Your Project Calculations

Project Name: Sunil Trehan - 25.6kW South of Driveway

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=Sunil%20Trehan%20-%2025.6kW%20South%20of%20Driveway&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/4_2023

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=K5OrxxlXOLV3etXnA4xVu1oClvztEXH0STBuh277csBpLxGGIm42PM0MT5NQDNsW

Array Specification

Product:	Beam
Unique ID:	5P-19.75-6TOP-HD-24-L-4Hx16W-IE4C
Duty Classification:	HD
Module Width:	44.61 in
Module Length:	67.83in
Number of Rows:	4
Number of Columns:	16
Total Number of Modules:	64
Desired Tilt Angle:	15
Front Edge Clearance:	2
Total Array Height at Tilt:	5.87 ft
Total Frame Length:	90.50 ft
Frame Weight:	3257 lbs
Array Dimensions N/S:	15.04 ft
Array Dimensions E/W:	91.77 ft
Rail Length:	180.44 in
Rail Spacing:	2.83 ft
Rail Check:	Not Checked

Support Specifications

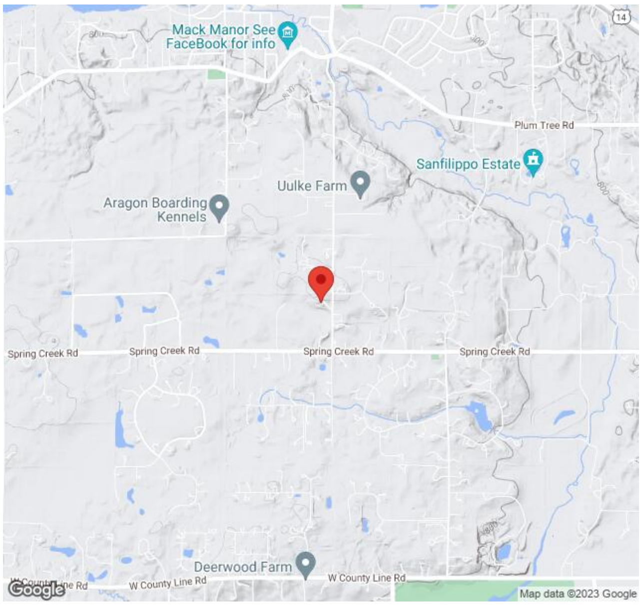
Pole Size:	6in Pipe Sch 40
Pole Length above Grade:	3.95 ft
Number of Poles:	5
Pole Spacing:	19.75 ft

Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 4.75 ft Pile 2: 5.00 ft Pile 3: 5.25 ft Pile 4: 5.00 ft Pile 5: 4.75 ft
Foundation Volume:	14.667 y^3
Foundation Result:	PASSED
Mount Twist:	0.490768 kip

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	112 Braeburn Rd, Barrington, IL 60010, USA
Wind Speed:	100 mph
Snow Load:	25 psf
Design Uplift Pressure:	Multiple pressures
Design Downforce Pressure:	Multiple pressures
Design Snow Pressure:	0.015120 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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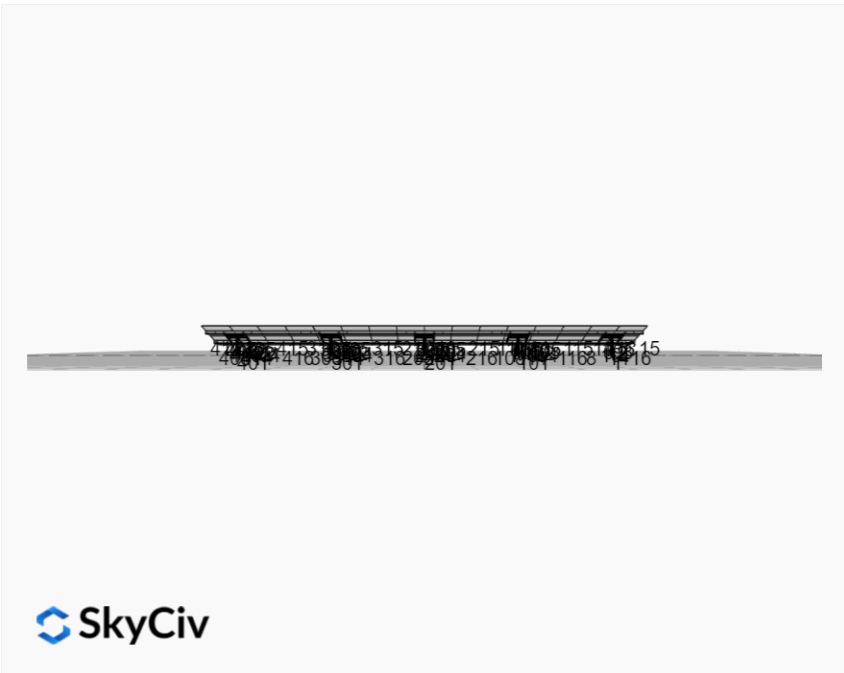
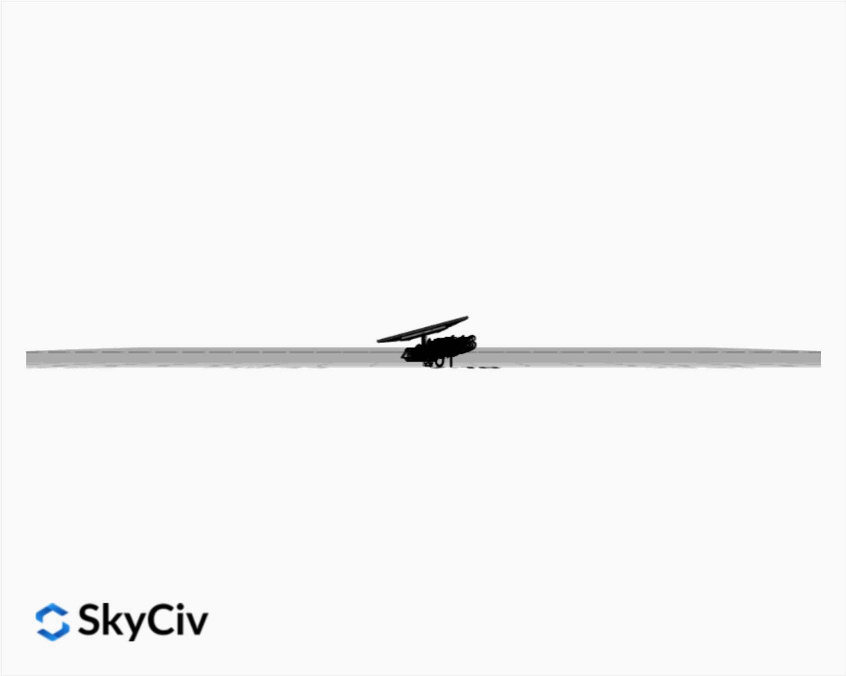
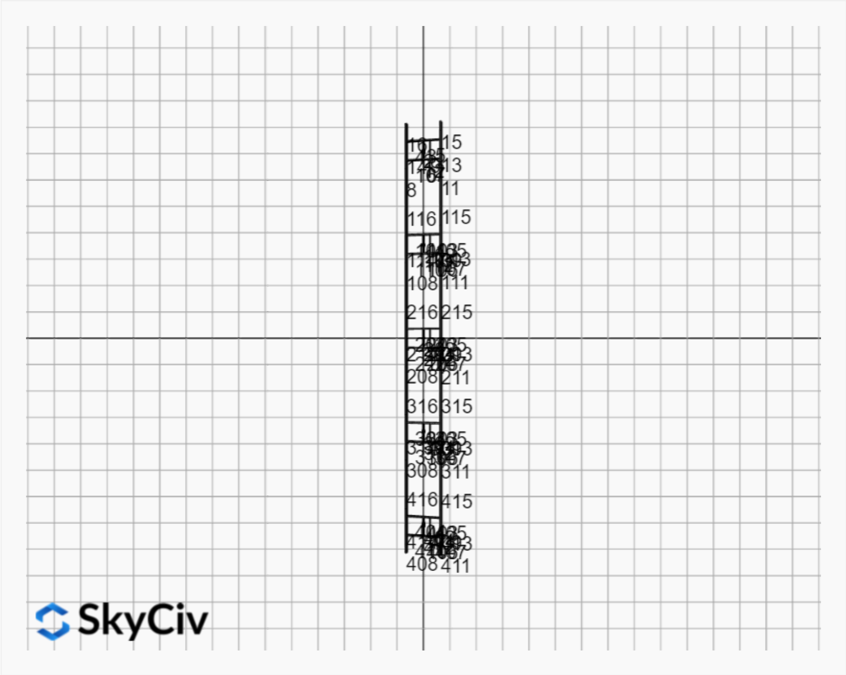
Design Notes:

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



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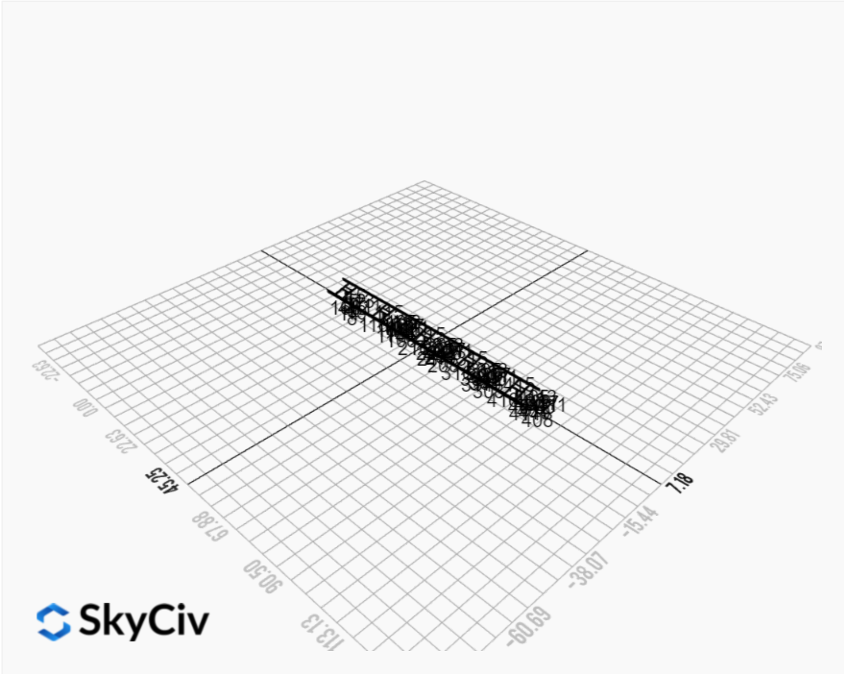
108 111
216 215
208 211
316 315
308 311
416 415
408 411


-22.63
0.00
22.63
45.25
67.88
90.50
113.13
75.06
52.43
29.81
7.18
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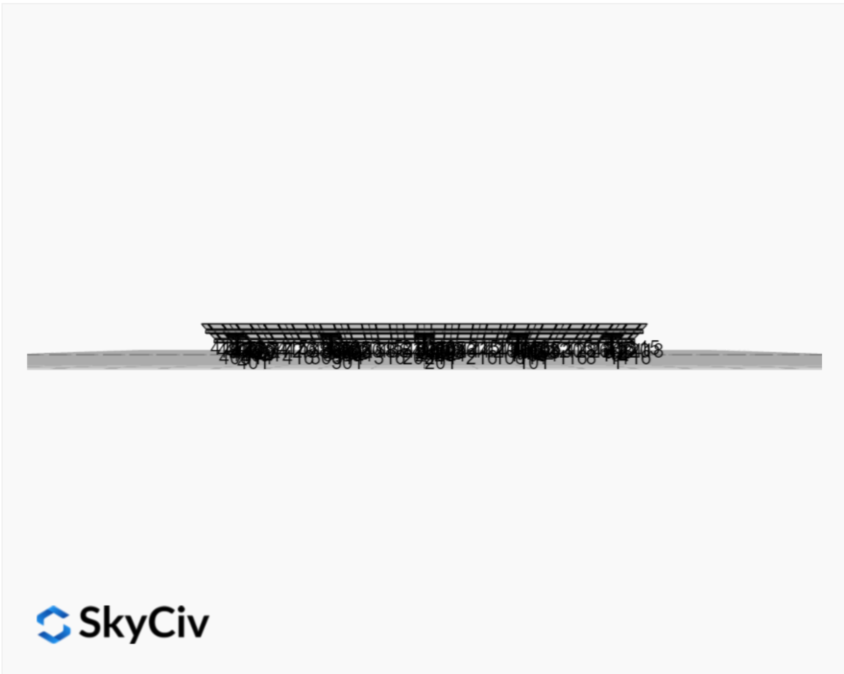
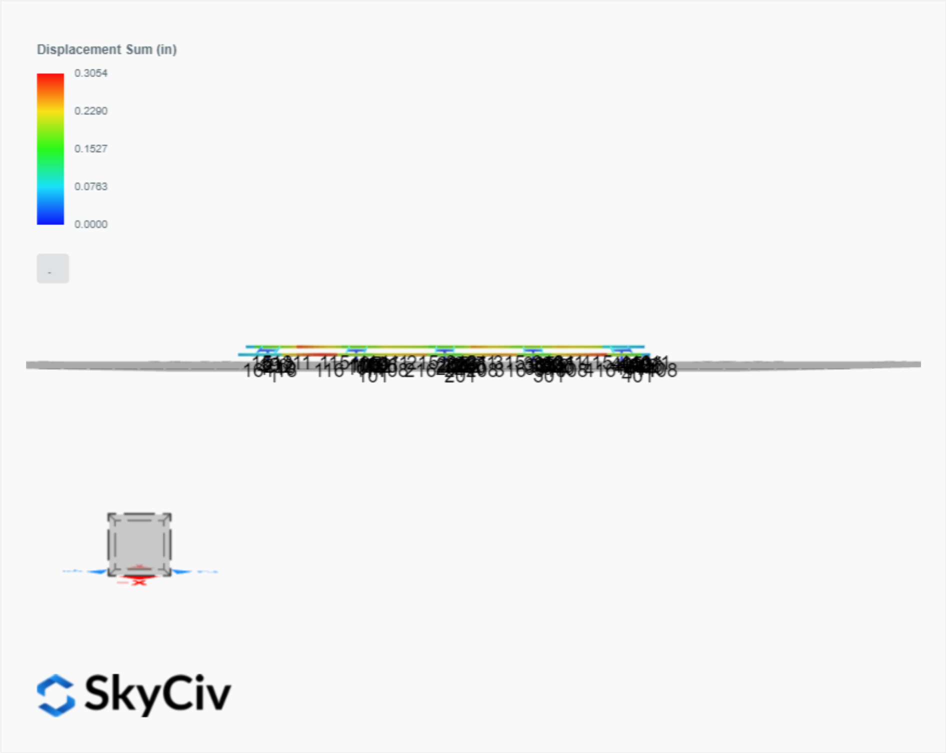
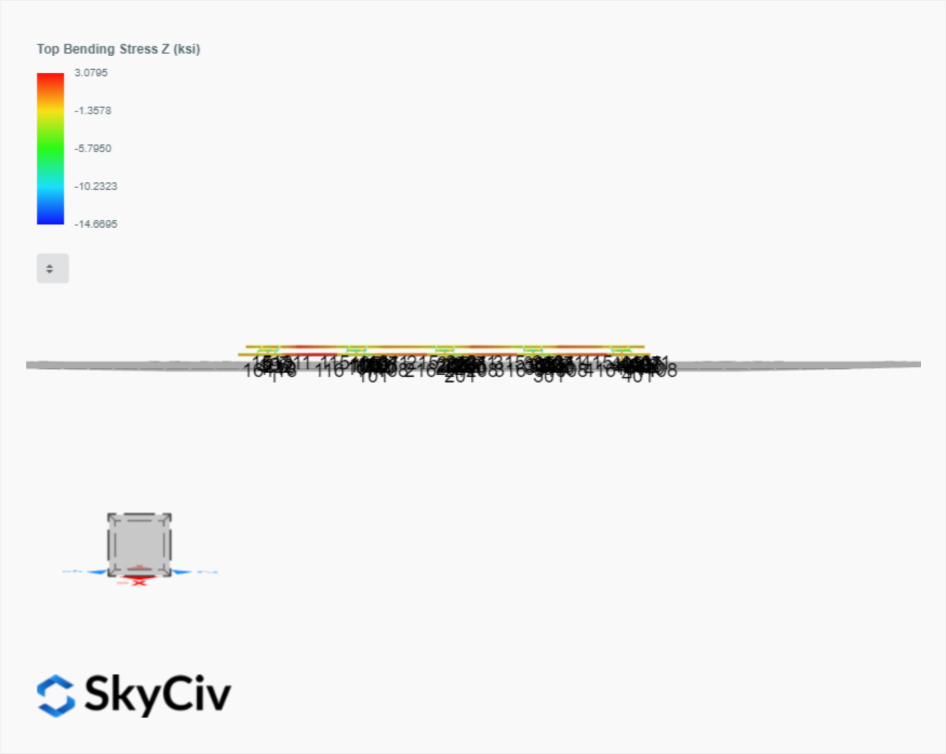
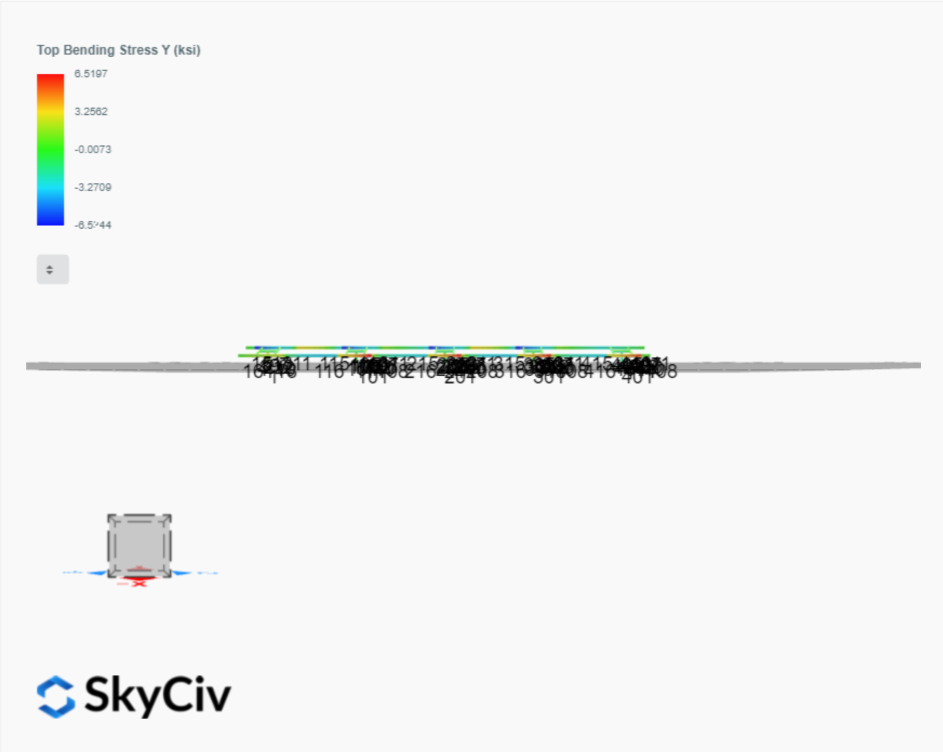
-38.07
-60.69
SkyCiv

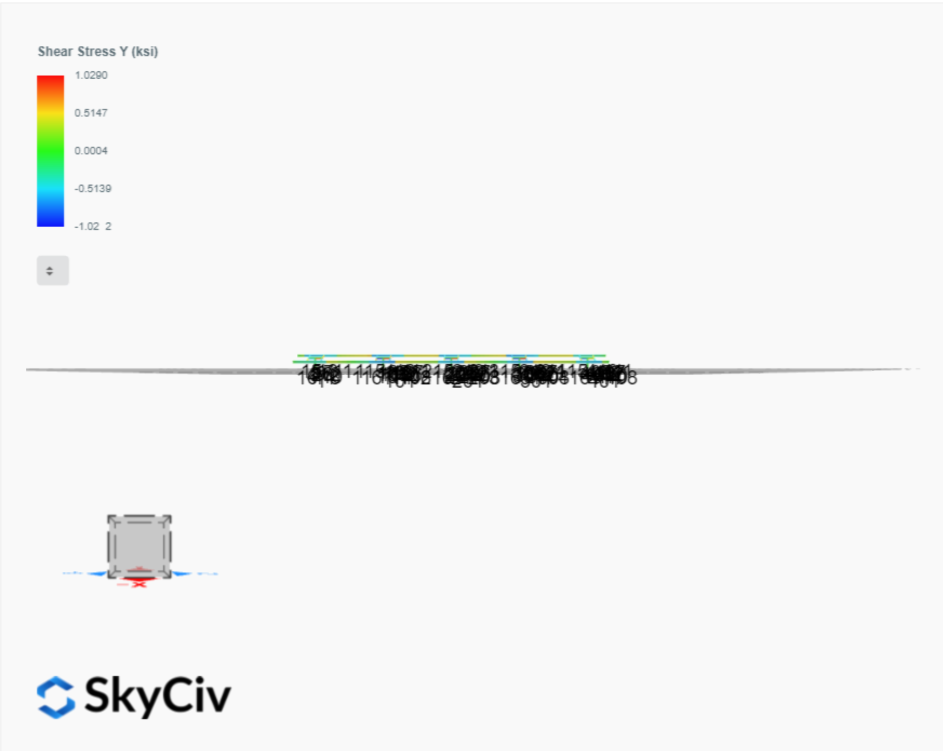

SkyCiv

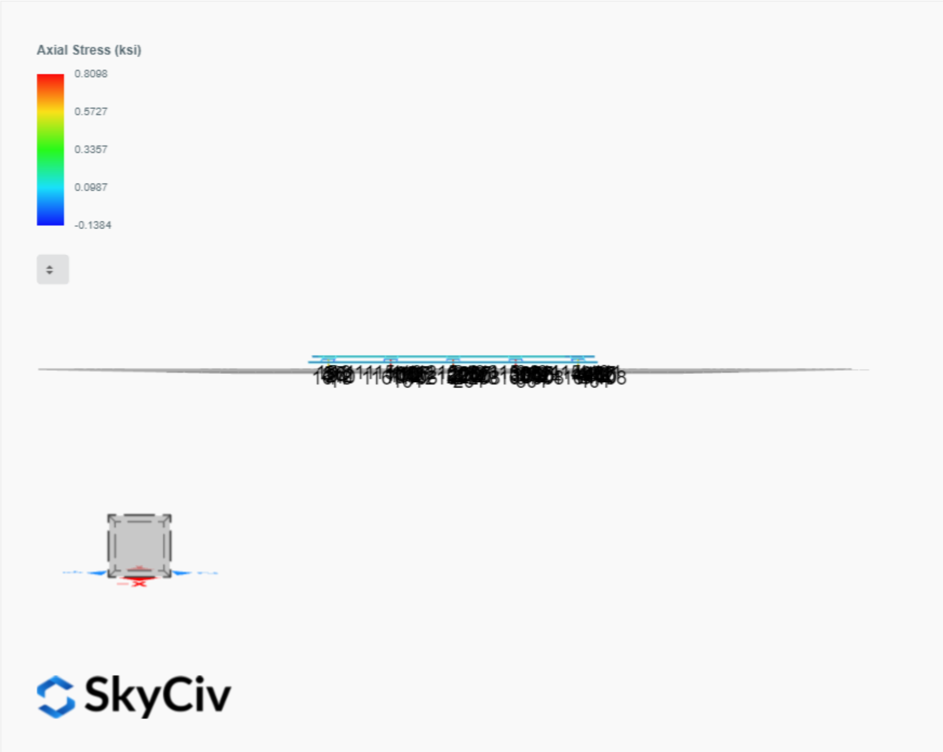
FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
6.5197
3.2562
-0.0073
-3.2709
SkyCiv


Shear Stress Y (ksi)
1.0290
0.5147
0.0004
-0.5139
SkyCiv


Axial Stress (ksi)
0.8098
0.5727
0.3357
0.0987
-0.1384
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	0.0163	1.6553	0.1318	-0.0393	-0.0261	-0.0313
ULS: 2. D + L	0.0163	1.6553	0.1318	-0.0393	-0.0261	-0.0313
ULS: 3. D + (S or Lr or R)	0.0553	4.9308	0.4486	-0.1332	-0.0891	-0.1671
ULS: 3. D + (S or Lr or R)	0.0163	1.6553	0.1318	-0.0393	-0.0261	-0.0313
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0455	4.1119	0.3694	-0.1097	-0.0733	-0.1331
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0163	1.6553	0.1318	-0.0393	-0.0261	-0.0313
ULS: 5b. D + 0.7E	0.0163	1.6553	0.1318	-0.0393	-0.0261	-0.0313
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0455	4.1119	0.3694	-0.1097	-0.0733	-0.1331
ULS: 8. 0.6D + 0.7E	0.0098	0.9932	0.0791	-0.0236	-0.0157	-0.0188
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.7629	4.5529	0.4143	-0.1538	-0.2546	4.2983
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.7629	4.5529	0.4143	-0.1538	-0.2546	4.2983
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.6049	-0.5419	-0.0779	0.0444	0.1416	-0.7721
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.5336	-0.2464	-0.0613	0.0411	0.1368	-9.6731
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.5388	6.2851	0.5813	-0.1956	-0.2447	3.1141
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.5388	6.2851	0.5813	-0.1956	-0.2447	3.1141
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.4870	2.4641	0.2121	-0.0470	0.0524	-0.6887
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.4335	2.6857	0.2245	-0.0495	0.0489	-7.3645
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.5681	3.8285	0.3437	-0.1252	-0.1975	3.2159
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.5681	3.8285	0.3437	-0.1252	-0.1975	3.2159
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.4577	0.0074	-0.0254	0.0235	0.0996	-0.5869
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.4043	0.2290	-0.0131	0.0210	0.0961	-7.2627
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.7694	3.8908	0.3616	-0.1381	-0.2442	4.3108
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.7694	3.8908	0.3616	-0.1381	-0.2442	4.3108
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.5984	-1.2040	-0.1306	0.0601	0.1520	-0.7595
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.5271	-0.9085	-0.1140	0.0568	0.1473	-9.6606

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	9.6412
Shear X	-1.2986
Shear Z	0.9046
Moment X	-0.2946
Moment Y (Twist)	0.4444
Moment Z	16.2550

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	6.2851
Shear X	-0.7694
Shear Z	0.5813
Moment X	-0.1956
Moment Y (Twist)	0.2546
Moment Z	9.6731

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	-0.0195	2.1747	-0.0189	0.0057	0.0252	0.0973
ULS: 2. D + L	-0.0195	2.1747	-0.0189	0.0057	0.0252	0.0973
ULS: 3. D + (S or Lr or R)	-0.0662	6.6944	-0.0645	0.0195	0.0858	0.2736
ULS: 3. D + (S or Lr or R)	-0.0195	2.1747	-0.0189	0.0057	0.0252	0.0973
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0545	5.5644	-0.0531	0.0160	0.0707	0.2295
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0195	2.1747	-0.0189	0.0057	0.0252	0.0973
ULS: 5b. D + 0.7E	-0.0195	2.1747	-0.0189	0.0057	0.0252	0.0973

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0545	5.5644	-0.0531	0.0160	0.0707	0.2295
ULS: 8. 0.6D + 0.7E	-0.0117	1.3048	-0.0114	0.0034	0.0151	0.0584
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.0944	6.1968	-0.0624	0.0211	0.0570	5.8848
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.0944	6.1968	-0.0624	0.0211	0.0570	5.8848
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.7985	-0.8783	0.0150	-0.0070	-0.0019	-1.0294
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.6775	-0.4549	0.0060	-0.0009	0.0131	-12.3770
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.8607	8.5810	-0.0857	0.0276	0.0945	4.5702
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.8607	8.5810	-0.0857	0.0276	0.0945	4.5702
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.5590	3.2747	-0.0276	0.0065	0.0503	-0.6155
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.4682	3.5923	-0.0344	0.0111	0.0615	-9.1262
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.8256	5.1913	-0.0515	0.0173	0.0490	4.4379
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.8256	5.1913	-0.0515	0.0173	0.0490	4.4379
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.5940	-0.1151	0.0065	-0.0038	0.0049	-0.7478
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.5033	0.2025	-0.0002	0.0007	0.0161	-9.2584
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.0866	5.3269	-0.0548	0.0188	0.0469	5.8459
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.0866	5.3269	-0.0548	0.0188	0.0469	5.8459
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.8063	-1.7482	0.0226	-0.0092	-0.0120	-1.0683
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.6853	-1.3248	0.0136	-0.0032	0.0030	-12.4159

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	13.1937
Shear X	-1.8384
Shear Z	-0.1327
Moment X	0.0424
Moment Y (Twist)	0.1542
Moment Z	20.7904

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	8.5810
Shear X	-1.0944
Shear Z	-0.0857
Moment X	0.0276
Moment Y (Twist)	0.0945
Moment Z	12.4159

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	0.0065	2.0761	-0.0008	0.0088	0.0013	0.0117
ULS: 2. D + L	0.0065	2.0761	-0.0008	0.0088	0.0013	0.0117
ULS: 3. D + (S or Lr or R)	0.0221	6.3589	-0.0026	0.0298	0.0045	-0.0177
ULS: 3. D + (S or Lr or R)	0.0065	2.0761	-0.0008	0.0088	0.0013	0.0117
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0182	5.2882	-0.0022	0.0245	0.0037	-0.0103
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0065	2.0761	-0.0008	0.0088	0.0013	0.0117
ULS: 5b. D + 0.7E	0.0065	2.0761	-0.0008	0.0088	0.0013	0.0117
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0182	5.2882	-0.0022	0.0245	0.0037	-0.0103
ULS: 8. 0.6D + 0.7E	0.0039	1.2456	-0.0005	0.0053	0.0008	0.0070
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.0116	5.8747	-0.0024	0.0284	0.0076	5.6564
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.0116	5.8747	-0.0024	0.0284	0.0076	5.6564
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.7786	-0.8042	0.0004	-0.0059	-0.0033	-0.9757
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.6744	-0.4175	0.0003	-0.0039	-0.0031	-12.4601
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.7454	8.1372	-0.0033	0.0393	0.0084	4.2232
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.7454	8.1372	-0.0033	0.0393	0.0084	4.2232
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.5973	3.1280	-0.0013	0.0135	0.0003	-0.7508
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.5191	3.4180	-0.0014	0.0150	0.0004	-9.3642

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.7571	4.9251	-0.0020	0.0235	0.0060	4.2452
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.7571	4.9251	-0.0020	0.0235	0.0060	4.2452
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.5856	-0.0841	0.0001	-0.0023	-0.0021	-0.7288
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.5074	0.2059	0.0000	-0.0007	-0.0020	-9.3422
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.0142	5.0443	-0.0021	0.0249	0.0071	5.6517
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.0142	5.0443	-0.0021	0.0249	0.0071	5.6517
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.7760	-1.6346	0.0007	-0.0094	-0.0038	-0.9803
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.6718	-1.2479	0.0006	-0.0074	-0.0036	-12.4648

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	12.5089
Shear X	-1.6969
Shear Z	-0.0052
Moment X	0.0611
Moment Y (Twist)	0.0136
Moment Z	20.9206

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	8.1372
Shear X	-1.0142
Shear Z	-0.0033
Moment X	0.0393
Moment Y (Twist)	0.0084
Moment Z	12.4648

Reaction Forces for Foundation 4 (Node ID#301), (kip, kip-ft)

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	-0.0192	2.1737	0.0251	0.0101	-0.0249	0.0964
ULS: 2. D + L	-0.0192	2.1737	0.0251	0.0101	-0.0249	0.0964
ULS: 3. D + (S or Lr or R)	-0.0654	6.6912	0.0856	0.0340	-0.0848	0.2707
ULS: 3. D + (S or Lr or R)	-0.0192	2.1737	0.0251	0.0101	-0.0249	0.0964
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0539	5.5618	0.0705	0.0280	-0.0699	0.2271
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0192	2.1737	0.0251	0.0101	-0.0249	0.0964
ULS: 5b. D + 0.7E	-0.0192	2.1737	0.0251	0.0101	-0.0249	0.0964
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0539	5.5618	0.0705	0.0280	-0.0699	0.2271
ULS: 8. 0.6D + 0.7E	-0.0115	1.3042	0.0151	0.0060	-0.0150	0.0578
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.0936	6.1938	0.0825	0.0300	-0.0571	5.8812
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.0936	6.1938	0.0825	0.0300	-0.0571	5.8812
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.7984	-0.8777	-0.0192	-0.0038	0.0027	-1.0300
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.6774	-0.4544	-0.0088	-0.0062	-0.0131	-12.3714
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.8597	8.5769	0.1135	0.0430	-0.0940	4.5658
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.8597	8.5769	0.1135	0.0430	-0.0940	4.5658
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.5593	3.2733	0.0372	0.0176	-0.0491	-0.6177
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.4686	3.5907	0.0450	0.0158	-0.0610	-9.1237
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.8250	5.1888	0.0682	0.0250	-0.0491	4.4350
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.8250	5.1888	0.0682	0.0250	-0.0491	4.4350
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.5940	-0.1148	-0.0081	-0.0004	-0.0042	-0.7484
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.5032	0.2026	-0.0003	-0.0022	-0.0160	-9.2544
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.0859	5.3243	0.0724	0.0260	-0.0472	5.8427
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.0859	5.3243	0.0724	0.0260	-0.0472	5.8427
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.8061	-1.7472	-0.0293	-0.0079	0.0127	-1.0685
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.6851	-1.3239	-0.0189	-0.0103	-0.0031	-12.4099

Worst Case Reactions LRFD

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	13.1873
Shear X	-1.8369
Shear Z	0.1759
Moment X	0.0674
Moment Y (Twist)	0.1532
Moment Z	20.7796

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

Result	Value (kip, kip-ft)
Axial	8.5769
Shear X	-1.0936
Shear Z	0.1135
Moment X	0.0430
Moment Y (Twist)	0.0940
Moment Z	12.4099

Reaction Forces for Foundation 5 (Node ID#401), (kip, kip-ft)

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	0.0160	1.6569	-0.1372	0.0583	0.0319	-0.0302
ULS: 2. D + L	0.0160	1.6569	-0.1372	0.0583	0.0319	-0.0302
ULS: 3. D + (S or Lr or R)	0.0543	4.9362	-0.4671	0.1979	0.1088	-0.1632
ULS: 3. D + (S or Lr or R)	0.0160	1.6569	-0.1372	0.0583	0.0319	-0.0302
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0447	4.1164	-0.3846	0.1630	0.0896	-0.1299
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0160	1.6569	-0.1372	0.0583	0.0319	-0.0302
ULS: 5b. D + 0.7E	0.0160	1.6569	-0.1372	0.0583	0.0319	-0.0302
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0447	4.1164	-0.3846	0.1630	0.0896	-0.1299
ULS: 8. 0.6D + 0.7E	0.0096	0.9941	-0.0823	0.0350	0.0192	-0.0181
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.7641	4.5580	-0.4321	0.2152	0.2799	4.3017
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.7641	4.5580	-0.4321	0.2152	0.2799	4.3017
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.6053	-0.5430	0.0817	-0.0571	-0.1504	-0.7750
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.5339	-0.2471	0.0639	-0.0495	-0.1435	-9.6670
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.5404	6.2922	-0.6058	0.2807	0.2756	3.1190
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.5404	6.2922	-0.6058	0.2807	0.2756	3.1190
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.4867	2.4665	-0.2204	0.0764	-0.0472	-0.6885
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.4332	2.6884	-0.2338	0.0822	-0.0420	-7.3576
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.5691	3.8327	-0.3584	0.1760	0.2179	3.2187
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.5691	3.8327	-0.3584	0.1760	0.2179	3.2187
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.4579	0.0070	0.0269	-0.0283	-0.1048	-0.5888
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.4044	0.2289	0.0136	-0.0225	-0.0997	-7.2578
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.7705	3.8953	-0.3772	0.1919	0.2671	4.3137
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.7705	3.8953	-0.3772	0.1919	0.2671	4.3137
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.5989	-1.2057	0.1366	-0.0804	-0.1632	-0.7629
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.5275	-0.9099	0.1188	-0.0728	-0.1563	-9.6550

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	9.6521
Shear X	-1.3001
Shear Z	-0.9425
Moment X	0.4272
Moment Y (Twist)	0.4908
Moment Z	16.2441

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	6.2922
Shear X	-0.7705
Shear Z	-0.6058
Moment X	0.2807
Moment Y (Twist)	0.2799
Moment Z	9.6670

Project Details

Design Code:	AISC 360-16 LRFD
Provision:	LRFD
Country:	United States
User Name:	sales@mtsolar.us
Project Name:	Sunil Trehan - 25.6kW South of Driveway
Unit System:	imperial

Design Input Information

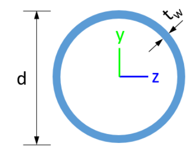
Design Factors

Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

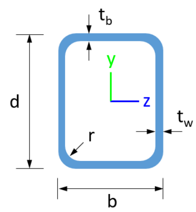
Design Materials

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

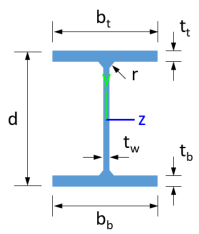
Section Dimensions



ID	Name	d (in)	t_w (in)					
2	2in Pipe Sch 80	2.38	0.22					
5	4in Pipe Sch 80	4.50	0.34					
7	6in Pipe Sch 40	6.63	0.28					



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

7	6in Pipe Sch 40	5.58	56.28	28.14	28.14	0.00	11.28	11.28
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	7	8.29	8.29	3.95	-	300	200	1
2	5	1.26	1.26	1.93	-	300	200	1
3	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.17,1.17,1.28,1.16,1.18,1.18,1.16,1.17,1.17,1.17,1.18,1.18,1.18,1.18,1.32,1.16,1.17,1.17,1.16,1.17	300	200	1
4	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.69,1.69,1.67,1.67,1.63,1.68,1.67,1.67,1.65,1.69,1.67,1.67,1.68,1.67,1.68,1.68,1.60,1.69,1.67,1.67,1.66,1.69	300	200	1
5	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.85,1.66,1.67,1.67,1.65,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.95,1.65,1.67,1.67,1.66,1.66	300	200	1
6	16	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.33,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.19,1.19,1.19,1.19,1.36,1.17,1.18,1.18,1.18,1.18	300	200	1
7	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.89,1.66,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.99,1.66,1.67,1.67,1.66,1.67	300	200	1
8	19	1.33	1.33	2.05	1.31,1.31,1.31,1.31,1.31,1.31,1.30,1.30,1.35,1.46,1.30,1.30,1.33,1.73,1.31,1.31,1.31,1.34,1.30,1.30,1.35,1.46,1.30,1.30,1.33,2.07	300	200	1
9	2	2.60	2.60	4.00	-	300	200	1
10	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.64,1.68,1.67,1.67,1.66,1.69,1.67,1.67,1.68,1.67,1.68,1.68,1.62,1.69,1.67,1.67,1.66,1.69	300	200	1
11	19	1.33	1.33	2.05	1.32,1.32,1.32,1.32,1.32,1.32,1.33,1.33,1.41,1.47,1.33,1.33,1.28,1.41,1.32,1.32,1.33,1.27,1.33,1.33,1.45,1.47,1.33,1.33,1.29,1.40	300	200	1
12	5	1.30	1.30	2.00	-	300	200	1
13	19	1.14	1.14	1.75	2.30,2.30,2.30,2.30,2.30,2.30,2.28,2.28,1.21,1.92,2.28,2.28,2.15,2.13,2.29,2.29,2.28,2.13,2.28,2.28,1.22,1.92,2.28,2.28,2.20,2.17	300	200	1
14	19	1.14	1.14	1.75	1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48	300	200	1
15	19	4.20	4.20	2.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
16	19	4.20	4.20	2.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
17	19	2.60	2.60	4.00	1.31,1.31,1.31,1.31,1.31,1.31,1.32,1.32,1.91,1.39,1.32,1.32,1.28,1.37,1.32,1.32,1.32,1.28,1.32,1.32,1.64,1.40,1.32,1.32,1.29,1.36	300	200	1
18	19	1.14	1.14	1.75	1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48	300	200	1
19	19	2.60	2.60	4.00	1.30,1.30,1.30,1.31,1.30,1.30,1.30,1.30,1.41,1.42,1.30,1.30,1.35,1.53,1.31,1.31,1.29,1.33,1.30,1.30,1.43,1.41,1.30,1.30,1.35,1.60	300	200	1
20	19	1.14	1.14	1.75	2.32,2.32,2.32,2.32,2.32,2.32,2.35,2.35,2.25,1.94,2.35,2.35,2.28,1.61,2.33,2.33,2.33,2.26,2.34,2.34,2.25,1.95,2.36,2.36,2.29,1.50	300	200	1
21	19	2.60	2.60	4.00	1.08,1.08,1.08,1.08,1.08,1.08,1.09,1.09,1.03,1.14,1.09,1.09,1.07,1.12,1.09,1.09,1.09,1.07,1.09,1.09,1.04,1.15,1.09,1.09,1.07,1.12	300	200	1
22	19	1.14	1.14	1.75	1.45,1.45,1.45,1.45,1.45,1.45,1.46,1.46,1.06,1.64,1.46,1.46,1.42,1.56,1.46,1.46,1.46,1.40,1.46,1.46,1.07,1.64,1.47,1.47,1.42,1.55	300	200	1
23	19	2.60	2.60	4.00	1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.10,1.14,1.08,1.08,1.09,1.29,1.08,1.08,1.08,1.09,1.08,1.08,1.10,1.14,1.08,1.08,1.09,1.81	30	20	1

					[illegible]	0	0	
24	19	1.14	1.14	1.75	1.39,1.39,1.39,1.39,1.39,1.39,1.38,1.38,1.41,1.46,1.38,1.38,1.40,1.59,1.39,1.39,1.39,1.40,1.38,1.38,1.41,1.47,1.38,1.38,1.40,1.72	300	200	1
25	19	2.60	2.60	4.00	1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.19,1.09,1.08,1.08,1.09,1.08,1.08,1.08,1.08,1.08,1.08,1.12,1.09,1.08,1.08,1.08,1.09	300	200	1
26	19	1.14	1.14	1.75	1.44,1.43,1.44,1.43,1.43,1.44,1.43,1.43,1.26,1.41,1.43,1.43,1.45,1.42,1.43,1.43,1.45,1.43,1.43,1.27,1.41,1.43,1.43,1.45,1.42	300	200	1
27	19	2.60	2.60	4.00	1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.09,1.09,1.08,1.08,1.08,1.10,1.08,1.08,1.08,1.08,1.08,1.08,1.09,1.09,1.08,1.08,1.08,1.10	300	200	1
28	19	1.14	1.14	1.75	1.45,1.45,1.45,1.45,1.45,1.45,1.45,1.45,1.42,1.42,1.45,1.45,1.43,1.39,1.45,1.45,1.45,1.44,1.45,1.45,1.42,1.42,1.45,1.45,1.44,1.38	300	200	1
29	19	2.60	2.60	4.00	1.08,1.08,1.08,1.08,1.08,1.08,1.09,1.09,1.04,1.14,1.09,1.09,1.07,1.12,1.08,1.08,1.06,1.09,1.09,1.04,1.14,1.09,1.09,1.07,1.11	300	200	1
30	19	1.14	1.14	1.75	1.39,1.39,1.39,1.39,1.39,1.39,1.40,1.40,1.21,1.47,1.40,1.40,1.37,1.44,1.40,1.40,1.40,1.36,1.40,1.40,1.23,1.47,1.40,1.40,1.38,1.44	300	200	1
31	19	2.60	2.60	4.00	1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.10,1.14,1.08,1.08,1.09,1.29,1.08,1.08,1.08,1.09,1.08,1.08,1.10,1.13,1.08,1.08,1.09,1.81	300	200	1
32	19	1.14	1.14	1.75	1.44,1.44,1.44,1.44,1.44,1.44,1.43,1.43,1.48,1.60,1.43,1.43,1.46,2.05,1.44,1.44,1.43,1.47,1.43,1.43,1.48,1.60,1.43,1.43,1.46,2.30	300	200	1
33	19	2.60	2.60	4.00	1.29,1.29,1.29,1.29,1.29,1.29,1.29,1.29,1.92,1.37,1.30,1.30,1.26,1.35,1.29,1.29,1.30,1.25,1.29,1.29,1.65,1.38,1.30,1.30,1.26,1.34	300	200	1
34	19	1.14	1.14	1.75	2.27,2.27,2.27,2.27,2.27,2.27,2.26,2.26,1.21,1.86,2.26,2.26,2.27,2.03,2.27,2.27,2.26,2.15,2.26,2.26,1.22,1.85,2.25,2.25,2.35,2.07	300	200	1
35	19	2.60	2.60	4.00	1.28,1.28,1.28,1.28,1.28,1.28,1.28,1.28,1.39,1.40,1.28,1.28,1.33,1.51,1.28,1.28,1.27,1.31,1.28,1.28,1.40,1.39,1.28,1.28,1.32,1.59	300	200	1
36	19	1.14	1.14	1.75	1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48	300	200	1
37	19	3.10	3.10	4.76	1.67,1.67,1.67,1.67,1.67,1.67,1.69,1.69,1.60,1.47,1.70,1.70,1.64,1.33,1.68,1.68,1.68,1.62,1.69,1.69,1.60,1.47,1.70,1.70,1.64,1.26	300	200	1
38	19	3.67	3.67	5.65	1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.10,1.11,1.09,1.09,1.09,1.13,1.09,1.09,1.09,1.09,1.09,1.09,1.10,1.11,1.09,1.09,1.09,1.15	300	200	1
39	19	1.24	1.24	1.90	2.11,2.11,2.11,2.11,2.11,2.11,2.11,2.11,2.31,2.38,2.11,2.11,2.13,2.31,2.11,2.11,2.11,2.12,2.11,2.11,2.34,2.38,2.11,2.11,2.13,2.28	300	200	1
40	19	3.05	3.05	4.70	1.82,1.82,1.82,1.82,1.82,1.82,1.85,1.85,1.74,1.61,1.86,1.86,1.79,1.46,1.84,1.84,1.84,1.76,1.85,1.85,1.75,1.61,1.86,1.86,1.79,1.39	300	200	1
41	19	3.67	3.67	5.65	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.06,1.04,1.04,1.04,1.10,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.06,1.04,1.04,1.04,1.14	300	200	1
42	19	1.19	1.19	1.84	1.32,1.32,1.32,1.32,1.32,1.32,1.31,1.31,1.36,1.49,1.30,1.30,1.34,1.83,1.31,1.31,1.31,1.35,1.31,1.31,1.36,1.49,1.30,1.30,1.34,2.10	300	200	1
43	5	0.04	0.04	0.07	-	300	200	1
44	5	1.26	1.26	1.93	-	300	200	1
45	19	3.53	3.53	5.44	1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.78,1.05,1.03,1.03,1.03,1.04,1.03,1.03,1.03,1.02,1.03,1.03,1.67,1.05,1.03,1.03,1.03,1.04	300	200	1
46	19	1.72	1.72	2.65	1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.00,1.19,1.24,1.24,1.28,1.21,1.25,1.25,1.25,1.29,1.25,1.25,1.01,1.19,1.24,1.24,1.27,1.21	300	200	1
47	19	3.67	3.67	5.65	1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.47,1.11,1.09,1.09,1.08,1.11,1.09,1.09,1.09,1.08,1.09,1.09,1.42,1.11,1.09,1.09,1.09,1.11	300	200	1
48	19	3.58	3.58	5.51	1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.42,1.10,1.08,1.08,1.07,1.10,1.08,1.08,1.07,1.08,1.08,1.38,1.10,1.08,1.08,1.08,1.09	300	200	1
49	19	1.76	1.76	2.71	1.23,1.23,1.23,1.23,1.23,1.23,1.23,1.23,1.05,1.17,1.23,1.23,1.26,1.19,1.23,1.23,1.23,1.28,1.23,1.23,1.04,1.17,1.23,1.23,1.25,1.19	300	200	1

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50	19	3.67	3.67	5.65	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.89,1.06,1.04,1.04,1.03,1.05,1.04,1.04,1.04,1.03,1.04,1.04,1.77,1.06,1.04,1.04,1.03,1.05	300	200	1
101	7	8.29	8.29	3.95	-	300	200	1
102	5	1.30	1.30	2.00	-	300	200	1
103	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.34,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.37,1.17,1.18,1.18,1.17,1.18	300	200	1
104	16	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.68,1.69,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.69,1.67,1.67,1.68,1.68,1.68,1.68,1.63,1.69,1.67,1.67,1.66,1.69	300	200	1
105	16	1.52	1.52	2.33	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,2.02,1.67,1.68,1.68,1.66,1.67,1.67,1.67,1.68,1.68,1.68,1.68,2.11,1.66,1.67,1.67,1.67,1.67	300	200	1
106	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.31,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.34,1.17,1.18,1.18,1.17,1.18	300	200	1
107	16	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.89,1.66,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.99,1.66,1.67,1.67,1.66,1.67	300	200	1
108	19	1.33	1.33	2.05	2.36,2.36,2.36,2.35,2.36,2.36,2.34,2.34,2.25,2.08,2.34,2.34,2.38,1.78,2.35,2.35,2.35,2.33,2.34,2.34,2.28,2.08,2.33,2.33,2.38,1.58	300	200	1
109	2	2.60	2.60	4.00	-	300	200	1
110	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.69,1.67,1.67,1.68,1.67,1.68,1.68,1.63,1.69,1.67,1.67,1.66,1.69	300	200	1
111	19	1.33	1.33	2.05	2.37,2.36,2.37,2.36,2.36,2.37,2.38,2.38,1.08,2.07,2.39,2.39,2.31,2.09,2.37,2.37,2.37,2.28,2.38,2.38,1.09,2.07,2.39,2.39,2.32,2.10	300	200	1
112	5	1.30	1.30	2.00	-	300	200	1
113	19	1.14	1.14	1.75	1.39,1.39,1.39,1.39,1.39,1.39,1.40,1.40,1.20,1.47,1.40,1.40,1.37,1.44,1.39,1.39,1.40,1.36,1.40,1.40,1.22,1.47,1.40,1.40,1.38,1.44	300	200	1
114	19	1.14	1.14	1.75	1.45,1.45,1.45,1.45,1.45,1.45,1.44,1.44,1.49,1.61,1.43,1.43,1.46,2.06,1.44,1.44,1.44,1.48,1.44,1.44,1.49,1.61,1.43,1.43,1.46,2.30	300	200	1
115	19	3.10	3.10	4.76	1.66,1.66,1.66,1.66,1.66,1.66,1.64,1.64,1.02,1.46,1.63,1.63,1.74,1.52,1.65,1.65,1.65,1.80,1.64,1.64,1.01,1.46,1.63,1.63,1.72,1.53	300	200	1
116	19	3.53	3.53	5.44	1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.04,1.05,1.03,1.03,1.03,1.08,1.03,1.03,1.03,1.04,1.03,1.03,1.04,1.05,1.03,1.03,1.03,1.12	300	200	1
201	7	8.29	8.29	3.95	-	300	200	1
202	5	1.30	1.30	2.00	-	300	200	1
203	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.29,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.32,1.17,1.18,1.18,1.17,1.18	300	200	1
204	16	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.68,1.69,1.68,1.68,1.65,1.68,1.68,1.68,1.66,1.69,1.68,1.68,1.68,1.68,1.68,1.68,1.63,1.69,1.68,1.68,1.67,1.69	300	200	1
205	16	1.52	1.52	2.33	1.69,1.68,1.69,1.68,1.68,1.69,1.68,1.68,1.85,1.67,1.68,1.68,1.66,1.67,1.68,1.68,1.68,1.68,1.68,1.68,1.94,1.67,1.68,1.68,1.67,1.67	300	200	1
206	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.29,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.32,1.17,1.18,1.18,1.17,1.18	300	200	1
207	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.84,1.66,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.94,1.66,1.67,1.67,1.66,1.67	300	200	1
208	19	1.33	1.33	2.05	2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.11,2.13,2.09,2.09,2.10,2.37,2.09,2.09,2.09,2.10,2.09,2.09,2.12,2.12,2.09,2.09,2.10,2.33	300	200	1
209	2	2.60	2.60	4.00	-	300	200	1

210	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.68,1.67,1.67,1.67,1.67,1.68,1.68,1.62,1.68,1.67,1.67,1.66,1.68	300	200	1
211	19	1.33	1.33	2.05	2.10,2.10,2.10,2.10,2.10,2.10,2.10,1.66,2.15,2.10,2.10,2.08,2.11,2.10,2.10,2.10,2.08,2.10,2.10,1.75,2.15,2.10,2.10,2.09,2.11	300	200	1
212	5	1.30	1.30	2.00	-	300	200	1
213	19	1.14	1.14	1.75	1.44,1.44,1.44,1.44,1.44,1.44,1.44,1.44,1.26,1.42,1.44,1.44,1.45,1.42,1.44,1.44,1.44,1.45,1.44,1.44,1.28,1.41,1.44,1.44,1.45,1.42	300	200	1
214	19	1.14	1.14	1.75	1.44,1.44,1.44,1.44,1.44,1.44,1.44,1.44,1.42,1.41,1.44,1.44,1.43,1.39,1.44,1.44,1.45,1.43,1.44,1.44,1.42,1.41,1.44,1.44,1.43,1.37	300	200	1
215	19	1.24	1.24	1.90	2.12,2.12,2.12,2.12,2.12,2.12,2.12,2.12,1.56,2.37,2.12,2.12,2.11,2.31,2.12,2.12,2.13,2.11,2.12,2.12,1.63,2.37,2.12,2.12,2.11,2.29	300	200	1
216	19	1.72	1.72	2.65	1.25,1.26,1.25,1.26,1.25,1.25,1.26,1.26,1.23,1.20,1.26,1.26,1.25,1.15,1.26,1.26,1.26,1.24,1.26,1.26,1.24,1.20,1.26,1.26,1.25,1.13	300	200	1
301	7	8.29	8.29	3.95	-	300	200	1
302	5	1.30	1.30	2.00	-	300	200	1
303	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.31,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.34,1.17,1.18,1.18,1.17,1.18	300	200	1
304	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.69,1.67,1.67,1.68,1.67,1.68,1.68,1.63,1.69,1.67,1.67,1.66,1.69	300	200	1
305	16	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.89,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.68,1.68,1.68,1.68,1.99,1.66,1.67,1.67,1.67,1.67	300	200	1
306	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.34,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.37,1.17,1.18,1.18,1.17,1.18	300	200	1
307	16	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,2.02,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.68,1.67,1.67,2.11,1.66,1.67,1.67,1.66,1.67	300	200	1
308	19	1.33	1.33	2.05	2.10,2.10,2.10,2.10,2.10,2.10,2.11,2.11,2.08,1.74,2.12,2.12,2.09,1.43,2.11,2.11,2.11,2.08,2.11,2.11,2.08,1.74,2.12,2.12,2.09,1.32	300	200	1
309	2	2.60	2.60	4.00	-	300	200	1
310	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.69,1.67,1.67,1.68,1.67,1.68,1.68,1.63,1.69,1.67,1.67,1.66,1.69	300	200	1
311	19	1.33	1.33	2.05	2.10,2.10,2.10,2.10,2.10,2.10,2.09,2.09,1.01,1.70,2.09,2.09,2.14,1.88,2.10,2.10,2.10,2.37,2.09,2.09,1.01,1.70,2.09,2.09,2.13,1.91	300	200	1
312	5	1.30	1.30	2.00	-	300	200	1
313	19	1.14	1.14	1.75	1.44,1.44,1.44,1.44,1.44,1.44,1.46,1.46,1.06,1.63,1.46,1.46,1.41,1.55,1.45,1.45,1.45,1.39,1.46,1.46,1.07,1.63,1.46,1.46,1.42,1.54	300	200	1
314	19	1.14	1.14	1.75	1.39,1.39,1.39,1.39,1.39,1.39,1.38,1.38,1.41,1.46,1.38,1.38,1.40,1.58,1.39,1.39,1.39,1.41,1.38,1.38,1.41,1.47,1.38,1.38,1.40,1.71	300	200	1
315	19	3.05	3.05	4.70	1.81,1.81,1.81,1.81,1.81,1.81,1.79,1.79,1.04,1.59,1.78,1.78,1.88,1.65,1.80,1.80,1.80,1.88,1.79,1.79,1.05,1.59,1.78,1.78,1.88,1.66	300	200	1
316	19	3.58	3.58	5.51	1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.09,1.10,1.08,1.08,1.08,1.12,1.08,1.08,1.08,1.08,1.08,1.08,1.09,1.10,1.08,1.08,1.08,1.14	300	200	1
401	7	8.29	8.29	3.95	-	300	200	1
402	5	1.30	1.30	2.00	-	300	200	1
403	16	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.33,1.18,1.19,1.19,1.17,1.18,1.19,1.19,1.19,1.19,1.19,1.19,1.36,1.18,1.19,1.19,1.18,1.18	300	200	1

404	16	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.69,1.69,1.68,1.68,1.65,1.68,1.68,1.68,1.66,1.69,1.68,1.68,1.68,1.68,1.68, 1.68,1.62,1.69,1.68,1.68,1.67,1.69	300	200	1
405	16	1.52	1.52	2.33	1.69,1.68,1.69,1.68,1.68,1.69,1.68,1.68,1.91,1.67,1.68,1.68,1.66,1.67,1.68,1.68,1.68,1.68,1.68, 1.68,2.01,1.67,1.68,1.68,1.67,1.67	300	200	1
406	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.17,1.17,1.27,1.16,1.17,1.17,1.16,1.17,1.17,1.17,1.18,1.18,1.18, 1.18,1.32,1.16,1.17,1.17,1.16,1.17	300	200	1
407	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.85,1.66,1.67,1.67,1.65,1.66,1.67,1.67,1.67,1.67,1.67, 1.67,1.95,1.65,1.67,1.67,1.66,1.66	300	200	1
408	19	4.20	4.20	2.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33, 2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
409	2	2.60	2.60	4.00	-	300	200	1
410	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.69,1.69,1.67,1.67,1.63,1.68,1.67,1.67,1.65,1.69,1.67,1.67,1.68,1.67,1.68, 1.68,1.60,1.69,1.67,1.67,1.66,1.69	300	200	1
411	19	4.20	4.20	2.00	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, 2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
412	5	0.04	0.04	0.07	-	300	200	1
413	19	1.14	1.14	1.75	1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48,1.48, 1.48,1.48,1.48,1.48,1.48,1.48,1.48	300	200	1
414	19	1.14	1.14	1.75	2.29,2.29,2.29,2.29,2.29,2.29,2.31,2.31,2.23,1.87,2.32,2.32,2.26,1.58,2.30,2.30,2.30,2.24,2.31, 2.31,2.23,1.88,2.32,2.32,2.26,1.48	300	200	1
415	19	1.19	1.19	1.84	1.33,1.33,1.33,1.33,1.33,1.33,1.34,1.34,1.35,1.50,1.34,1.34,1.28,1.43,1.33,1.33,1.34,1.27,1.34, 1.34,1.38,1.50,1.34,1.34,1.29,1.42	300	200	1
416	19	1.76	1.76	2.71	1.24,1.24,1.24,1.24,1.24,1.24,1.24,1.24,1.21,1.17,1.25,1.25,1.23,1.12,1.24,1.24,1.24,1.22,1.24, 1.24,1.22,1.17,1.25,1.25,1.23,1.09	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	251.16	217.61	42.30	42.30	75.35	75.35
2	198.33	196.83	21.95	21.95	59.50	59.50
3	116.10	115.41	15.79	11.10	42.08	23.28
4	116.10	111.33	15.79	11.10	42.08	23.28
5	116.10	114.23	15.79	11.10	42.08	23.28
6	116.10	115.41	15.79	11.10	42.08	23.28
7	116.10	114.23	15.79	11.10	42.08	23.28
8	133.20	126.01	32.87	6.12	40.24	43.62
9	66.48	58.89	3.82	3.82	19.94	19.94
10	116.10	111.33	15.79	11.10	42.08	23.28
11	133.20	126.01	32.87	6.12	40.24	43.62
12	198.33	196.72	21.95	21.95	59.50	59.50
13	133.20	126.79	32.87	6.12	40.24	43.62
14	133.20	126.79	32.87	6.12	40.24	43.62
15	133.20	102.39	32.87	6.12	40.24	43.62
16	133.20	102.39	32.87	6.12	40.24	43.62
17	133.20	118.19	32.87	6.12	40.24	43.62
18	133.20	126.79	32.87	6.12	40.24	43.62
19	133.20	118.19	32.87	6.12	40.24	43.62
20	133.20	126.79	32.87	6.12	40.24	43.62
21	133.20	118.19	31.83	6.12	40.24	43.62
22	133.20	126.79	32.87	6.12	40.24	43.62
23	133.20	118.19	32.87	6.12	40.24	43.62

23	133.20	118.19	32.87	6.12	40.24	43.62
24	133.20	126.79	32.87	6.12	40.24	43.62
25	133.20	118.19	32.87	6.12	40.24	43.62
26	133.20	126.79	32.87	6.12	40.24	43.62
27	133.20	118.19	32.87	6.12	40.24	43.62
28	133.20	126.79	32.87	6.12	40.24	43.62
29	133.20	118.19	32.14	6.12	40.24	43.62
30	133.20	126.79	32.87	6.12	40.24	43.62
31	133.20	118.19	32.87	6.12	40.24	43.62
32	133.20	126.79	32.87	6.12	40.24	43.62
33	133.20	118.19	32.87	6.12	40.24	43.62
34	133.20	126.79	32.87	6.12	40.24	43.62
35	133.20	118.19	32.87	6.12	40.24	43.62
36	133.20	126.79	32.87	6.12	40.24	43.62
37	133.20	113.98	32.87	6.12	40.24	43.62
38	133.20	108.38	29.58	6.12	40.24	43.62
39	133.20	126.41	32.87	6.12	40.24	43.62
40	133.20	114.37	32.87	6.12	40.24	43.62
41	133.20	108.38	28.22	6.12	40.24	43.62
42	133.20	126.58	32.87	6.12	40.24	43.62
43	198.33	198.33	21.95	21.95	59.50	59.50
44	198.33	196.83	21.95	21.95	59.50	59.50
45	133.20	109.79	28.18	6.12	40.24	43.62
46	133.20	124.11	32.87	6.12	40.24	43.62
47	133.20	108.38	29.30	6.12	40.24	43.62
48	133.20	109.35	29.39	6.12	40.24	43.62
49	133.20	123.87	32.87	6.12	40.24	43.62
50	133.20	108.38	27.95	6.12	40.24	43.62
101	251.16	217.61	42.30	42.30	75.35	75.35
102	198.33	196.72	21.95	21.95	59.50	59.50
103	116.10	115.41	15.79	11.10	42.08	23.28
104	116.10	111.33	15.79	11.10	42.08	23.28
105	116.10	114.23	15.79	11.10	42.08	23.28
106	116.10	115.41	15.79	11.10	42.08	23.28
107	116.10	114.23	15.79	11.10	42.08	23.28
108	133.20	126.01	32.87	6.12	40.24	43.62
109	66.48	58.89	3.82	3.82	19.94	19.94
110	116.10	111.33	15.79	11.10	42.08	23.28
111	133.20	126.01	32.87	6.12	40.24	43.62
112	198.33	196.72	21.95	21.95	59.50	59.50
113	133.20	126.79	32.87	6.12	40.24	43.62
114	133.20	126.79	32.87	6.12	40.24	43.62
115	133.20	113.98	29.46	6.12	40.24	43.62
116	133.20	109.79	28.45	6.12	40.24	43.62
201	251.16	217.61	42.30	42.30	75.35	75.35
202	198.33	196.72	21.95	21.95	59.50	59.50
203	116.10	115.41	15.79	11.10	42.08	23.28
204	116.10	111.33	15.79	11.10	42.08	23.28
205	116.10	114.23	15.79	11.10	42.08	23.28
206	116.10	115.41	15.79	11.10	42.08	23.28
207	116.10	114.23	15.79	11.10	42.08	23.28
208	133.20	126.01	32.87	6.12	40.24	43.62
209	66.48	58.89	3.82	3.82	19.94	19.94
210	116.10	111.33	15.79	11.10	42.08	23.28

211	133.20	126.01	32.87	6.12	40.24	43.62
212	198.33	196.72	21.95	21.95	59.50	59.50
213	133.20	126.79	32.87	6.12	40.24	43.62
214	133.20	126.79	32.87	6.12	40.24	43.62
215	133.20	126.41	32.87	6.12	40.24	43.62
216	133.20	124.11	32.87	6.12	40.24	43.62
301	251.16	217.61	42.30	42.30	75.35	75.35
302	198.33	196.72	21.95	21.95	59.50	59.50
303	116.10	115.41	15.79	11.10	42.08	23.28
304	116.10	111.33	15.79	11.10	42.08	23.28
305	116.10	114.23	15.79	11.10	42.08	23.28
306	116.10	115.41	15.79	11.10	42.08	23.28
307	116.10	114.23	15.79	11.10	42.08	23.28
308	133.20	126.01	32.87	6.12	40.24	43.62
309	66.48	58.89	3.82	3.82	19.94	19.94
310	116.10	111.33	15.79	11.10	42.08	23.28
311	133.20	126.01	32.87	6.12	40.24	43.62
312	198.33	196.72	21.95	21.95	59.50	59.50
313	133.20	126.79	32.87	6.12	40.24	43.62
314	133.20	126.79	32.87	6.12	40.24	43.62
315	133.20	114.37	30.49	6.12	40.24	43.62
316	133.20	109.35	29.67	6.12	40.24	43.62
401	251.16	217.61	42.30	42.30	75.35	75.35
402	198.33	196.72	21.95	21.95	59.50	59.50
403	116.10	115.41	15.79	11.10	42.08	23.28
404	116.10	111.33	15.79	11.10	42.08	23.28
405	116.10	114.23	15.79	11.10	42.08	23.28
406	116.10	115.41	15.79	11.10	42.08	23.28
407	116.10	114.23	15.79	11.10	42.08	23.28
408	133.20	102.39	32.87	6.12	40.24	43.62
409	66.48	58.89	3.82	3.82	19.94	19.94
410	116.10	111.33	15.79	11.10	42.08	23.28
411	133.20	102.39	32.87	6.12	40.24	43.62
412	198.33	198.33	21.95	21.95	59.50	59.50
413	133.20	126.79	32.87	6.12	40.24	43.62
414	133.20	126.79	32.87	6.12	40.24	43.62
415	133.20	126.58	32.87	6.12	40.24	43.62
416	133.20	123.87	32.87	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	0.044	0.384	0.091	0.017	0.012	0.387	#32	0.221	Not Required	Pass
2	0.003	0.273	0.049	0.067	0.010	0.310	#21	0.051	Not Required	Pass
3	0.004	0.480	0.025	0.047	0.009	0.506	#21	0.045	Not Required	Pass
4	0.002	0.449	0.069	0.045	0.016	0.518	#21	0.120	Not Required	Pass
5	0.004	0.298	0.017	0.048	0.004	0.311	#21	0.074	Not Required	Pass
6	0.005	0.650	0.081	0.067	0.021	0.734	#21	0.045	Not Required	Pass
7	0.005	0.402	0.104	0.065	0.029	0.440	#21	0.074	Not Required	Pass
8	0.002	0.123	0.072	0.040	0.008	0.159	#21	0.095	Not Required	Pass
9	0.003	0.069	0.068	0.002	0.005	0.139	#21	0.204	Not Required	Pass
10	0.007	0.609	0.063	0.062	0.012	0.620	#21	0.080	Not Required	Pass
11	0.005	0.127	0.079	0.042	0.008	0.155	#21	0.095	Not Required	Pass

12	0.002	0.460	0.071	0.094	0.012	0.513	#21	0.053	Not Required	Pass
13	0.005	0.065	0.200	0.056	0.011	0.265	#21	0.081	Not Required	Pass
14	0.000	0.064	0.069	0.028	0.005	0.132	#21	Not Required	Not Required	Pass
15	0.000	0.019	0.020	0.016	0.003	0.039	#21	Not Required	Not Required	Pass
16	0.000	0.018	0.020	0.015	0.003	0.038	#21	Not Required	Not Required	Pass
17	0.001	0.091	0.056	0.020	0.004	0.147	#21	0.186	Not Required	Pass
18	0.000	0.068	0.069	0.029	0.005	0.136	#21	Not Required	Not Required	Pass
19	0.003	0.086	0.100	0.019	0.007	0.168	#21	0.186	Not Required	Pass
20	0.002	0.056	0.191	0.052	0.011	0.240	#24	0.081	Not Required	Pass
21	0.002	0.193	0.048	0.017	0.003	0.242	#21	0.186	Not Required	Pass
22	0.005	0.174	0.201	0.067	0.011	0.377	#21	0.081	Not Required	Pass
23	0.005	0.191	0.056	0.016	0.003	0.245	#21	0.186	Not Required	Pass
24	0.002	0.171	0.194	0.060	0.011	0.366	#21	0.081	Not Required	Pass
25	0.002	0.176	0.043	0.016	0.003	0.219	#21	0.186	Not Required	Pass
26	0.005	0.161	0.199	0.061	0.011	0.363	#21	0.081	Not Required	Pass
27	0.005	0.168	0.046	0.015	0.003	0.216	#21	0.186	Not Required	Pass
28	0.002	0.149	0.193	0.057	0.011	0.342	#21	0.081	Not Required	Pass
29	0.002	0.193	0.050	0.017	0.003	0.244	#21	0.186	Not Required	Pass
30	0.005	0.178	0.195	0.063	0.011	0.375	#21	0.081	Not Required	Pass
31	0.005	0.191	0.058	0.016	0.004	0.249	#21	0.186	Not Required	Pass
32	0.003	0.171	0.200	0.064	0.011	0.372	#21	0.081	Not Required	Pass
33	0.001	0.091	0.057	0.020	0.004	0.148	#21	0.186	Not Required	Pass
34	0.006	0.069	0.201	0.056	0.011	0.271	#21	0.081	Not Required	Pass
35	0.003	0.086	0.102	0.018	0.008	0.173	#21	0.186	Not Required	Pass
36	0.000	0.064	0.069	0.028	0.005	0.132	#21	Not Required	Not Required	Pass
37	0.003	0.151	0.101	0.051	0.009	0.252	#21	0.221	Not Required	Pass
38	0.002	0.134	0.110	0.030	0.006	0.244	#21	0.262	Not Required	Pass
39	0.002	0.046	0.074	0.044	0.008	0.115	#21	0.088	Not Required	Pass
40	0.002	0.110	0.100	0.047	0.008	0.210	#21	0.218	Not Required	Pass
41	0.003	0.197	0.111	0.026	0.006	0.308	#21	0.262	Not Required	Pass
42	0.003	0.113	0.071	0.040	0.008	0.140	#21	0.085	Not Required	Pass
43	0.003	0.285	0.051	0.067	0.010	0.324	#21	0.002	Not Required	Pass
44	0.003	0.267	0.048	0.066	0.010	0.304	#21	0.051	Not Required	Pass
45	0.006	0.210	0.109	0.026	0.006	0.319	#21	0.252	Not Required	Pass
46	0.005	0.117	0.102	0.033	0.006	0.222	#21	0.123	Not Required	Pass
47	0.006	0.143	0.112	0.032	0.006	0.257	#21	0.262	Not Required	Pass
48	0.006	0.143	0.112	0.031	0.006	0.257	#21	0.256	Not Required	Pass
49	0.006	0.158	0.101	0.037	0.006	0.261	#21	0.126	Not Required	Pass
50	0.007	0.208	0.110	0.028	0.006	0.318	#21	0.262	Not Required	Pass
101	0.061	0.491	0.013	0.024	0.002	0.496	#32	0.221	Not Required	Pass
102	0.001	0.535	0.092	0.112	0.016	0.610	#21	0.035	Not Required	Pass
103	0.005	0.789	0.038	0.080	0.006	0.829	#21	0.045	Not Required	Pass
104	0.005	0.748	0.081	0.076	0.017	0.800	#21	0.080	Not Required	Pass
105	0.005	0.488	0.091	0.079	0.023	0.514	#21	0.074	Not Required	Pass
106	0.005	0.765	0.028	0.077	0.004	0.792	#21	0.045	Not Required	Pass
107	0.005	0.474	0.082	0.077	0.020	0.493	#21	0.074	Not Required	Pass
108	0.002	0.058	0.074	0.047	0.008	0.132	#21	0.095	Not Required	Pass
109	0.007	0.081	0.033	0.001	0.001	0.118	#21	0.204	Not Required	Pass
110	0.005	0.722	0.086	0.073	0.019	0.786	#21	0.080	Not Required	Pass
111	0.005	0.058	0.075	0.049	0.008	0.136	#21	0.095	Not Required	Pass
112	0.002	0.509	0.087	0.108	0.015	0.578	#21	0.035	Not Required	Pass
113	0.005	0.178	0.195	0.063	0.011	0.375	#21	0.081	Not Required	Pass
114	0.002	0.169	0.200	0.064	0.011	0.371	#21	0.081	Not Required	Pass
115	0.006	0.161	0.101	0.054	0.009	0.264	#21	0.221	Not Required	Pass

116	0.003	0.198	0.111	0.024	0.006	0.309	#21	0.252	Not Required	Pass
201	0.057	0.495	0.002	0.022	0.000	0.497	#32	0.221	Not Required	Pass
202	0.001	0.495	0.083	0.105	0.014	0.559	#21	0.035	Not Required	Pass
203	0.005	0.738	0.032	0.075	0.005	0.772	#21	0.045	Not Required	Pass
204	0.005	0.691	0.081	0.070	0.017	0.748	#21	0.080	Not Required	Pass
205	0.005	0.456	0.086	0.074	0.022	0.479	#21	0.074	Not Required	Pass
206	0.005	0.736	0.031	0.074	0.004	0.770	#21	0.045	Not Required	Pass
207	0.005	0.456	0.086	0.074	0.022	0.479	#21	0.074	Not Required	Pass
208	0.002	0.052	0.074	0.044	0.008	0.114	#21	0.095	Not Required	Pass
209	0.007	0.074	0.025	0.001	0.000	0.102	#21	0.204	Not Required	Pass
210	0.005	0.689	0.081	0.070	0.017	0.747	#21	0.080	Not Required	Pass
211	0.005	0.054	0.077	0.047	0.008	0.124	#21	0.095	Not Required	Pass
212	0.002	0.491	0.082	0.104	0.014	0.555	#21	0.035	Not Required	Pass
213	0.005	0.160	0.197	0.061	0.011	0.360	#21	0.081	Not Required	Pass
214	0.002	0.150	0.193	0.057	0.011	0.343	#21	0.081	Not Required	Pass
215	0.005	0.047	0.078	0.047	0.009	0.126	#21	0.088	Not Required	Pass
216	0.002	0.110	0.100	0.031	0.006	0.209	#21	0.123	Not Required	Pass
301	0.061	0.491	0.015	0.024	0.002	0.496	#32	0.221	Not Required	Pass
302	0.002	0.508	0.087	0.108	0.015	0.576	#21	0.035	Not Required	Pass
303	0.006	0.763	0.027	0.077	0.003	0.788	#21	0.045	Not Required	Pass
304	0.005	0.720	0.087	0.073	0.019	0.786	#21	0.080	Not Required	Pass
305	0.005	0.472	0.082	0.076	0.020	0.491	#21	0.074	Not Required	Pass
306	0.005	0.790	0.039	0.080	0.006	0.832	#21	0.045	Not Required	Pass
307	0.005	0.489	0.092	0.079	0.024	0.516	#21	0.074	Not Required	Pass
308	0.003	0.062	0.078	0.051	0.009	0.127	#21	0.095	Not Required	Pass
309	0.007	0.082	0.034	0.001	0.001	0.120	#21	0.204	Not Required	Pass
310	0.006	0.749	0.080	0.076	0.017	0.799	#21	0.080	Not Required	Pass
311	0.006	0.069	0.080	0.054	0.008	0.129	#21	0.095	Not Required	Pass
312	0.001	0.536	0.092	0.112	0.016	0.611	#21	0.053	Not Required	Pass
313	0.006	0.175	0.200	0.067	0.011	0.378	#21	0.081	Not Required	Pass
314	0.002	0.171	0.194	0.060	0.011	0.366	#21	0.081	Not Required	Pass
315	0.005	0.118	0.102	0.049	0.008	0.223	#21	0.218	Not Required	Pass
316	0.002	0.134	0.109	0.029	0.006	0.244	#21	0.256	Not Required	Pass
401	0.044	0.384	0.098	0.017	0.013	0.388	#32	0.221	Not Required	Pass
402	0.002	0.467	0.072	0.095	0.012	0.521	#21	0.053	Not Required	Pass
403	0.005	0.655	0.083	0.068	0.021	0.740	#21	0.045	Not Required	Pass
404	0.007	0.614	0.062	0.062	0.012	0.622	#21	0.080	Not Required	Pass
405	0.005	0.404	0.106	0.066	0.029	0.443	#21	0.074	Not Required	Pass
406	0.004	0.473	0.026	0.047	0.009	0.501	#21	0.045	Not Required	Pass
407	0.004	0.294	0.016	0.047	0.004	0.308	#21	0.074	Not Required	Pass
408	0.000	0.018	0.020	0.015	0.003	0.038	#21	Not Required	Not Required	Pass
409	0.003	0.071	0.069	0.003	0.005	0.142	#21	0.204	Not Required	Pass
410	0.002	0.443	0.071	0.045	0.016	0.515	#21	0.120	Not Required	Pass
411	0.000	0.019	0.020	0.016	0.003	0.039	#21	Not Required	Not Required	Pass
412	0.003	0.279	0.050	0.066	0.010	0.317	#21	0.002	Not Required	Pass
413	0.000	0.068	0.069	0.029	0.005	0.136	#21	Not Required	Not Required	Pass
414	0.003	0.060	0.191	0.053	0.011	0.243	#24	0.081	Not Required	Pass
415	0.006	0.117	0.080	0.043	0.009	0.138	#21	0.085	Not Required	Pass
416	0.003	0.148	0.101	0.036	0.006	0.250	#21	0.126	Not Required	Pass

Definitions

Φ_t Safety factor for tensile

Φ Safety factor for compression

Φ_c	Safety factor for compression
Φ_b	Safety factor for flexure
Φ_v	Safety factor for shear
E	Modulus of elasticity
F_y	Specified minimum yield stress
F_u	Specified minimum tensile strength
A	Cross-sectional area
J	Torsional constant
I_{yp}	Moment of inertia about the Y axes
I_{zp}	Moment of inertia about the Z axes
I_w	Warping constant
S_{yp}	Plastic section modulus about the Y axis
S_{zp}	Plastic section modulus about the Z axis
KL	Effective length
C_b	Buckling modification factor (from all load combinations)
L_b	Length between braced points
LST	Limited slenderness for tension
LSC	Limited slenderness for compression
LD	Limited deflection
P_n	Nominal axial strength (tension/comression)
M_n	Nominal flexural strength (about Z/Y axis)
V_n	Nominal shear strength (along Z/Y axis)
P	Design ratio in case of axial force
M_z	Design ratio in case of bending about Z axis
M_y	Design ratio in case of bending about Y axis
V_y	Design ratio in case of shear along Y axis
V_z	Design ratio in case of shear along Z axis
(P,M_z,M_y)	Design ratio in case of axial force and bending action
KL/r	Design ratio in case of section slenderness
δ	Design ratio in case of member deflection
OK	Capacity is provided
NG	Capacity is not provided

REFERENCES	CALCULATIONS	RESULTS

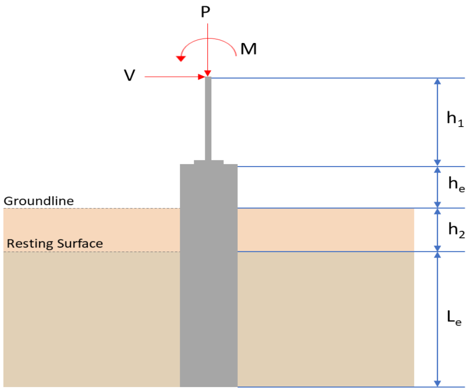
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \text{in}$ - Pile width
$D = 48\ \text{in}$ - Pile depth
$L = 4.75\ \text{ft}$ - Total pile length
$h_1 = 0\ \text{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \text{ft}$ - Depth to resisting surface
$h_e = 0\ \text{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	6.285	9.641
V_x (kip)	-0.769	-1.299
V_z (kip)	0.581	0.905
M_x (kipft)	-0.196	-0.295
M_z (kipft)	9.673	16.255

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.769\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.12245\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(9.673\ \text{kipft}) + ((-0.769\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 1.5403\ \text{kipft/ft}$$

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:
$L_{e,x} = 4.4858\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.581\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.092516\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.196\ \text{kipft}) + ((0.581\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.03121\ \text{kipft/ft}$$

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:
$L_{e,z} = 2.5551\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(4.4858\ \text{ft}), (2.5551\ \text{ft})]$$

$$L_{e,req} = 4.486\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (4.75\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 4.75\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(4.486\ \text{ft})}{(4.75\ \text{ft})}$$

$$Ratio = 0.94442$$

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

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

$$q = \frac{(6.285\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.39281\ \text{kip/ft}^2$$

$q = 0.39281\ \text{kip/ft}^2$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.39281\ \text{kip/ft}^2\right)}{(2000\ \text{psf})}$$

$$Ratio = 0.19641$$

Status: **PASS**
Ratio: **0.200**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(4.75\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 1.1875$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.12245\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 1.5403\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.5403\ \text{kipft/ft}) \times (4.75\ \text{ft})) + \left(3 \times (-0.12245\ \text{kip/ft}) \times (4.75\ \text{ft})^2\right)}{(6 \times (1.5403\ \text{kipft/ft})) + (4 \times (-0.12245\ \text{kip/ft}) \times (4.75\ \text{ft}))}$$

$$a = 3.2463\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (1.5403\ \text{kipft/ft})) + (3 \times (-0.12245\ \text{kip/ft}) \times (4.75\ \text{ft}))]^2}{(4.75\ \text{ft})^2 \times [(3 \times (1.5403\ \text{kipft/ft})) + (2 \times (-0.12245\ \text{kip/ft}) \times (4.75\ \text{ft}))]}$$

$$p = 0.1875\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (1.5403\ \text{kipft/ft})) + ((-0.12245\ \text{kip/ft}) \times (4.75\ \text{ft}))]}{(4.75\ \text{ft})^2}$$

$$s = 0.66453\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(3.2463\ \text{ft})}{2}$$

$$p_a = 0.24347\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.1875\ \text{kip/ft}^2\right)}{\left(0.24347\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.77011$$

Status: **PASS**
Ratio: **0.770**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (4.75\ \mathrm{ft})$$

$$p_s = 0.7125\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.66453\ \mathrm{kip/ft^2}\right)}{\left(0.7125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.93268$$

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

Considering z-direction:

$H_o = 0.092516\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.03121\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.03121\ \mathrm{kipft/ft}) \times (4.75\ \mathrm{ft})) + \left(3 \times (0.092516\ \mathrm{kip/ft}) \times (4.75\ \mathrm{ft})^2\right)}{(6 \times (0.03121\ \mathrm{kipft/ft})) + (4 \times (0.092516\ \mathrm{kip/ft}) \times (4.75\ \mathrm{ft}))}$$

$$a = 3.5244\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.03121\ \mathrm{kipft/ft})) + (3 \times (0.092516\ \mathrm{kip/ft}) \times (4.75\ \mathrm{ft}))]^{\,2}}{(4.75\ \mathrm{ft})^2 \times [(3 \times (0.03121\ \mathrm{kipft/ft})) + (2 \times (0.092516\ \mathrm{kip/ft}) \times (4.75\ \mathrm{ft}))]}$$

$$p = 0.07119\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.03121\ \mathrm{kipft/ft})) + ((0.092516\ \mathrm{kip/ft}) \times (4.75\ \mathrm{ft}))]}{(4.75\ \mathrm{ft})^2}$$

$$s = 0.13346\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(3.5244\ \mathrm{ft})}{2}$$

$$p_a = 0.26433\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.07119\ \mathrm{kip/ft^2}\right)}{\left(0.26433\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.26932$$

Status: **PASS**
Ratio: **0.270**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (4.75\ \mathrm{ft})$$

$$p_s = 0.7125\ \mathrm{kip/ft^2}$$

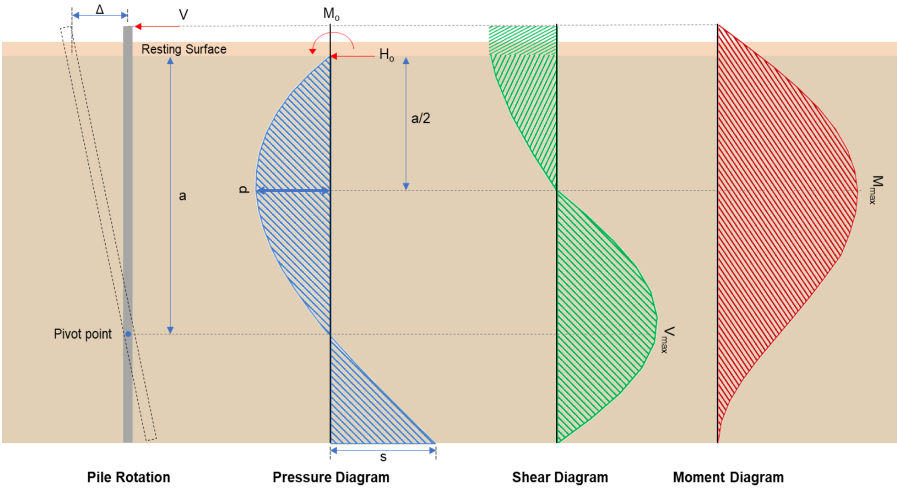
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.13346\ \mathrm{kip/ft^2})}{(0.7125\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.18731$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.299\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.20685\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(16.255\ \mathrm{kipft}) + ((-1.299\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 2.5884\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(2.5884\ \mathrm{kipft/ft})}{(-0.20685\ \mathrm{kip/ft})}$$

$$E = 12.513\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.5884\ \mathrm{kipft/ft}) \times (4.75\ \mathrm{ft})) + \left(3 \times (-0.20685\ \mathrm{kip/ft}) \times (4.75\ \mathrm{ft})^2\right)}{(6 \times (2.5884\ \mathrm{kipft/ft})) + (4 \times (-0.20685\ \mathrm{kip/ft}) \times (4.75\ \mathrm{ft}))}$$

$$a = 3.2466\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.20685\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.513\ \mathrm{ft})}{(4.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(3.2466\ \mathrm{ft})}{(4.75\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (12.513\ \mathrm{ft})}{(4.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(3.2466\ \mathrm{ft})}{(4.75\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 4.4053\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.20685\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (4.75\ \mathrm{ft})) \times \left[\left(\frac{(12.513\ \mathrm{ft})}{(4.75\ \mathrm{ft})} + \frac{(3.2466\ \mathrm{ft})}{2 \times (4.75\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (12.513\ \mathrm{ft})}{(4.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(3.2466\ \mathrm{ft})}{2 \times (4.75\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (12.513\ \mathrm{ft})}{(4.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(3.2466\ \mathrm{ft})}{2 \times (4.75\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 10.104\ \mathrm{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.905\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = 0.14411\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.295\ \mathrm{kipft}) + ((0.905\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.046975\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.046975\ \mathrm{kipft/ft})}{(0.14411\ \mathrm{kip/ft})}$$

$$E = 0.32597\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.046975\ \mathrm{kipft/ft}) \times (4.75\ \mathrm{ft})) + \left(3 \times (0.14411\ \mathrm{kip/ft}) \times (4.75\ \mathrm{ft})^2\right)}{(6 \times (0.046975\ \mathrm{kipft/ft})) + (4 \times (0.14411\ \mathrm{kip/ft}) \times (4.75\ \mathrm{ft}))}$$

$$a = 3.5256\ \mathrm{ft}$$

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

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

$$V_{max} = ((0.14411\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (0.32597\ \mathrm{ft})}{(4.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(3.5256\ \mathrm{ft})}{(4.75\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (0.32597\ \mathrm{ft})}{(4.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(3.5256\ \mathrm{ft})}{(4.75\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.4634\ \mathrm{kip}$$

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

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

$$M_{max} = ((0.14411\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (4.75\ \mathrm{ft})) \times \left[\left(\frac{(0.32597\ \mathrm{ft})}{(4.75\ \mathrm{ft})} + \frac{(3.5256\ \mathrm{ft})}{2 \times (4.75\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (0.32597\ \mathrm{ft})}{(4.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(3.5256\ \mathrm{ft})}{2 \times (4.75\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (0.32597\ \mathrm{ft})}{(4.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(3.5256\ \mathrm{ft})}{2 \times (4.75\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.86034 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(9.641 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (3 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -101.94 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-101.94 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

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

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(9.641\ \mathrm{kip})}{(3183.4\ \mathrm{kip})}$$

$$Ratio = 0.0030285$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

$b_w = 48\ \mathrm{in}$ - Effective width,

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

$$d = 0.80 \times (48\ \mathrm{in})$$

$$d = 38.4\ \mathrm{in}$$

22.5.5.1.3 λ_s - size effect modification factor

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

$$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(38.4\ \mathrm{in})}{10}}}, 1\right]$$

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$, $P = 9.641\ \mathrm{kip} \rightarrow 9641\ \mathrm{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(3000\ \mathrm{psi})} + \frac{(9641\ \mathrm{lbf})}{6 \times \left(2304\ \mathrm{in}^2\right)}\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$

$$V_{c,a} = 131.08\ \mathrm{kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(324.49\ \mathrm{kip}), (131.08\ \mathrm{kip}), (406.27\ \mathrm{kip})\right]$$

$$V_c = 131.08\ \mathrm{kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((131.08\text{ kip}) + (50.894\text{ kip}))$$

$$\phi V_n = 118.28\text{ kip}$$

Considering x-direction:

$V_{max} = 4.4053\text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(4.4053\text{ kip})}{(118.28\text{ kip})}$$

$$Ratio = 0.037244$$

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

Considering z-direction:

$V_{max} = 0.4634\text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.4634\text{ kip})}{(118.28\text{ kip})}$$

$$Ratio = 0.0039177$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

	$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(3ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 273.423kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (3\ \text{ksi}) \times \left(18432\ \text{in}^3\right)$$ $$\phi M_{n,2} = 2545.9\ \text{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(273.42\ \text{kipft}), (2545.9\ \text{kipft})]$$ $$\phi M_n = 273.42\ \text{kipft}$$ **Considering x-direction:** $M_{max} = 10.104\ \text{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(10.104\ \text{kipft})}{(273.42\ \text{kipft})}$$ $$Ratio = 0.036953$$	Status: **PASS** Ratio: **0.040**
	Considering z-direction: $M_{max} = 0.86034\ \text{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.86034\ \text{kipft})}{(273.42\ \text{kipft})}$$ $$Ratio = 0.0031465$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

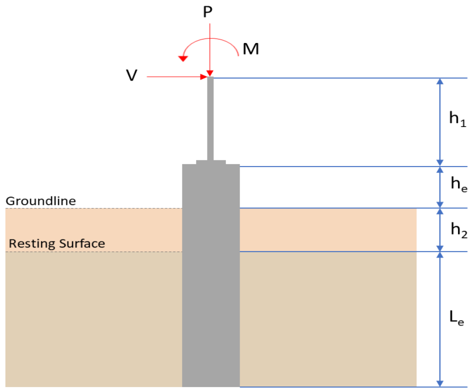
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 4.75\ \mathrm{ft}$ - 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)	6.292	9.652
V_x (kip)	-0.770	-1.300
V_z (kip)	-0.606	-0.943
M_x (kipft)	0.281	0.427
M_z (kipft)	9.667	16.244

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,

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

$$H_o = \frac{(-0.77\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.12261\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(9.667\ \text{kipft}) + ((-0.77\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 1.5393\ \text{kipft/ft}$$

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:
$L_{e,x} = 4.484\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.606\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.096497\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.281\ \text{kipft}) + ((-0.606\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.044745\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 0.58392\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(4.484\ \text{ft}), (0.58392\ \text{ft})]$$

$$L_{e,req} = 4.484\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (4.75\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 4.75\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(4.484\ \text{ft})}{(4.75\ \text{ft})}$$

$$Ratio = 0.944$$

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

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

$$q = \frac{(6.292\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.39325\ \text{kip/ft}^2$$

$q = 0.39325\ \text{kip/ft}^2$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.39325\ \text{kip/ft}^2)}{(2000\ \text{psf})}$$

$$Ratio = 0.19662$$

Status: **PASS**
Ratio: **0.200**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(4.75\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 1.1875$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.12261\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 1.5393\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.5393\ \text{kipft/ft}) \times (4.75\ \text{ft})) + \left(3 \times (-0.12261\ \text{kip/ft}) \times (4.75\ \text{ft})^2\right)}{(6 \times (1.5393\ \text{kipft/ft})) + (4 \times (-0.12261\ \text{kip/ft}) \times (4.75\ \text{ft}))}$$

$$a = 3.2464\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (1.5393\ \text{kipft/ft})) + (3 \times (-0.12261\ \text{kip/ft}) \times (4.75\ \text{ft}))]^2}{(4.75\ \text{ft})^2 \times [(3 \times (1.5393\ \text{kipft/ft})) + (2 \times (-0.12261\ \text{kip/ft}) \times (4.75\ \text{ft}))]}$$

$$p = 0.18722\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (1.5393\ \text{kipft/ft})) + ((-0.12261\ \text{kip/ft}) \times (4.75\ \text{ft}))]}{(4.75\ \text{ft})^2}$$

$$s = 0.66382\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(3.2464\ \text{ft})}{2}$$

$$p_a = 0.24348\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.18722\ \text{kip/ft}^2)}{(0.24348\ \text{kip/ft}^2)}$$

$$Ratio = 0.76894$$

Status: **PASS**
Ratio: **0.770**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (4.75\ \mathrm{ft})$$

$$p_s = 0.7125\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.66382\ \mathrm{kip/ft^2}\right)}{\left(0.7125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.93168$$

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

Considering z-direction:

$H_o = -0.096497\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.044745\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.044745\ \mathrm{kipft/ft}) \times (4.75\ \mathrm{ft})) + \left(3 \times (-0.096497\ \mathrm{kip/ft}) \times (4.75\ \mathrm{ft})^2\right)}{(6 \times (0.044745\ \mathrm{kipft/ft})) + (4 \times (-0.096497\ \mathrm{kip/ft}) \times (4.75\ \mathrm{ft}))}$$

$$a = 3.5119\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.044745\ \mathrm{kipft/ft})) + (3 \times (-0.096497\ \mathrm{kip/ft}) \times (4.75\ \mathrm{ft}))]^2}{(4.75\ \mathrm{ft})^2 \times [(3 \times (0.044745\ \mathrm{kipft/ft})) + (2 \times (-0.096497\ \mathrm{kip/ft}) \times (4.75\ \mathrm{ft}))]}$$

$$p = -0.060776\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.044745\ \mathrm{kipft/ft})) + ((-0.096497\ \mathrm{kip/ft}) \times (4.75\ \mathrm{ft}))]}{(4.75\ \mathrm{ft})^2}$$

$$s = -0.098093\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(3.5119\ \mathrm{ft})}{2}$$

$$p_a = 0.2634\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.060776\ \mathrm{kip/ft^2}\right)}{\left(0.2634\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.23074$$

Status: **PASS**
Ratio: **-0.230**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (4.75\ \mathrm{ft})$$

$$p_s = 0.7125\ \mathrm{kip/ft^2}$$

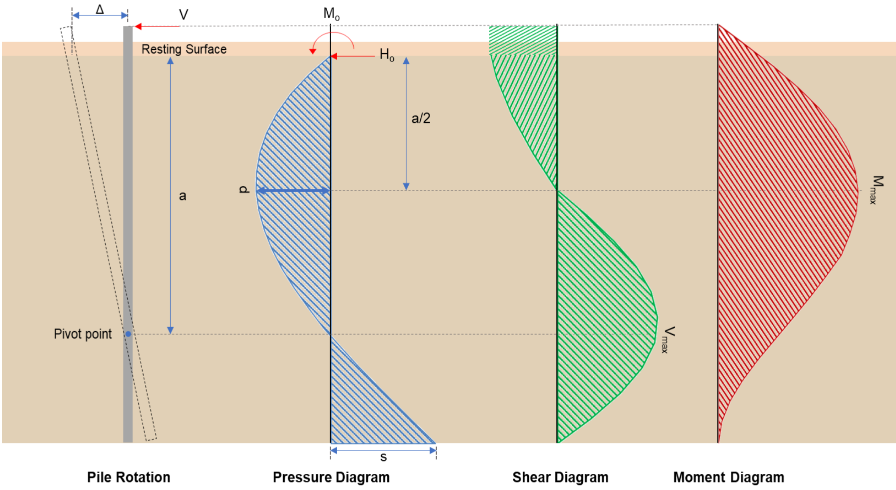
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.098093\ \mathrm{kip/ft^2}\right)}{\left(0.7125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.13767$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.3\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.20701\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(16.244\ \mathrm{kipft}) + ((-1.3\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 2.5866\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(2.5866\ \mathrm{kipft/ft})}{(-0.20701\ \mathrm{kip/ft})}$$

$$E = 12.495\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.5866\ \mathrm{kipft/ft}) \times (4.75\ \mathrm{ft})) + \left(3 \times (-0.20701\ \mathrm{kip/ft}) \times (4.75\ \mathrm{ft})^2\right)}{(6 \times (2.5866\ \mathrm{kipft/ft})) + (4 \times (-0.20701\ \mathrm{kip/ft}) \times (4.75\ \mathrm{ft}))}$$

$$a = 3.2467\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.20701\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.495\ \mathrm{ft})}{(4.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(3.2467\ \mathrm{ft})}{(4.75\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (12.495\ \mathrm{ft})}{(4.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(3.2467\ \mathrm{ft})}{(4.75\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 4.4031\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.20701\ \text{kip/ft}) \times (48\ \text{in}) \times (4.75\ \text{ft})) \times \left[\left(\frac{(12.495\ \text{ft})}{(4.75\ \text{ft})} + \frac{(3.2467\ \text{ft})}{2 \times (4.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (12.495\ \text{ft})}{(4.75\ \text{ft})} + 3\right) \times \left(\frac{(3.2467\ \text{ft})}{2 \times (4.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (12.495\ \text{ft})}{(4.75\ \text{ft})} + 2\right) \times \left(\frac{(3.2467\ \text{ft})}{2 \times (4.75\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 10.098\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.943\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.15016\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.427\ \text{kipft}) + ((-0.943\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.067994\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.067994\ \text{kipft/ft})}{(-0.15016\ \text{kip/ft})}$$

$$E = 0.45281\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.067994\ \text{kipft/ft}) \times (4.75\ \text{ft})) + \left(3 \times (-0.15016\ \text{kip/ft}) \times (4.75\ \text{ft})^2\right)}{(6 \times (0.067994\ \text{kipft/ft})) + (4 \times (-0.15016\ \text{kip/ft}) \times (4.75\ \text{ft}))}$$

$$a = 3.513\ \text{ft}$$

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

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

$$V_{max} = ((-0.15016\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (0.45281\ \text{ft})}{(4.75\ \text{ft})} + 3\right) \times \left(\frac{(3.513\ \text{ft})}{(4.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (0.45281\ \text{ft})}{(4.75\ \text{ft})} + 2\right) \times \left(\frac{(3.513\ \text{ft})}{(4.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.51023\ \text{kip}$$

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

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

$$M_{max} = ((-0.15016\ \text{kip/ft}) \times (48\ \text{in}) \times (4.75\ \text{ft})) \times \left[\left(\frac{(0.45281\ \text{ft})}{(4.75\ \text{ft})} + \frac{(3.513\ \text{ft})}{2 \times (4.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (0.45281\ \text{ft})}{(4.75\ \text{ft})} + 3\right) \times \left(\frac{(3.513\ \text{ft})}{2 \times (4.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (0.45281\ \text{ft})}{(4.75\ \text{ft})} + 2\right) \times \left(\frac{(3.513\ \text{ft})}{2 \times (4.75\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.96113 \text{ kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(9.652 \text{ kip})}{(0.65)\times(0.8)} - (0.85 \times (3 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2))\right]$$

$$A_{st,required} = -101.94 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-101.94 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

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

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

	Axial Compression Strength (ACI 318-19, LRFD)	
22.4.2.2	ϕP_N - Allowable axial compressive strength $$\phi P_N = \phi\,0.80\,\left[\left(0.85\,f'_{ck}\,\left[A_g - A_{st}\right]\right) + \left(f_{yk}\,A_{st}\right)\right]$$ $$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (3\text{ ksi}) \times \left[\left(2304\text{ in}^2\right) - \left(4.2951\text{ in}^2\right)\right]\right) + \left((60\text{ ksi}) \times \left(4.2951\text{ in}^2\right)\right)\right]$$ $$\phi P_N = 3183.4\text{ kip}$$ $Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(9.652\text{ kip})}{(3183.4\text{ kip})}$$ $$Ratio = 0.003032$$	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 $f'_{ck} = 3\text{ ksi} \rightarrow 3000\text{ psi}$, $P = 9.652\text{ kip} \rightarrow 9652\text{ lbf}$,	
22.5.5.1.1(a)	$V_{c,a}$ - Shear strength of concrete (a) $$V_{c,a} = \left[2\,\lambda_s\,\sqrt{f'_{ck}} + \frac{P}{6\,A_g}\right]\,b_w\,d$$ $$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(3000\text{ psi})} + \frac{(9652\text{ lbf})}{6 \times \left(2304\text{ in}^2\right)}\right] \times (48\text{ in}) \times (38.4\text{ in})$$ $$V_{c,a} = 131.08\text{ kip}$$ 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 $$V_c = Min\left[V_{c,max}, V_{c,a}, V_{c,b}\right]$$ $$V_c = Min\left[(324.49\text{ kip}), (131.08\text{ kip}), (406.27\text{ kip})\right]$$ $$V_c = 131.08\text{ kip}$$	

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((131.08 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 118.28 \text{ kip}$$

Considering x-direction:

$V_{max} = 4.4031 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(4.4031 \text{ kip})}{(118.28 \text{ kip})}$$

$$Ratio = 0.037225$$

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

Considering z-direction:

$V_{max} = 0.51023 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.51023 \text{ kip})}{(118.28 \text{ kip})}$$

$$Ratio = 0.0043136$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

	$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(3ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 273.423kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (3\text{ ksi}) \times \left(18432\text{ in}^3\right)$$ $$\phi M_{n,2} = 2545.9\text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(273.42\text{ kipft}), (2545.9\text{ kipft})]$$ $$\phi M_n = 273.42\text{ kipft}$$ **Considering x-direction:** $M_{max} = 10.098\text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(10.098\text{ kipft})}{(273.42\text{ kipft})}$$ $$Ratio = 0.036933$$	Status: **PASS** Ratio: **0.040**
	Considering z-direction: $M_{max} = 0.96113\text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.96113\text{ kipft})}{(273.42\text{ kipft})}$$ $$Ratio = 0.0035152$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

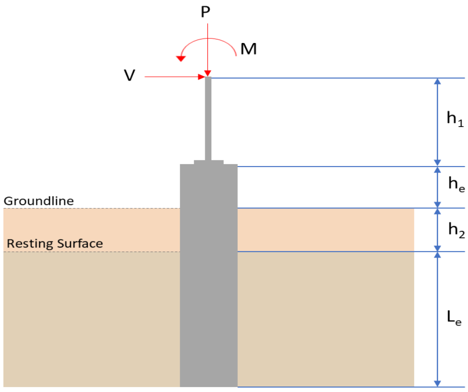
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \text{in}$ - Pile width
$D = 48\ \text{in}$ - Pile depth
$L = 5\ \text{ft}$ - Total pile length
$h_1 = 0\ \text{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \text{ft}$ - Depth to resisting surface
$h_e = 0\ \text{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	8.581	13.194
V_x (kip)	-1.094	-1.838
V_z (kip)	-0.086	-0.133
M_x (kipft)	0.028	0.042
M_z (kipft)	12.416	20.790

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.094\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.1742\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(12.416 \text{ kipft}) + ((-1.094 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 1.9771 \text{ kipft/ft}$$

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:
$L_{e,x} = 4.7672 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.086 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.013694 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.028 \text{ kipft}) + ((-0.086 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.0044586 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 0.37181 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(4.7672 \text{ ft}), (0.37181 \text{ ft})]$$

$$L_{e,req} = 4.767 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 5 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(4.767 \text{ ft})}{(5 \text{ ft})}$$

$$Ratio = 0.9534$$

Status: **PASS**
Ratio: **0.950**

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(8.581 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.53631 \text{ kip/ft}^2$$

$q = 0.53631\ \text{kip/ft}$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.53631\ \text{kip/ft}^2\right)}{(2000\ \text{psf})}$$

$$Ratio = 0.26816$$

Status: **PASS**
Ratio: **0.270**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(5\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 1.25$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.1742\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 1.9771\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.9771\ \text{kipft/ft}) \times (5\ \text{ft})) + \left(3 \times (-0.1742\ \text{kip/ft}) \times (5\ \text{ft})^2\right)}{(6 \times (1.9771\ \text{kipft/ft})) + (4 \times (-0.1742\ \text{kip/ft}) \times (5\ \text{ft}))}$$

$$a = 3.4279\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (1.9771\ \text{kipft/ft})) + (3 \times (-0.1742\ \text{kip/ft}) \times (5\ \text{ft}))]^{\ 2}}{(5\ \text{ft})^2 \times [(3 \times (1.9771\ \text{kipft/ft})) + (2 \times (-0.1742\ \text{kip/ft}) \times (5\ \text{ft}))]}$$

$$p = 0.2008\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (1.9771\ \text{kipft/ft})) + ((-0.1742\ \text{kip/ft}) \times (5\ \text{ft}))]}{(5\ \text{ft})^2}$$

$$s = 0.73995\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(3.4279\ \text{ft})}{2}$$

$$p_a = 0.25709\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.2008\ \text{kip/ft}^2\right)}{\left(0.25709\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.78103$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (5\ \mathrm{ft})$$

$$p_s = 0.75\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.73995\ \mathrm{kip/ft^2}\right)}{\left(0.75\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.9866$$

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

Considering z-direction:

$H_o = -0.013694\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.0044586\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0044586\ \mathrm{kipft/ft}) \times (5\ \mathrm{ft})) + \left(3 \times (-0.013694\ \mathrm{kip/ft}) \times (5\ \mathrm{ft})^2\right)}{(6 \times (0.0044586\ \mathrm{kipft/ft})) + (4 \times (-0.013694\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))}$$

$$a = 3.7129\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.0044586\ \mathrm{kipft/ft})) + (3 \times (-0.013694\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))]^{\ 2}}{(5\ \mathrm{ft})^2 \times [(3 \times (0.0044586\ \mathrm{kipft/ft})) + (2 \times (-0.013694\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))]}$$

$$p = -0.0085426\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.0044586\ \mathrm{kipft/ft})) + ((-0.013694\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))]}{(5\ \mathrm{ft})^2}$$

$$s = -0.014293\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(3.7129\ \mathrm{ft})}{2}$$

$$p_a = 0.27847\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.0085426\ \mathrm{kip/ft^2}\right)}{\left(0.27847\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.030677$$

Status: **PASS**
Ratio: **-0.030**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (5\ \mathrm{ft})$$

$$p_s = 0.75\ \mathrm{kip/ft^2}$$

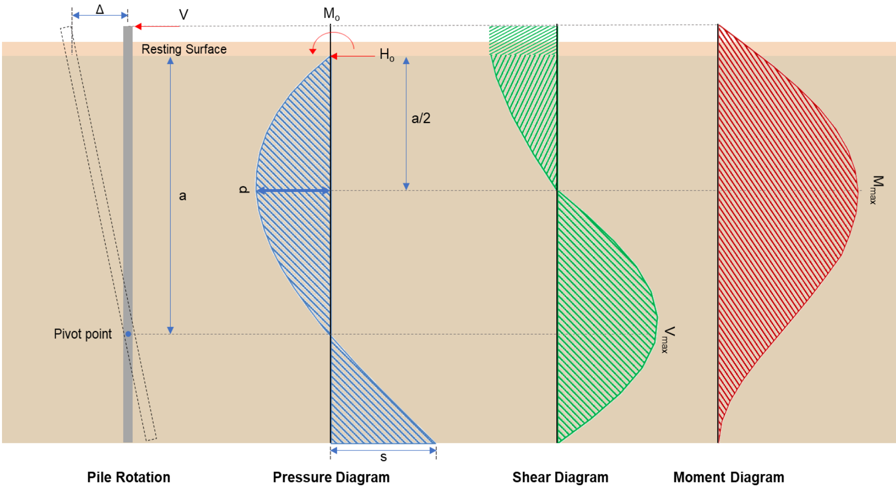
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.014293\ \text{kip/ft}^2\right)}{\left(0.75\ \text{kip/ft}^2\right)}$$

$$Ratio = -0.019057$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.838\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.29268\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(20.79\ \text{kipft}) + ((-1.838\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 3.3105\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(3.3105\ \text{kipft/ft})}{(-0.29268\ \text{kip/ft})}$$

$$E = 11.311\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (3.3105\ \text{kipft/ft}) \times (5\ \text{ft})) + \left(3 \times (-0.29268\ \text{kip/ft}) \times (5\ \text{ft})^2\right)}{(6 \times (3.3105\ \text{kipft/ft})) + (4 \times (-0.29268\ \text{kip/ft}) \times (5\ \text{ft}))}$$

$$a = 3.4282\ \text{ft}$$

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

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

$$V_{max} = ((-0.29268\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (11.311\ \text{ft})}{(5\ \text{ft})} + 3\right) \times \left(\frac{(3.4282\ \text{ft})}{(5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (11.311\ \text{ft})}{(5\ \text{ft})} + 2\right) \times \left(\frac{(3.4282\ \text{ft})}{(5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 5.4603\ \text{kip}$$

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

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

$$M_{max} = ((-0.29268 \text{ kip/ft}) \times (48 \text{ in}) \times (5 \text{ ft})) \times \left[\left(\frac{(11.311 \text{ ft})}{(5 \text{ ft})} + \frac{(3.4282 \text{ ft})}{2 \times (5 \text{ ft})}\right) - \left[\left(\frac{4 \times (11.311 \text{ ft})}{(5 \text{ ft})} + 3\right) \times \left(\frac{(3.4282 \text{ ft})}{2 \times (5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (11.311 \text{ ft})}{(5 \text{ ft})} + 2\right) \times \left(\frac{(3.4282 \text{ ft})}{2 \times (5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 13.118 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.133 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.021178 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.042 \text{ kipft}) + ((-0.133 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.0066879 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.0066879 \text{ kipft/ft})}{(-0.021178 \text{ kip/ft})}$$

$$E = 0.31579 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0066879 \text{ kipft/ft}) \times (5 \text{ ft})) + \left(3 \times (-0.021178 \text{ kip/ft}) \times (5 \text{ ft})^2\right)}{(6 \times (0.0066879 \text{ kipft/ft})) + (4 \times (-0.021178 \text{ kip/ft}) \times (5 \text{ ft}))}$$

$$a = 3.7139 \text{ ft}$$

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

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

$$V_{max} = ((-0.021178 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (0.31579 \text{ ft})}{(5 \text{ ft})} + 3\right) \times \left(\frac{(3.7139 \text{ ft})}{(5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (0.31579 \text{ ft})}{(5 \text{ ft})} + 2\right) \times \left(\frac{(3.7139 \text{ ft})}{(5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.067312 \text{ kip}$$

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

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

$$M_{max} = ((-0.021178 \text{ kip/ft}) \times (48 \text{ in}) \times (5 \text{ ft})) \times \left[\left(\frac{(0.31579 \text{ ft})}{(5 \text{ ft})} + \frac{(3.7139 \text{ ft})}{2 \times (5 \text{ ft})}\right) - \left[\left(\frac{4 \times (0.31579 \text{ ft})}{(5 \text{ ft})} + 3\right) \times \left(\frac{(3.7139 \text{ ft})}{2 \times (5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (0.31579 \text{ ft})}{(5 \text{ ft})} + 2\right) \times \left(\frac{(3.7139 \text{ ft})}{2 \times (5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.13113 \text{ kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(13.194 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (3 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -101.82 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-101.82 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

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

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(13.194\ \text{kip})}{(3183.4\ \text{kip})}$$

$$Ratio = 0.0041446$$

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 $f'_{ck} = 3\ \text{ksi} \rightarrow 3000\ \text{psi}$, $P = 13.194\ \text{kip} \rightarrow 13194\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(3000\ \text{psi})} + \frac{(13194\ \text{lbf})}{6 \times (2304\ \text{in}^2)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 131.55\ \text{kip}$$

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

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

$$V_c = Min\left[(324.49\ \text{kip}), (131.55\ \text{kip}), (406.27\ \text{kip})\right]$$

$$V_c = 131.55\ \text{kip}$$

	The following variables were converted to be consistent with empirical formula $f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}$,	
22.5.1.2	$V_{s,a}$ - Shear strength of steel (a) $$V_{s,a} = 8\sqrt{f'_{ck}}\, b_w\, d$$ $$V_{s,a} = 8 \times \sqrt{(3000 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$$ $$V_{s,a} = 807.65 \text{ kip}$$ A_v - Ties rebar area, $$A_v = \frac{\pi\, d_{ties}^2}{4}$$ $$A_v = \frac{\pi \times (0.375 \text{ in})^2}{4}$$ $$A_v = 0.11045 \text{ in}^2$$	
22.5.8.5.3	$V_{s,b}$ - Shear strength of steel (b) $$V_{s,b} = \frac{2\, A_v\, f_{ywk}\, d}{s_{ties}}$$ $$V_{s,b} = \frac{2 \times \left(0.11045 \text{ in}^2\right) \times (60 \text{ ksi}) \times (38.4 \text{ in})}{(10 \text{ in})}$$ $$V_{s,b} = 50.894 \text{ kip}$$ V_s - Governing shear strength of steel $$V_s = MIN\left[V_{s,a}, V_{s,b}\right]$$ $$V_s = MIN\left[(807.65 \text{ kip}), (50.894 \text{ kip})\right]$$ $$V_s = 50.894 \text{ kip}$$	
22.5.1.1	ϕV_n - Allowable shear strength $$\phi V_n = \phi\,(V_c + V_s)$$ $$\phi V_n = (0.65) \times ((131.55 \text{ kip}) + (50.894 \text{ kip}))$$ $$\phi V_n = 118.59 \text{ kip}$$ **Considering x-direction:** $V_{max} = 5.4603 \text{ kip}$ - Maximum shear force in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(5.4603 \text{ kip})}{(118.59 \text{ kip})}$$ $$Ratio = 0.046044$$	Status: **PASS** Ratio: **0.050**
	Considering z-direction: $V_{max} = 0.067312 \text{ kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.067312 \text{ kip})}{(118.59 \text{ kip})}$$ $$Ratio = 0.0005676$$	Status: **PASS** Ratio: **0.000**
	Flexural Strength (ACI 318-19, LRFD) S_m - Section modulus $$S_m = \frac{b\, D^2}{6}$$ $$S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$$ $$S_m = 18432 \text{ in}^3$$	

	$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f'_c)} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(3ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 273.423kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f'_{ck}\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (3 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$ $$\phi M_{n,2} = 2545.9 \text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(273.42 \text{ kipft}), (2545.9 \text{ kipft})]$$ $$\phi M_n = 273.42 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 13.118 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(13.118 \text{ kipft})}{(273.42 \text{ kipft})}$$ $$Ratio = 0.047975$$	Status: **PASS** Ratio: **0.050**
	Considering z-direction: $M_{max} = 0.13113 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.13113 \text{ kipft})}{(273.42 \text{ kipft})}$$ $$Ratio = 0.00047958$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

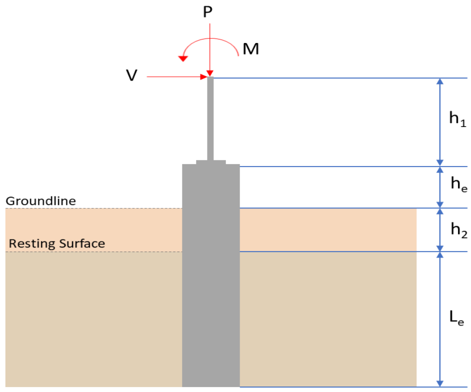
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48$ in - Pile width
$D = 48$ in - Pile depth
$L = 5$ ft - Total pile length
$h_1 = 0$ ft - Lateral load height from the top of the pile,
$h_2 = 0$ ft - Depth to resisting surface
$h_e = 0$ ft - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	8.577	13.187
V_x (kip)	-1.094	-1.837
V_z (kip)	0.113	0.176
M_x (kipft)	0.043	0.067
M_z (kipft)	12.410	20.780

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.094\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = -0.1742\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(12.41\ \text{kipft}) + ((-1.094\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 1.9761\ \text{kipft/ft}$$

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:
$L_{e,x} = 4.7662\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.113\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.017994\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.043\ \text{kipft}) + ((0.113\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.0068471\ \text{kipft/ft}$$

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:
$L_{e,z} = 1.2343\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(4.7662\ \text{ft}), (1.2343\ \text{ft})]$$

$$L_{e,req} = 4.766\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (5\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 5\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(4.766\ \text{ft})}{(5\ \text{ft})}$$

$$Ratio = 0.9532$$

Status: **PASS**
Ratio: **0.950**

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(8.577\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.53606\ \text{kip/ft}^2$$

$q = 0.53606 \text{ kip/ft}^2$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.53606 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.26803$$

Status: **PASS**
Ratio: **0.270**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(5 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.25$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.1742 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 1.9761 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.9761 \text{ kipft/ft}) \times (5 \text{ ft})) + \left(3 \times (-0.1742 \text{ kip/ft}) \times (5 \text{ ft})^2\right)}{(6 \times (1.9761 \text{ kipft/ft})) + (4 \times (-0.1742 \text{ kip/ft}) \times (5 \text{ ft}))}$$

$$a = 3.428 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (1.9761 \text{ kipft/ft})) + (3 \times (-0.1742 \text{ kip/ft}) \times (5 \text{ ft}))]^{\,2}}{(5 \text{ ft})^2 \times [(3 \times (1.9761 \text{ kipft/ft})) + (2 \times (-0.1742 \text{ kip/ft}) \times (5 \text{ ft}))]}$$

$$p = 0.20065 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (1.9761 \text{ kipft/ft})) + ((-0.1742 \text{ kip/ft}) \times (5 \text{ ft}))]}{(5 \text{ ft})^2}$$

$$s = 0.73949 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(3.428 \text{ ft})}{2}$$

$$p_a = 0.2571 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.20065 \text{ kip/ft}^2)}{(0.2571 \text{ kip/ft}^2)}$$

$$Ratio = 0.78043$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (5\ \mathrm{ft})$$

$$p_s = 0.75\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.73949\ \mathrm{kip/ft^2})}{(0.75\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.986$$

Status: PASS
Ratio: 0.990

Considering z-direction:

$H_o = 0.017994\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.0068471\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0068471\ \mathrm{kipft/ft}) \times (5\ \mathrm{ft})) + \left(3 \times (0.017994\ \mathrm{kip/ft}) \times (5\ \mathrm{ft})^2\right)}{(6 \times (0.0068471\ \mathrm{kipft/ft})) + (4 \times (0.017994\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))}$$

$$a = 3.7073\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.0068471\ \mathrm{kipft/ft})) + (3 \times (0.017994\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))]^2}{(5\ \mathrm{ft})^2 \times [(3 \times (0.0068471\ \mathrm{kipft/ft})) + (2 \times (0.017994\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))]}$$

$$p = 0.013226\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.0068471\ \mathrm{kipft/ft})) + ((0.017994\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))]}{(5\ \mathrm{ft})^2}$$

$$s = 0.024879\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(3.7073\ \mathrm{ft})}{2}$$

$$p_a = 0.27805\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.013226\ \mathrm{kip/ft^2})}{(0.27805\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.047567$$

Status: PASS
Ratio: 0.050

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (5\ \mathrm{ft})$$

$$p_s = 0.75\ \mathrm{kip/ft^2}$$

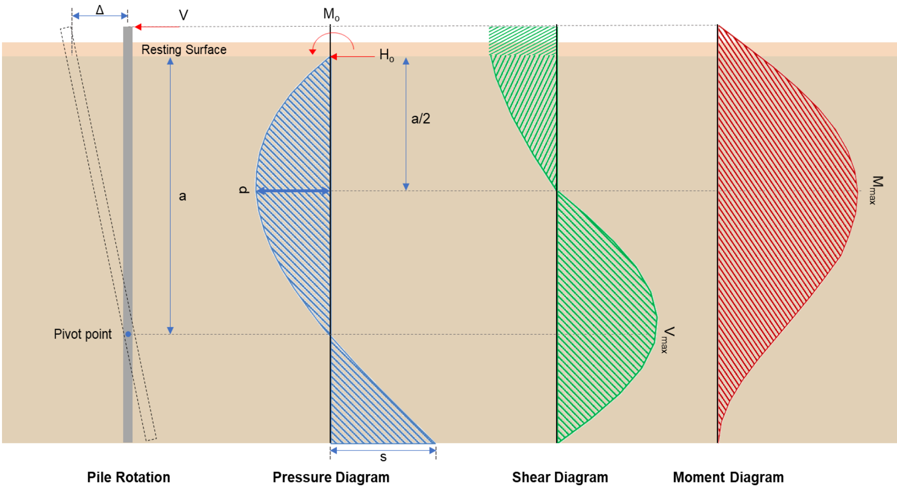
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.024879\ \mathrm{kip/ft^2})}{(0.75\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.033172$$

Status: **PASS**
Ratio: **0.030**



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.837\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.29252\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(20.78\ \mathrm{kipft}) + ((-1.837\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 3.3089\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(3.3089\ \mathrm{kipft/ft})}{(-0.29252\ \mathrm{kip/ft})}$$

$$E = 11.312\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (3.3089\ \mathrm{kipft/ft}) \times (5\ \mathrm{ft})) + \left(3 \times (-0.29252\ \mathrm{kip/ft}) \times (5\ \mathrm{ft})^2\right)}{(6 \times (3.3089\ \mathrm{kipft/ft})) + (4 \times (-0.29252\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))}$$

$$a = 3.4282\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.29252\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (11.312\ \mathrm{ft})}{(5\ \mathrm{ft})} + 3\right) \times \left(\frac{(3.4282\ \mathrm{ft})}{(5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (11.312\ \mathrm{ft})}{(5\ \mathrm{ft})} + 2\right) \times \left(\frac{(3.4282\ \mathrm{ft})}{(5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 5.4577\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.29252 \text{ kip/ft}) \times (48 \text{ in}) \times (5 \text{ ft})) \times \left[\left(\frac{(11.312 \text{ ft})}{(5 \text{ ft})} + \frac{(3.4282 \text{ ft})}{2 \times (5 \text{ ft})} \right) - \left[\left(\frac{4 \times (11.312 \text{ ft})}{(5 \text{ ft})} + 3 \right) \times \left(\frac{(3.4282 \text{ ft})}{2 \times (5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (11.312 \text{ ft})}{(5 \text{ ft})} + 2 \right) \times \left(\frac{(3.4282 \text{ ft})}{2 \times (5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 13.111 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.176 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.028025 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.067 \text{ kipft}) + ((0.176 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.010669 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.010669 \text{ kipft/ft})}{(0.028025 \text{ kip/ft})}$$

$$E = 0.38068 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.010669 \text{ kipft/ft}) \times (5 \text{ ft})) + \left(3 \times (0.028025 \text{ kip/ft}) \times (5 \text{ ft})^2\right)}{(6 \times (0.010669 \text{ kipft/ft})) + (4 \times (0.028025 \text{ kip/ft}) \times (5 \text{ ft}))}$$

$$a = 3.7073 \text{ ft}$$

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

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

$$V_{max} = ((0.028025 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (0.38068 \text{ ft})}{(5 \text{ ft})} + 3 \right) \times \left(\frac{(3.7073 \text{ ft})}{(5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (0.38068 \text{ ft})}{(5 \text{ ft})} + 2 \right) \times \left(\frac{(3.7073 \text{ ft})}{(5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.091555 \text{ kip}$$

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

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

$$M_{max} = ((0.028025 \text{ kip/ft}) \times (48 \text{ in}) \times (5 \text{ ft})) \times \left[\left(\frac{(0.38068 \text{ ft})}{(5 \text{ ft})} + \frac{(3.7073 \text{ ft})}{2 \times (5 \text{ ft})} \right) - \left[\left(\frac{4 \times (0.38068 \text{ ft})}{(5 \text{ ft})} + 3 \right) \times \left(\frac{(3.7073 \text{ ft})}{2 \times (5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (0.38068 \text{ ft})}{(5 \text{ ft})} + 2 \right) \times \left(\frac{(3.7073 \text{ ft})}{2 \times (5 \text{ ft})} \right)^4 \right] \right]$$

	$M_{max} = 0.17969$ kipft		

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 3$ ksi - Concrete strength,
$f_{yk} = 60$ 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,
$A_g = 2304$ 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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(13.187\text{ kip})}{(0.65)\times(0.8)} - (0.85\times(3\text{ ksi})\times(2304\text{ in}^2))}{(60\text{ ksi}) - (0.85\times(3\text{ ksi}))}, (0.08\times(2304\text{ in}^2))\right]$$

$$A_{st,required} = -101.82\text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-101.82\text{ in}^2), (0.0018\times(2304\text{ in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

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

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(13.187\ \mathrm{kip})}{(3183.4\ \mathrm{kip})}$$

$$Ratio = 0.0041424$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

$b_w = 48\ \mathrm{in}$ - Effective width,

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

$$d = 0.80 \times (48\ \mathrm{in})$$

$$d = 38.4\ \mathrm{in}$$

22.5.5.1.3 λ_s - size effect modification factor

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

$$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(38.4\ \mathrm{in})}{10}}}, 1\right]$$

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$, $P = 13.187\ \mathrm{kip} \rightarrow 13187\ \mathrm{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(3000\ \mathrm{psi})} + \frac{(13187\ \mathrm{lbf})}{6 \times (2304\ \mathrm{in}^2)}\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$

$$V_{c,a} = 131.55\ \mathrm{kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(324.49\ \mathrm{kip}), (131.55\ \mathrm{kip}), (406.27\ \mathrm{kip})\right]$$

$$V_c = 131.55\ \mathrm{kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((131.55\ \mathrm{kip}) + (50.894\ \mathrm{kip}))$$

$$\phi V_n = 118.59\ \mathrm{kip}$$

Considering x-direction:

$V_{max} = 5.4577\ \mathrm{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(5.4577\ \mathrm{kip})}{(118.59\ \mathrm{kip})}$$

$$Ratio = 0.046021$$

Status: **PASS**
Ratio: **0.050**

Considering z-direction:

$V_{max} = 0.091555\ \mathrm{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.091555\ \mathrm{kip})}{(118.59\ \mathrm{kip})}$$

$$Ratio = 0.00077203$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

	$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(3ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 273.423kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (3\text{ ksi}) \times \left(18432\text{ in}^3\right)$$ $$\phi M_{n,2} = 2545.9\text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(273.42\text{ kipft}), (2545.9\text{ kipft})]$$ $$\phi M_n = 273.42\text{ kipft}$$ **Considering x-direction:** $M_{max} = 13.111\text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(13.111\text{ kipft})}{(273.42\text{ kipft})}$$ $$Ratio = 0.047952$$	Status: **PASS** Ratio: **0.050**
	Considering z-direction: $M_{max} = 0.17969\text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.17969\text{ kipft})}{(273.42\text{ kipft})}$$ $$Ratio = 0.00065719$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

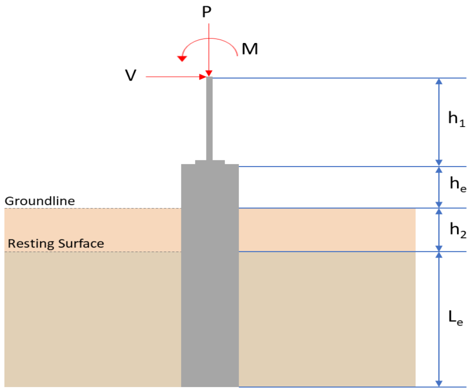
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \text{in}$ - Pile width
$D = 48\ \text{in}$ - Pile depth
$L = 5.25\ \text{ft}$ - Total pile length
$h_1 = 0\ \text{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \text{ft}$ - Depth to resisting surface
$h_e = 0\ \text{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	8.137	12.509
V_x (kip)	-1.014	-1.697
V_z (kip)	-0.003	-0.005
M_x (kipft)	0.039	0.061
M_z (kipft)	12.465	20.921

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.014\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.16146\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(12.465 \text{ kipft}) + ((-1.014 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 1.9849 \text{ kipft/ft}$$

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:
$L_{e,x} = 4.8215 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.003 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.00047771 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.039 \text{ kipft}) + ((-0.003 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

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

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 0.77988 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(4.8215 \text{ ft}), (0.77988 \text{ ft})]$$

$$L_{e,req} = 4.821 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (5.25 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 5.25 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(4.821 \text{ ft})}{(5.25 \text{ ft})}$$

$$Ratio = 0.91829$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(8.137 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.50856 \text{ kip/ft}^2$$

$q = 0.50856\ \text{kip/ft}^2$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.50856\ \text{kip/ft}^2\right)}{(2000\ \text{psf})}$$

$$Ratio = 0.25428$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(5.25\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 1.3125$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.16146\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 1.9849\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.9849\ \text{kipft/ft}) \times (5.25\ \text{ft})) + \left(3 \times (-0.16146\ \text{kip/ft}) \times (5.25\ \text{ft})^2\right)}{(6 \times (1.9849\ \text{kipft/ft})) + (4 \times (-0.16146\ \text{kip/ft}) \times (5.25\ \text{ft}))}$$

$$a = 3.597\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (1.9849\ \text{kipft/ft})) + (3 \times (-0.16146\ \text{kip/ft}) \times (5.25\ \text{ft})]^{\ 2}}{(5.25\ \text{ft})^2 \times [(3 \times (1.9849\ \text{kipft/ft})) + (2 \times (-0.16146\ \text{kip/ft}) \times (5.25\ \text{ft}))]}$$

$$p = 0.18605\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (1.9849\ \text{kipft/ft})) + ((-0.16146\ \text{kip/ft}) \times (5.25\ \text{ft}))]}{(5.25\ \text{ft})^2}$$

$$s = 0.67963\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(3.597\ \text{ft})}{2}$$

$$p_a = 0.26977\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.18605\ \text{kip/ft}^2\right)}{\left(0.26977\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.68964$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \text{psf/ft}) \times (5.25\ \text{ft})$$

$$p_s = 0.7875\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.67963\ \text{kip/ft}^2\right)}{\left(0.7875\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.86302$$

Status: **PASS**
Ratio: **0.860**

Considering z-direction:

$H_o = -0.00047771\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.0062102\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0062102\ \text{kipft/ft}) \times (5.25\ \text{ft})) + \left(3 \times (-0.00047771\ \text{kip/ft}) \times (5.25\ \text{ft})^2\right)}{(6 \times (0.0062102\ \text{kipft/ft})) + (4 \times (-0.00047771\ \text{kip/ft}) \times (5.25\ \text{ft}))}$$

$$a = 3.5928\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.0062102\ \text{kipft/ft})) + (3 \times (-0.00047771\ \text{kip/ft}) \times (5.25\ \text{ft}))]^2}{(5.25\ \text{ft})^2 \times [(3 \times (0.0062102\ \text{kipft/ft})) + (2 \times (-0.00047771\ \text{kip/ft}) \times (5.25\ \text{ft}))]}$$

$$p = 0.00059934\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.0062102\ \text{kipft/ft})) + ((-0.00047771\ \text{kip/ft}) \times (5.25\ \text{ft}))]}{(5.25\ \text{ft})^2}$$

$$s = 0.0021578\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(3.5928\ \text{ft})}{2}$$

$$p_a = 0.26946\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.00059934\ \text{kip/ft}^2\right)}{\left(0.26946\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.0022242$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \text{psf/ft}) \times (5.25\ \text{ft})$$

$$p_s = 0.7875\ \text{kip/ft}^2$$

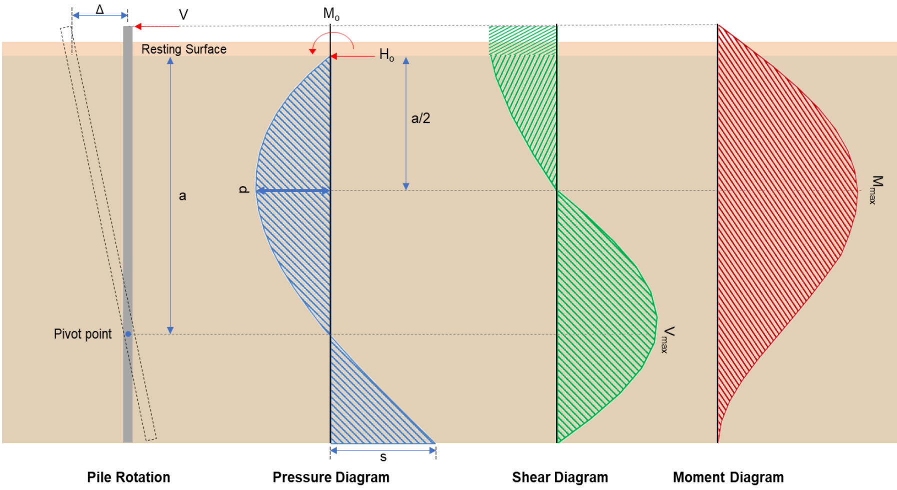
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0021578\ \mathrm{kip/ft^2})}{(0.7875\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.0027401$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.697\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.27022\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(20.921\ \mathrm{kipft}) + ((-1.697\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 3.3314\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(3.3314\ \mathrm{kipft/ft})}{(-0.27022\ \mathrm{kip/ft})}$$

$$E = 12.328\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (3.3314\ \mathrm{kipft/ft}) \times (5.25\ \mathrm{ft})) + \left(3 \times (-0.27022\ \mathrm{kip/ft}) \times (5.25\ \mathrm{ft})^2\right)}{(6 \times (3.3314\ \mathrm{kipft/ft})) + (4 \times (-0.27022\ \mathrm{kip/ft}) \times (5.25\ \mathrm{ft}))}$$

$$a = 3.5967\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.27022\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.328\ \mathrm{ft})}{(5.25\ \mathrm{ft})} + 3\right) \times \left(\frac{(3.5967\ \mathrm{ft})}{(5.25\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (12.328\ \mathrm{ft})}{(5.25\ \mathrm{ft})} + 2\right) \times \left(\frac{(3.5967\ \mathrm{ft})}{(5.25\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 5.2063\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.27022\text{ kip/ft})\times(48\text{ in})\times(5.25\text{ ft}))\times\left[\left(\frac{(12.328\text{ ft})}{(5.25\text{ ft})}+\frac{(3.5967\text{ ft})}{2\times(5.25\text{ ft})}\right) - \left[\left(\frac{4\times(12.328\text{ ft})}{(5.25\text{ ft})}+3\right)\times\left(\frac{(3.5967\text{ ft})}{2\times(5.25\text{ ft})}\right)^3\right]+\left[\left(\frac{3\times(12.328\text{ ft})}{(5.25\text{ ft})}+2\right)\times\left(\frac{(3.5967\text{ ft})}{2\times(5.25\text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 13.149\text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

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

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

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.061\text{ kipft})+((-0.005\text{ kip})\times(0\text{ ft}))}{1.57\times(48\text{ in})}$$

$$M_o = 0.0097134\text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.0097134\text{ kipft/ft})}{(-0.00079618\text{ kip/ft})}$$

$$E = 12.2\text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4\times(0.0097134\text{ kipft/ft})\times(5.25\text{ ft}))+\left(3\times(-0.00079618\text{ kip/ft})\times(5.25\text{ ft})^2\right)}{(6\times(0.0097134\text{ kipft/ft}))+(4\times(-0.00079618\text{ kip/ft})\times(5.25\text{ ft}))}$$

$$a = 3.5975\text{ ft}$$

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

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

$$V_{max} = ((-0.00079618\text{ kip/ft})\times(48\text{ in}))\times\left[1-\left[3\times\left(\frac{4\times(12.2\text{ ft})}{(5.25\text{ ft})}+3\right)\times\left(\frac{(3.5975\text{ ft})}{(5.25\text{ ft})}\right)^2\right]+\left[4\times\left(\frac{3\times(12.2\text{ ft})}{(5.25\text{ ft})}+2\right)\times\left(\frac{(3.5975\text{ ft})}{(5.25\text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.015202\text{ kip}$$

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

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

$$M_{max} = ((-0.00079618\text{ kip/ft})\times(48\text{ in})\times(5.25\text{ ft}))\times\left[\left(\frac{(12.2\text{ ft})}{(5.25\text{ ft})}+\frac{(3.5975\text{ ft})}{2\times(5.25\text{ ft})}\right) - \left[\left(\frac{4\times(12.2\text{ ft})}{(5.25\text{ ft})}+3\right)\times\left(\frac{(3.5975\text{ ft})}{2\times(5.25\text{ ft})}\right)^3\right]+\left[\left(\frac{3\times(12.2\text{ ft})}{(5.25\text{ ft})}+2\right)\times\left(\frac{(3.5975\text{ ft})}{2\times(5.25\text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.038381 \text{ kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(12.509 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (3 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -101.85 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-101.85 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

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 $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(12.509\ \text{kip})}{(3183.4\ \text{kip})}$$ $$Ratio = 0.0039294$$	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 $f'_{ck} = 3\ \text{ksi} \rightarrow 3000\ \text{psi}$,$P = 12.509\ \text{kip} \rightarrow 12509\ \text{lbf}$,	
22.5.5.1.1(a)	$V_{c,a}$ - Shear strength of concrete (a) $$V_{c,a} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \frac{P}{6\, A_g}\right]\, b_w\, d$$ $$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(3000\ \text{psi})} + \frac{(12509\ \text{lbf})}{6 \times \left(2304\ \text{in}^2\right)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$ $$V_{c,a} = 131.46\ \text{kip}$$ 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 $$V_c = Min\left[V_{c,max}, V_{c,a}, V_{c,b}\right]$$ $$V_c = Min\left[(324.49\ \text{kip}), (131.46\ \text{kip}), (406.27\ \text{kip})\right]$$ $$V_c = 131.46\ \text{kip}$$	

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((131.46\ \text{kip}) + (50.894\ \text{kip}))$$

$$\phi V_n = 118.53\ \text{kip}$$

Considering x-direction:

$V_{max} = 5.2063\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(5.2063\ \text{kip})}{(118.53\ \text{kip})}$$

$$Ratio = 0.043923$$

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

Considering z-direction:

$V_{max} = 0.015202\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.015202\ \text{kip})}{(118.53\ \text{kip})}$$

$$Ratio = 0.00012825$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

	$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(3ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 273.423kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f'_{ck}\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (3 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$ $$\phi M_{n,2} = 2545.9 \text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(273.42 \text{ kipft}), (2545.9 \text{ kipft})]$$ $$\phi M_n = 273.42 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 13.149 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(13.149 \text{ kipft})}{(273.42 \text{ kipft})}$$ $$Ratio = 0.048091$$	Status: **PASS** Ratio: **0.050**
	Considering z-direction: $M_{max} = 0.038381 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.038381 \text{ kipft})}{(273.42 \text{ kipft})}$$ $$Ratio = 0.00014037$$	Status: **PASS** Ratio: **0.000**