Your Project Calculations

Project Name: OtterTailSolar-RevA

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=OtterTailSolar-RevA&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/5_2023

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=dm2lKRkngCqkzBkR4pjnQxz1RToqYzTYO06dycYe4a2PV4W6oGHtIkY31QglqOJt

Array Specification

Product:	Beam
Unique ID:	3P-22.5-10TOP-XD-72-L-4Hx9W-HB1L
Duty Classification:	XD
Module Width:	40.63 in
Module Length:	86.81in
Number of Rows:	4
Number of Columns:	9
Total Number of Modules:	36
Desired Tilt Angle:	35
Front Edge Clearance:	4
Total Array Height at Tilt:	11.82 ft
Total Frame Length:	64.50 ft
Frame Weight:	3330 lbs
Array Dimensions N/S:	13.71 ft
Array Dimensions E/W:	65.86 ft
Rail Length:	164.52 in
Rail Spacing:	3.66 ft
Rail Check:	PASS (50% utilized)

Support Specifications

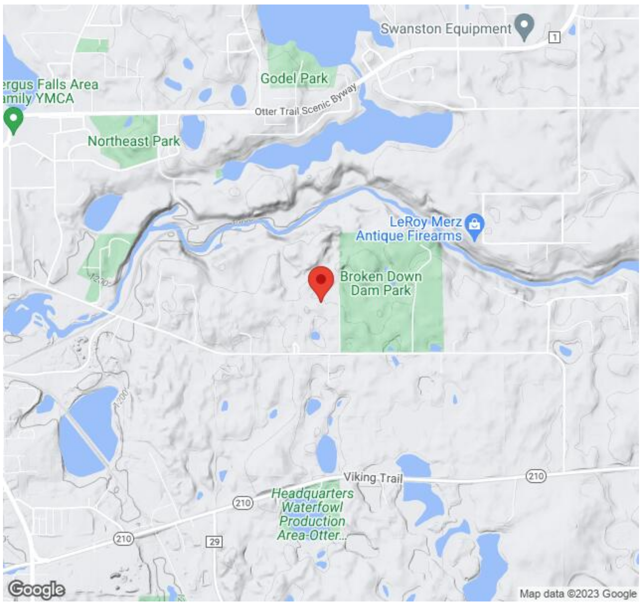
Pole Size:	10in Pipe Sch 40
Pole Length above Grade:	7.93 ft
Number of Poles:	3
Pole Spacing:	22.5 ft

Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 6.25 ft Pile 2: 6.50 ft Pile 3: 6.25 ft
Foundation Volume:	11.259 y^3
Foundation Result:	PASSED
Mount Twist:	0.415356 kip

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	2701 Main St, Fergus Falls, MN 56537, USA
Wind Speed:	105 mph
Snow Load:	50 psf
Design Uplift Pressure:	Multiple pressures
Design Downforce Pressure:	Multiple pressures
Design Snow Pressure:	0.019244 ksf



Design Disclaimer

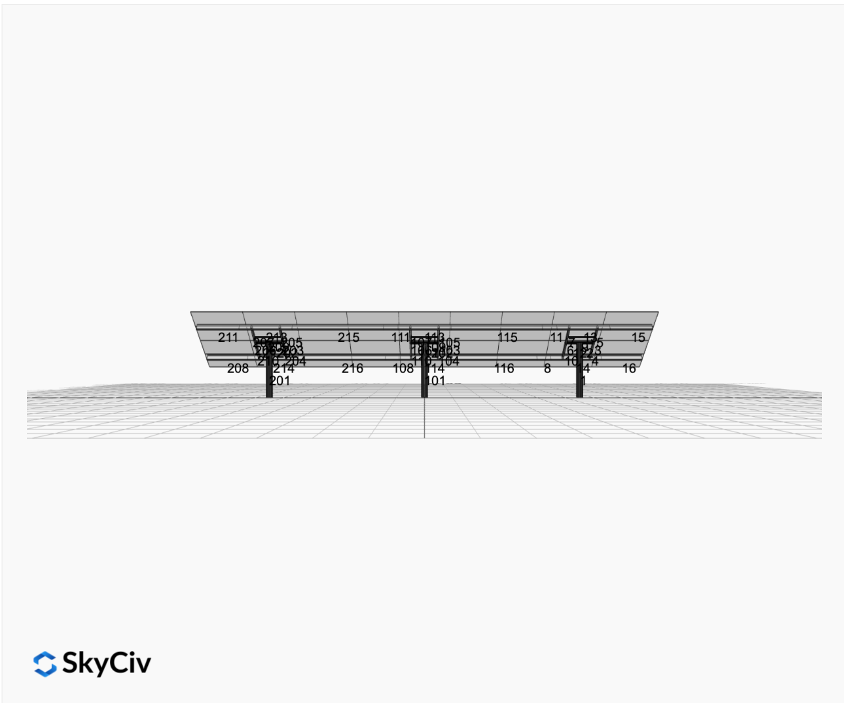
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

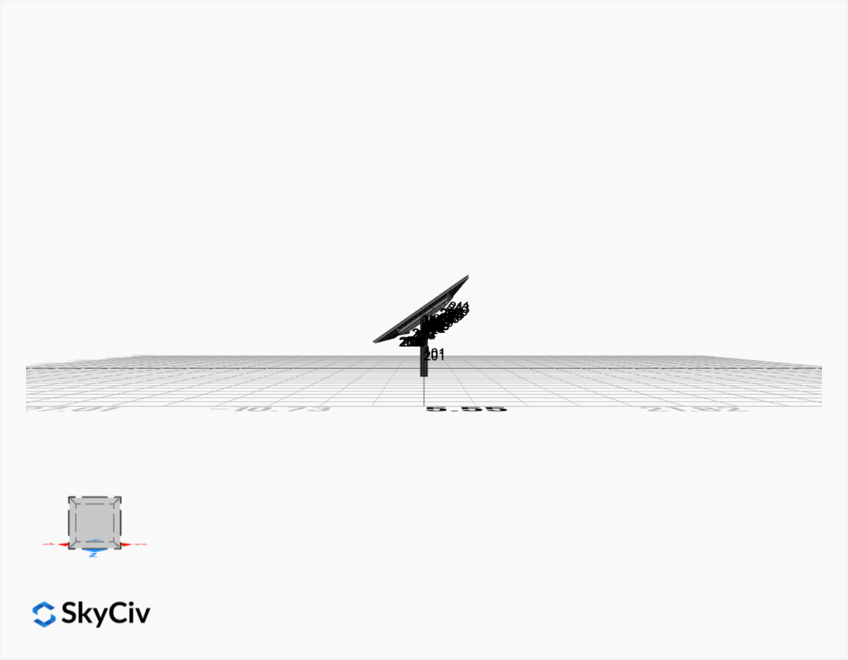
AutoDesigner Input

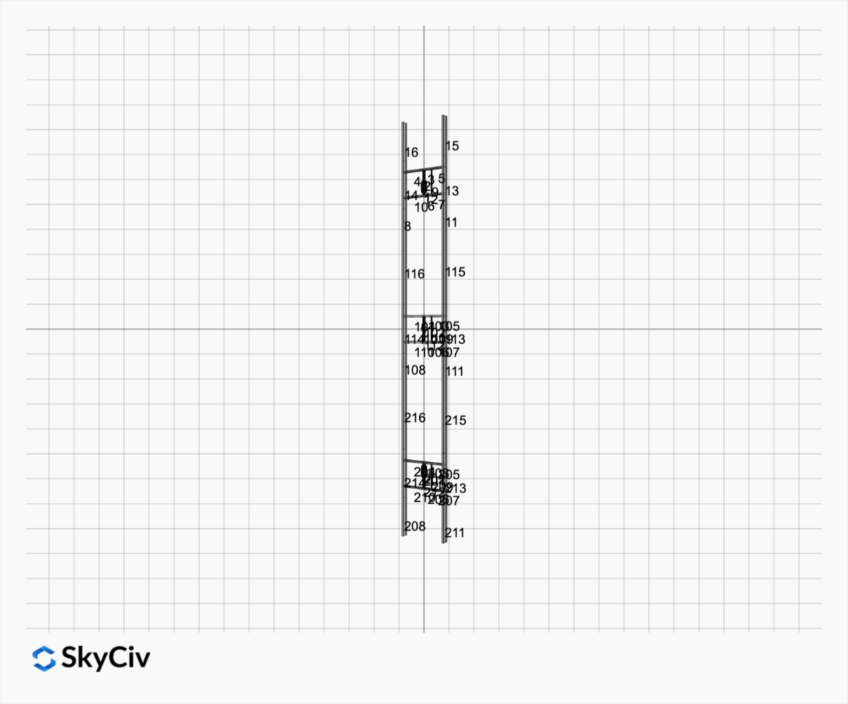
{"wind_speed_override":null,"snow_load_override":null,"direct_snow_load":false,"product_type":"Beam","project_id":"OtterTailSolar-RevA","site_address":"2701 Main St, Fergus Falls, MN 56537, USA","module_width":40.63,"module_length":86.81,"number_rows":"4","number_columns":9,"pole_mount_section":"4_40","core_pipe_width":65,"core_pipe_section":"2_40","adjuster_section":"2_40","core_beam_height":65,"core_beam_section":"HSS3x2x1/8","main_pipe_section":"2_12GA","pole_spacing":"15","tilt_angle":35,"ground_clearance":4,"risk_category":"I","exposure_category":"C","frame_duty_override":"XD","pole_override":"auto","soil_type":"sand","foundation_type":"Square","foundation_size":48,"check_rails":true}

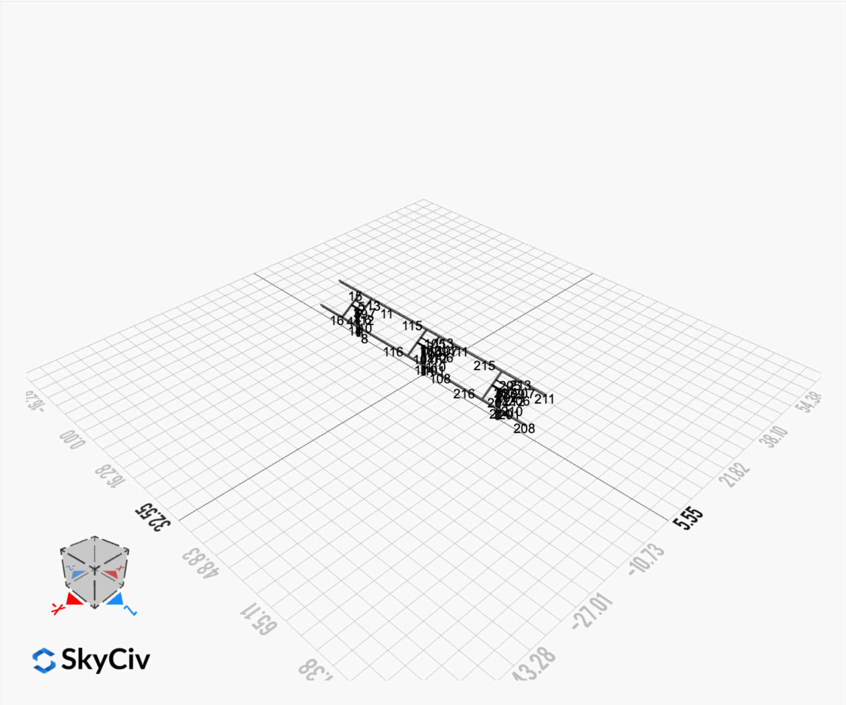
Design Notes:

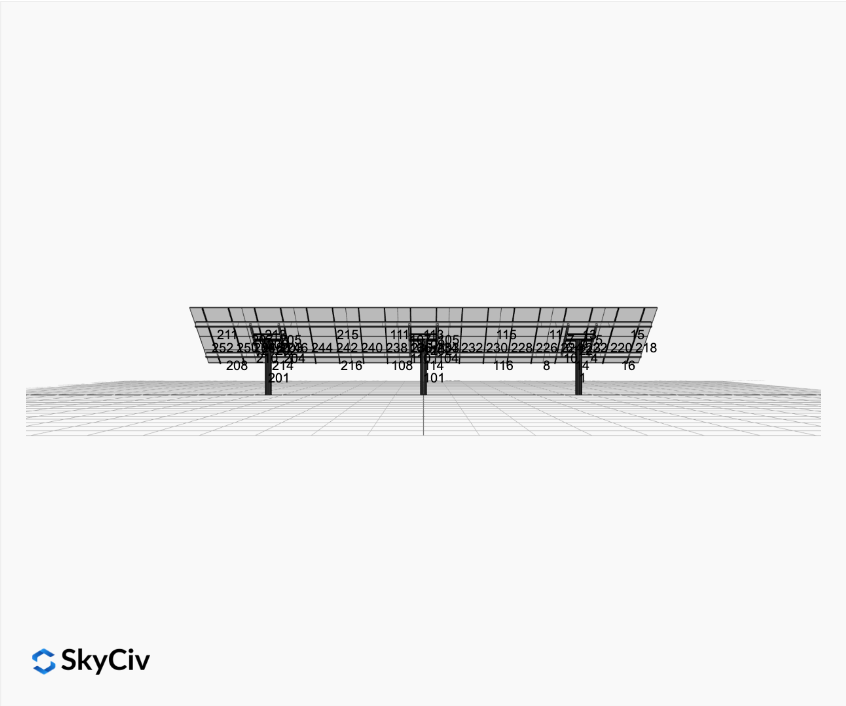
- AISC Deflection checks are set to L/1 due to structure design intent





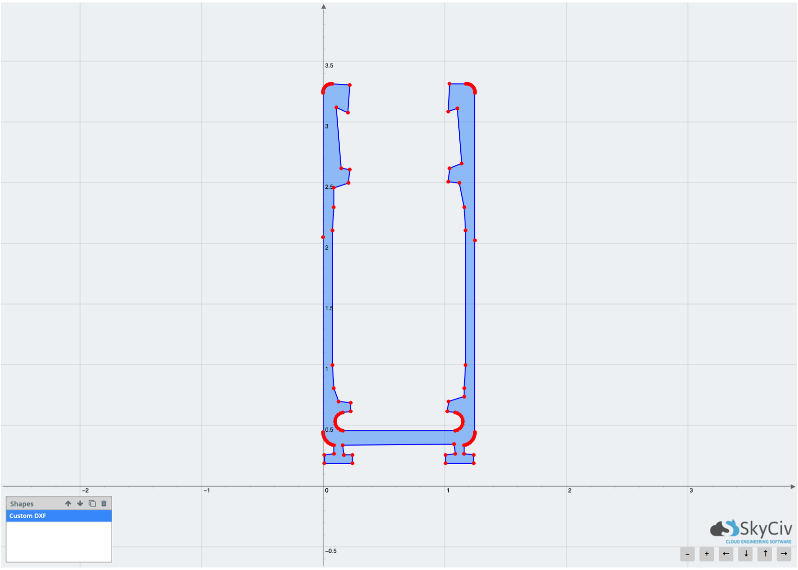




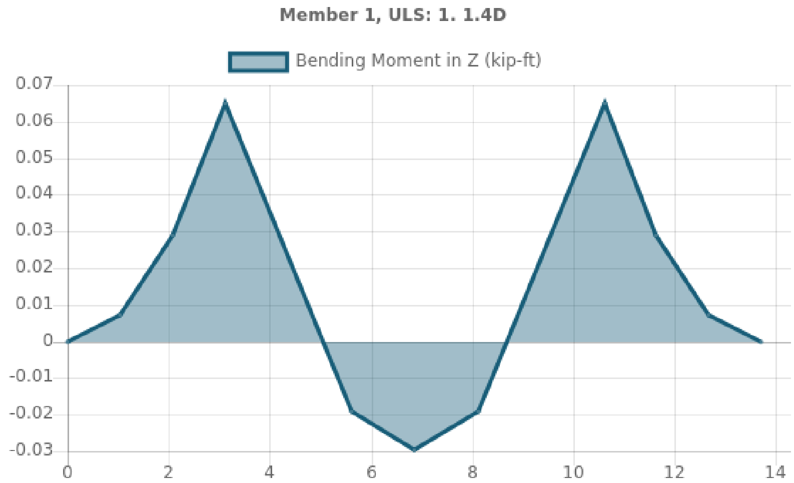


Rail Design Check

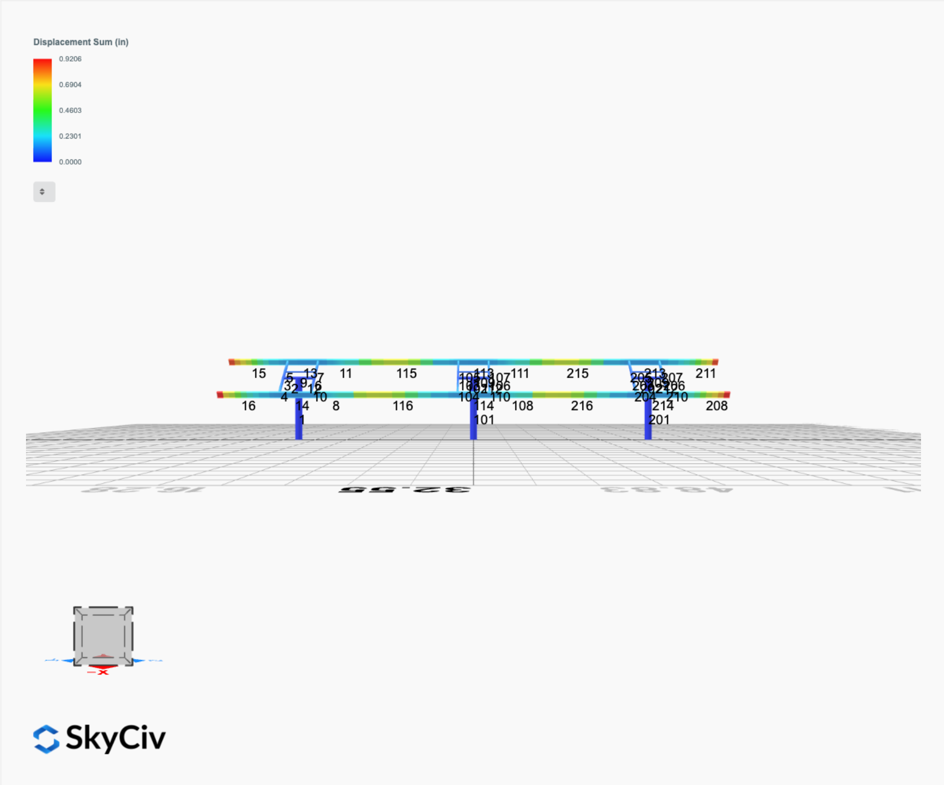
Rail Length: 13.71 ft
Additional Restraints Required: None
Tributary Width: 3.65875 ft
Material: Aluminium
Density: 169 lb/ft^3
Elasticity Modulus: 10000 ksi
Fy: 34.5 ksi
Fu: 37 ksi
Snow (X): 0.0577 kip/ft
Snow (Y): -0.0404 kip/ft
Wind uplift Case A: 0.1088 kip/ft
Wind uplift Case A: 0.1088 kip/ft
Wind uplift Case B (X): 0.0000 kip/ft
Wind uplift Case B (Y): 0.1471 kip/ft

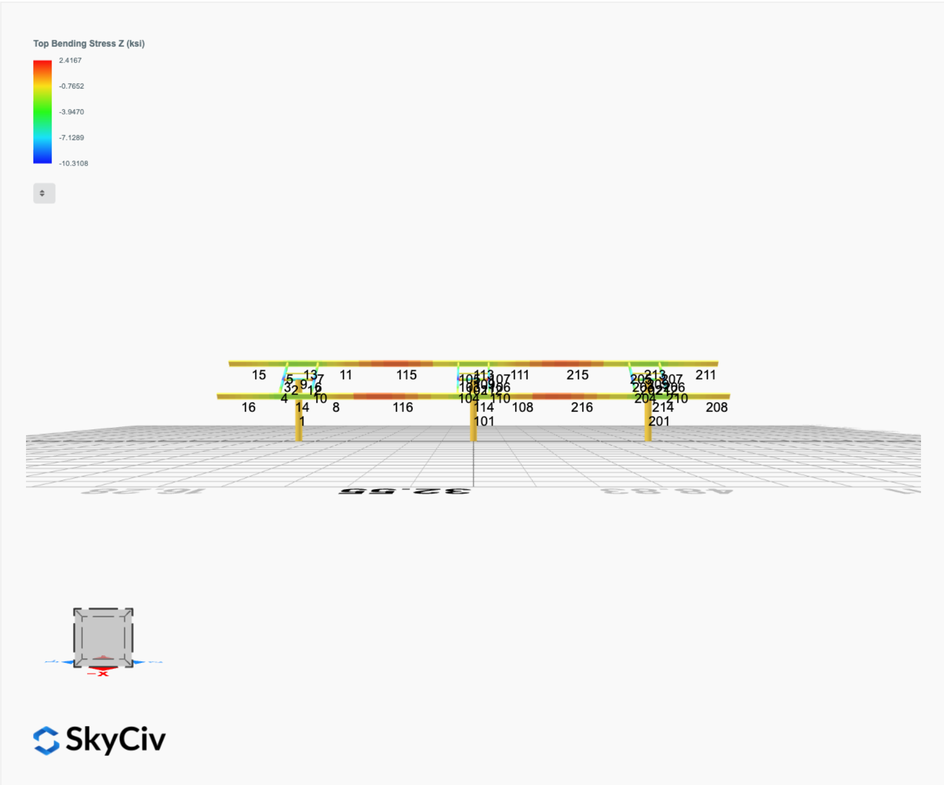


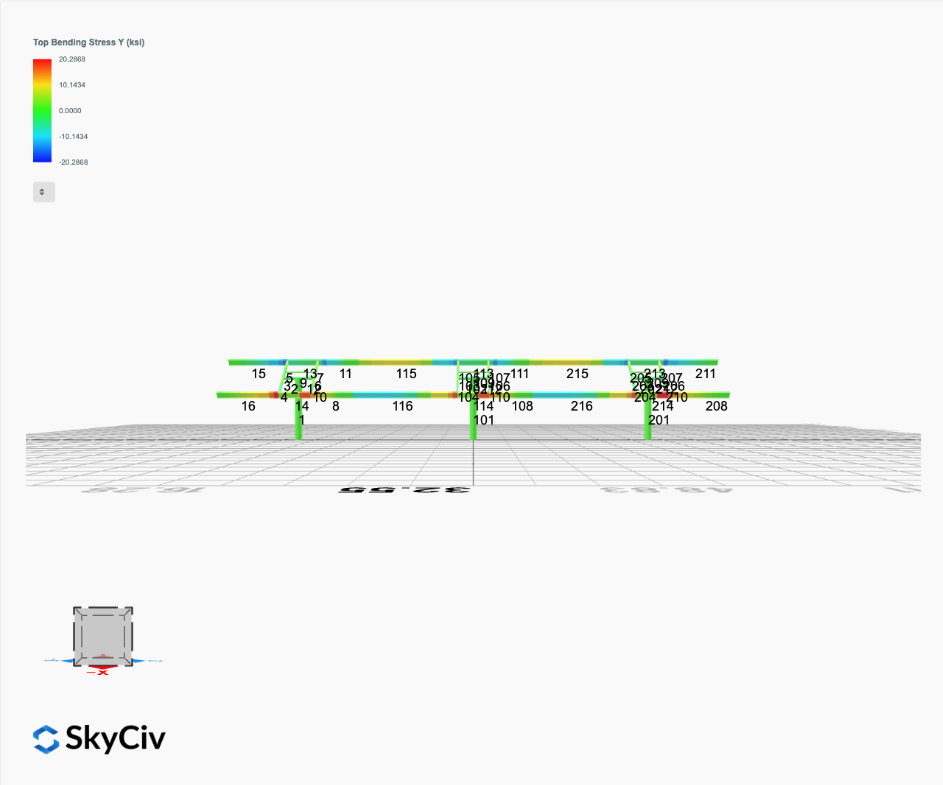
Result Check	Max Limit	Max Value	Utility	Status
Custom Stress Limit	34.5	17.12370379	0.496	PASS
Material Yield	34.5	17.12370379	0.496	PASS
Material Strength	37	17.12370379	0.463	PASS

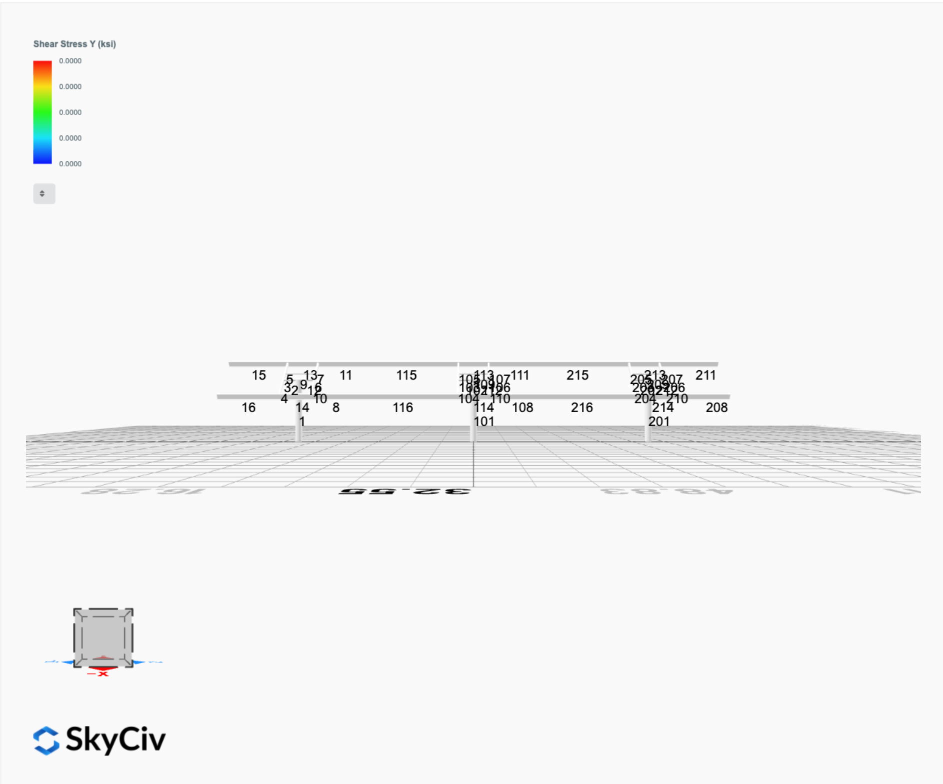


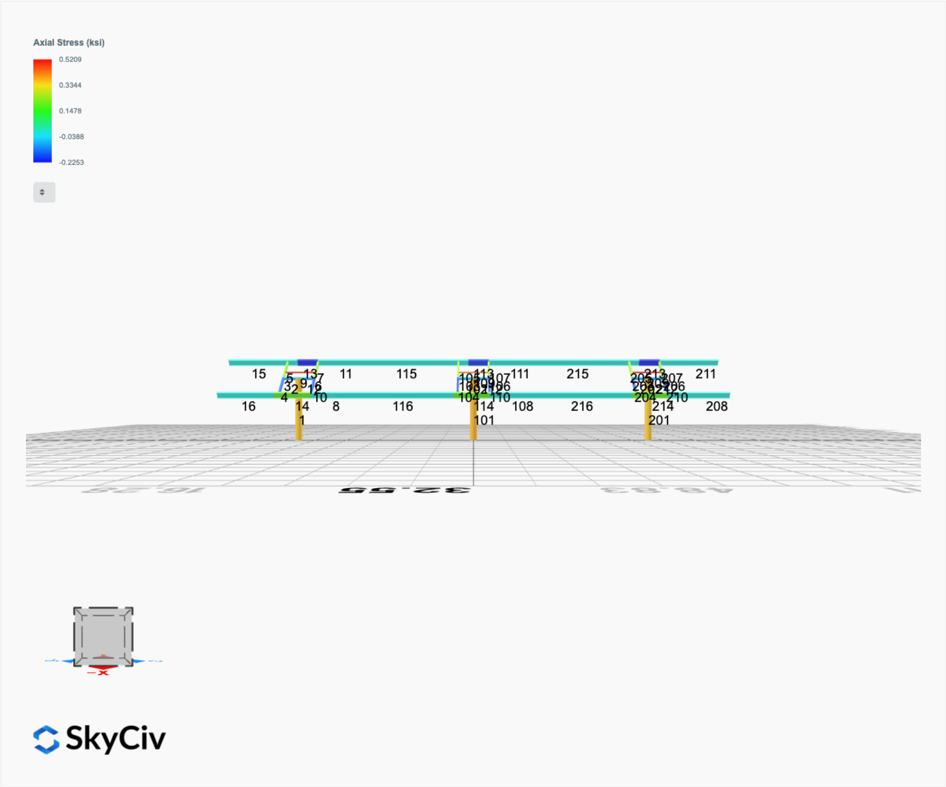
FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
20.2868
10.1434
0.0000
-10.1434
-20.2868
15
11
115
111
215
211
16
8
116
108
216
208
14
1
114
101
214
201
SkyCiv


Shear Stress Y (ksi)
0.0000
0.0000
0.0000
0.0000
0.0000
15
11
115
111
215
211
16
8
116
108
216
208
14
1
114
101
214
201
SkyCiv


Axial Stress (ksi)
0.5209
0.3344
0.1478
-0.0388
-0.2253
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	-0.0083	2.4616	-0.0044	0.0052	0.0629	0.0911
ULS: 2. D + L	-0.0083	2.4616	-0.0044	0.0052	0.0629	0.0911
ULS: 3. D + (S or Lr or R)	-0.0283	7.0290	-0.0148	0.0187	0.2154	0.2631
ULS: 3. D + (S or Lr or R)	-0.0083	2.4616	-0.0044	0.0052	0.0629	0.0911
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0233	5.8871	-0.0122	0.0153	0.1773	0.2201
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0083	2.4616	-0.0044	0.0052	0.0629	0.0911
ULS: 5b. D + 0.7E	-0.0083	2.4616	-0.0044	0.0052	0.0629	0.0911
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0233	5.8871	-0.0122	0.0153	0.1773	0.2201
ULS: 8. 0.6D + 0.7E	-0.0050	1.4770	-0.0027	0.0031	0.0378	0.0547
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.6127	7.6076	-0.0346	-0.0103	0.1781	29.2261
ULS: 5a. D + 0.6W_Wind downforce Case B only	-3.6127	7.6076	-0.0346	-0.0103	0.1781	29.2261
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.0328	-1.8802	0.0210	0.0182	-0.0346	-23.9290
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.5273	-1.1578	0.0154	0.0155	-0.0120	-30.2181
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.7266	9.7466	-0.0349	0.0037	0.2637	22.0713
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.7266	9.7466	-0.0349	0.0037	0.2637	22.0713
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.2576	2.6308	0.0069	0.0252	0.1041	-17.7950
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.8784	3.1726	0.0026	0.0231	0.1210	-22.5118
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.7116	6.3211	-0.0271	-0.0064	0.1493	21.9423
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.7116	6.3211	-0.0271	-0.0064	0.1493	21.9423
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.2726	-0.7947	0.0147	0.0150	-0.0102	-17.9240
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.8934	-0.2529	0.0104	0.0129	0.0067	-22.6408
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.6094	6.6230	-0.0329	-0.0124	0.1529	29.1896
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-3.6094	6.6230	-0.0329	-0.0124	0.1529	29.1896
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.0362	-2.8649	0.0228	0.0162	-0.0597	-23.9655
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.5307	-2.1425	0.0171	0.0134	-0.0372	-30.2545

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	14.5501
Shear X	-6.0274
Shear Z	-0.0610
Moment X	0.0388
Moment Y (Twist)	0.4154
Moment Z	50.5539

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	9.7466
Shear X	-3.6127
Shear Z	-0.0349
Moment X	0.0252
Moment Y (Twist)	0.2637
Moment Z	30.2545

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	0.0166	2.5585	-0.0000	0.0000	0.0000	-0.0965
ULS: 2. D + L	0.0166	2.5585	-0.0000	0.0000	0.0000	-0.0965
ULS: 3. D + (S or Lr or R)	0.0566	7.3633	-0.0000	0.0000	-0.0000	-0.3782
ULS: 3. D + (S or Lr or R)	0.0166	2.5585	-0.0000	0.0000	0.0000	-0.0965
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0466	6.1621	-0.0000	0.0000	-0.0000	-0.3078
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0166	2.5585	-0.0000	0.0000	0.0000	-0.0965
ULS: 5b. D + 0.7E	0.0166	2.5585	-0.0000	0.0000	0.0000	-0.0965

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0466	6.1621	-0.0000	0.0000	-0.0000	-0.3078
ULS: 8. 0.6D + 0.7E	0.0099	1.5351	-0.0000	0.0000	0.0000	-0.0579
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.7294	7.9115	-0.0000	0.0000	0.0000	30.1471
ULS: 5a. D + 0.6W_Wind downforce Case B only	-3.7294	7.9115	-0.0000	0.0000	0.0000	30.1471
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.1774	-1.9584	-0.0000	0.0000	0.0000	-25.0251
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.6479	-1.2031	-0.0000	0.0000	0.0000	-31.4826
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.7629	10.1769	-0.0000	0.0000	-0.0000	22.3750
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.7629	10.1769	-0.0000	0.0000	-0.0000	22.3750
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.4172	2.7744	-0.0000	0.0000	-0.0000	-19.0041
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.0201	3.3409	-0.0000	0.0000	-0.0000	-23.8473
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.7929	6.5733	-0.0000	0.0000	0.0000	22.5862
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.7929	6.5733	-0.0000	0.0000	0.0000	22.5862
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.3872	-0.8292	-0.0000	0.0000	0.0000	-18.7929
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.9901	-0.2627	-0.0000	0.0000	0.0000	-23.6361
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.7360	6.8882	-0.0000	0.0000	0.0000	30.1857
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-3.7360	6.8882	-0.0000	0.0000	0.0000	30.1857
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.1708	-2.9818	-0.0000	0.0000	0.0000	-24.9864
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.6413	-2.2265	-0.0000	0.0000	0.0000	-31.4440

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	15.2187
Shear X	-6.2433
Shear Z	-0.0000
Moment X	0.0003
Moment Y (Twist)	0.0001
Moment Z	52.8166

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	10.1769
Shear X	-3.7360
Shear Z	-0.0000
Moment X	0.0000
Moment Y (Twist)	0.0000
Moment Z	31.4826

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	-0.0083	2.4616	0.0044	-0.0051	-0.0629	0.0911
ULS: 2. D + L	-0.0083	2.4616	0.0044	-0.0051	-0.0629	0.0911
ULS: 3. D + (S or Lr or R)	-0.0283	7.0290	0.0148	-0.0187	-0.2154	0.2631
ULS: 3. D + (S or Lr or R)	-0.0083	2.4616	0.0044	-0.0051	-0.0629	0.0911
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0233	5.8871	0.0122	-0.0153	-0.1773	0.2201
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0083	2.4616	0.0044	-0.0051	-0.0629	0.0911
ULS: 5b. D + 0.7E	-0.0083	2.4616	0.0044	-0.0051	-0.0629	0.0911
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0233	5.8871	0.0122	-0.0153	-0.1773	0.2201
ULS: 8. 0.6D + 0.7E	-0.0050	1.4770	0.0027	-0.0031	-0.0378	0.0547
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.6127	7.6076	0.0346	0.0103	-0.1781	29.2261
ULS: 5a. D + 0.6W_Wind downforce Case B only	-3.6127	7.6076	0.0346	0.0103	-0.1781	29.2261
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.0328	-1.8802	-0.0210	-0.0182	0.0346	-23.9290
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.5273	-1.1578	-0.0154	-0.0154	0.0120	-30.2181
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.7266	9.7466	0.0349	-0.0037	-0.2637	22.0713
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.7266	9.7466	0.0349	-0.0037	-0.2637	22.0713
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.2576	2.6308	-0.0069	-0.0251	-0.1042	-17.7950
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.8784	3.1726	-0.0026	-0.0230	-0.1211	-22.5118

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	-2.7116	6.3211	0.0271	0.0065	-0.1493	21.9423
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.7116	6.3211	0.0271	0.0065	-0.1493	21.9423
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.2726	-0.7947	-0.0147	-0.0149	0.0102	-17.9240
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.8934	-0.2529	-0.0104	-0.0129	-0.0067	-22.6408
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.6094	6.6230	0.0329	0.0124	-0.1529	29.1896
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-3.6094	6.6230	0.0329	0.0124	-0.1529	29.1896
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.0362	-2.8649	-0.0228	-0.0162	0.0597	-23.9654
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.5307	-2.1425	-0.0171	-0.0134	0.0372	-30.2545

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	14.5501
Shear X	-6.0274
Shear Z	0.0610
Moment X	-0.0386
Moment Y (Twist)	0.4154
Moment Z	50.5546

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	9.7466
Shear X	-3.6127
Shear Z	0.0349
Moment X	-0.0251
Moment Y (Twist)	0.2637
Moment Z	30.2545

Project Details

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

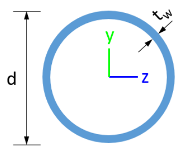
User Name: sales@mtsolar.us
Unit System: imperial

Design Input Information

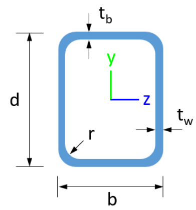
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

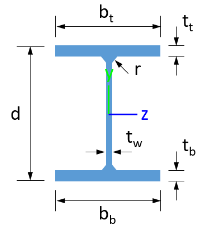
Section Dimensions



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



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



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

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

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

Member Properties

Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	11	16.66	16.66	7.93	-	300	200	1
2	6	1.30	1.30	2.00	-	300	200	1
3	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
4	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.71,1.67,1.67,1.66,1.63,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.75,1.67,1.67,1.66,1.65	300	200	1
5	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66	300	200	1
6	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
7	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66	300	200	1
8	20	1.33	1.33	2.05	2.21,2.20,2.21,2.20,2.20,2.21,2.21,2.21,2.21,1.86,2.21,2.21,2.21,2.29,2.20,2.20,2.19,2.16,2.21,2.21,2.21,1.86,2.21,2.21,2.21,2.26	300	200	1
9	3	2.60	2.60	4.00	-	300	200	1
10	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.71,1.67,1.67,1.66,1.62,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.74,1.67,1.67,1.66,1.64	300	200	1
11	20	1.33	1.33	2.05	2.21,2.20,2.21,2.20,2.20,2.21,2.19,2.19,2.19,2.14,2.19,2.19,2.19,2.15,2.20,2.20,2.21,2.23,2.19,2.19,2.18,2.14,2.19,2.19,2.19,2.15	300	200	1
12	6	1.30	1.30	2.00	-	300	200	1
13	20	4.88	4.00	7.50	1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08	300	200	1
14	20	4.88	4.00	7.50	1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.61,1.08,1.08,1.08,1.07,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.61,1.08,1.08,1.08,1.07	300	200	1
15	20	12.60	12.60	6.00	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	20	12.60	12.60	6.00	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	11	16.66	16.66	7.93	-	300	200	1
102	6	1.30	1.30	2.00	-	300	200	1
103	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
104	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.71,1.67,1.67,1.66,1.63,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.75,1.67,1.67,1.66,1.65	300	200	1
105	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66	300	200	1
106	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
107	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66	300	200	1

108	20	1.33	1.33	2.05	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.36,2.33,2.33,2.32,2.30,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.37,2.33,2.33,2.32,2.31	300	200	1
109	3	2.60	2.60	4.00	-	300	200	1
110	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.71,1.67,1.67,1.66,1.63,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.75,1.67,1.67,1.66,1.65	300	200	1
111	20	1.33	1.33	2.05	2.31,2.31,2.31,2.31,2.31,2.31,2.33,2.33,2.37,2.36,2.34,2.34,2.35,2.35,2.32,2.32,2.28,2.23,2.33,2.33,2.36,2.36,2.34,2.34,2.35,2.35	300	200	1
112	6	1.30	1.30	2.00	-	300	200	1
113	20	4.88	4.00	7.50	1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.02,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03	300	200	1
114	20	4.88	4.00	7.50	1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,2.03,1.03,1.03,1.03,1.02,1.03,1.03,1.03,1.03,1.03,1.03,2.03,1.03,1.03,1.03,1.02	300	200	1
115	20	8.42	8.42	12.95	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.15,1.15,1.15,1.15,1.15,1.15,1.16,1.16,1.17,1.18,1.16,1.16,1.15,1.15,1.15,1.15,1.15,1.15	300	200	1
116	20	8.42	8.42	12.95	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.17,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16	300	200	1
201	11	16.66	16.66	7.93	-	300	200	1
202	6	1.30	1.30	2.00	-	300	200	1
203	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
204	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.71,1.67,1.67,1.66,1.62,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.74,1.67,1.67,1.66,1.64	300	200	1
205	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66	300	200	1
206	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
207	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66	300	200	1
208	20	12.60	12.60	6.00	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	3	2.60	2.60	4.00	-	300	200	1
210	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.71,1.67,1.67,1.66,1.63,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.75,1.67,1.67,1.66,1.65	300	200	1
211	20	12.60	12.60	6.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
212	6	1.30	1.30	2.00	-	300	200	1
213	20	4.88	4.00	7.50	1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08	300	200	1
214	20	4.88	4.00	7.50	1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.61,1.08,1.08,1.08,1.07,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.60,1.08,1.08,1.08,1.07	300	200	1
215	20	8.42	8.42	12.95	1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.20,1.19,1.19,1.19,1.20,1.19,1.19,1.19,1.18,1.19,1.19,1.19,1.20,1.19,1.19,1.19,1.20	300	200	1
216	20	8.42	8.42	12.95	1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.22,1.19,1.19,1.19,1.17,1.19,1.19,1.19,1.20,1.19,1.19,1.19,1.22,1.19,1.19,1.19,1.18	300	200	1

Member Design Capacity

Member Design Capacity

Member ID	$\Phi_t P_n$ (kip)	$\Phi_c P_n$ (kip)	$\Phi_b M_{zn}$ (k-ft)	$\Phi_b M_{yn}$ (k-ft)	$\Phi_v V_{yn}$ (kip)	$\Phi_v V_{zn}$ (kip)
1	535.87	431.59	147.68	147.68	160.76	160.76
2	251.01	248.88	27.16	27.16	75.30	75.30
3	151.65	150.70	20.17	14.14	54.12	28.95
4	151.65	145.15	20.17	14.14	54.12	28.95
5	151.65	149.10	20.17	14.14	54.12	28.95
6	151.65	150.70	20.17	14.14	54.12	28.95
7	151.65	149.10	20.17	14.14	54.12	28.95
8	159.30	142.47	46.90	6.46	56.26	44.91
9	75.10	66.32	4.25	4.25	22.53	22.53
10	151.65	145.15	20.17	14.14	54.12	28.95
11	159.30	142.47	46.90	6.46	56.26	44.91
12	251.01	248.88	27.16	27.16	75.30	75.30
13	159.30	116.35	33.01	6.46	56.26	44.91
14	159.30	116.35	32.70	6.46	56.26	44.91
15	159.30	21.54	46.90	6.46	56.26	44.91
16	159.30	21.54	46.90	6.46	56.26	44.91
101	535.87	431.59	147.68	147.68	160.76	160.76
102	251.01	248.88	27.16	27.16	75.30	75.30
103	151.65	150.70	20.17	14.14	54.12	28.95
104	151.65	145.15	20.17	14.14	54.12	28.95
105	151.65	149.10	20.17	14.14	54.12	28.95
106	151.65	150.70	20.17	14.14	54.12	28.95
107	151.65	149.10	20.17	14.14	54.12	28.95
108	159.30	142.47	46.90	6.46	56.26	44.91
109	75.10	66.32	4.25	4.25	22.53	22.53
110	151.65	145.15	20.17	14.14	54.12	28.95
111	159.30	142.47	46.90	6.46	56.26	44.91
112	251.01	248.88	27.16	27.16	75.30	75.30
113	159.30	116.35	31.17	6.46	56.26	44.91
114	159.30	116.35	31.17	6.46	56.26	44.91
115	159.30	48.27	15.28	6.46	56.26	44.91
116	159.30	48.27	15.41	6.46	56.26	44.91
201	535.87	431.59	147.68	147.68	160.76	160.76
202	251.01	248.88	27.16	27.16	75.30	75.30
203	151.65	150.70	20.17	14.14	54.12	28.95
204	151.65	145.15	20.17	14.14	54.12	28.95
205	151.65	149.10	20.17	14.14	54.12	28.95
206	151.65	150.70	20.17	14.14	54.12	28.95
207	151.65	149.10	20.17	14.14	54.12	28.95
208	159.30	21.54	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	21.54	46.90	6.46	56.26	44.91
212	251.01	248.88	27.16	27.16	75.30	75.30
213	159.30	116.35	33.01	6.46	56.26	44.91
214	159.30	116.35	32.70	6.46	56.26	44.91
215	159.30	48.27	15.67	6.46	56.26	44.91
216	159.30	48.27	15.54	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	0.034	0.342	0.003	0.037	0.000	0.348	#13	0.272	Not Required	Pass
2	0.006	0.433	0.229	0.095	0.041	0.659	#13	0.036	Not Required	Pass
3	0.009	0.683	0.051	0.068	0.004	0.706	#13	0.046	Not Required	Pass
4	0.009	0.665	0.213	0.067	0.044	0.741	#21	0.082	Not Required	Pass
5	0.009	0.423	0.222	0.068	0.058	0.451	#13	0.076	Not Required	Pass
6	0.010	0.665	0.054	0.066	0.005	0.686	#13	0.046	Not Required	Pass
7	0.010	0.413	0.215	0.066	0.057	0.442	#21	0.076	Not Required	Pass
8	0.000	0.075	0.260	0.045	0.022	0.329	#21	0.102	Not Required	Pass
9	0.027	0.064	0.050	0.001	0.000	0.120	#13	0.206	Not Required	Pass
10	0.009	0.646	0.208	0.065	0.044	0.734	#21	0.082	Not Required	Pass
11	0.000	0.077	0.264	0.046	0.022	0.333	#21	0.102	Not Required	Pass
12	0.006	0.418	0.216	0.093	0.039	0.629	#13	0.036	Not Required	Pass
13	0.010	0.324	0.603	0.057	0.027	0.885	#21	0.306	Not Required	Pass
14	0.011	0.321	0.603	0.056	0.027	0.882	#21	0.204	Not Required	Pass
15	0.000	0.130	0.361	0.036	0.017	0.480	#21	Not Required	Not Required	Pass
16	0.000	0.127	0.361	0.035	0.017	0.479	#21	Not Required	Not Required	Pass
101	0.035	0.358	0.000	0.039	0.000	0.359	#32	0.272	Not Required	Pass
102	0.005	0.442	0.226	0.098	0.041	0.662	#13	0.036	Not Required	Pass
103	0.010	0.700	0.049	0.070	0.001	0.728	#13	0.046	Not Required	Pass
104	0.010	0.682	0.201	0.068	0.042	0.762	#21	0.082	Not Required	Pass
105	0.010	0.435	0.209	0.069	0.055	0.461	#13	0.076	Not Required	Pass
106	0.010	0.700	0.049	0.070	0.001	0.728	#13	0.046	Not Required	Pass
107	0.010	0.435	0.209	0.069	0.055	0.461	#13	0.076	Not Required	Pass
108	0.000	0.053	0.260	0.043	0.022	0.309	#21	0.102	Not Required	Pass
109	0.024	0.058	0.049	0.001	0.000	0.110	#13	0.206	Not Required	Pass
110	0.010	0.682	0.201	0.068	0.042	0.762	#21	0.082	Not Required	Pass
111	0.000	0.054	0.263	0.044	0.022	0.313	#21	0.102	Not Required	Pass
112	0.005	0.442	0.226	0.098	0.041	0.662	#13	0.036	Not Required	Pass
113	0.010	0.255	0.557	0.054	0.027	0.773	#21	0.306	Not Required	Pass
114	0.011	0.255	0.554	0.053	0.027	0.767	#21	0.306	Not Required	Pass
115	0.000	0.411	0.298	0.044	0.022	0.674	#21	0.644	Not Required	Pass
116	0.000	0.401	0.302	0.043	0.022	0.673	#21	0.644	Not Required	Pass
201	0.034	0.342	0.003	0.037	0.000	0.348	#13	0.272	Not Required	Pass
202	0.006	0.418	0.216	0.093	0.039	0.629	#13	0.036	Not Required	Pass
203	0.010	0.665	0.054	0.066	0.005	0.686	#13	0.046	Not Required	Pass
204	0.009	0.646	0.208	0.065	0.044	0.734	#21	0.082	Not Required	Pass
205	0.010	0.413	0.215	0.066	0.057	0.442	#21	0.076	Not Required	Pass
206	0.009	0.683	0.051	0.068	0.004	0.706	#13	0.046	Not Required	Pass
207	0.009	0.423	0.222	0.068	0.058	0.451	#13	0.076	Not Required	Pass
208	0.000	0.127	0.361	0.035	0.017	0.479	#21	Not Required	Not Required	Pass
209	0.027	0.064	0.050	0.001	0.000	0.120	#13	0.206	Not Required	Pass
210	0.009	0.665	0.213	0.067	0.044	0.741	#21	0.082	Not Required	Pass
211	0.000	0.130	0.361	0.036	0.017	0.480	#21	Not Required	Not Required	Pass
212	0.006	0.433	0.229	0.095	0.041	0.659	#13	0.036	Not Required	Pass
213	0.010	0.324	0.603	0.057	0.027	0.885	#21	0.204	Not Required	Pass
214	0.011	0.321	0.603	0.056	0.027	0.882	#21	0.306	Not Required	Pass
215	0.000	0.406	0.298	0.046	0.022	0.669	#21	0.644	Not Required	Pass
216	0.000	0.396	0.302	0.045	0.022	0.669	#21	0.644	Not Required	Pass

Definitions

Φ_t Safety factor for tensile

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

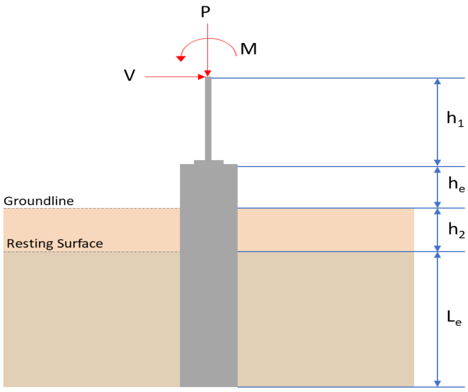
SkyCiv Foundation Design

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
$L = 6.25\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	9.747	14.550
V_x (kip)	-3.613	-6.027
V_z (kip)	-0.035	-0.061
M_x (kipft)	0.025	0.039
M_z (kipft)	30.255	50.554

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,

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

$$H_o = \frac{(-3.613\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.57532\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(30.255\ \text{kipft}) + ((-3.613\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 4.8177\ \text{kipft/ft}$$

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:
$L_{e,x} = 5.7261\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.035\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.0055732\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.025\ \text{kipft}) + ((-0.035\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.0039809\ \text{kipft/ft}$$

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:
$L_{e,z} = 0.52348\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(5.7261\ \text{ft}), (0.52348\ \text{ft})]$$

$$L_{e,req} = 5.726\ \text{ft}$$

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

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

$$Ratio = \frac{(5.726\ \text{ft})}{(6.25\ \text{ft})}$$

$$Ratio = 0.91616$$

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

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

$$q = \frac{(9.747\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.60919\ \text{kip/ft}^2$$

SkyCiv

$q = 0.60919\ \mathrm{kip/ft^2}$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.60919\ \mathrm{kip/ft^2})}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.30459$$

Status: **PASS**
Ratio: **0.300**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

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

$$L/D = 1.5625$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.57532\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 4.8177\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.8177\ \mathrm{kipft/ft}) \times (6.25\ \mathrm{ft})) + \left(3 \times (-0.57532\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft})^2\right)}{(6 \times (4.8177\ \mathrm{kipft/ft})) + (4 \times (-0.57532\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))}$$

$$a = 4.3397\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (4.8177\ \mathrm{kipft/ft})) + (3 \times (-0.57532\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]^2}{(6.25\ \mathrm{ft})^2 \times [(3 \times (4.8177\ \mathrm{kipft/ft})) + (2 \times (-0.57532\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]}$$

$$p = 0.19029\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (4.8177\ \mathrm{kipft/ft})) + ((-0.57532\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]}{(6.25\ \mathrm{ft})^2}$$

$$s = 0.92768\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.3397\ \mathrm{ft})}{2}$$

$$p_a = 0.32548\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.19029\ \mathrm{kip/ft^2})}{(0.32548\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.58465$$

Status: **PASS**
Ratio: **0.580**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.92768\text{ kip/ft}^2\right)}{\left(0.9375\text{ kip/ft}^2\right)}$$

$$Ratio = 0.98953$$

Status: **PASS**
Ratio: **0.990**

Considering z-direction:

$H_o = -0.0055732\text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 0.0039809\text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0039809\text{ kipft/ft}) \times (6.25\text{ ft})) + \left(3 \times (-0.0055732\text{ kip/ft}) \times (6.25\text{ ft})^2\right)}{(6 \times (0.0039809\text{ kipft/ft})) + (4 \times (-0.0055732\text{ kip/ft}) \times (6.25\text{ ft}))}$$

$$a = 4.6113\text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.0039809\text{ kipft/ft})) + (3 \times (-0.0055732\text{ kip/ft}) \times (6.25\text{ ft}))]^{\,2}}{(6.25\text{ ft})^2 \times [(3 \times (0.0039809\text{ kipft/ft})) + (2 \times (-0.0055732\text{ kip/ft}) \times (6.25\text{ ft}))]}$$

$$p = -0.0026096\text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.0039809\text{ kipft/ft})) + ((-0.0055732\text{ kip/ft}) \times (6.25\text{ ft}))]}{(6.25\text{ ft})^2}$$

$$s = -0.0041274\text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\text{ psf/ft}) \times \frac{(4.6113\text{ ft})}{2}$$

$$p_a = 0.34585\text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.0026096\text{ kip/ft}^2\right)}{\left(0.34585\text{ kip/ft}^2\right)}$$

$$Ratio = -0.0075455$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

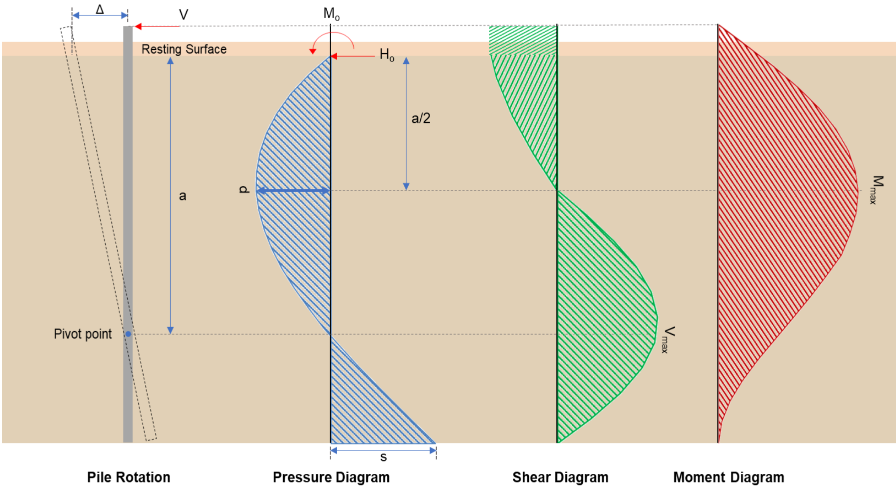
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(-0.0041274 \text{ kip/ft}^2)}{(0.9375 \text{ kip/ft}^2)}$$

$$Ratio = -0.0044025$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-6.027 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.95971 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(50.554 \text{ kipft}) + ((-6.027 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 8.05 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(8.05 \text{ kipft/ft})}{(-0.95971 \text{ kip/ft})}$$

$$E = 8.3879 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.05 \text{ kipft/ft}) \times (6.25 \text{ ft})) + \left(3 \times (-0.95971 \text{ kip/ft}) \times (6.25 \text{ ft})^2\right)}{(6 \times (8.05 \text{ kipft/ft})) + (4 \times (-0.95971 \text{ kip/ft}) \times (6.25 \text{ ft}))}$$

$$a = 4.3395 \text{ ft}$$

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

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

$$V_{max} = ((-0.95971 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (8.3879 \text{ ft})}{(6.25 \text{ ft})} + 3\right) \times \left(\frac{(4.3395 \text{ ft})}{(6.25 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (8.3879 \text{ ft})}{(6.25 \text{ ft})} + 2\right) \times \left(\frac{(4.3395 \text{ ft})}{(6.25 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 11.648 \text{ kip}$$

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

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

$$M_{max} = ((-0.95971 \text{ kip/ft}) \times (48 \text{ in}) \times (6.25 \text{ ft})) \times \left[\left(\frac{(8.3879 \text{ ft})}{(6.25 \text{ ft})} + \frac{(4.3395 \text{ ft})}{2 \times (6.25 \text{ ft})} \right) - \left[\left(\frac{4 \times (8.3879 \text{ ft})}{(6.25 \text{ ft})} + 3 \right) \times \left(\frac{(4.3395 \text{ ft})}{2 \times (6.25 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (8.3879 \text{ ft})}{(6.25 \text{ ft})} + 2 \right) \times \left(\frac{(4.3395 \text{ ft})}{2 \times (6.25 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 34.229 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.061 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0097134 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.039 \text{ kipft}) + ((-0.061 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.0062102 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.0062102 \text{ kipft/ft})}{(-0.0097134 \text{ kip/ft})}$$

$$E = 0.63934 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0062102 \text{ kipft/ft}) \times (6.25 \text{ ft})) + \left(3 \times (-0.0097134 \text{ kip/ft}) \times (6.25 \text{ ft})^2\right)}{(6 \times (0.0062102 \text{ kipft/ft})) + (4 \times (-0.0097134 \text{ kip/ft}) \times (6.25 \text{ ft}))}$$

$$a = 4.6182 \text{ ft}$$

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

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

$$V_{max} = ((-0.0097134 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (0.63934 \text{ ft})}{(6.25 \text{ ft})} + 3 \right) \times \left(\frac{(4.6182 \text{ ft})}{(6.25 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (0.63934 \text{ ft})}{(6.25 \text{ ft})} + 2 \right) \times \left(\frac{(4.6182 \text{ ft})}{(6.25 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.033468 \text{ kip}$$

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

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

$$M_{max} = ((-0.0097134 \text{ kip/ft}) \times (48 \text{ in}) \times (6.25 \text{ ft})) \times \left[\left(\frac{(0.63934 \text{ ft})}{(6.25 \text{ ft})} + \frac{(4.6182 \text{ ft})}{2 \times (6.25 \text{ ft})} \right) - \left[\left(\frac{4 \times (0.63934 \text{ ft})}{(6.25 \text{ ft})} + 3 \right) \times \left(\frac{(4.6182 \text{ ft})}{2 \times (6.25 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (0.63934 \text{ ft})}{(6.25 \text{ ft})} + 2 \right) \times \left(\frac{(4.6182 \text{ ft})}{2 \times (6.25 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.083245 \text{ kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(14.55 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (3 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -101.78 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-101.78 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

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

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(14.55\ \text{kip})}{(3183.4\ \text{kip})}$$

$$Ratio = 0.0045706$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \text{ksi} \rightarrow 3000\ \text{psi}$, $P = 14.55\ \text{kip} \rightarrow 14550\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(3000\ \text{psi})} + \frac{(14550\ \text{lbf})}{6 \times (2304\ \text{in}^2)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 131.73\ \text{kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(324.49\ \text{kip}), (131.73\ \text{kip}), (406.27\ \text{kip})\right]$$

$$V_c = 131.73\ \text{kip}$$

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

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

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

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

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

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

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((131.73 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 118.71 \text{ kip}$$

Considering x-direction:

$V_{max} = 11.648 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(11.648 \text{ kip})}{(118.71 \text{ kip})}$$

$$Ratio = 0.098122$$

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

Considering z-direction:

$V_{max} = 0.033468 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.033468 \text{ kip})}{(118.71 \text{ kip})}$$

$$Ratio = 0.00028194$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

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

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

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

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

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:

$M_{max} = 34.229 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(34.229 \text{ kipft})}{(273.42 \text{ kipft})}$$

$$Ratio = 0.12519$$

Status: **PASS**
Ratio: **0.130**

Considering z-direction:

$M_{max} = 0.083245 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.083245 \text{ kipft})}{(273.42 \text{ kipft})}$$

$$Ratio = 0.00030446$$

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

REFERENCES	CALCULATIONS	RESULTS

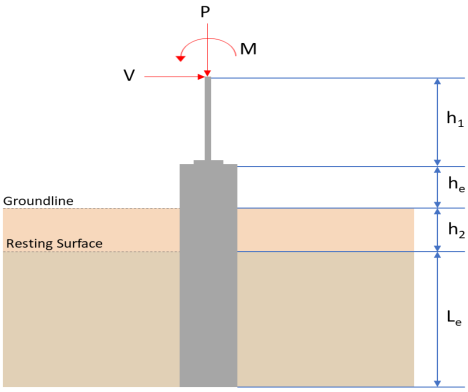
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

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

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	9.747	14.550
V_x (kip)	-3.613	-6.027
V_z (kip)	0.035	0.061
M_x (kipft)	-0.025	-0.039
M_z (kipft)	30.255	50.555

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,

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

$$H_o = \frac{(-3.613\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.57532\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(30.255 \text{ kipft}) + ((-3.613 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 4.8177 \text{ kipft/ft}$$

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:
$L_{e,x} = 5.7261 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.035 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0055732 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.025 \text{ kipft}) + ((0.035 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.0039809 \text{ kipft/ft}$$

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:
$L_{e,z} = 0.84359 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(5.7261 \text{ ft}), (0.84359 \text{ ft})]$$

$$L_{e,req} = 5.726 \text{ ft}$$

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

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

$$Ratio = \frac{(5.726 \text{ ft})}{(6.25 \text{ ft})}$$

$$Ratio = 0.91616$$

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

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

$$q = \frac{(9.747 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.60919 \text{ kip/ft}^2$$

$q = 0.60919\ \text{kip/ft}^2$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.60919\ \text{kip/ft}^2\right)}{(2000\ \text{psf})}$$

$$Ratio = 0.30459$$

Status: **PASS**
Ratio: **0.300**

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:

$H_o = -0.57532\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 4.8177\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.8177\ \text{kipft/ft}) \times (6.25\ \text{ft})) + \left(3 \times (-0.57532\ \text{kip/ft}) \times (6.25\ \text{ft})^2\right)}{(6 \times (4.8177\ \text{kipft/ft})) + (4 \times (-0.57532\ \text{kip/ft}) \times (6.25\ \text{ft}))}$$

$$a = 4.3397\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (4.8177\ \text{kipft/ft})) + (3 \times (-0.57532\ \text{kip/ft}) \times (6.25\ \text{ft}))]^2}{(6.25\ \text{ft})^2 \times [(3 \times (4.8177\ \text{kipft/ft})) + (2 \times (-0.57532\ \text{kip/ft}) \times (6.25\ \text{ft}))]}$$

$$p = 0.19029\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (4.8177\ \text{kipft/ft})) + ((-0.57532\ \text{kip/ft}) \times (6.25\ \text{ft}))]}{(6.25\ \text{ft})^2}$$

$$s = 0.92768\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(4.3397\ \text{ft})}{2}$$

$$p_a = 0.32548\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.19029\ \text{kip/ft}^2\right)}{\left(0.32548\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.58465$$

Status: **PASS**
Ratio: **0.580**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.92768\ \text{kip/ft}^2\right)}{\left(0.9375\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.98953$$

Status: **PASS**
Ratio: **0.990**

Considering z-direction:

$H_o = 0.0055732\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.0039809\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0039809\ \text{kipft/ft}) \times (6.25\ \text{ft})) + \left(3 \times (0.0055732\ \text{kip/ft}) \times (6.25\ \text{ft})^2\right)}{(6 \times (0.0039809\ \text{kipft/ft})) + (4 \times (0.0055732\ \text{kip/ft}) \times (6.25\ \text{ft}))}$$

$$a = 4.6113\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.0039809\ \text{kipft/ft})) + (3 \times (0.0055732\ \text{kip/ft}) \times (6.25\ \text{ft}))]^{\ 2}}{(6.25\ \text{ft})^2 \times [(3 \times (0.0039809\ \text{kipft/ft})) + (2 \times (0.0055732\ \text{kip/ft}) \times (6.25\ \text{ft}))]}$$

$$p = 0.0034118\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.0039809\ \text{kipft/ft})) + ((0.0055732\ \text{kip/ft}) \times (6.25\ \text{ft}))]}{(6.25\ \text{ft})^2}$$

$$s = 0.0065732\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(4.6113\ \text{ft})}{2}$$

$$p_a = 0.34585\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0034118\ \text{kip/ft}^2\right)}{\left(0.34585\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.009865$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

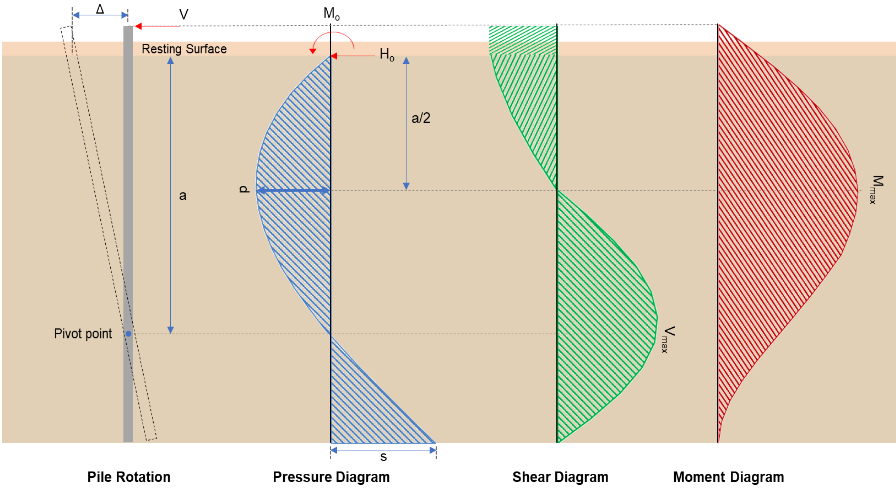
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0065732\ \text{kip/ft}^2)}{(0.9375\ \text{kip/ft}^2)}$$

$$Ratio = 0.0070115$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-6.027\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.95971\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(50.555\ \text{kipft}) + ((-6.027\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 8.0502\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(8.0502\ \text{kipft/ft})}{(-0.95971\ \text{kip/ft})}$$

$$E = 8.3881\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.0502\ \text{kipft/ft}) \times (6.25\ \text{ft})) + \left(3 \times (-0.95971\ \text{kip/ft}) \times (6.25\ \text{ft})^2\right)}{(6 \times (8.0502\ \text{kipft/ft})) + (4 \times (-0.95971\ \text{kip/ft}) \times (6.25\ \text{ft}))}$$

$$a = 4.3395\ \text{ft}$$

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

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

$$V_{max} = ((-0.95971\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (8.3881\ \text{ft})}{(6.25\ \text{ft})} + 3\right) \times \left(\frac{(4.3395\ \text{ft})}{(6.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (8.3881\ \text{ft})}{(6.25\ \text{ft})} + 2\right) \times \left(\frac{(4.3395\ \text{ft})}{(6.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 11.648\ \text{kip}$$

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

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

$$M_{max} = ((-0.95971\ \text{kip/ft}) \times (48\ \text{in}) \times (6.25\ \text{ft})) \times \left[\left(\frac{(8.3881\ \text{ft})}{(6.25\ \text{ft})} + \frac{(4.3395\ \text{ft})}{2 \times (6.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (8.3881\ \text{ft})}{(6.25\ \text{ft})} + 3\right) \times \left(\frac{(4.3395\ \text{ft})}{2 \times (6.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (8.3881\ \text{ft})}{(6.25\ \text{ft})} + 2\right) \times \left(\frac{(4.3395\ \text{ft})}{2 \times (6.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 34.229\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.061\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.0097134\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.039\ \text{kipft}) + ((0.061\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.0062102\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.0062102\ \text{kipft/ft})}{(0.0097134\ \text{kip/ft})}$$

$$E = 0.63934\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0062102\ \text{kipft/ft}) \times (6.25\ \text{ft})) + \left(3 \times (0.0097134\ \text{kip/ft}) \times (6.25\ \text{ft})^2\right)}{(6 \times (0.0062102\ \text{kipft/ft})) + (4 \times (0.0097134\ \text{kip/ft}) \times (6.25\ \text{ft}))}$$

$$a = 4.6182\ \text{ft}$$

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

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

$$V_{max} = ((0.0097134\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (0.63934\ \text{ft})}{(6.25\ \text{ft})} + 3\right) \times \left(\frac{(4.6182\ \text{ft})}{(6.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (0.63934\ \text{ft})}{(6.25\ \text{ft})} + 2\right) \times \left(\frac{(4.6182\ \text{ft})}{(6.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.033468\ \text{kip}$$

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

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

$$M_{max} = ((0.0097134\ \text{kip/ft}) \times (48\ \text{in}) \times (6.25\ \text{ft})) \times \left[\left(\frac{(0.63934\ \text{ft})}{(6.25\ \text{ft})} + \frac{(4.6182\ \text{ft})}{2 \times (6.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (0.63934\ \text{ft})}{(6.25\ \text{ft})} + 3\right) \times \left(\frac{(4.6182\ \text{ft})}{2 \times (6.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (0.63934\ \text{ft})}{(6.25\ \text{ft})} + 2\right) \times \left(\frac{(4.6182\ \text{ft})}{2 \times (6.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.083245 \text{ kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(14.55 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (3 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -101.78 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-101.78 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

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

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(14.55\ \text{kip})}{(3183.4\ \text{kip})}$$

$$Ratio = 0.0045706$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \text{ksi} \rightarrow 3000\ \text{psi}$, $P = 14.55\ \text{kip} \rightarrow 14550\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(3000\ \text{psi})} + \frac{(14550\ \text{lbf})}{6 \times \left(2304\ \text{in}^2\right)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 131.73\ \text{kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(324.49\ \text{kip}), (131.73\ \text{kip}), (406.27\ \text{kip})\right]$$

$$V_c = 131.73\ \text{kip}$$

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

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

$$\phi V_n = (0.65) \times ((131.73\ \mathrm{kip}) + (50.894\ \mathrm{kip}))$$

$$\phi V_n = 118.71\ \mathrm{kip}$$

Considering x-direction:

$V_{max} = 11.648\ \mathrm{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(11.648\ \mathrm{kip})}{(118.71\ \mathrm{kip})}$$

$$Ratio = 0.098124$$

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

Considering z-direction:

$V_{max} = 0.033468\ \mathrm{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.033468\ \mathrm{kip})}{(118.71\ \mathrm{kip})}$$

$$Ratio = 0.00028194$$

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:
$\phi M_{n,1}$

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

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

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

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

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

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

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

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:

$M_{max} = 34.229 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(34.229 \text{ kipft})}{(273.42 \text{ kipft})}$$

$$Ratio = 0.12519$$

Status: **PASS**
Ratio: **0.130**

Considering z-direction:

$M_{max} = 0.083245 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.083245 \text{ kipft})}{(273.42 \text{ kipft})}$$

$$Ratio = 0.00030446$$

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

REFERENCES	CALCULATIONS	RESULTS

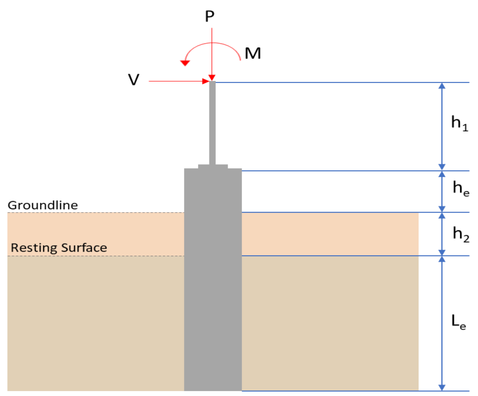
SkyCiv Foundation Design

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
$L = 6.5\ \text{ft}$ - 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)	10.177	15.219
V_x (kip)	-3.736	-6.243
V_z (kip)	0.000	0.000
M_x (kipft)	0.000	0.000
M_z (kipft)	31.483	52.817

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,

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

$$H_o = \frac{(-3.736\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.5949\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(31.483 \text{ kipft}) + ((-3.736 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 5.0132 \text{ kipft/ft}$$

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:
$L_{e,x} = 5.7921 \text{ ft}$ - 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,

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

$$L_{e,req} = MAX[(5.7921 \text{ ft}), (0 \text{ ft})]$$

$$L_{e,req} = 5.792 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 6.5 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(5.792 \text{ ft})}{(6.5 \text{ ft})}$$

$$Ratio = 0.89108$$

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

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

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

$$q = \frac{(10.177 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.63606 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.63606 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.31803$$

Status: **PASS**
Ratio: **0.320**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(6.5 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.625$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.5949 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 5.0132 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.0132 \text{ kipft/ft}) \times (6.5 \text{ ft})) + \left(3 \times (-0.5949 \text{ kip/ft}) \times (6.5 \text{ ft})^2\right)}{(6 \times (5.0132 \text{ kipft/ft})) + (4 \times (-0.5949 \text{ kip/ft}) \times (6.5 \text{ ft}))}$$

$$a = 4.5173 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (5.0132 \text{ kipft/ft})) + (3 \times (-0.5949 \text{ kip/ft}) \times (6.5 \text{ ft}))]^2}{(6.5 \text{ ft})^2 \times [(3 \times (5.0132 \text{ kipft/ft})) + (2 \times (-0.5949 \text{ kip/ft}) \times (6.5 \text{ ft}))]}$$

$$p = 0.17358 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (5.0132 \text{ kipft/ft})) + ((-0.5949 \text{ kip/ft}) \times (6.5 \text{ ft}))]}{(6.5 \text{ ft})^2}$$

$$s = 0.87473 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.5173 \text{ ft})}{2}$$

$$p_a = 0.3388 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.17358 \text{ kip/ft}^2\right)}{\left(0.3388 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.51235$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150 \text{ psf/ft}) \times (6.5 \text{ ft})$$

$$p_s = 0.975 \text{ kip/ft}^2$$

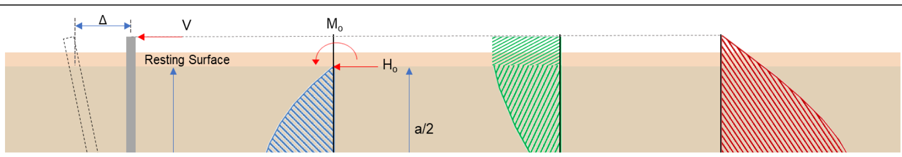
$Ratio$ - Lateral soil capacity

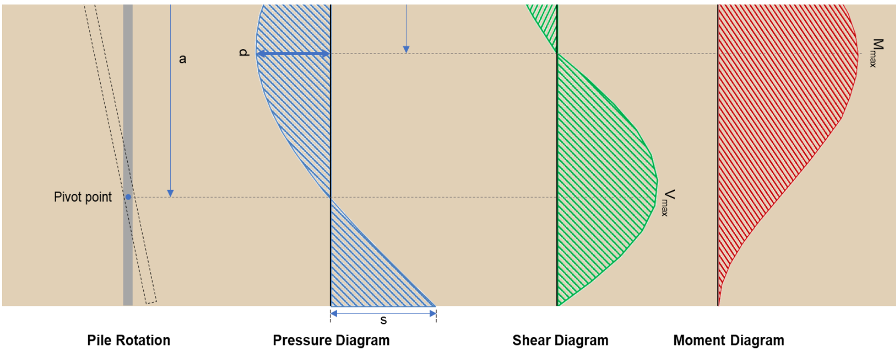
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{\left(0.87473 \text{ kip/ft}^2\right)}{\left(0.975 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.89716$$

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





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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-6.243\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = -0.99411\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(52.817\text{ kipft}) + ((-6.243\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 8.4104\text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(8.4104\text{ kipft/ft})}{(-0.99411\text{ kip/ft})}$$

$$E = 8.4602\text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.4104\text{ kipft/ft}) \times (6.5\text{ ft})) + \left(3 \times (-0.99411\text{ kip/ft}) \times (6.5\text{ ft})^2\right)}{(6 \times (8.4104\text{ kipft/ft})) + (4 \times (-0.99411\text{ kip/ft}) \times (6.5\text{ ft}))}$$

$$a = 4.5168\text{ ft}$$

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

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

$$V_{max} = ((-0.99411\text{ kip/ft}) \times (48\text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (8.4602\text{ ft})}{(6.5\text{ ft})} + 3\right) \times \left(\frac{(4.5168\text{ ft})}{(6.5\text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (8.4602\text{ ft})}{(6.5\text{ ft})} + 2\right) \times \left(\frac{(4.5168\text{ ft})}{(6.5\text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 11.781\text{ kip}$$

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

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

$$M_{max} = ((-0.99411\text{ kip/ft}) \times (48\text{ in}) \times (6.5\text{ ft})) \times \left[\left(\frac{(8.4602\text{ ft})}{(6.5\text{ ft})} + \frac{(4.5168\text{ ft})}{2 \times (6.5\text{ ft})}\right) - \left[\left(\frac{4 \times (8.4602\text{ ft})}{(6.5\text{ ft})} + 3\right) \times \left(\frac{(4.5168\text{ ft})}{2 \times (6.5\text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (8.4602\text{ ft})}{(6.5\text{ ft})} + 2\right) \times \left(\frac{(4.5168\text{ ft})}{2 \times (6.5\text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 35.949 \text{ kipft}$$

	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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(15.219 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (3 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -101.76 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-101.76 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

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

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(15.219\ \text{kip})}{(3183.4\ \text{kip})}$$

$$Ratio = 0.0047807$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \text{ksi} \rightarrow 3000\ \text{psi}$, $P = 15.219\ \text{kip} \rightarrow 15219\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(3000\ \text{psi})} + \frac{(15219\ \text{lbf})}{6 \times \left(2304\ \text{in}^2\right)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 131.82\ \text{kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(324.49\ \text{kip}), (131.82\ \text{kip}), (406.27\ \text{kip})\right]$$

$$V_c = 131.82\ \text{kip}$$

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

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

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

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

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

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

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((131.82\text{ kip}) + (50.894\text{ kip}))$$

$$\phi V_n = 118.77\text{ kip}$$

Considering x-direction:

$V_{max} = 11.781\text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(11.781\text{ kip})}{(118.77\text{ kip})}$$

$$Ratio = 0.099192$$

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

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:
$\phi M_{n,1}$

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

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

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

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

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

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

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

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

Therefore,
ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 35.949\ \mathrm{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(35.949\ \mathrm{kipft})}{(273.42\ \mathrm{kipft})}$$

$$Ratio = 0.13148$$

Status: **PASS**
Ratio: **0.130**