Your Project Calculations

Project Name: PowerRevA

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=PowerRevA&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/3_2023

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=NpBiAYatwX7Dj86zbeMkppenu3SLeszqfkxaS8XzCxEbQnV4FDwtqLNYbz6RH1JD

Array Specification

Product:	Beam
Unique ID:	3P-17-8TOP-HD-12-L-5Hx6W-1K9K
Duty Classification:	HD
Module Width:	44.65 in
Module Length:	89.53in
Number of Rows:	5
Number of Columns:	6
Total Number of Modules:	30
Desired Tilt Angle:	45
Front Edge Clearance:	7
Total Array Height at Tilt:	20.23 ft
Total Frame Length:	43.50 ft
Frame Weight:	3290 lbs
Array Dimensions N/S:	18.81 ft
Array Dimensions E/W:	45.27 ft
Rail Length:	225.75 in
Rail Spacing:	3.73 ft
Rail Check:	Not Checked

Support Specifications

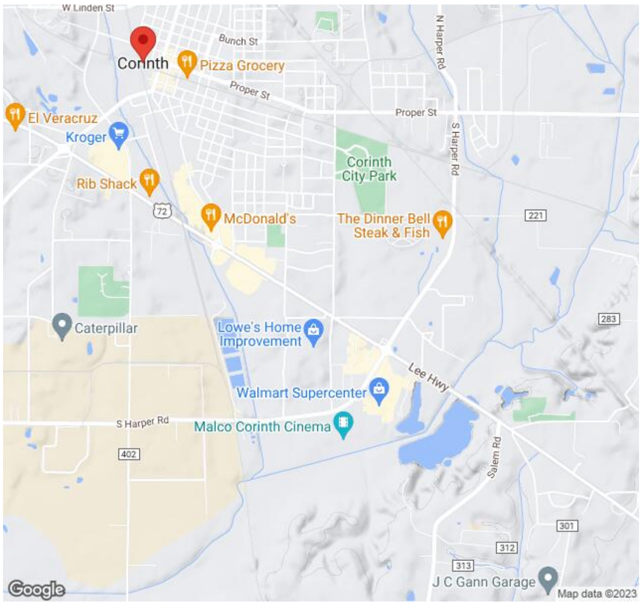
Pole Size:	8in Pipe Sch 80
Pole Length above Grade:	13.65 ft
Number of Poles:	3
Pole Spacing:	17 ft

Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 7.25 ft Pile 2: 7.75 ft Pile 3: 7.25 ft
Foundation Volume:	13.185 y^3
Foundation Result:	PASSED

Site Info

Risk Category:	I
Exposure:	B
Soil Classification:	sand
Site Location:	1525 Hwy 72 E, Corinth, MS 38834, USA
Wind Speed:	100 mph
Snow Load:	10 psf
Design Uplift Pressure:	Multiple pressures
Design Downforce Pressure:	Multiple pressures
Design Snow Pressure:	0.001944 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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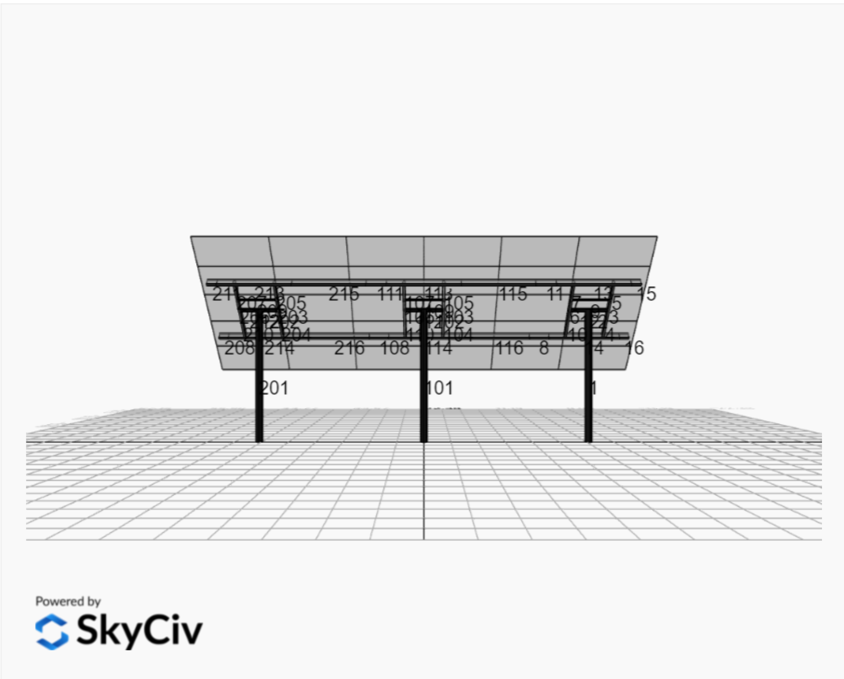
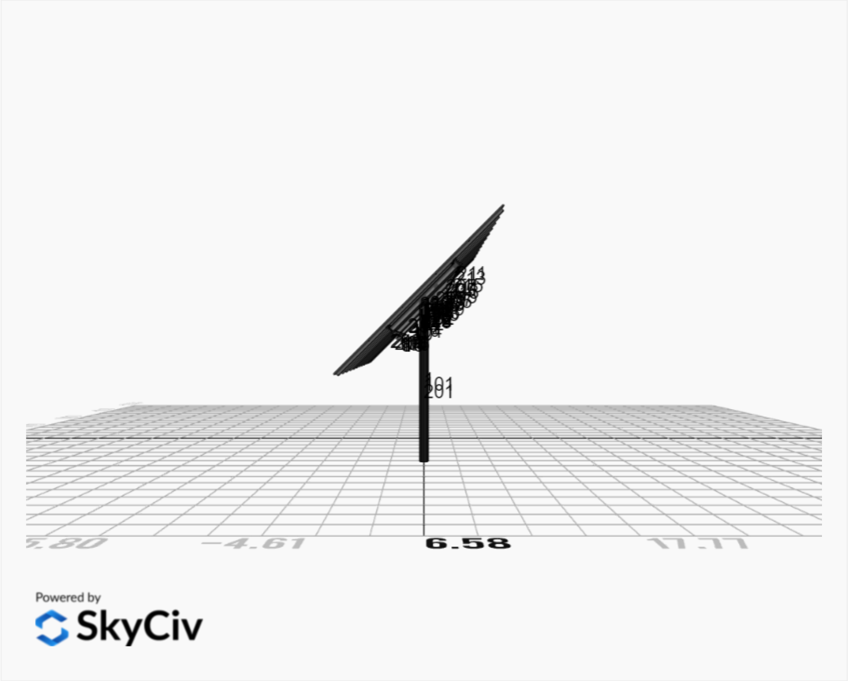
Design Notes:

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

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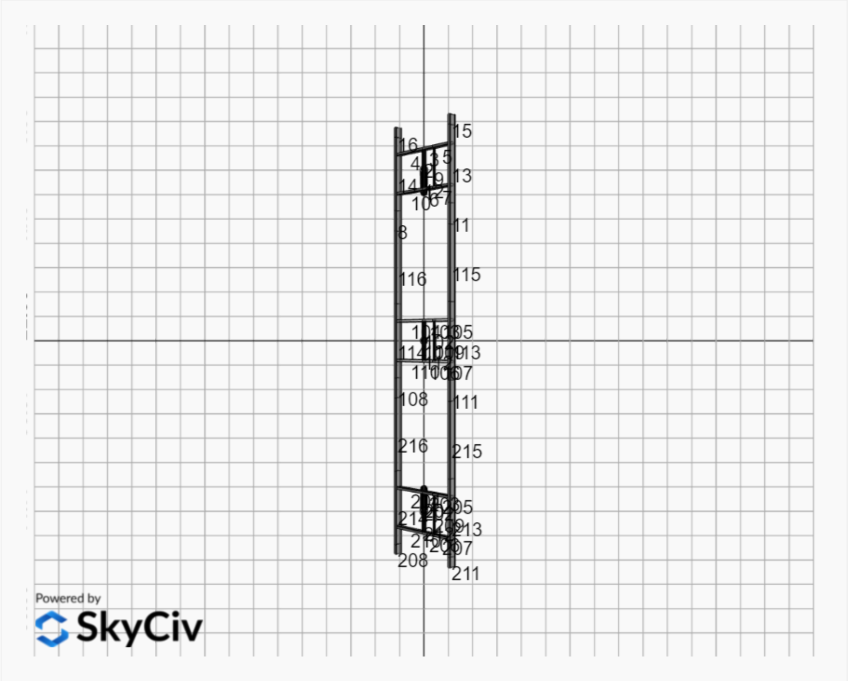
Powered by
SkyCiv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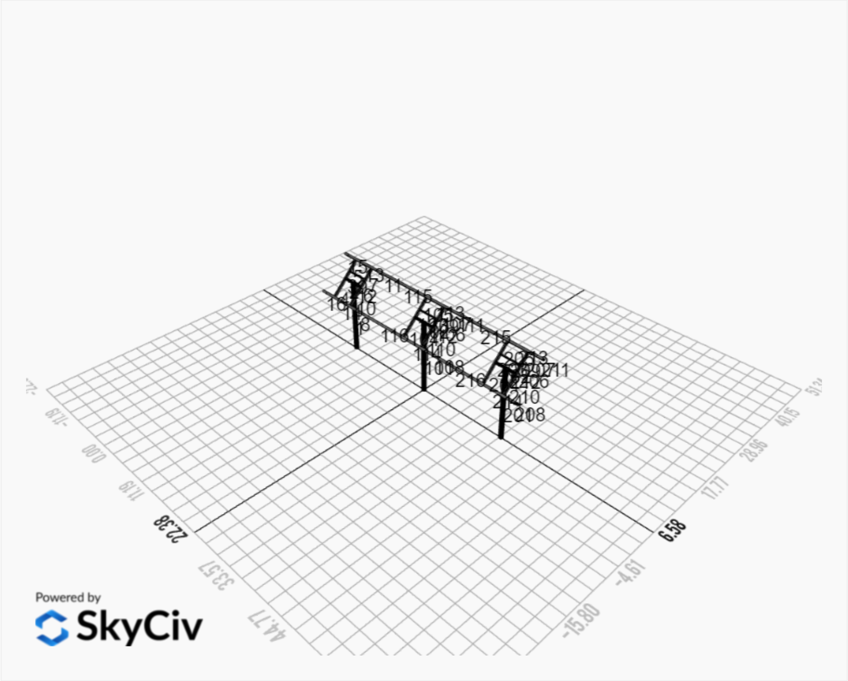
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6.58
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17.77
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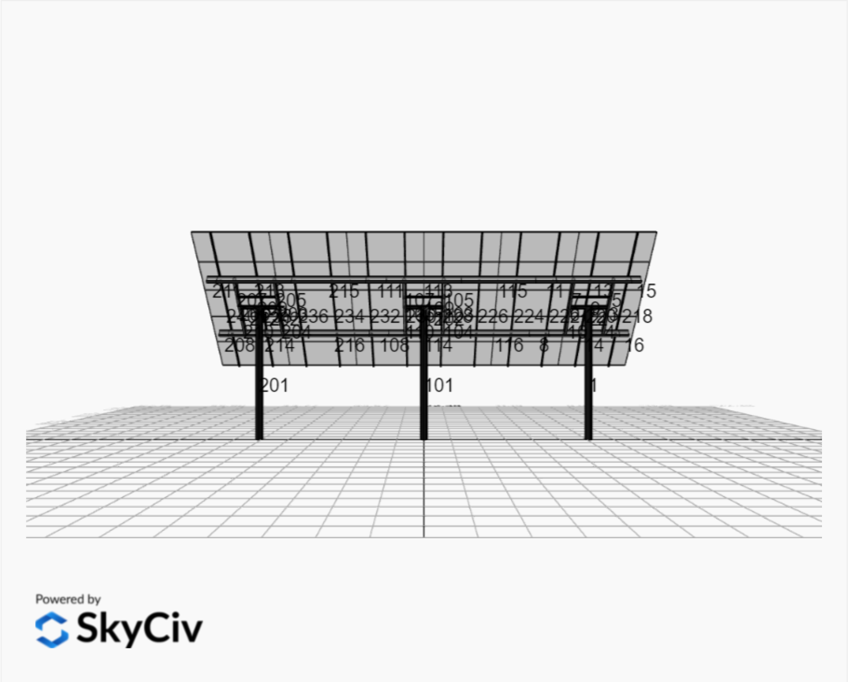
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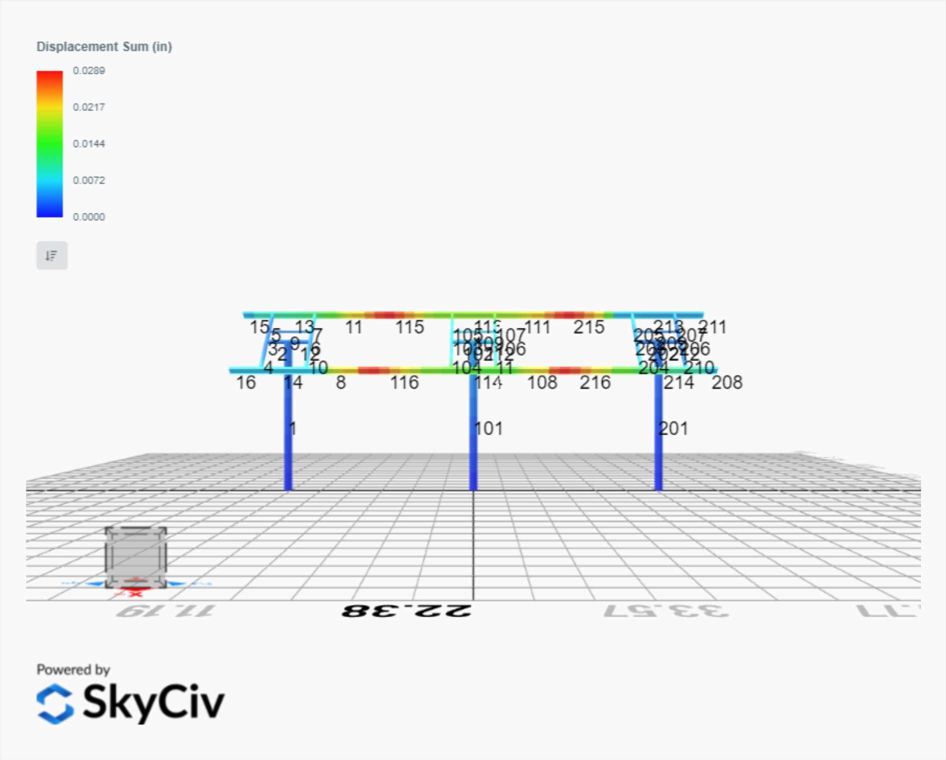
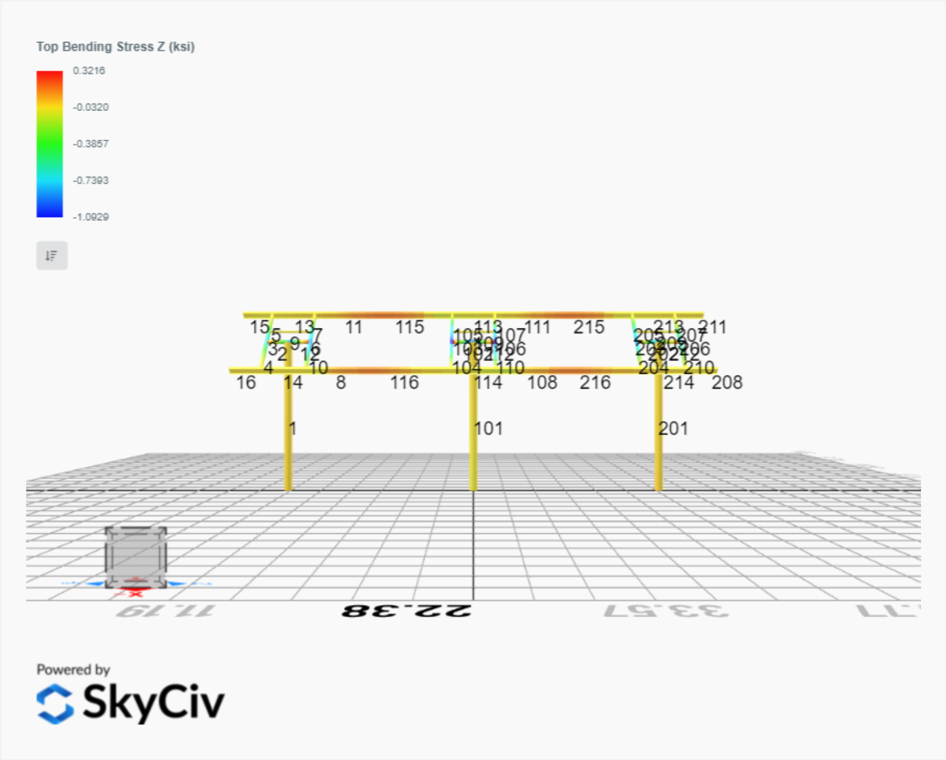
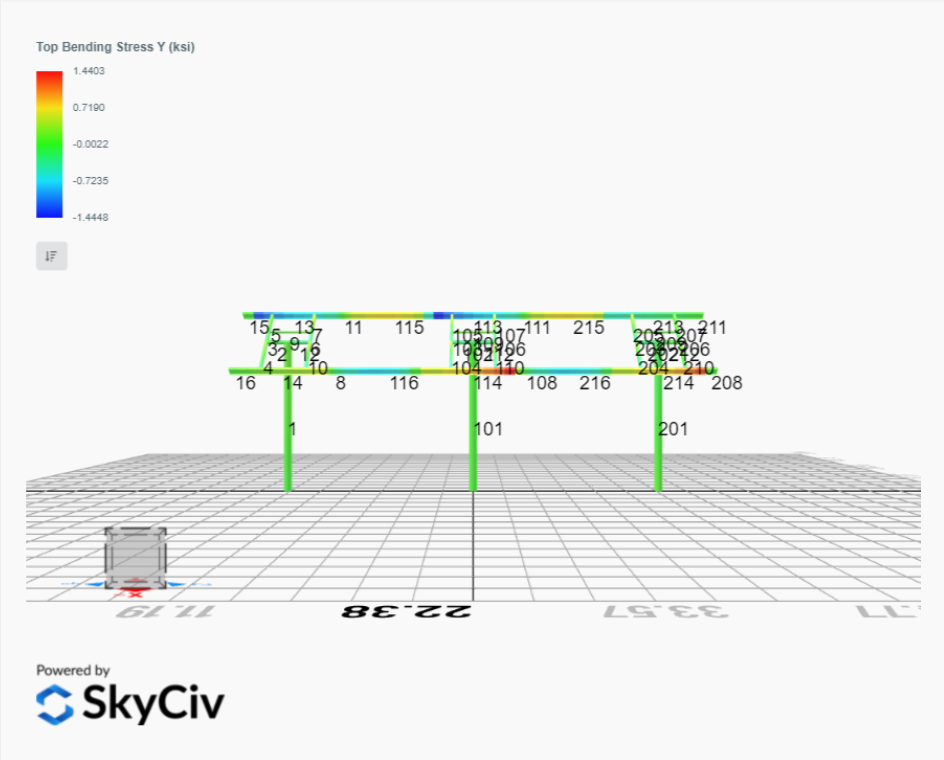
Powered by
SkyCiv

FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
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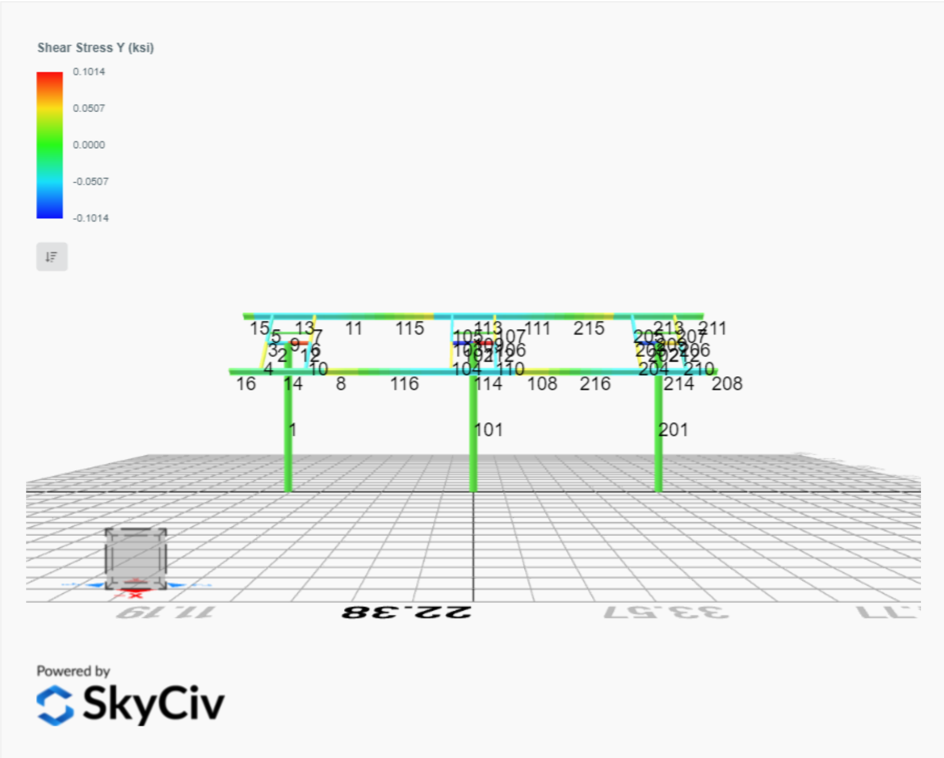
-0.0022
-0.7235
-1.4448
Powered by
SkyCiv


Shear Stress Y (ksi)
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-0.1014
Powered by
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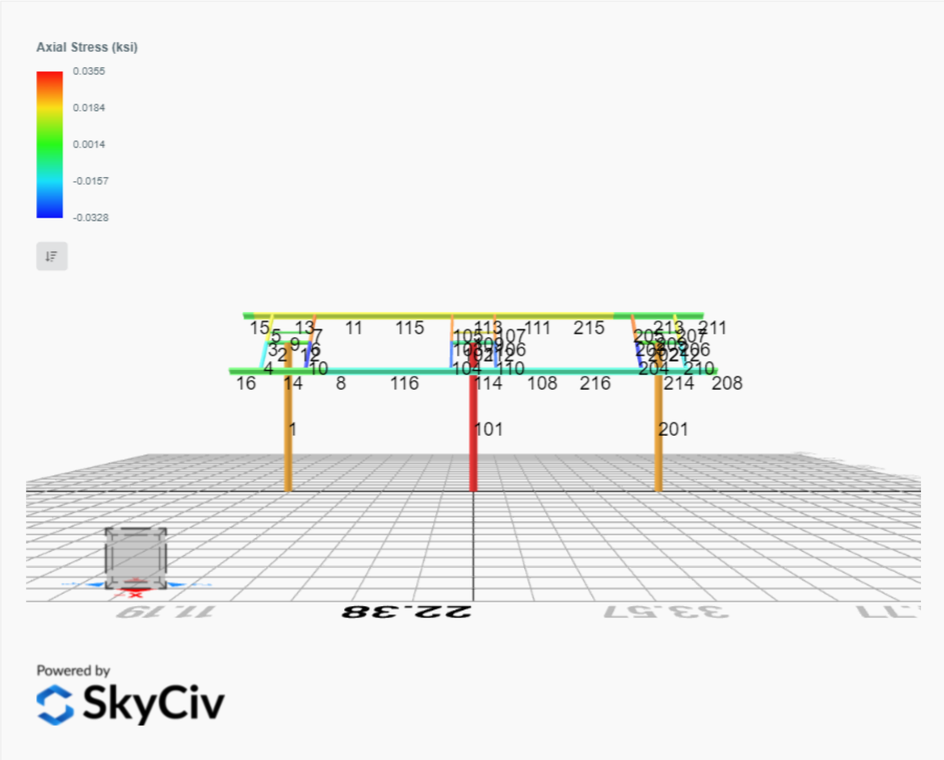
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Powered by
SkyCiv

Reaction Forces for Foundation 1 (Node ID#1), (kip, kip-ft)

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	0.0204	2.1904	0.0619	0.2567	-0.0854	-0.2265
ULS: 2. D + L	0.0204	2.1904	0.0619	0.2567	-0.0854	-0.2265
ULS: 3. D + (S or Lr or R)	0.0253	2.5261	0.0769	0.3190	-0.1063	-0.2868
ULS: 3. D + (S or Lr or R)	0.0204	2.1904	0.0619	0.2567	-0.0854	-0.2265
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0241	2.4422	0.0732	0.3034	-0.1011	-0.2717
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0204	2.1904	0.0619	0.2567	-0.0854	-0.2265
ULS: 5b. D + 0.7E	0.0204	2.1904	0.0619	0.2567	-0.0854	-0.2265
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0241	2.4422	0.0732	0.3034	-0.1011	-0.2717
ULS: 8. 0.6D + 0.7E	0.0122	1.3142	0.0371	0.1540	-0.0513	-0.1359
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.7227	4.8456	0.2780	1.1078	-1.2567	38.9911
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.7227	4.8456	0.2780	1.1078	-1.2567	38.9911
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.9935	0.2762	-0.0881	-0.3333	0.7269	-26.5438
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.7896	0.4863	-0.0845	-0.3189	0.7141	-29.2004
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.0332	4.4336	0.2352	0.9418	-0.9795	29.1415
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.0332	4.4336	0.2352	0.9418	-0.9795	29.1415
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.5039	1.0065	-0.0393	-0.1391	0.5082	-20.0097
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.3510	1.1641	-0.0367	-0.1283	0.4986	-22.0021
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.0369	4.1818	0.2239	0.8951	-0.9639	29.1867
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.0369	4.1818	0.2239	0.8951	-0.9639	29.1867
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.5002	0.7547	-0.0506	-0.1858	0.5238	-19.9645
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.3473	0.9123	-0.0479	-0.1750	0.5142	-21.9569
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.7309	3.9694	0.2532	1.0052	-1.2225	39.0817
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.7309	3.9694	0.2532	1.0052	-1.2225	39.0817
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.9853	-0.6000	-0.1129	-0.4360	0.7610	-26.4532
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.7814	-0.3898	-0.1093	-0.4216	0.7483	-29.1098

Worst Case Reactions LRFD

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

Result	Value
Axial	7.2236
Shear X	-4.5718
Shear Z	0.4438
Moment X	1.7663
Moment Z	65.7007

Worst Case Reactions ASD

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

Result	Value
Axial	4.8456
Shear X	-2.7309
Shear Z	0.2780
Moment X	1.1078
Moment Z	39.0817

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	-0.0408	2.6756	0.0000	0.0000	0.0000	0.5211
ULS: 2. D + L	-0.0408	2.6756	0.0000	0.0000	0.0000	0.5211
ULS: 3. D + (S or Lr or R)	-0.0507	3.1290	0.0000	0.0000	0.0000	0.6423
ULS: 3. D + (S or Lr or R)	-0.0408	2.6756	0.0000	0.0000	0.0000	0.5211
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0482	3.0157	0.0000	0.0000	0.0000	0.6120
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0408	2.6756	0.0000	0.0000	0.0000	0.5211
ULS: 5b. D + 0.7E	-0.0408	2.6756	0.0000	0.0000	0.0000	0.5211
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0482	3.0157	0.0000	0.0000	0.0000	0.6120

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 8. 0.6D + 0.7E	-0.0245	1.6054	0.0000	0.0000	0.0000	0.3127
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.4371	6.2479	0.0000	0.0000	0.0000	48.2184
ULS: 5a. D + 0.6W_Wind downforce Case B only	-3.4371	6.2479	0.0000	0.0000	0.0000	48.2184
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.4387	0.0784	0.0000	0.0000	0.0000	-31.6746
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.0905	0.4141	0.0000	0.0000	0.0000	-34.0338
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.5955	5.6948	0.0000	0.0000	0.0000	36.3850
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.5955	5.6948	0.0000	0.0000	0.0000	36.3850
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.8114	1.0677	0.0000	0.0000	0.0000	-23.5348
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.5503	1.3195	0.0000	0.0000	0.0000	-25.3041
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.5880	5.3548	0.0000	0.0000	0.0000	36.2941
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.5880	5.3548	0.0000	0.0000	0.0000	36.2941
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.8188	0.7277	0.0000	0.0000	0.0000	-23.6257
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.5577	0.9795	0.0000	0.0000	0.0000	-25.3950
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.4208	5.1776	0.0000	0.0000	0.0000	48.0100
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-3.4208	5.1776	0.0000	0.0000	0.0000	48.0100
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.4550	-0.9919	0.0000	0.0000	0.0000	-31.8830
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.1068	-0.6562	0.0000	0.0000	0.0000	-34.2422

Worst Case Reactions LRFD

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

Result	Value
Axial	9.3872
Shear X	-5.7072
Shear Z	-0.0000
Moment X	0.0001
Moment Z	80.9523

Worst Case Reactions ASD

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

Result	Value
Axial	6.2479
Shear X	-3.4371
Shear Z	0.0000
Moment X	0.0000
Moment Z	48.2184

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	0.0204	2.1904	-0.0619	-0.2567	0.0855	-0.2265
ULS: 2. D + L	0.0204	2.1904	-0.0619	-0.2567	0.0855	-0.2265
ULS: 3. D + (S or Lr or R)	0.0253	2.5261	-0.0769	-0.3190	0.1063	-0.2868
ULS: 3. D + (S or Lr or R)	0.0204	2.1904	-0.0619	-0.2567	0.0855	-0.2265
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0241	2.4422	-0.0732	-0.3034	0.1011	-0.2717
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0204	2.1904	-0.0619	-0.2567	0.0855	-0.2265
ULS: 5b. D + 0.7E	0.0204	2.1904	-0.0619	-0.2567	0.0855	-0.2265
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0241	2.4422	-0.0732	-0.3034	0.1011	-0.2717
ULS: 8. 0.6D + 0.7E	0.0122	1.3142	-0.0371	-0.1540	0.0513	-0.1359
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.7227	4.8456	-0.2780	-1.1078	1.2567	38.9911
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.7227	4.8456	-0.2780	-1.1078	1.2567	38.9911
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.9935	0.2762	0.0881	0.3333	-0.7269	-26.5438
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.7896	0.4863	0.0845	0.3189	-0.7141	-29.2004
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.0332	4.4336	-0.2352	-0.9418	0.9795	29.1415
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.0332	4.4336	-0.2352	-0.9418	0.9795	29.1415
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.5039	1.0065	0.0393	0.1391	-0.5082	-20.0097
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.3510	1.1641	0.0367	0.1283	-0.4986	-22.0021
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.0369	4.1818	-0.2239	-0.8951	0.9639	29.1867
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.0369	4.1818	-0.2239	-0.8951	0.9639	29.1867

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.5002	0.7547	0.0506	0.1858	-0.5238	-19.9645
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.3473	0.9123	0.0479	0.1750	-0.5142	-21.9569
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.7309	3.9694	-0.2532	-1.0052	1.2225	39.0817
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.7309	3.9694	-0.2532	-1.0052	1.2225	39.0817
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.9853	-0.6000	0.1129	0.4360	-0.7610	-26.4532
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.7814	-0.3898	0.1093	0.4216	-0.7483	-29.1098

Worst Case Reactions LRFD

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

Result	Value
Axial	7.2236
Shear X	-4.5718
Shear Z	-0.4438
Moment X	-1.7664
Moment Z	65.7017

Worst Case Reactions ASD

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

Result	Value
Axial	4.8456
Shear X	-2.7309
Shear Z	-0.2780
Moment X	-1.1078
Moment Z	39.0817

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
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Design Materials			
ID	E (ksi)	F_y (ksi)	F_u (ksi)
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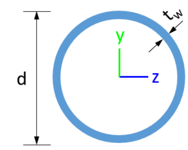
Section Dimensions



ID	Name	d (in)	t_w (in)					
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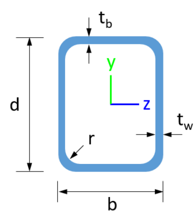
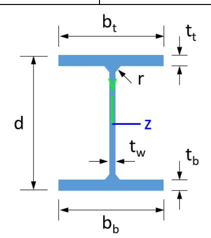
5	4in Pipe Sch 80	4.50	0.34					
10	8in Pipe Sch 80	8.63	0.50					



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



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

Section Properties								
ID	Name	A (in^2)	J (in^4)	I_{yp} (in^4)	I_{zp} (in^4)	I_w (in^6)	S_{yp} (in^3)	S_{zp} (in^3)
2	2in Pipe Sch 80	1.48	1.74	0.87	0.87	0.00	1.02	1.02
5	4in Pipe Sch 80	4.41	19.22	9.61	9.61	0.00	5.85	5.85
10	8in Pipe Sch 80	12.76	211.43	105.72	105.72	0.00	33.05	33.05

16	HSS5x3x3/16	2.58	8.64	3.85	8.53	92.39	2.96	4.21
19	W8x10	2.96	0.04	2.09	30.80	30.90	1.66	8.87

Member Properties								
Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	10	28.67	28.67	13.65	-	300	200	1
2	5	2.00	2.00	2.00	-	300	200	1
3	16	1.42	1.42	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.17,1.16,1.16,1.17,1.17,1.16,1.16,1.17,1.17,1.12,1.16,1.17,1.17,1.14,1.16,1.17,1.17,1.16,1.17	300	200	1
4	16	3.75	3.75	3.75	1.69,1.69,1.69,1.69,1.69,1.69,1.67,1.67,1.66,1.48,1.67,1.67,1.66,1.55,1.67,1.67,1.62,1.70,1.67,1.67,1.64,1.74,1.67,1.67,1.66,1.63	300	200	1
5	16	2.33	2.33	2.33	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.63,1.65,1.67,1.67,1.64,1.65,1.67,1.67,1.66,1.66	300	200	1
6	16	1.42	1.42	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.19,1.19,1.18,1.18,1.19,1.19,1.17,1.18,1.19,1.19,1.18,1.18,1.19,1.19,1.18,1.18	300	200	1
7	16	2.33	2.33	2.33	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.65,1.66,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.67	300	200	1
8	19	2.05	2.05	2.05	1.22,1.22,1.22,1.22,1.22,1.22,1.23,1.23,1.23,1.17,1.23,1.23,1.23,1.17,1.23,1.23,1.24,1.28,1.23,1.23,1.24,1.50,1.23,1.23,1.23,1.18	300	200	1
9	2	4.00	4.00	4.00	-	300	200	1
10	16	3.75	3.75	3.75	1.69,1.68,1.69,1.68,1.69,1.69,1.67,1.67,1.66,1.64,1.67,1.67,1.66,1.64,1.67,1.67,1.64,1.71,1.67,1.67,1.65,1.87,1.67,1.67,1.66,1.65	300	200	1
11	19	2.05	2.05	2.05	1.25,1.25,1.25,1.25,1.25,1.25,1.28,1.28,1.30,1.30,1.28,1.28,1.29,1.30,1.27,1.27,1.37,1.34,1.28,1.28,1.32,1.32,1.28,1.28,1.29,1.30	300	200	1
12	5	2.00	2.00	2.00	-	300	200	1
13	19	1.75	1.75	1.75	2.11,2.11,2.11,2.11,2.11,2.11,2.22,2.22,2.35,2.33,2.23,2.23,2.36,2.33,2.15,2.15,2.24,2.27,2.16,2.16,2.30,2.30,2.24,2.24,2.31,2.34	300	200	1
14	19	1.75	1.75	1.75	1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71	300	200	1
15	19	1.00	1.00	1.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33	300	200	1
16	19	1.00	1.00	1.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32	300	200	1
17	19	4.00	4.00	4.00	1.52,1.52,1.52,1.52,1.52,1.52,1.46,1.46,1.39,1.55,1.46,1.46,1.40,1.55,1.47,1.47,1.25,1.56,1.47,1.47,1.33,1.55,1.46,1.46,1.41,1.55	300	200	1
18	19	1.75	1.75	1.75	1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71	300	200	1
19	19	4.00	4.00	4.00	1.53,1.53,1.53,1.53,1.53,1.53,1.48,1.48,1.54,1.67,1.48,1.48,1.54,1.64,1.49,1.49,1.53,2.58,1.49,1.49,1.54,2.06,1.48,1.48,1.53,1.56	300	200	1
20	19	1.75	1.75	1.75	2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.09,1.50,2.08,2.08,2.09,1.56,2.08,2.08,2.10,2.34,2.08,2.08,2.09,1.77,2.08,2.08,2.09,1.67	300	200	1
21	19	4.00	4.00	4.00	1.15,1.15,1.15,1.15,1.15,1.15,1.40,1.40,3.22,3.17,1.41,1.41,3.13,3.12,1.30,1.30,1.02,1.05,1.33,1.33,1.05,1.10,1.43,1.43,1.98,2.20	300	200	1
22	19	1.75	1.75	1.75	2.11,2.11,2.11,2.11,2.11,2.11,2.08,2.08,1.54,1.68,2.08,2.08,1.57,1.71,2.11,2.11,1.12,1.33,2.10,2.10,1.28,1.46,2.07,2.07,1.66,1.78	300	200	1
23	19	4.00	4.00	4.00	1.12,1.12,1.12,1.12,1.12,1.12,1.15,1.15,1.18,1.15,1.15,1.15,1.18,1.14,1.14,1.14,1.41,1.11,1.15,1.15,1.24,1.10,1.15,1.15,1.17,1.14	300	200	1

24	19	1.75	1.75	1.75	1.79,1.79,1.79,1.79,1.79,1.79,2.17,2.17,2.25,1.72,2.18,2.18,2.24,2.04,2.06,2.06,2.09,1.47,2.09,2.09,2.34,1.30,2.20,2.20,2.23,2.15	300	200	1
25	19	4.00	4.00	4.00	1.52,1.52,1.52,1.52,1.52,1.52,1.46,1.46,1.39,1.55,1.46,1.46,1.40,1.55,1.47,1.47,1.25,1.56,1.47,1.47,1.33,1.55,1.46,1.46,1.41,1.55	300	200	1
26	19	1.75	1.75	1.75	2.11,2.11,2.11,2.11,2.11,2.11,2.22,2.22,2.35,2.33,2.23,2.23,2.36,2.33,2.15,2.15,2.24,2.27,2.16,2.16,2.30,2.30,2.24,2.24,2.31,2.34	300	200	1
27	19	4.00	4.00	4.00	1.53,1.53,1.53,1.53,1.53,1.53,1.48,1.48,1.54,1.67,1.48,1.48,1.54,1.64,1.49,1.49,1.54,2.58,1.49,1.49,1.54,2.06,1.48,1.48,1.54,1.56	300	200	1
28	19	1.75	1.75	1.75	1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71	300	200	1
101	10	28.67	28.67	13.65	-	300	200	1
102	5	2.00	2.00	2.00	-	300	200	1
103	16	1.42	1.42	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.15,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
104	16	3.75	3.75	3.75	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.66,1.63,1.67,1.67,1.66,1.64,1.67,1.67,1.64,1.70,1.67,1.67,1.65,1.74,1.67,1.67,1.66,1.65	300	200	1
105	16	2.33	2.33	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.64,1.66,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
106	16	1.42	1.42	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.15,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
107	16	2.33	2.33	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.64,1.66,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
108	19	2.05	2.05	2.05	1.52,1.52,1.52,1.52,1.52,1.52,1.39,1.39,1.35,1.20,1.39,1.39,1.35,1.23,1.42,1.42,1.24,2.07,1.41,1.41,1.30,1.76,1.39,1.39,1.36,1.28	300	200	1
109	2	4.00	4.00	4.00	-	300	200	1
110	16	3.75	3.75	3.75	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.66,1.63,1.67,1.67,1.66,1.64,1.67,1.67,1.64,1.70,1.67,1.67,1.65,1.74,1.67,1.67,1.66,1.65	300	200	1
111	19	2.05	2.05	2.05	1.40,1.40,1.40,1.40,1.40,1.40,1.23,1.23,1.17,1.18,1.22,1.22,1.17,1.19,1.25,1.25,1.05,1.12,1.24,1.24,1.11,1.15,1.22,1.22,1.18,1.20	300	200	1
112	5	2.00	2.00	2.00	-	300	200	1
113	19	1.75	1.75	1.75	2.11,2.11,2.11,2.11,2.11,2.11,2.08,2.08,1.54,1.68,2.08,2.08,1.57,1.71,2.11,2.11,1.12,1.33,2.10,2.10,1.28,1.46,2.07,2.07,1.66,1.78	300	200	1
114	19	1.75	1.75	1.75	1.79,1.79,1.79,1.79,1.79,1.79,2.17,2.17,2.25,1.71,2.18,2.18,2.24,2.03,2.06,2.06,2.09,1.47,2.09,2.09,2.34,1.30,2.21,2.21,2.23,2.15	300	200	1
115	19	7.45	7.45	7.45	1.11,1.11,1.11,1.11,1.11,1.11,1.07,1.07,1.05,1.06,1.07,1.07,1.05,1.06,1.08,1.08,1.04,1.04,1.07,1.07,1.04,1.05,1.07,1.07,1.06,1.06	300	200	1
116	19	7.45	7.45	7.45	1.14,1.14,1.14,1.14,1.14,1.14,1.11,1.11,1.10,1.07,1.11,1.11,1.10,1.08,1.12,1.12,1.08,1.22,1.12,1.12,1.09,1.84,1.11,1.11,1.11,1.09	300	200	1
201	10	28.67	28.67	13.65	-	300	200	1
202	5	2.00	2.00	2.00	-	300	200	1
203	16	1.42	1.42	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.19,1.19,1.18,1.18,1.19,1.19,1.17,1.18,1.19,1.19,1.18,1.18,1.19,1.19,1.18,1.18	300	200	1
204	16	3.75	3.75	3.75	1.69,1.68,1.69,1.68,1.69,1.69,1.67,1.67,1.66,1.64,1.67,1.67,1.66,1.64,1.67,1.67,1.64,1.71,1.67,1.67,1.65,1.87,1.67,1.67,1.66,1.65	300	200	1
205	16	2.33	2.33	2.33	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.65,1.66,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.67	300	200	1

206	16	1.42	1.42	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.17,1.16,1.16,1.17,1.17,1.16,1.16,1.17,1.17,1.12,1.16,1.17,1.17,1.14,1.16,1.17,1.17,1.16,1.17	300	200	1
207	16	2.33	2.33	2.33	1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.63,1.65,1.67,1.67,1.64,1.65,1.67,1.67,1.66,1.66	300	200	1
208	19	1.00	1.00	1.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32	300	200	1
209	2	4.00	4.00	4.00	-	300	200	1
210	16	3.75	3.75	3.75	1.69,1.69,1.69,1.69,1.69,1.67,1.67,1.66,1.48,1.67,1.67,1.66,1.55,1.67,1.67,1.62,1.70,1.67,1.67,1.64,1.74,1.67,1.67,1.66,1.63	300	200	1
211	19	1.00	1.00	1.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33	300	200	1
212	5	2.00	2.00	2.00	-	300	200	1
213	19	1.75	1.75	1.75	1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71	300	200	1
214	19	1.75	1.75	1.75	2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.09,1.49,2.08,2.08,2.09,1.55,2.08,2.08,2.10,2.33,2.08,2.08,2.09,1.76,2.08,2.08,2.09,1.66	300	200	1
215	19	7.45	7.45	7.45	1.07,1.07,1.07,1.07,1.07,1.07,1.09,1.09,1.10,1.10,1.09,1.09,1.10,1.10,1.08,1.08,1.19,1.13,1.09,1.09,1.13,1.11,1.09,1.09,1.09,1.09	300	200	1
216	19	7.45	7.45	7.45	1.06,1.06,1.06,1.06,1.06,1.06,1.07,1.07,1.07,1.06,1.07,1.07,1.07,1.06,1.06,1.06,1.08,1.08,1.06,1.06,1.07,1.14,1.07,1.07,1.07,1.06	300	200	1

Member Design Capacity

Member ID	$\Phi_t P_n$ (kip)	$\Phi_c P_n$ (kip)	$\Phi_b M_{zn}$ (k-ft)	$\Phi_b M_{yn}$ (k-ft)	$\Phi_v V_{yn}$ (kip)	$\Phi_v V_{zn}$ (kip)
1	574.32	201.81	123.94	123.94	172.30	172.30
2	198.33	194.54	21.95	21.95	59.50	59.50
3	116.10	114.47	15.79	11.10	42.08	23.28
4	116.10	105.13	15.79	11.10	42.08	23.28
5	116.10	111.72	15.79	11.10	42.08	23.28
6	116.10	114.47	15.79	11.10	42.08	23.28
7	116.10	111.72	15.79	11.10	42.08	23.28
8	133.20	122.14	32.87	6.12	40.24	43.62
9	66.48	49.90	3.82	3.82	19.94	19.94
10	116.10	105.13	15.79	11.10	42.08	23.28
11	133.20	122.14	32.87	6.12	40.24	43.62
12	198.33	194.54	21.95	21.95	59.50	59.50
13	133.20	123.94	32.87	6.12	40.24	43.62
14	133.20	123.94	32.87	6.12	40.24	43.62
15	133.20	127.27	32.87	6.12	40.24	43.62
16	133.20	127.27	32.87	6.12	40.24	43.62
17	133.20	104.94	32.87	6.12	40.24	43.62
18	133.20	123.94	32.87	6.12	40.24	43.62
19	133.20	104.94	32.87	6.12	40.24	43.62
20	133.20	123.94	32.87	6.12	40.24	43.62
21	133.20	104.94	31.52	6.12	40.24	43.62
22	133.20	123.94	32.87	6.12	40.24	43.62
23	133.20	104.94	32.87	6.12	40.24	43.62
24	133.20	123.94	32.87	6.12	40.24	43.62
25	133.20	104.94	32.87	6.12	40.24	43.62
26	133.20	123.94	32.87	6.12	40.24	43.62
27	133.20	104.94	32.87	6.12	40.24	43.62

28	133.20	123.94	32.87	6.12	40.24	43.62
101	574.32	201.81	123.94	123.94	172.30	172.30
102	198.33	194.54	21.95	21.95	59.50	59.50
103	116.10	114.47	15.79	11.10	42.08	23.28
104	116.10	105.13	15.79	11.10	42.08	23.28
105	116.10	111.72	15.79	11.10	42.08	23.28
106	116.10	114.47	15.79	11.10	42.08	23.28
107	116.10	111.72	15.79	11.10	42.08	23.28
108	133.20	122.14	32.87	6.12	40.24	43.62
109	66.48	49.90	3.82	3.82	19.94	19.94
110	116.10	105.13	15.79	11.10	42.08	23.28
111	133.20	122.14	32.87	6.12	40.24	43.62
112	198.33	194.54	21.95	21.95	59.50	59.50
113	133.20	123.94	32.87	6.12	40.24	43.62
114	133.20	123.94	32.87	6.12	40.24	43.62
115	133.20	58.22	23.95	6.12	40.24	43.62
116	133.20	58.22	24.64	6.12	40.24	43.62
201	574.32	201.81	123.94	123.94	172.30	172.30
202	198.33	194.54	21.95	21.95	59.50	59.50
203	116.10	114.47	15.79	11.10	42.08	23.28
204	116.10	105.13	15.79	11.10	42.08	23.28
205	116.10	111.72	15.79	11.10	42.08	23.28
206	116.10	114.47	15.79	11.10	42.08	23.28
207	116.10	111.72	15.79	11.10	42.08	23.28
208	133.20	127.27	32.87	6.12	40.24	43.62
209	66.48	49.90	3.82	3.82	19.94	19.94
210	116.10	105.13	15.79	11.10	42.08	23.28
211	133.20	127.27	32.87	6.12	40.24	43.62
212	198.33	194.54	21.95	21.95	59.50	59.50
213	133.20	123.94	32.87	6.12	40.24	43.62
214	133.20	123.94	32.87	6.12	40.24	43.62
215	133.20	58.22	24.64	6.12	40.24	43.62
216	133.20	58.22	24.41	6.12	40.24	43.62

Design Ratio

Member ID	P	M_z	M_y	V_y	V_z	(P,M_z,M_y)	Worst LC	KL/r	δ	Status
1	0.036	0.530	0.035	0.026	0.003	0.562	#13	0.598	Not Required	Pass
2	0.000	0.148	0.143	0.041	0.031	0.291	#13	0.081	Not Required	Pass
3	0.003	0.386	0.015	0.037	0.007	0.401	#13	0.070	Not Required	Pass
4	0.003	0.337	0.050	0.034	0.011	0.387	#13	0.123	Not Required	Pass
5	0.003	0.239	0.012	0.038	0.003	0.246	#13	0.115	Not Required	Pass
6	0.005	0.602	0.047	0.062	0.014	0.645	#13	0.070	Not Required	Pass
7	0.005	0.373	0.061	0.060	0.014	0.381	#13	0.115	Not Required	Pass
8	0.003	0.108	0.060	0.030	0.007	0.169	#13	0.146	Not Required	Pass
9	0.002	0.058	0.058	0.003	0.003	0.116	#13	0.313	Not Required	Pass
10	0.005	0.512	0.074	0.051	0.017	0.530	#13	0.123	Not Required	Pass
11	0.002	0.121	0.055	0.037	0.007	0.176	#13	0.146	Not Required	Pass
12	0.002	0.343	0.237	0.069	0.046	0.581	#13	0.081	Not Required	Pass
13	0.002	0.048	0.147	0.051	0.009	0.180	#16	0.125	Not Required	Pass
14	0.000	0.032	0.037	0.019	0.004	0.062	#13	Not Required	Not Required	Pass
15	0.000	0.005	0.005	0.008	0.001	0.009	#13	Not Required	Not Required	Pass
16	0.000	0.004	0.005	0.007	0.001	0.008	#13	Not Required	Not Required	Pass

17	0.001	0.063	0.036	0.019	0.003	0.079	#13	0.286	Not Required	Pass
18	0.000	0.035	0.037	0.021	0.004	0.066	#13	Not Required	Not Required	Pass
19	0.002	0.049	0.063	0.016	0.006	0.102	#13	0.286	Not Required	Pass
20	0.003	0.051	0.148	0.042	0.009	0.159	#15	0.125	Not Required	Pass
21	0.002	0.044	0.037	0.015	0.003	0.082	#13	0.286	Not Required	Pass
22	0.002	0.062	0.170	0.048	0.010	0.197	#13	0.125	Not Required	Pass
23	0.007	0.086	0.041	0.014	0.003	0.130	#13	0.286	Not Required	Pass
24	0.003	0.069	0.171	0.047	0.010	0.242	#13	0.125	Not Required	Pass
25	0.001	0.063	0.036	0.019	0.003	0.079	#13	0.286	Not Required	Pass
26	0.002	0.048	0.147	0.051	0.009	0.180	#16	0.125	Not Required	Pass
27	0.002	0.049	0.063	0.016	0.006	0.102	#13	0.286	Not Required	Pass
28	0.000	0.032	0.037	0.019	0.004	0.062	#13	Not Required	Not Required	Pass
101	0.047	0.653	0.000	0.033	0.000	0.676	#13	0.598	Not Required	Pass
102	0.001	0.324	0.244	0.073	0.048	0.569	#13	0.081	Not Required	Pass
103	0.005	0.613	0.035	0.061	0.009	0.641	#13	0.070	Not Required	Pass
104	0.005	0.587	0.072	0.059	0.015	0.637	#13	0.123	Not Required	Pass
105	0.005	0.380	0.074	0.061	0.019	0.399	#13	0.115	Not Required	Pass
106	0.005	0.613	0.035	0.061	0.009	0.641	#13	0.070	Not Required	Pass
107	0.005	0.380	0.074	0.061	0.019	0.399	#13	0.115	Not Required	Pass
108	0.003	0.090	0.074	0.035	0.007	0.099	#13	0.146	Not Required	Pass
109	0.007	0.035	0.040	0.001	0.000	0.079	#13	0.313	Not Required	Pass
110	0.005	0.587	0.072	0.059	0.015	0.637	#13	0.123	Not Required	Pass
111	0.002	0.129	0.074	0.035	0.007	0.136	#13	0.146	Not Required	Pass
112	0.001	0.324	0.244	0.073	0.048	0.569	#13	0.081	Not Required	Pass
113	0.002	0.062	0.170	0.048	0.010	0.197	#13	0.125	Not Required	Pass
114	0.003	0.069	0.171	0.047	0.010	0.242	#13	0.125	Not Required	Pass
115	0.005	0.204	0.076	0.035	0.007	0.273	#13	0.532	Not Required	Pass
116	0.006	0.162	0.077	0.035	0.007	0.238	#13	0.532	Not Required	Pass
201	0.036	0.530	0.035	0.026	0.003	0.562	#13	0.598	Not Required	Pass
202	0.002	0.343	0.237	0.069	0.046	0.581	#13	0.081	Not Required	Pass
203	0.005	0.602	0.047	0.062	0.014	0.645	#13	0.070	Not Required	Pass
204	0.005	0.512	0.074	0.051	0.017	0.530	#13	0.123	Not Required	Pass
205	0.005	0.373	0.061	0.060	0.014	0.381	#13	0.115	Not Required	Pass
206	0.003	0.386	0.015	0.037	0.007	0.401	#13	0.070	Not Required	Pass
207	0.003	0.239	0.012	0.038	0.003	0.246	#13	0.115	Not Required	Pass
208	0.000	0.004	0.005	0.007	0.001	0.008	#13	Not Required	Not Required	Pass
209	0.002	0.058	0.058	0.003	0.003	0.116	#13	0.313	Not Required	Pass
210	0.003	0.337	0.050	0.034	0.011	0.387	#13	0.123	Not Required	Pass
211	0.000	0.005	0.005	0.008	0.001	0.009	#13	Not Required	Not Required	Pass
212	0.000	0.148	0.143	0.041	0.031	0.291	#13	0.081	Not Required	Pass
213	0.000	0.035	0.037	0.021	0.004	0.066	#13	Not Required	Not Required	Pass
214	0.003	0.051	0.148	0.042	0.009	0.159	#15	0.125	Not Required	Pass
215	0.005	0.212	0.075	0.037	0.007	0.270	#13	0.532	Not Required	Pass
216	0.006	0.174	0.076	0.030	0.007	0.243	#13	0.532	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

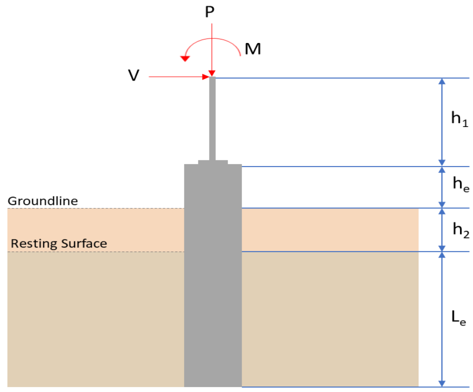
SkyCiv Foundation Design

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
$L = 7.25\ \mathrm{ft}$ - 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)	4.846	7.224
V_x (kip)	-2.731	-4.572
V_z (kip)	0.278	0.444
M_x (kipft)	1.108	1.766
M_z (kipft)	39.082	65.701

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,

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

$$H_o = \frac{(-2.731\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.43487\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(39.082\ \text{kipft}) + ((-2.731\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 6.2232\ \text{kipft/ft}$$

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:
$L_{e,x} = 6.8362\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.278\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.044268\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.108\ \text{kipft}) + ((0.278\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.17643\ \text{kipft/ft}$$

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:
$L_{e,z} = 2.7807\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.8362\ \text{ft}), (2.7807\ \text{ft})]$$

$$L_{e,req} = 6.836\ \text{ft}$$

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

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

$$Ratio = \frac{(6.836\ \text{ft})}{(7.25\ \text{ft})}$$

$$Ratio = 0.9429$$

Status: PASS
Ratio: 0.940

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

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

$$q = \frac{(4.846\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.30288\ \text{kip/ft}^2$$

$$q = 0.30288 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.30288 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.15144$$

Status: **PASS**
Ratio: **0.150**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7.25 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.8125$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.43487 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 6.2232 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.2232 \text{ kipft/ft}) \times (7.25 \text{ ft})) + \left(3 \times (-0.43487 \text{ kip/ft}) \times (7.25 \text{ ft})^2\right)}{(6 \times (6.2232 \text{ kipft/ft})) + (4 \times (-0.43487 \text{ kip/ft}) \times (7.25 \text{ ft}))}$$

$$a = 4.9859 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (6.2232 \text{ kipft/ft})) + (3 \times (-0.43487 \text{ kip/ft}) \times (7.25 \text{ ft}))]^2}{(7.25 \text{ ft})^2 \times [(3 \times (6.2232 \text{ kipft/ft})) + (2 \times (-0.43487 \text{ kip/ft}) \times (7.25 \text{ ft}))]}$$

$$p = 0.27492 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (6.2232 \text{ kipft/ft})) + ((-0.43487 \text{ kip/ft}) \times (7.25 \text{ ft}))]}{(7.25 \text{ ft})^2}$$

$$s = 1.0609 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.9859 \text{ ft})}{2}$$

$$p_a = 0.37394 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.27492 \text{ kip/ft}^2)}{(0.37394 \text{ kip/ft}^2)}$$

$$Ratio = 0.7352$$

Status: **PASS**
Ratio: **0.740**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(1.0609\ \mathrm{kip/ft^2})}{(1.0875\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.97551$$

Status: **PASS**
Ratio: **0.980**

Considering z-direction:

$H_o = 0.044268\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.17643\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.17643\ \mathrm{kipft/ft}) \times (7.25\ \mathrm{ft})) + \left(3 \times (0.044268\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft})^2\right)}{(6 \times (0.17643\ \mathrm{kipft/ft})) + (4 \times (0.044268\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))}$$

$$a = 5.1645\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.17643\ \mathrm{kipft/ft})) + (3 \times (0.044268\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]^{\,2}}{(7.25\ \mathrm{ft})^2 \times [(3 \times (0.17643\ \mathrm{kipft/ft})) + (2 \times (0.044268\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]}$$

$$p = 0.033919\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.17643\ \mathrm{kipft/ft})) + ((0.044268\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]}{(7.25\ \mathrm{ft})^2}$$

$$s = 0.076915\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.1645\ \mathrm{ft})}{2}$$

$$p_a = 0.38733\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.033919\ \mathrm{kip/ft^2})}{(0.38733\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.08757$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

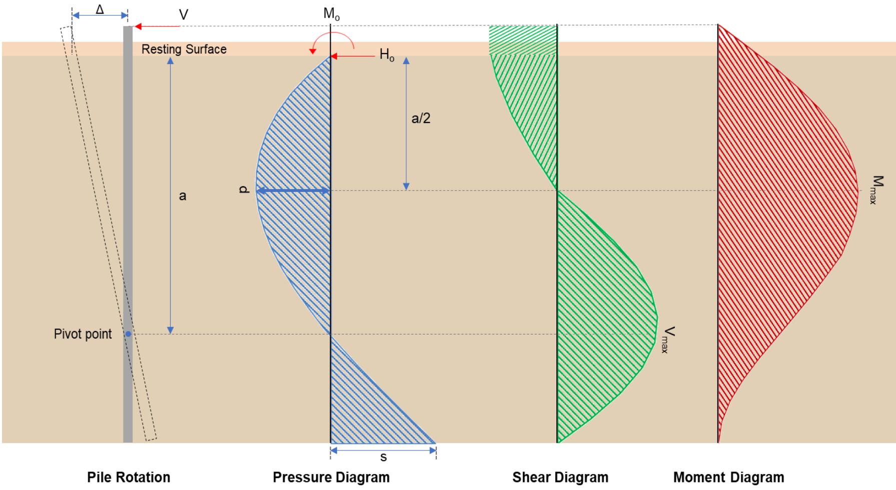
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.076915\ \mathrm{kip/ft^2}\right)}{\left(1.0875\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.070726$$

Status: **PASS**
Ratio: **0.070**



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.572\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.72803\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(65.701\ \mathrm{kipft}) + ((-4.572\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 10.462\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(10.462\ \mathrm{kipft/ft})}{(-0.72803\ \mathrm{kip/ft})}$$

$$E = 14.37\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (10.462\ \mathrm{kipft/ft}) \times (7.25\ \mathrm{ft})) + \left(3 \times (-0.72803\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft})^2\right)}{(6 \times (10.462\ \mathrm{kipft/ft})) + (4 \times (-0.72803\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))}$$

$$a = 4.9854\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.72803\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.37\ \mathrm{ft})}{(7.25\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.9854\ \mathrm{ft})}{(7.25\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.37\ \mathrm{ft})}{(7.25\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.9854\ \mathrm{ft})}{(7.25\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 12.136\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.72803 \text{ kip/ft}) \times (48 \text{ in}) \times (7.25 \text{ ft})) \times \left[\left(\frac{(14.37 \text{ ft})}{(7.25 \text{ ft})} + \frac{(4.9854 \text{ ft})}{2 \times (7.25 \text{ ft})} \right) - \left[\left(\frac{4 \times (14.37 \text{ ft})}{(7.25 \text{ ft})} + 3 \right) \times \left(\frac{(4.9854 \text{ ft})}{2 \times (7.25 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (14.37 \text{ ft})}{(7.25 \text{ ft})} + 2 \right) \times \left(\frac{(4.9854 \text{ ft})}{2 \times (7.25 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 42.073 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.444 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.070701 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.766 \text{ kipft}) + ((0.444 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.28121 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.28121 \text{ kipft/ft})}{(0.070701 \text{ kip/ft})}$$

$$E = 3.9775 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.28121 \text{ kipft/ft}) \times (7.25 \text{ ft})) + \left(3 \times (0.070701 \text{ kip/ft}) \times (7.25 \text{ ft})^2\right)}{(6 \times (0.28121 \text{ kipft/ft})) + (4 \times (0.070701 \text{ kip/ft}) \times (7.25 \text{ ft}))}$$

$$a = 5.1648 \text{ ft}$$

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

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

$$V_{max} = ((0.070701 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.9775 \text{ ft})}{(7.25 \text{ ft})} + 3 \right) \times \left(\frac{(5.1648 \text{ ft})}{(7.25 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (3.9775 \text{ ft})}{(7.25 \text{ ft})} + 2 \right) \times \left(\frac{(5.1648 \text{ ft})}{(7.25 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.4627 \text{ kip}$$

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

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

$$M_{max} = ((0.070701 \text{ kip/ft}) \times (48 \text{ in}) \times (7.25 \text{ ft})) \times \left[\left(\frac{(3.9775 \text{ ft})}{(7.25 \text{ ft})} + \frac{(5.1648 \text{ ft})}{2 \times (7.25 \text{ ft})} \right) - \left[\left(\frac{4 \times (3.9775 \text{ ft})}{(7.25 \text{ ft})} + 3 \right) \times \left(\frac{(5.1648 \text{ ft})}{2 \times (7.25 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (3.9775 \text{ ft})}{(7.25 \text{ ft})} + 2 \right) \times \left(\frac{(5.1648 \text{ ft})}{2 \times (7.25 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 1.4942 \text{ kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(7.224 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (3 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -102.02 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-102.02 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

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

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

$$Ratio = \frac{(7.224\ \text{kip})}{(3183.4\ \text{kip})}$$

$$Ratio = 0.0022693$$

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 $f'_{ck} = 3\ \text{ksi} \rightarrow 3000\ \text{psi}$, $P = 7.224\ \text{kip} \rightarrow 7224\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(3000\ \text{psi})} + \frac{(7224\ \text{lbf})}{6 \times \left(2304\ \text{in}^2\right)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 130.76\ \text{kip}$$

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

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

$$V_c = Min\left[(324.49\ \text{kip}), (130.76\ \text{kip}), (406.27\ \text{kip})\right]$$

$$V_c = 130.76\ \text{kip}$$

	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 $$\phi V_n = \phi\ (V_c + V_s)$$ $$\phi V_n = (0.65) \times ((130.76\ \text{kip}) + (50.894\ \text{kip}))$$ $$\phi V_n = 118.07\ \text{kip}$$ **Considering x-direction:** $V_{max} = 12.136\ \text{kip}$ - Maximum shear force in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(12.136\ \text{kip})}{(118.07\ \text{kip})}$$ $$Ratio = 0.10279$$	Status: **PASS** Ratio: **0.100**
	Considering z-direction: $V_{max} = 0.4627\ \text{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.4627\ \text{kip})}{(118.07\ \text{kip})}$$ $$Ratio = 0.0039187$$	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: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(3ksi)} \times 18432.001 in^3$$ $$\phi M_{n,1} = 273.423 kipft$$	
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:** $M_{max} = 42.073 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(42.073 \text{ kipft})}{(273.42 \text{ kipft})}$$ $$Ratio = 0.15388$$	Status: **PASS** Ratio: **0.150**
	Considering z-direction: $M_{max} = 1.4942 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(1.4942 \text{ kipft})}{(273.42 \text{ kipft})}$$ $$Ratio = 0.0054647$$	Status: **PASS** Ratio: **0.010**

REFERENCES	CALCULATIONS	RESULTS

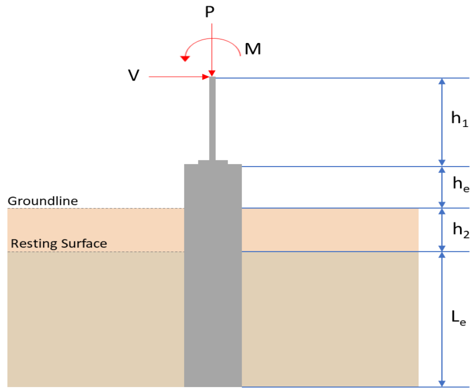
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 7.25\ \mathrm{ft}$ - 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)	4.846	7.224
V_x (kip)	-2.731	-4.572
V_z (kip)	-0.278	-0.444
M_x (kipft)	-1.108	-1.766
M_z (kipft)	39.082	65.702

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,

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

$$H_o = \frac{(-2.731\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.43487\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(39.082 \text{ kipft}) + ((-2.731 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 6.2232 \text{ kipft/ft}$$

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:
$L_{e,x} = 6.8362 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.278 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.044268 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.108 \text{ kipft}) + ((-0.278 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.17643 \text{ kipft/ft}$$

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:
$L_{e,z} = 2.0535 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.8362 \text{ ft}), (2.0535 \text{ ft})]$$

$$L_{e,req} = 6.836 \text{ ft}$$

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

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

$$Ratio = \frac{(6.836 \text{ ft})}{(7.25 \text{ ft})}$$

$$Ratio = 0.9429$$

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

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

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

$$q = \frac{(4.846 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.30288 \text{ kip/ft}^2$$

$$q = 0.30288\ \mathrm{kip/ft}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.30288\ \mathrm{kip/ft^2}\right)}{\left(2000\ \mathrm{psf}\right)}$$

$$Ratio = 0.15144$$

Status: **PASS**
Ratio: **0.150**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7.25\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1.8125$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.43487\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 6.2232\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.2232\ \mathrm{kipft/ft}) \times (7.25\ \mathrm{ft})) + \left(3 \times (-0.43487\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft})^2\right)}{(6 \times (6.2232\ \mathrm{kipft/ft})) + (4 \times (-0.43487\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))}$$

$$a = 4.9859\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (6.2232\ \mathrm{kipft/ft})) + (3 \times (-0.43487\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]^2}{(7.25\ \mathrm{ft})^2 \times [(3 \times (6.2232\ \mathrm{kipft/ft})) + (2 \times (-0.43487\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]}$$

$$p = 0.27492\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (6.2232\ \mathrm{kipft/ft})) + ((-0.43487\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]}{(7.25\ \mathrm{ft})^2}$$

$$s = 1.0609\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.9859\ \mathrm{ft})}{2}$$

$$p_a = 0.37394\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.27492\ \mathrm{kip/ft^2}\right)}{\left(0.37394\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.7352$$

Status: **PASS**
Ratio: **0.740**

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

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

$$Ratio = \frac{\left(1.0609\text{ kip/ft}^2\right)}{\left(1.0875\text{ kip/ft}^2\right)}$$

$$Ratio = 0.97551$$

Status: **PASS**
Ratio: **0.980**

Considering z-direction:

$H_o = -0.044268\text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 0.17643\text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.17643\text{ kipft/ft}) \times (7.25\text{ ft})) + \left(3 \times (-0.044268\text{ kip/ft}) \times (7.25\text{ ft})^2\right)}{(6 \times (0.17643\text{ kipft/ft})) + (4 \times (-0.044268\text{ kip/ft}) \times (7.25\text{ ft}))}$$

$$a = 5.1645\text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.17643\text{ kipft/ft})) + (3 \times (-0.044268\text{ kip/ft}) \times (7.25\text{ ft}))]^{\,2}}{(7.25\text{ ft})^2 \times [(3 \times (0.17643\text{ kipft/ft})) + (2 \times (-0.044268\text{ kip/ft}) \times (7.25\text{ ft}))]}$$

$$p = -0.0083769\text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.17643\text{ kipft/ft})) + ((-0.044268\text{ kip/ft}) \times (7.25\text{ ft}))]}{(7.25\text{ ft})^2}$$

$$s = 0.0036444\text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\text{ psf/ft}) \times \frac{(5.1645\text{ ft})}{2}$$

$$p_a = 0.38733\text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.0083769\text{ kip/ft}^2\right)}{\left(0.38733\text{ kip/ft}^2\right)}$$

$$Ratio = -0.021627$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

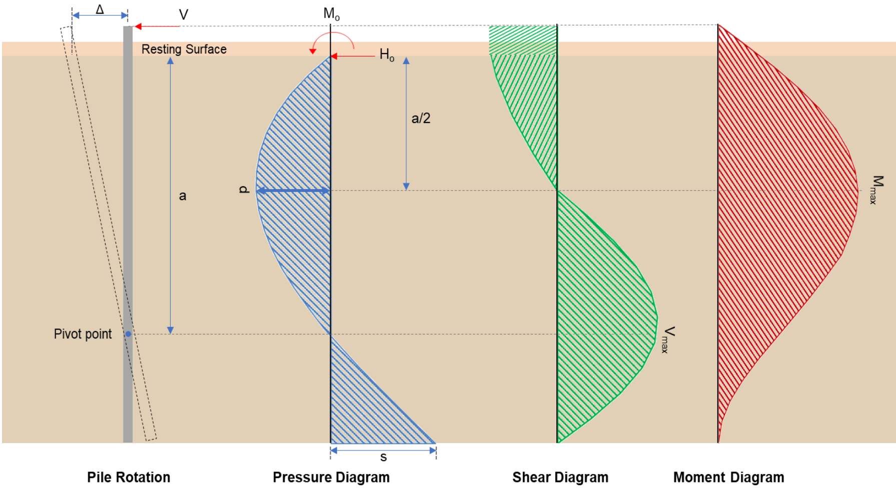
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0036444 \text{ kip/ft}^2)}{(1.0875 \text{ kip/ft}^2)}$$

$$Ratio = 0.0033512$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.572 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.72803 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(65.702 \text{ kipft}) + ((-4.572 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 10.462 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(10.462 \text{ kipft/ft})}{(-0.72803 \text{ kip/ft})}$$

$$E = 14.371 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (10.462 \text{ kipft/ft}) \times (7.25 \text{ ft})) + \left(3 \times (-0.72803 \text{ kip/ft}) \times (7.25 \text{ ft})^2\right)}{(6 \times (10.462 \text{ kipft/ft})) + (4 \times (-0.72803 \text{ kip/ft}) \times (7.25 \text{ ft}))}$$

$$a = 4.9854 \text{ ft}$$

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

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

$$V_{max} = ((-0.72803 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.371 \text{ ft})}{(7.25 \text{ ft})} + 3\right) \times \left(\frac{(4.9854 \text{ ft})}{(7.25 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.371 \text{ ft})}{(7.25 \text{ ft})} + 2\right) \times \left(\frac{(4.9854 \text{ ft})}{(7.25 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 12.136 \text{ kip}$$

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

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

$$M_{max} = ((-0.72803 \text{ kip/ft}) \times (48 \text{ in}) \times (7.25 \text{ ft})) \times \left[\left(\frac{(14.371 \text{ ft})}{(7.25 \text{ ft})} + \frac{(4.9854 \text{ ft})}{2 \times (7.25 \text{ ft})}\right) - \left[\left(\frac{4 \times (14.371 \text{ ft})}{(7.25 \text{ ft})} + 3\right) \times \left(\frac{(4.9854 \text{ ft})}{2 \times (7.25 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (14.371 \text{ ft})}{(7.25 \text{ ft})} + 2\right) \times \left(\frac{(4.9854 \text{ ft})}{2 \times (7.25 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 42.074 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.444 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.070701 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.766 \text{ kipft}) + ((-0.444 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.28121 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.28121 \text{ kipft/ft})}{(-0.070701 \text{ kip/ft})}$$

$$E = 3.9775 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.28121 \text{ kipft/ft}) \times (7.25 \text{ ft})) + \left(3 \times (-0.070701 \text{ kip/ft}) \times (7.25 \text{ ft})^2\right)}{(6 \times (0.28121 \text{ kipft/ft})) + (4 \times (-0.070701 \text{ kip/ft}) \times (7.25 \text{ ft}))}$$

$$a = 5.1648 \text{ ft}$$

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

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

$$V_{max} = ((-0.070701 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.9775 \text{ ft})}{(7.25 \text{ ft})} + 3\right) \times \left(\frac{(5.1648 \text{ ft})}{(7.25 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.9775 \text{ ft})}{(7.25 \text{ ft})} + 2\right) \times \left(\frac{(5.1648 \text{ ft})}{(7.25 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.4627 \text{ kip}$$

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

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

$$M_{max} = ((-0.070701 \text{ kip/ft}) \times (48 \text{ in}) \times (7.25 \text{ ft})) \times \left[\left(\frac{(3.9775 \text{ ft})}{(7.25 \text{ ft})} + \frac{(5.1648 \text{ ft})}{2 \times (7.25 \text{ ft})}\right) - \left[\left(\frac{4 \times (3.9775 \text{ ft})}{(7.25 \text{ ft})} + 3\right) \times \left(\frac{(5.1648 \text{ ft})}{2 \times (7.25 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.9775 \text{ ft})}{(7.25 \text{ ft})} + 2\right) \times \left(\frac{(5.1648 \text{ ft})}{2 \times (7.25 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 1.4942 \text{ kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(7.224 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (3 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -102.02 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-102.02 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

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

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

$$Ratio = \frac{(7.224\ \text{kip})}{(3183.4\ \text{kip})}$$

$$Ratio = 0.0022693$$

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 $f'_{ck} = 3\ \text{ksi} \rightarrow 3000\ \text{psi}$, $P = 7.224\ \text{kip} \rightarrow 7224\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(3000\ \text{psi})} + \frac{(7224\ \text{lbf})}{6 \times (2304\ \text{in}^2)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 130.76\ \text{kip}$$

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

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

$$V_c = Min\left[(324.49\ \text{kip}), (130.76\ \text{kip}), (406.27\ \text{kip})\right]$$

$$V_c = 130.76\ \text{kip}$$

	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) $$V_{s,b} = \frac{2\, A_v\, f_{ywk}\, d}{s_{ties}}$$ $$V_{s,b} = \frac{2 \times (0.11045\ \mathrm{in}^2) \times (60\ \mathrm{ksi}) \times (38.4\ \mathrm{in})}{(10\ \mathrm{in})}$$ $$V_{s,b} = 50.894\ \mathrm{kip}$$ V_s - Governing shear strength of steel $$V_s = MIN[V_{s,a}, V_{s,b}]$$ $$V_s = MIN[(807.65\ \mathrm{kip}), (50.894\ \mathrm{kip})]$$ $$V_s = 50.894\ \mathrm{kip}$$	
22.5.1.1	ϕV_n - Allowable shear strength $$\phi V_n = \phi\ (V_c + V_s)$$ $$\phi V_n = (0.65) \times ((130.76\ \mathrm{kip}) + (50.894\ \mathrm{kip}))$$ $$\phi V_n = 118.07\ \mathrm{kip}$$ **Considering x-direction:** $V_{max} = 12.136\ \mathrm{kip}$ - Maximum shear force in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(12.136\ \mathrm{kip})}{(118.07\ \mathrm{kip})}$$ $$Ratio = 0.10279$$	Status: **PASS** Ratio: **0.100**
	Considering z-direction: $V_{max} = 0.4627\ \mathrm{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.4627\ \mathrm{kip})}{(118.07\ \mathrm{kip})}$$ $$Ratio = 0.0039187$$	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:** $M_{max} = 42.074 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(42.074 \text{ kipft})}{(273.42 \text{ kipft})}$$ $$Ratio = 0.15388$$	Status: **PASS** Ratio: **0.150**
	Considering z-direction: $M_{max} = 1.4942 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(1.4942 \text{ kipft})}{(273.42 \text{ kipft})}$$ $$Ratio = 0.0054647$$	Status: **PASS** Ratio: **0.010**

REFERENCES	CALCULATIONS	RESULTS

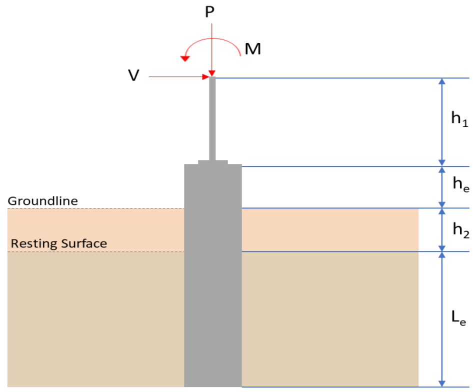
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 7.75\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	6.248	9.387
V_x (kip)	-3.437	-5.707
V_z (kip)	0.000	0.000
M_x (kipft)	0.000	0.000
M_z (kipft)	48.218	80.952

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,

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

$$H_o = \frac{(-3.437\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.54729\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(48.218 \text{ kipft}) + ((-3.437 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 7.678 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 7.2242 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

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

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.2242 \text{ ft}), (0 \text{ ft})]$$

$$L_{e,req} = 7.224 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.224 \text{ ft})}{(7.75 \text{ ft})}$$

$$Ratio = 0.93213$$

Status: PASS
Ratio: 0.930

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\,D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(6.248 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.3905 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.3905 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.19525$$

Status: PASS
Ratio: 0.200

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

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

$$L/D = 1.9375$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.54729\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 7.678\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.678\ \text{kipft/ft}) \times (7.75\ \text{ft})) + \left(3 \times (-0.54729\ \text{kip/ft}) \times (7.75\ \text{ft})^2\right)}{(6 \times (7.678\ \text{kipft/ft})) + (4 \times (-0.54729\ \text{kip/ft}) \times (7.75\ \text{ft}))}$$

$$a = 5.3405\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (7.678\ \text{kipft/ft})) + (3 \times (-0.54729\ \text{kip/ft}) \times (7.75\ \text{ft}))]^2}{(7.75\ \text{ft})^2 \times [(3 \times (7.678\ \text{kipft/ft})) + (2 \times (-0.54729\ \text{kip/ft}) \times (7.75\ \text{ft}))]}$$

$$p = 0.27766\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (7.678\ \text{kipft/ft})) + ((-0.54729\ \text{kip/ft}) \times (7.75\ \text{ft}))]}{(7.75\ \text{ft})^2}$$

$$s = 1.1103\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(5.3405\ \text{ft})}{2}$$

$$p_a = 0.40054\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.27766\ \text{kip/ft}^2\right)}{\left(0.40054\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.69321$$

Status: **PASS**
Ratio: **0.690**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

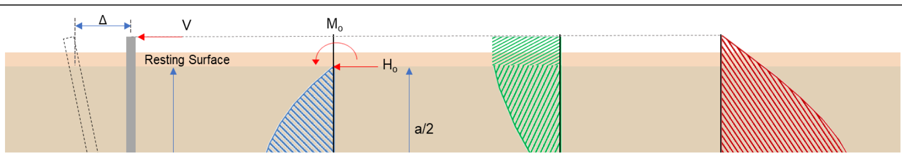
$Ratio$ - Lateral soil capacity

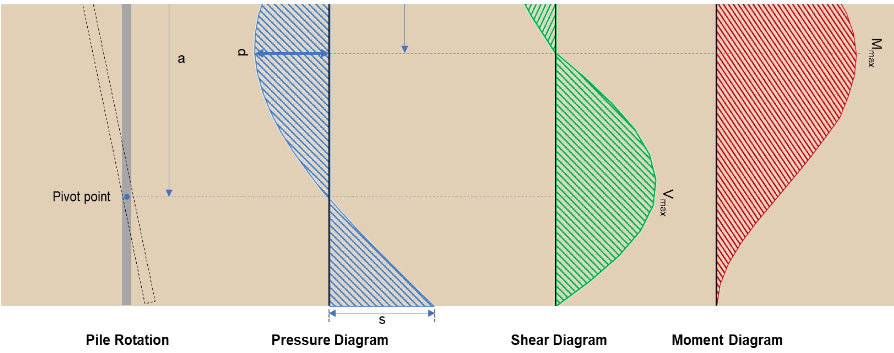
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{\left(1.1103\ \text{kip/ft}^2\right)}{\left(1.1625\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.95509$$

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





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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-5.707\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = -0.90876\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(80.952\text{ kipft}) + ((-5.707\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 12.89\text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(12.89\text{ kipft/ft})}{(-0.90876\text{ kip/ft})}$$

$$E = 14.185\text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (12.89\text{ kipft/ft}) \times (7.75\text{ ft})) + \left(3 \times (-0.90876\text{ kip/ft}) \times (7.75\text{ ft})^2\right)}{(6 \times (12.89\text{ kipft/ft})) + (4 \times (-0.90876\text{ kip/ft}) \times (7.75\text{ ft}))}$$

$$a = 5.3391\text{ ft}$$

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

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

$$V_{max} = ((-0.90876\text{ kip/ft}) \times (48\text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.185\text{ ft})}{(7.75\text{ ft})} + 3\right) \times \left(\frac{(5.3391\text{ ft})}{(7.75\text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.185\text{ ft})}{(7.75\text{ ft})} + 2\right) \times \left(\frac{(5.3391\text{ ft})}{(7.75\text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 14.171\text{ kip}$$

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

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

$$M_{max} = ((-0.90876\text{ kip/ft}) \times (48\text{ in}) \times (7.75\text{ ft})) \times \left[\left(\frac{(14.185\text{ ft})}{(7.75\text{ ft})} + \frac{(5.3391\text{ ft})}{2 \times (7.75\text{ ft})}\right) - \left[\left(\frac{4 \times (14.185\text{ ft})}{(7.75\text{ ft})} + 3\right) \times \left(\frac{(5.3391\text{ ft})}{2 \times (7.75\text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (14.185\text{ ft})}{(7.75\text{ ft})} + 2\right) \times \left(\frac{(5.3391\text{ ft})}{2 \times (7.75\text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 52.353 \text{ kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(9.387 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (3 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -101.95 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-101.95 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

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

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(9.387\ \text{kip})}{(3183.4\ \text{kip})}$$

$$Ratio = 0.0029487$$

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 $f'_{ck} = 3\ \text{ksi} \rightarrow 3000\ \text{psi}$,$P = 9.387\ \text{kip} \rightarrow 9387\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(3000\ \text{psi})} + \frac{(9387\ \text{lbf})}{6 \times (2304\ \text{in}^2)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 131.05\ \text{kip}$$

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

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

$$V_c = Min\left[(324.49\ \text{kip}), (131.05\ \text{kip}), (406.27\ \text{kip})\right]$$

$$V_c = 131.05\ \text{kip}$$

22.5.1.2	The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \text{ksi} \rightarrow 3000\ \text{psi}$, $V_{s,a}$ - 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 $$\phi V_n = \phi\ (V_c + V_s)$$ $$\phi V_n = (0.65) \times ((131.05\ \text{kip}) + (50.894\ \text{kip}))$$ $$\phi V_n = 118.26\ \text{kip}$$ **Considering x-direction:** $V_{max} = 14.171\ \text{kip}$ - Maximum shear force in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(14.171\ \text{kip})}{(118.26\ \text{kip})}$$ $$Ratio = 0.11983$$	Status: **PASS** Ratio: **0.120**
	Flexural Strength (ACI 318-19, LRFD) S_m - Section modulus $$S_m = \frac{b\, D^2}{6}$$ $$S_m = \frac{(48\ \text{in}) \times (48\ \text{in})^2}{6}$$ $$S_m = 18432\ \text{in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f'_c)} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(3ksi)} \times 18432.001 in^3$$ $$\phi M_{n,1} = 273.423 kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f'_c\, S_m$$	

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

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

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

Therefore,
ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 52.353 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(52.353 \text{ kipft})}{(273.42 \text{ kipft})}$$

$$Ratio = 0.19147$$

Status: **PASS**
Ratio: **0.190**