Your Project Calculations

Project Name: TOP-35-5x7-26deg-8ft PALO CEDRO

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=TOP-35-5x7-26deg-8ft%20PALO%20CEDRO&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/2_2024

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=TbvtlPI5mP3YazQTqoHBjsbGPpRSlsl6FTEVIFGSHbEoGnGoNL5mE7IXG8SGoMtg

Array Specification

Product:	Beam
Unique ID:	3P-19.75-8TOP-HD-24-L-5Hx7W-HI27
Duty Classification:	HD
Module Width:	41.10 in
Module Length:	87.20in
Number of Rows:	5
Number of Columns:	7
Total Number of Modules:	35
Desired Tilt Angle:	26
Front Edge Clearance:	8
Total Array Height at Tilt:	15.55 ft
Total Frame Length:	51.00 ft
Frame Weight:	2674 lbs
Array Dimensions N/S:	17.33 ft
Array Dimensions E/W:	51.45 ft
Rail Length:	208.00 in
Rail Spacing:	3.63 ft
Rail Check:	Not Checked

Support Specifications

Pole Size:	8in Pipe Sch 40
Pole Length above Grade:	11.80 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: 6.00 ft Pile 2: 6.25 ft Pile 3: 6.00 ft
Foundation Volume:	10.815 y^3
Foundation Result:	PASSED
Mount Twist:	0.830226 kip

Site Info

Risk Category:	I
Exposure:	B
Soil Classification:	sand
Site Location:	10410 Oriole Ln, Palo Cedro, CA 96073, USA
Wind Speed:	100 mph
Snow Load:	32 psf
Design Uplift Pressure:	Multiple pressures
Design Downforce Pressure:	Multiple pressures
Design Snow Pressure:	0.015483 ksf

Design Disclaimer

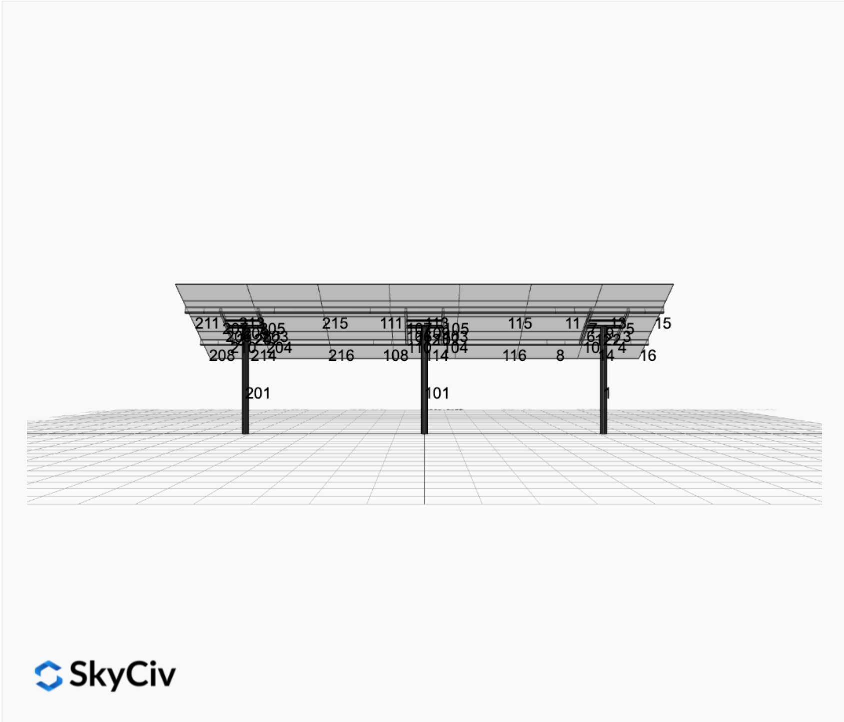
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

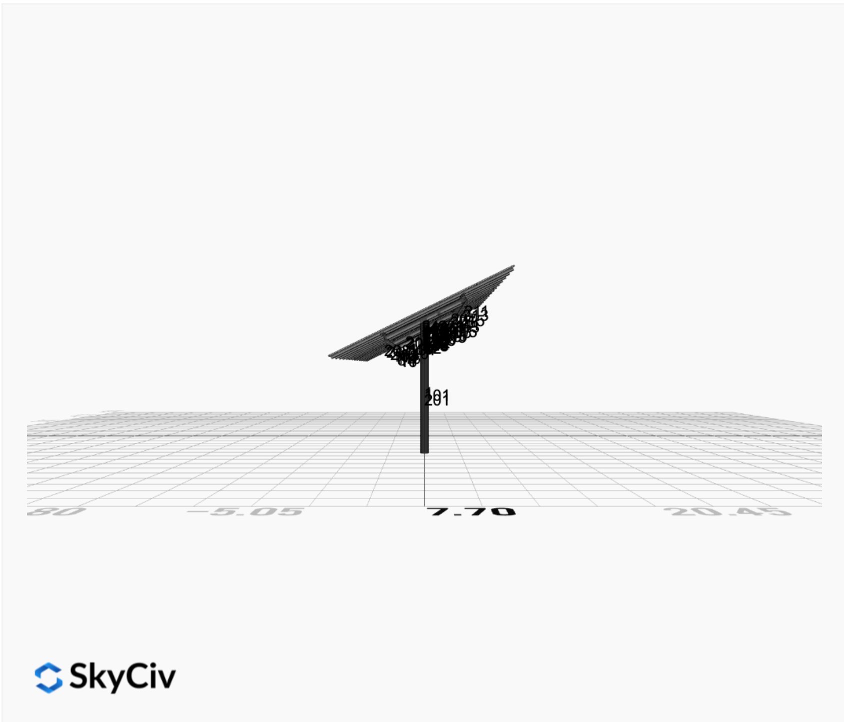
AutoDesigner Input

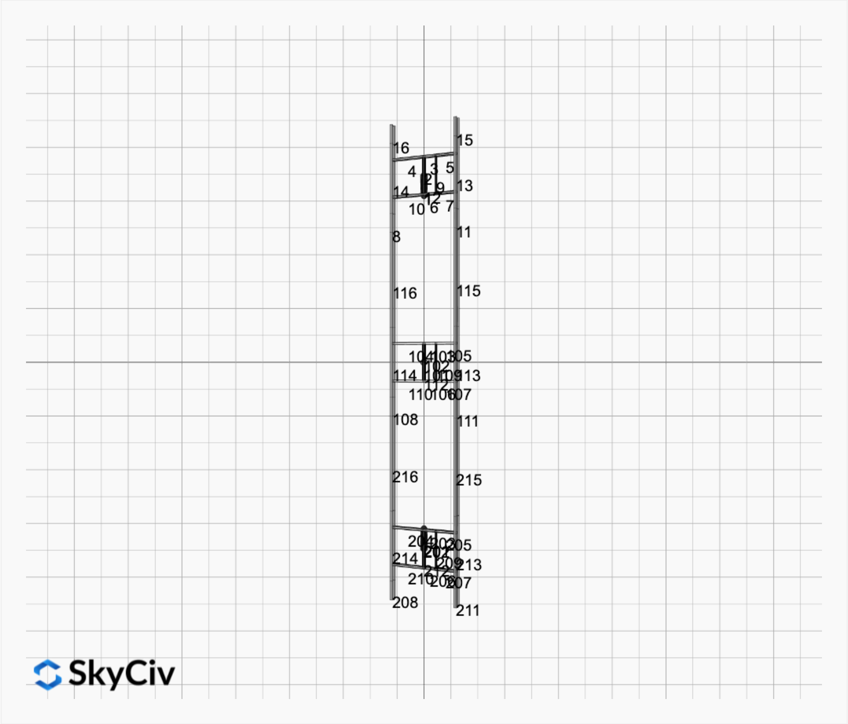

```
{"product_type":"Beam","project_id":"TOP-35-5x7-26deg-8ft PALO CEDRO","site_address":"10410 Oriole Ln, Palo Cedro, CA 96073, USA","module_width":41.1,"module_length":87.2,"number_rows":"5","number_columns":7,"pole_mount_section":"4_40","core_pipe_width":65,"core_pipe_section":"2_40","adjuster_section":"2_40","core_beam_height":65,"core_beam_section":"HSS3x2x1/8","main_pipe_section":"2_12GA","pole_spacing":"15","tilt_angle":26,"ground_clearance":8,"risk_category":"I","exposure_category":"B","frame_duty_override":"auto","pole_override":"auto","soil_type":"sand","customer_foundation_override":"48_Square","foundation_type":"Square","foundation_size":48,"check_rails":false,"wind_speed_override":100,"snow_load_override":32,"direct_snow_load":false,"add_angle_brace":false}
```

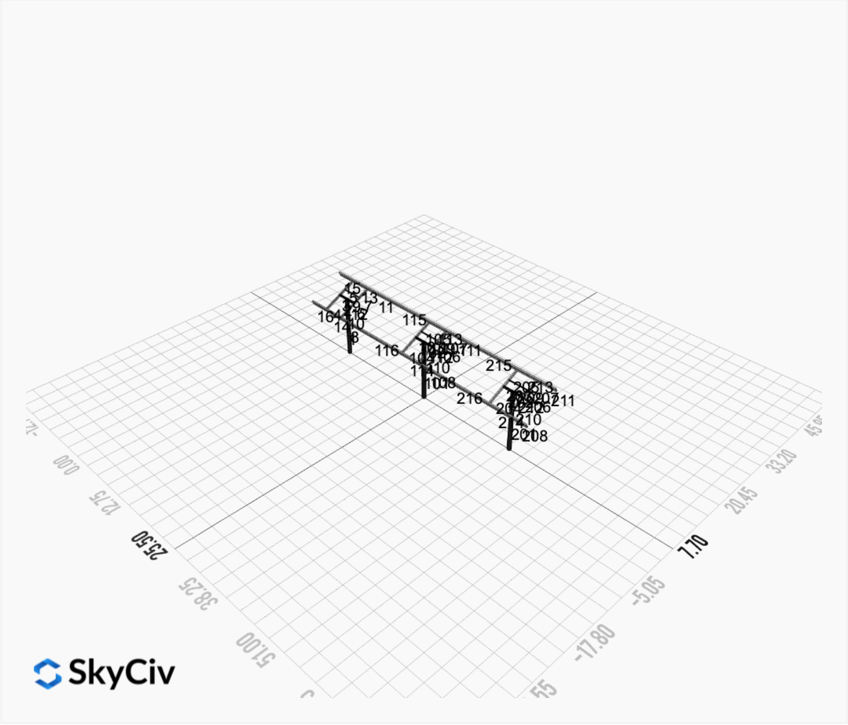

Design Notes:

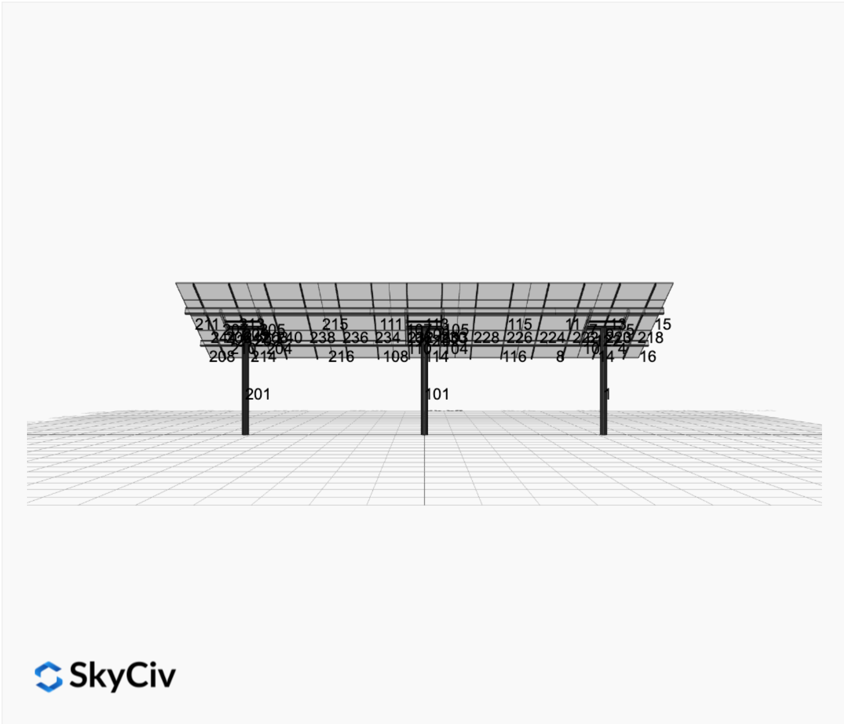
- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Soil Parameters used in this Autodesign are all estimates, proper geotechnical reports are required to confirm soil profiles
- Wind speeds, snow loads and other site specific results are based on ASCE 7 2016
- Steel frame design checks are based on AISC 360 2016 (LRFD)
- Foundation Design and Sizing is approximate only


211
215
111
115
11
15
208
214
216
108
114
116
8
16
204
104
201
101
SkyCiv

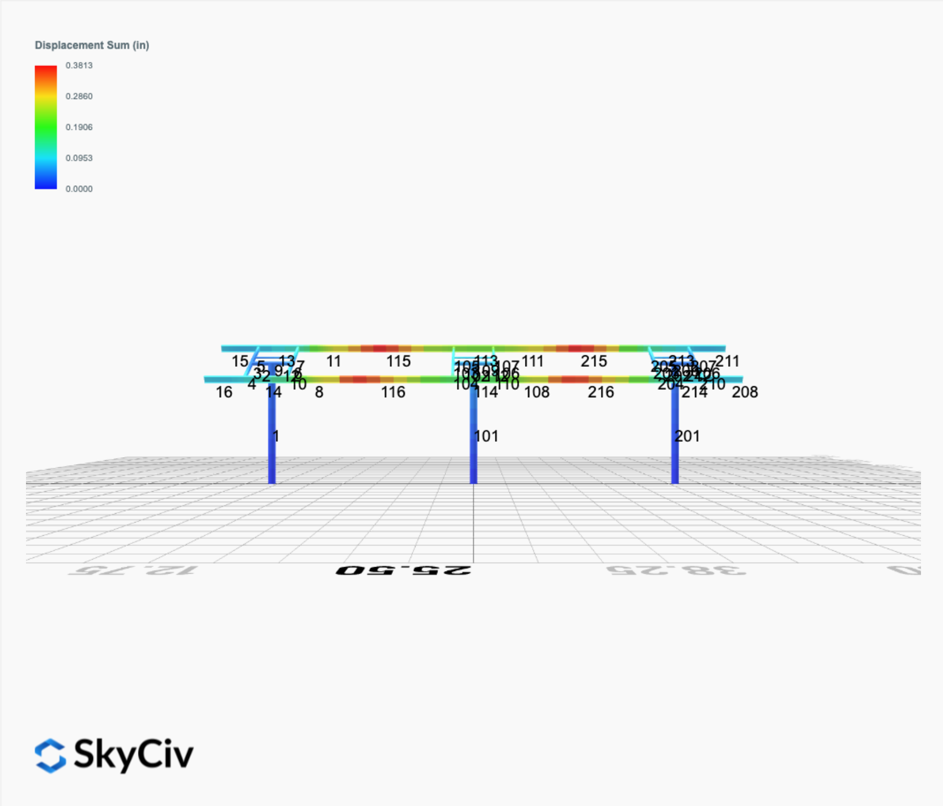

-5.05
7.70
20.45
SkyCiv

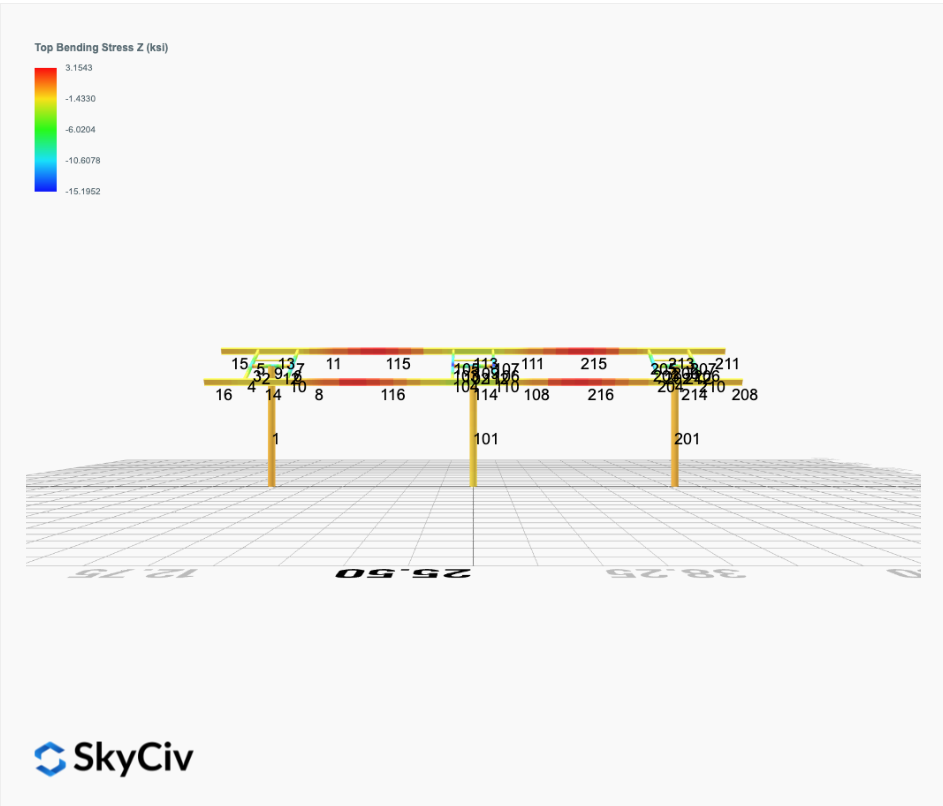


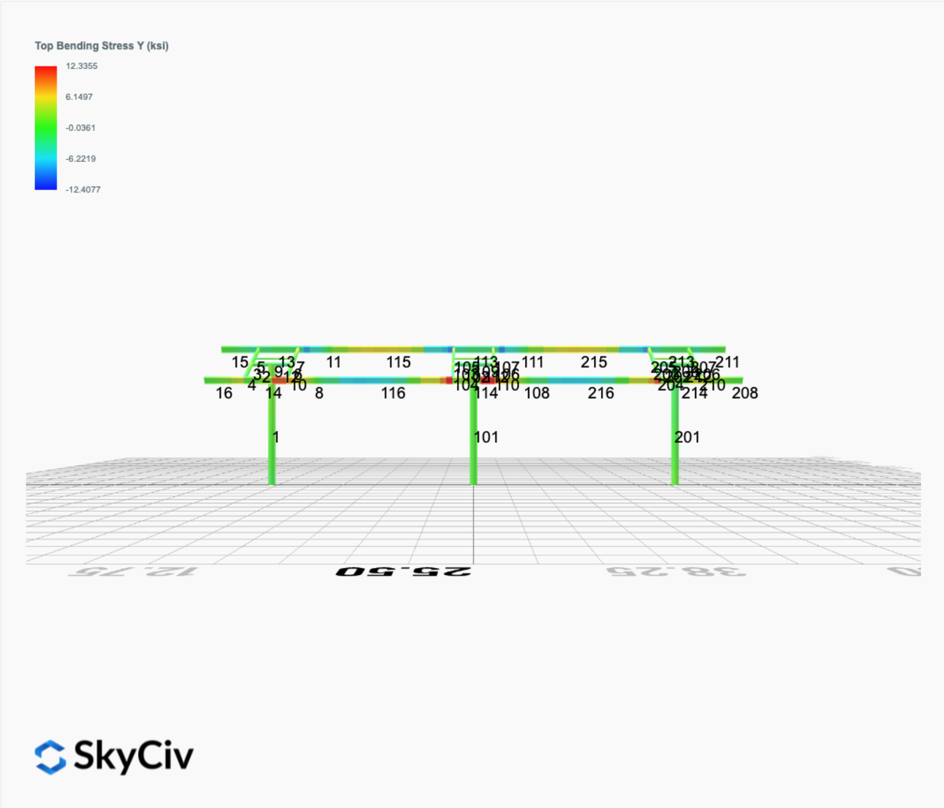


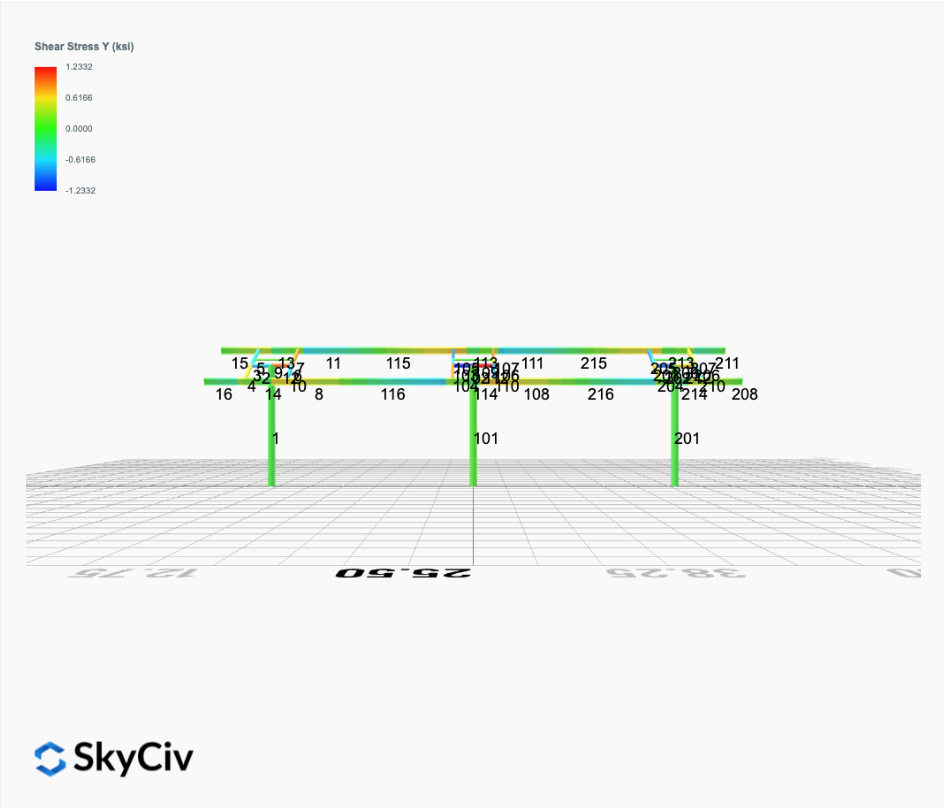

211
215
111
115
15
238
236
234
228
226
224
218
208
214
216
108
116
16
201
101
SkyCiv

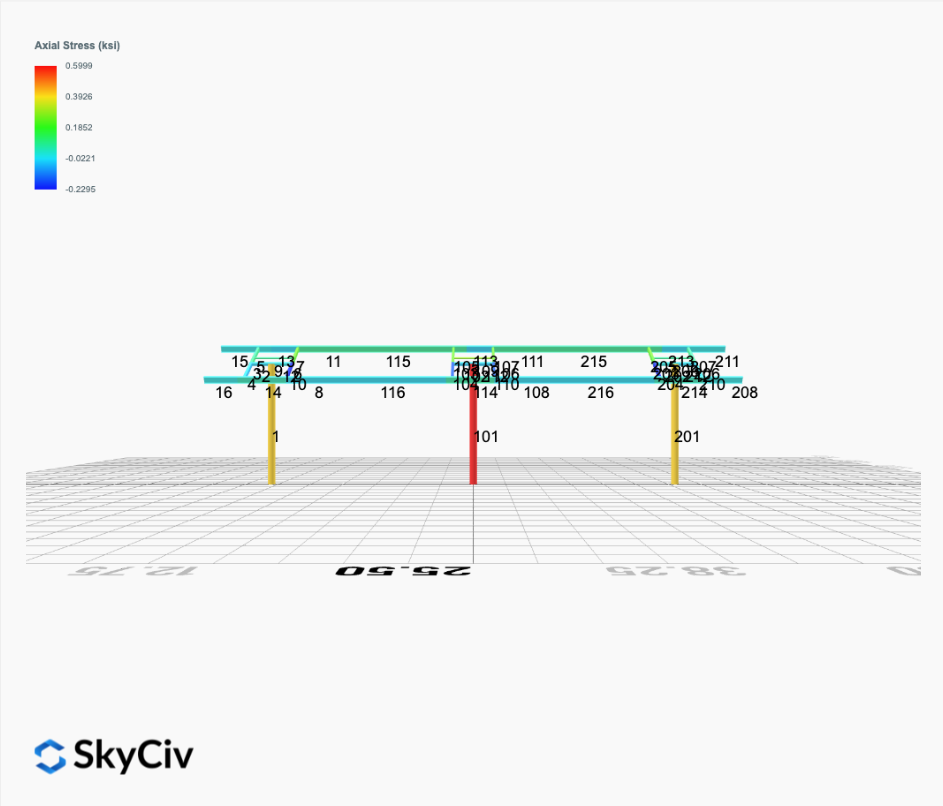
FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
12.3355
6.1497
-0.0361
-6.2219
-12.4077
SkyCiv


Shear Stress Y (ksi)
1.2332
0.6166
0.0000
-0.6166
-1.2332
SkyCiv


Axial Stress (ksi)
0.5999
0.3926
0.1852
-0.0221
-0.2295
1
101
201
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	0.0225	2.0294	0.0787	0.2762	-0.0569	-0.2113
ULS: 2. D + L	0.0225	2.0294	0.0787	0.2762	-0.0569	-0.2113
ULS: 3. D + (S or Lr or R)	0.0778	5.6609	0.2726	0.9574	-0.1978	-0.7851
ULS: 3. D + (S or Lr or R)	0.0225	2.0294	0.0787	0.2762	-0.0569	-0.2113
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0640	4.7530	0.2241	0.7871	-0.1626	-0.6417
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0225	2.0294	0.0787	0.2762	-0.0569	-0.2113
ULS: 5b. D + 0.7E	0.0225	2.0294	0.0787	0.2762	-0.0569	-0.2113
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0640	4.7530	0.2241	0.7871	-0.1626	-0.6417
ULS: 8. 0.6D + 0.7E	0.0135	1.2176	0.0472	0.1657	-0.0342	-0.1268
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.3915	4.8624	0.2705	0.9285	-0.4680	17.0961
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.3915	4.8624	0.2705	0.9285	-0.4680	17.0961
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.2509	-0.4355	-0.0846	-0.2781	0.2924	-14.5030
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.0918	-0.0878	-0.0793	-0.2596	0.2904	-19.2577
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.9966	6.8778	0.3680	1.2764	-0.4708	12.3389
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.9966	6.8778	0.3680	1.2764	-0.4708	12.3389
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.9853	2.9043	0.1017	0.3714	0.0995	-11.3604
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.8660	3.1651	0.1056	0.3853	0.0980	-14.9264
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.0380	4.1542	0.2226	0.7654	-0.3652	12.7692
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.0380	4.1542	0.2226	0.7654	-0.3652	12.7692
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.9438	0.1807	-0.0438	-0.1395	0.2051	-10.9301
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.8245	0.4415	-0.0398	-0.1256	0.2036	-14.4961
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.4005	4.0507	0.2390	0.8181	-0.4452	17.1806
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.4005	4.0507	0.2390	0.8181	-0.4452	17.1806
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.2419	-1.2473	-0.1161	-0.3886	0.3152	-14.4185
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.0828	-0.8995	-0.1108	-0.3701	0.3132	-19.1732

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	10.6083
Shear X	-2.3568
Shear Z	0.5686
Moment X	1.9832
Moment Y (Twist)	0.8299
Moment Z	32.8379

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	6.8778
Shear X	-1.4005
Shear Z	0.3680
Moment X	1.2764
Moment Y (Twist)	0.4708
Moment Z	19.2577

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	-0.0451	2.6028	0.0000	0.0000	0.0000	0.5065
ULS: 2. D + L	-0.0451	2.6028	0.0000	0.0000	0.0000	0.5065
ULS: 3. D + (S or Lr or R)	-0.1556	7.6415	0.0000	-0.0000	0.0001	1.7137
ULS: 3. D + (S or Lr or R)	-0.0451	2.6028	0.0000	0.0000	0.0000	0.5065
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.1280	6.3818	0.0000	-0.0000	0.0001	1.4119
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0451	2.6028	0.0000	0.0000	0.0000	0.5065
ULS: 5b. D + 0.7E	-0.0451	2.6028	0.0000	0.0000	0.0000	0.5065

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.1280	6.3818	0.0000	-0.0000	0.0001	1.4119
ULS: 8. 0.6D + 0.7E	-0.0270	1.5617	0.0000	0.0000	0.0000	0.3039
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.9045	6.5475	0.0000	-0.0000	0.0000	22.7510
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.9045	6.5475	0.0000	-0.0000	0.0000	22.7510
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.5813	-0.8390	0.0000	-0.0000	0.0000	-17.8289
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.2952	-0.2956	0.0000	0.0000	0.0000	-23.0419
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.5225	9.3404	0.0000	-0.0000	0.0001	18.0953
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.5225	9.3404	0.0000	-0.0000	0.0001	18.0953
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.0918	3.8005	0.0000	-0.0000	0.0001	-12.3397
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.8772	4.2081	0.0000	-0.0000	0.0001	-16.2495
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.4396	5.5613	0.0000	-0.0000	0.0000	17.1899
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.4396	5.5613	0.0000	-0.0000	0.0000	17.1899
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.1747	0.0214	0.0000	-0.0000	0.0000	-13.2451
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.9601	0.4290	0.0000	0.0000	0.0000	-17.1548
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.8864	5.5064	0.0000	-0.0000	0.0000	22.5484
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.8864	5.5064	0.0000	-0.0000	0.0000	22.5484
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.5993	-1.8802	0.0000	-0.0000	0.0000	-18.0315
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.3132	-1.3367	0.0000	0.0000	0.0000	-23.2446

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	14.4690
Shear X	-3.2035
Shear Z	0.0000
Moment X	0.0001
Moment Y (Twist)	0.0005
Moment Z	39.2475

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	9.3404
Shear X	-1.9045
Shear Z	0.0000
Moment X	-0.0000
Moment Y (Twist)	0.0001
Moment Z	23.2446

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	0.0225	2.0294	-0.0787	-0.2762	0.0569	-0.2113
ULS: 2. D + L	0.0225	2.0294	-0.0787	-0.2762	0.0569	-0.2113
ULS: 3. D + (S or Lr or R)	0.0778	5.6609	-0.2726	-0.9576	0.1979	-0.7850
ULS: 3. D + (S or Lr or R)	0.0225	2.0294	-0.0787	-0.2762	0.0569	-0.2113
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0640	4.7530	-0.2241	-0.7872	0.1627	-0.6416
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0225	2.0294	-0.0787	-0.2762	0.0569	-0.2113
ULS: 5b. D + 0.7E	0.0225	2.0294	-0.0787	-0.2762	0.0569	-0.2113
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0640	4.7530	-0.2241	-0.7872	0.1627	-0.6416
ULS: 8. 0.6D + 0.7E	0.0135	1.2176	-0.0472	-0.1657	0.0342	-0.1268
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.3915	4.8624	-0.2705	-0.9285	0.4680	17.0961
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.3915	4.8624	-0.2705	-0.9285	0.4680	17.0961
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.2509	-0.4355	0.0846	0.2781	-0.2924	-14.5030
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.0918	-0.0878	0.0793	0.2596	-0.2904	-19.2577
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.9966	6.8778	-0.3680	-1.2765	0.4709	12.3390
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.9966	6.8778	-0.3680	-1.2765	0.4709	12.3390
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.9853	2.9043	-0.1017	-0.3715	-0.0993	-11.3603
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.8660	3.1651	-0.1056	-0.3854	-0.0979	-14.9263

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.0380	4.1542	-0.2226	-0.7654	0.3652	12.7693
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.0380	4.1542	-0.2226	-0.7654	0.3652	12.7693
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.9438	0.1807	0.0438	0.1395	-0.2051	-10.9301
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.8245	0.4415	0.0398	0.1256	-0.2036	-14.4961
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.4005	4.0507	-0.2390	-0.8181	0.4452	17.1806
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.4005	4.0507	-0.2390	-0.8181	0.4452	17.1806
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.2419	-1.2473	0.1161	0.3886	-0.3152	-14.4184
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.0828	-0.8995	0.1108	0.3700	-0.3132	-19.1731

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	10.6083
Shear X	-2.3568
Shear Z	-0.5686
Moment X	-1.9836
Moment Y (Twist)	0.8302
Moment Z	32.8383

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	6.8778
Shear X	-1.4005
Shear Z	-0.3680
Moment X	-1.2765
Moment Y (Twist)	0.4709
Moment Z	19.2577

Project Details

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

User Name: sales@mtsolar.us
Project Name: TOP-35-5x7-26deg-8ft PALO CEDRO
Unit System: imperial

Design Input Information

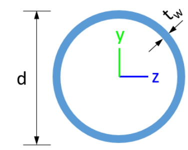
Design Factors

Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

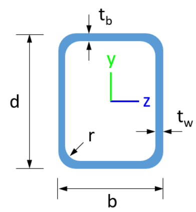
Design Materials

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

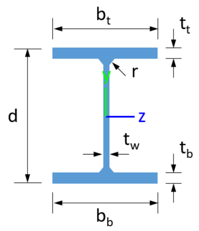
Section Dimensions



ID	Name	d (in)	t_w (in)					
2	2in Pipe Sch 80	2.38	0.22					
5	4in Pipe Sch 80	4.50	0.34					
9	8in Pipe Sch 40	8.63	0.32					



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



ID	Name	d (in)	t_w (in)	b_t (in)	b_b (in)	t_t (in)	t_b (in)	r (in)
19	W8x10	7.89	0.17	3.94	3.94	0.20	0.20	0.30

Section Properties

ID	Name	A (in^2)	J (in^4)	I_{yp} (in^4)	I_{zp} (in^4)	I_w (in^6)	S_{yp} (in^3)	S_{zp} (in^3)
2	2in Pipe Sch 80	1.48	1.74	0.87	0.87	0.00	1.02	1.02
5	4in Pipe Sch 80	4.41	19.22	9.61	9.61	0.00	5.85	5.85

9	8in Pipe Sch 40	8.40	144.98	72.49	72.49	0.00	22.21	22.21
16	HSS5x3x3/16	2.58	8.64	3.85	8.53	0.73	2.96	4.21
19	W8x10	2.96	0.04	2.09	30.80	30.90	1.66	8.87

Member Properties								
Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	9	24.78	24.78	11.80	-	300	200	1
2	5	1.30	1.30	2.00	-	300	200	1
3	16	0.92	0.92	1.42	1.18,1.18,1.18,1.17,1.18,1.18,1.17,1.17,1.15,1.16,1.17,1.17,1.16,1.17,1.17,1.17,1.18,1.18,1.18,1.18,1.13,1.16,1.17,1.17,1.16,1.17	300	200	1
4	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.64,1.68,1.67,1.67,1.65,1.71,1.67,1.67,1.68,1.67,1.68,1.68,1.60,1.70,1.67,1.67,1.66,1.72	300	200	1
5	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.62,1.65,1.67,1.67,1.66,1.66	300	200	1
6	16	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.19,1.19,1.19,1.19,1.16,1.18,1.19,1.19,1.18,1.18	300	200	1
7	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66	300	200	1
8	19	1.33	1.33	2.05	1.32,1.32,1.32,1.32,1.32,1.32,1.32,1.32,1.30,1.45,1.31,1.31,1.31,2.12,1.32,1.32,1.32,1.34,1.32,1.32,1.31,1.45,1.31,1.31,1.31,1.45	300	200	1
9	2	2.60	2.60	4.00	-	300	200	1
10	16	2.44	2.44	3.75	1.69,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.74,1.67,1.67,1.67,1.67,1.67,1.67,1.63,1.70,1.67,1.67,1.66,1.15	300	200	1
11	19	1.33	1.33	2.05	1.35,1.35,1.35,1.35,1.35,1.35,1.37,1.37,1.47,1.49,1.38,1.38,1.40,1.44,1.36,1.36,1.33,1.29,1.37,1.37,1.47,1.49,1.38,1.38,1.39,1.43	300	200	1
12	5	1.30	1.30	2.00	-	300	200	1
13	19	4.88	4.00	7.50	1.17,1.17,1.17,1.17,1.17,1.17,1.15,1.15,1.13,1.29,1.15,1.15,1.14,1.20,1.16,1.16,1.18,1.14,1.15,1.15,1.14,1.29,1.15,1.15,1.14,1.20	300	200	1
14	19	4.88	4.00	7.50	1.17,1.17,1.17,1.17,1.17,1.17,1.16,1.16,1.15,1.42,1.16,1.16,1.16,2.13,1.16,1.16,1.17,1.21,1.16,1.16,1.15,1.42,1.16,1.16,1.16,1.89	300	200	1
15	19	4.20	4.20	2.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
16	19	4.20	4.20	2.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
101	9	24.78	24.78	11.80	-	300	200	1
102	5	1.30	1.30	2.00	-	300	200	1
103	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.17,1.18,1.18,1.18,1.18	300	200	1
104	16	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.73,1.67,1.67,1.67,1.67,1.67,1.67,1.63,1.69,1.67,1.67,1.66,3.01	300	200	1
105	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66	300	200	1
106	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.17,1.18,1.18,1.18,1.18	300	200	1
107	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66	30	20	1

					[illegible]	0	0	
108	19	1.33	1.33	2.05	2.11,2.11,2.11,2.11,2.11,2.10,2.10,2.09,1.62,2.10,2.10,2.10,1.13,2.11,2.11,2.11,2.09,2.10,2.10,2.09,1.61,2.10,2.10,2.10,1.05	300	200	1
109	2	2.60	2.60	4.00	-	300	200	1
110	16	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.73,1.67,1.67,1.67,1.67,1.67,1.67,1.63,1.69,1.67,1.67,1.66,3.00	300	200	1
111	19	1.33	1.33	2.05	2.07,2.07,2.07,2.07,2.07,2.07,1.74,1.74,1.27,1.31,1.69,1.69,1.52,1.43,1.91,1.91,2.11,2.29,1.75,1.75,1.28,1.32,1.67,1.67,1.56,1.46	300	200	1
112	5	1.30	1.30	2.00	-	300	200	1
113	19	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.10,1.11,1.04,1.04,1.05,1.07,1.04,1.04,1.03,1.03,1.04,1.04,1.10,1.11,1.04,1.04,1.05,1.06	300	200	1
114	19	4.88	4.00	7.50	1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.14,1.03,1.03,1.03,1.05,1.03,1.03,1.03,1.03,1.03,1.03,1.04,1.13,1.03,1.03,1.03,1.01	300	200	1
115	19	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.14,1.14,1.07,1.08,1.13,1.13,1.12,1.10,1.15,1.15,1.17,1.22,1.14,1.14,1.07,1.08,1.13,1.13,1.12,1.11	300	200	1
116	19	6.63	6.63	10.20	1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.12,1.17,1.17,1.17,1.07,1.17,1.17,1.18,1.16,1.17,1.17,1.17,1.12,1.17,1.17,1.17,1.52	300	200	1
201	9	24.78	24.78	11.80	-	300	200	1
202	5	1.30	1.30	2.00	-	300	200	1
203	16	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.19,1.19,1.19,1.19,1.16,1.18,1.19,1.19,1.18,1.18	300	200	1
204	16	2.44	2.44	3.75	1.69,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.74,1.67,1.67,1.67,1.67,1.67,1.67,1.63,1.70,1.67,1.67,1.66,1.15	300	200	1
205	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66	300	200	1
206	16	0.92	0.92	1.42	1.18,1.18,1.18,1.17,1.18,1.18,1.17,1.17,1.15,1.16,1.17,1.17,1.16,1.17,1.17,1.17,1.18,1.18,1.18,1.18,1.13,1.16,1.17,1.17,1.16,1.17	300	200	1
207	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.62,1.65,1.67,1.67,1.66,1.66	300	200	1
208	19	4.20	4.20	2.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
209	2	2.60	2.60	4.00	-	300	200	1
210	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.64,1.68,1.67,1.67,1.65,1.71,1.67,1.67,1.68,1.67,1.68,1.68,1.60,1.70,1.67,1.67,1.66,1.72	300	200	1
211	19	4.20	4.20	2.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
212	5	1.30	1.30	2.00	-	300	200	1
213	19	4.88	4.00	7.50	1.17,1.17,1.17,1.17,1.17,1.17,1.15,1.15,1.13,1.29,1.15,1.15,1.14,1.20,1.16,1.16,1.18,1.14,1.15,1.15,1.14,1.29,1.15,1.15,1.14,1.20	300	200	1
214	19	4.88	4.00	7.50	1.17,1.17,1.17,1.17,1.17,1.17,1.16,1.16,1.15,1.42,1.16,1.16,1.16,2.13,1.16,1.16,1.17,1.21,1.16,1.16,1.16,1.42,1.16,1.16,1.16,1.90	300	200	1
215	19	6.63	6.63	10.20	1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.11,1.12,1.09,1.09,1.10,1.10,1.09,1.09,1.09,1.10,1.09,1.09,1.11,1.12,1.09,1.09,1.09,1.10	300	200	1
216	19	6.63	6.63	10.20	1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.10,1.09,1.09,1.09,1.22,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.10,1.09,1.09,1.09,1.94	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	178.71	83.29	83.29	113.39	113.39
2	198.33	196.72	21.95	21.95	59.50	59.50
3	116.10	115.41	15.79	11.10	42.08	23.28
4	116.10	111.33	15.79	11.10	42.08	23.28
5	116.10	114.23	15.79	11.10	42.08	23.28
6	116.10	115.41	15.79	11.10	42.08	23.28
7	116.10	114.23	15.79	11.10	42.08	23.28
8	133.20	126.01	32.87	6.12	40.24	43.62
9	66.48	58.89	3.82	3.82	19.94	19.94
10	116.10	111.33	15.79	11.10	42.08	23.28
11	133.20	126.01	32.87	6.12	40.24	43.62
12	198.33	196.72	21.95	21.95	59.50	59.50
13	133.20	104.94	25.88	6.12	40.24	43.62
14	133.20	104.94	26.40	6.12	40.24	43.62
15	133.20	102.39	32.87	6.12	40.24	43.62
16	133.20	102.39	32.87	6.12	40.24	43.62
101	377.97	178.71	83.29	83.29	113.39	113.39
102	198.33	196.72	21.95	21.95	59.50	59.50
103	116.10	115.41	15.79	11.10	42.08	23.28
104	116.10	111.33	15.79	11.10	42.08	23.28
105	116.10	114.23	15.79	11.10	42.08	23.28
106	116.10	115.41	15.79	11.10	42.08	23.28
107	116.10	114.23	15.79	11.10	42.08	23.28
108	133.20	126.01	32.87	6.12	40.24	43.62
109	66.48	58.89	3.82	3.82	19.94	19.94
110	116.10	111.33	15.79	11.10	42.08	23.28
111	133.20	126.01	32.87	6.12	40.24	43.62
112	198.33	196.72	21.95	21.95	59.50	59.50
113	133.20	104.94	23.53	6.12	40.24	43.62
114	133.20	104.94	23.04	6.12	40.24	43.62
115	133.20	69.16	16.61	6.12	40.24	43.62
116	133.20	69.16	16.54	6.12	40.24	43.62
201	377.97	178.71	83.29	83.29	113.39	113.39
202	198.33	196.72	21.95	21.95	59.50	59.50
203	116.10	115.41	15.79	11.10	42.08	23.28
204	116.10	111.33	15.79	11.10	42.08	23.28
205	116.10	114.23	15.79	11.10	42.08	23.28
206	116.10	115.41	15.79	11.10	42.08	23.28
207	116.10	114.23	15.79	11.10	42.08	23.28
208	133.20	102.39	32.87	6.12	40.24	43.62
209	66.48	58.89	3.82	3.82	19.94	19.94
210	116.10	111.33	15.79	11.10	42.08	23.28
211	133.20	102.39	32.87	6.12	40.24	43.62
212	198.33	196.72	21.95	21.95	59.50	59.50
213	133.20	104.94	25.88	6.12	40.24	43.62
214	133.20	104.94	26.41	6.12	40.24	43.62
215	133.20	69.16	16.82	6.12	40.24	43.62
216	133.20	69.16	16.84	6.12	40.24	43.62

Design Ratio

Member ID	P	M_z	M_y	V_y	V_z	(P,M_z,M_y)	Worst LC	KL/r	δ	Status
1	0.059	0.394	0.057	0.021	0.005	0.399	#16	0.506	Not Required	Pass
2	0.002	0.279	0.090	0.068	0.018	0.346	#21	0.053	Not Required	Pass
3	0.006	0.470	0.021	0.046	0.003	0.482	#21	0.045	Not Required	Pass
4	0.005	0.462	0.074	0.047	0.019	0.538	#21	0.080	Not Required	Pass
5	0.005	0.292	0.048	0.047	0.012	0.298	#21	0.074	Not Required	Pass
6	0.010	0.678	0.098	0.070	0.026	0.781	#21	0.045	Not Required	Pass
7	0.010	0.420	0.159	0.067	0.039	0.460	#21	0.074	Not Required	Pass
8	0.003	0.126	0.138	0.042	0.016	0.196	#21	0.095	Not Required	Pass
9	0.006	0.069	0.078	0.003	0.005	0.146	#21	0.204	Not Required	Pass
10	0.011	0.649	0.141	0.065	0.030	0.717	#21	0.080	Not Required	Pass
11	0.005	0.124	0.144	0.044	0.016	0.191	#21	0.095	Not Required	Pass
12	0.001	0.494	0.128	0.104	0.023	0.589	#21	0.053	Not Required	Pass
13	0.006	0.116	0.367	0.058	0.020	0.431	#21	0.286	Not Required	Pass
14	0.004	0.110	0.360	0.055	0.020	0.416	#24	0.190	Not Required	Pass
15	0.000	0.019	0.036	0.016	0.005	0.055	#21	Not Required	Not Required	Pass
16	0.000	0.019	0.036	0.016	0.005	0.055	#21	Not Required	Not Required	Pass
101	0.081	0.470	0.000	0.028	0.000	0.502	#13	0.506	Not Required	Pass
102	0.003	0.541	0.157	0.118	0.027	0.668	#21	0.053	Not Required	Pass
103	0.010	0.786	0.058	0.079	0.009	0.847	#21	0.045	Not Required	Pass
104	0.010	0.795	0.164	0.080	0.035	0.907	#21	0.080	Not Required	Pass
105	0.010	0.488	0.171	0.078	0.043	0.534	#21	0.074	Not Required	Pass
106	0.010	0.786	0.058	0.079	0.009	0.847	#21	0.045	Not Required	Pass
107	0.010	0.488	0.171	0.078	0.043	0.534	#21	0.074	Not Required	Pass
108	0.003	0.066	0.161	0.054	0.016	0.210	#21	0.095	Not Required	Pass
109	0.015	0.070	0.046	0.001	0.000	0.122	#21	0.204	Not Required	Pass
110	0.010	0.795	0.164	0.080	0.035	0.907	#21	0.080	Not Required	Pass
111	0.005	0.085	0.164	0.052	0.016	0.191	#21	0.095	Not Required	Pass
112	0.003	0.541	0.157	0.118	0.027	0.668	#21	0.053	Not Required	Pass
113	0.006	0.232	0.392	0.066	0.020	0.603	#21	0.286	Not Required	Pass
114	0.007	0.273	0.390	0.067	0.021	0.637	#21	0.286	Not Required	Pass
115	0.009	0.340	0.202	0.052	0.016	0.550	#21	0.473	Not Required	Pass
116	0.004	0.319	0.203	0.054	0.016	0.523	#21	0.473	Not Required	Pass
201	0.059	0.394	0.057	0.021	0.005	0.399	#16	0.506	Not Required	Pass
202	0.001	0.494	0.128	0.104	0.023	0.589	#21	0.053	Not Required	Pass
203	0.010	0.678	0.098	0.070	0.026	0.781	#21	0.045	Not Required	Pass
204	0.011	0.649	0.141	0.065	0.030	0.717	#21	0.080	Not Required	Pass
205	0.010	0.420	0.159	0.067	0.039	0.460	#21	0.074	Not Required	Pass
206	0.006	0.470	0.021	0.046	0.003	0.482	#21	0.045	Not Required	Pass
207	0.005	0.292	0.048	0.047	0.012	0.298	#21	0.074	Not Required	Pass
208	0.000	0.019	0.036	0.016	0.005	0.055	#21	Not Required	Not Required	Pass
209	0.006	0.069	0.078	0.003	0.005	0.146	#21	0.204	Not Required	Pass
210	0.005	0.462	0.074	0.047	0.019	0.538	#21	0.080	Not Required	Pass
211	0.000	0.019	0.036	0.016	0.005	0.055	#21	Not Required	Not Required	Pass
212	0.002	0.279	0.090	0.068	0.018	0.346	#21	0.053	Not Required	Pass
213	0.006	0.116	0.367	0.058	0.020	0.431	#21	0.190	Not Required	Pass
214	0.004	0.110	0.360	0.055	0.020	0.416	#24	0.286	Not Required	Pass
215	0.009	0.359	0.202	0.044	0.016	0.562	#21	0.473	Not Required	Pass
216	0.004	0.345	0.201	0.042	0.016	0.543	#21	0.473	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

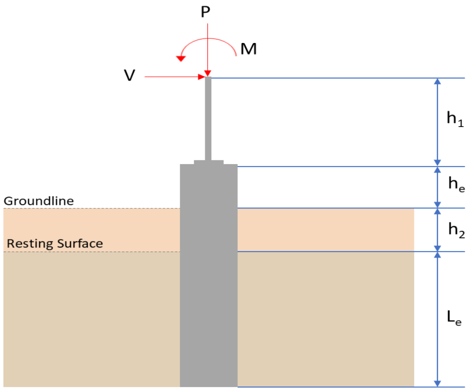
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 6\ \mathrm{ft}$ - 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)	6.878	10.608
V_x (kip)	-1.401	-2.357
V_z (kip)	0.368	0.569
M_x (kipft)	1.276	1.983
M_z (kipft)	19.258	32.838

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.401\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.22309\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(19.258\ \text{kipft}) + ((-1.401\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 3.0666\ \text{kipft/ft}$$

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:
$L_{e,x} = 5.5508\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.368\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.058599\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.276\ \text{kipft}) + ((0.368\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.20318\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 2.9916\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(5.5508\ \text{ft}), (2.9916\ \text{ft})]$$

$$L_{e,req} = 5.551\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 6\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(5.551\ \text{ft})}{(6\ \text{ft})}$$

$$Ratio = 0.92517$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(6.878\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.42987\ \text{kip/ft}^2$$

$q = 0.42987\ \mathrm{kip/ft}^2$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.42987\ \mathrm{kip/ft}^2)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.21494$$

Status: **PASS**
Ratio: **0.210**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(6\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1.5$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.22309\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 3.0666\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (3.0666\ \mathrm{kipft/ft}) \times (6\ \mathrm{ft})) + \left(3 \times (-0.22309\ \mathrm{kip/ft}) \times (6\ \mathrm{ft})^2\right)}{(6 \times (3.0666\ \mathrm{kipft/ft})) + (4 \times (-0.22309\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))}$$

$$a = 4.1127\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (3.0666\ \mathrm{kipft/ft})) + (3 \times (-0.22309\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))]^{\ 2}}{(6\ \mathrm{ft})^2 \times [(3 \times (3.0666\ \mathrm{kipft/ft})) + (2 \times (-0.22309\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))]}$$

$$p = 0.21743\ \mathrm{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (3.0666\ \mathrm{kipft/ft})) + ((-0.22309\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))]}{(6\ \mathrm{ft})^2}$$

$$s = 0.7991\ \mathrm{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.1127\ \mathrm{ft})}{2}$$

$$p_a = 0.30845\ \mathrm{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.21743\ \mathrm{kip/ft}^2)}{(0.30845\ \mathrm{kip/ft}^2)}$$

$$Ratio = 0.70489$$

Status: **PASS**
Ratio: **0.700**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6\ \mathrm{ft})$$

$$p_s = 0.9\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.7991\ \mathrm{kip/ft^2}\right)}{\left(0.9\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.88789$$

Status: **PASS**
Ratio: **0.890**

Considering z-direction:

$H_o = 0.058599\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.20318\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.20318\ \mathrm{kipft/ft}) \times (6\ \mathrm{ft})) + \left(3 \times (0.058599\ \mathrm{kip/ft}) \times (6\ \mathrm{ft})^2\right)}{(6 \times (0.20318\ \mathrm{kipft/ft})) + (4 \times (0.058599\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))}$$

$$a = 4.2678\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.20318\ \mathrm{kipft/ft})) + (3 \times (0.058599\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))]^{\,2}}{(6\ \mathrm{ft})^2 \times [(3 \times (0.20318\ \mathrm{kipft/ft})) + (2 \times (0.058599\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))]}$$

$$p = 0.055349\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.20318\ \mathrm{kipft/ft})) + ((0.058599\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))]}{(6\ \mathrm{ft})^2}$$

$$s = 0.12633\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.2678\ \mathrm{ft})}{2}$$

$$p_a = 0.32009\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.055349\ \mathrm{kip/ft^2}\right)}{\left(0.32009\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.17292$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6\ \mathrm{ft})$$

$$p_s = 0.9\ \mathrm{kip/ft^2}$$

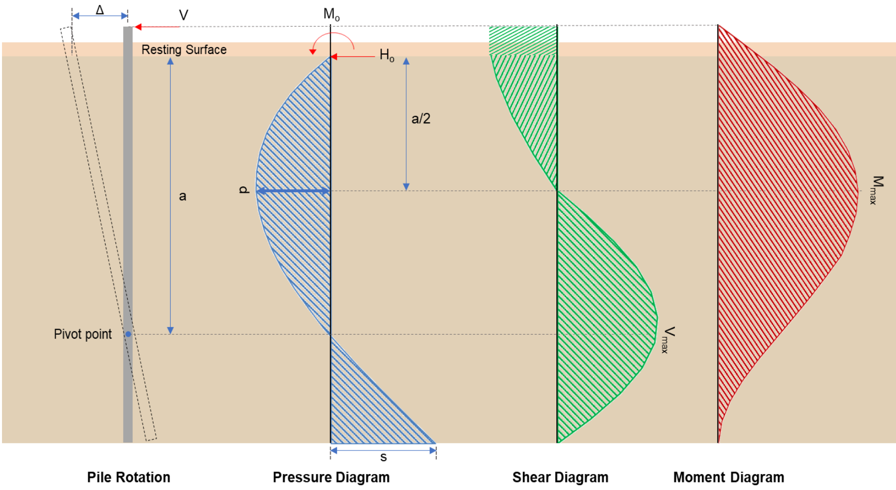
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.12633\ \mathrm{kip/ft^2})}{(0.9\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.14036$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.357\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.37532\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(32.838\ \mathrm{kipft}) + ((-2.357\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 5.229\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(5.229\ \mathrm{kipft/ft})}{(-0.37532\ \mathrm{kip/ft})}$$

$$E = 13.932\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.229\ \mathrm{kipft/ft}) \times (6\ \mathrm{ft})) + \left(3 \times (-0.37532\ \mathrm{kip/ft}) \times (6\ \mathrm{ft})^2\right)}{(6 \times (5.229\ \mathrm{kipft/ft})) + (4 \times (-0.37532\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))}$$

$$a = 4.1115\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.37532\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (13.932\ \mathrm{ft})}{(6\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.1115\ \mathrm{ft})}{(6\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (13.932\ \mathrm{ft})}{(6\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.1115\ \mathrm{ft})}{(6\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 7.1613\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.37532\ \text{kip/ft}) \times (48\ \text{in}) \times (6\ \text{ft})) \times \left[\left(\frac{(13.932\ \text{ft})}{(6\ \text{ft})} + \frac{(4.1115\ \text{ft})}{2 \times (6\ \text{ft})}\right) - \left[\left(\frac{4 \times (13.932\ \text{ft})}{(6\ \text{ft})} + 3\right) \times \left(\frac{(4.1115\ \text{ft})}{2 \times (6\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (13.932\ \text{ft})}{(6\ \text{ft})} + 2\right) \times \left(\frac{(4.1115\ \text{ft})}{2 \times (6\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 20.663\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.569\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.090605\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.983\ \text{kipft}) + ((0.569\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.31576\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.31576\ \text{kipft/ft})}{(0.090605\ \text{kip/ft})}$$

$$E = 3.4851\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.31576\ \text{kipft/ft}) \times (6\ \text{ft})) + \left(3 \times (0.090605\ \text{kip/ft}) \times (6\ \text{ft})^2\right)}{(6 \times (0.31576\ \text{kipft/ft})) + (4 \times (0.090605\ \text{kip/ft}) \times (6\ \text{ft}))}$$

$$a = 4.2672\ \text{ft}$$

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

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

$$V_{max} = ((0.090605\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.4851\ \text{ft})}{(6\ \text{ft})} + 3\right) \times \left(\frac{(4.2672\ \text{ft})}{(6\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.4851\ \text{ft})}{(6\ \text{ft})} + 2\right) \times \left(\frac{(4.2672\ \text{ft})}{(6\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.61343\ \text{kip}$$

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

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

$$M_{max} = ((0.090605\ \text{kip/ft}) \times (48\ \text{in}) \times (6\ \text{ft})) \times \left[\left(\frac{(3.4851\ \text{ft})}{(6\ \text{ft})} + \frac{(4.2672\ \text{ft})}{2 \times (6\ \text{ft})}\right) - \left[\left(\frac{4 \times (3.4851\ \text{ft})}{(6\ \text{ft})} + 3\right) \times \left(\frac{(4.2672\ \text{ft})}{2 \times (6\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.4851\ \text{ft})}{(6\ \text{ft})} + 2\right) \times \left(\frac{(4.2672\ \text{ft})}{2 \times (6\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 1.6459 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(10.608 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.244 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.244 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

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**	
22.4.2.2	**Axial Compression Strength (ACI 318-19, LRFD)** ϕP_N - Allowable axial compressive strength $$\phi P_N = \phi\, 0.80\, \left[\left(0.85\, f'_{ck}\, \left[A_g - A_{st}\right]\right) + \left(f_{yk}\, A_{st}\right)\right]$$ $$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \mathrm{ksi}) \times \left[\left(2304\ \mathrm{in}^2\right) - \left(4.2951\ \mathrm{in}^2\right)\right]\right) + \left((60\ \mathrm{ksi}) \times \left(4.2951\ \mathrm{in}^2\right)\right)\right]$$ $$\phi P_N = 2675.2\ \mathrm{kip}$$ $Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(10.608\ \mathrm{kip})}{(2675.2\ \mathrm{kip})}$$ $$Ratio = 0.0039653$$	Status: **PASS** Ratio: **0.000**
22.5.2.2 22.5.5.1.3 22.5.5.1.1 22.5.5.1.1(a) 22.5.5.1.2	**Shear Strength (ACI 318-19, LRFD)** **Parameters:** $b_w = 48\ \mathrm{in}$ - Effective width, d - Effective depth $$d = 0.80\, D$$ $$d = 0.80 \times (48\ \mathrm{in})$$ $$d = 38.4\ \mathrm{in}$$ λ_s - size effect modification factor $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1\right]$$ $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(38.4\ \mathrm{in})}{10}}}, 1\right]$$ $$\lambda_s = 0.64282$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \to 2500\ \mathrm{psi}$, $V_{c,max}$ - Max shear strength of concrete $$V_{c,max} = 5\, \lambda_s\, \sqrt{f'_{ck}}\, b_w\, d$$ $$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\ \mathrm{psi})} \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$ $$V_{c,max} = 296.21\ \mathrm{kip}$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \to 2500\ \mathrm{psi}$, $P = 10.608\ \mathrm{kip} \to 10608\ \mathrm{lbf}$, $V_{c,a}$ - Shear strength of concrete (a) $$V_{c,a} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \frac{P}{6\, A_g}\right]\, b_w\, d$$ $$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \mathrm{psi})} + \frac{(10608\ \mathrm{lbf})}{6 \times (2304\ \mathrm{in}^2)}\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$ $$V_{c,a} = 119.9\ \mathrm{kip}$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \to 2500\ \mathrm{psi}$, $V_{c,b}$ - Shear strength of concrete (b) $$V_{c,b} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \left(0.05\, f'_{ck}\right)\right]\, b_w\, d$$ $$V_{c,b} = \left[2 \times (0.64282) \times \sqrt{(2500\ \mathrm{psi})} + (0.05 \times (2500\ \mathrm{psi}))\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$ $$V_{c,b} = 348.89\ \mathrm{kip}$$ V_c - Governing shear strength of concrete $$V_c = Min\left[V_{c,max}, V_{c,a}, V_{c,b}\right]$$ $$V_c = Min\left[(296.21\ \mathrm{kip}), (119.9\ \mathrm{kip}), (348.89\ \mathrm{kip})\right]$$ $$V_c = 119.9\ \mathrm{kip}$$	

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.9\ \text{kip}) + (50.894\ \text{kip}))$$

$$\phi V_n = 111.02\ \text{kip}$$

Considering x-direction:

$V_{max} = 7.1613\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(7.1613\ \text{kip})}{(111.02\ \text{kip})}$$

$$Ratio = 0.064507$$

Status: **PASS**
Ratio: **0.060**

Considering z-direction:

$V_{max} = 0.61343\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.61343\ \text{kip})}{(111.02\ \text{kip})}$$

$$Ratio = 0.0055256$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

	$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f'_{ck}\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6 \text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$ $$\phi M_n = 249.6 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 20.663 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(20.663 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.082785$$	Status: **PASS** Ratio: **0.080**
	Considering z-direction: $M_{max} = 1.6459 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(1.6459 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.0065943$$	Status: **PASS** Ratio: **0.010**

REFERENCES	CALCULATIONS	RESULTS

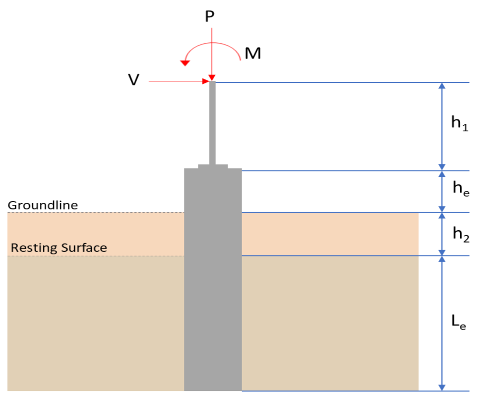
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48$ in - Pile width
$D = 48$ in - Pile depth
$L = 6$ ft - Total pile length
$h_1 = 0$ ft - Lateral load height from the top of the pile,
$h_2 = 0$ ft - Depth to resisting surface
$h_e = 0$ 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)	6.878	10.608
V_x (kip)	-1.401	-2.357
V_z (kip)	-0.368	-0.569
M_x (kipft)	-1.276	-1.984
M_z (kipft)	19.258	32.838

Material Properties

$f'_{ck} = 2.5$ 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,

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

$$H_o = \frac{(-1.401 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.22309 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(19.258\ \mathrm{kipft}) + ((-1.401\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 3.0666\ \mathrm{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 5.5508\ \mathrm{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.368\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.058599\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.276\ \mathrm{kipft}) + ((-0.368\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.20318\ \mathrm{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 2.0765\ \mathrm{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(5.5508\ \mathrm{ft}), (2.0765\ \mathrm{ft})]$$

$$L_{e,req} = 5.551\ \mathrm{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6\ \mathrm{ft}) - (0\ \mathrm{ft}) - (0\ \mathrm{ft})$$

$$L_e = 6\ \mathrm{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(5.551\ \mathrm{ft})}{(6\ \mathrm{ft})}$$

$$Ratio = 0.92517$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(6.878\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.42987\ \mathrm{kip/ft}^2$$

$$q = 0.42987\ \mathrm{kip/ft}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.42987\ \mathrm{kip/ft^2}\right)}{\left(2000\ \mathrm{psf}\right)}$$

$$Ratio = 0.21494$$

Status: **PASS**
Ratio: **0.210**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{\left(6\ \mathrm{ft}\right)}{\left(48\ \mathrm{in}\right)}$$

$$L/D = 1.5$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.22309\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 3.0666\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{\left(4 \times \left(3.0666\ \mathrm{kipft/ft}\right) \times \left(6\ \mathrm{ft}\right)\right) + \left(3 \times \left(-0.22309\ \mathrm{kip/ft}\right) \times \left(6\ \mathrm{ft}\right)^2\right)}{\left(6 \times \left(3.0666\ \mathrm{kipft/ft}\right)\right) + \left(4 \times \left(-0.22309\ \mathrm{kip/ft}\right) \times \left(6\ \mathrm{ft}\right)\right)}$$

$$a = 4.1127\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times \left[\left(4 \times \left(3.0666\ \mathrm{kipft/ft}\right)\right) + \left(3 \times \left(-0.22309\ \mathrm{kip/ft}\right) \times \left(6\ \mathrm{ft}\right)\right)\right]^2}{\left(6\ \mathrm{ft}\right)^2 \times \left[\left(3 \times \left(3.0666\ \mathrm{kipft/ft}\right)\right) + \left(2 \times \left(-0.22309\ \mathrm{kip/ft}\right) \times \left(6\ \mathrm{ft}\right)\right)\right]}$$

$$p = 0.21743\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times \left[\left(2 \times \left(3.0666\ \mathrm{kipft/ft}\right)\right) + \left(\left(-0.22309\ \mathrm{kip/ft}\right) \times \left(6\ \mathrm{ft}\right)\right)\right]}{\left(6\ \mathrm{ft}\right)^2}$$

$$s = 0.7991\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = \left(150\ \mathrm{psf/ft}\right) \times \frac{\left(4.1127\ \mathrm{ft}\right)}{2}$$

$$p_a = 0.30845\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.21743\ \mathrm{kip/ft^2}\right)}{\left(0.30845\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.70489$$

Status: **PASS**
Ratio: **0.700**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6\ \mathrm{ft})$$

$$p_s = 0.9\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.7991\ \mathrm{kip/ft^2}\right)}{\left(0.9\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.88789$$

Status: **PASS**
Ratio: **0.890**

Considering z-direction:

$H_o = -0.058599\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.20318\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.20318\ \mathrm{kipft/ft}) \times (6\ \mathrm{ft})) + \left(3 \times (-0.058599\ \mathrm{kip/ft}) \times (6\ \mathrm{ft})^2\right)}{(6 \times (0.20318\ \mathrm{kipft/ft})) + (4 \times (-0.058599\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))}$$

$$a = 4.2678\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.20318\ \mathrm{kipft/ft})) + (3 \times (-0.058599\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))]^{\ 2}}{(6\ \mathrm{ft})^2 \times [(3 \times (0.20318\ \mathrm{kipft/ft})) + (2 \times (-0.058599\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))]}$$

$$p = -0.013035\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.20318\ \mathrm{kipft/ft})) + ((-0.058599\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))]}{(6\ \mathrm{ft})^2}$$

$$s = 0.0091295\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.2678\ \mathrm{ft})}{2}$$

$$p_a = 0.32009\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.013035\ \mathrm{kip/ft^2}\right)}{\left(0.32009\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.040723$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6\ \mathrm{ft})$$

$$p_s = 0.9\ \mathrm{kip/ft^2}$$

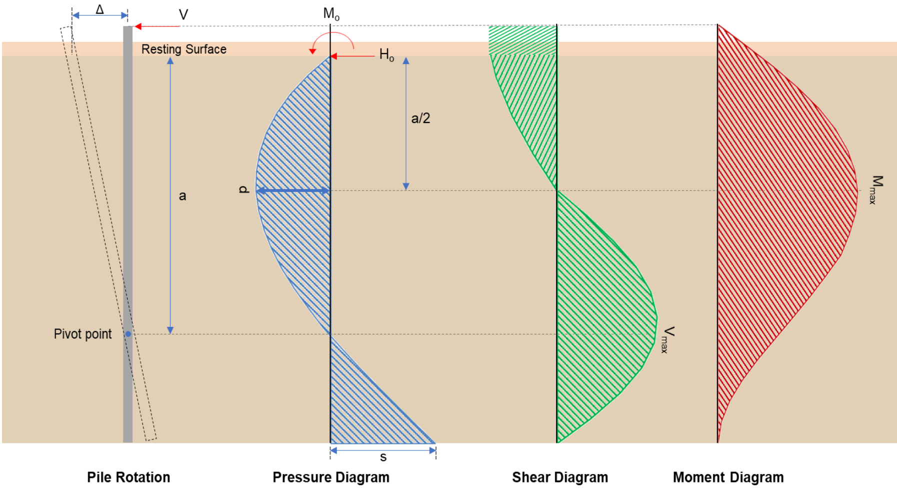
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0091295\ \mathrm{kip/ft^2}\right)}{\left(0.9\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.010144$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.357\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.37532\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(32.838\ \mathrm{kipft}) + ((-2.357\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 5.229\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(5.229\ \mathrm{kipft/ft})}{(-0.37532\ \mathrm{kip/ft})}$$

$$E = 13.932\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.229\ \mathrm{kipft/ft}) \times (6\ \mathrm{ft})) + \left(3 \times (-0.37532\ \mathrm{kip/ft}) \times (6\ \mathrm{ft})^2\right)}{(6 \times (5.229\ \mathrm{kipft/ft})) + (4 \times (-0.37532\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))}$$

$$a = 4.1115\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.37532\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (13.932\ \mathrm{ft})}{(6\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.1115\ \mathrm{ft})}{(6\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (13.932\ \mathrm{ft})}{(6\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.1115\ \mathrm{ft})}{(6\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 7.1613\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.37532 \text{ kip/ft}) \times (48 \text{ in}) \times (6 \text{ ft})) \times \left[\left(\frac{(13.932 \text{ ft})}{(6 \text{ ft})} + \frac{(4.1115 \text{ ft})}{2 \times (6 \text{ ft})}\right) - \left[\left(\frac{4 \times (13.932 \text{ ft})}{(6 \text{ ft})} + 3\right) \times \left(\frac{(4.1115 \text{ ft})}{2 \times (6 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (13.932 \text{ ft})}{(6 \text{ ft})} + 2\right) \times \left(\frac{(4.1115 \text{ ft})}{2 \times (6 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 20.663 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.569 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.090605 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.984 \text{ kipft}) + ((-0.569 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.31592 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.31592 \text{ kipft/ft})}{(-0.090605 \text{ kip/ft})}$$

$$E = 3.4868 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.31592 \text{ kipft/ft}) \times (6 \text{ ft})) + \left(3 \times (-0.090605 \text{ kip/ft}) \times (6 \text{ ft})^2\right)}{(6 \times (0.31592 \text{ kipft/ft})) + (4 \times (-0.090605 \text{ kip/ft}) \times (6 \text{ ft}))}$$

$$a = 4.2671 \text{ ft}$$

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

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

$$V_{max} = ((-0.090605 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.4868 \text{ ft})}{(6 \text{ ft})} + 3\right) \times \left(\frac{(4.2671 \text{ ft})}{(6 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.4868 \text{ ft})}{(6 \text{ ft})} + 2\right) \times \left(\frac{(4.2671 \text{ ft})}{(6 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.61362 \text{ kip}$$

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

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

$$M_{max} = ((-0.090605 \text{ kip/ft}) \times (48 \text{ in}) \times (6 \text{ ft})) \times \left[\left(\frac{(3.4868 \text{ ft})}{(6 \text{ ft})} + \frac{(4.2671 \text{ ft})}{2 \times (6 \text{ ft})}\right) - \left[\left(\frac{4 \times (3.4868 \text{ ft})}{(6 \text{ ft})} + 3\right) \times \left(\frac{(4.2671 \text{ ft})}{2 \times (6 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.4868 \text{ ft})}{(6 \text{ ft})} + 2\right) \times \left(\frac{(4.2671 \text{ ft})}{2 \times (6 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 1.6465 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(10.608 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.244 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.244 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

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

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

	Axial Compression Strength (ACI 318-19, LRFD)	
22.4.2.2	ϕP_N - Allowable axial compressive strength $$\phi P_N = \phi\, 0.80\, \left[\left(0.85\, f'_{ck}\, \left[A_g - A_{st}\right]\right) + \left(f_{yk}\, A_{st}\right)\right]$$ $$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(2304\ \text{in}^2\right) - \left(4.2951\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(4.2951\ \text{in}^2\right)\right)\right]$$ $$\phi P_N = 2675.2\ \text{kip}$$	
	$Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(10.608\ \text{kip})}{(2675.2\ \text{kip})}$$ $$Ratio = 0.0039653$$	Status: **PASS** Ratio: **0.000**

	Shear Strength (ACI 318-19, LRFD)	
	Parameters:	
	$b_w = 48\ \text{in}$ - Effective width,	
22.5.2.2	d - Effective depth $$d = 0.80\, D$$ $$d = 0.80 \times (48\ \text{in})$$ $$d = 38.4\ \text{in}$$	
22.5.5.1.3	λ_s - size effect modification factor $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1\right]$$ $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(38.4\ \text{in})}{10}}}, 1\right]$$ $$\lambda_s = 0.64282$$	
	The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,	
22.5.5.1.1	$V_{c,max}$ - Max shear strength of concrete $$V_{c,max} = 5\, \lambda_s\, \sqrt{f'_{ck}}\, b_w\, d$$ $$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$ $$V_{c,max} = 296.21\ \text{kip}$$	
	The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 10.608\ \text{kip} \rightarrow 10608\ \text{lbf}$,	
22.5.5.1.1(a)	$V_{c,a}$ - Shear strength of concrete (a) $$V_{c,a} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \frac{P}{6\, A_g}\right]\, b_w\, d$$ $$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(10608\ \text{lbf})}{6 \times \left(2304\ \text{in}^2\right)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$ $$V_{c,a} = 119.9\ \text{kip}$$	
	The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,	
22.5.5.1.2	$V_{c,b}$ - Shear strength of concrete (b) $$V_{c,b} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \left(0.05\, f'_{ck}\right)\right]\, b_w\, d$$ $$V_{c,b} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + (0.05 \times (2500\ \text{psi}))\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$ $$V_{c,b} = 348.89\ \text{kip}$$	
	V_c - Governing shear strength of concrete $$V_c = Min\left[V_{c,max}, V_{c,a}, V_{c,b}\right]$$ $$V_c = Min\left[(296.21\ \text{kip}), (119.9\ \text{kip}), (348.89\ \text{kip})\right]$$ $$V_c = 119.9\ \text{kip}$$	

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.9\ \mathrm{kip}) + (50.894\ \mathrm{kip}))$$

$$\phi V_n = 111.02\ \mathrm{kip}$$

Considering x-direction:

$V_{max} = 7.1613\ \mathrm{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(7.1613\ \mathrm{kip})}{(111.02\ \mathrm{kip})}$$

$$Ratio = 0.064507$$

Status: **PASS**
Ratio: **0.060**

Considering z-direction:

$V_{max} = 0.61362\ \mathrm{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.61362\ \mathrm{kip})}{(111.02\ \mathrm{kip})}$$

$$Ratio = 0.0055273$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

	$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \mathrm{ksi}) \times \left(18432\ \mathrm{in}^3\right)$$ $$\phi M_{n,2} = 2121.6\ \mathrm{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\ \mathrm{kipft}), (2121.6\ \mathrm{kipft})]$$ $$\phi M_n = 249.6\ \mathrm{kipft}$$ **Considering x-direction:** $M_{max} = 20.663\ \mathrm{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(20.663\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$ $$Ratio = 0.082785$$	Status: **PASS** Ratio: **0.080**
	Considering z-direction: $M_{max} = 1.6465\ \mathrm{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(1.6465\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$ $$Ratio = 0.0065965$$	Status: **PASS** Ratio: **0.010**

REFERENCES	CALCULATIONS	RESULTS

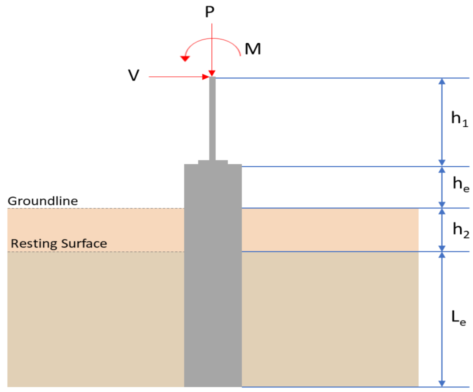
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48$ in - Pile width
$D = 48$ in - Pile depth
$L = 6.25$ ft - Total pile length
$h_1 = 0$ ft - Lateral load height from the top of the pile,
$h_2 = 0$ ft - Depth to resisting surface
$h_e = 0$ ft - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	9.340	14.469
V_x (kip)	-1.904	-3.204
V_z (kip)	0.000	0.000
M_x (kipft)	0.000	0.000
M_z (kipft)	23.245	39.247

Material Properties

$f'_{ck} = 2.5$ 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,

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

$$H_o = \frac{(-1.904 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.30318 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(23.245 \text{ kipft}) + ((-1.904 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 3.7014 \text{ kipft/ft}$$

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:
$L_{e,x} = 5.762 \text{ ft}$ - 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,

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

$$L_{e,req} = MAX[(5.762 \text{ ft}), (0 \text{ ft})]$$

$$L_{e,req} = 5.762 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6.25 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 6.25 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(5.762 \text{ ft})}{(6.25 \text{ ft})}$$

$$Ratio = 0.92192$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\,D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(9.34 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.58375 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.58375 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.29187$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(6.25 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.5625$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.30318\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 3.7014\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (3.7014\ \mathrm{kipft/ft}) \times (6.25\ \mathrm{ft})) + \left(3 \times (-0.30318\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft})^2\right)}{(6 \times (3.7014\ \mathrm{kipft/ft})) + (4 \times (-0.30318\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))}$$

$$a = 4.2992\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (3.7014\ \mathrm{kipft/ft})) + (3 \times (-0.30318\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]^2}{(6.25\ \mathrm{ft})^2 \times [(3 \times (3.7014\ \mathrm{kipft/ft})) + (2 \times (-0.30318\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]}$$

$$p = 0.21838\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (3.7014\ \mathrm{kipft/ft})) + ((-0.30318\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]}{(6.25\ \mathrm{ft})^2}$$

$$s = 0.84602\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.2992\ \mathrm{ft})}{2}$$

$$p_a = 0.32244\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.21838\ \mathrm{kip/ft^2})}{(0.32244\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.67726$$

Status: **PASS**
Ratio: **0.680**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6.25\ \mathrm{ft})$$

$$p_s = 0.9375\ \mathrm{kip/ft^2}$$

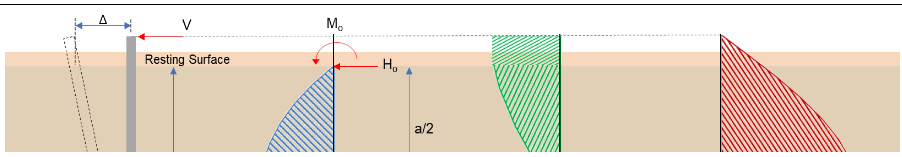
$Ratio$ - Lateral soil capacity

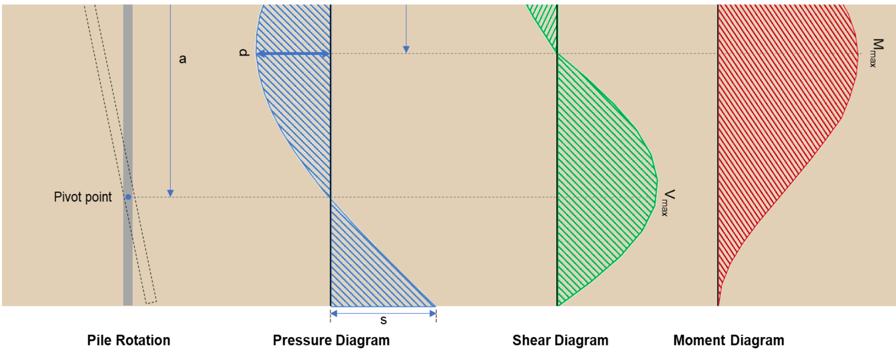
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{(0.84602\ \mathrm{kip/ft^2})}{(0.9375\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.90242$$

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





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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.204 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.51019 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(39.247 \text{ kipft}) + ((-3.204 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 6.2495 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(6.2495 \text{ kipft/ft})}{(-0.51019 \text{ kip/ft})}$$

$$E = 12.249 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.2495 \text{ kipft/ft}) \times (6.25 \text{ ft})) + \left(3 \times (-0.51019 \text{ kip/ft}) \times (6.25 \text{ ft})^2\right)}{(6 \times (6.2495 \text{ kipft/ft})) + (4 \times (-0.51019 \text{ kip/ft}) \times (6.25 \text{ ft}))}$$

$$a = 4.2989 \text{ ft}$$

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

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

$$V_{max} = ((-0.51019 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.249 \text{ ft})}{(6.25 \text{ ft})} + 3\right) \times \left(\frac{(4.2989 \text{ ft})}{(6.25 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (12.249 \text{ ft})}{(6.25 \text{ ft})} + 2\right) \times \left(\frac{(4.2989 \text{ ft})}{(6.25 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 8.4246 \text{ kip}$$

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

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

$$M_{max} = ((-0.51019 \text{ kip/ft}) \times (48 \text{ in}) \times (6.25 \text{ ft})) \times \left[\left(\frac{(12.249 \text{ ft})}{(6.25 \text{ ft})} + \frac{(4.2989 \text{ ft})}{2 \times (6.25 \text{ ft})}\right) - \left[\left(\frac{4 \times (12.249 \text{ ft})}{(6.25 \text{ ft})} + 3\right) \times \left(\frac{(4.2989 \text{ ft})}{2 \times (6.25 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (12.249 \text{ ft})}{(6.25 \text{ ft})} + 2\right) \times \left(\frac{(4.2989 \text{ ft})}{2 \times (6.25 \text{ ft})}\right)^4\right]\right]$$

	$M_{max} = 25.167 \text{ kipft}$		

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(14.469 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.115 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.115 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

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**		

22.4.2.2	**Axial Compression Strength (ACI 318-19, LRFD)** ϕP_N - Allowable axial compressive strength $$\phi P_N = \phi\, 0.80\ \left[\left(0.85\, f'_{ck}\ \left[A_g - A_{st}\right]\right) + \left(f_{yk}\, A_{st}\right)\right]$$ $$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \mathrm{ksi}) \times \left[\left(2304\ \mathrm{in}^2\right) - \left(4.2951\ \mathrm{in}^2\right)\right]\right) + \left((60\ \mathrm{ksi}) \times \left(4.2951\ \mathrm{in}^2\right)\right)\right]$$ $$\phi P_N = 2675.2\ \mathrm{kip}$$ $Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(14.469\ \mathrm{kip})}{(2675.2\ \mathrm{kip})}$$ $$Ratio = 0.0054086$$	Status: **PASS** Ratio: **0.010**
22.5.2.2 22.5.5.1.3 22.5.5.1.1 22.5.5.1.1(a) 22.5.5.1.2	**Shear Strength (ACI 318-19, LRFD)** **Parameters:** $b_w = 48\ \mathrm{in}$ - Effective width, d - Effective depth $$d = 0.80\ D$$ $$d = 0.80 \times (48\ \mathrm{in})$$ $$d = 38.4\ \mathrm{in}$$ λ_s - size effect modification factor $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1\right]$$ $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(38.4\ \mathrm{in})}{10}}}, 1\right]$$ $$\lambda_s = 0.64282$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$, $V_{c,max}$ - Max shear strength of concrete $$V_{c,max} = 5\ \lambda_s\ \sqrt{f'_{ck}}\ b_w\ d$$ $$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\ \mathrm{psi})} \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$ $$V_{c,max} = 296.21\ \mathrm{kip}$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$, $P = 14.469\ \mathrm{kip} \rightarrow 14469\ \mathrm{lbf}$, $V_{c,a}$ - Shear strength of concrete (a) $$V_{c,a} = \left[2\ \lambda_s\ \sqrt{f'_{ck}} + \frac{P}{6\ A_g}\right]\ b_w\ d$$ $$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \mathrm{psi})} + \frac{(14469\ \mathrm{lbf})}{6 \times (2304\ \mathrm{in}^2)}\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$ $$V_{c,a} = 120.41\ \mathrm{kip}$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$, $V_{c,b}$ - Shear strength of concrete (b) $$V_{c,b} = \left[2\ \lambda_s\ \sqrt{f'_{ck}} + \left(0.05\ f'_{ck}\right)\right]\ b_w\ d$$ $$V_{c,b} = \left[2 \times (0.64282) \times \sqrt{(2500\ \mathrm{psi})} + (0.05 \times (2500\ \mathrm{psi}))\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$ $$V_{c,b} = 348.89\ \mathrm{kip}$$ V_c - Governing shear strength of concrete $$V_c = Min\left[V_{c,max}, V_{c,a}, V_{c,b}\right]$$ $$V_c = Min\left[(296.21\ \mathrm{kip}), (120.41\ \mathrm{kip}), (348.89\ \mathrm{kip})\right]$$ $$V_c = 120.41\ \mathrm{kip}$$	

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((120.41\ \mathrm{kip}) + (50.894\ \mathrm{kip}))$$

$$\phi V_n = 111.35\ \mathrm{kip}$$

Considering x-direction:

$V_{max} = 8.4246\ \mathrm{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(8.4246\ \mathrm{kip})}{(111.35\ \mathrm{kip})}$$

$$Ratio = 0.075658$$

Status: **PASS**
Ratio: **0.080**

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

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

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

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

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

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

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

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

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

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

Therefore,
ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 25.167\ \mathrm{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(25.167\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$

$$Ratio = 0.10083$$

Status: **PASS**
Ratio: **0.100**