Your Project Calculations

Project Name: USDCampusPhase1-C

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=USDCampusPhase1-C&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/6_2023

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=AAsQfn0rtpkrQ4dZ5QV5CdWHn4EkDIBiBoLJ6M1PIqW7xnXNXfcyPIOpJ5xemGxI

Array Specification

Product:	Beam
Unique ID:	3P-22.5-8TOP-SD-57-L-5Hx9W-LL3A
Duty Classification:	SD
Module Width:	44.60 in
Module Length:	82.60in
Number of Rows:	5
Number of Columns:	9
Total Number of Modules:	45
Desired Tilt Angle:	10
Front Edge Clearance:	15
Total Array Height at Tilt:	18.25 ft
Total Frame Length:	62.00 ft
Frame Weight:	3001 lbs
Array Dimensions N/S:	18.79 ft
Array Dimensions E/W:	62.70 ft
Rail Length:	225.50 in
Rail Spacing:	3.48 ft
Rail Check:	PASS (46% utilized)

Support Specifications

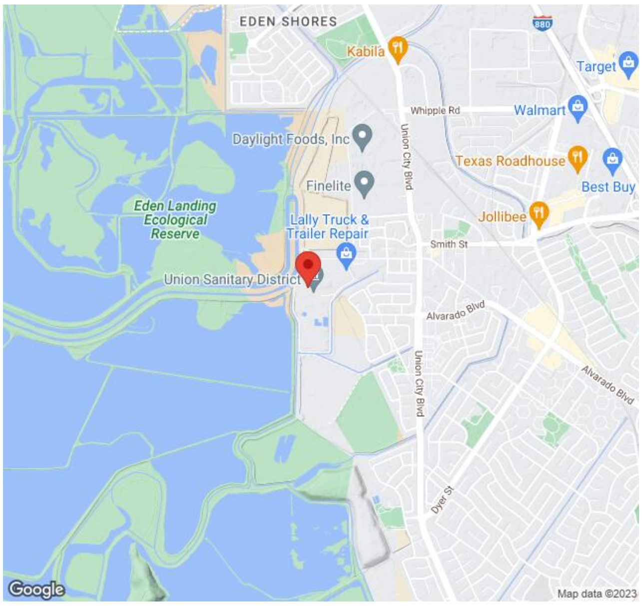
Pole Size:	8in Pipe Sch 40
Pole Length above Grade:	16.63 ft
Number of Poles:	3
Pole Spacing:	22.5 ft

Foundation Specifications

Foundation Type:	Round
Foundation Dimensions:	Ø36 in
Foundation Depth (below grade):	Pile 1: 7.00 ft Pile 2: 7.25 ft Pile 3: 7.00 ft
Foundation Volume:	5.563 y^3
Foundation Result:	PASSED
Mount Twist:	0.089998 kip

Site Info

Risk Category:	I
Exposure:	B
Soil Classification:	sand
Site Location:	5072 Benson Rd, Union City, CA 94587, USA
Wind Speed:	85 mph
Snow Load:	0 psf
Design Uplift Pressure:	Multiple pressures
Design Downforce Pressure:	Multiple pressures
Design Snow Pressure:	0.000000 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

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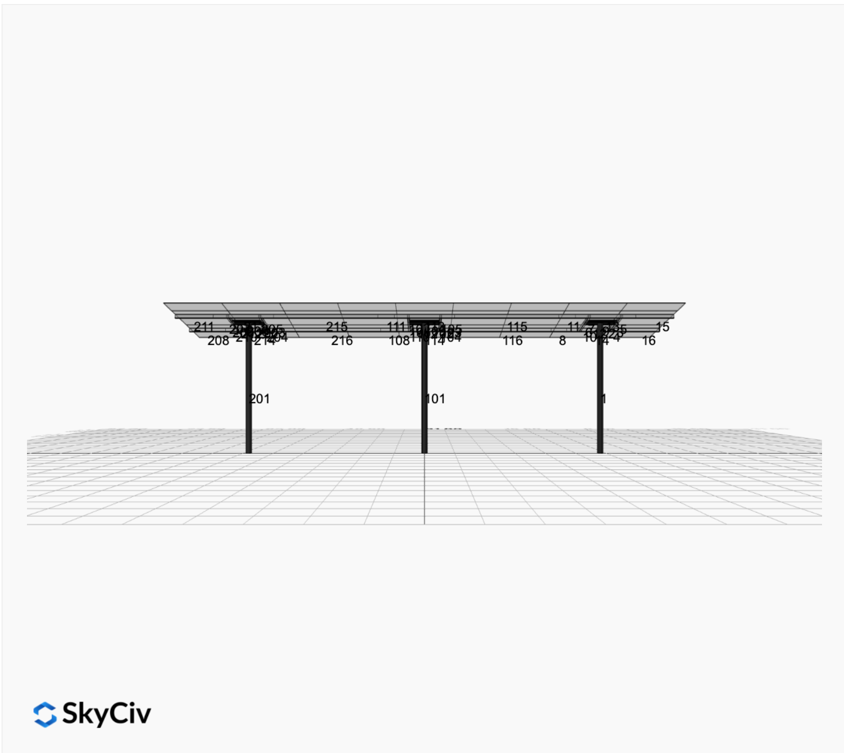
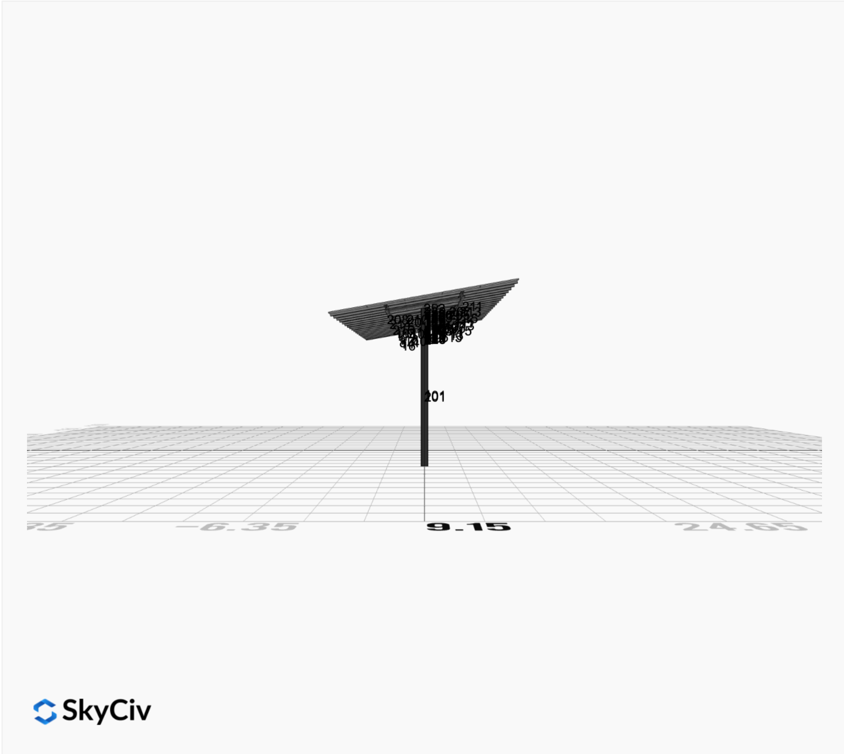
Design Notes:

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




201
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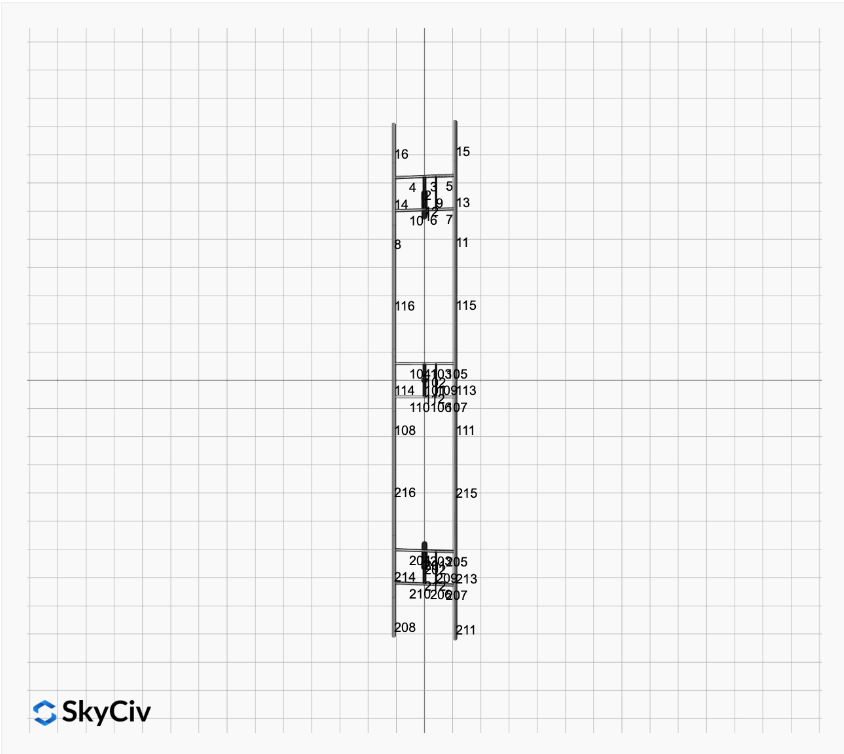
9.15
24.85
SkyCiv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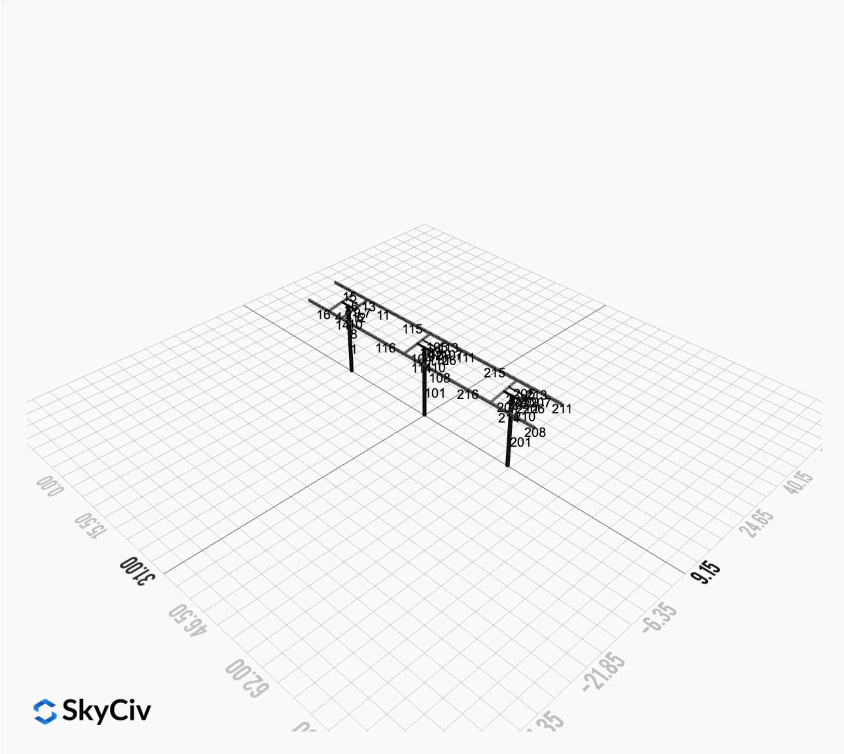
208
211
SkyCiv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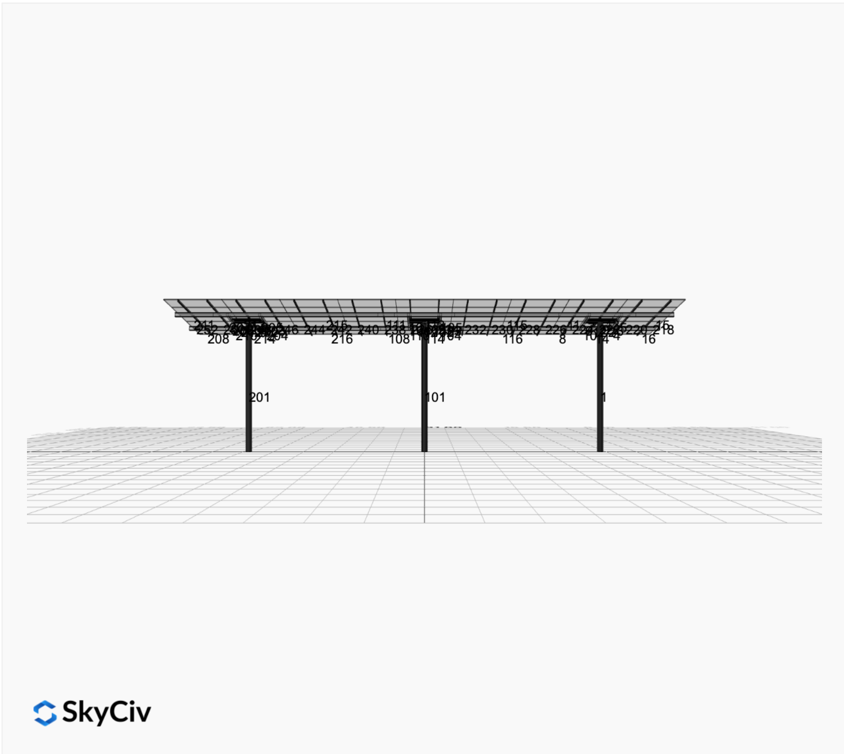
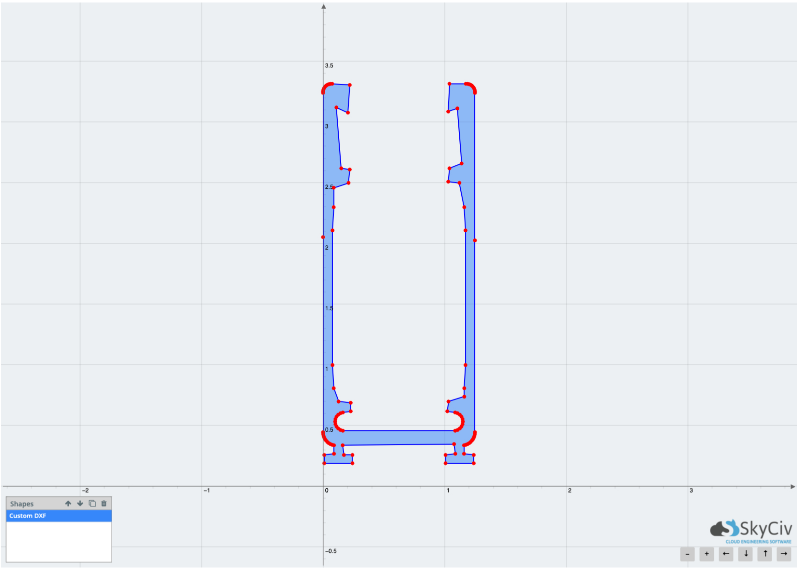
15.50
31.00
46.50
62.00
9.15
-6.35
-21.85
24.65
40.15
115
116
215
216
101
108
201
208
211
SkyCiv

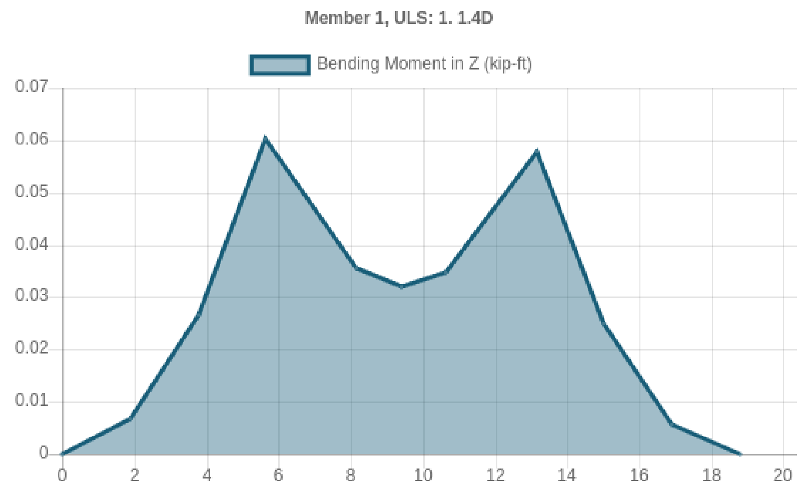

208
216
116
201
101
SkyCiv

Rail Design Check

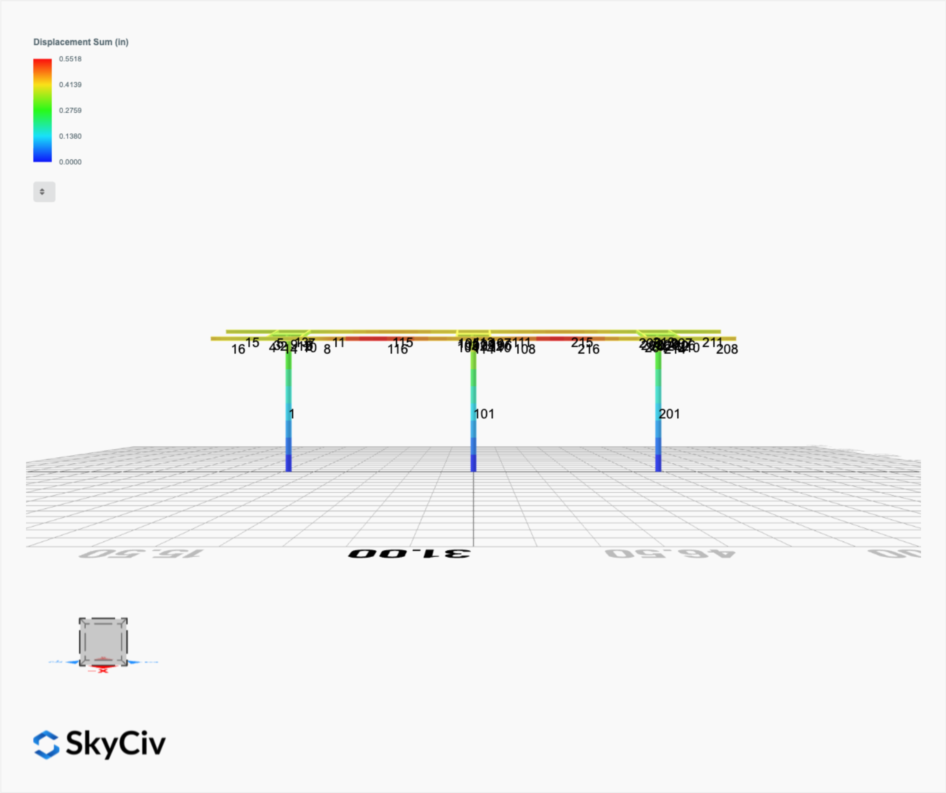
Rail Length: 18.791666666666668 ft
Additional Restraints Required: None
Tributary Width: 3.4833333333333333 ft
Material: Aluminium
Density: 169 lb/ft^3
Elasticity Modulus: 10000 ksi
Fy: 34.5 ksi
Fu: 37 ksi
Wind uplift Case A (X): 0.0000 kip/ft
Wind uplift Case A (Y): 0.0303 kip/ft
Wind uplift Case A: 0.0193 kip/ft
Wind uplift Case B: 0.0193 kip/ft
Wind uplift Case B (X): 0.0000 kip/ft
Wind uplift Case B (Y): 0.0432 kip/ft

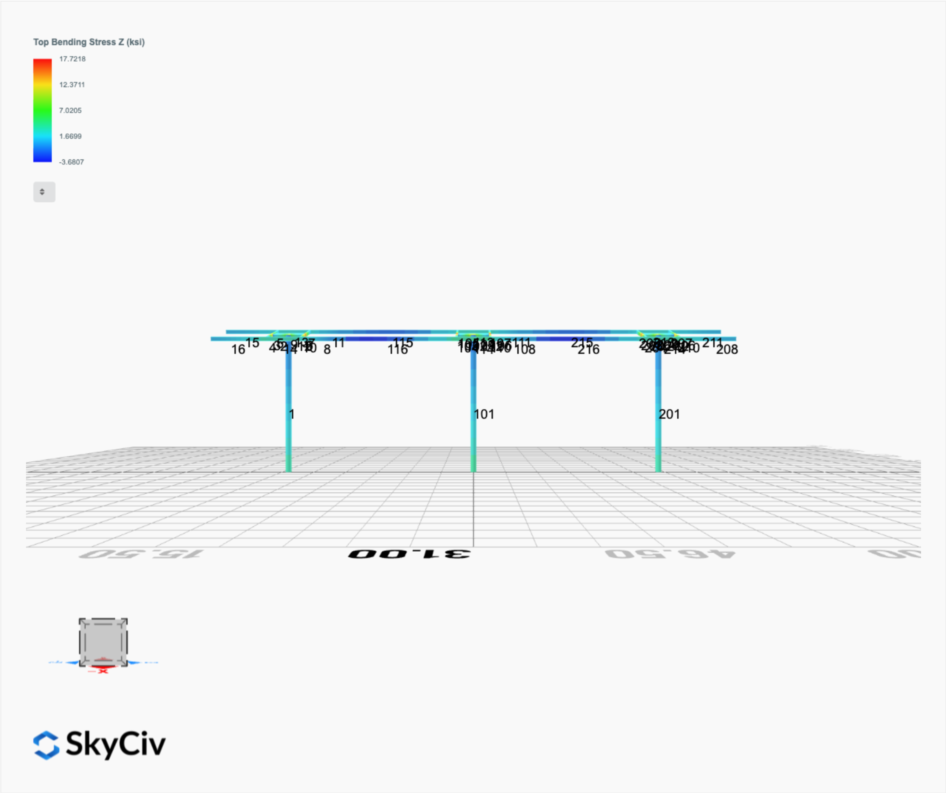


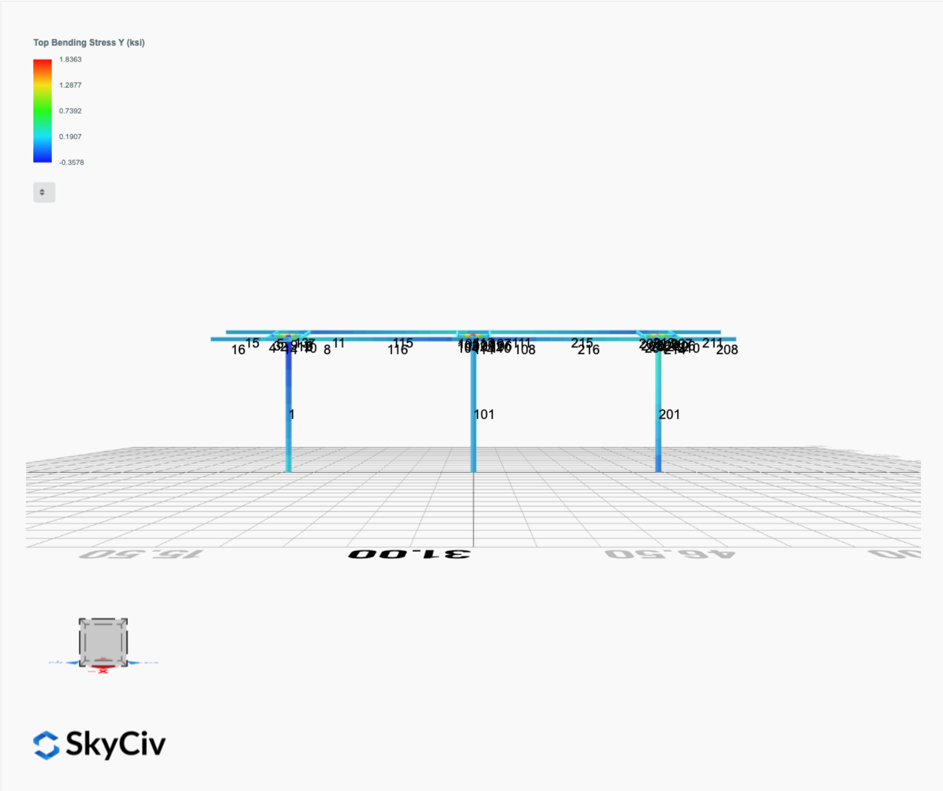
Result Check	Max Limit	Max Value	Utility	Status
Custom Stress Limit	34.5	15.71619624	0.456	PASS
Material Yield	34.5	15.71619624	0.456	PASS
Material Strength	37	15.71619624	0.425	PASS



FEM Results (Envelope Worst Case for each member)



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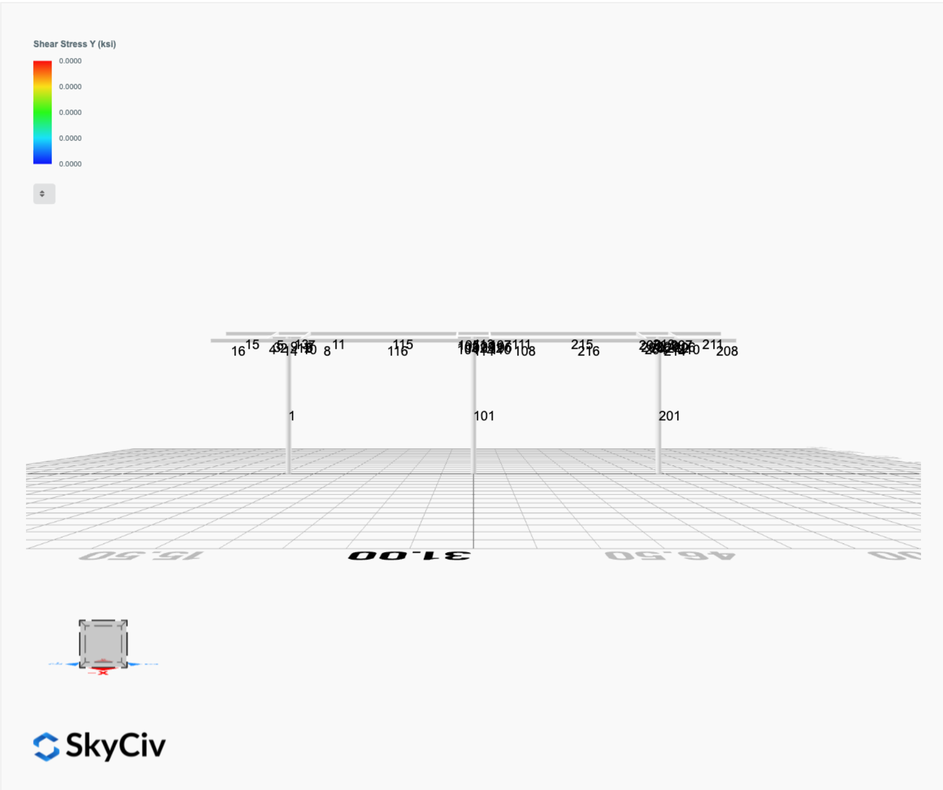
0.1907
-0.3578
101
201
31.00
SkyCiv


Shear Stress Y (ksi)
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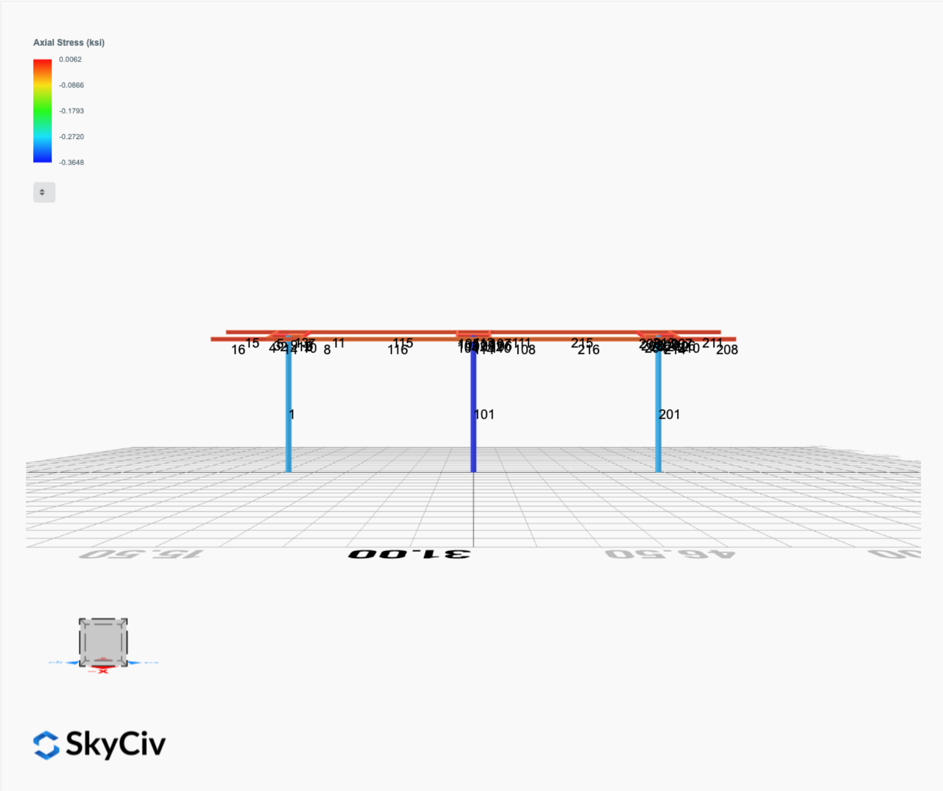
0.0000
0.0000
0.0000
0.0000
101
201
31.00
SkyCiv


Axial Stress (ksi)
0.0062
-0.0866
-0.1793
-0.2720
-0.3648
1
101
201
31.00
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	0.0032	2.6316	0.0330	0.1739	-0.0096	-0.0270
ULS: 2. D + L	0.0032	2.6316	0.0330	0.1739	-0.0096	-0.0270
ULS: 3. D + (S or Lr or R)	0.0032	2.6316	0.0330	0.1739	-0.0096	-0.0270
ULS: 3. D + (S or Lr or R)	0.0032	2.6316	0.0330	0.1739	-0.0096	-0.0270
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0032	2.6316	0.0330	0.1739	-0.0096	-0.0270
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0032	2.6316	0.0330	0.1739	-0.0096	-0.0270
ULS: 5b. D + 0.7E	0.0032	2.6316	0.0330	0.1739	-0.0096	-0.0270
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0032	2.6316	0.0330	0.1739	-0.0096	-0.0270
ULS: 8. 0.6D + 0.7E	0.0019	1.5789	0.0198	0.1043	-0.0058	-0.0162
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.3981	4.8552	0.0727	0.3813	-0.0561	8.5590
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.3981	4.8552	0.0727	0.3813	-0.0561	8.5590
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.2807	1.0734	0.0067	0.0368	0.0180	-3.2807
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.2534	1.2727	0.0069	0.0385	0.0254	-9.2552
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.2978	4.2993	0.0628	0.3294	-0.0445	6.4125
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.2978	4.2993	0.0628	0.3294	-0.0445	6.4125
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.2113	1.4629	0.0133	0.0711	0.0111	-2.4673
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1909	1.6124	0.0134	0.0723	0.0166	-6.9481
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.2978	4.2993	0.0628	0.3294	-0.0445	6.4125
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.2978	4.2993	0.0628	0.3294	-0.0445	6.4125
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.2113	1.4629	0.0133	0.0711	0.0111	-2.4673
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1909	1.6124	0.0134	0.0723	0.0166	-6.9481
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.3994	3.8025	0.0595	0.3117	-0.0523	8.5698
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.3994	3.8025	0.0595	0.3117	-0.0523	8.5698
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.2795	0.0208	-0.0065	-0.0327	0.0219	-3.2699
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.2521	0.2201	-0.0063	-0.0311	0.0292	-9.2444

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	6.8640
Shear X	-0.6689
Shear Z	0.1062
Moment X	0.5575
Moment Y (Twist)	0.0900
Moment Z	15.8239

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	4.8552
Shear X	-0.3994
Shear Z	0.0727
Moment X	0.3813
Moment Y (Twist)	0.0561
Moment Z	9.2552

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	-0.0064	2.9912	-0.0000	0.0000	0.0000	0.1222
ULS: 2. D + L	-0.0064	2.9912	-0.0000	0.0000	0.0000	0.1222
ULS: 3. D + (S or Lr or R)	-0.0064	2.9912	-0.0000	0.0000	0.0000	0.1222
ULS: 3. D + (S or Lr or R)	-0.0064	2.9912	-0.0000	0.0000	0.0000	0.1222
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0064	2.9912	-0.0000	0.0000	0.0000	0.1222
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0064	2.9912	-0.0000	0.0000	0.0000	0.1222
ULS: 5b. D + 0.7E	-0.0064	2.9912	-0.0000	0.0000	0.0000	0.1222

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0064	2.9912	-0.0000	0.0000	0.0000	0.1222
ULS: 8. 0.6D + 0.7E	-0.0038	1.7947	-0.0000	0.0000	0.0000	0.0733
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.4494	5.6088	0.0000	-0.0000	0.0000	9.6425
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.4494	5.6088	0.0000	-0.0000	0.0000	9.6425
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.3122	1.1530	0.0000	-0.0000	0.0000	-3.5667
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.2535	1.3966	-0.0000	0.0000	0.0000	-9.9328
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.3387	4.9544	0.0000	-0.0000	0.0000	7.2624
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.3387	4.9544	0.0000	-0.0000	0.0000	7.2624
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.2325	1.6125	0.0000	-0.0000	0.0000	-2.6445
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1885	1.7953	-0.0000	0.0000	0.0000	-7.4190
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.3387	4.9544	0.0000	-0.0000	0.0000	7.2624
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.3387	4.9544	0.0000	-0.0000	0.0000	7.2624
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.2325	1.6125	0.0000	-0.0000	0.0000	-2.6445
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1885	1.7953	-0.0000	0.0000	0.0000	-7.4190
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.4469	4.4124	0.0000	-0.0000	0.0000	9.5936
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.4469	4.4124	0.0000	-0.0000	0.0000	9.5936
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.3147	-0.0435	0.0000	-0.0000	0.0000	-3.6155
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.2561	0.2002	-0.0000	0.0000	0.0000	-9.9817

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	7.9519
Shear X	-0.7447
Shear Z	-0.0000
Moment X	0.0000
Moment Y (Twist)	0.0000
Moment Z	17.0808

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	5.6088
Shear X	-0.4494
Shear Z	0.0000
Moment X	-0.0000
Moment Y (Twist)	0.0000
Moment Z	9.9817

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	0.0032	2.6316	-0.0330	-0.1739	0.0096	-0.0270
ULS: 2. D + L	0.0032	2.6316	-0.0330	-0.1739	0.0096	-0.0270
ULS: 3. D + (S or Lr or R)	0.0032	2.6316	-0.0330	-0.1739	0.0096	-0.0270
ULS: 3. D + (S or Lr or R)	0.0032	2.6316	-0.0330	-0.1739	0.0096	-0.0270
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0032	2.6316	-0.0330	-0.1739	0.0096	-0.0270
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0032	2.6316	-0.0330	-0.1739	0.0096	-0.0270
ULS: 5b. D + 0.7E	0.0032	2.6316	-0.0330	-0.1739	0.0096	-0.0270
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0032	2.6316	-0.0330	-0.1739	0.0096	-0.0270
ULS: 8. 0.6D + 0.7E	0.0019	1.5789	-0.0198	-0.1043	0.0058	-0.0162
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.3981	4.8552	-0.0727	-0.3813	0.0561	8.5590
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.3981	4.8552	-0.0727	-0.3813	0.0561	8.5590
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.2807	1.0734	-0.0067	-0.0368	-0.0180	-3.2807
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.2534	1.2727	-0.0069	-0.0385	-0.0254	-9.2552
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.2978	4.2993	-0.0628	-0.3294	0.0445	6.4125
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.2978	4.2993	-0.0628	-0.3294	0.0445	6.4125
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.2113	1.4629	-0.0133	-0.0711	-0.0111	-2.4673
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1909	1.6124	-0.0134	-0.0723	-0.0166	-6.9481

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	-0.2978	4.2993	-0.0628	-0.3294	0.0445	6.4125
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.2978	4.2993	-0.0628	-0.3294	0.0445	6.4125
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.2113	1.4629	-0.0133	-0.0711	-0.0111	-2.4673
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1909	1.6124	-0.0134	-0.0723	-0.0166	-6.9481
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.3994	3.8025	-0.0595	-0.3117	0.0523	8.5698
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.3994	3.8025	-0.0595	-0.3117	0.0523	8.5698
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.2795	0.0208	0.0065	0.0327	-0.0219	-3.2699
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.2521	0.2201	0.0063	0.0311	-0.0292	-9.2444

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	6.8640
Shear X	-0.6689
Shear Z	-0.1062
Moment X	-0.5575
Moment Y (Twist)	0.0900
Moment Z	15.8240

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	4.8552
Shear X	-0.3994
Shear Z	-0.0727
Moment X	-0.3813
Moment Y (Twist)	0.0561
Moment Z	9.2552

Project Details

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

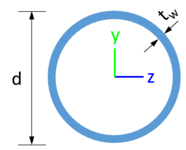
User Name: sales@mtsolar.us
Unit System: imperial

Design Input Information

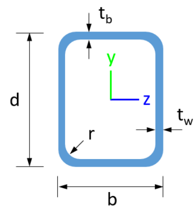
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

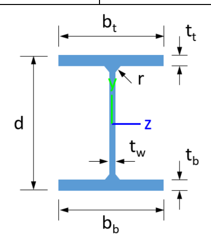
Section Dimensions



ID	Name	d (in)	t_w (in)					
1	2in Pipe Sch 40	2.38	0.15					
4	4in Pipe Sch 40	4.50	0.24					
9	8in Pipe Sch 40	8.63	0.32					



ID	Name	d (in)	b (in)	t_w (in)	t_b (in)	r (in)		
15	HSS5x3x1/8	5.00	3.00	0.12	0.12	0.12		



ID	Name	d (in)	t_w (in)	b_t (in)	b_b (in)	t_t (in)	t_b (in)	r (in)
18	W6x9	5.90	0.17	3.94	3.94	0.21	0.21	0.25

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)
1	2in Pipe Sch 40	1.07	1.33	0.67	0.67	0.00	0.76	0.76
4	4in Pipe Sch 40	3.17	14.47	7.23	7.23	0.00	4.31	4.31
9	8in Pipe Sch 40	8.40	144.98	72.49	72.49	0.00	22.21	22.21

15	HSS5x3x1/8	1.77	6.02	2.75	6.03	152.35	2.07	2.93
18	W6x9	2.68	0.04	2.20	16.40	17.70	1.72	6.23

Member Properties

Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	9	34.93	34.93	16.63	-	300	200	1
2	4	1.30	1.30	2.00	-	300	200	1
3	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.21,1.17,1.18,1.18,1.21,1.17,1.18,1.18,1.19,1.34,1.18,1.18,1.19,1.34,1.18,1.18,1.12,1.17	300	200	1
4	15	2.44	2.44	3.75	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.63,1.68,1.67,1.67,1.63,1.68,1.67,1.67,1.70,1.68,1.67,1.67,1.70,1.68,1.67,1.67,1.65,1.68	300	200	1
5	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.71,1.66,1.67,1.67,1.71,1.66,1.67,1.67,1.68,1.89,1.67,1.67,1.68,1.89,1.67,1.67,1.61,1.66	300	200	1
6	15	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.21,1.18,1.18,1.18,1.21,1.18,1.18,1.18,1.19,1.27,1.18,1.18,1.19,1.27,1.18,1.18,1.14,1.18	300	200	1
7	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.71,1.66,1.67,1.67,1.71,1.66,1.67,1.67,1.68,1.85,1.67,1.67,1.68,1.85,1.67,1.67,1.63,1.66	300	200	1
8	18	1.33	1.33	2.05	2.11,2.11,2.11,2.11,2.11,2.11,2.11,2.13,2.21,2.11,2.11,2.13,2.21,2.11,2.11,2.10,2.13,2.11,2.11,2.10,2.13,2.11,2.11,2.12,2.36	300	200	1
9	1	2.60	2.60	4.00	-	300	200	1
10	15	2.44	2.44	3.75	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.64,1.68,1.67,1.67,1.64,1.68,1.67,1.67,1.70,1.68,1.67,1.67,1.70,1.68,1.67,1.67,1.65,1.68	300	200	1
11	18	1.33	1.33	2.05	2.12,2.12,2.12,2.12,2.12,2.12,2.13,2.13,2.14,2.35,2.13,2.13,2.14,2.35,2.13,2.13,2.12,1.03,2.13,2.13,2.12,1.03,2.13,2.13,2.10,2.35	300	200	1
12	4	1.30	1.30	2.00	-	300	200	1
13	18	4.88	4.00	7.50	1.07,1.07,1.07,1.07,1.07,1.07,1.08,1.08,1.17,1.13,1.08,1.08,1.17,1.13,1.08,1.08,1.08,1.09,1.08,1.08,1.08,1.09,1.08,1.08,1.03,1.09	300	200	1
14	18	4.88	4.00	7.50	1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.10,1.11,1.07,1.07,1.10,1.11,1.07,1.07,1.06,1.09,1.07,1.07,1.06,1.09,1.07,1.07,1.09,1.13	300	200	1
15	18	9.97	9.97	4.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
16	18	9.97	9.97	4.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
101	9	34.93	34.93	16.63	-	300	200	1
102	4	1.30	1.30	2.00	-	300	200	1
103	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.21,1.17,1.18,1.18,1.21,1.17,1.18,1.18,1.19,1.25,1.18,1.18,1.19,1.25,1.18,1.18,1.14,1.17	300	200	1
104	15	2.44	2.44	3.75	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.64,1.68,1.67,1.67,1.64,1.68,1.67,1.67,1.69,1.68,1.67,1.67,1.69,1.68,1.67,1.67,1.66,1.68	300	200	1
105	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.71,1.66,1.67,1.67,1.71,1.66,1.67,1.67,1.68,1.77,1.67,1.67,1.68,1.77,1.67,1.67,1.63,1.66	300	200	1
106	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.21,1.17,1.18,1.18,1.21,1.17,1.18,1.18,1.19,1.25,1.18,1.18,1.19,1.25,1.18,1.18,1.14,1.17	300	200	1
107	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.71,1.66,1.67,1.67,1.71,1.66,1.67,1.67,1.68,1.77,1.67,1.67,1.68,1.77,1.67,1.67,1.63,1.66	300	200	1

108	18	1.33	1.33	2.05	2.25,2.25,2.25,2.25,2.25,2.25,2.24,2.24,2.27,2.33,2.24,2.24,2.27,2.33,2.25,2.25,2.24,2.29,2.25,2.25,2.24,2.29,2.24,2.24,2.27,2.36	300	200	1
109	1	2.60	2.60	4.00	-	300	200	1
110	15	2.44	2.44	3.75	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.64,1.68,1.67,1.67,1.64,1.68,1.67,1.67,1.69,1.68,1.67,1.67,1.69,1.68,1.67,1.67,1.66,1.68	300	200	1
111	18	1.33	1.33	2.05	2.26,2.26,2.26,2.26,2.26,2.26,2.28,2.28,2.25,2.13,2.28,2.28,2.25,2.13,2.28,2.28,2.26,1.22,2.28,2.28,2.26,1.22,2.29,2.29,2.27,2.25	300	200	1
112	4	1.30	1.30	2.00	-	300	200	1
113	18	4.88	4.00	7.50	1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.16,1.11,1.03,1.03,1.16,1.11,1.03,1.03,1.03,1.01,1.03,1.03,1.03,1.01,1.03,1.03,1.02,1.08	300	200	1
114	18	4.88	4.00	7.50	1.03,1.03,1.03,1.03,1.03,1.03,1.02,1.02,1.06,1.08,1.02,1.02,1.06,1.08,1.02,1.02,1.02,1.03,1.02,1.02,1.02,1.03,1.02,1.02,1.03,1.12	300	200	1
115	18	8.42	8.42	12.95	1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.17,1.18,1.15,1.17,1.17,1.18,1.15,1.17,1.17,1.18,2.45,1.17,1.17,1.18,2.45,1.17,1.17,1.18,1.15	300	200	1
116	18	8.42	8.42	12.95	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.16,1.18,1.18,1.17,1.16,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.16	300	200	1
201	9	34.93	34.93	16.63	-	300	200	1
202	4	1.30	1.30	2.00	-	300	200	1
203	15	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.21,1.18,1.18,1.18,1.21,1.18,1.18,1.18,1.19,1.27,1.18,1.18,1.19,1.27,1.18,1.18,1.14,1.18	300	200	1
204	15	2.44	2.44	3.75	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.64,1.68,1.67,1.67,1.64,1.68,1.67,1.67,1.70,1.68,1.67,1.67,1.70,1.68,1.67,1.67,1.65,1.68	300	200	1
205	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.71,1.66,1.67,1.67,1.71,1.66,1.67,1.67,1.68,1.85,1.67,1.67,1.68,1.85,1.67,1.67,1.63,1.66	300	200	1
206	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.21,1.17,1.18,1.18,1.21,1.17,1.18,1.18,1.19,1.34,1.18,1.18,1.19,1.34,1.18,1.18,1.12,1.17	300	200	1
207	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.71,1.66,1.67,1.67,1.71,1.66,1.67,1.67,1.68,1.89,1.67,1.67,1.68,1.89,1.67,1.67,1.61,1.66	300	200	1
208	18	9.97	9.97	4.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
209	1	2.60	2.60	4.00	-	300	200	1
210	15	2.44	2.44	3.75	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.63,1.68,1.67,1.67,1.63,1.68,1.67,1.67,1.70,1.68,1.67,1.67,1.70,1.68,1.67,1.67,1.65,1.68	300	200	1
211	18	9.97	9.97	4.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
212	4	1.30	1.30	2.00	-	300	200	1
213	18	4.88	4.00	7.50	1.07,1.07,1.07,1.07,1.07,1.07,1.08,1.08,1.17,1.13,1.08,1.08,1.17,1.13,1.08,1.08,1.08,1.09,1.08,1.08,1.08,1.09,1.08,1.08,1.03,1.09	300	200	1
214	18	4.88	4.00	7.50	1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.10,1.11,1.07,1.07,1.10,1.11,1.07,1.07,1.06,1.09,1.07,1.07,1.06,1.09,1.07,1.07,1.09,1.13	300	200	1
215	18	8.42	8.42	12.95	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.15,1.16,1.14,1.14,1.15,1.16,1.14,1.14,1.14,1.75,1.14,1.14,1.14,1.75,1.14,1.14,1.14,1.16	300	200	1
216	18	8.42	8.42	12.95	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.15,1.14,1.14,1.14,1.15,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.16	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	377.97	93.23	83.29	83.29	113.39	113.39
2	142.83	141.72	16.17	16.17	42.85	42.85
3	79.65	74.02	10.99	4.60	29.14	16.61
4	79.65	72.01	10.99	4.60	29.14	16.61
5	79.65	73.44	10.99	4.60	29.14	16.61
6	79.65	74.02	10.99	4.60	29.14	16.61
7	79.65	73.44	10.99	4.60	29.14	16.61
8	120.60	117.88	23.36	6.45	30.09	45.74
9	48.35	43.11	2.85	2.85	14.51	14.51
10	79.65	72.01	10.99	4.60	29.14	16.61
11	120.60	117.88	23.36	6.45	30.09	45.74
12	142.83	141.72	16.17	16.17	42.85	42.85
13	120.60	98.23	18.13	6.45	30.09	45.74
14	120.60	98.23	18.66	6.45	30.09	45.74
15	120.60	34.69	23.36	6.45	30.09	45.74
16	120.60	34.69	23.36	6.45	30.09	45.74
101	377.97	93.23	83.29	83.29	113.39	113.39
102	142.83	141.72	16.17	16.17	42.85	42.85
103	79.65	74.02	10.99	4.60	29.14	16.61
104	79.65	72.01	10.99	4.60	29.14	16.61
105	79.65	73.44	10.99	4.60	29.14	16.61
106	79.65	74.02	10.99	4.60	29.14	16.61
107	79.65	73.44	10.99	4.60	29.14	16.61
108	120.60	117.88	23.36	6.45	30.09	45.74
109	48.35	43.11	2.85	2.85	14.51	14.51
110	79.65	72.01	10.99	4.60	29.14	16.61
111	120.60	117.88	23.36	6.45	30.09	45.74
112	142.83	141.72	16.17	16.17	42.85	42.85
113	120.60	98.23	17.78	6.45	30.09	45.74
114	120.60	98.23	17.96	6.45	30.09	45.74
115	120.60	48.60	11.32	6.45	30.09	45.74
116	120.60	48.60	11.42	6.45	30.09	45.74
201	377.97	93.23	83.29	83.29	113.39	113.39
202	142.83	141.72	16.17	16.17	42.85	42.85
203	79.65	74.02	10.99	4.60	29.14	16.61
204	79.65	72.01	10.99	4.60	29.14	16.61
205	79.65	73.44	10.99	4.60	29.14	16.61
206	79.65	74.02	10.99	4.60	29.14	16.61
207	79.65	73.44	10.99	4.60	29.14	16.61
208	120.60	34.69	23.36	6.45	30.09	45.74
209	48.35	43.11	2.85	2.85	14.51	14.51
210	79.65	72.01	10.99	4.60	29.14	16.61
211	120.60	34.69	23.36	6.45	30.09	45.74
212	142.83	141.72	16.17	16.17	42.85	42.85
213	120.60	98.23	18.13	6.45	30.09	45.74
214	120.60	98.23	18.66	6.45	30.09	45.74
215	120.60	48.60	11.22	6.45	30.09	45.74
216	120.60	48.60	11.22	6.45	30.09	45.74

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	0.074	0.190	0.014	0.006	0.001	0.219	#13	0.713	Not Required	Pass
2	0.001	0.316	0.043	0.068	0.007	0.359	#13	0.034	Not Required	Pass
3	0.002	0.552	0.012	0.055	0.001	0.557	#13	0.044	Not Required	Pass
4	0.001	0.431	0.044	0.044	0.006	0.468	#13	0.078	Not Required	Pass
5	0.002	0.342	0.039	0.055	0.006	0.345	#13	0.073	Not Required	Pass
6	0.002	0.636	0.024	0.065	0.003	0.661	#13	0.044	Not Required	Pass
7	0.002	0.394	0.060	0.064	0.009	0.408	#13	0.073	Not Required	Pass
8	0.001	0.044	0.030	0.033	0.002	0.053	#13	0.088	Not Required	Pass
9	0.003	0.077	0.018	0.002	0.001	0.096	#13	0.198	Not Required	Pass
10	0.002	0.498	0.058	0.050	0.007	0.507	#13	0.078	Not Required	Pass
11	0.000	0.052	0.031	0.043	0.002	0.060	#13	0.088	Not Required	Pass
12	0.001	0.391	0.048	0.079	0.008	0.439	#13	0.052	Not Required	Pass
13	0.001	0.211	0.057	0.053	0.003	0.231	#13	0.265	Not Required	Pass
14	0.001	0.169	0.057	0.041	0.003	0.190	#13	0.177	Not Required	Pass
15	0.000	0.085	0.022	0.028	0.001	0.104	#13	Not Required	Not Required	Pass
16	0.000	0.067	0.022	0.022	0.001	0.086	#13	Not Required	Not Required	Pass
101	0.085	0.205	0.000	0.007	0.000	0.240	#13	0.713	Not Required	Pass
102	0.001	0.415	0.053	0.086	0.009	0.468	#13	0.034	Not Required	Pass
103	0.002	0.693	0.017	0.070	0.002	0.707	#13	0.044	Not Required	Pass
104	0.002	0.551	0.058	0.056	0.007	0.587	#13	0.078	Not Required	Pass
105	0.002	0.430	0.061	0.070	0.009	0.446	#13	0.073	Not Required	Pass
106	0.002	0.693	0.017	0.070	0.002	0.707	#13	0.044	Not Required	Pass
107	0.002	0.430	0.061	0.070	0.009	0.446	#13	0.073	Not Required	Pass
108	0.001	0.058	0.031	0.036	0.002	0.089	#13	0.088	Not Required	Pass
109	0.004	0.074	0.015	0.001	0.000	0.091	#13	0.198	Not Required	Pass
110	0.002	0.551	0.058	0.056	0.007	0.587	#13	0.078	Not Required	Pass
111	0.000	0.065	0.031	0.045	0.002	0.097	#13	0.088	Not Required	Pass
112	0.001	0.415	0.053	0.086	0.009	0.468	#13	0.034	Not Required	Pass
113	0.001	0.237	0.058	0.055	0.003	0.288	#13	0.265	Not Required	Pass
114	0.002	0.205	0.058	0.044	0.003	0.251	#13	0.265	Not Required	Pass
115	0.001	0.314	0.031	0.045	0.002	0.343	#13	0.557	Not Required	Pass
116	0.001	0.246	0.031	0.036	0.002	0.273	#13	0.557	Not Required	Pass
201	0.074	0.190	0.014	0.006	0.001	0.219	#13	0.713	Not Required	Pass
202	0.001	0.391	0.048	0.079	0.008	0.439	#13	0.052	Not Required	Pass
203	0.002	0.636	0.024	0.065	0.003	0.661	#13	0.044	Not Required	Pass
204	0.002	0.498	0.058	0.050	0.007	0.507	#13	0.078	Not Required	Pass
205	0.002	0.394	0.060	0.064	0.009	0.408	#13	0.073	Not Required	Pass
206	0.002	0.552	0.012	0.055	0.001	0.557	#13	0.044	Not Required	Pass
207	0.002	0.342	0.039	0.055	0.006	0.345	#13	0.073	Not Required	Pass
208	0.000	0.067	0.022	0.022	0.001	0.086	#13	Not Required	Not Required	Pass
209	0.003	0.077	0.018	0.002	0.001	0.096	#13	0.198	Not Required	Pass
210	0.001	0.431	0.044	0.044	0.006	0.468	#13	0.078	Not Required	Pass
211	0.000	0.085	0.022	0.028	0.001	0.104	#13	Not Required	Not Required	Pass
212	0.001	0.316	0.043	0.068	0.007	0.359	#13	0.034	Not Required	Pass
213	0.001	0.211	0.057	0.053	0.003	0.231	#13	0.177	Not Required	Pass
214	0.001	0.169	0.057	0.041	0.003	0.190	#13	0.265	Not Required	Pass
215	0.001	0.322	0.031	0.043	0.002	0.347	#13	0.557	Not Required	Pass
216	0.001	0.252	0.030	0.033	0.002	0.279	#13	0.557	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

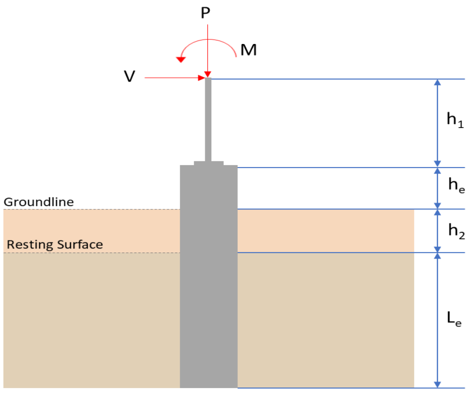
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36\ \text{in}$ - Pile diameter
$L = 7\ \text{ft}$ - Total pile length
$h_1 = 0\ \text{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \text{ft}$ - Depth to resisting surface
$h_e = 0\ \text{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	4.855	6.864
V_x (kip)	-0.399	-0.669
V_z (kip)	0.073	0.106
M_x (kipft)	0.381	0.557
M_z (kipft)	9.255	15.824

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,

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

$$H_o = \frac{(-0.399\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.133\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(9.255 \text{ kipft}) + ((-0.399 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 3.085 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 6.7198 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.073 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.024333 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.381 \text{ kipft}) + ((0.073 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.127 \text{ kipft/ft}$$

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:
$L_{e,z} = 2.8201 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.7198 \text{ ft}), (2.8201 \text{ ft})]$$

$$L_{e,req} = 6.72 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.72 \text{ ft})}{(7 \text{ ft})}$$

$$Ratio = 0.96$$

Status: **PASS**
Ratio: **0.960**

End-bearing Capacity (ASD)

A - Pile cros-section area

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

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

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

q - End-bearing pressure

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

$$q = \frac{(4.855 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 0.68684 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.68684 \text{ kip/ft}^2\right)}{(2000 \text{ psf})}$$

$$Ratio = 0.34342$$

Status: **PASS**
Ratio: **0.340**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7 \text{ ft})}{(36 \text{ in})}$$

$$L/D = 2.3333$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.133 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 3.085 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (3.085 \text{ kipft/ft}) \times (7 \text{ ft})) + \left(3 \times (-0.133 \text{ kip/ft}) \times (7 \text{ ft})^2\right)}{(6 \times (3.085 \text{ kipft/ft})) + (4 \times (-0.133 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.7644 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (3.085 \text{ kipft/ft})) + (3 \times (-0.133 \text{ kip/ft}) \times (7 \text{ ft}))]^{\,2}}{(7 \text{ ft})^2 \times [(3 \times (3.085 \text{ kipft/ft})) + (2 \times (-0.133 \text{ kip/ft}) \times (7 \text{ ft}))]}$$

$$p = 0.29639 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (3.085 \text{ kipft/ft})) + ((-0.133 \text{ kip/ft}) \times (7 \text{ ft}))]}{(7 \text{ ft})^2}$$

$$s = 1.0077 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.7644 \text{ ft})}{2}$$

$$p_a = 0.35733 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.29639 \text{ kip/ft}^2\right)}{\left(0.35733 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.82946$$

Status: **PASS**
Ratio: **0.830**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.0077\ \mathrm{kip/ft^2}\right)}{\left(1.05\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.95972$$

Status: **PASS**
Ratio: **0.960**

Considering z-direction:

$H_o = 0.024333\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.127\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.127\ \mathrm{kipft/ft}) \times (7\ \mathrm{ft})) + \left(3 \times (0.024333\ \mathrm{kip/ft}) \times (7\ \mathrm{ft})^2\right)}{(6 \times (0.127\ \mathrm{kipft/ft})) + (4 \times (0.024333\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))}$$

$$a = 4.942\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.127\ \mathrm{kipft/ft})) + (3 \times (0.024333\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))]^{\,2}}{(7\ \mathrm{ft})^2 \times [(3 \times (0.127\ \mathrm{kipft/ft})) + (2 \times (0.024333\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))]}$$

$$p = 0.034591\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (0.127\ \mathrm{kipft/ft})) + ((0.024333\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))]}{(7\ \mathrm{ft})^2}$$

$$s = 0.081619\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.942\ \mathrm{ft})}{2}$$

$$p_a = 0.37065\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.034591\ \mathrm{kip/ft^2}\right)}{\left(0.37065\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.093324$$

Status: **PASS**
Ratio: **0.090**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

$Ratio$ - Lateral soil capacity

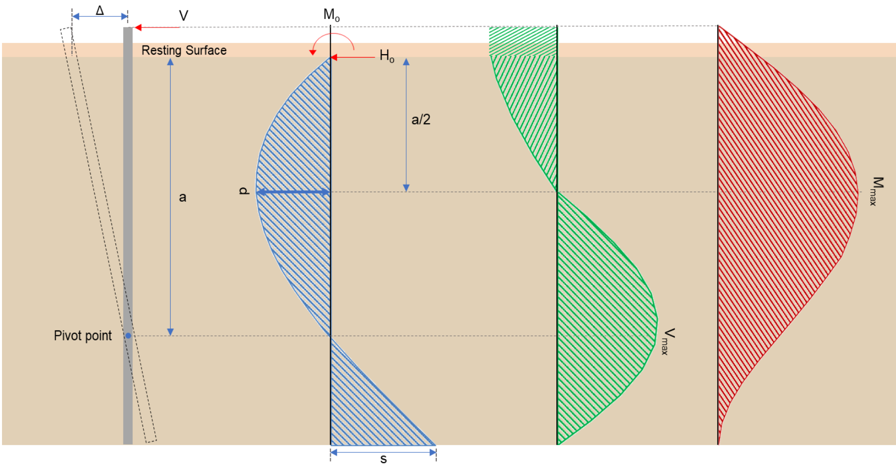
$$Ratio = \frac{s}{\ }$$

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

$$Ratio = \frac{(0.081619\ \mathrm{kip/ft^2})}{(1.05\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.077733$$

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



Pile Rotation
Pressure Diagram
Shear Diagram
Moment Diagram

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.669\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.223\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(15.824\ \mathrm{kipft}) + ((-0.669\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 5.2747\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(5.2747\ \mathrm{kipft/ft})}{(-0.223\ \mathrm{kip/ft})}$$

$$E = 23.653\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.2747\ \mathrm{kipft/ft}) \times (7\ \mathrm{ft})) + \left(3 \times (-0.223\ \mathrm{kip/ft}) \times (7\ \mathrm{ft})^2\right)}{(6 \times (5.2747\ \mathrm{kipft/ft})) + (4 \times (-0.223\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))}$$

$$a = 4.7628\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.223\ \mathrm{kip/ft}) \times (36\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (23.653\ \mathrm{ft})}{(7\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.7628\ \mathrm{ft})}{(7\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (23.653\ \mathrm{ft})}{(7\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.7628\ \mathrm{ft})}{(7\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 4.4462 \text{ kip}$$

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

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

$$M_{max} = ((-0.223 \text{ kip/ft}) \times (36 \text{ in}) \times (7 \text{ ft})) \times \left[\left(\frac{(23.653 \text{ ft})}{(7 \text{ ft})} + \frac{(4.7628 \text{ ft})}{2 \times (7 \text{ ft})}\right) - \left[\left(\frac{4 \times (23.653 \text{ ft})}{(7 \text{ ft})} + 3\right) \times \left(\frac{(4.7628 \text{ ft})}{2 \times (7 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (23.653 \text{ ft})}{(7 \text{ ft})} + 2\right) \times \left(\frac{(4.7628 \text{ ft})}{2 \times (7 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 15.133 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.106 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.035333 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.557 \text{ kipft}) + ((0.106 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.18567 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.18567 \text{ kipft/ft})}{(0.035333 \text{ kip/ft})}$$

$$E = 5.2547 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.18567 \text{ kipft/ft}) \times (7 \text{ ft})) + \left(3 \times (0.035333 \text{ kip/ft}) \times (7 \text{ ft})^2\right)}{(6 \times (0.18567 \text{ kipft/ft})) + (4 \times (0.035333 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.941 \text{ ft}$$

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

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

$$V_{max} = ((0.035333 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (5.2547 \text{ ft})}{(7 \text{ ft})} + 3\right) \times \left(\frac{(4.941 \text{ ft})}{(7 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (5.2547 \text{ ft})}{(7 \text{ ft})} + 2\right) \times \left(\frac{(4.941 \text{ ft})}{(7 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.21103 \text{ kip}$$

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

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

$$M_{max} = ((0.035333 \text{ kip/ft}) \times (36 \text{ in}) \times (7 \text{ ft})) \times \left[\left(\frac{(5.2547 \text{ ft})}{(7 \text{ ft})} + \frac{(4.941 \text{ ft})}{2 \times (7 \text{ ft})}\right) - \left[\left(\frac{4 \times (5.2547 \text{ ft})}{(7 \text{ ft})} + 3\right) \times \left(\frac{(4.941 \text{ ft})}{2 \times (7 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (5.2547 \text{ ft})}{(7 \text{ ft})} + 2\right) \times \left(\frac{(4.941 \text{ ft})}{2 \times (7 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.67202 \text{ kipft}$$

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(6.864 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (3 \text{ ksi}) \times \left(1017.9 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, \left(0.08 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -44.964 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-44.964 \text{ in}^2\right), \left(0.0018 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.99533$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

Main reinforcement: **6 - #5 (0.625 in)**
Ties: **#3(0.375 in) - 10 in**

22.4.2.2	**Axial Compression Strength (ACI 318-19, LRFD)** ϕP_N - Allowable axial compressive strength $$\phi P_N = \phi\, 0.85\ \left[\left(0.85\, f'_{ck}\ [A_g - A_{st}]\right) + (f_{yk}\, A_{st})\right]$$ $$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (3\ \mathrm{ksi}) \times \left[\left(1017.9\ \mathrm{in}^2\right) - \left(1.8408\ \mathrm{in}^2\right)\right]\right) + \left((60\ \mathrm{ksi}) \times \left(1.8408\ \mathrm{in}^2\right)\right)\right]$$ $$\phi P_N = 1492.5\ \mathrm{kip}$$ $Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(6.864\ \mathrm{kip})}{(1492.5\ \mathrm{kip})}$$ $$Ratio = 0.004599$$	Status: **PASS** Ratio: **0.000**

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.71796$$

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

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

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

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(3000\ \mathrm{psi})} \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$

$$V_{c,max} = 203.86\ \mathrm{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$, $P = 6.864\ \mathrm{kip} \rightarrow 6864\ \mathrm{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(3000\ \mathrm{psi})} + \frac{(6864\ \mathrm{lbf})}{6 \times (1017.9\ \mathrm{in}^2)}\right] \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$

$$V_{c,a} = 82.708\ \mathrm{kip}$$

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

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

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

$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(3000\ \mathrm{psi})} + (0.05 \times (3000\ \mathrm{psi}))\right] \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$

$$V_{c,b} = 237.06\ \mathrm{kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(203.86\ \mathrm{kip}), (82.708\ \mathrm{kip}), (237.06\ \mathrm{kip})\right]$$

$$V_c = 82.708\ \text{kip}$$

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)

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

$$V_{s,a} = 8 \times \sqrt{(3000\ \text{psi})} \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{s,a} = 454.3\ \text{kip}$$

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

$$V_s = MIN\left[(454.3\ \text{kip}), (38.17\ \text{kip})\right]$$

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((82.708\ \text{kip}) + (38.17\ \text{kip}))$$

$$\phi V_n = 78.571\ \text{kip}$$

Considering x-direction:

$V_{max} = 4.4462\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(4.4462\ \text{kip})}{(78.571\ \text{kip})}$$

$$Ratio = 0.056588$$

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

Considering z-direction:

$V_{max} = 0.21103\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.21103\ \text{kip})}{(78.571\ \text{kip})}$$

$$Ratio = 0.0026858$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

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

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

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

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(3ksi)} \times 4580.442in^3$$

$$\phi M_{n,1} = 67.947kipft$$

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

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

$$\phi M_{n,2} = (0.65) \times 0.85 \times (3 \text{ ksi}) \times \left(4580.4 \text{ in}^3\right)$$

$$\phi M_{n,2} = 632.67 \text{ kipft}$$

Therefore,
ϕM_n - Allowable flexural strength,

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

$$\phi M_n = MIN[(67.947 \text{ kipft}), (632.67 \text{ kipft})]$$

$$\phi M_n = 67.947 \text{ kipft}$$

Considering x-direction:

$M_{max} = 15.133 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(15.133 \text{ kipft})}{(67.947 \text{ kipft})}$$

$$Ratio = 0.22272$$

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

Considering z-direction:

$M_{max} = 0.67202 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.67202 \text{ kipft})}{(67.947 \text{ kipft})}$$

$$Ratio = 0.0098904$$

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

REFERENCES	CALCULATIONS	RESULTS

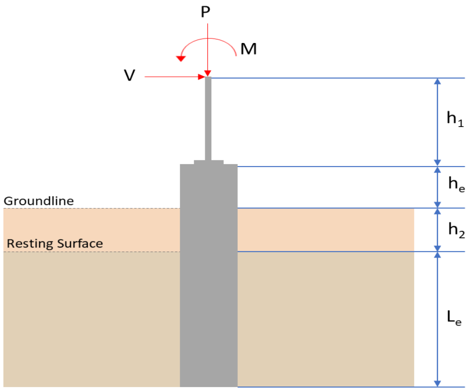
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round

$D = 36$ in - Pile diameter

$L = 7$ 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)	4.855	6.864
V_x (kip)	-0.399	-0.669
V_z (kip)	-0.073	-0.106
M_x (kipft)	-0.381	-0.557
M_z (kipft)	9.255	15.824

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.399\text{ kip})}{(36\text{ in})}$$

$$H_o = -0.133\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(9.255\ \text{kipft}) + ((-0.399\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 3.085\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 6.7198\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.073\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.024333\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.381\ \text{kipft}) + ((-0.073\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.127\ \text{kipft/ft}$$

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:
$L_{e,z} = 2.2157\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.7198\ \text{ft}), (2.2157\ \text{ft})]$$

$$L_{e,req} = 6.72\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.72\ \text{ft})}{(7\ \text{ft})}$$

$$Ratio = 0.96$$

Status: **PASS**
Ratio: **0.960**

End-bearing Capacity (ASD)

A - Pile cros-section area

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

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

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

q - End-bearing pressure

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

$$q = \frac{(4.855\ \text{kip})}{(7.0686\ \text{ft}^2)}$$

$$q = 0.68684\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.68684\ \mathrm{kip/ft^2}\right)}{\left(2000\ \mathrm{psf}\right)}$$

$$Ratio = 0.34342$$

Status: **PASS**
Ratio: **0.340**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{\left(7\ \mathrm{ft}\right)}{\left(36\ \mathrm{in}\right)}$$

$$L/D = 2.3333$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.133\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 3.085\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{\left(4 \times \left(3.085\ \mathrm{kipft/ft}\right) \times \left(7\ \mathrm{ft}\right)\right) + \left(3 \times \left(-0.133\ \mathrm{kip/ft}\right) \times \left(7\ \mathrm{ft}\right)^2\right)}{\left(6 \times \left(3.085\ \mathrm{kipft/ft}\right)\right) + \left(4 \times \left(-0.133\ \mathrm{kip/ft}\right) \times \left(7\ \mathrm{ft}\right)\right)}$$

$$a = 4.7644\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times \left[\left(4 \times \left(3.085\ \mathrm{kipft/ft}\right)\right) + \left(3 \times \left(-0.133\ \mathrm{kip/ft}\right) \times \left(7\ \mathrm{ft}\right)\right)\right]^{\ 2}}{\left(7\ \mathrm{ft}\right)^2 \times \left[\left(3 \times \left(3.085\ \mathrm{kipft/ft}\right)\right) + \left(2 \times \left(-0.133\ \mathrm{kip/ft}\right) \times \left(7\ \mathrm{ft}\right)\right)\right]}$$

$$p = 0.29639\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times \left[\left(2 \times \left(3.085\ \mathrm{kipft/ft}\right)\right) + \left(\left(-0.133\ \mathrm{kip/ft}\right) \times \left(7\ \mathrm{ft}\right)\right)\right]}{\left(7\ \mathrm{ft}\right)^2}$$

$$s = 1.0077\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = \left(150\ \mathrm{psf/ft}\right) \times \frac{\left(4.7644\ \mathrm{ft}\right)}{2}$$

$$p_a = 0.35733\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.29639\ \mathrm{kip/ft^2}\right)}{\left(0.35733\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.82946$$

Status: **PASS**
Ratio: **0.830**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

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

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

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.0077\ \text{kip/ft}^2\right)}{\left(1.05\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.95972$$

Status: **PASS**
Ratio: **0.960**

Considering z-direction:

$H_o = -0.024333\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.127\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.127\ \text{kipft/ft}) \times (7\ \text{ft})) + \left(3 \times (-0.024333\ \text{kip/ft}) \times (7\ \text{ft})^2\right)}{(6 \times (0.127\ \text{kipft/ft})) + (4 \times (-0.024333\ \text{kip/ft}) \times (7\ \text{ft}))}$$

$$a = 4.942\ \text{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.127\ \text{kipft/ft})) + (3 \times (-0.024333\ \text{kip/ft}) \times (7\ \text{ft}))]^{\ 2}}{(7\ \text{ft})^2 \times [(3 \times (0.127\ \text{kipft/ft})) + (2 \times (-0.024333\ \text{kip/ft}) \times (7\ \text{ft}))]}$$

$$p = 5.3645{\times}10^{-6}\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (0.127\ \text{kipft/ft})) + ((-0.024333\ \text{kip/ft}) \times (7\ \text{ft}))]}{(7\ \text{ft})^2}$$

$$s = 0.016093\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(4.942\ \text{ft})}{2}$$

$$p_a = 0.37065\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(5.3645{\times}10^{-6}\ \text{kip/ft}^2\right)}{\left(0.37065\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.000014473$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

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

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

$Ratio$ - Lateral soil capacity

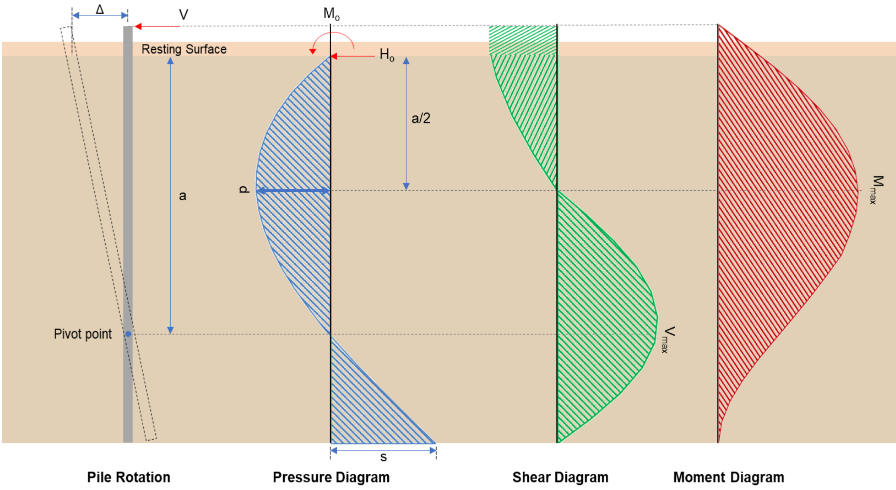
$$Ratio = \frac{s}{\ }$$

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

$$Ratio = \frac{(0.016093\ \text{kip/ft}^2)}{(1.05\ \text{kip/ft}^2)}$$

$$Ratio = 0.015327$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.669\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.223\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(15.824\ \text{kipft}) + ((-0.669\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 5.2747\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(5.2747\ \text{kipft/ft})}{(-0.223\ \text{kip/ft})}$$

$$E = 23.653\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.2747\ \text{kipft/ft}) \times (7\ \text{ft})) + \left(3 \times (-0.223\ \text{kip/ft}) \times (7\ \text{ft})^2\right)}{(6 \times (5.2747\ \text{kipft/ft})) + (4 \times (-0.223\ \text{kip/ft}) \times (7\ \text{ft}))}$$

$$a = 4.7628\ \text{ft}$$

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

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

$$V_{max} = ((-0.223\ \text{kip/ft}) \times (36\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (23.653\ \text{ft})}{(7\ \text{ft})} + 3\right) \times \left(\frac{(4.7628\ \text{ft})}{(7\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (23.653\ \text{ft})}{(7\ \text{ft})} + 2\right) \times \left(\frac{(4.7628\ \text{ft})}{(7\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 4.4462 \text{ kip}$$

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

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

$$M_{max} = ((-0.223 \text{ kip/ft}) \times (36 \text{ in}) \times (7 \text{ ft})) \times \left[\left(\frac{(23.653 \text{ ft})}{(7 \text{ ft})} + \frac{(4.7628 \text{ ft})}{2 \times (7 \text{ ft})} \right) - \left[\left(\frac{4 \times (23.653 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left(\frac{(4.7628 \text{ ft})}{2 \times (7 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (23.653 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left(\frac{(4.7628 \text{ ft})}{2 \times (7 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 15.133 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.106 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.035333 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.557 \text{ kipft}) + ((-0.106 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.18567 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.18567 \text{ kipft/ft})}{(-0.035333 \text{ kip/ft})}$$

$$E = 5.2547 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.18567 \text{ kipft/ft}) \times (7 \text{ ft})) + \left(3 \times (-0.035333 \text{ kip/ft}) \times (7 \text{ ft})^2\right)}{(6 \times (0.18567 \text{ kipft/ft})) + (4 \times (-0.035333 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.941 \text{ ft}$$

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

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

$$V_{max} = ((-0.035333 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (5.2547 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left(\frac{(4.941 \text{ ft})}{(7 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (5.2547 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left(\frac{(4.941 \text{ ft})}{(7 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.21103 \text{ kip}$$

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

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

$$M_{max} = ((-0.035333 \text{ kip/ft}) \times (36 \text{ in}) \times (7 \text{ ft})) \times \left[\left(\frac{(5.2547 \text{ ft})}{(7 \text{ ft})} + \frac{(4.941 \text{ ft})}{2 \times (7 \text{ ft})} \right) - \left[\left(\frac{4 \times (5.2547 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left(\frac{(4.941 \text{ ft})}{2 \times (7 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (5.2547 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left(\frac{(4.941 \text{ ft})}{2 \times (7 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.67202 \text{ kipft}$$

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(6.864 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (3 \text{ ksi}) \times \left(1017.9 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, \left(0.08 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -44.964 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-44.964 \text{ in}^2\right), \left(0.0018 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.99533$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

	Main reinforcement: **6 - #5 (0.625 in)** Ties: **#3(0.375 in) - 10 in**		

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

$$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (3\ \mathrm{ksi}) \times \left[\left(1017.9\ \mathrm{in}^2\right) - \left(1.8408\ \mathrm{in}^2\right)\right]\right) + \left((60\ \mathrm{ksi}) \times \left(1.8408\ \mathrm{in}^2\right)\right)\right]$$

$$\phi P_N = 1492.5\ \mathrm{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(6.864\ \mathrm{kip})}{(1492.5\ \mathrm{kip})}$$

$$Ratio = 0.004599$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.71796$$

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

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

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

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(3000\ \mathrm{psi})} \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$

$$V_{c,max} = 203.86\ \mathrm{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$, $P = 6.864\ \mathrm{kip} \rightarrow 6864\ \mathrm{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(3000\ \mathrm{psi})} + \frac{(6864\ \mathrm{lbf})}{6 \times \left(1017.9\ \mathrm{in}^2\right)}\right] \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$

$$V_{c,a} = 82.708\ \mathrm{kip}$$

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

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

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

$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(3000\ \mathrm{psi})} + (0.05 \times (3000\ \mathrm{psi}))\right] \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$

$$V_{c,b} = 237.06\ \mathrm{kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(203.86\ \mathrm{kip}), (82.708\ \mathrm{kip}), (237.06\ \mathrm{kip})\right]$$

$$V_c = 82.708 \text{ kip}$$

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)

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

$$V_{s,a} = 8 \times \sqrt{(3000 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{s,a} = 454.3 \text{ kip}$$

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

$$V_s = MIN\left[(454.3 \text{ kip}), (38.17 \text{ kip})\right]$$

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((82.708 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 78.571 \text{ kip}$$

Considering x-direction:

$V_{max} = 4.4462 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(4.4462 \text{ kip})}{(78.571 \text{ kip})}$$

$$Ratio = 0.056588$$

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

Considering z-direction:

$V_{max} = 0.21103 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.21103 \text{ kip})}{(78.571 \text{ kip})}$$

$$Ratio = 0.0026858$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

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

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

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

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(3ksi)} \times 4580.442 in^3$$

$$\phi M_{n,1} = 67.947 kipft$$

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

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

$$\phi M_{n,2} = (0.65) \times 0.85 \times (3 \text{ ksi}) \times \left(4580.4 \text{ in}^3\right)$$

$$\phi M_{n,2} = 632.67 \text{ kipft}$$

Therefore,
ϕM_n - Allowable flexural strength,

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

$$\phi M_n = MIN[(67.947 \text{ kipft}), (632.67 \text{ kipft})]$$

$$\phi M_n = 67.947 \text{ kipft}$$

Considering x-direction:

$M_{max} = 15.133 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(15.133 \text{ kipft})}{(67.947 \text{ kipft})}$$

$$Ratio = 0.22272$$

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

Considering z-direction:

$M_{max} = 0.67202 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.67202 \text{ kipft})}{(67.947 \text{ kipft})}$$

$$Ratio = 0.0098904$$

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

REFERENCES	CALCULATIONS	RESULTS

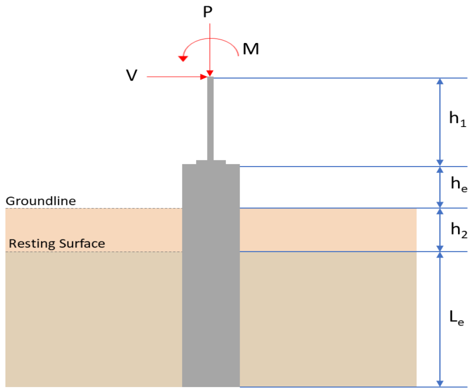
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36 \text{ in}$ - Pile diameter
$L = 7.25 \text{ ft}$ - 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)	5.609	7.952
V_x (kip)	-0.449	-0.745
V_z (kip)	0.000	0.000
M_x (kipft)	0.000	0.000
M_z (kipft)	9.982	17.081

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,

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

$$H_o = \frac{(-0.449 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.14967 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(9.982 \text{ kipft}) + ((-0.449 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 3.3273 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 6.8504 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

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

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.8504 \text{ ft}), (0 \text{ ft})]$$

$$L_{e,req} = 6.85 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7.25 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 7.25 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.85 \text{ ft})}{(7.25 \text{ ft})}$$

$$Ratio = 0.94483$$

Status: **PASS**
Ratio: **0.940**

End-bearing Capacity (ASD)

A - Pile cros-section area

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

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

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

q - End-bearing pressure

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

$$q = \frac{(5.609 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 0.79351 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.79351 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.39676$$

Status: **PASS**
Ratio: **0.400**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7.25 \text{ ft})}{(36 \text{ in})}$$

$$L/D = 2.4167$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.14967\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 3.3273\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (3.3273\ \text{kipft/ft}) \times (7.25\ \text{ft})) + \left(3 \times (-0.14967\ \text{kip/ft}) \times (7.25\ \text{ft})^2\right)}{(6 \times (3.3273\ \text{kipft/ft})) + (4 \times (-0.14967\ \text{kip/ft}) \times (7.25\ \text{ft}))}$$

$$a = 4.9412\ \text{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (3.3273\ \text{kipft/ft})) + (3 \times (-0.14967\ \text{kip/ft}) \times (7.25\ \text{ft}))]^2}{(7.25\ \text{ft})^2 \times [(3 \times (3.3273\ \text{kipft/ft})) + (2 \times (-0.14967\ \text{kip/ft}) \times (7.25\ \text{ft}))]}$$

$$p = 0.29\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (3.3273\ \text{kipft/ft})) + ((-0.14967\ \text{kip/ft}) \times (7.25\ \text{ft}))]}{(7.25\ \text{ft})^2}$$

$$s = 0.99868\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(4.9412\ \text{ft})}{2}$$

$$p_a = 0.37059\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.29\ \text{kip/ft}^2)}{(0.37059\ \text{kip/ft}^2)}$$

$$Ratio = 0.78254$$

Status: **PASS**
Ratio: **0.780**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \text{psf/ft}) \times (7.25\ \text{ft})$$

$$p_s = 1.0875\ \text{kip/ft}^2$$

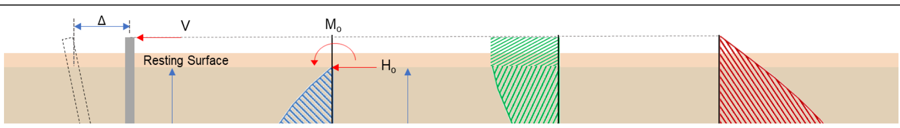
$Ratio$ - Lateral soil capacity

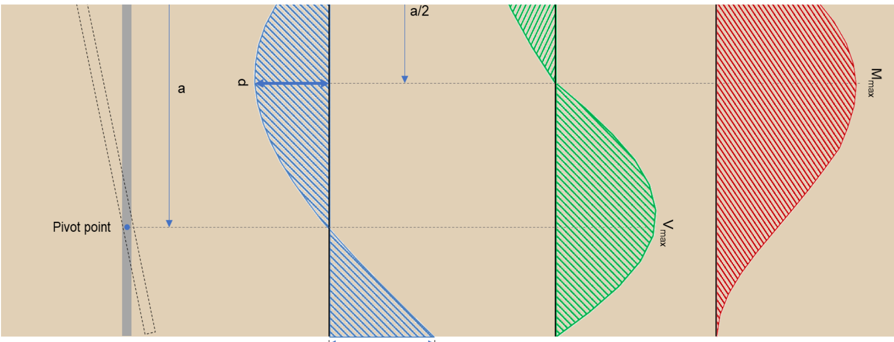
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{(0.99868\ \text{kip/ft}^2)}{(1.0875\ \text{kip/ft}^2)}$$

$$Ratio = 0.91833$$

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





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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.745\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.24833\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(17.081\ \text{kipft}) + ((-0.745\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 5.6937\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(5.6937\ \text{kipft/ft})}{(-0.24833\ \text{kip/ft})}$$

$$E = 22.928\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.6937\ \text{kipft/ft}) \times (7.25\ \text{ft})) + \left(3 \times (-0.24833\ \text{kip/ft}) \times (7.25\ \text{ft})^2\right)}{(6 \times (5.6937\ \text{kipft/ft})) + (4 \times (-0.24833\ \text{kip/ft}) \times (7.25\ \text{ft}))}$$

$$a = 4.9385\ \text{ft}$$

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

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

$$V_{max} = ((-0.24833\ \text{kip/ft}) \times (36\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (22.928\ \text{ft})}{(7.25\ \text{ft})} + 3\right) \times \left(\frac{(4.9385\ \text{ft})}{(7.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (22.928\ \text{ft})}{(7.25\ \text{ft})} + 2\right) \times \left(\frac{(4.9385\ \text{ft})}{(7.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 4.6648\ \text{kip}$$

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

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

$$M_{max} = ((-0.24833\ \text{kip/ft}) \times (36\ \text{in}) \times (7.25\ \text{ft})) \times \left[\left(\frac{(22.928\ \text{ft})}{(7.25\ \text{ft})} + \frac{(4.9385\ \text{ft})}{2 \times (7.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (22.928\ \text{ft})}{(7.25\ \text{ft})} + 3\right) \times \left(\frac{(4.9385\ \text{ft})}{2 \times (7.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (22.928\ \text{ft})}{(7.25\ \text{ft})} + 2\right) \times \left(\frac{(4.9385\ \text{ft})}{2 \times (7.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 16.416 \text{ kipft}$$

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(7.952 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (3 \text{ ksi}) \times \left(1017.9 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, \left(0.08 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -44.929 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-44.929 \text{ in}^2\right), \left(0.0018 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.99533$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

	Main reinforcement: **6 - #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 $$\phi P_N = \phi\, 0.85\, \left[\left(0.85\, f'_{ck}\, \left[A_g - A_{st}\right]\right) + \left(f_{yk}\, A_{st}\right)\right]$$ $$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (3\ \mathrm{ksi}) \times \left[\left(1017.9\ \mathrm{in}^2\right) - \left(1.8408\ \mathrm{in}^2\right)\right]\right) + \left((60\ \mathrm{ksi}) \times \left(1.8408\ \mathrm{in}^2\right)\right)\right]$$ $$\phi P_N = 1492.5\ \mathrm{kip}$$ $Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(7.952\ \mathrm{kip})}{(1492.5\ \mathrm{kip})}$$ $$Ratio = 0.005328$$	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:** $b_w = 36\ \mathrm{in}$ - Effective width, d - Effective depth $$d = 0.80\, D$$ $$d = 0.80 \times (36\ \mathrm{in})$$ $$d = 28.8\ \mathrm{in}$$ λ_s - size effect modification factor $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1\right]$$ $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(28.8\ \mathrm{in})}{10}}}, 1\right]$$ $$\lambda_s = 0.71796$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$, $V_{c,max}$ - Max shear strength of concrete $$V_{c,max} = 5\, \lambda_s\, \sqrt{f'_{ck}}\, b_w\, d$$ $$V_{c,max} = 5 \times (0.71796) \times \sqrt{(3000\ \mathrm{psi})} \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$ $$V_{c,max} = 203.86\ \mathrm{kip}$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$, $P = 7.952\ \mathrm{kip} \rightarrow 7952\ \mathrm{lbf}$, $V_{c,a}$ - Shear strength of concrete (a) $$V_{c,a} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \frac{P}{6\, A_g}\right]\, b_w\, d$$ $$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(3000\ \mathrm{psi})} + \frac{(7952\ \mathrm{lbf})}{6 \times (1017.9\ \mathrm{in}^2)}\right] \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$ $$V_{c,a} = 82.893\ \mathrm{kip}$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$, $V_{c,b}$ - Shear strength of concrete (b) $$V_{c,b} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \left(0.05\, f'_{ck}\right)\right]\, b_w\, d$$ $$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(3000\ \mathrm{psi})} + (0.05 \times (3000\ \mathrm{psi}))\right] \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$ $$V_{c,b} = 237.06\ \mathrm{kip}$$ V_c - Governing shear strength of concrete $$V_c = Min\left[V_{c,max}, V_{c,a}, V_{c,b}\right]$$ $$V_c = Min\left[(203.86\ \mathrm{kip}), (82.893\ \mathrm{kip}), (237.06\ \mathrm{kip})\right]$$	

	$$V_c = 82.893 \text{ kip}$$ 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) $$V_{s,a} = 8\sqrt{f'_{ck}}\, b_w\, d$$ $$V_{s,a} = 8 \times \sqrt{(3000 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$$ $$V_{s,a} = 454.3 \text{ kip}$$ A_v - Ties rebar area, $$A_v = \frac{\pi\, d_{ties}^2}{4}$$ $$A_v = \frac{\pi \times (0.375 \text{ in})^2}{4}$$ $$A_v = 0.11045 \text{ in}^2$$	
22.5.8.5.3	$V_{s,b}$ - Shear strength of steel (b) $$V_{s,b} = \frac{2\, A_v\, f_{ywk}\, d}{s_{ties}}$$ $$V_{s,b} = \frac{2 \times \left(0.11045 \text{ in}^2\right) \times (60 \text{ ksi}) \times (28.8 \text{ in})}{(10 \text{ in})}$$ $$V_{s,b} = 38.17 \text{ kip}$$ V_s - Governing shear strength of steel $$V_s = MIN\left[V_{s,a}, V_{s,b}\right]$$ $$V_s = MIN\left[(454.3 \text{ kip}), (38.17 \text{ kip})\right]$$ $$V_s = 38.17 \text{ kip}$$	
22.5.1.1	ϕV_n - Allowable shear strength $$\phi V_n = \phi\, (V_c + V_s)$$ $$\phi V_n = (0.65) \times ((82.893 \text{ kip}) + (38.17 \text{ kip}))$$ $$\phi V_n = 78.691 \text{ kip}$$ **Considering x-direction:** $V_{max} = 4.6648 \text{ kip}$ - Maximum shear force in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(4.6648 \text{ kip})}{(78.691 \text{ kip})}$$ $$Ratio = 0.05928$$	Status: **PASS** Ratio: **0.060**
	Flexural Strength (ACI 318-19, LRFD) S_m - Section modulus $$S_m = \frac{\pi\, D^3}{32}$$ $$S_m = \frac{\pi \times (36 \text{ in})^3}{32}$$ $$S_m = 4580.4 \text{ in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f'_c)} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(3ksi)} \times 4580.442 in^3$$ $$\phi M_{n,1} = 67.947 kipft$$	
14.5.2.1b	$\phi M_{n,2}$	

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

$$\phi M_{n,2} = (0.65) \times 0.85 \times (3\ \mathrm{ksi}) \times \left(4580.4\ \mathrm{in}^3\right)$$

$$\phi M_{n,2} = 632.67\ \mathrm{kipft}$$

Therefore,
ϕM_n - Allowable flexural strength,

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

$$\phi M_n = MIN[(67.947\ \mathrm{kipft}), (632.67\ \mathrm{kipft})]$$

$$\phi M_n = 67.947\ \mathrm{kipft}$$

Considering x-direction:

$M_{max} = 16.416\ \mathrm{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(16.416\ \mathrm{kipft})}{(67.947\ \mathrm{kipft})}$$

$$Ratio = 0.2416$$

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