{ kip/ft}) \times (15 \text{ ft}))]}{(15 \text{ ft})^2}$$

$$s = 0.069438 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(10.929 \text{ ft})}{2}$$

$$p_a = 0.81968 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.033953 \text{ kip/ft}^2\right)}{\left(0.81968 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.041422$$

Status: **PASS**
Ratio: **0.040**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150 \text{ psf/ft}) \times (15 \text{ ft})$$

$$p_s = 2.25 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

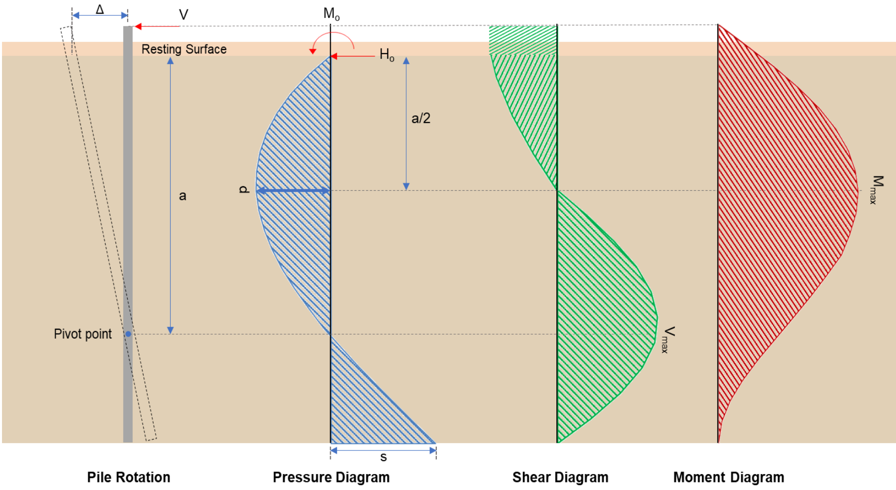
$$Ratio = \frac{s}{\ }$$

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

$$Ratio = \frac{(0.069438\ \mathrm{kip/ft^2})}{(2.25\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.030861$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-5.763\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -1.921\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(73.644\ \mathrm{kipft}) + ((-5.763\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 24.548\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(24.548\ \mathrm{kipft/ft})}{(-1.921\ \mathrm{kip/ft})}$$

$$E = 12.779\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (24.548\ \mathrm{kipft/ft}) \times (15\ \mathrm{ft})) + \left(3 \times (-1.921\ \mathrm{kip/ft}) \times (15\ \mathrm{ft})^2\right)}{(6 \times (24.548\ \mathrm{kipft/ft})) + (4 \times (-1.921\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))}$$

$$a = 10.549\ \mathrm{ft}$$

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

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

$$V_{max} = ((-1.921\ \mathrm{kip/ft}) \times (36\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.779\ \mathrm{ft})}{(15\ \mathrm{ft})} + 3\right) \times \left(\frac{(10.549\ \mathrm{ft})}{(15\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (12.779\ \mathrm{ft})}{(15\ \mathrm{ft})} + 2\right) \times \left(\frac{(10.549\ \mathrm{ft})}{(15\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 12.5\ \text{kip}$$

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

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

$$M_{max} = ((-1.921\ \text{kip/ft}) \times (36\ \text{in}) \times (15\ \text{ft})) \times \left[\left(\frac{(12.779\ \text{ft})}{(15\ \text{ft})} + \frac{(10.549\ \text{ft})}{2 \times (15\ \text{ft})}\right) - \left[\left(\frac{4 \times (12.779\ \text{ft})}{(15\ \text{ft})} + 3\right) \times \left(\frac{(10.549\ \text{ft})}{2 \times (15\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (12.779\ \text{ft})}{(15\ \text{ft})} + 2\right) \times \left(\frac{(10.549\ \text{ft})}{2 \times (15\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 85.979\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(0.343\ \text{kip})}{(36\ \text{in})}$$

$$H_o = 0.11433\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.195\ \text{kipft}) + ((0.343\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.39833\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.39833\ \text{kipft/ft})}{(0.11433\ \text{kip/ft})}$$

$$E = 3.484\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.39833\ \text{kipft/ft}) \times (15\ \text{ft})) + \left(3 \times (0.11433\ \text{kip/ft}) \times (15\ \text{ft})^2\right)}{(6 \times (0.39833\ \text{kipft/ft})) + (4 \times (0.11433\ \text{kip/ft}) \times (15\ \text{ft}))}$$

$$a = 10.927\ \text{ft}$$

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

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

$$V_{max} = ((0.11433\ \text{kip/ft}) \times (36\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.484\ \text{ft})}{(15\ \text{ft})} + 3\right) \times \left(\frac{(10.927\ \text{ft})}{(15\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.484\ \text{ft})}{(15\ \text{ft})} + 2\right) \times \left(\frac{(10.927\ \text{ft})}{(15\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.37216\ \text{kip}$$

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

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

$$M_{max} = ((0.11433\ \text{kip/ft}) \times (36\ \text{in}) \times (15\ \text{ft})) \times \left[\left(\frac{(3.484\ \text{ft})}{(15\ \text{ft})} + \frac{(10.927\ \text{ft})}{2 \times (15\ \text{ft})}\right) - \left[\left(\frac{4 \times (3.484\ \text{ft})}{(15\ \text{ft})} + 3\right) \times \left(\frac{(10.927\ \text{ft})}{2 \times (15\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.484\ \text{ft})}{(15\ \text{ft})} + 2\right) \times \left(\frac{(10.927\ \text{ft})}{2 \times (15\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 2.3364 \text{ kipft}$$

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 $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1017.9 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(10.861 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(1017.9 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -37.034 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-37.034 \text{ in}^2\right), \left(0.0018 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{min} = 1.8322 \text{ in}^2$$

n_{rebar} - Required number of reinforcement,

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

$$n_{rebar} = \frac{\left(1.8322 \text{ in}^2\right)}{\left(0.3068 \text{ in}^2\right)}$$

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

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

$$A_{st} = (6) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 1.8408 \text{ in}^2$$

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(1.8322 \text{ in}^2\right)}{\left(1.8408 \text{ in}^2\right)}$$

$$Ratio = 0.99533$$

Status: **PASS**
Ratio: **1.000**

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

$$s_{ties} = Min\left[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (36 \text{ in})\right]$$

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

Summary:

Main reinforcement: **6 - #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

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

$$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(1017.9\ \text{in}^2\right) - \left(1.8408\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(1.8408\ \text{in}^2\right)\right)\right]$$

$$\phi P_N = 1253.9\ \text{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(10.861\ \text{kip})}{(1253.9\ \text{kip})}$$

$$Ratio = 0.0086617$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

$b_w = 36\ \text{in}$ - Effective width,
22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

$$d = 0.80 \times (36\ \text{in})$$

$$d = 28.8\ \text{in}$$

22.5.5.1.3 λ_s - size effect modification factor

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

$$\lambda_s = MIN\left[\sqrt{\frac{2}{1+\frac{(28.8\ \text{in})}{10}}}, 1\right]$$

$$\lambda_s = 0.71796$$

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

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

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500\ \text{psi})} \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,max} = 186.09\ \text{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 10.861\ \text{kip} \rightarrow 10861\ \text{lbf}$,
22.5.5.1.1(a) $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\ \text{psi})} + \frac{(10861\ \text{lbf})}{6 \times (1017.9\ \text{in}^2)}\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,a} = 76.282\ \text{kip}$$

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)

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

$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(2500\ \text{psi})} + (0.05 \times (2500\ \text{psi}))\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,b} = 204.04\ \text{kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(186.09\ \text{kip}), (76.282\ \text{kip}), (204.04\ \text{kip})\right]$$

$$V_c = 76.282 \text{ kip}$$

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)

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

$$V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{s,a} = 414.72 \text{ kip}$$

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)

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

$$V_{s,b} = \frac{2 \times \left(0.11045 \text{ in}^2\right) \times (60 \text{ ksi}) \times (28.8 \text{ in})}{(10 \text{ in})}$$

$$V_{s,b} = 38.17 \text{ kip}$$

V_s - Governing shear strength of steel

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

$$V_s = MIN\left[(414.72 \text{ kip}), (38.17 \text{ kip})\right]$$

$$V_s = 38.17 \text{ kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((76.282 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 74.394 \text{ kip}$$

Considering x-direction:

$V_{max} = 12.5 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(12.5 \text{ kip})}{(74.394 \text{ kip})}$$

$$Ratio = 0.16802$$

Status: **PASS**
Ratio: **0.170**

Considering z-direction:

$V_{max} = 0.37216 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.37216 \text{ kip})}{(74.394 \text{ kip})}$$

$$Ratio = 0.0050026$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{\pi\, D^3}{32}$$

$$S_m = \frac{\pi \times (36 \text{ in})^3}{32}$$

$$S_m = 4580.4 \text{ in}^3$$

SkyCiv

	$S_m = 4580.4\ \mathrm{in}^3$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 4580.442in^3$$ $$\phi M_{n,1} = 62.027kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\ 0.85\ f_{ck}'\ S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \mathrm{ksi}) \times \left(4580.4\ \mathrm{in}^3\right)$$ $$\phi M_{n,2} = 527.23\ \mathrm{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(62.027\ \mathrm{kipft}), (527.23\ \mathrm{kipft})]$$ $$\phi M_n = 62.027\ \mathrm{kipft}$$ **Considering x-direction:** $M_{max} = 85.979\ \mathrm{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(85.979\ \mathrm{kipft})}{(62.027\ \mathrm{kipft})}$$ $$Ratio = 1.3862$$	Status: **FAIL** Ratio: **1.390**
	Considering z-direction: $M_{max} = 2.3364\ \mathrm{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(2.3364\ \mathrm{kipft})}{(62.027\ \mathrm{kipft})}$$ $$Ratio = 0.037667$$	Status: **PASS** Ratio: **0.040**

REFERENCES	CALCULATIONS	RESULTS

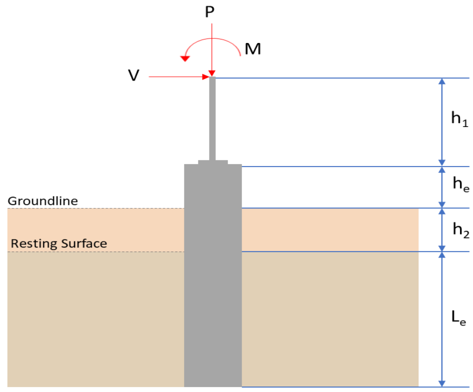
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36\ \mathrm{in}$ - Pile diameter
$L = 15\ \mathrm{ft}$ - 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)	7.197	10.861
V_x (kip)	-3.458	-5.763
V_z (kip)	-0.227	-0.343
M_x (kipft)	-0.784	-1.195
M_z (kipft)	43.719	73.645

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,

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

$$H_o = \frac{(-3.458\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -1.1527\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(43.719\ \text{kipft}) + ((-3.458\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 14.573\ \text{kipft/ft}$$

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:
$L_{e,x} = 9.3446\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(-0.227\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.075667\ \text{kip/ft}$$

M_o - Moment per length of pile,

$$M_o = \frac{M_x + (V_z\ H)}{D}$$

$$M_o = \frac{(0.784\ \text{kipft}) + ((-0.227\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.26133\ \text{kipft/ft}$$

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:
$L_{e,z} = 2.476\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(9.3446\ \text{ft}), (2.476\ \text{ft})]$$

$$L_{e,req} = 9.345\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (15\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 15\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(9.345\ \text{ft})}{(15\ \text{ft})}$$

$$Ratio = 0.623$$

Status: **PASS**
Ratio: **0.620**

End-bearing Capacity (ASD)

A - Pile cros-section area

$$A = \pi \left(\frac{D}{2}\right)^2$$

$$A = \pi \times \left(\frac{(36\ \text{in})}{2}\right)^2$$

$$A = 7.0686\ \text{ft}^2$$

q - End-bearing pressure

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

$$q = \frac{(7.197\ \text{kip})}{(7.0686\ \text{ft}^2)}$$

$$q = 1.0182\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(1.0182\ \mathrm{kip/ft^2}\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.50908$$

Status: **PASS**
Ratio: **0.510**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(15\ \mathrm{ft})}{(36\ \mathrm{in})}$$

$$L/D = 5$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -1.1527\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 14.573\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (14.573\ \mathrm{kipft/ft}) \times (15\ \mathrm{ft})) + \left(3 \times (-1.1527\ \mathrm{kip/ft}) \times (15\ \mathrm{ft})^2\right)}{(6 \times (14.573\ \mathrm{kipft/ft})) + (4 \times (-1.1527\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))}$$

$$a = 10.552\ \mathrm{ft}$$

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

$$p = \frac{1.178\ [(4\, M_o) + (3\, H_o\, L_e)]^2}{L_e^2\ [(3\, M_o) + (2\, H_o\, L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (14.573\ \mathrm{kipft/ft})) + (3 \times (-1.1527\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))]^2}{(15\ \mathrm{ft})^2 \times [(3 \times (14.573\ \mathrm{kipft/ft})) + (2 \times (-1.1527\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))]}$$

$$p = 0.023627\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\ [(2\, M_o) + (H_o\, L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (14.573\ \mathrm{kipft/ft})) + ((-1.1527\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))]}{(15\ \mathrm{ft})^2}$$

$$s = 0.49663\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(10.552\ \mathrm{ft})}{2}$$

$$p_a = 0.7914\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.023627\ \mathrm{kip/ft^2}\right)}{\left(0.7914\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.029854$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (15\ \mathrm{ft})$$

$$p_s = 2.25\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.49663\ \mathrm{kip/ft^2}\right)}{(2.25\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.22073$$

Status: **PASS**
Ratio: **0.220**

Considering z-direction:

$H_o = -0.075667\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.26133\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.26133\ \mathrm{kipft/ft}) \times (15\ \mathrm{ft})) + \left(3 \times (-0.075667\ \mathrm{kip/ft}) \times (15\ \mathrm{ft})^2\right)}{(6 \times (0.26133\ \mathrm{kipft/ft})) + (4 \times (-0.075667\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))}$$

$$a = 10.929\ \mathrm{ft}$$

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

$$p = \frac{1.178\,[(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\,[(3\,M_o) + (2\,H_o\,L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (0.26133\ \mathrm{kipft/ft})) + (3 \times (-0.075667\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))]^2}{(15\ \mathrm{ft})^2 \times [(3 \times (0.26133\ \mathrm{kipft/ft})) + (2 \times (-0.075667\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))]}$$

$$p = -0.019618\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\,[(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (0.26133\ \mathrm{kipft/ft})) + ((-0.075667\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))]}{(15\ \mathrm{ft})^2}$$

$$s = -0.02565\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(10.929\ \mathrm{ft})}{2}$$

$$p_a = 0.81968\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.019618\ \mathrm{kip/ft^2}\right)}{(0.81968\ \mathrm{kip/ft^2})}$$

$$Ratio = -0.023933$$

Status: **PASS**
Ratio: **-0.020**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (15\ \mathrm{ft})$$

$$p_s = 2.25\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

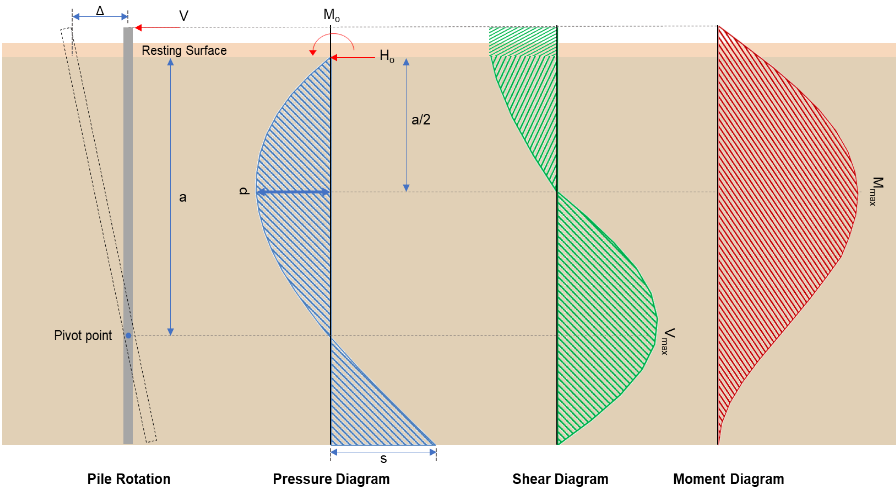
$$Ratio = \frac{s}{\ }$$

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

$$Ratio = \frac{(-0.02565\ \mathrm{kip/ft^2})}{(2.25\ \mathrm{kip/ft^2})}$$

$$Ratio = -0.0114$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-5.763\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -1.921\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(73.645\ \mathrm{kipft}) + ((-5.763\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 24.548\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(24.548\ \mathrm{kipft/ft})}{(-1.921\ \mathrm{kip/ft})}$$

$$E = 12.779\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (24.548\ \mathrm{kipft/ft}) \times (15\ \mathrm{ft})) + \left(3 \times (-1.921\ \mathrm{kip/ft}) \times (15\ \mathrm{ft})^2\right)}{(6 \times (24.548\ \mathrm{kipft/ft})) + (4 \times (-1.921\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))}$$

$$a = 10.549\ \mathrm{ft}$$

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

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

$$V_{max} = ((-1.921\ \mathrm{kip/ft}) \times (36\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.779\ \mathrm{ft})}{(15\ \mathrm{ft})} + 3\right) \times \left(\frac{(10.549\ \mathrm{ft})}{(15\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (12.779\ \mathrm{ft})}{(15\ \mathrm{ft})} + 2\right) \times \left(\frac{(10.549\ \mathrm{ft})}{(15\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 12.5 \text{ kip}$$

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

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

$$M_{max} = ((-1.921 \text{ kip/ft}) \times (36 \text{ in}) \times (15 \text{ ft})) \times \left[\left(\frac{(12.779 \text{ ft})}{(15 \text{ ft})} + \frac{(10.549 \text{ ft})}{2 \times (15 \text{ ft})} \right) - \left[\left(\frac{4 \times (12.779 \text{ ft})}{(15 \text{ ft})} + 3 \right) \times \left(\frac{(10.549 \text{ ft})}{2 \times (15 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (12.779 \text{ ft})}{(15 \text{ ft})} + 2 \right) \times \left(\frac{(10.549 \text{ ft})}{2 \times (15 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 85.98 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(-0.343 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.11433 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.195 \text{ kipft}) + ((-0.343 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.39833 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.39833 \text{ kipft/ft})}{(-0.11433 \text{ kip/ft})}$$

$$E = 3.484 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.39833 \text{ kipft/ft}) \times (15 \text{ ft})) + \left(3 \times (-0.11433 \text{ kip/ft}) \times (15 \text{ ft})^2\right)}{(6 \times (0.39833 \text{ kipft/ft})) + (4 \times (-0.11433 \text{ kip/ft}) \times (15 \text{ ft}))}$$

$$a = 10.927 \text{ ft}$$

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

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

$$V_{max} = ((-0.11433 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.484 \text{ ft})}{(15 \text{ ft})} + 3 \right) \times \left(\frac{(10.927 \text{ ft})}{(15 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (3.484 \text{ ft})}{(15 \text{ ft})} + 2 \right) \times \left(\frac{(10.927 \text{ ft})}{(15 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.37216 \text{ kip}$$

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

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

$$M_{max} = ((-0.11433 \text{ kip/ft}) \times (36 \text{ in}) \times (15 \text{ ft})) \times \left[\left(\frac{(3.484 \text{ ft})}{(15 \text{ ft})} + \frac{(10.927 \text{ ft})}{2 \times (15 \text{ ft})} \right) - \left[\left(\frac{4 \times (3.484 \text{ ft})}{(15 \text{ ft})} + 3 \right) \times \left(\frac{(10.927 \text{ ft})}{2 \times (15 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (3.484 \text{ ft})}{(15 \text{ ft})} + 2 \right) \times \left(\frac{(10.927 \text{ ft})}{2 \times (15 \text{ ft})} \right)^4 \right] \right]$$

	$$M_{max} = 2.3364 \text{ kipft}$$	
	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	$\alpha = 0.85$ - Alpha factor for axial strength, $A_g = 1017.9 \text{ in}^2$ - Gross area of concrete, **Longitudinal reinforcement:** Required reinforcement due to axial load, $A_{st,required}$	
22.4.2.2, 10.6.1.1	$A_{st,required}$ $$A_{st,required} = Min\left[\frac{\frac{P}{\phi\ \alpha} - \left(0.85\ f'_{ck}\ A_g\right)}{f_{yk} - \left(0.85\ f'_{ck}\right)}, \left(0.08\ A_g\right)\right]$$ $$A_{st,required} = Min\left[\frac{\frac{(10.861 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(1017.9 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$ $$A_{st,required} = -37.034 \text{ in}^2$$ A_{min} - Governing minimum reinforcement area, $$A_{min} = Max\left[A_{st,required}, \left(0.0018\ A_g\right)\right]$$ $$A_{min} = Max\left[\left(-37.034 \text{ in}^2\right), \left(0.0018 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$ $$A_{min} = 1.8322 \text{ in}^2$$ n_{rebar} - Required number of reinforcement, $$n_{rebar} = \frac{A_{min}}{A_{rebar}}$$ $$n_{rebar} = \frac{\left(1.8322 \text{ in}^2\right)}{\left(0.3068 \text{ in}^2\right)}$$ $$n_{rebar} = 6$$ A_{st} - Actual total reinforcement area, $$A_{st} = n_{rebar}\ \frac{\pi\ d_{bar}^2}{4}$$ $$A_{st} = (6) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$ $$A_{st} = 1.8408 \text{ in}^2$$ $Ratio$ - Capacity $$Ratio = \frac{A_{min}}{A_{st}}$$ $$Ratio = \frac{\left(1.8322 \text{ in}^2\right)}{\left(1.8408 \text{ in}^2\right)}$$ $$Ratio = 0.99533$$	Status: **PASS** Ratio: **1.000**
25.2.3	s_{rebar} - Minimum spacing of reinforcement, $$s_{rebar} = Max\left[1.5, \left(1.5\ d_{bar}\right)\right]$$ $$s_{rebar} = Max\left[1.5, (1.5 \times (0.625 \text{ in}))\right]$$ $$s_{rebar} = 1.5 \text{ in}$$ **Ties:**	
25.7.2.2	Since longitudinal reinforcement is $\leq$ No. 10ø: Use #3(0.375 in)	
25.7.2.1	s_{ties} - Maximum center-to-center spacing of ties, $$s_{ties} = Min\left[\left(16\ d_{bar}\right), \left(48\ d_{ties}\right), D\right]$$ $$s_{ties} = Min\left[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (36 \text{ in})\right]$$ $$s_{ties} = 10 \text{ in}$$ **Summary:**	

	Main reinforcement: **6 - #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

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

$$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(1017.9\ \text{in}^2\right) - \left(1.8408\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(1.8408\ \text{in}^2\right)\right)\right]$$

$$\phi P_N = 1253.9\ \text{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(10.861\ \text{kip})}{(1253.9\ \text{kip})}$$

$$Ratio = 0.0086617$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

$b_w = 36\ \text{in}$ - Effective width,

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

$$d = 0.80 \times (36\ \text{in})$$

$$d = 28.8\ \text{in}$$

22.5.5.1.3 λ_s - size effect modification factor

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

$$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(28.8\ \text{in})}{10}}}, 1\right]$$

$$\lambda_s = 0.71796$$

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

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

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500\ \text{psi})} \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,max} = 186.09\ \text{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 10.861\ \text{kip} \rightarrow 10861\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\ \text{psi})} + \frac{(10861\ \text{lbf})}{6 \times (1017.9\ \text{in}^2)}\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,a} = 76.282\ \text{kip}$$

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)

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

$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(2500\ \text{psi})} + (0.05 \times (2500\ \text{psi}))\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,b} = 204.04\ \text{kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(186.09\ \text{kip}), (76.282\ \text{kip}), (204.04\ \text{kip})\right]$$

$$V_c = 76.282\ \text{kip}$$

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)

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

$$V_{s,a} = 8 \times \sqrt{(2500\ \text{psi})} \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{s,a} = 414.72\ \text{kip}$$

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)

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

$$V_{s,b} = \frac{2 \times \left(0.11045\ \text{in}^2\right) \times (60\ \text{ksi}) \times (28.8\ \text{in})}{(10\ \text{in})}$$

$$V_{s,b} = 38.17\ \text{kip}$$

V_s - Governing shear strength of steel

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

$$V_s = MIN\left[(414.72\ \text{kip}), (38.17\ \text{kip})\right]$$

$$V_s = 38.17\ \text{kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((76.282\ \text{kip}) + (38.17\ \text{kip}))$$

$$\phi V_n = 74.394\ \text{kip}$$

Considering x-direction:

$V_{max} = 12.5\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(12.5\ \text{kip})}{(74.394\ \text{kip})}$$

$$Ratio = 0.16802$$

Status: **PASS**
Ratio: **0.170**

Considering z-direction:

$V_{max} = 0.37216\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.37216\ \text{kip})}{(74.394\ \text{kip})}$$

$$Ratio = 0.0050026$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{\pi\, D^3}{32}$$

$$S_m = \frac{\pi \times (36\ \text{in})^3}{32}$$

$$S_m = 4580.4\ \text{in}^3$$

	$S_m = 4580.4\ \text{in}^3$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f'_c)} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 4580.442in^3$$ $$\phi M_{n,1} = 62.027kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\ 0.85\ f'_{ck}\ S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \text{ksi}) \times \left(4580.4\ \text{in}^3\right)$$ $$\phi M_{n,2} = 527.23\ \text{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(62.027\ \text{kipft}), (527.23\ \text{kipft})]$$ $$\phi M_n = 62.027\ \text{kipft}$$ **Considering x-direction:** $M_{max} = 85.98\ \text{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(85.98\ \text{kipft})}{(62.027\ \text{kipft})}$$ $$Ratio = 1.3862$$	Status: **FAIL** Ratio: **1.390**
	Considering z-direction: $M_{max} = 2.3364\ \text{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(2.3364\ \text{kipft})}{(62.027\ \text{kipft})}$$ $$Ratio = 0.037667$$	Status: **PASS** Ratio: **0.040**