Your Project Calculations

Project Name: MTSOLAR_Pat_Nelson

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

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=NnfJcQhY03Zny3i31YrSo2PJs2ETCwXdjUSDEBhcs2mTPa6IQzPwC4zDoOuuAwpx

Array Specification

Product:	Beam
Unique ID:	3P-17-10TOP-XD-24-L-5Hx8W-J5BF
Duty Classification:	XD
Module Width:	44.66 in
Module Length:	67.80in
Number of Rows:	5
Number of Columns:	8
Total Number of Modules:	40
Desired Tilt Angle:	45
Front Edge Clearance:	5
Total Array Height at Tilt:	18.23 ft
Total Frame Length:	45.50 ft
Frame Weight:	3325 lbs
Array Dimensions N/S:	18.82 ft
Array Dimensions E/W:	45.87 ft
Rail Length:	225.80 in
Rail Spacing:	2.82 ft
Rail Check:	Not Checked

Support Specifications

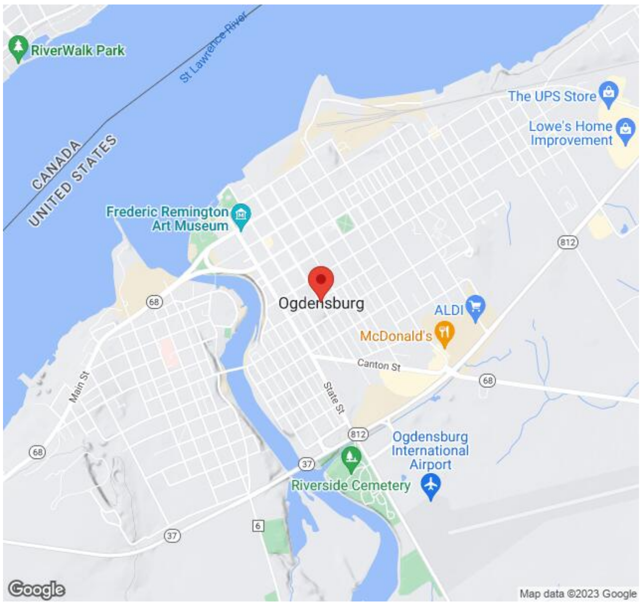
Pole Size:	10in Pipe Sch 40
Pole Length above Grade:	11.65 ft
Number of Poles:	3
Pole Spacing:	17 ft

Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 7.75 ft Pile 2: 8.00 ft Pile 3: 7.75 ft
Foundation Volume:	13.926 y^3
Foundation Result:	PASSED
Mount Twist:	1.726541 kip

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	Ogdensburg, NY 13669, USA
Wind Speed:	100 mph
Snow Load:	60 psf
Design Uplift Pressure:	Multiple pressures
Design Downforce Pressure:	Multiple pressures
Design Snow Pressure:	0.016495 ksf



Design Disclaimer

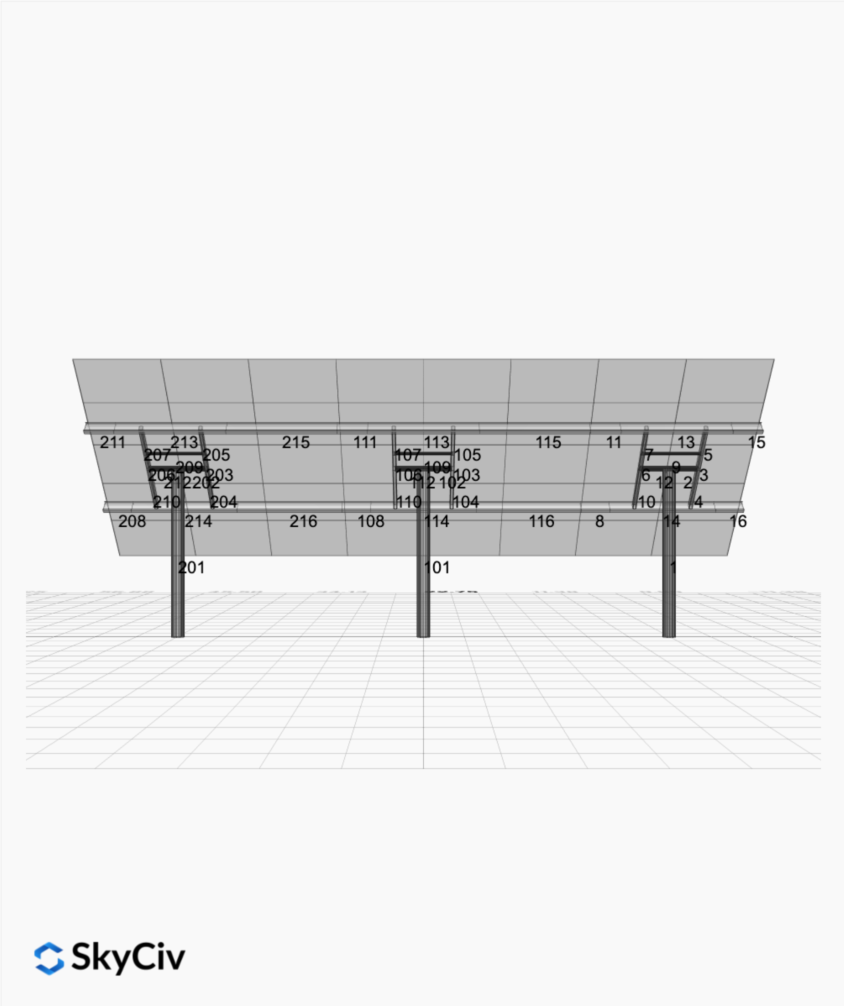
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

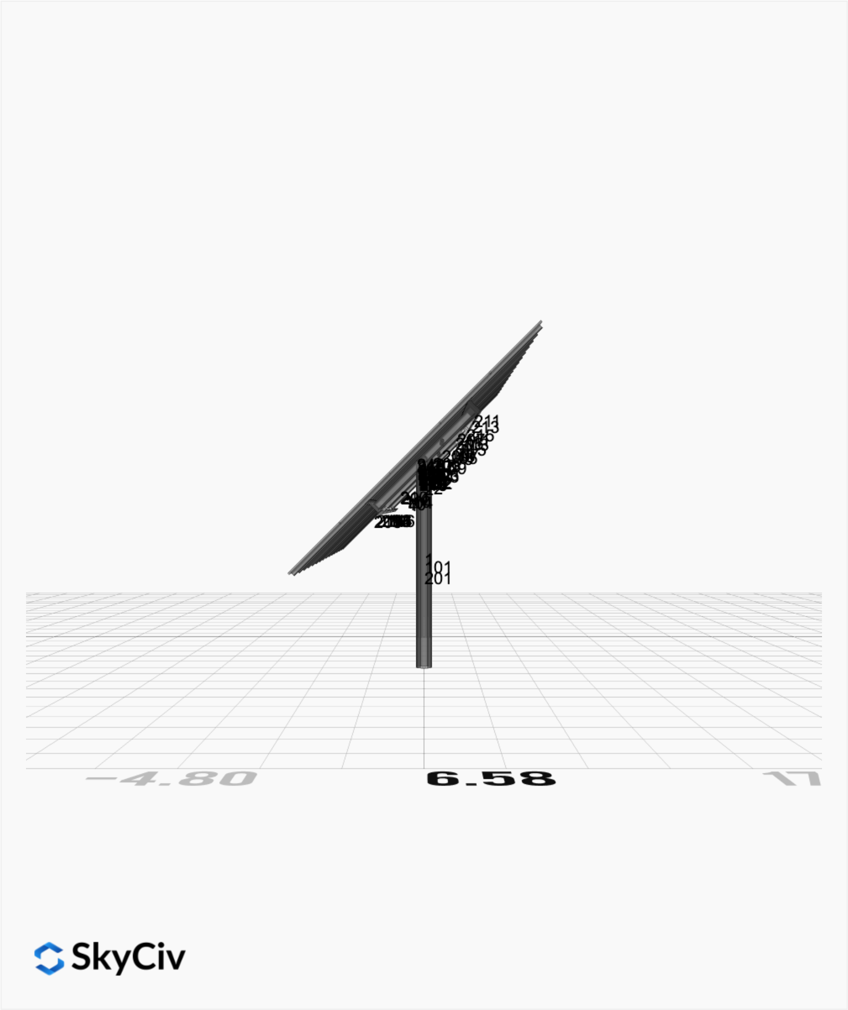
AutoDesigner Input

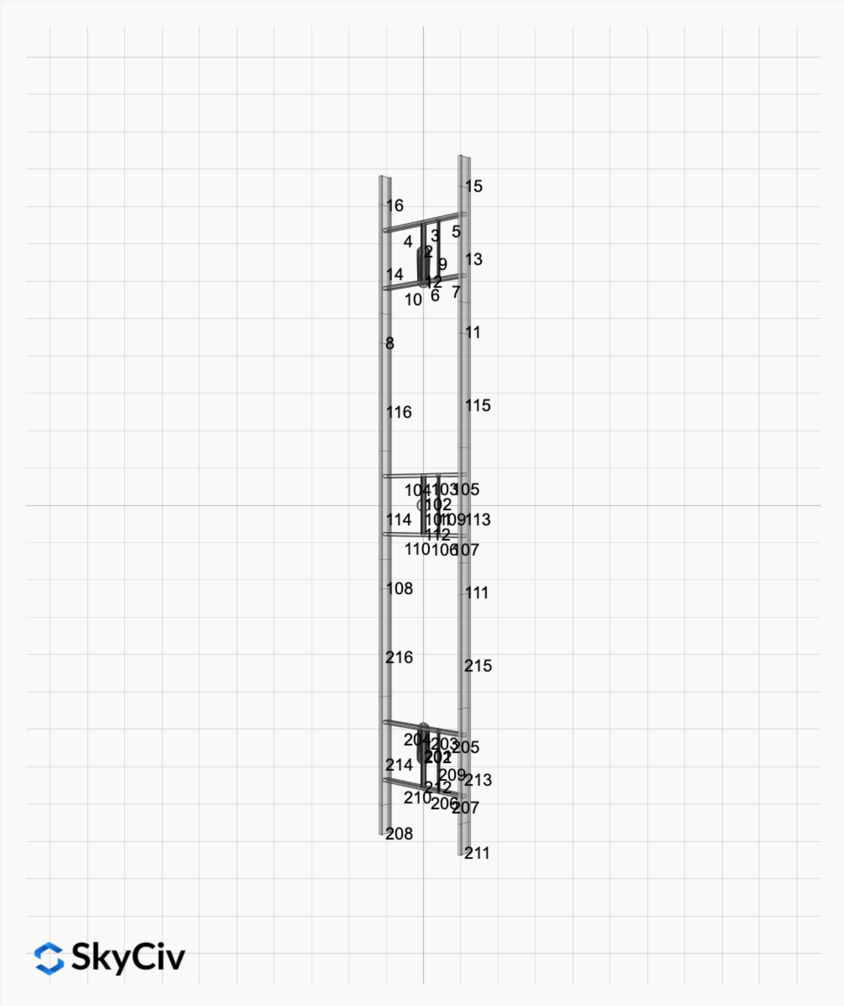

```
{"wind_speed_override":null,"snow_load_override":null,"direct_snow_load":false,"product_type":"Beam","project_id":"MTSOLAR_Pat_Nelson","site_address":"Ogdensburg, NY 13669, USA","module_width":44.66,"module_length":67.8,"number_rows":"5","number_columns":8,"pole_mount_section":"4_40","core_pipe_width":65,"core_pipe_section":"2_40","adjuster_section":"2_40","core_beam_height":65,"core_beam_section":"HSS3x2x1/8","main_pipe_section":"2_12GA","pole_spacing":"15","tilt_angle":45,"ground_clearance":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}
```

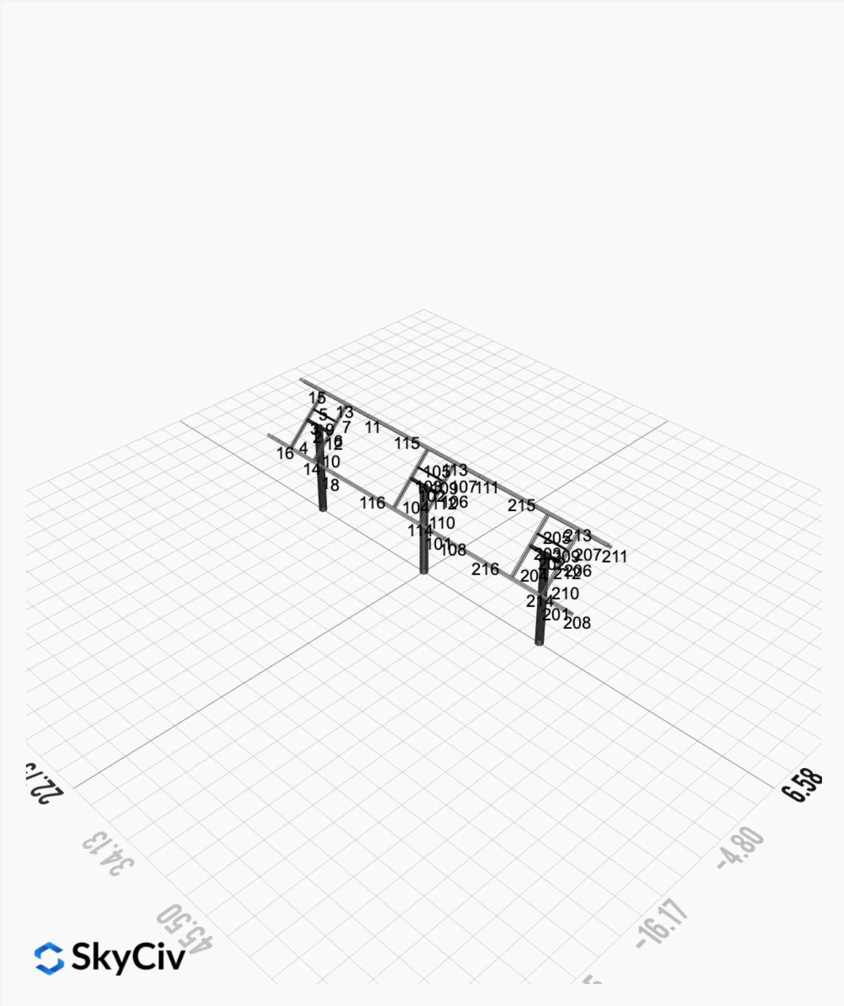

Design Notes:

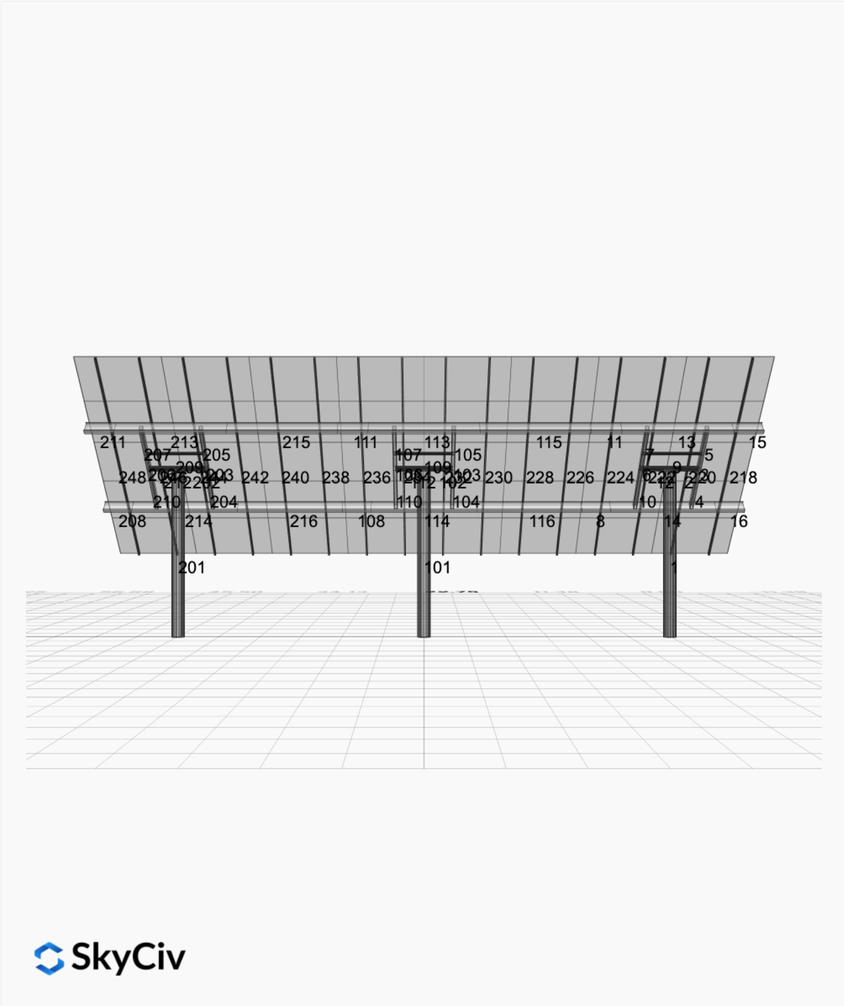
- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Design and Sizing is approximate only



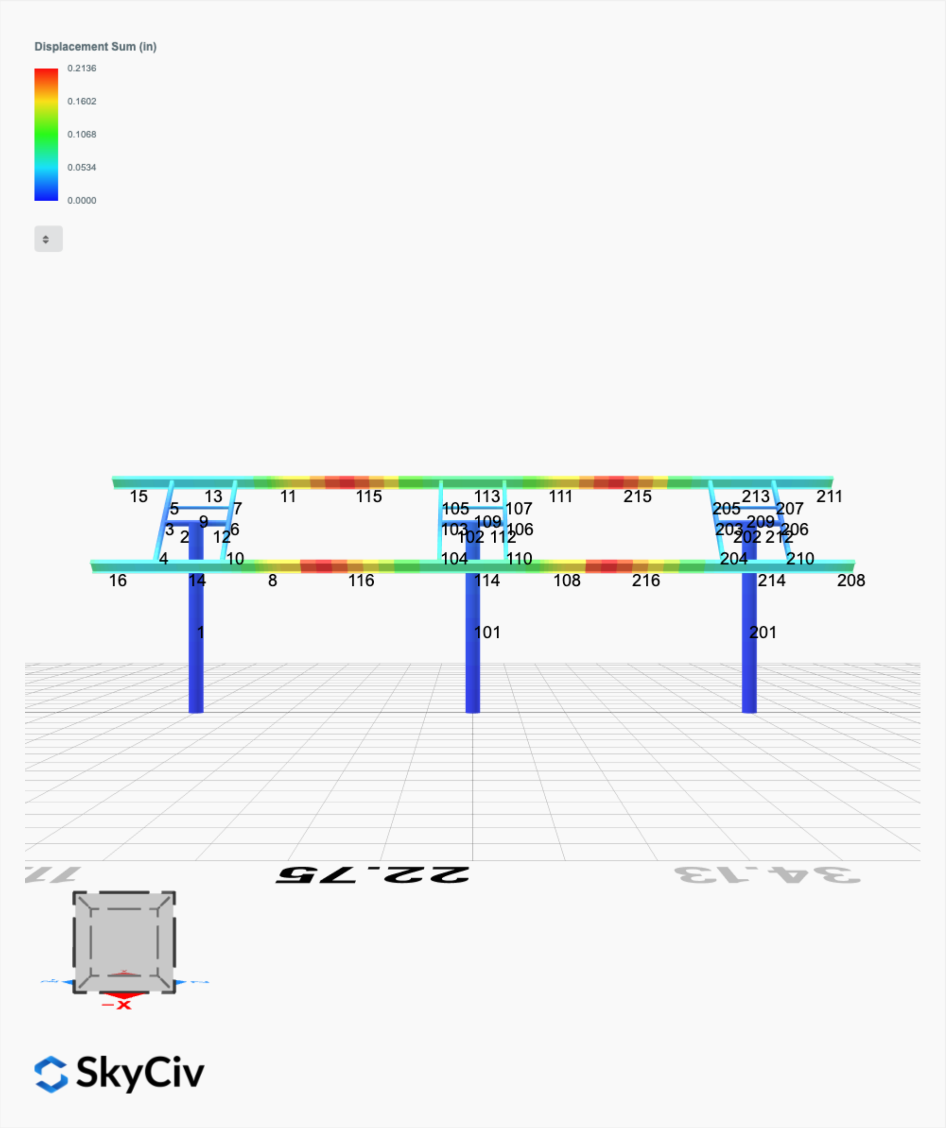

-4.80
6.58
17

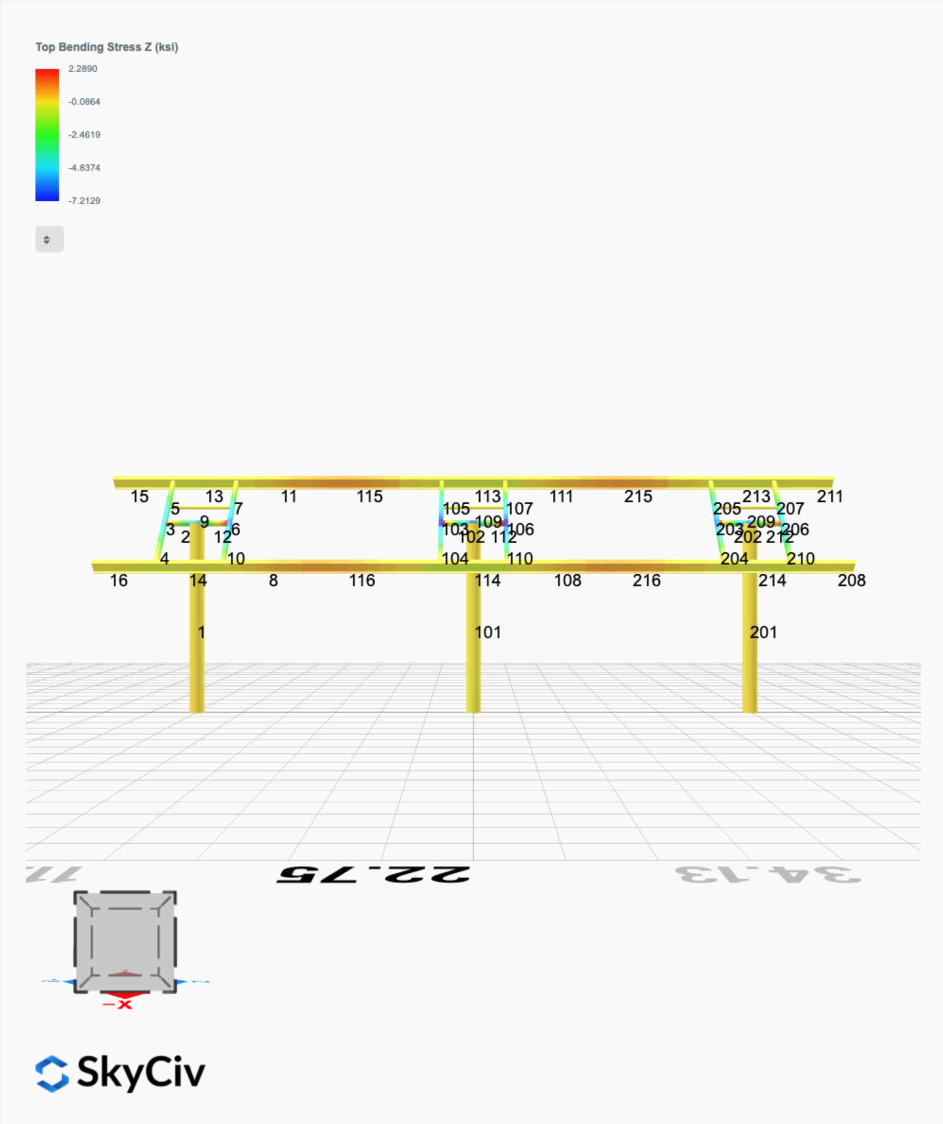

16
15
4
3
5
2
9
13
14
12
10
6
7
8
11
116
115
104
103
105
102
114
101
109
113
112
110
106
107
108
111
216
215
204
203
205
202
214
209
213
212
210
206
207
208
211
SkyCiv


34.13
45.50
6.58
-4.80
-16.17
SkyCiv

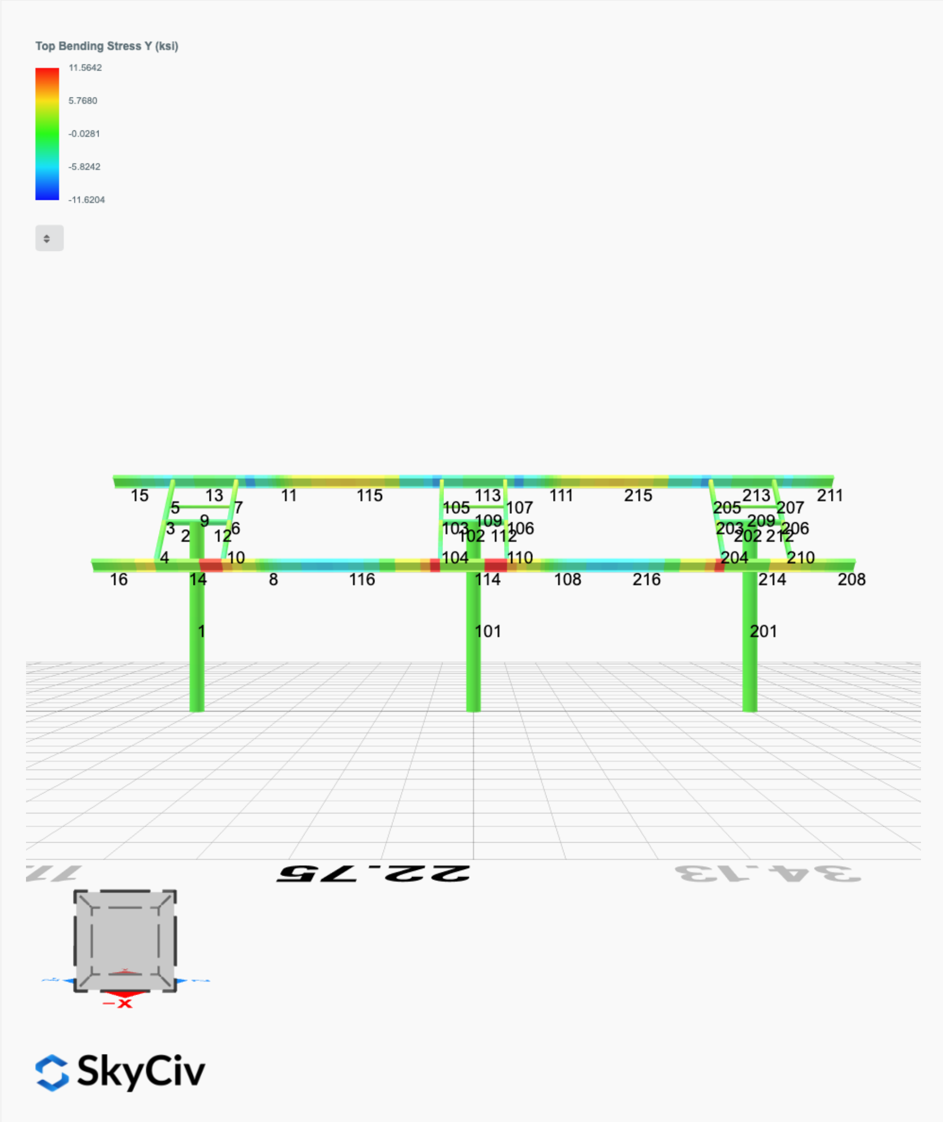


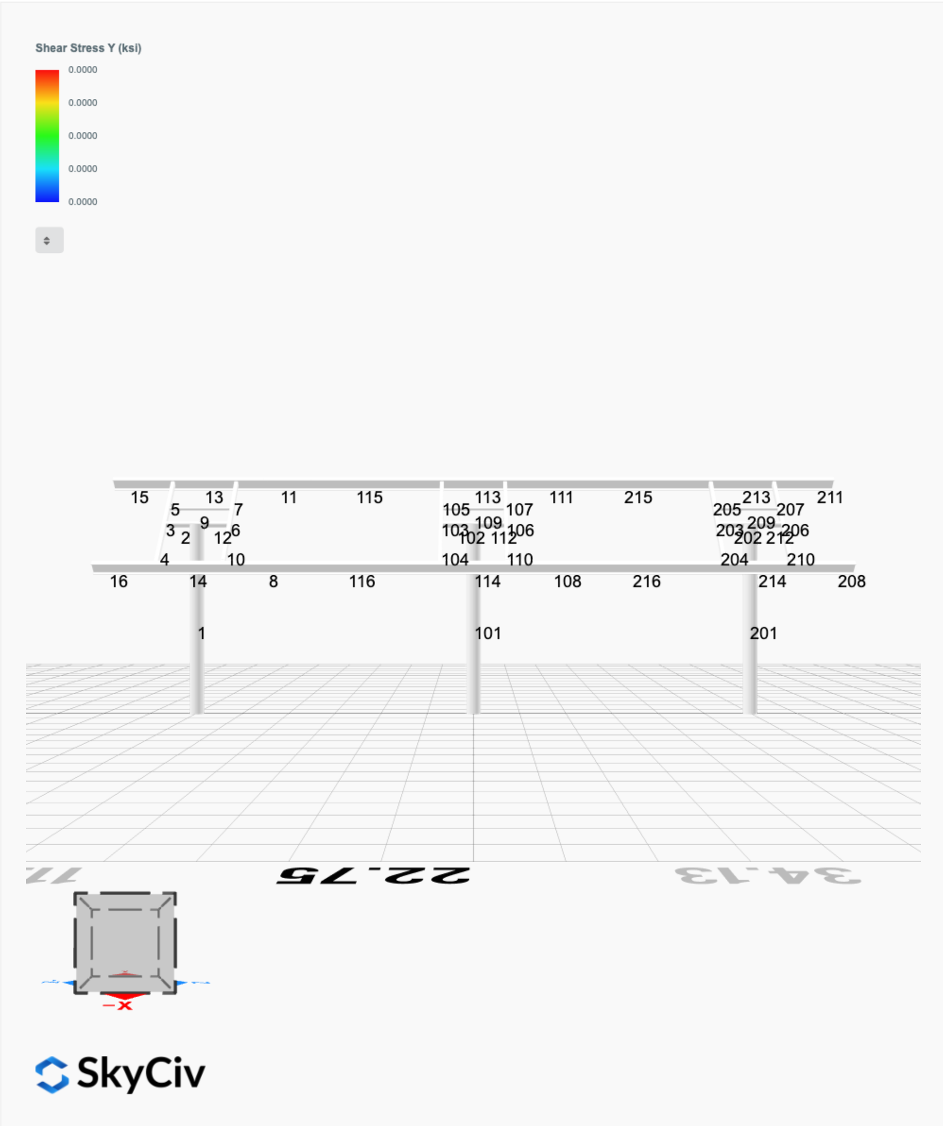
FEM Results (Envelope Worst Case for each member)

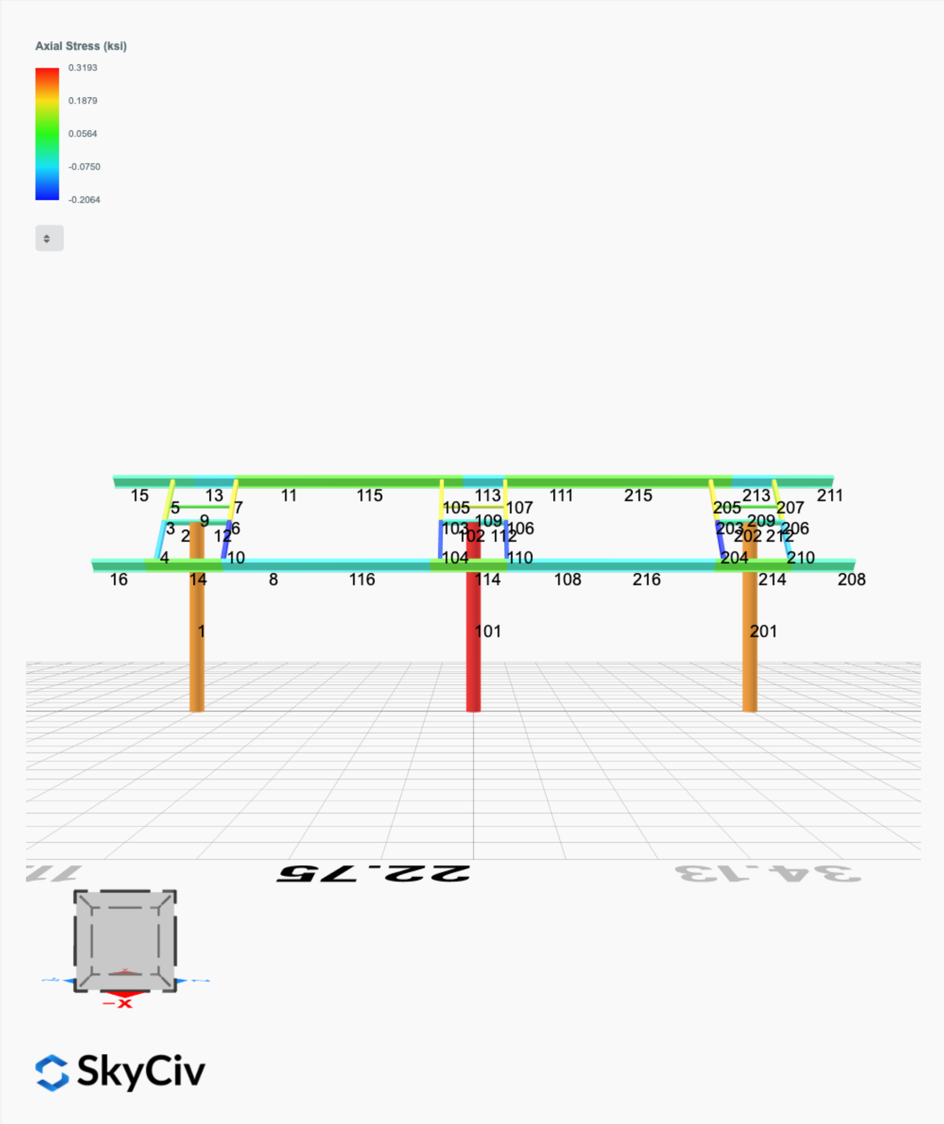




Top Bending Stress Z (ksi)
2.2890
-0.0864
-2.4619
-4.8374
-7.2129
15
13
11
115
105
113
107
111
215
205
213
207
211
5
7
9
109
209
3
2
12
6
103
102
112
106
203
202
212
206
4
10
104
110
204
210
16
14
8
116
114
108
216
214
208
1
101
201
22.75
34.13
SkyCiv


Top Bending Stress Y (ksi)
11.5642
5.7680
-0.0281
-5.8242
-11.6204
15
13
11
115
113
111
215
213
211
5
7
105
107
205
207
9
109
209
3
2
12
6
103
102
112
106
203
202
212
206
4
10
104
110
204
210
16
14
8
116
114
108
216
214
208
1
101
201
22.75
34.13
-x
SkyCiv


Shear Stress Y (ksi)
0.0000
0.0000
0.0000
0.0000
0.0000
15 13 11 115 113 111 215 213 211
5 7 105 107 205 207
9 109 209
3 2 12 6 103 102 112 106 203 202 212 206
4 10 104 110 204 210
16 14 8 116 114 108 216 214 208
1 101 201
22.75
34.13
SkyCiv


Axial Stress (ksi)
0.3193
0.1879
0.0564
-0.0750
-0.2064
22.75
34.13
-X
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	0.0150	2.2999	0.0434	0.1375	-0.0228	-0.1352
ULS: 2. D + L	0.0150	2.2999	0.0434	0.1375	-0.0228	-0.1352
ULS: 3. D + (S or Lr or R)	0.0451	5.3918	0.1300	0.4129	-0.0697	-0.4446
ULS: 3. D + (S or Lr or R)	0.0150	2.2999	0.0434	0.1375	-0.0228	-0.1352
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0376	4.6188	0.1083	0.3441	-0.0580	-0.3673
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0150	2.2999	0.0434	0.1375	-0.0228	-0.1352
ULS: 5b. D + 0.7E	0.0150	2.2999	0.0434	0.1375	-0.0228	-0.1352
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0376	4.6188	0.1083	0.3441	-0.0580	-0.3673
ULS: 8. 0.6D + 0.7E	0.0090	1.3799	0.0260	0.0825	-0.0137	-0.0811
ULS: 5a. D + 0.6W_Wind downforce Case A only	-4.1777	6.4456	0.2186	0.6367	-1.0248	50.9312
ULS: 5a. D + 0.6W_Wind downforce Case B only	-4.1777	6.4456	0.2186	0.6367	-1.0248	50.9312
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.0399	-0.6935	-0.0787	-0.2101	0.6755	-34.3948
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.7074	-0.3567	-0.0761	-0.2023	0.6657	-39.0133
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.1070	7.7281	0.2397	0.7184	-0.8095	37.9326
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.1070	7.7281	0.2397	0.7184	-0.8095	37.9326
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.3062	2.3738	0.0168	0.0833	0.4657	-26.0619
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.0569	2.6264	0.0187	0.0892	0.4584	-29.5258
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.1296	5.4092	0.1748	0.5119	-0.7743	38.1646
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.1296	5.4092	0.1748	0.5119	-0.7743	38.1646
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.2837	0.0548	-0.0482	-0.1232	0.5009	-25.8299
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.0343	0.3075	-0.0462	-0.1173	0.4936	-29.2938
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-4.1838	5.5257	0.2012	0.5816	-1.0157	50.9853
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-4.1838	5.5257	0.2012	0.5816	-1.0157	50.9853
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.0339	-1.6135	-0.0961	-0.2651	0.6846	-34.3407
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.7014	-1.2766	-0.0934	-0.2573	0.6748	-38.9592

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	11.2170
Shear X	-6.9880
Shear Z	0.3886
Moment X	1.1386
Moment Y (Twist)	1.7263
Moment Z	85.4181

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	7.7281
Shear X	-4.1838
Shear Z	0.2397
Moment X	0.7184
Moment Y (Twist)	1.0248
Moment Z	50.9853

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	-0.0301	2.6571	0.0000	0.0000	0.0000	0.3450
ULS: 2. D + L	-0.0301	2.6571	0.0000	0.0000	0.0000	0.3450
ULS: 3. D + (S or Lr or R)	-0.0902	6.4590	0.0000	0.0000	0.0000	0.9992
ULS: 3. D + (S or Lr or R)	-0.0301	2.6571	0.0000	0.0000	0.0000	0.3450
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0751	5.5085	0.0000	0.0000	0.0000	0.8356
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0301	2.6571	0.0000	0.0000	0.0000	0.3450
ULS: 5b. D + 0.7E	-0.0301	2.6571	0.0000	0.0000	0.0000	0.3450

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0751	5.5085	0.0000	0.0000	0.0000	0.8356
ULS: 8. 0.6D + 0.7E	-0.0180	1.5943	0.0000	0.0000	0.0000	0.2070
ULS: 5a. D + 0.6W_Wind downforce Case A only	-5.0098	7.7309	0.0000	0.0000	0.0000	60.1993
ULS: 5a. D + 0.6W_Wind downforce Case B only	-5.0098	7.7309	0.0000	0.0000	0.0000	60.1993
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.5887	-1.0246	0.0000	0.0000	0.0000	-39.9728
ULS: 5a. D + 0.6W_Wind uplift Case B only	3.1162	-0.5608	0.0000	0.0000	0.0000	-44.5409
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.8099	9.3139	0.0000	0.0000	0.0000	45.7264
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.8099	9.3139	0.0000	0.0000	0.0000	45.7264
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.6389	2.7473	0.0000	0.0000	0.0000	-29.4027
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.2845	3.0951	0.0000	0.0000	0.0000	-32.8288
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.7649	6.4625	0.0000	0.0000	0.0000	45.2357
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.7649	6.4625	0.0000	0.0000	0.0000	45.2357
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.6840	-0.1041	0.0000	0.0000	0.0000	-29.8934
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.3296	0.2437	0.0000	0.0000	0.0000	-33.3195
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-4.9978	6.6681	0.0000	0.0000	0.0000	60.0613
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-4.9978	6.6681	0.0000	0.0000	0.0000	60.0613
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.6007	-2.0874	0.0000	0.0000	0.0000	-40.1108
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	3.1282	-1.6237	0.0000	0.0000	0.0000	-44.6789

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	13.5426
Shear X	-8.3608
Shear Z	0.0000
Moment X	0.0002
Moment Y (Twist)	0.0002
Moment Z	101.2540

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	9.3139
Shear X	-5.0098
Shear Z	0.0000
Moment X	0.0000
Moment Y (Twist)	0.0000
Moment Z	60.1993

Reaction Forces for Foundation 3 (Node ID#201), (kip, kip-ft)

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	0.0150	2.2999	-0.0434	-0.1375	0.0228	-0.1352
ULS: 2. D + L	0.0150	2.2999	-0.0434	-0.1375	0.0228	-0.1352
ULS: 3. D + (S or Lr or R)	0.0451	5.3918	-0.1300	-0.4129	0.0698	-0.4446
ULS: 3. D + (S or Lr or R)	0.0150	2.2999	-0.0434	-0.1375	0.0228	-0.1352
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0376	4.6188	-0.1083	-0.3441	0.0580	-0.3672
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0150	2.2999	-0.0434	-0.1375	0.0228	-0.1352
ULS: 5b. D + 0.7E	0.0150	2.2999	-0.0434	-0.1375	0.0228	-0.1352
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0376	4.6188	-0.1083	-0.3441	0.0580	-0.3672
ULS: 8. 0.6D + 0.7E	0.0090	1.3799	-0.0260	-0.0825	0.0137	-0.0811
ULS: 5a. D + 0.6W_Wind downforce Case A only	-4.1777	6.4456	-0.2186	-0.6367	1.0248	50.9312
ULS: 5a. D + 0.6W_Wind downforce Case B only	-4.1777	6.4456	-0.2186	-0.6367	1.0248	50.9312
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.0399	-0.6935	0.0787	0.2101	-0.6755	-34.3947
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.7074	-0.3567	0.0761	0.2023	-0.6657	-39.0133
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.1070	7.7281	-0.2397	-0.7184	0.8095	37.9326
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.1070	7.7281	-0.2397	-0.7184	0.8095	37.9326
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.3062	2.3738	-0.0168	-0.0833	-0.4657	-26.0619
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.0569	2.6264	-0.0187	-0.0892	-0.4583	-29.5258

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.1296	5.4092	-0.1748	-0.5119	0.7743	38.1646
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.1296	5.4092	-0.1748	-0.5119	0.7743	38.1646
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.2837	0.0548	0.0482	0.1232	-0.5009	-25.8299
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.0343	0.3075	0.0462	0.1173	-0.4935	-29.2938
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-4.1838	5.5257	-0.2012	-0.5816	1.0157	50.9853
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-4.1838	5.5257	-0.2012	-0.5816	1.0157	50.9853
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.0339	-1.6135	0.0961	0.2651	-0.6846	-34.3407
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.7014	-1.2766	0.0934	0.2573	-0.6748	-38.9592

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	11.2170
Shear X	-6.9880
Shear Z	-0.3886
Moment X	-1.1385
Moment Y (Twist)	1.7265
Moment Z	85.4193

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	7.7281
Shear X	-4.1838
Shear Z	-0.2397
Moment X	-0.7184
Moment Y (Twist)	1.0248
Moment Z	50.9853

Project Details

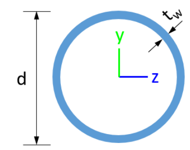
Design Code:	AISC 360-16 LRFD
Provision:	LRFD
Country:	United States
User Name:	sales@mtsolar.us
Unit System:	imperial

Design Input Information

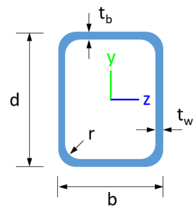
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

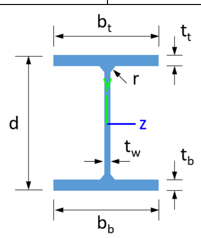
Section Dimensions



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	24.47	24.47	11.65	-	300	200	1
2	6	1.30	1.30	2.00	-	300	200	1
3	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.19,1.27,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.17	300	200	1
4	17	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.69,1.69,1.67,1.67,1.66,1.48,1.67,1.67,1.66,1.64,1.67,1.67,1.70,1.68,1.67,1.67,1.65,2.36,1.67,1.67,1.66,1.65	300	200	1
5	17	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.23,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
6	17	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.06,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
7	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.55,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
8	20	1.33	1.33	2.05	1.29,1.29,1.29,1.29,1.29,1.29,1.29,1.29,1.16,1.29,1.29,1.29,1.24,1.29,1.29,1.30,1.31,1.29,1.29,1.29,1.10,1.29,1.29,1.29,1.25	300	200	1
9	3	2.60	2.60	4.00	-	300	200	1
10	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.62,1.67,1.67,1.66,1.65,1.67,1.67,1.70,1.68,1.67,1.67,1.65,1.51,1.67,1.67,1.66,1.66	300	200	1
11	20	1.33	1.33	2.05	1.30,1.30,1.30,1.30,1.30,1.30,1.32,1.32,1.33,1.34,1.32,1.32,1.32,1.33,1.31,1.31,1.26,2.01,1.32,1.32,1.33,1.34,1.32,1.32,1.32,1.33	300	200	1
12	6	1.30	1.30	2.00	-	300	200	1
13	20	4.88	4.00	7.50	1.21,1.21,1.21,1.21,1.21,1.21,1.21,1.21,1.19,1.25,1.21,1.21,1.20,1.25,1.21,1.21,1.24,1.88,1.21,1.21,1.19,1.25,1.21,1.21,1.20,1.24	300	200	1
14	20	4.88	4.00	7.50	1.20,1.20,1.20,1.20,1.20,1.19,1.19,1.21,1.30,1.19,1.19,1.21,1.15,1.19,1.19,1.19,1.28,1.19,1.19,1.21,1.39,1.19,1.19,1.21,1.12	300	200	1
15	20	4.20	4.20	2.00	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
16	20	4.20	4.20	2.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33	300	200	1
101	11	24.47	24.47	11.65	-	300	200	1
102	6	1.30	1.30	2.00	-	300	200	1
103	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.23,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
104	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.61,1.67,1.67,1.66,1.65,1.67,1.67,1.69,1.68,1.67,1.67,1.66,1.43,1.67,1.67,1.66,1.66	300	200	1
105	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.74,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
106	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.23,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
107	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.74,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1

108	20	1.33	1.33	2.05	1.52,1.52,1.52,1.52,1.52,1.52,1.44,1.44,1.39,1.43,1.44,1.44,1.41,1.49,1.47,1.47,2.08,1.53,1.44,1.44,1.38,1.39,1.43,1.43,1.41,1.49	300	200	1
109	3	2.60	2.60	4.00	-	300	200	1
110	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.61,1.67,1.67,1.66,1.65,1.67,1.67,1.69,1.68,1.67,1.67,1.66,1.43,1.67,1.67,1.66,1.66	300	200	1
111	20	1.33	1.33	2.05	1.44,1.44,1.44,1.44,1.44,1.44,1.29,1.29,1.22,1.23,1.29,1.29,1.25,1.25,1.34,1.34,2.33,1.11,1.30,1.30,1.22,1.23,1.28,1.28,1.26,1.25	300	200	1
112	6	1.30	1.30	2.00	-	300	200	1
113	20	4.88	4.00	7.50	1.06,1.06,1.06,1.06,1.06,1.06,1.09,1.09,1.35,1.57,1.10,1.10,1.11,1.21,1.08,1.08,1.03,1.00,1.09,1.09,1.50,1.68,1.10,1.10,1.11,1.14	300	200	1
114	20	4.88	4.00	7.50	1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.07,1.03,1.06,1.06,1.07,1.04,1.06,1.06,1.04,1.06,1.06,1.06,1.07,1.02,1.06,1.06,1.07,1.04	300	200	1
115	20	4.84	4.84	7.45	1.12,1.12,1.12,1.12,1.12,1.12,1.09,1.09,1.07,1.07,1.08,1.08,1.08,1.07,1.10,1.10,1.31,1.53,1.09,1.09,1.07,1.07,1.08,1.08,1.08,1.08	300	200	1
116	20	4.84	4.84	7.45	1.13,1.13,1.13,1.13,1.13,1.13,1.12,1.12,1.11,1.14,1.12,1.12,1.11,1.13,1.12,1.12,1.23,1.13,1.12,1.12,1.11,1.15,1.12,1.12,1.11,1.13	300	200	1
201	11	24.47	24.47	11.65	-	300	200	1
202	6	1.30	1.30	2.00	-	300	200	1
203	17	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.06,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
204	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.62,1.67,1.67,1.66,1.65,1.67,1.67,1.70,1.68,1.67,1.67,1.65,1.51,1.67,1.67,1.66,1.66	300	200	1
205	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.55,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
206	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.19,1.27,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.17	300	200	1
207	17	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.23,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
208	20	4.20	4.20	2.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33	300	200	1
209	3	2.60	2.60	4.00	-	300	200	1
210	17	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.69,1.67,1.67,1.66,1.48,1.67,1.67,1.66,1.64,1.67,1.67,1.70,1.68,1.67,1.67,1.65,2.36,1.67,1.67,1.66,1.65	300	200	1
211	20	4.20	4.20	2.00	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
212	6	1.30	1.30	2.00	-	300	200	1
213	20	4.88	4.00	7.50	1.21,1.21,1.21,1.21,1.21,1.21,1.21,1.21,1.19,1.25,1.21,1.21,1.20,1.25,1.21,1.21,1.24,1.90,1.21,1.21,1.19,1.25,1.21,1.21,1.20,1.24	300	200	1
214	20	4.88	4.00	7.50	1.20,1.20,1.20,1.20,1.20,1.20,1.19,1.19,1.21,1.29,1.19,1.19,1.21,1.14,1.20,1.20,1.19,1.28,1.19,1.19,1.21,1.39,1.19,1.19,1.21,1.12	300	200	1
215	20	4.84	4.84	7.45	1.08,1.08,1.08,1.08,1.08,1.08,1.09,1.09,1.10,1.10,1.09,1.09,1.10,1.10,1.09,1.09,1.09,1.78,1.09,1.09,1.10,1.10,1.09,1.09,1.10,1.10	300	200	1
216	20	4.84	4.84	7.45	1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.05,1.08,1.08,1.08,1.07,1.08,1.08,1.08,1.08,1.08,1.08,1.04,1.08,1.08,1.08,1.07	300	200	1

Member Design Capacity

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	335.89	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	36.37	6.46	56.26	44.91
14	159.30	116.35	34.23	6.46	56.26	44.91
15	159.30	113.66	46.90	6.46	56.26	44.91
16	159.30	113.66	46.90	6.46	56.26	44.91
101	535.87	335.89	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	142.47	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	142.47	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	30.56	6.46	56.26	44.91
114	159.30	116.35	31.17	6.46	56.26	44.91
115	159.30	104.63	32.89	6.46	56.26	44.91
116	159.30	104.63	34.12	6.46	56.26	44.91
201	535.87	335.89	147.68	147.68	160.76	160.76
202	251.01	248.88	27.16	27.16	75.30	75.30
203	151.65	150.70	20.17	14.14	54.12	28.95
204	151.65	145.15	20.17	14.14	54.12	28.95
205	151.65	149.10	20.17	14.14	54.12	28.95
206	151.65	150.70	20.17	14.14	54.12	28.95
207	151.65	149.10	20.17	14.14	54.12	28.95
208	159.30	113.66	46.90	6.46	56.26	44.91
209	75.10	66.32	4.25	4.25	22.53	22.53
210	151.65	145.15	20.17	14.14	54.12	28.95
211	159.30	113.66	46.90	6.46	56.26	44.91
212	251.01	248.88	27.16	27.16	75.30	75.30
213	159.30	116.35	36.37	6.46	56.26	44.91
214	159.30	116.35	34.23	6.46	56.26	44.91
215	159.30	104.63	33.20	6.46	56.26	44.91
216	159.30	104.63	31.97	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	0.033	0.578	0.023	0.043	0.002	0.603	#13	0.400	Not Required	Pass
2	0.001	0.259	0.206	0.061	0.042	0.465	#13	0.054	Not Required	Pass
3	0.007	0.543	0.042	0.053	0.009	0.563	#13	0.046	Not Required	Pass
4	0.006	0.481	0.071	0.048	0.018	0.531	#13	0.082	Not Required	Pass
5	0.007	0.337	0.060	0.054	0.015	0.338	#13	0.076	Not Required	Pass
6	0.010	0.679	0.092	0.069	0.026	0.732	#13	0.046	Not Required	Pass
7	0.010	0.421	0.130	0.067	0.032	0.436	#13	0.076	Not Required	Pass
8	0.003	0.096	0.114	0.033	0.018	0.191	#21	0.102	Not Required	Pass
9	0.003	0.050	0.065	0.002	0.003	0.115	#13	0.206	Not Required	Pass
10	0.010	0.593	0.126	0.059	0.029	0.615	#13	0.082	Not Required	Pass
11	0.003	0.110	0.111	0.039	0.018	0.197	#21	0.102	Not Required	Pass
12	0.001	0.383	0.270	0.081	0.051	0.653	#13	0.054	Not Required	Pass
13	0.004	0.115	0.367	0.053	0.025	0.406	#21	0.306	Not Required	Pass
14	0.005	0.102	0.364	0.045	0.025	0.388	#21	0.204	Not Required	Pass
15	0.000	0.019	0.053	0.016	0.008	0.068	#21	Not Required	Not Required	Pass
16	0.000	0.017	0.053	0.015	0.008	0.067	#21	Not Required	Not Required	Pass
101	0.040	0.686	0.000	0.052	0.000	0.706	#13	0.400	Not Required	Pass
102	0.002	0.390	0.288	0.086	0.056	0.678	#13	0.054	Not Required	Pass
103	0.010	0.720	0.073	0.072	0.017	0.760	#13	0.046	Not Required	Pass
104	0.010	0.674	0.132	0.067	0.030	0.729	#13	0.082	Not Required	Pass
105	0.010	0.447	0.135	0.071	0.034	0.466	#13	0.076	Not Required	Pass
106	0.010	0.720	0.073	0.072	0.017	0.760	#13	0.046	Not Required	Pass
107	0.010	0.447	0.135	0.071	0.034	0.466	#13	0.076	Not Required	Pass
108	0.003	0.083	0.111	0.037	0.019	0.163	#21	0.102	Not Required	Pass
109	0.008	0.043	0.049	0.001	0.000	0.095	#13	0.206	Not Required	Pass
110	0.010	0.674	0.132	0.067	0.030	0.729	#13	0.082	Not Required	Pass
111	0.003	0.113	0.113	0.038	0.018	0.180	#21	0.102	Not Required	Pass
112	0.002	0.390	0.288	0.086	0.056	0.678	#13	0.054	Not Required	Pass
113	0.004	0.105	0.379	0.052	0.025	0.454	#21	0.306	Not Required	Pass
114	0.006	0.142	0.377	0.049	0.025	0.474	#21	0.306	Not Required	Pass
115	0.005	0.200	0.202	0.038	0.018	0.356	#21	0.370	Not Required	Pass
116	0.003	0.164	0.201	0.037	0.019	0.334	#21	0.370	Not Required	Pass
201	0.033	0.578	0.023	0.043	0.002	0.603	#13	0.400	Not Required	Pass
202	0.001	0.383	0.270	0.081	0.051	0.653	#13	0.054	Not Required	Pass
203	0.010	0.679	0.092	0.069	0.026	0.732	#13	0.046	Not Required	Pass
204	0.010	0.593	0.126	0.059	0.029	0.615	#13	0.082	Not Required	Pass
205	0.010	0.421	0.130	0.067	0.032	0.436	#13	0.076	Not Required	Pass
206	0.007	0.543	0.042	0.053	0.009	0.563	#13	0.046	Not Required	Pass
207	0.007	0.337	0.060	0.054	0.015	0.338	#13	0.076	Not Required	Pass
208	0.000	0.017	0.053	0.015	0.008	0.067	#21	Not Required	Not Required	Pass
209	0.003	0.050	0.065	0.002	0.003	0.115	#13	0.206	Not Required	Pass
210	0.006	0.481	0.071	0.048	0.018	0.531	#13	0.082	Not Required	Pass
211	0.000	0.019	0.053	0.016	0.008	0.068	#21	Not Required	Not Required	Pass
212	0.001	0.259	0.206	0.061	0.042	0.465	#13	0.054	Not Required	Pass
213	0.004	0.115	0.367	0.053	0.025	0.406	#21	0.204	Not Required	Pass
214	0.005	0.102	0.364	0.045	0.025	0.387	#21	0.306	Not Required	Pass
215	0.005	0.207	0.201	0.039	0.018	0.358	#21	0.370	Not Required	Pass
216	0.003	0.172	0.202	0.033	0.018	0.340	#21	0.370	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
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

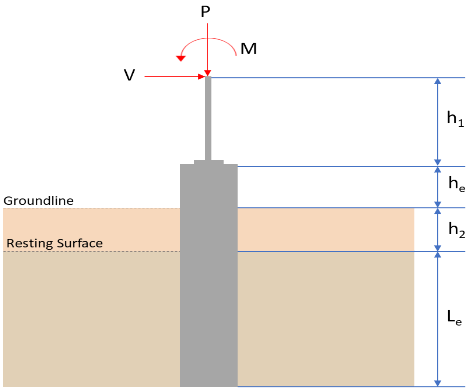
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \text{in}$ - Pile width
$D = 48\ \text{in}$ - Pile depth
$L = 7.75\ \text{ft}$ - 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)	7.728	11.217
V_x (kip)	-4.184	-6.988
V_z (kip)	0.240	0.389
M_x (kipft)	0.718	1.139
M_z (kipft)	50.985	85.418

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,

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

$$H_o = \frac{(-4.184\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.66624\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(50.985\ \mathrm{kipft}) + ((-4.184\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 8.1186\ \mathrm{kipft/ft}$$

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:
$L_{e,x} = 7.1404\ \mathrm{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.24\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = 0.038217\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.718\ \mathrm{kipft}) + ((0.24\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.11433\ \mathrm{kipft/ft}$$

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:
$L_{e,z} = 2.4537\ \mathrm{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.1404\ \mathrm{ft}), (2.4537\ \mathrm{ft})]$$

$$L_{e,req} = 7.14\ \mathrm{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7.75\ \mathrm{ft}) - (0\ \mathrm{ft}) - (0\ \mathrm{ft})$$

$$L_e = 7.75\ \mathrm{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.14\ \mathrm{ft})}{(7.75\ \mathrm{ft})}$$

$$Ratio = 0.92129$$

Status: **PASS**
Ratio: **0.920**

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

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

$$q = \frac{(7.728\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.483\ \mathrm{kip/ft}^2$$

$$q = 0.483\ \mathrm{kip/ft}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.483\ \mathrm{kip/ft^2})}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.2415$$

Status: **PASS**
Ratio: **0.240**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7.75\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1.9375$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.66624\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 8.1186\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.1186\ \mathrm{kipft/ft}) \times (7.75\ \mathrm{ft})) + \left(3 \times (-0.66624\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft})^2\right)}{(6 \times (8.1186\ \mathrm{kipft/ft})) + (4 \times (-0.66624\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))}$$

$$a = 5.359\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (8.1186\ \mathrm{kipft/ft})) + (3 \times (-0.66624\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]^2}{(7.75\ \mathrm{ft})^2 \times [(3 \times (8.1186\ \mathrm{kipft/ft})) + (2 \times (-0.66624\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]}$$

$$p = 0.25676\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (8.1186\ \mathrm{kipft/ft})) + ((-0.66624\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]}{(7.75\ \mathrm{ft})^2}$$

$$s = 1.1062\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.359\ \mathrm{ft})}{2}$$

$$p_a = 0.40192\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.25676\ \mathrm{kip/ft^2})}{(0.40192\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.63883$$

Status: **PASS**
Ratio: **0.640**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.75\ \mathrm{ft})$$

$$p_s = 1.1625\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.1062\ \mathrm{kip/ft^2}\right)}{\left(1.1625\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.9516$$

Status: PASS
Ratio: 0.950

Considering z-direction:

$H_o = 0.038217\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.11433\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.11433\ \mathrm{kipft/ft}) \times (7.75\ \mathrm{ft})) + \left(3 \times (0.038217\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft})^2\right)}{(6 \times (0.11433\ \mathrm{kipft/ft})) + (4 \times (0.038217\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))}$$

$$a = 5.5757\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.11433\ \mathrm{kipft/ft})) + (3 \times (0.038217\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]^{\ 2}}{(7.75\ \mathrm{ft})^2 \times [(3 \times (0.11433\ \mathrm{kipft/ft})) + (2 \times (0.038217\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]}$$

$$p = 0.024182\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.11433\ \mathrm{kipft/ft})) + ((0.038217\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]}{(7.75\ \mathrm{ft})^2}$$

$$s = 0.052429\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.5757\ \mathrm{ft})}{2}$$

$$p_a = 0.41818\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.024182\ \mathrm{kip/ft^2}\right)}{\left(0.41818\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.057826$$

Status: PASS
Ratio: 0.060

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.75\ \mathrm{ft})$$

$$p_s = 1.1625\ \mathrm{kip/ft^2}$$

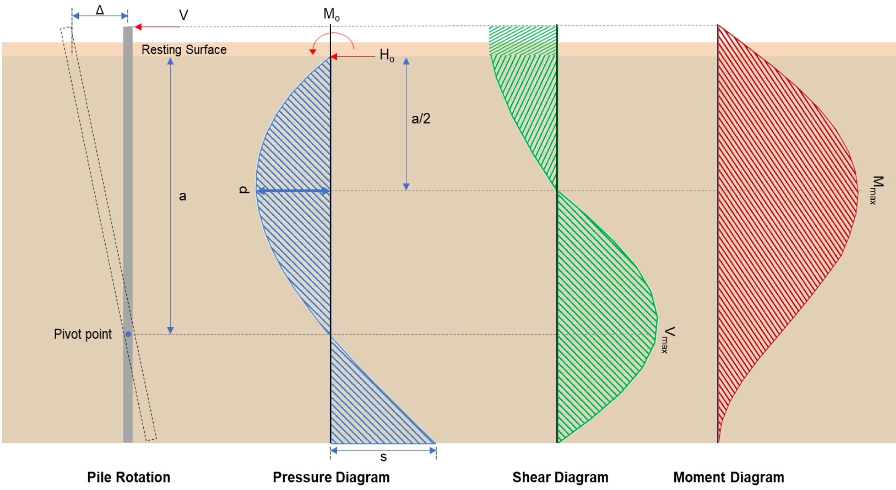
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.052429\ \mathrm{kip/ft^2})}{(1.1625\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.045101$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-6.988\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -1.1127\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(85.418\ \mathrm{kipft}) + ((-6.988\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 13.602\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(13.602\ \mathrm{kipft/ft})}{(-1.1127\ \mathrm{kip/ft})}$$

$$E = 12.224\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (13.602\ \mathrm{kipft/ft}) \times (7.75\ \mathrm{ft})) + \left(3 \times (-1.1127\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft})^2\right)}{(6 \times (13.602\ \mathrm{kipft/ft})) + (4 \times (-1.1127\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))}$$

$$a = 5.3585\ \mathrm{ft}$$

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

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

$$V_{max} = ((-1.1127\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.224\ \mathrm{ft})}{(7.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.3585\ \mathrm{ft})}{(7.75\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (12.224\ \mathrm{ft})}{(7.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.3585\ \mathrm{ft})}{(7.75\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 15.357\ \mathrm{kip}$$

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

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

$$M_{max} = ((-1.1127\ \text{kip/ft}) \times (48\ \text{in}) \times (7.75\ \text{ft})) \times \left[\left(\frac{(12.224\ \text{ft})}{(7.75\ \text{ft})} + \frac{(5.3585\ \text{ft})}{2 \times (7.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (12.224\ \text{ft})}{(7.75\ \text{ft})} + 3\right) \times \left(\frac{(5.3585\ \text{ft})}{2 \times (7.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (12.224\ \text{ft})}{(7.75\ \text{ft})} + 2\right) \times \left(\frac{(5.3585\ \text{ft})}{2 \times (7.75\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 56.381\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.389\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.061943\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.139\ \text{kipft}) + ((0.389\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.18137\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.18137\ \text{kipft/ft})}{(0.061943\ \text{kip/ft})}$$

$$E = 2.928\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.18137\ \text{kipft/ft}) \times (7.75\ \text{ft})) + \left(3 \times (0.061943\ \text{kip/ft}) \times (7.75\ \text{ft})^2\right)}{(6 \times (0.18137\ \text{kipft/ft})) + (4 \times (0.061943\ \text{kip/ft}) \times (7.75\ \text{ft}))}$$

$$a = 5.5789\ \text{ft}$$

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

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

$$V_{max} = ((0.061943\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.928\ \text{ft})}{(7.75\ \text{ft})} + 3\right) \times \left(\frac{(5.5789\ \text{ft})}{(7.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (2.928\ \text{ft})}{(7.75\ \text{ft})} + 2\right) \times \left(\frac{(5.5789\ \text{ft})}{(7.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.33144\ \text{kip}$$

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

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

$$M_{max} = ((0.061943\ \text{kip/ft}) \times (48\ \text{in}) \times (7.75\ \text{ft})) \times \left[\left(\frac{(2.928\ \text{ft})}{(7.75\ \text{ft})} + \frac{(5.5789\ \text{ft})}{2 \times (7.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (2.928\ \text{ft})}{(7.75\ \text{ft})} + 3\right) \times \left(\frac{(5.5789\ \text{ft})}{2 \times (7.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (2.928\ \text{ft})}{(7.75\ \text{ft})} + 2\right) \times \left(\frac{(5.5789\ \text{ft})}{2 \times (7.75\ \text{ft})}\right)^4\right]\right]$$

	$M_{max} = 1.1137 \text{ kipft}$		

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(11.217 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.223 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.223 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

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,

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

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

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

Ties:

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

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

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

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

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

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

$$Ratio = \frac{(11.217\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.004193$$

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 $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 11.217\ \text{kip} \rightarrow 11217\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(11217\ \text{lbf})}{6 \times \left(2304\ \text{in}^2\right)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 119.98\ \text{kip}$$

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

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

$$V_c = Min\left[(296.21\ \text{kip}), (119.98\ \text{kip}), (348.89\ \text{kip})\right]$$

$$V_c = 119.98\ \text{kip}$$

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

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

$$\phi V_n = (0.65) \times ((119.98 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.07 \text{ kip}$$

Considering x-direction:

$V_{max} = 15.357 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(15.357 \text{ kip})}{(111.07 \text{ kip})}$$

$$Ratio = 0.13827$$

Status: **PASS**
Ratio: **0.140**

Considering z-direction:

$V_{max} = 0.33144 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.33144 \text{ kip})}{(111.07 \text{ kip})}$$

$$Ratio = 0.0029841$$

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:** $M_{max} = 56.381 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(56.381 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.22588$$	Status: **PASS** Ratio: **0.230**
	Considering z-direction: $M_{max} = 1.1137 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(1.1137 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.0044619$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

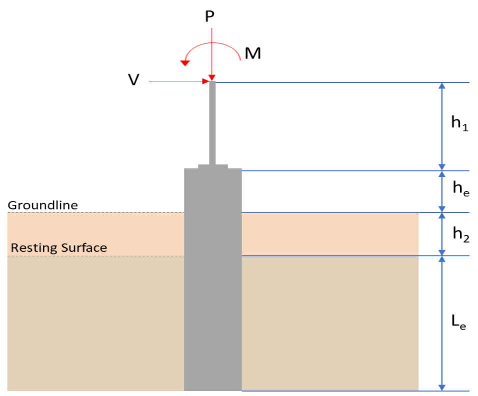
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48 \text{ in}$ - Pile width
$D = 48 \text{ in}$ - Pile depth
$L = 7.75 \text{ ft}$ - 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)	7.728	11.217
V_x (kip)	-4.184	-6.988
V_z (kip)	-0.240	-0.389
M_x (kipft)	-0.718	-1.138
M_z (kipft)	50.985	85.419

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,

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

$$H_o = \frac{(-4.184 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.66624 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(50.985 \text{ kipft}) + ((-4.184 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 8.1186 \text{ kipft/ft}$$

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:
$L_{e,x} = 7.1404 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.24 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.038217 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.718 \text{ kipft}) + ((-0.24 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.11433 \text{ kipft/ft}$$

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:
$L_{e,z} = 1.7301 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.1404 \text{ ft}), (1.7301 \text{ ft})]$$

$$L_{e,req} = 7.14 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7.75 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 7.75 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.14 \text{ ft})}{(7.75 \text{ ft})}$$

$$Ratio = 0.92129$$

Status: **PASS**
Ratio: **0.920**

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(7.728 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.483 \text{ kip/ft}^2$$

$$q = 0.483\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.483\ \mathrm{kip/ft^2}\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.2415$$

Status: **PASS**
Ratio: **0.240**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7.75\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1.9375$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.66624\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 8.1186\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.1186\ \mathrm{kipft/ft}) \times (7.75\ \mathrm{ft})) + \left(3 \times (-0.66624\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft})^2\right)}{(6 \times (8.1186\ \mathrm{kipft/ft})) + (4 \times (-0.66624\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))}$$

$$a = 5.359\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (8.1186\ \mathrm{kipft/ft})) + (3 \times (-0.66624\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]^{\ 2}}{(7.75\ \mathrm{ft})^2 \times [(3 \times (8.1186\ \mathrm{kipft/ft})) + (2 \times (-0.66624\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]}$$

$$p = 0.25676\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (8.1186\ \mathrm{kipft/ft})) + ((-0.66624\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]}{(7.75\ \mathrm{ft})^2}$$

$$s = 1.1062\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.359\ \mathrm{ft})}{2}$$

$$p_a = 0.40192\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.25676\ \mathrm{kip/ft^2}\right)}{\left(0.40192\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.63883$$

Status: **PASS**
Ratio: **0.640**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.75\ \mathrm{ft})$$

$$p_s = 1.1625\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.1062\ \mathrm{kip/ft^2}\right)}{\left(1.1625\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.9516$$

Status: **PASS**
Ratio: **0.950**

Considering z-direction:

$H_o = -0.038217\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.11433\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.11433\ \mathrm{kipft/ft}) \times (7.75\ \mathrm{ft})) + \left(3 \times (-0.038217\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft})^2\right)}{(6 \times (0.11433\ \mathrm{kipft/ft})) + (4 \times (-0.038217\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))}$$

$$a = 5.5757\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.11433\ \mathrm{kipft/ft})) + (3 \times (-0.038217\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]^{\ 2}}{(7.75\ \mathrm{ft})^2 \times [(3 \times (0.11433\ \mathrm{kipft/ft})) + (2 \times (-0.038217\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]}$$

$$p = -0.0093112\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.11433\ \mathrm{kipft/ft})) + ((-0.038217\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]}{(7.75\ \mathrm{ft})^2}$$

$$s = -0.0067446\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.5757\ \mathrm{ft})}{2}$$

$$p_a = 0.41818\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.0093112\ \mathrm{kip/ft^2}\right)}{\left(0.41818\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.022266$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.75\ \mathrm{ft})$$

$$p_s = 1.1625\ \mathrm{kip/ft^2}$$

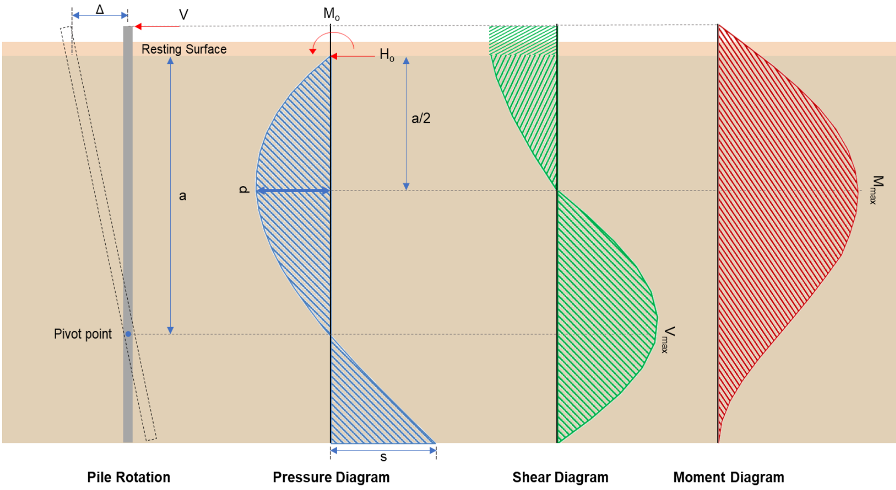
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.0067446\ \mathrm{kip/ft^2}\right)}{\left(1.1625\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.0058018$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-6.988\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -1.1127\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(85.419\ \mathrm{kipft}) + ((-6.988\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 13.602\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(13.602\ \mathrm{kipft/ft})}{(-1.1127\ \mathrm{kip/ft})}$$

$$E = 12.224\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (13.602\ \mathrm{kipft/ft}) \times (7.75\ \mathrm{ft})) + \left(3 \times (-1.1127\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft})^2\right)}{(6 \times (13.602\ \mathrm{kipft/ft})) + (4 \times (-1.1127\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))}$$

$$a = 5.3585\ \mathrm{ft}$$

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

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

$$V_{max} = ((-1.1127\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.224\ \mathrm{ft})}{(7.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.3585\ \mathrm{ft})}{(7.75\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (12.224\ \mathrm{ft})}{(7.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.3585\ \mathrm{ft})}{(7.75\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 15.357\ \mathrm{kip}$$

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

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

$$M_{max} = ((-1.1127\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (7.75\ \mathrm{ft})) \times \left[\left(\frac{(12.224\ \mathrm{ft})}{(7.75\ \mathrm{ft})} + \frac{(5.3585\ \mathrm{ft})}{2 \times (7.75\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (12.224\ \mathrm{ft})}{(7.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.3585\ \mathrm{ft})}{2 \times (7.75\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (12.224\ \mathrm{ft})}{(7.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.3585\ \mathrm{ft})}{2 \times (7.75\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 56.381\ \mathrm{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.389\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.061943\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.138\ \mathrm{kipft}) + ((-0.389\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.18121\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.18121\ \mathrm{kipft/ft})}{(-0.061943\ \mathrm{kip/ft})}$$

$$E = 2.9254\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.18121\ \mathrm{kipft/ft}) \times (7.75\ \mathrm{ft})) + \left(3 \times (-0.061943\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft})^2\right)}{(6 \times (0.18121\ \mathrm{kipft/ft})) + (4 \times (-0.061943\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))}$$

$$a = 5.579\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.061943\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.9254\ \mathrm{ft})}{(7.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.579\ \mathrm{ft})}{(7.75\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (2.9254\ \mathrm{ft})}{(7.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.579\ \mathrm{ft})}{(7.75\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.3313\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.061943\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (7.75\ \mathrm{ft})) \times \left[\left(\frac{(2.9254\ \mathrm{ft})}{(7.75\ \mathrm{ft})} + \frac{(5.579\ \mathrm{ft})}{2 \times (7.75\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (2.9254\ \mathrm{ft})}{(7.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.579\ \mathrm{ft})}{2 \times (7.75\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (2.9254\ \mathrm{ft})}{(7.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.579\ \mathrm{ft})}{2 \times (7.75\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 1.1131 \text{ kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(11.217 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.223 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.223 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

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,

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

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

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

Ties:

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

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

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

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

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

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(11.217\ \mathrm{kip})}{(2675.2\ \mathrm{kip})}$$

$$Ratio = 0.004193$$

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 $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$, $P = 11.217\ \mathrm{kip} \rightarrow 11217\ \mathrm{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \mathrm{psi})} + \frac{(11217\ \mathrm{lbf})}{6 \times (2304\ \mathrm{in}^2)}\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$

$$V_{c,a} = 119.98\ \mathrm{kip}$$

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

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

$$V_c = Min\left[(296.21\ \mathrm{kip}), (119.98\ \mathrm{kip}), (348.89\ \mathrm{kip})\right]$$

$$V_c = 119.98\ \mathrm{kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.98\ \mathrm{kip}) + (50.894\ \mathrm{kip}))$$

$$\phi V_n = 111.07\ \mathrm{kip}$$

Considering x-direction:

$V_{max} = 15.357\ \mathrm{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(15.357\ \mathrm{kip})}{(111.07\ \mathrm{kip})}$$

$$Ratio = 0.13827$$

Status: **PASS**
Ratio: **0.140**

Considering z-direction:

$V_{max} = 0.3313\ \mathrm{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.3313\ \mathrm{kip})}{(111.07\ \mathrm{kip})}$$

$$Ratio = 0.0029828$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

	$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$	
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:** $M_{max} = 56.381 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(56.381 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.22589$$	Status: **PASS** Ratio: **0.230**
	Considering z-direction: $M_{max} = 1.1131 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(1.1131 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.0044596$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

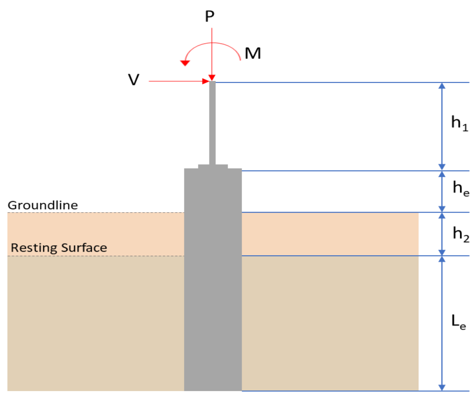
SkyCiv Foundation Design

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)	9.314	13.543
V_x (kip)	-5.010	-8.361
V_z (kip)	0.000	0.000
M_x (kipft)	0.000	0.000
M_z (kipft)	60.199	101.254

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,

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

$$H_o = \frac{(-5.01\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.79777\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(60.199 \text{ kipft}) + ((-5.01 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 9.5858 \text{ kipft/ft}$$

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:
$L_{e,x} = 7.4349 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

$L_{e,z} = 0 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.4349 \text{ ft}), (0 \text{ ft})]$$

$$L_{e,req} = 7.435 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.435 \text{ ft})}{(8 \text{ ft})}$$

$$Ratio = 0.92937$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\,D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(9.314 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.58213 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.58213 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.29106$$

Status: **PASS**
Ratio: **0.290**

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:

$H_o = -0.79777\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 9.5858\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (9.5858\ \mathrm{kipft/ft}) \times (8\ \mathrm{ft})) + \left(3 \times (-0.79777\ \mathrm{kip/ft}) \times (8\ \mathrm{ft})^2\right)}{(6 \times (9.5858\ \mathrm{kipft/ft})) + (4 \times (-0.79777\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))}$$

$$a = 5.5383\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (9.5858\ \mathrm{kipft/ft})) + (3 \times (-0.79777\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]^{\ 2}}{(8\ \mathrm{ft})^2 \times [(3 \times (9.5858\ \mathrm{kipft/ft})) + (2 \times (-0.79777\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]}$$

$$p = 0.27003\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (9.5858\ \mathrm{kipft/ft})) + ((-0.79777\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]}{(8\ \mathrm{ft})^2}$$

$$s = 1.199\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.5383\ \mathrm{ft})}{2}$$

$$p_a = 0.41537\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.27003\ \mathrm{kip/ft^2}\right)}{\left(0.41537\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.65008$$

Status: **PASS**
Ratio: **0.650**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

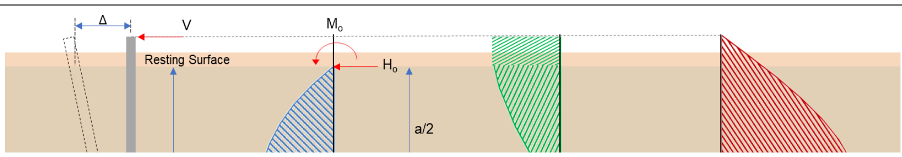
$Ratio$ - Lateral soil capacity

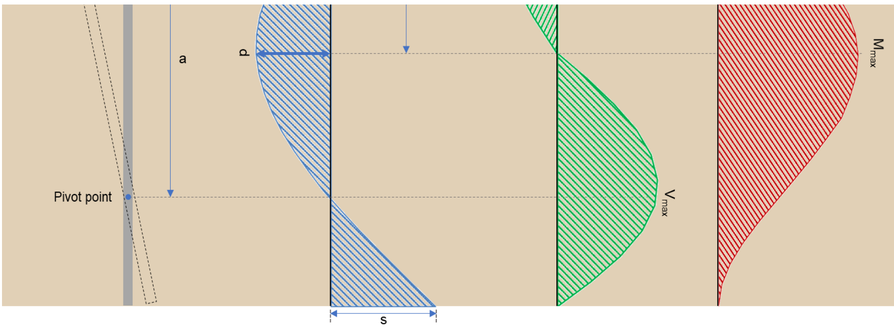
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{\left(1.199\ \mathrm{kip/ft^2}\right)}{\left(1.2\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.99918$$

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





Pile Rotation **Pressure Diagram** **Shear Diagram** **Moment Diagram**

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-8.361\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -1.3314\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(101.25\ \text{kipft}) + ((-8.361\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 16.123\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(16.123\ \text{kipft/ft})}{(-1.3314\ \text{kip/ft})}$$

$$E = 12.11\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (16.123\ \text{kipft/ft}) \times (8\ \text{ft})) + \left(3 \times (-1.3314\ \text{kip/ft}) \times (8\ \text{ft})^2\right)}{(6 \times (16.123\ \text{kipft/ft})) + (4 \times (-1.3314\ \text{kip/ft}) \times (8\ \text{ft}))}$$

$$a = 5.5372\ \text{ft}$$

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

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

$$V_{max} = ((-1.3314\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.11\ \text{ft})}{(8\ \text{ft})} + 3\right) \times \left(\frac{(5.5372\ \text{ft})}{(8\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (12.11\ \text{ft})}{(8\ \text{ft})} + 2\right) \times \left(\frac{(5.5372\ \text{ft})}{(8\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 17.776\ \text{kip}$$

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

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

$$M_{max} = ((-1.3314\ \text{kip/ft}) \times (48\ \text{in}) \times (8\ \text{ft})) \times \left[\left(\frac{(12.11\ \text{ft})}{(8\ \text{ft})} + \frac{(5.5372\ \text{ft})}{2 \times (8\ \text{ft})}\right) - \left[\left(\frac{4 \times (12.11\ \text{ft})}{(8\ \text{ft})} + 3\right) \times \left(\frac{(5.5372\ \text{ft})}{2 \times (8\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (12.11\ \text{ft})}{(8\ \text{ft})} + 2\right) \times \left(\frac{(5.5372\ \text{ft})}{2 \times (8\ \text{ft})}\right)^4\right]\right]$$

	$M_{max} = 67.245\ \mathrm{kipft}$		

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(13.543\ \mathrm{kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5\ \mathrm{ksi}) \times \left(2304\ \mathrm{in}^2\right)\right)}{(60\ \mathrm{ksi}) - (0.85 \times (2.5\ \mathrm{ksi}))}, \left(0.08 \times \left(2304\ \mathrm{in}^2\right)\right)\right]$$

$$A_{st,required} = -84.146\ \mathrm{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.146\ \mathrm{in}^2\right), \left(0.0018 \times \left(2304\ \mathrm{in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

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,

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

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

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

Summary:

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

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

22.4.2.2	**Axial Compression Strength (ACI 318-19, LRFD)** 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 $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(13.543\ \text{kip})}{(2675.2\ \text{kip})}$$ $$Ratio = 0.0050625$$	Status: **PASS** Ratio: **0.010**

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 $f'_{ck} = 2.5\ \text{ksi} \to 2500\ \text{psi}$,

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 $f'_{ck} = 2.5\ \text{ksi} \to 2500\ \text{psi}$, $P = 13.543\ \text{kip} \to 13543\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(13543\ \text{lbf})}{6 \times (2304\ \text{in}^2)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 120.29\ \text{kip}$$

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

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

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

$$V_c = Min\left[(296.21\ \text{kip}), (120.29\ \text{kip}), (348.89\ \text{kip})\right]$$

$$V_c = 120.29\ \text{kip}$$

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

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

$$\phi V_n = (0.65) \times ((120.29\ \text{kip}) + (50.894\ \text{kip}))$$

$$\phi V_n = 111.27\ \text{kip}$$

Considering x-direction:

$V_{max} = 17.776\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(17.776\ \text{kip})}{(111.27\ \text{kip})}$$

$$Ratio = 0.15976$$

Status: **PASS**
Ratio: **0.160**

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 $\phi M_{n,2}$

$$\phi M_{n,2} = \phi\, 0.85\, f'_c\, S_m$$

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

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

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

Therefore,
ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 67.245\ \mathrm{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(67.245\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$

$$Ratio = 0.26941$$

Status: **PASS**
Ratio: **0.270**