Your Project Calculations

Project Name: MTSOLAR_D8BDD67A25C8

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=MTSOLAR_D8BDD67A25C8&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/4_2023

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=U017UYYsqttiLfOZagv4fpwSPytN0pkIpaYy4gjdg22awCMZsiSyJuqVQzxHRIUx

Array Specification

Product:	Beam
Unique ID:	3P-19.75-8TOP-XD-57-L-3Hx8W-1H6F
Duty Classification:	XD
Module Width:	42.00 in
Module Length:	84.00in
Number of Rows:	3
Number of Columns:	8
Total Number of Modules:	24
Desired Tilt Angle:	45
Front Edge Clearance:	5
Total Array Height at Tilt:	12.47 ft
Total Frame Length:	56.50 ft
Frame Weight:	2924 lbs
Array Dimensions N/S:	10.63 ft
Array Dimensions E/W:	56.67 ft
Rail Length:	127.50 in
Rail Spacing:	3.50 ft
Rail Check:	Not Checked

Support Specifications

Pole Size:	8in Pipe Sch 40
Pole Length above Grade:	8.76 ft
Number of Poles:	3
Pole Spacing:	19.75 ft

Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 7.00 ft Pile 2: 7.00 ft Pile 3: 7.00 ft
Foundation Volume:	12.444 y^3
Foundation Result:	PASSED

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	8711 Emil Dr, Wasilla, AK 99654, USA
Wind Speed:	120 mph
Snow Load:	123.84 psf
Design Uplift Pressure:	Multiple pressures
Design Downforce Pressure:	Multiple pressures
Design Snow Pressure:	0.024073 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.

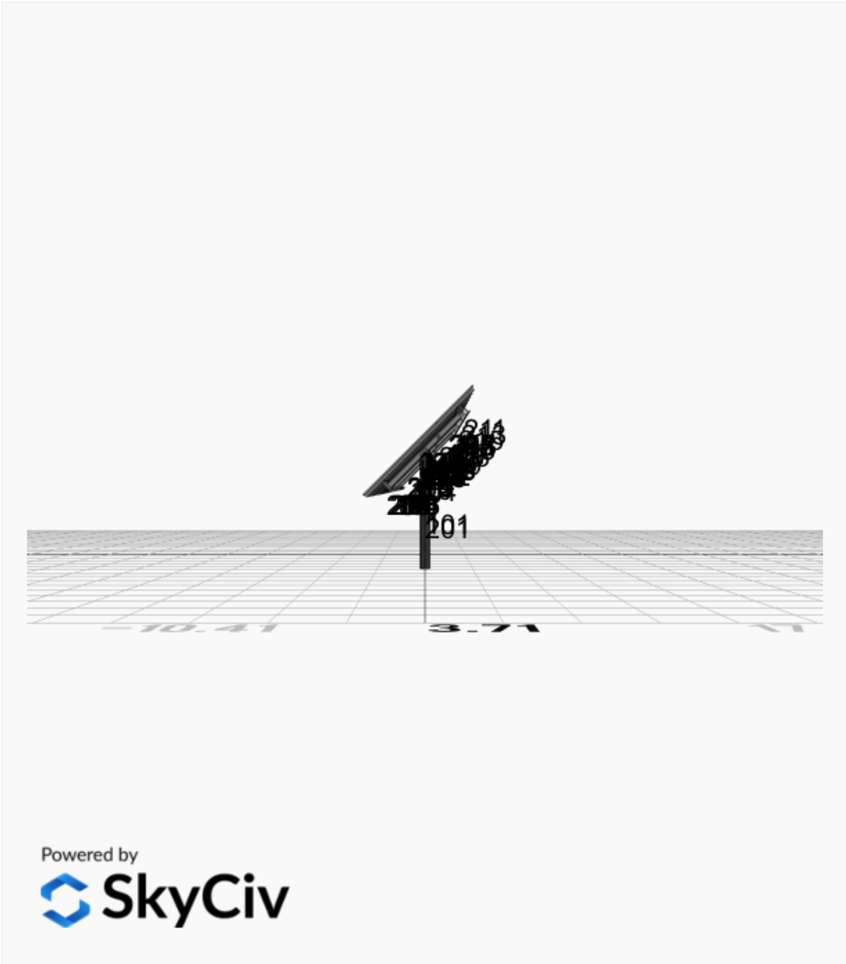
AutoDesigner Input

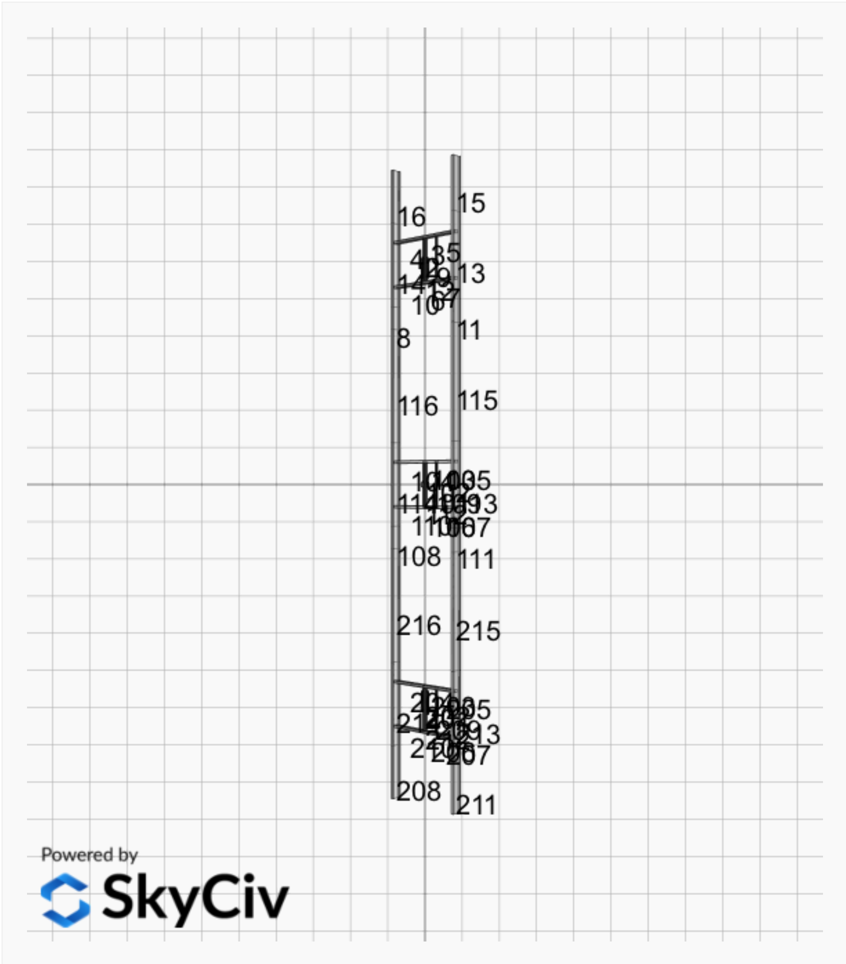

```
{"wind_speed_override":null,"snow_load_override":null,"direct_snow_load":false,"product_type":"Beam","project_id":"MTSOLAR_D8BDD67A25C8","site_address":"8711 Emil Dr, Wasilla, AK 99654, USA","module_width":42,"module_length":84,"number_rows":"3","number_columns":8,"pole_mount_section":"4_40","core_pipe_width":65,"core_pipe_section":"2_40","adjuster_section":"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":"XD","pole_override":"8_40","soil_type":"sand","foundation_type":"Square","foundation_size":48,"check_rails":false}
```

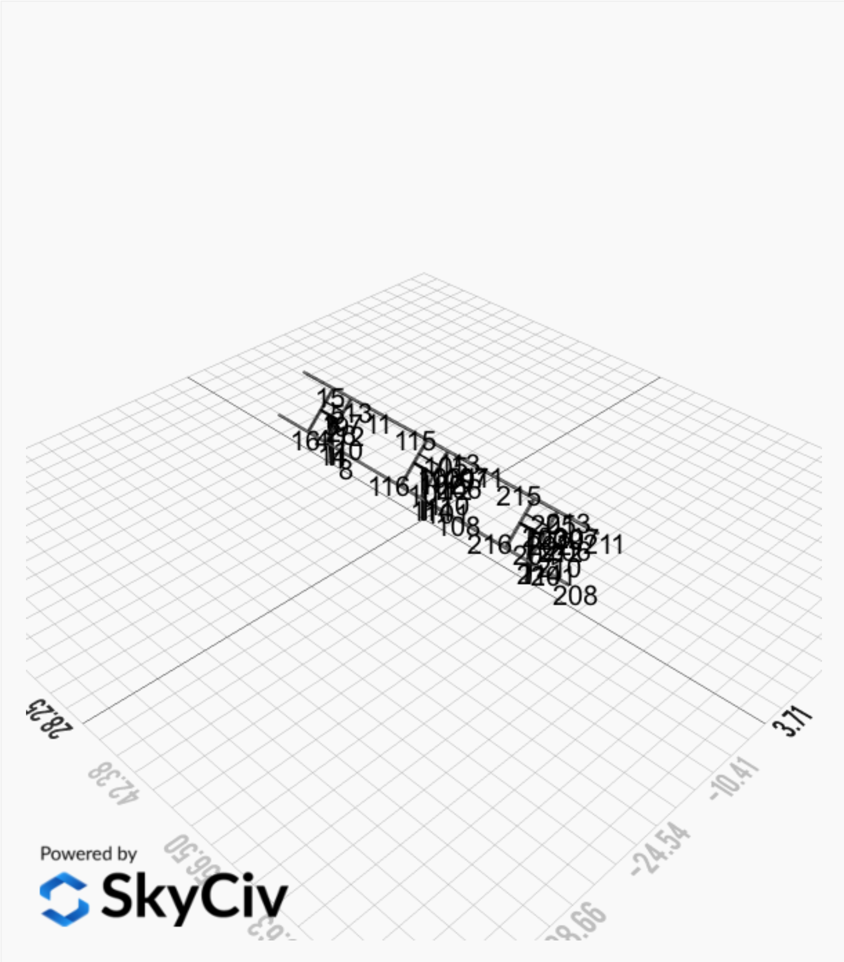

Design Notes:

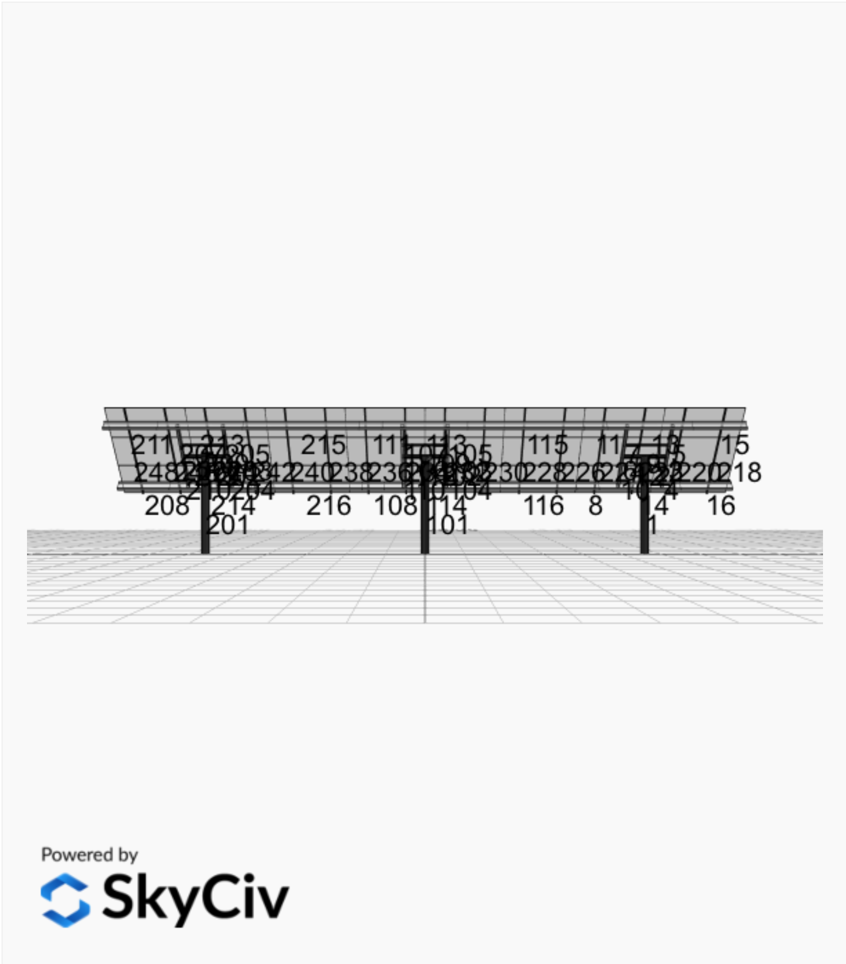
- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Design and Sizing is approximate only


211
215
115
15
208
216
108
116
8
16
201
101
Powered by
SkyCiv

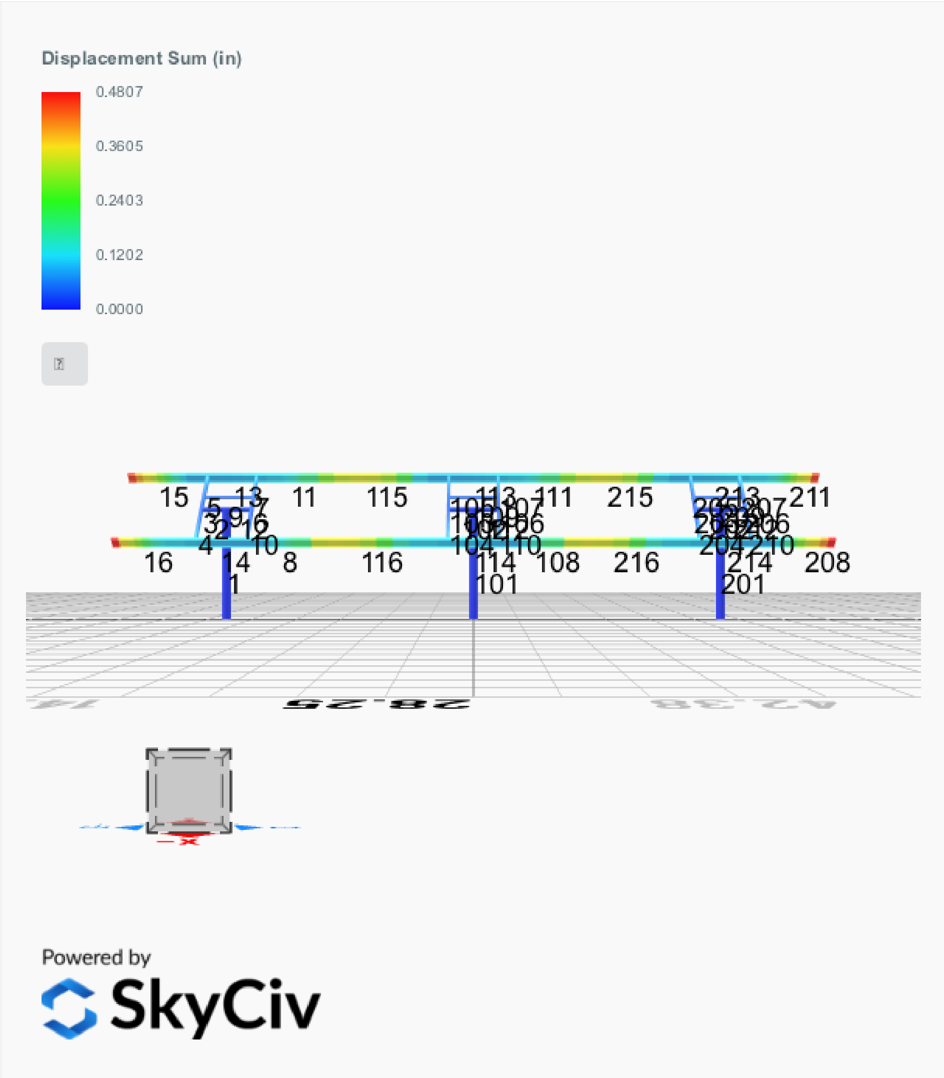

201
Powered by
SkyCiv

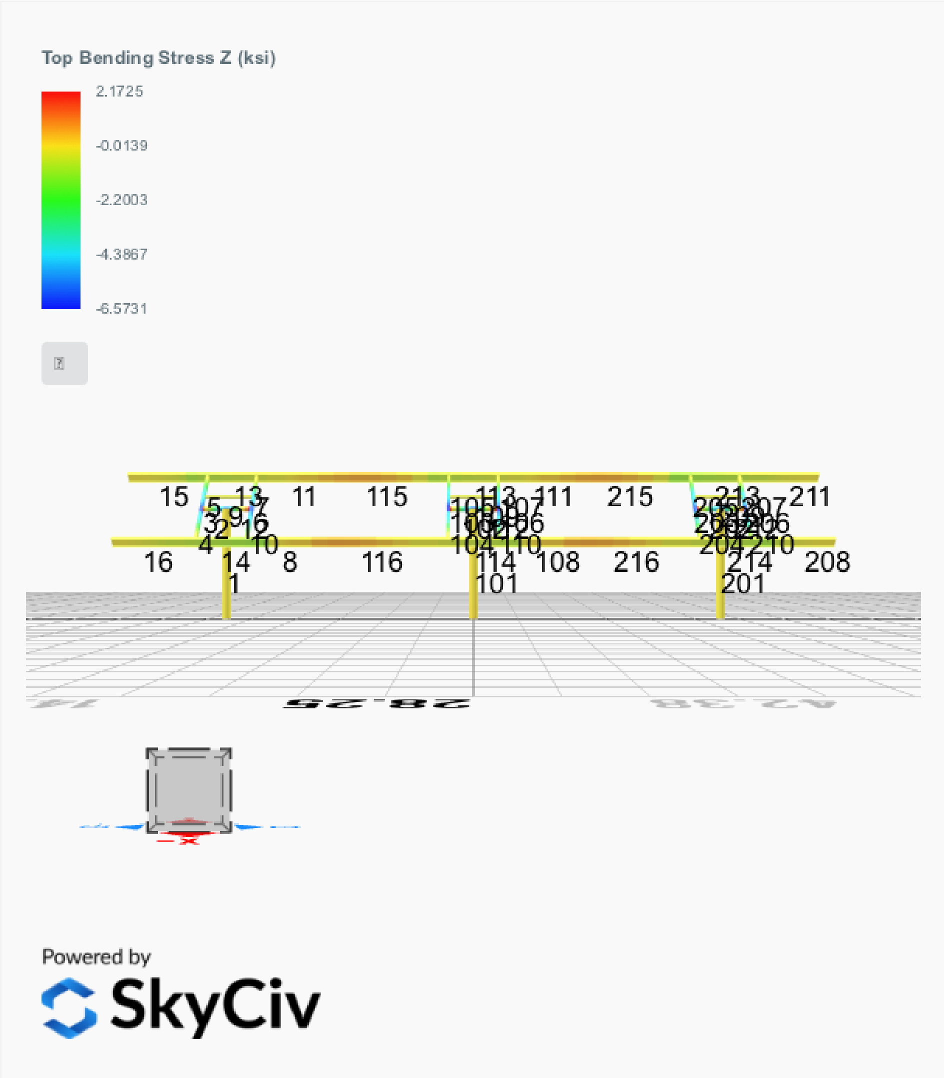

16
15
13
11
8
116
115
108
111
216
215
208
211
Powered by
SkyCiv

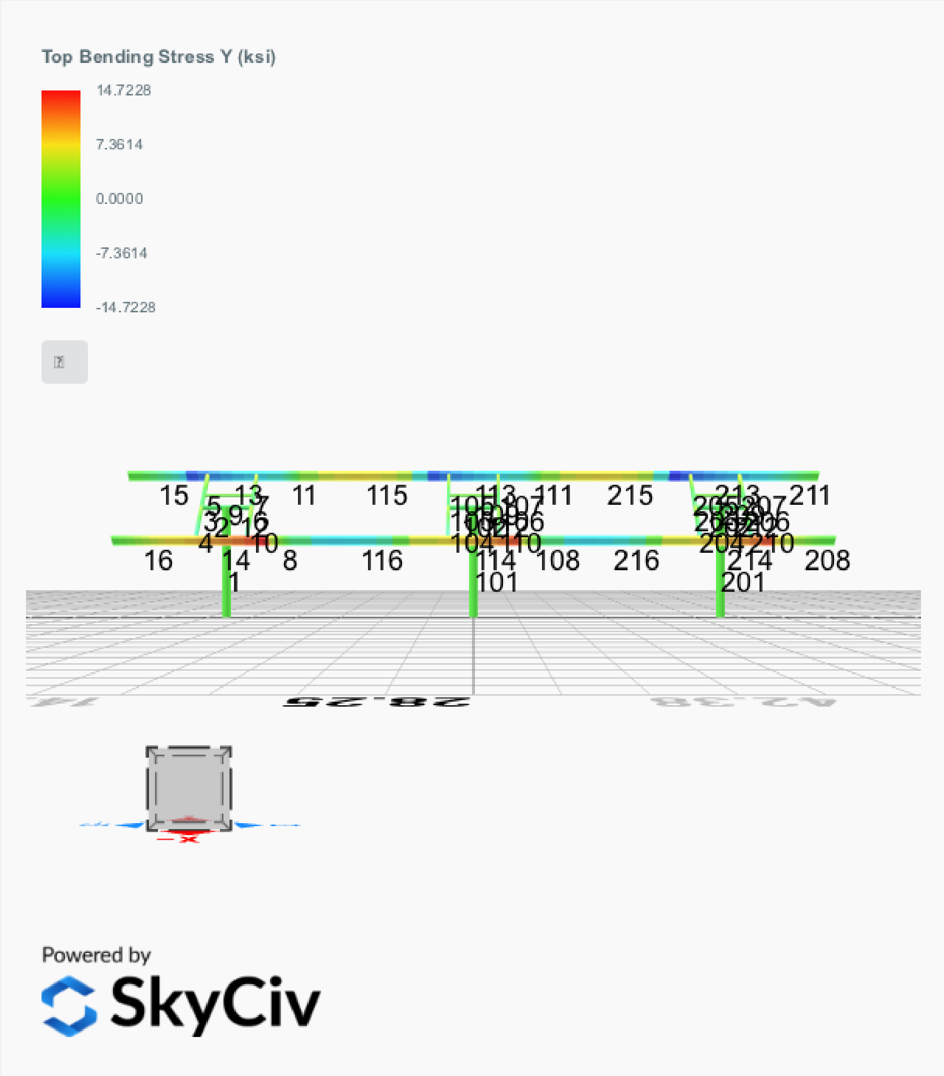


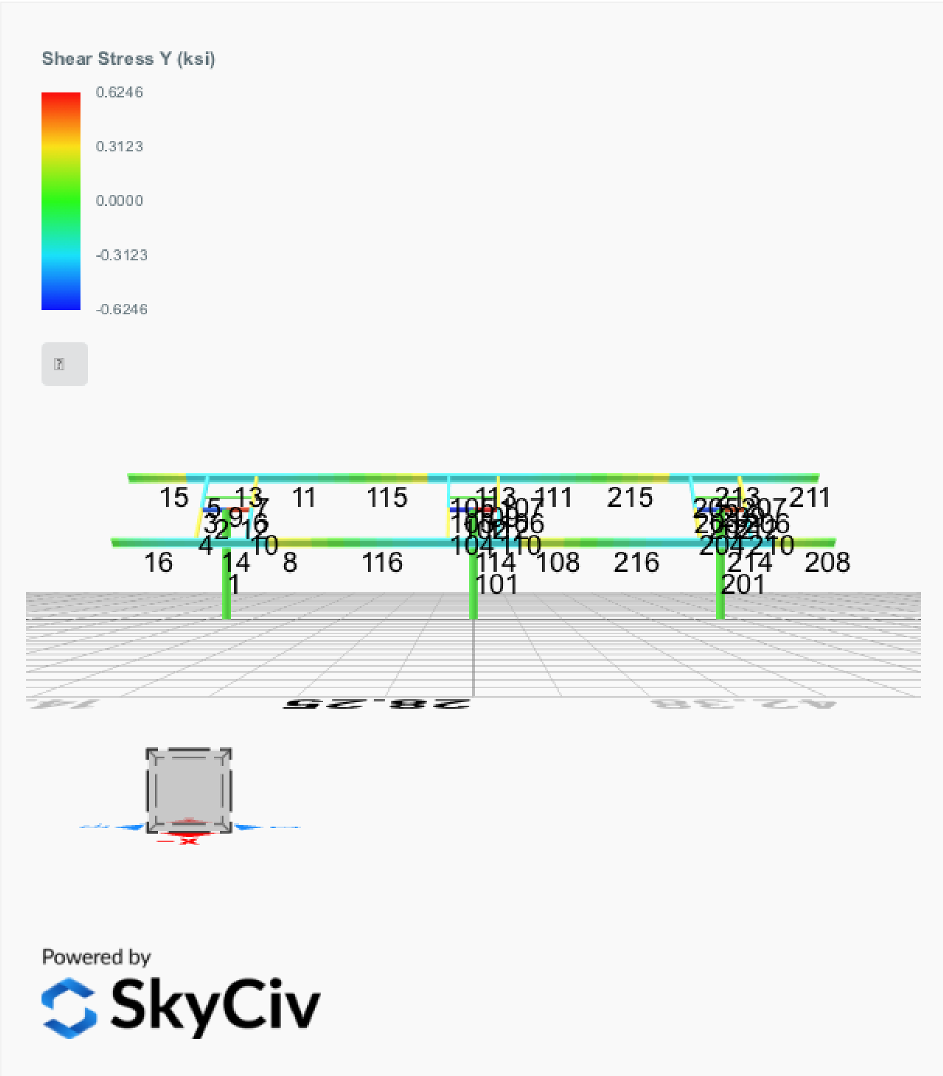

211
215
115
15
248
218
208
216
108
116
8
16
201
101
Powered by
SkyCiv

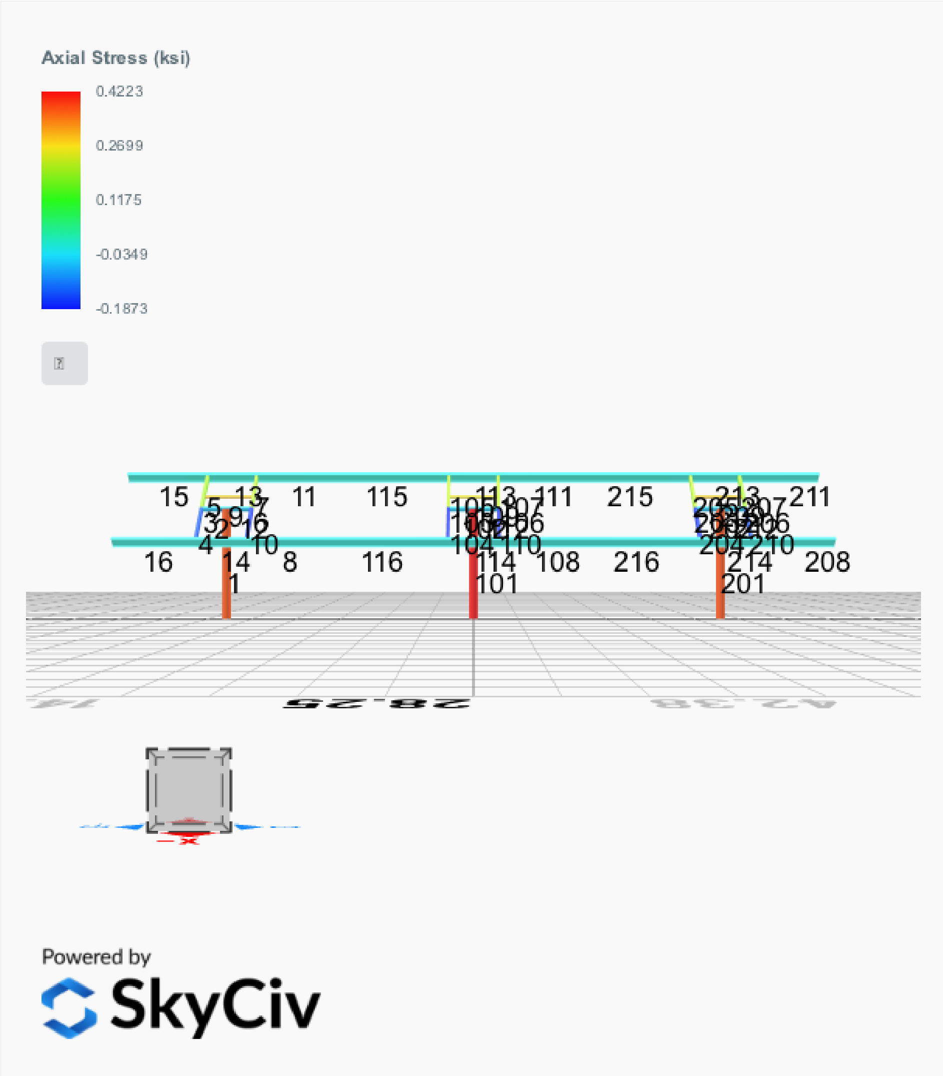
FEM Results (Envelope Worst Case for each member)




Top Bending Stress Z (ksi)
2.1725
-0.0139
-2.2003
-4.3867
-6.5731
Powered by
SkyCiv


Top Bending Stress Y (ksi)
14.7228
7.3614
0.0000
-7.3614
-14.7228
15
13
11
115
111
215
211
16
14
8
116
108
216
208
101
201
Powered by
SkyCiv


Shear Stress Y (ksi)
0.6246
0.3123
0.0000
-0.3123
-0.6246
Powered by
SkyCiv


Axial Stress (ksi)
0.4223
0.2699
0.1175
-0.0349
-0.1873
Powered by
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	-0.0050	1.9083	0.0014	0.0059	0.0304	0.0633
ULS: 2. D + L	-0.0050	1.9083	0.0014	0.0059	0.0304	0.0633
ULS: 3. D + (S or Lr or R)	-0.0169	5.2443	0.0052	0.0213	0.1024	0.1676
ULS: 3. D + (S or Lr or R)	-0.0050	1.9083	0.0014	0.0059	0.0304	0.0633
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0139	4.4103	0.0042	0.0175	0.0844	0.1415
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0050	1.9083	0.0014	0.0059	0.0304	0.0633
ULS: 5b. D + 0.7E	-0.0050	1.9083	0.0014	0.0059	0.0304	0.0633
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0139	4.4103	0.0042	0.0175	0.0844	0.1415
ULS: 8. 0.6D + 0.7E	-0.0030	1.1450	0.0008	0.0035	0.0182	0.0380
ULS: 5a. D + 0.6W_Wind downforce Case A only	-4.4300	6.3278	0.0012	0.0051	0.0262	40.9001
ULS: 5a. D + 0.6W_Wind downforce Case B only	-4.4300	6.3278	0.0012	0.0051	0.0262	40.9001
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.1945	-1.2877	0.0028	0.0090	0.0286	-26.7449
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.8225	-0.9147	-0.0010	0.0013	0.0426	-32.4233
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.3327	7.7249	0.0041	0.0169	0.0812	30.7692
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.3327	7.7249	0.0041	0.0169	0.0812	30.7692
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.3857	2.0133	0.0052	0.0198	0.0831	-19.9646
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.1067	2.2930	0.0025	0.0140	0.0936	-24.2234
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.3238	5.2229	0.0013	0.0053	0.0272	30.6909
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.3238	5.2229	0.0013	0.0053	0.0272	30.6909
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.3946	-0.4887	0.0024	0.0082	0.0291	-20.0429
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.1156	-0.2090	-0.0004	0.0024	0.0396	-24.3017
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-4.4280	5.5644	0.0007	0.0028	0.0140	40.8748
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-4.4280	5.5644	0.0007	0.0028	0.0140	40.8748
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.1965	-2.0510	0.0022	0.0067	0.0165	-26.7702
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.8245	-1.6780	-0.0015	-0.0011	0.0305	-32.4486

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
Axial	11.3240
Shear X	-7.3875
Shear Z	0.0086
Moment X	0.0343
Moment Z	68.7504

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
Axial	7.7249
Shear X	-4.4300
Shear Z	0.0052
Moment X	0.0213
Moment Z	40.9001

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	0.0101	1.9956	-0.0000	0.0000	0.0000	-0.0544
ULS: 2. D + L	0.0101	1.9956	-0.0000	0.0000	0.0000	-0.0544
ULS: 3. D + (S or Lr or R)	0.0338	5.5425	0.0000	0.0000	0.0000	-0.2274
ULS: 3. D + (S or Lr or R)	0.0101	1.9956	-0.0000	0.0000	0.0000	-0.0544
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0279	4.6558	0.0000	0.0000	0.0000	-0.1841
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0101	1.9956	-0.0000	0.0000	0.0000	-0.0544
ULS: 5b. D + 0.7E	0.0101	1.9956	-0.0000	0.0000	0.0000	-0.0544
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0279	4.6558	0.0000	0.0000	0.0000	-0.1841

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 8. 0.6D + 0.7E	0.0061	1.1974	-0.0000	0.0000	0.0000	-0.0326
ULS: 5a. D + 0.6W_Wind downforce Case A only	-4.5783	6.5951	-0.0000	0.0000	0.0000	42.1480
ULS: 5a. D + 0.6W_Wind downforce Case B only	-4.5783	6.5951	-0.0000	0.0000	0.0000	42.1480
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.3325	-1.3338	-0.0000	0.0000	0.0000	-27.7772
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.9327	-0.9360	-0.0000	0.0000	0.0000	-33.5321
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.4134	8.1054	0.0000	0.0000	0.0000	31.4677
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.4134	8.1054	0.0000	0.0000	0.0000	31.4677
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.5197	2.1587	0.0000	0.0000	0.0000	-20.9762
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.2199	2.4570	0.0000	0.0000	0.0000	-25.2924
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.4312	5.4453	-0.0000	0.0000	0.0000	31.5974
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.4312	5.4453	-0.0000	0.0000	0.0000	31.5974
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.5019	-0.5014	-0.0000	0.0000	0.0000	-20.8465
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.2021	-0.2031	-0.0000	0.0000	0.0000	-25.1627
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-4.5823	5.7969	-0.0000	0.0000	0.0000	42.1697
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-4.5823	5.7969	-0.0000	0.0000	0.0000	42.1697
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.3284	-2.1320	-0.0000	0.0000	0.0000	-27.7554
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.9287	-1.7343	-0.0000	0.0000	0.0000	-33.5103

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
Axial	11.9022
Shear X	-7.6473
Shear Z	-0.0000
Moment X	0.0001
Moment Z	70.7730

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
Axial	8.1054
Shear X	-4.5823
Shear Z	0.0000
Moment X	0.0000
Moment Z	42.1697

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	-0.0050	1.9083	-0.0014	-0.0059	-0.0304	0.0633
ULS: 2. D + L	-0.0050	1.9083	-0.0014	-0.0059	-0.0304	0.0633
ULS: 3. D + (S or Lr or R)	-0.0169	5.2443	-0.0052	-0.0213	-0.1024	0.1676
ULS: 3. D + (S or Lr or R)	-0.0050	1.9083	-0.0014	-0.0059	-0.0304	0.0633
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0139	4.4103	-0.0042	-0.0175	-0.0844	0.1416
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0050	1.9083	-0.0014	-0.0059	-0.0304	0.0633
ULS: 5b. D + 0.7E	-0.0050	1.9083	-0.0014	-0.0059	-0.0304	0.0633
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0139	4.4103	-0.0042	-0.0175	-0.0844	0.1416
ULS: 8. 0.6D + 0.7E	-0.0030	1.1450	-0.0008	-0.0035	-0.0182	0.0380
ULS: 5a. D + 0.6W_Wind downforce Case A only	-4.4300	6.3278	-0.0012	-0.0051	-0.0262	40.9001
ULS: 5a. D + 0.6W_Wind downforce Case B only	-4.4300	6.3278	-0.0012	-0.0051	-0.0262	40.9001
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.1945	-1.2877	-0.0028	-0.0090	-0.0286	-26.7449
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.8225	-0.9147	0.0010	-0.0013	-0.0426	-32.4233
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.3327	7.7249	-0.0041	-0.0169	-0.0812	30.7692
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.3327	7.7249	-0.0041	-0.0169	-0.0812	30.7692
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.3857	2.0133	-0.0052	-0.0198	-0.0831	-19.9646
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.1067	2.2930	-0.0025	-0.0140	-0.0936	-24.2234
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.3238	5.2229	-0.0013	-0.0053	-0.0272	30.6909
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.3238	5.2229	-0.0013	-0.0053	-0.0272	30.6909

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 uplift Case A only	2.3946	-0.4887	-0.0024	-0.0082	-0.0291	-20.0429
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.1156	-0.2090	0.0004	-0.0024	-0.0396	-24.3017
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-4.4280	5.5644	-0.0007	-0.0027	-0.0140	40.8748
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-4.4280	5.5644	-0.0007	-0.0027	-0.0140	40.8748
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.1965	-2.0510	-0.0022	-0.0067	-0.0165	-26.7702
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.8245	-1.6780	0.0015	0.0011	-0.0305	-32.4486

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
Axial	11.3240
Shear X	-7.3875
Shear Z	-0.0086
Moment X	-0.0342
Moment Z	68.7515

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
Axial	7.7249
Shear X	-4.4300
Shear Z	-0.0052
Moment X	-0.0213
Moment Z	40.9001

Project Details

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

Design Input Information

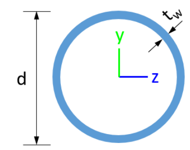
Design Factors

Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

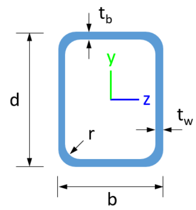
Design Materials

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

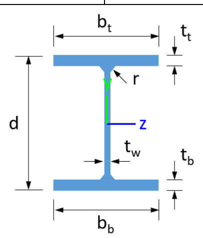
Section Dimensions



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					
9	8in Pipe Sch 40	8.63	0.32					



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
9	8in Pipe Sch 40	8.40	144.98	72.49	72.49	0.00	22.21	22.21

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	9	18.39	18.39	8.76	-	300	200	1
2	6	1.30	1.30	2.00	-	300	200	1
3	17	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.19,1.00,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
4	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.69,1.69,1.67,1.67,1.66,1.62,1.67,1.67,1.66,1.65,1.67,1.67,1.70,1.68,1.67,1.67,1.65,1.56,1.67,1.67,1.66,1.66	300	200	1
5	17	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.50,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66	300	200	1
6	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.10,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
7	17	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.58,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66	300	200	1
8	20	1.33	1.33	2.05	2.12,2.12,2.12,2.12,2.12,2.12,2.12,2.11,2.05,2.12,2.12,2.12,2.09,2.12,2.12,2.33,2.22,2.12,2.12,2.12,2.06,2.11,2.11,2.12,2.09	300	200	1
9	3	2.60	2.60	4.00	-	300	200	1
10	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.69,1.69,1.67,1.67,1.66,1.62,1.67,1.67,1.66,1.65,1.67,1.67,1.70,1.68,1.67,1.67,1.65,1.56,1.67,1.67,1.66,1.66	300	200	1
11	20	1.33	1.33	2.05	2.12,2.12,2.12,2.12,2.12,2.12,2.12,2.12,2.12,2.14,2.12,2.12,2.12,2.13,2.12,2.12,2.13,2.24,2.12,2.12,2.12,2.14,2.12,2.12,2.12,2.13	300	200	1
12	6	1.30	1.30	2.00	-	300	200	1
13	20	1.14	1.14	1.75	1.42,1.42,1.42,1.42,1.42,1.42,1.42,1.42,1.42,1.41,1.42,1.42,1.42,1.41,1.42,1.42,1.42,1.34,1.42,1.42,1.42,1.41,1.42,1.42,1.42,1.41	300	200	1
14	20	1.14	1.14	1.75	1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25	300	200	1
15	20	9.97	9.97	4.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
16	20	9.97	9.97	4.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
17	20	2.60	2.60	4.00	1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.14,1.13,1.13,1.13,1.13,1.13,1.13,1.14,1.02,1.13,1.13,1.13,1.14,1.13,1.13,1.13,1.13	300	200	1
18	20	1.14	1.14	1.75	1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25	300	200	1
19	20	2.60	2.60	4.00	1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.08,1.13,1.13,1.13,1.11,1.13,1.13,1.13,1.14,1.13,1.13,1.13,1.08,1.13,1.13,1.13,1.11	300	200	1
20	20	1.14	1.14	1.75	1.42,1.42,1.42,1.42,1.42,1.42,1.42,1.42,1.42,1.51,1.42,1.42,1.42,1.45,1.42,1.42,1.40,1.41,1.42,1.42,1.42,1.51,1.42,1.42,1.42,1.44	300	200	1
21	20	2.60	2.60	4.00	1.08,1.08,1.08,1.08,1.08,1.08,1.09,1.09,1.10,1.11,1.09,1.09,1.09,1.10,1.09,1.09,1.07,1.00,1.09,1.09,1.10,1.11,1.09,1.09,1.09,1.10	300	200	1
22	20	1.14	1.14	1.75	1.47,1.47,1.47,1.47,1.47,1.47,1.53,1.53,1.60,1.58,1.54,1.54,1.56,1.56,1.51,1.51,1.35,1.00,1.53,1.53,1.60,1.58,1.54,1.54,1.56,1.56	300	200	1
23	20	2.60	2.60	4.00	1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.09,1.05,1.08,1.08,1.09,1.07,1.08,1.08,1.07,1.09,1.08,1.08,1.09,1.05,1.08,1.08,1.09,1.07	300	200	1

24	20	1.14	1.14	1.75	1.49,1.49,1.49,1.49,1.49,1.49,1.50,1.50,1.51,1.56,1.50,1.50,1.51,1.51,1.50,1.50,1.44,1.48,1.50,1.50,1.51,1.55,1.50,1.50,1.50,1.51	300	200	1
25	20	2.60	2.60	4.00	1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.14,1.02,1.13,1.13,1.13,1.14,1.13,1.13,1.13,1.13	300	200	1
26	20	1.14	1.14	1.75	1.42,1.42,1.42,1.42,1.42,1.42,1.42,1.42,1.41,1.42,1.42,1.42,1.41,1.42,1.42,1.42,1.33,1.42,1.42,1.42,1.41,1.42,1.42,1.42,1.41	300	200	1
27	20	2.60	2.60	4.00	1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.08,1.13,1.13,1.13,1.11,1.13,1.13,1.13,1.14,1.13,1.13,1.13,1.08,1.13,1.13,1.13,1.11	300	200	1
28	20	1.14	1.14	1.75	1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25	300	200	1
101	9	18.39	18.39	8.76	-	300	200	1
102	6	1.30	1.30	2.00	-	300	200	1
103	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
104	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.69,1.69,1.67,1.67,1.66,1.62,1.67,1.67,1.66,1.65,1.67,1.67,1.70,1.68,1.67,1.67,1.65,1.57,1.67,1.67,1.66,1.66	300	200	1
105	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.38,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66	300	200	1
106	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
107	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.38,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66	300	200	1
108	20	1.33	1.33	2.05	2.06,2.06,2.06,2.06,2.06,2.06,2.06,2.06,2.05,1.86,2.06,2.06,2.06,2.05,2.06,2.06,2.09,2.07,2.06,2.06,2.05,1.89,2.06,2.06,2.06,2.05	300	200	1
109	3	2.60	2.60	4.00	-	300	200	1
110	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.69,1.69,1.67,1.67,1.66,1.62,1.67,1.67,1.66,1.65,1.67,1.67,1.70,1.68,1.67,1.67,1.65,1.57,1.67,1.67,1.66,1.66	300	200	1
111	20	1.33	1.33	2.05	2.07,2.07,2.07,2.08,2.07,2.07,1.95,1.95,1.75,1.79,1.92,1.92,1.84,1.85,2.05,2.05,2.25,1.02,1.96,1.96,1.75,1.80,1.92,1.92,1.86,1.86	300	200	1
112	6	1.30	1.30	2.00	-	300	200	1
113	20	1.14	1.14	1.75	1.47,1.47,1.47,1.47,1.47,1.47,1.53,1.53,1.60,1.58,1.54,1.54,1.56,1.56,1.51,1.51,1.35,1.00,1.53,1.53,1.60,1.58,1.54,1.54,1.56,1.56	300	200	1
114	20	1.14	1.14	1.75	1.49,1.49,1.49,1.49,1.49,1.49,1.50,1.50,1.51,1.56,1.50,1.50,1.51,1.51,1.50,1.50,1.44,1.48,1.50,1.50,1.51,1.55,1.50,1.50,1.50,1.51	300	200	1
115	20	6.63	6.63	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.13,1.13,1.12,1.12,1.13,1.13,1.13,1.13,1.14,1.14,1.22,1.30,1.13,1.13,1.12,1.12,1.13,1.13,1.13,1.13	300	200	1
116	20	6.63	6.63	10.20	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.13,1.14,1.14,1.14,1.14,1.14,1.14,1.16,1.14,1.14,1.14,1.14,1.13,1.14,1.14,1.14,1.14	300	200	1
201	9	18.39	18.39	8.76	-	300	200	1
202	6	1.30	1.30	2.00	-	300	200	1
203	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.10,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
204	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.69,1.69,1.67,1.67,1.66,1.62,1.67,1.67,1.66,1.65,1.67,1.67,1.70,1.68,1.67,1.67,1.65,1.56,1.67,1.67,1.66,1.66	300	200	1
205	17	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.58,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66	300	200	1

206	17	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.19,1.00,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
207	17	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.50,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66	300	200	1
208	20	9.97	9.97	4.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
209	3	2.60	2.60	4.00	-	300	200	1
210	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.69,1.69,1.67,1.67,1.66,1.62,1.67,1.67,1.66,1.65,1.67,1.67,1.70,1.68,1.67,1.67,1.65,1.56,1.67,1.67,1.66,1.66	300	200	1
211	20	9.97	9.97	4.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
212	6	1.30	1.30	2.00	-	300	200	1
213	20	1.14	1.14	1.75	1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25	300	200	1
214	20	1.14	1.14	1.75	1.42,1.42,1.42,1.42,1.42,1.42,1.42,1.42,1.42,1.52,1.42,1.42,1.42,1.45,1.42,1.42,1.40,1.41,1.42,1.42,1.42,1.51,1.42,1.42,1.42,1.45	300	200	1
215	20	6.63	6.63	10.20	1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.18,1.17,1.17,1.17,1.18,1.17,1.17,1.16,1.58,1.17,1.17,1.18,1.18,1.17,1.17,1.17,1.18	300	200	1
216	20	6.63	6.63	10.20	1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.14,1.17,1.17,1.17,1.16,1.17,1.17,1.18,1.18,1.17,1.17,1.17,1.14,1.17,1.17,1.17,1.16	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	377.97	250.21	83.29	83.29	113.39	113.39
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	143.45	46.90	6.46	56.26	44.91
14	159.30	143.45	46.90	6.46	56.26	44.91
15	159.30	34.37	46.90	6.46	56.26	44.91
16	159.30	34.37	46.90	6.46	56.26	44.91
17	159.30	132.71	43.77	6.46	56.26	44.91
18	159.30	143.45	46.90	6.46	56.26	44.91
19	159.30	132.71	46.35	6.46	56.26	44.91
20	159.30	143.45	46.90	6.46	56.26	44.91
21	159.30	132.71	42.91	6.46	56.26	44.91
22	159.30	143.45	46.90	6.46	56.26	44.91
23	159.30	132.71	45.06	6.46	56.26	44.91
24	159.30	143.45	46.90	6.46	56.26	44.91
25	159.30	132.71	43.77	6.46	56.26	44.91
26	159.30	143.45	46.90	6.46	56.26	44.91
27	159.30	132.71	46.35	6.46	56.26	44.91

28	159.30	143.45	46.90	6.46	56.26	44.91
101	377.97	250.21	83.29	83.29	113.39	113.39
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	143.45	46.90	6.46	56.26	44.91
114	159.30	143.45	46.90	6.46	56.26	44.91
115	159.30	75.13	21.57	6.46	56.26	44.91
116	159.30	75.13	21.76	6.46	56.26	44.91
201	377.97	250.21	83.29	83.29	113.39	113.39
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	34.37	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	34.37	46.90	6.46	56.26	44.91
212	251.01	248.88	27.16	27.16	75.30	75.30
213	159.30	143.45	46.90	6.46	56.26	44.91
214	159.30	143.45	46.90	6.46	56.26	44.91
215	159.30	75.13	22.34	6.46	56.26	44.91
216	159.30	75.13	21.96	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	0.045	0.825	0.000	0.065	0.000	0.848	#13	0.376	Not Required	Pass
2	0.003	0.337	0.260	0.073	0.049	0.597	#13	0.036	Not Required	Pass
3	0.008	0.633	0.045	0.063	0.004	0.658	#13	0.046	Not Required	Pass
4	0.008	0.569	0.152	0.057	0.032	0.616	#13	0.082	Not Required	Pass
5	0.008	0.392	0.157	0.063	0.040	0.410	#13	0.076	Not Required	Pass
6	0.009	0.635	0.052	0.063	0.005	0.663	#13	0.046	Not Required	Pass
7	0.009	0.394	0.159	0.063	0.042	0.415	#13	0.076	Not Required	Pass
8	0.000	0.039	0.161	0.037	0.018	0.188	#21	0.102	Not Required	Pass
9	0.016	0.046	0.050	0.001	0.000	0.097	#13	0.206	Not Required	Pass
10	0.009	0.566	0.154	0.056	0.034	0.618	#13	0.082	Not Required	Pass
11	0.000	0.043	0.164	0.041	0.018	0.193	#21	0.102	Not Required	Pass
12	0.003	0.338	0.257	0.074	0.049	0.596	#13	0.036	Not Required	Pass
13	0.000	0.139	0.419	0.052	0.024	0.524	#21	0.087	Not Required	Pass
14	0.000	0.147	0.439	0.038	0.019	0.559	#21	Not Required	Not Required	Pass
15	0.000	0.087	0.234	0.031	0.014	0.303	#21	Not Required	Not Required	Pass
16	0.000	0.078	0.234	0.028	0.014	0.298	#21	Not Required	Not Required	Pass

17	0.007	0.176	0.095	0.018	0.007	0.236	#21	0.133	Not Required	Pass
18	0.000	0.163	0.439	0.042	0.019	0.567	#21	Not Required	Not Required	Pass
19	0.007	0.161	0.106	0.016	0.007	0.240	#21	0.199	Not Required	Pass
20	0.000	0.124	0.416	0.047	0.024	0.513	#21	0.087	Not Required	Pass
21	0.007	0.127	0.081	0.013	0.006	0.187	#21	0.133	Not Required	Pass
22	0.000	0.111	0.417	0.049	0.024	0.508	#21	0.087	Not Required	Pass
23	0.007	0.123	0.089	0.012	0.006	0.193	#21	0.199	Not Required	Pass
24	0.000	0.105	0.415	0.045	0.024	0.501	#21	0.087	Not Required	Pass
25	0.007	0.176	0.095	0.018	0.007	0.236	#21	0.133	Not Required	Pass
26	0.000	0.139	0.419	0.052	0.024	0.524	#21	0.087	Not Required	Pass
27	0.007	0.161	0.106	0.016	0.007	0.240	#21	0.199	Not Required	Pass
28	0.000	0.147	0.439	0.038	0.019	0.559	#21	Not Required	Not Required	Pass
101	0.048	0.850	0.000	0.067	0.000	0.873	#13	0.376	Not Required	Pass
102	0.003	0.350	0.264	0.077	0.051	0.615	#13	0.036	Not Required	Pass
103	0.009	0.657	0.056	0.065	0.008	0.687	#13	0.046	Not Required	Pass
104	0.009	0.594	0.149	0.059	0.032	0.645	#13	0.082	Not Required	Pass
105	0.009	0.408	0.154	0.065	0.039	0.426	#13	0.076	Not Required	Pass
106	0.009	0.657	0.056	0.065	0.008	0.687	#13	0.046	Not Required	Pass
107	0.009	0.408	0.154	0.065	0.039	0.426	#13	0.076	Not Required	Pass
108	0.000	0.048	0.160	0.035	0.018	0.179	#21	0.102	Not Required	Pass
109	0.014	0.043	0.048	0.001	0.000	0.094	#13	0.206	Not Required	Pass
110	0.009	0.594	0.149	0.059	0.032	0.645	#13	0.082	Not Required	Pass
111	0.000	0.057	0.163	0.038	0.018	0.181	#21	0.102	Not Required	Pass
112	0.003	0.350	0.264	0.077	0.051	0.615	#13	0.036	Not Required	Pass
113	0.000	0.111	0.417	0.049	0.024	0.508	#21	0.087	Not Required	Pass
114	0.000	0.105	0.415	0.045	0.024	0.501	#21	0.087	Not Required	Pass
115	0.001	0.240	0.228	0.038	0.018	0.415	#21	0.507	Not Required	Pass
116	0.000	0.216	0.230	0.035	0.018	0.404	#21	0.507	Not Required	Pass
201	0.045	0.825	0.000	0.065	0.000	0.848	#13	0.376	Not Required	Pass
202	0.003	0.338	0.257	0.074	0.049	0.596	#13	0.036	Not Required	Pass
203	0.009	0.635	0.052	0.063	0.005	0.663	#13	0.046	Not Required	Pass
204	0.009	0.566	0.154	0.056	0.034	0.618	#13	0.082	Not Required	Pass
205	0.009	0.394	0.159	0.063	0.042	0.415	#13	0.076	Not Required	Pass
206	0.008	0.633	0.045	0.063	0.004	0.658	#13	0.046	Not Required	Pass
207	0.008	0.392	0.157	0.063	0.040	0.410	#13	0.076	Not Required	Pass
208	0.000	0.078	0.234	0.028	0.014	0.298	#21	Not Required	Not Required	Pass
209	0.016	0.046	0.050	0.001	0.000	0.097	#13	0.206	Not Required	Pass
210	0.008	0.569	0.152	0.057	0.032	0.616	#13	0.082	Not Required	Pass
211	0.000	0.087	0.234	0.031	0.014	0.303	#21	Not Required	Not Required	Pass
212	0.003	0.337	0.260	0.073	0.049	0.597	#13	0.036	Not Required	Pass
213	0.000	0.163	0.439	0.042	0.019	0.567	#21	Not Required	Not Required	Pass
214	0.000	0.124	0.416	0.047	0.024	0.513	#21	0.087	Not Required	Pass
215	0.001	0.238	0.228	0.041	0.018	0.412	#21	0.507	Not Required	Pass
216	0.000	0.211	0.230	0.037	0.018	0.401	#21	0.507	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

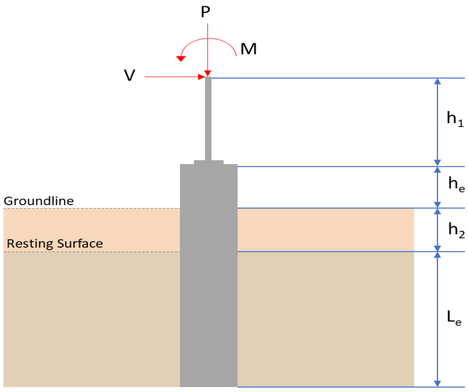
SkyCiv Foundation Design

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
$L = 7 \text{ ft}$ - 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)	7.725	11.324
V_x (kip)	-4.430	-7.387
V_z (kip)	0.005	0.009
M_x (kipft)	0.021	0.034
M_z (kipft)	40.900	68.750

Material Properties

$f'_{ck} = 3 \text{ ksi}$ - 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,

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

$$H_o = \frac{(-4.43 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.70541 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(40.9\ \text{kipft}) + ((-4.43\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 6.5127\ \text{kipft/ft}$$

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:
$L_{e,x} = 6.3267\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.005\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.00079618\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.021\ \text{kipft}) + ((0.005\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.0033439\ \text{kipft/ft}$$

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:
$L_{e,z} = 0.66892\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.3267\ \text{ft}), (0.66892\ \text{ft})]$$

$$L_{e,req} = 6.327\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 7\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.327\ \text{ft})}{(7\ \text{ft})}$$

$$Ratio = 0.90386$$

Status: **PASS**
Ratio: **0.900**

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

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

$$q = \frac{(7.725\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.48281\ \text{kip/ft}^2$$

$$q = 0.48281\ \text{kip/ft}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.48281\ \text{kip/ft}^2\right)}{(2000\ \text{psf})}$$

$$Ratio = 0.24141$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 1.75$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.70541\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 6.5127\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.5127\ \text{kipft/ft}) \times (7\ \text{ft})) + \left(3 \times (-0.70541\ \text{kip/ft}) \times (7\ \text{ft})^2\right)}{(6 \times (6.5127\ \text{kipft/ft})) + (4 \times (-0.70541\ \text{kip/ft}) \times (7\ \text{ft}))}$$

$$a = 4.8625\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (6.5127\ \text{kipft/ft})) + (3 \times (-0.70541\ \text{kip/ft}) \times (7\ \text{ft}))]^{\,2}}{(7\ \text{ft})^2 \times [(3 \times (6.5127\ \text{kipft/ft})) + (2 \times (-0.70541\ \text{kip/ft}) \times (7\ \text{ft}))]}$$

$$p = 0.20003\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (6.5127\ \text{kipft/ft})) + ((-0.70541\ \text{kip/ft}) \times (7\ \text{ft}))]}{(7\ \text{ft})^2}$$

$$s = 0.99032\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(4.8625\ \text{ft})}{2}$$

$$p_a = 0.36469\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.20003\ \text{kip/ft}^2\right)}{\left(0.36469\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.5485$$

Status: **PASS**
Ratio: **0.550**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7\ \mathrm{ft})$$

$$p_s = 1.05\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.99032\ \mathrm{kip/ft^2})}{(1.05\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.94316$$

Status: PASS
Ratio: 0.940

Considering z-direction:

$H_o = 0.00079618\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.0033439\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0033439\ \mathrm{kipft/ft}) \times (7\ \mathrm{ft})) + \left(3 \times (0.00079618\ \mathrm{kip/ft}) \times (7\ \mathrm{ft})^2\right)}{(6 \times (0.0033439\ \mathrm{kipft/ft})) + (4 \times (0.00079618\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))}$$

$$a = 4.9737\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.0033439\ \mathrm{kipft/ft})) + (3 \times (0.00079618\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))]^2}{(7\ \mathrm{ft})^2 \times [(3 \times (0.0033439\ \mathrm{kipft/ft})) + (2 \times (0.00079618\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))]}$$

$$p = 0.0006546\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.0033439\ \mathrm{kipft/ft})) + ((0.00079618\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))]}{(7\ \mathrm{ft})^2}$$

$$s = 0.0015014\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.9737\ \mathrm{ft})}{2}$$

$$p_a = 0.37303\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0006546\ \mathrm{kip/ft^2})}{(0.37303\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.0017548$$

Status: PASS
Ratio: 0.000

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7\ \mathrm{ft})$$

$$p_s = 1.05\ \mathrm{kip/ft^2}$$

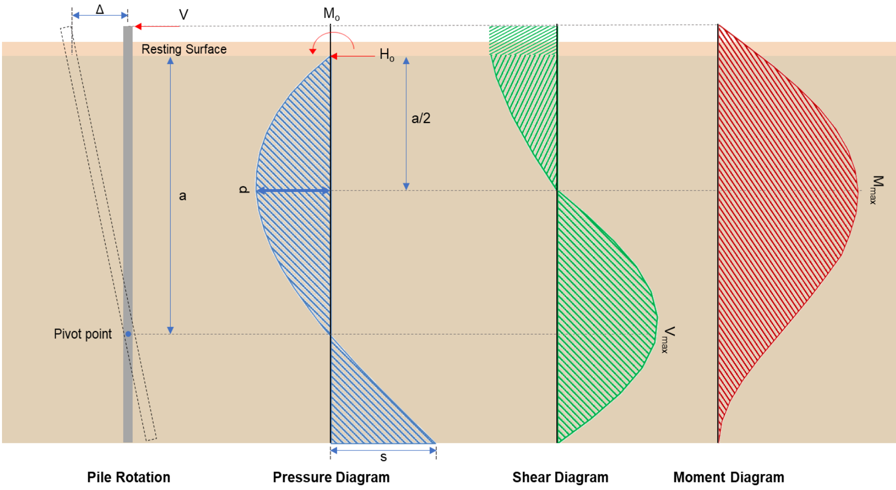
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0015014\ \text{kip/ft}^2)}{(1.05\ \text{kip/ft}^2)}$$

$$Ratio = 0.0014299$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-7.387\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -1.1763\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(68.75\ \text{kipft}) + ((-7.387\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 10.947\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(10.947\ \text{kipft/ft})}{(-1.1763\ \text{kip/ft})}$$

$$E = 9.3069\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (10.947\ \text{kipft/ft}) \times (7\ \text{ft})) + \left(3 \times (-1.1763\ \text{kip/ft}) \times (7\ \text{ft})^2\right)}{(6 \times (10.947\ \text{kipft/ft})) + (4 \times (-1.1763\ \text{kip/ft}) \times (7\ \text{ft}))}$$

$$a = 4.8615\ \text{ft}$$

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

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

$$V_{max} = ((-1.1763\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (9.3069\ \text{ft})}{(7\ \text{ft})} + 3\right) \times \left(\frac{(4.8615\ \text{ft})}{(7\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (9.3069\ \text{ft})}{(7\ \text{ft})} + 2\right) \times \left(\frac{(4.8615\ \text{ft})}{(7\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 14.172\ \text{kip}$$

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

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

$$M_{max} = ((-1.1763 \text{ kip/ft}) \times (48 \text{ in}) \times (7 \text{ ft})) \times \left[\left(\frac{(9.3069 \text{ ft})}{(7 \text{ ft})} + \frac{(4.8615 \text{ ft})}{2 \times (7 \text{ ft})} \right) - \left[\left(\frac{4 \times (9.3069 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left(\frac{(4.8615 \text{ ft})}{2 \times (7 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (9.3069 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left(\frac{(4.8615 \text{ ft})}{2 \times (7 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 46.623 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.009 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0014331 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.034 \text{ kipft}) + ((0.009 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.005414 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.005414 \text{ kipft/ft})}{(0.0014331 \text{ kip/ft})}$$

$$E = 3.7778 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.005414 \text{ kipft/ft}) \times (7 \text{ ft})) + \left(3 \times (0.0014331 \text{ kip/ft}) \times (7 \text{ ft})^2\right)}{(6 \times (0.005414 \text{ kipft/ft})) + (4 \times (0.0014331 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.989 \text{ ft}$$

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

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

$$V_{max} = ((0.0014331 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.7778 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left(\frac{(4.989 \text{ ft})}{(7 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (3.7778 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left(\frac{(4.989 \text{ ft})}{(7 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.0092893 \text{ kip}$$

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

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

$$M_{max} = ((0.0014331 \text{ kip/ft}) \times (48 \text{ in}) \times (7 \text{ ft})) \times \left[\left(\frac{(3.7778 \text{ ft})}{(7 \text{ ft})} + \frac{(4.989 \text{ ft})}{2 \times (7 \text{ ft})} \right) - \left[\left(\frac{4 \times (3.7778 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left(\frac{(4.989 \text{ ft})}{2 \times (7 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (3.7778 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left(\frac{(4.989 \text{ ft})}{2 \times (7 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.02893 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 3 \text{ ksi}$ - Concrete strength,
$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
Table 22.4.2.1 $\alpha = 0.8$ - Alpha factor for axial strength,
$A_g = 2304 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(11.324 \text{ kip})}{(0.65)\times(0.8)} - (0.85 \times (3 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2))\right]$$

$$A_{st,required} = -101.89 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-101.89 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

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

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

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

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

$$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (3\ \mathrm{ksi}) \times \left[\left(2304\ \mathrm{in}^2\right) - \left(4.2951\ \mathrm{in}^2\right)\right]\right) + \left((60\ \mathrm{ksi}) \times \left(4.2951\ \mathrm{in}^2\right)\right)\right]$$

$$\phi P_N = 3183.4\ \mathrm{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(11.324\ \mathrm{kip})}{(3183.4\ \mathrm{kip})}$$

$$Ratio = 0.0035572$$

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 $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$,

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

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

$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(3000\ \mathrm{psi})} \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$

$$V_{c,max} = 324.49\ \mathrm{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$, $P = 11.324\ \mathrm{kip} \rightarrow 11324\ \mathrm{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(3000\ \mathrm{psi})} + \frac{(11324\ \mathrm{lbf})}{6 \times \left(2304\ \mathrm{in}^2\right)}\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$

$$V_{c,a} = 131.3\ \mathrm{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$,

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

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

$$V_{c,b} = \left[2 \times (0.64282) \times \sqrt{(3000\ \mathrm{psi})} + (0.05 \times (3000\ \mathrm{psi}))\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$

$$V_{c,b} = 406.27\ \mathrm{kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(324.49\ \mathrm{kip}), (131.3\ \mathrm{kip}), (406.27\ \mathrm{kip})\right]$$

$$V_c = 131.3\ \mathrm{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$,

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

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

$$V_{s,a} = 8 \times \sqrt{(3000\ \mathrm{psi})} \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$

$$V_{s,a} = 807.65\ \mathrm{kip}$$

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

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

$$V_s = MIN\left[(807.65\ \mathrm{kip}), (50.894\ \mathrm{kip})\right]$$

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((131.3\ \mathrm{kip}) + (50.894\ \mathrm{kip}))$$

$$\phi V_n = 118.43\ \mathrm{kip}$$

Considering x-direction:

$V_{max} = 14.172\ \mathrm{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(14.172\ \mathrm{kip})}{(118.43\ \mathrm{kip})}$$

$$Ratio = 0.11967$$

Status: **PASS**
Ratio: **0.120**

Considering z-direction:

$V_{max} = 0.0092893\ \mathrm{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.0092893\ \mathrm{kip})}{(118.43\ \mathrm{kip})}$$

$$Ratio = 0.000078438$$

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: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(3ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 273.423kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (3\ \text{ksi}) \times \left(18432\ \text{in}^3\right)$$ $$\phi M_{n,2} = 2545.9\ \text{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(273.42\ \text{kipft}), (2545.9\ \text{kipft})]$$ $$\phi M_n = 273.42\ \text{kipft}$$ **Considering x-direction:** $M_{max} = 46.623\ \text{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(46.623\ \text{kipft})}{(273.42\ \text{kipft})}$$ $$Ratio = 0.17052$$	Status: **PASS** Ratio: **0.170**
	Considering z-direction: $M_{max} = 0.02893\ \text{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.02893\ \text{kipft})}{(273.42\ \text{kipft})}$$ $$Ratio = 0.00010581$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

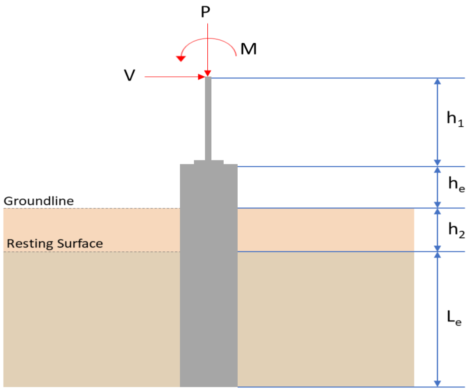
SkyCiv Foundation Design

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
$L = 7\ \text{ft}$ - 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)	8.105	11.902
V_x (kip)	-4.582	-7.647
V_z (kip)	0.000	0.000
M_x (kipft)	0.000	0.000
M_z (kipft)	42.170	70.773

Material Properties

$f'_{ck} = 3\ \text{ksi}$ - 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,

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

$$H_o = \frac{(-4.582\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.72962\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(42.17\ \text{kipft}) + ((-4.582\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 6.715\ \text{kipft/ft}$$

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:
$L_{e,x} = 6.3692\ \text{ft}$ - 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,

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

$$L_{e,req} = MAX[(6.3692\ \text{ft}), (0\ \text{ft})]$$

$$L_{e,req} = 6.369\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 7\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.369\ \text{ft})}{(7\ \text{ft})}$$

$$Ratio = 0.90986$$

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

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

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

$$q = \frac{(8.105\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.50656\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.50656\ \text{kip/ft}^2)}{(2000\ \text{psf})}$$

$$Ratio = 0.25328$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 1.75$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.72962 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 6.715 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.715 \text{ kipft/ft}) \times (7 \text{ ft})) + \left(3 \times (-0.72962 \text{ kip/ft}) \times (7 \text{ ft})^2\right)}{(6 \times (6.715 \text{ kipft/ft})) + (4 \times (-0.72962 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.8629 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (6.715 \text{ kipft/ft})) + (3 \times (-0.72962 \text{ kip/ft}) \times (7 \text{ ft}))]^{\ 2}}{(7 \text{ ft})^2 \times [(3 \times (6.715 \text{ kipft/ft})) + (2 \times (-0.72962 \text{ kip/ft}) \times (7 \text{ ft}))]}$$

$$p = 0.20519 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (6.715 \text{ kipft/ft})) + ((-0.72962 \text{ kip/ft}) \times (7 \text{ ft}))]}{(7 \text{ ft})^2}$$

$$s = 1.0191 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.8629 \text{ ft})}{2}$$

$$p_a = 0.36472 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.20519 \text{ kip/ft}^2\right)}{\left(0.36472 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.5626$$

Status: **PASS**
Ratio: **0.560**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150 \text{ psf/ft}) \times (7 \text{ ft})$$

$$p_s = 1.05 \text{ kip/ft}^2$$

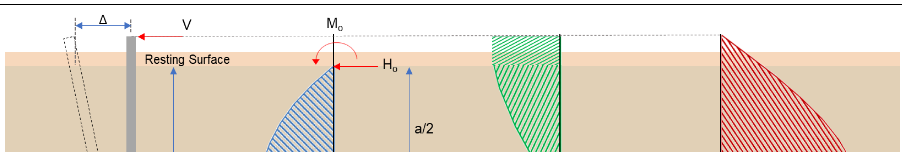
$Ratio$ - Lateral soil capacity

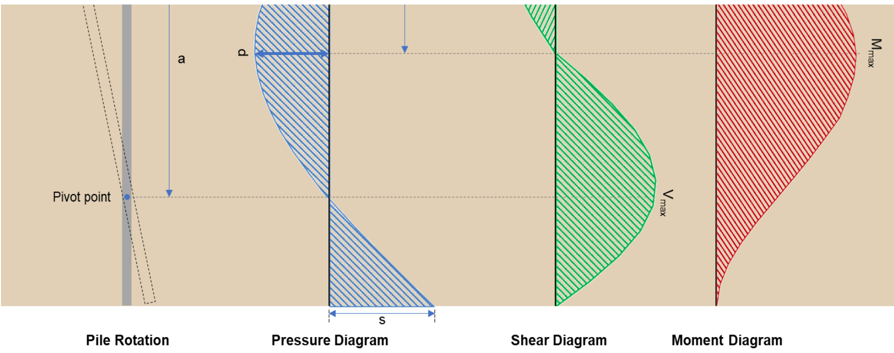
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{\left(1.0191 \text{ kip/ft}^2\right)}{\left(1.05 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.97057$$

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





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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-7.647\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = -1.2177\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(70.773\text{ kipft}) + ((-7.647\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 11.27\text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(11.27\text{ kipft/ft})}{(-1.2177\text{ kip/ft})}$$

$$E = 9.255\text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (11.27\text{ kipft/ft}) \times (7\text{ ft})) + \left(3 \times (-1.2177\text{ kip/ft}) \times (7\text{ ft})^2\right)}{(6 \times (11.27\text{ kipft/ft})) + (4 \times (-1.2177\text{ kip/ft}) \times (7\text{ ft}))}$$

$$a = 4.8622\text{ ft}$$

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

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

$$V_{max} = ((-1.2177\text{ kip/ft}) \times (48\text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (9.255\text{ ft})}{(7\text{ ft})} + 3\right) \times \left(\frac{(4.8622\text{ ft})}{(7\text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (9.255\text{ ft})}{(7\text{ ft})} + 2\right) \times \left(\frac{(4.8622\text{ ft})}{(7\text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 14.607\text{ kip}$$

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

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

$$M_{max} = ((-1.2177\text{ kip/ft}) \times (48\text{ in}) \times (7\text{ ft})) \times \left[\left(\frac{(9.255\text{ ft})}{(7\text{ ft})} + \frac{(4.8622\text{ ft})}{2 \times (7\text{ ft})}\right) - \left[\left(\frac{4 \times (9.255\text{ ft})}{(7\text{ ft})} + 3\right) \times \left(\frac{(4.8622\text{ ft})}{2 \times (7\text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (9.255\text{ ft})}{(7\text{ ft})} + 2\right) \times \left(\frac{(4.8622\text{ ft})}{2 \times (7\text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 48.041 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 3 \text{ ksi}$ - Concrete strength,

$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,

$\phi = 0.65$ - Reduction factor for axial strength,

Table 22.4.2.1 $\alpha = 0.8$ - Alpha factor for axial strength,

$A_g = 2304 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(11.902 \text{ kip})}{(0.65)\times(0.8)} - (0.85 \times (3 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2))\right]$$

$$A_{st,required} = -101.87 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-101.87 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

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

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

25.7.2.2 Since longitudinal reinforcement is $\leq$ No. 10ø: Use #3(0.375 in)

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

$$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (3\ \mathrm{ksi}) \times \left[\left(2304\ \mathrm{in}^2\right) - \left(4.2951\ \mathrm{in}^2\right)\right]\right) + \left((60\ \mathrm{ksi}) \times \left(4.2951\ \mathrm{in}^2\right)\right) \right]$$

$$\phi P_N = 3183.4\ \mathrm{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(11.902\ \mathrm{kip})}{(3183.4\ \mathrm{kip})}$$

$$Ratio = 0.0037387$$

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 $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$,

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

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

$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(3000\ \mathrm{psi})} \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$

$$V_{c,max} = 324.49\ \mathrm{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$,$P = 11.902\ \mathrm{kip} \rightarrow 11902\ \mathrm{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(3000\ \mathrm{psi})} + \frac{(11902\ \mathrm{lbf})}{6 \times \left(2304\ \mathrm{in}^2\right)}\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$

$$V_{c,a} = 131.38\ \mathrm{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$,

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

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

$$V_{c,b} = \left[2 \times (0.64282) \times \sqrt{(3000\ \mathrm{psi})} + (0.05 \times (3000\ \mathrm{psi}))\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$

$$V_{c,b} = 406.27\ \mathrm{kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(324.49\ \mathrm{kip}), (131.38\ \mathrm{kip}), (406.27\ \mathrm{kip})\right]$$

$$V_c = 131.38\ \mathrm{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$,

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

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

$$V_{s,a} = 8 \times \sqrt{(3000\ \mathrm{psi})} \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$

$$V_{s,a} = 807.65\ \mathrm{kip}$$

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

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

$$V_s = MIN\left[(807.65\ \mathrm{kip}), (50.894\ \mathrm{kip})\right]$$

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((131.38\ \mathrm{kip}) + (50.894\ \mathrm{kip}))$$

$$\phi V_n = 118.48\ \mathrm{kip}$$

Considering x-direction:

$V_{max} = 14.607\ \mathrm{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(14.607\ \mathrm{kip})}{(118.48\ \mathrm{kip})}$$

$$Ratio = 0.12329$$

Status: **PASS**
Ratio: **0.120**

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:
$\phi M_{n,1}$

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

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

$$\phi M_{n,1} = 273.423 kipft$$

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

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

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

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

$$\phi M_{n,2} = 2545.9\ \text{kipft}$$

Therefore,
ϕM_n - Allowable flexural strength,

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

$$\phi M_n = MIN[(273.42\ \text{kipft}), (2545.9\ \text{kipft})]$$

$$\phi M_n = 273.42\ \text{kipft}$$

Considering x-direction:

$M_{max} = 48.041\ \text{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(48.041\ \text{kipft})}{(273.42\ \text{kipft})}$$

$$Ratio = 0.1757$$

Status: **PASS**
Ratio: **0.180**

REFERENCES	CALCULATIONS	RESULTS

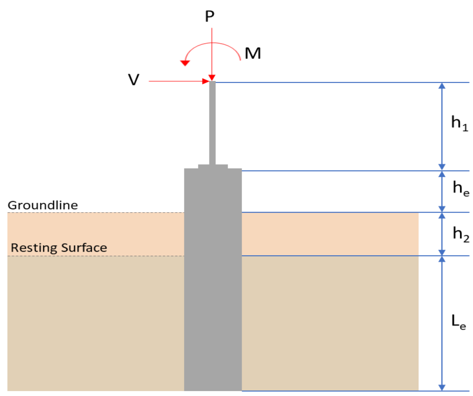
SkyCiv Foundation Design

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
$L = 7\ \mathrm{ft}$ - 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)	7.725	11.324
V_x (kip)	-4.430	-7.387
V_z (kip)	-0.005	-0.009
M_x (kipft)	-0.021	-0.034
M_z (kipft)	40.900	68.752

Material Properties

$f'_{ck} = 3\ \mathrm{ksi}$ - Concrete strength,

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.43\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.70541\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(40.9\ \text{kipft}) + ((-4.43\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 6.5127\ \text{kipft/ft}$$

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:
$L_{e,x} = 6.3267\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.005\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.00079618\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.021\ \text{kipft}) + ((-0.005\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.0033439\ \text{kipft/ft}$$

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:
$L_{e,z} = 0.61926\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.3267\ \text{ft}), (0.61926\ \text{ft})]$$

$$L_{e,req} = 6.327\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 7\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.327\ \text{ft})}{(7\ \text{ft})}$$

$$Ratio = 0.90386$$

Status: **PASS**
Ratio: **0.900**

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

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

$$q = \frac{(7.725\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.48281\ \text{kip/ft}^2$$

$$q = 0.48281 \text{ kip/ft}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.48281 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.24141$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.75$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.70541 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 6.5127 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.5127 \text{ kipft/ft}) \times (7 \text{ ft})) + \left(3 \times (-0.70541 \text{ kip/ft}) \times (7 \text{ ft})^2\right)}{(6 \times (6.5127 \text{ kipft/ft})) + (4 \times (-0.70541 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.8625 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (6.5127 \text{ kipft/ft})) + (3 \times (-0.70541 \text{ kip/ft}) \times (7 \text{ ft}))]^2}{(7 \text{ ft})^2 \times [(3 \times (6.5127 \text{ kipft/ft})) + (2 \times (-0.70541 \text{ kip/ft}) \times (7 \text{ ft}))]}$$

$$p = 0.20003 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (6.5127 \text{ kipft/ft})) + ((-0.70541 \text{ kip/ft}) \times (7 \text{ ft}))]}{(7 \text{ ft})^2}$$

$$s = 0.99032 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.8625 \text{ ft})}{2}$$

$$p_a = 0.36469 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.20003 \text{ kip/ft}^2)}{(0.36469 \text{ kip/ft}^2)}$$

$$Ratio = 0.5485$$

Status: **PASS**
Ratio: **0.550**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\text{ psf/ft}) \times (7\text{ ft})$$

$$p_s = 1.05\text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.99032\text{ kip/ft}^2\right)}{\left(1.05\text{ kip/ft}^2\right)}$$

$$Ratio = 0.94316$$

Status: PASS
Ratio: 0.940

Considering z-direction:

$H_o = -0.00079618\text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 0.0033439\text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0033439\text{ kipft/ft}) \times (7\text{ ft})) + \left(3 \times (-0.00079618\text{ kip/ft}) \times (7\text{ ft})^2\right)}{(6 \times (0.0033439\text{ kipft/ft})) + (4 \times (-0.00079618\text{ kip/ft}) \times (7\text{ ft}))}$$

$$a = 4.9737\text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.0033439\text{ kipft/ft})) + (3 \times (-0.00079618\text{ kip/ft}) \times (7\text{ ft}))]^2}{(7\text{ ft})^2 \times [(3 \times (0.0033439\text{ kipft/ft})) + (2 \times (-0.00079618\text{ kip/ft}) \times (7\text{ ft}))]}$$

$$p = -0.00015355\text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.0033439\text{ kipft/ft})) + ((-0.00079618\text{ kip/ft}) \times (7\text{ ft}))]}{(7\text{ ft})^2}$$

$$s = 0.00013649\text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\text{ psf/ft}) \times \frac{(4.9737\text{ ft})}{2}$$

$$p_a = 0.37303\text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.00015355\text{ kip/ft}^2\right)}{\left(0.37303\text{ kip/ft}^2\right)}$$

$$Ratio = -0.00041163$$

Status: PASS
Ratio: 0.000

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\text{ psf/ft}) \times (7\text{ ft})$$

$$p_s = 1.05\text{ kip/ft}^2$$

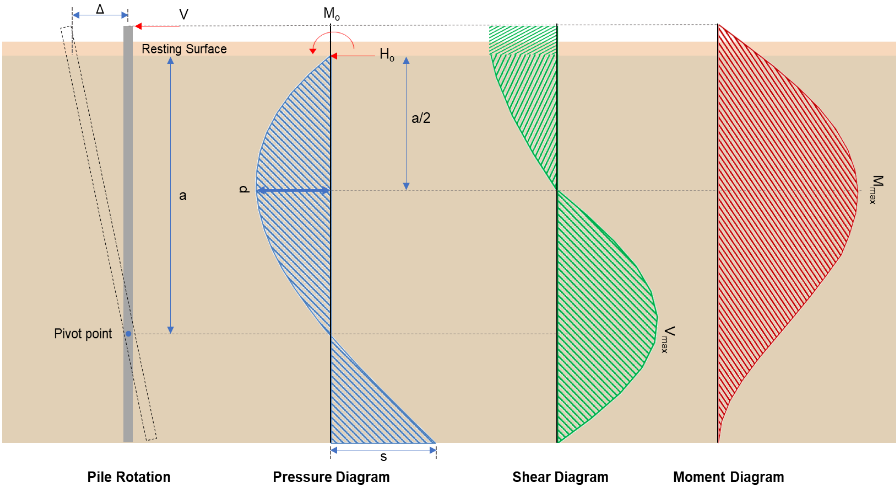
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.00013649\ \text{kip/ft}^2)}{(1.05\ \text{kip/ft}^2)}$$

$$Ratio = 0.00013$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-7.387\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -1.1763\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(68.752\ \text{kipft}) + ((-7.387\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 10.948\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(10.948\ \text{kipft/ft})}{(-1.1763\ \text{kip/ft})}$$

$$E = 9.3072\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (10.948\ \text{kipft/ft}) \times (7\ \text{ft})) + \left(3 \times (-1.1763\ \text{kip/ft}) \times (7\ \text{ft})^2\right)}{(6 \times (10.948\ \text{kipft/ft})) + (4 \times (-1.1763\ \text{kip/ft}) \times (7\ \text{ft}))}$$

$$a = 4.8615\ \text{ft}$$

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

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

$$V_{max} = ((-1.1763\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (9.3072\ \text{ft})}{(7\ \text{ft})} + 3\right) \times \left(\frac{(4.8615\ \text{ft})}{(7\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (9.3072\ \text{ft})}{(7\ \text{ft})} + 2\right) \times \left(\frac{(4.8615\ \text{ft})}{(7\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 14.173\ \text{kip}$$

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

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

$$M_{max} = ((-1.1763\ \text{kip/ft}) \times (48\ \text{in}) \times (7\ \text{ft})) \times \left[\left(\frac{(9.3072\ \text{ft})}{(7\ \text{ft})} + \frac{(4.8615\ \text{ft})}{2 \times (7\ \text{ft})}\right) - \left[\left(\frac{4 \times (9.3072\ \text{ft})}{(7\ \text{ft})} + 3\right) \times \left(\frac{(4.8615\ \text{ft})}{2 \times (7\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (9.3072\ \text{ft})}{(7\ \text{ft})} + 2\right) \times \left(\frac{(4.8615\ \text{ft})}{2 \times (7\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 46.624\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.009\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.0014331\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.034\ \text{kipft}) + ((-0.009\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.005414\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.005414\ \text{kipft/ft})}{(-0.0014331\ \text{kip/ft})}$$

$$E = 3.7778\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.005414\ \text{kipft/ft}) \times (7\ \text{ft})) + \left(3 \times (-0.0014331\ \text{kip/ft}) \times (7\ \text{ft})^2\right)}{(6 \times (0.005414\ \text{kipft/ft})) + (4 \times (-0.0014331\ \text{kip/ft}) \times (7\ \text{ft}))}$$

$$a = 4.989\ \text{ft}$$

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

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

$$V_{max} = ((-0.0014331\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.7778\ \text{ft})}{(7\ \text{ft})} + 3\right) \times \left(\frac{(4.989\ \text{ft})}{(7\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.7778\ \text{ft})}{(7\ \text{ft})} + 2\right) \times \left(\frac{(4.989\ \text{ft})}{(7\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.0092893\ \text{kip}$$

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

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

$$M_{max} = ((-0.0014331\ \text{kip/ft}) \times (48\ \text{in}) \times (7\ \text{ft})) \times \left[\left(\frac{(3.7778\ \text{ft})}{(7\ \text{ft})} + \frac{(4.989\ \text{ft})}{2 \times (7\ \text{ft})}\right) - \left[\left(\frac{4 \times (3.7778\ \text{ft})}{(7\ \text{ft})} + 3\right) \times \left(\frac{(4.989\ \text{ft})}{2 \times (7\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.7778\ \text{ft})}{(7\ \text{ft})} + 2\right) \times \left(\frac{(4.989\ \text{ft})}{2 \times (7\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.02893 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 3 \text{ ksi}$ - Concrete strength,
$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
Table 22.4.2.1 $\alpha = 0.8$ - Alpha factor for axial strength,
$A_g = 2304 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(11.324 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (3 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -101.89 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-101.89 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

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

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

$$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (3\ \mathrm{ksi}) \times \left[\left(2304\ \mathrm{in}^2\right) - \left(4.2951\ \mathrm{in}^2\right)\right]\right) + \left((60\ \mathrm{ksi}) \times \left(4.2951\ \mathrm{in}^2\right)\right)\right]$$

$$\phi P_N = 3183.4\ \mathrm{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(11.324\ \mathrm{kip})}{(3183.4\ \mathrm{kip})}$$

$$Ratio = 0.0035572$$

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 $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$,

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

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

$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(3000\ \mathrm{psi})} \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$

$$V_{c,max} = 324.49\ \mathrm{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$, $P = 11.324\ \mathrm{kip} \rightarrow 11324\ \mathrm{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(3000\ \mathrm{psi})} + \frac{(11324\ \mathrm{lbf})}{6 \times \left(2304\ \mathrm{in}^2\right)}\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$

$$V_{c,a} = 131.3\ \mathrm{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$,

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

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

$$V_{c,b} = \left[2 \times (0.64282) \times \sqrt{(3000\ \mathrm{psi})} + (0.05 \times (3000\ \mathrm{psi}))\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$

$$V_{c,b} = 406.27\ \mathrm{kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(324.49\ \mathrm{kip}), (131.3\ \mathrm{kip}), (406.27\ \mathrm{kip})\right]$$

$$V_c = 131.3\ \mathrm{kip}$$

	The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \mathrm{ksi} \to 3000\ \mathrm{psi}$,	
22.5.1.2	$V_{s,a}$ - Shear strength of steel (a) $$V_{s,a} = 8\sqrt{f'_{ck}}\, b_w\, d$$ $$V_{s,a} = 8 \times \sqrt{(3000\ \mathrm{psi})} \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$ $$V_{s,a} = 807.65\ \mathrm{kip}$$ 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 $$V_s = MIN\left[V_{s,a}, V_{s,b}\right]$$ $$V_s = MIN\left[(807.65\ \mathrm{kip}), (50.894\ \mathrm{kip})\right]$$ $$V_s = 50.894\ \mathrm{kip}$$	
22.5.1.1	ϕV_n - Allowable shear strength $$\phi V_n = \phi\ (V_c + V_s)$$ $$\phi V_n = (0.65) \times ((131.3\ \mathrm{kip}) + (50.894\ \mathrm{kip}))$$ $$\phi V_n = 118.43\ \mathrm{kip}$$ **Considering x-direction:** $V_{max} = 14.173\ \mathrm{kip}$ - Maximum shear force in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(14.173\ \mathrm{kip})}{(118.43\ \mathrm{kip})}$$ $$Ratio = 0.11967$$	Status: **PASS** Ratio: **0.120**
	Considering z-direction: $V_{max} = 0.0092893\ \mathrm{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.0092893\ \mathrm{kip})}{(118.43\ \mathrm{kip})}$$ $$Ratio = 0.000078438$$	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: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(3ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 273.423kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f'_{ck}\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (3 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$ $$\phi M_{n,2} = 2545.9 \text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(273.42 \text{ kipft}), (2545.9 \text{ kipft})]$$ $$\phi M_n = 273.42 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 46.624 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(46.624 \text{ kipft})}{(273.42 \text{ kipft})}$$ $$Ratio = 0.17052$$	Status: **PASS** Ratio: **0.170**
	Considering z-direction: $M_{max} = 0.02893 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.02893 \text{ kipft})}{(273.42 \text{ kipft})}$$ $$Ratio = 0.00010581$$	Status: **PASS** Ratio: **0.000**