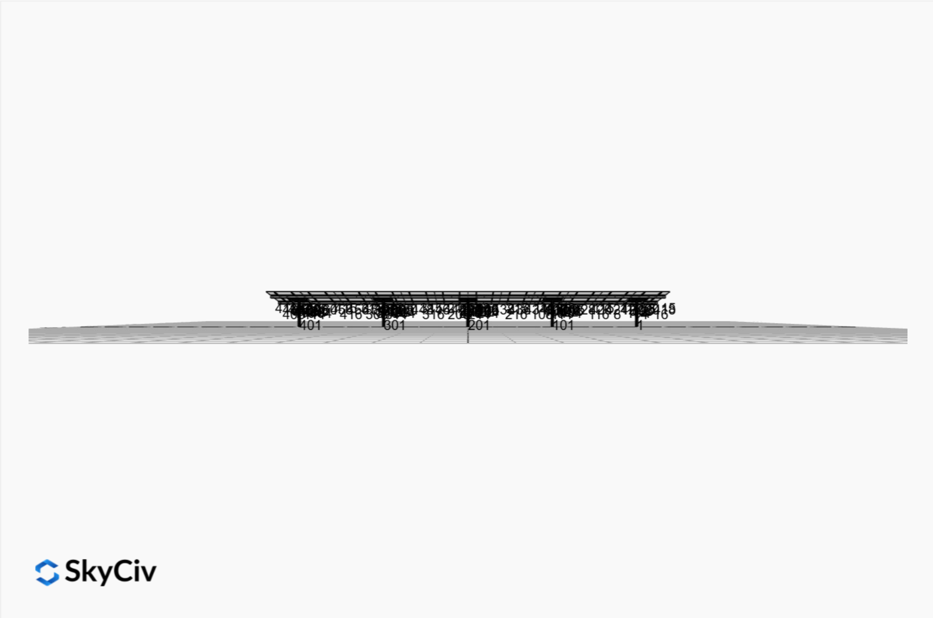
Project Details

Project Name: MTSOLAR_JL6F7LCFLBAG
Location: 1471 E Brooks Rd, Memphis, TN 38116, USA
Unique ID: 5P-19.75-6TOP-SD-24-L-4Hx12W-9711
Dealer: ______________________________

Date: Mon Oct 21 2024
Number of Modules: 48
Number of Poles: 5
Date Sold:
____



Array Dimensions N/S	15.06 ft
Array Dimensions E/W	90.72 ft
Winter Tilt Angle	10
Front Edge Clearance	5 ft

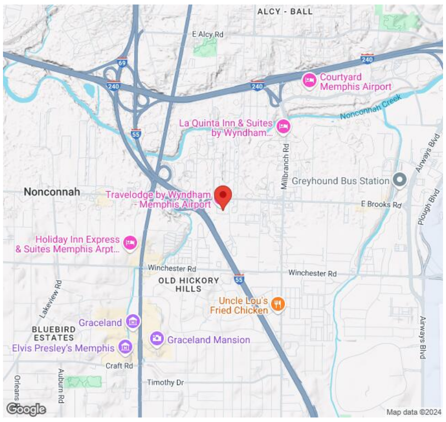
MT Solar Bill of Materials (5P-19.75-6TOP-SD-24-L-4Hx12W-9711)

Part	Short Description	BOM Qty
MTS-PC-6	6IN Pole Cap Assembly	5
MTS-HF-SD	H-Frame Assembly-SD	5
MTS-SD-Wing-24	24IN SD Wing	4
MTS-SD-Splice-90	90IN SD Splice	8
MTS-SD-Splice-57	57IN SD Splice	8
MTS-CLAMP-HOOK-4PK	Hook Clamp	12

Rail Bill of Materials

Part	Qty
Rails (179in)	24
Rail Attachment	48
Module Mid Clamp	72
Module End Clamp	48
Ground Lug	12

Site Details:



Site Address: 1471 E Brooks Rd, Memphis, TN 38116, USA

Array Specification

Duty Classification:	SD
Module Width:	44.68 in
Module Length:	89.72in
Number of Rows:	4
Number of Columns:	12
Total Number of Modules:	48
Winter Tilt Angle:	10
Front Edge Clearance:	5
Total Array Height at Tilt:	7.62 ft
Total Frame Length:	90.50 ft
Frame Weight:	4008 lbs
Array Dimensions N/S:	15.06 ft
Array Dimensions E/W:	90.72 ft
Rail Length:	180.72 in
Rail Spacing:	3.78 ft

Support Specifications

Pole Size:	6in Pipe Sch 40
Pole Length above Grade:	6.31 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: 4.00 ft Pile 2: 4.50 ft Pile 3: 4.50 ft Pile 4: 4.50 ft Pile 5: 4.00 ft
Foundation Volume:	12.741 y^3

Site Info

Risk Category:	I
Exposure:	B
Soil Classification:	sand
Site Location:	1471 E Brooks Rd, Memphis, TN 38116, USA
Wind Speed:	100 mph

Snow Load:	10 psf

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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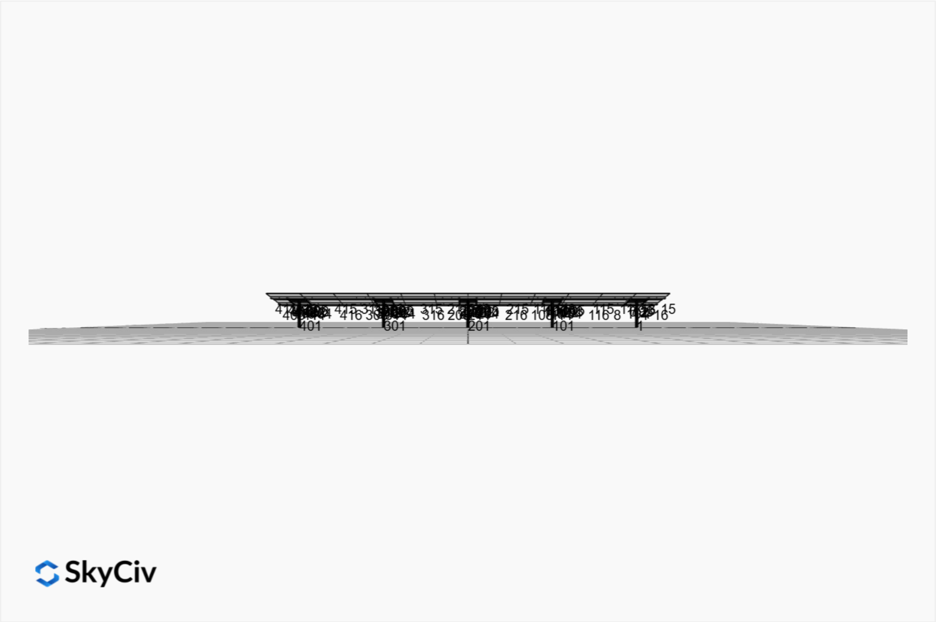
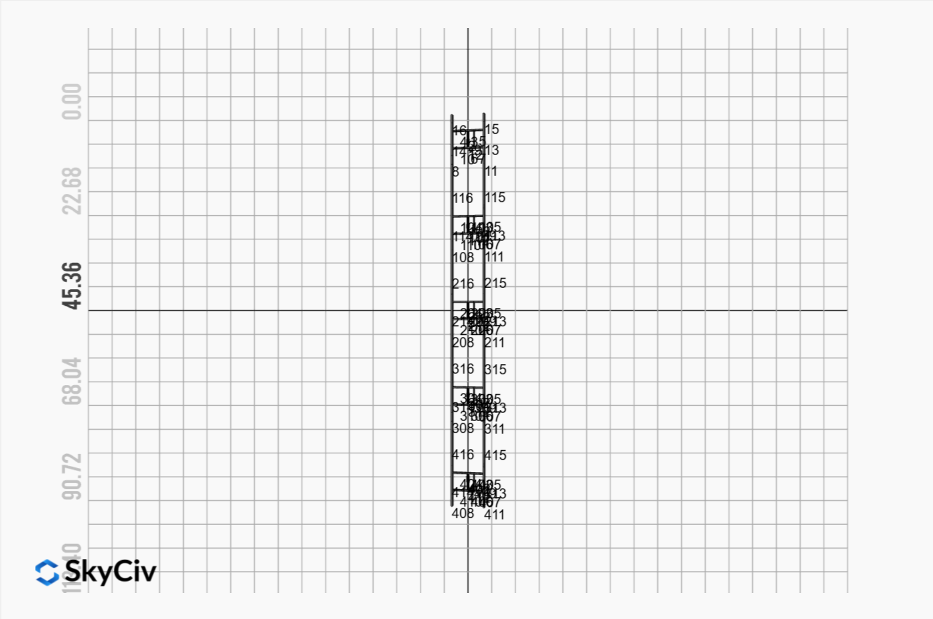
Design Notes:

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

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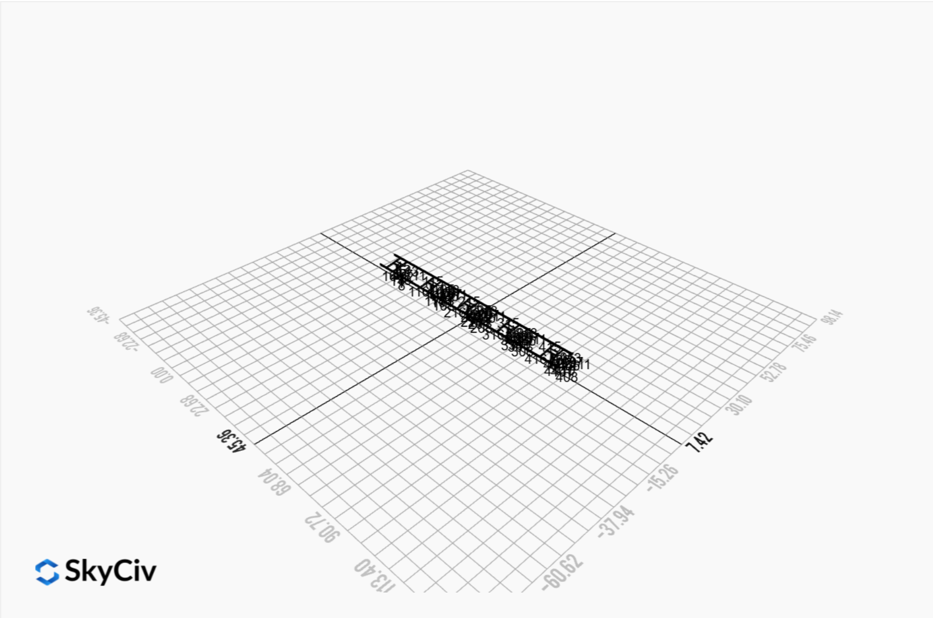
45.36
68.04
90.72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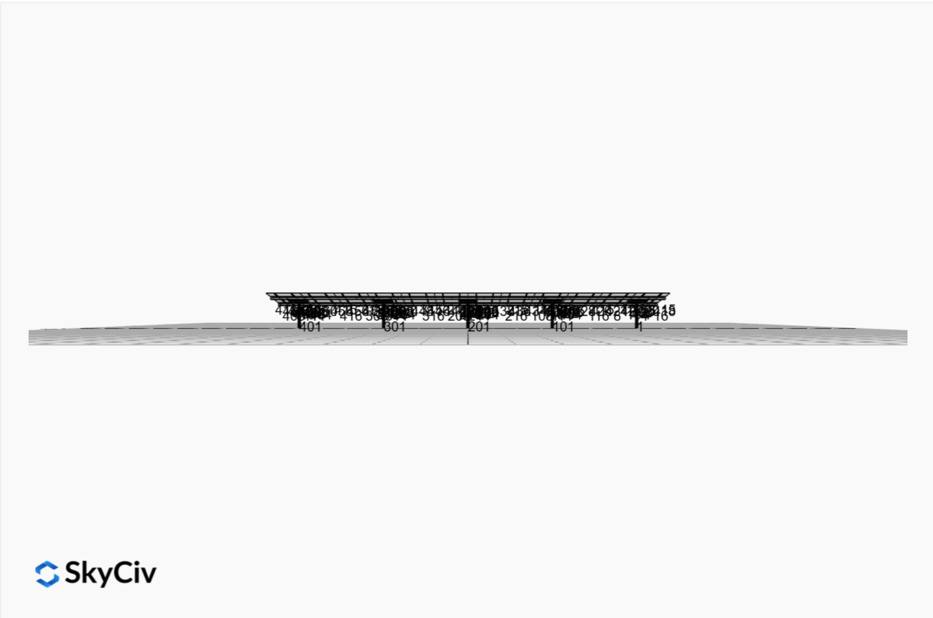
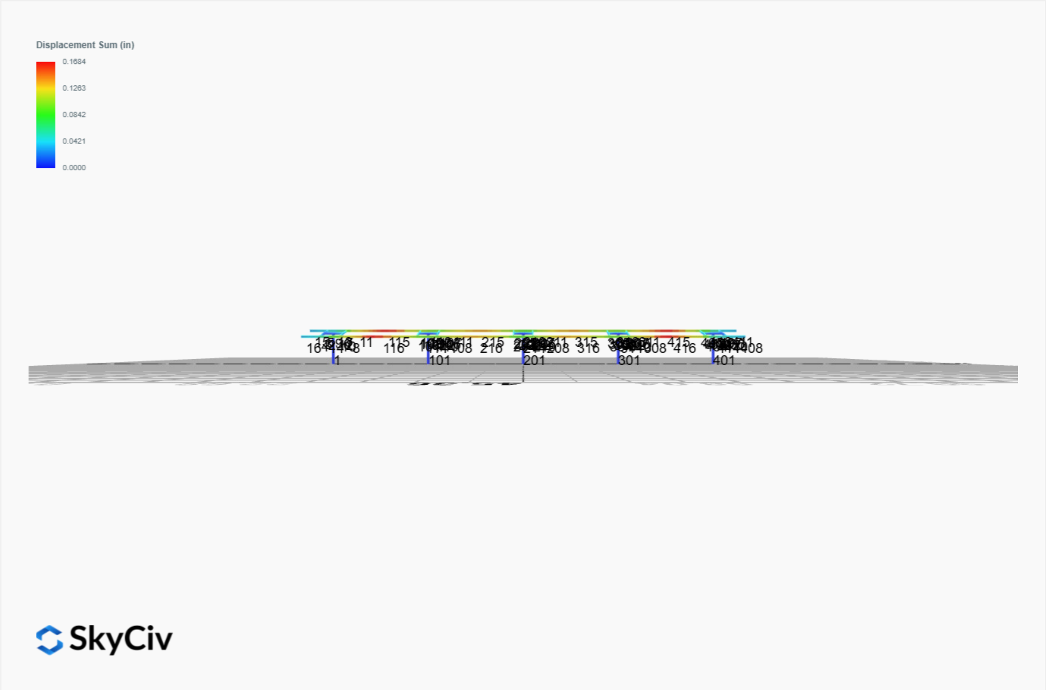
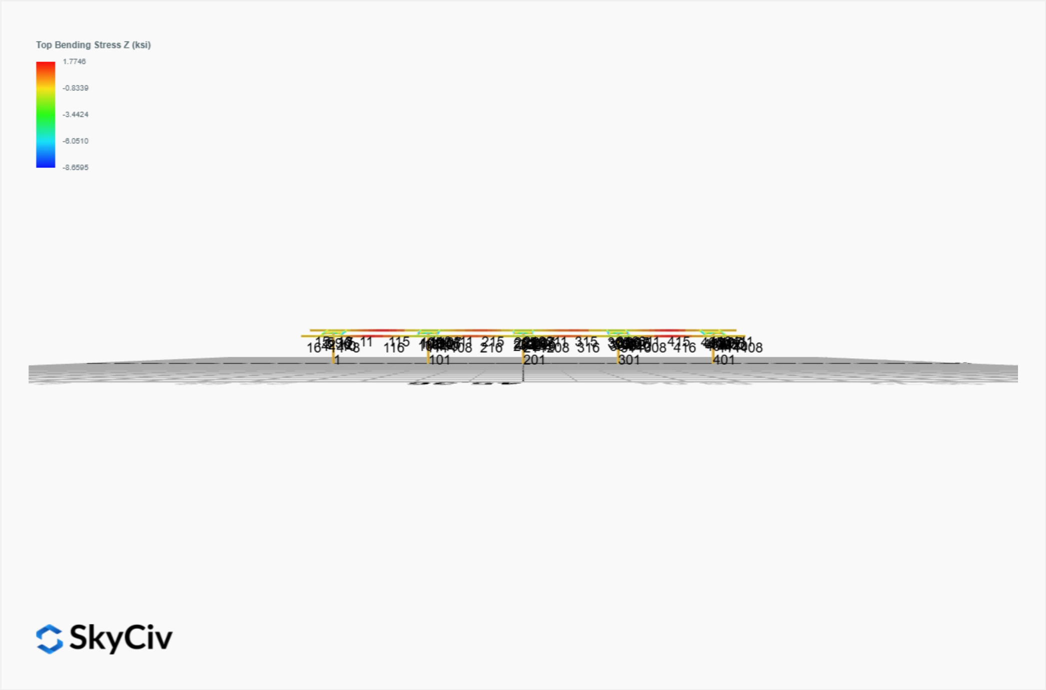
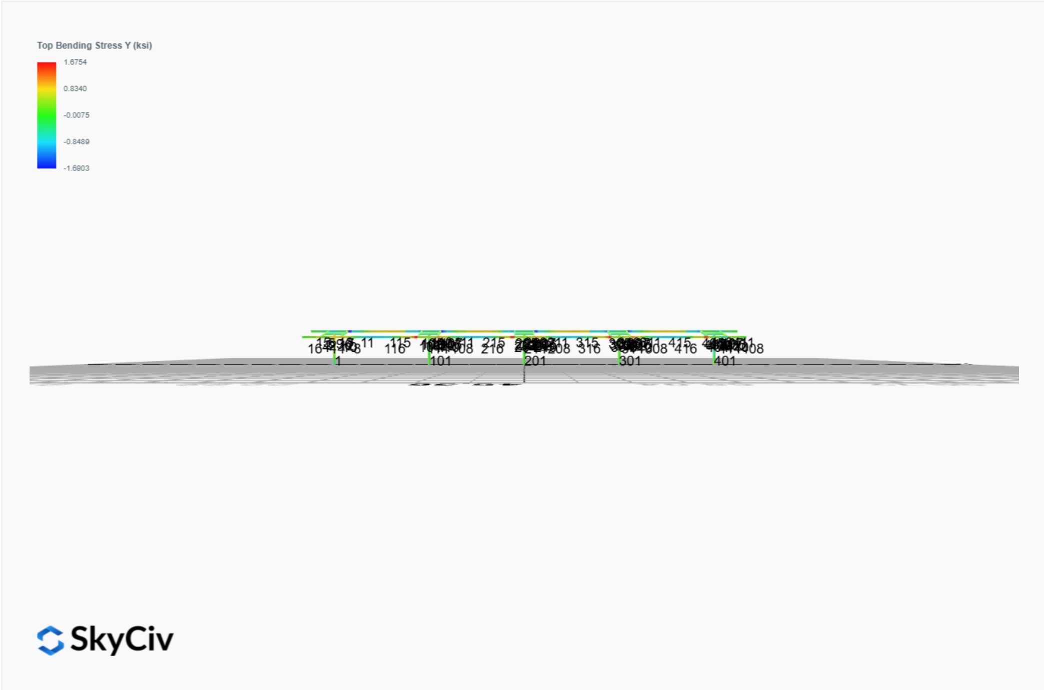


FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
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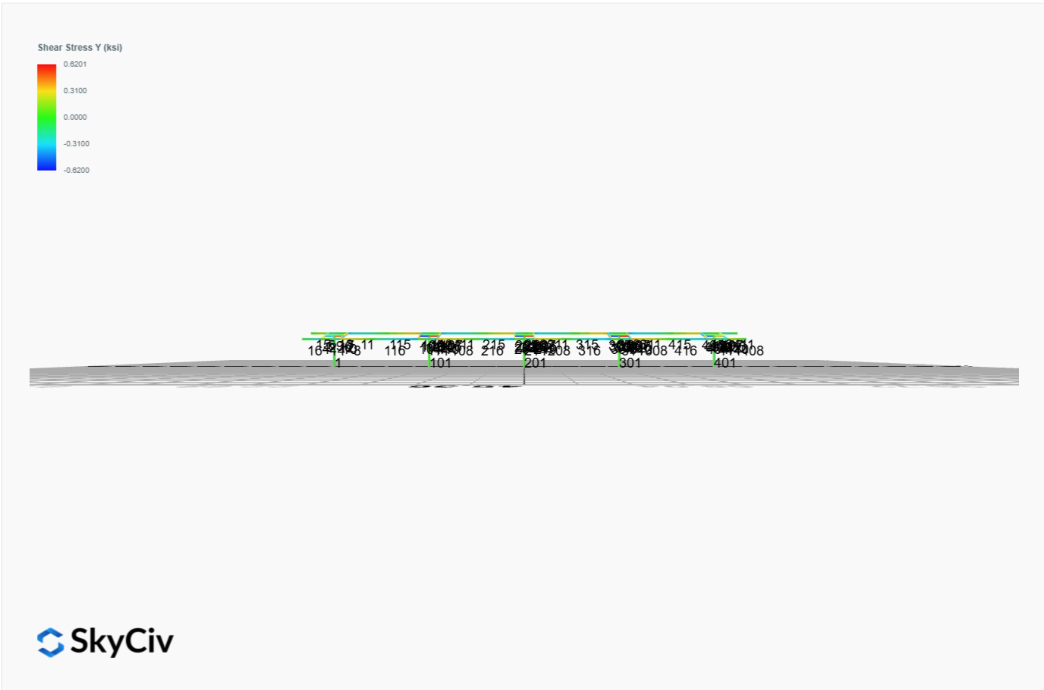
-0.0075
-0.8489
-1.6903


Shear Stress Y (ksi)
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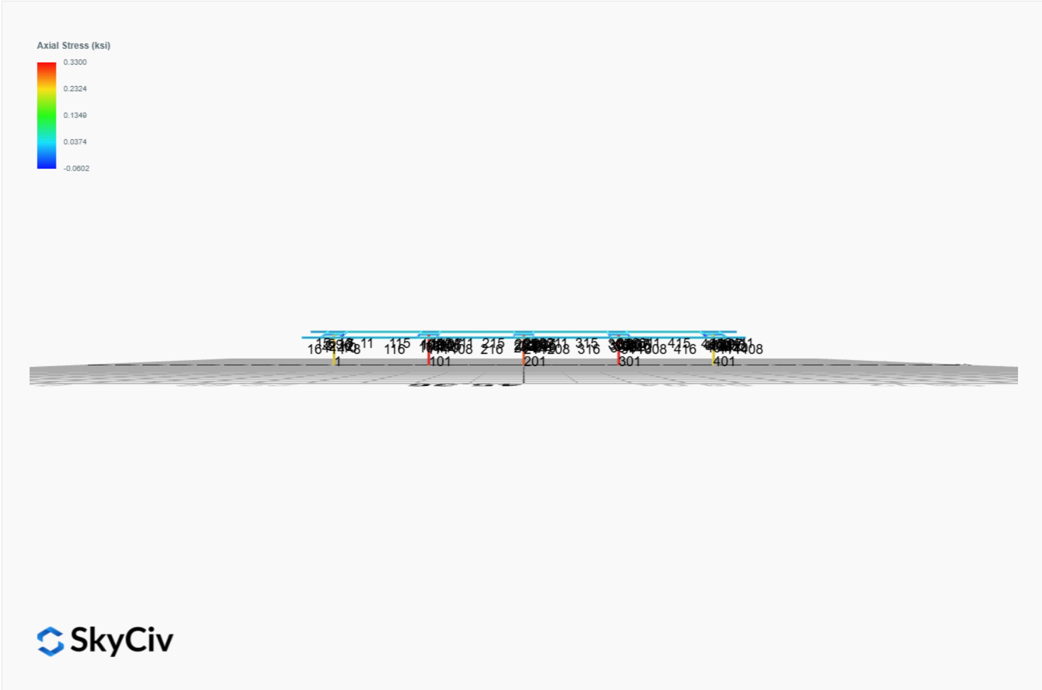
0.3100
0.0000
-0.3100
-0.6200


Axial Stress (ksi)
0.3300
0.2324
0.1349
0.0374
-0.0602
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	0.0096	1.5640	0.1229	0.1570	-0.0311	-0.0351
ULS: 2. D + L	0.0096	1.5640	0.1229	0.1570	-0.0311	-0.0351
ULS: 3. D + (S or Lr or R)	0.0196	2.9067	0.2506	0.3202	-0.0635	-0.0923
ULS: 3. D + (S or Lr or R)	0.0096	1.5640	0.1229	0.1570	-0.0311	-0.0351
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0171	2.5710	0.2187	0.2794	-0.0554	-0.0780
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0096	1.5640	0.1229	0.1570	-0.0311	-0.0351
ULS: 5b. D + 0.7E	0.0096	1.5640	0.1229	0.1570	-0.0311	-0.0351
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0171	2.5710	0.2187	0.2794	-0.0554	-0.0780
ULS: 8. 0.6D + 0.7E	0.0058	0.9384	0.0738	0.0942	-0.0187	-0.0211
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.3143	3.3673	0.2989	0.3733	-0.1268	3.4376
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.3143	3.3673	0.2989	0.3733	-0.1268	3.4376
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.2322	0.3001	0.0029	0.0088	0.0299	-0.3490
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.2150	0.4621	0.0116	0.0214	0.0365	-5.6333
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.2258	3.9235	0.3507	0.4416	-0.1271	2.5265
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.2258	3.9235	0.3507	0.4416	-0.1271	2.5265
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.1841	1.6231	0.1287	0.1682	-0.0096	-0.3134
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1711	1.7445	0.1352	0.1777	-0.0047	-4.2767
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.2333	2.9165	0.2549	0.3193	-0.1029	2.5694
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.2333	2.9165	0.2549	0.3193	-0.1029	2.5694
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.1766	0.6161	0.0329	0.0458	0.0147	-0.2705
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1636	0.7375	0.0395	0.0553	0.0196	-4.2338
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.3182	2.7417	0.2497	0.3105	-0.1143	3.4517
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.3182	2.7417	0.2497	0.3105	-0.1143	3.4517
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.2283	-0.3255	-0.0463	-0.0541	0.0424	-0.3349
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.2111	-0.1636	-0.0375	-0.0415	0.0489	-5.6193

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	5.5534
Shear X	-0.5399
Shear Z	0.5062
Moment X	0.6324
Moment Y (Twist)	0.2135
Moment Z	9.4814

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	3.9235
Shear X	-0.3182
Shear Z	0.3507
Moment X	0.4416
Moment Y (Twist)	0.1271
Moment Z	5.6333

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	-0.0112	2.0456	-0.0199	-0.0296	0.0088	0.0843
ULS: 2. D + L	-0.0112	2.0456	-0.0199	-0.0296	0.0088	0.0843
ULS: 3. D + (S or Lr or R)	-0.0228	3.8873	-0.0406	-0.0602	0.0179	0.1512
ULS: 3. D + (S or Lr or R)	-0.0112	2.0456	-0.0199	-0.0296	0.0088	0.0843
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0199	3.4268	-0.0355	-0.0526	0.0156	0.1344

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0112	2.0456	-0.0199	-0.0296	0.0088	0.0843
ULS: 5b. D + 0.7E	-0.0112	2.0456	-0.0199	-0.0296	0.0088	0.0843
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0199	3.4268	-0.0355	-0.0526	0.0156	0.1344
ULS: 8. 0.6D + 0.7E	-0.0067	1.2273	-0.0120	-0.0177	0.0053	0.0506
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.4421	4.5237	-0.0475	-0.0714	0.0158	4.6064
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.4421	4.5237	-0.0475	-0.0714	0.0158	4.6064
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.2955	0.3063	0.0003	0.0002	-0.0011	-0.4092
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.2443	0.5353	-0.0049	-0.0051	0.0125	-7.0311
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.3431	5.2855	-0.0561	-0.0839	0.0209	3.5260
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.3431	5.2855	-0.0561	-0.0839	0.0209	3.5260
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.2101	2.1224	-0.0203	-0.0303	0.0082	-0.2356
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1717	2.2942	-0.0242	-0.0342	0.0183	-5.2021
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.3344	3.9042	-0.0406	-0.0609	0.0140	3.4758
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.3344	3.9042	-0.0406	-0.0609	0.0140	3.4758
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.2188	0.7411	-0.0048	-0.0073	0.0014	-0.2858
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1804	0.9129	-0.0086	-0.0112	0.0115	-5.2523
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.4376	3.7055	-0.0395	-0.0596	0.0123	4.5727
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.4376	3.7055	-0.0395	-0.0596	0.0123	4.5727
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.3000	-0.5119	0.0083	0.0120	-0.0046	-0.4429
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.2488	-0.2829	0.0031	0.0068	0.0089	-7.0648

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	7.5061
Shear X	-0.7373
Shear Z	-0.0805
Moment X	-0.1211
Moment Y (Twist)	0.0310
Moment Z	11.8590

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	5.2855
Shear X	-0.4421
Shear Z	-0.0561
Moment X	-0.0839
Moment Y (Twist)	0.0209
Moment Z	7.0648

Reaction Forces for Foundation 3 (Node ID#201), (kip, kip-ft)

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	0.0032	1.9564	0.0003	-0.0000	-0.0002	0.0094
ULS: 2. D + L	0.0032	1.9564	0.0003	-0.0000	-0.0002	0.0094
ULS: 3. D + (S or Lr or R)	0.0065	3.7055	0.0005	-0.0001	-0.0003	-0.0015
ULS: 3. D + (S or Lr or R)	0.0032	1.9564	0.0003	-0.0000	-0.0002	0.0094
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0056	3.2682	0.0005	-0.0001	-0.0003	0.0013
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0032	1.9564	0.0003	-0.0000	-0.0002	0.0094
ULS: 5b. D + 0.7E	0.0032	1.9564	0.0003	-0.0000	-0.0002	0.0094
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0056	3.2682	0.0005	-0.0001	-0.0003	0.0013
ULS: 8. 0.6D + 0.7E	0.0019	1.1738	0.0002	-0.0000	-0.0001	0.0056
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.4118	4.3087	0.0006	-0.0001	-0.0005	4.4779
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.4118	4.3087	0.0006	-0.0001	-0.0005	4.4779
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.2943	0.3080	-0.0000	-0.0000	0.0000	-0.4122
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.2562	0.5183	0.0000	-0.0000	0.0001	-7.1334

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	-0.3056	5.0325	0.0008	-0.0001	-0.0005	3.3526
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.3056	5.0325	0.0008	-0.0001	-0.0005	3.3526
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.2240	2.0319	0.0003	-0.0001	-0.0002	-0.3149
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1954	2.1897	0.0003	-0.0001	-0.0001	-5.3558
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.3081	3.7206	0.0005	-0.0001	-0.0004	3.3608
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.3081	3.7206	0.0005	-0.0001	-0.0004	3.3608
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.2215	0.7201	0.0001	-0.0000	-0.0000	-0.3068
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1930	0.8778	0.0001	-0.0000	0.0000	-5.3477
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.4131	3.5261	0.0005	-0.0001	-0.0004	4.4741
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.4131	3.5261	0.0005	-0.0001	-0.0004	4.4741
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.2931	-0.4746	-0.0001	0.0000	0.0001	-0.4159
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.2549	-0.2643	-0.0001	-0.0000	0.0002	-7.1371

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	7.1426
Shear X	-0.6916
Shear Z	0.0011
Moment X	-0.0001
Moment Y (Twist)	0.0008
Moment Z	12.0271

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	5.0325
Shear X	-0.4131
Shear Z	0.0008
Moment X	-0.0001
Moment Y (Twist)	0.0005
Moment Z	7.1371

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	-0.0112	2.0456	0.0197	0.0285	-0.0086	0.0843
ULS: 2. D + L	-0.0112	2.0456	0.0197	0.0285	-0.0086	0.0843
ULS: 3. D + (S or Lr or R)	-0.0229	3.8874	0.0401	0.0580	-0.0175	0.1513
ULS: 3. D + (S or Lr or R)	-0.0112	2.0456	0.0197	0.0285	-0.0086	0.0843
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0200	3.4269	0.0350	0.0506	-0.0153	0.1346
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0112	2.0456	0.0197	0.0285	-0.0086	0.0843
ULS: 5b. D + 0.7E	-0.0112	2.0456	0.0197	0.0285	-0.0086	0.0843
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0200	3.4269	0.0350	0.0506	-0.0153	0.1346
ULS: 8. 0.6D + 0.7E	-0.0067	1.2274	0.0118	0.0171	-0.0051	0.0506
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.4421	4.5239	0.0468	0.0687	-0.0157	4.6066
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.4421	4.5239	0.0468	0.0687	-0.0157	4.6066
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.2955	0.3063	-0.0003	-0.0002	0.0013	-0.4091
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.2443	0.5353	0.0048	0.0049	-0.0121	-7.0314
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.3431	5.2856	0.0554	0.0808	-0.0206	3.5263
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.3431	5.2856	0.0554	0.0808	-0.0206	3.5263
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.2101	2.1224	0.0200	0.0291	-0.0079	-0.2355
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1717	2.2942	0.0239	0.0329	-0.0179	-5.2022
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.3344	3.9043	0.0400	0.0587	-0.0139	3.4761
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.3344	3.9043	0.0400	0.0587	-0.0139	3.4761
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.2188	0.7411	0.0047	0.0070	-0.0012	-0.2857
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1804	0.9129	0.0085	0.0108	-0.0112	-5.2525

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.4376	3.7056	0.0390	0.0573	-0.0123	4.5729
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.4376	3.7056	0.0390	0.0573	-0.0123	4.5729
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.3000	-0.5120	-0.0082	-0.0116	0.0047	-0.4428
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.2488	-0.2829	-0.0030	-0.0065	-0.0087	-7.0651

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	7.5063
Shear X	-0.7374
Shear Z	0.0795
Moment X	0.1166
Moment Y (Twist)	0.0305
Moment Z	11.8596

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	5.2856
Shear X	-0.4421
Shear Z	0.0554
Moment X	0.0808
Moment Y (Twist)	0.0206
Moment Z	7.0651

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	0.0096	1.5640	-0.1229	-0.1578	0.0311	-0.0352
ULS: 2. D + L	0.0096	1.5640	-0.1229	-0.1578	0.0311	-0.0352
ULS: 3. D + (S or Lr or R)	0.0196	2.9065	-0.2506	-0.3218	0.0635	-0.0924
ULS: 3. D + (S or Lr or R)	0.0096	1.5640	-0.1229	-0.1578	0.0311	-0.0352
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0171	2.5709	-0.2187	-0.2808	0.0554	-0.0781
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0096	1.5640	-0.1229	-0.1578	0.0311	-0.0352
ULS: 5b. D + 0.7E	0.0096	1.5640	-0.1229	-0.1578	0.0311	-0.0352
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0171	2.5709	-0.2187	-0.2808	0.0554	-0.0781
ULS: 8. 0.6D + 0.7E	0.0058	0.9384	-0.0738	-0.0947	0.0187	-0.0211
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.3143	3.3671	-0.2989	-0.3752	0.1266	3.4378
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.3143	3.3671	-0.2989	-0.3752	0.1266	3.4378
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.2322	0.3001	-0.0029	-0.0088	-0.0298	-0.3487
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.2150	0.4620	-0.0116	-0.0215	-0.0364	-5.6343
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.2258	3.9233	-0.3507	-0.4438	0.1270	2.5266
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.2258	3.9233	-0.3507	-0.4438	0.1270	2.5266
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.1841	1.6230	-0.1287	-0.1690	0.0098	-0.3132
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1711	1.7445	-0.1352	-0.1786	0.0048	-4.2774
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.2333	2.9163	-0.2549	-0.3209	0.1027	2.5695
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.2333	2.9163	-0.2549	-0.3209	0.1027	2.5695
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.1766	0.6161	-0.0329	-0.0461	-0.0146	-0.2703
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1636	0.7375	-0.0395	-0.0556	-0.0195	-4.2345
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.3181	2.7415	-0.2497	-0.3121	0.1141	3.4518
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.3181	2.7415	-0.2497	-0.3121	0.1141	3.4518
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.2283	-0.3255	0.0463	0.0543	-0.0422	-0.3346
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.2111	-0.1635	0.0375	0.0416	-0.0488	-5.6202

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.

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	5.5531
Shear X	-0.5399
Shear Z	-0.5062
Moment X	-0.6356
Moment Y (Twist)	0.2133
Moment Z	9.4830

Result	Value (kip, kip-ft)
Axial	3.9233
Shear X	-0.3181
Shear Z	-0.3507
Moment X	-0.4438
Moment Y (Twist)	0.1270
Moment Z	5.6343

Project Details

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

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

Design Input Information

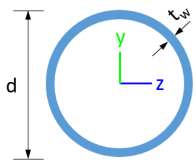
Design Factors

Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

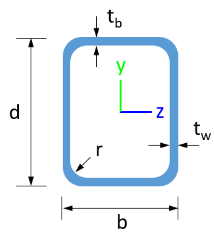
Design Materials

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

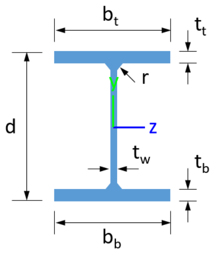
Section Dimensions



ID	Name	d (in)	t_w (in)					
1	2in Pipe Sch 40	2.38	0.15					
4	4in Pipe Sch 40	4.50	0.24					
7	6in Pipe Sch 40	6.63	0.28					



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



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

Section Properties

ID	Name	A (in^2)	J (in^4)	I_{yp} (in^4)	I_{zp} (in^4)	I_w (in^6)	S_{yp} (in^3)	S_{zp} (in^3)

1	2in Pipe Sch 40	1.07	1.33	0.67	0.67	0.00	0.76	0.76
4	4in Pipe Sch 40	3.17	14.47	7.23	7.23	0.00	4.31	4.31
7	6in Pipe Sch 40	5.58	56.28	28.14	28.14	0.00	11.28	11.28
15	HSS5x3x1/8	1.77	6.02	2.75	6.03	0.51	2.07	2.93
18	W6x9	2.68	0.04	2.20	16.40	17.70	1.72	6.23

Member Properties								
Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	7	13.25	13.25	6.31	-	300	200	1
2	4	1.30	1.30	2.00	-	300	200	1
3	15	0.92	0.92	1.42	1.18,1.18,1.18,1.17,1.18,1.18,1.17,1.17,1.20,1.16,1.17,1.17,1.42,1.16,1.17,1.17,1.18,1.18,1.17,1.17,1.19,1.12,1.17,1.17,1.14,1.16	300	200	1
4	15	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.59,1.68,1.67,1.67,1.64,1.68,1.67,1.67,1.68,1.67,1.68,1.68,1.79,1.68,1.67,1.67,1.65,1.68	300	200	1
5	15	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.70,1.65,1.67,1.67,1.40,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.69,1.61,1.67,1.67,1.64,1.66	300	200	1
6	15	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.20,1.18,1.19,1.19,1.07,1.18,1.19,1.19,1.19,1.19,1.19,1.19,1.20,1.15,1.19,1.19,1.17,1.18	300	200	1
7	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.69,1.66,1.67,1.67,1.55,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.68,1.62,1.67,1.67,1.64,1.66	300	200	1
8	18	1.33	1.33	2.05	1.34,1.34,1.34,1.34,1.34,1.34,1.32,1.32,1.45,1.46,1.32,1.32,1.38,1.53,1.33,1.33,1.33,1.37,1.32,1.32,1.26,1.42,1.32,1.32,1.37,1.62	300	200	1
9	1	2.60	2.60	4.00	-	300	200	1
10	15	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.61,1.68,1.67,1.67,1.64,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.75,1.68,1.67,1.67,1.65,1.68	300	200	1
11	18	1.33	1.33	2.05	1.35,1.35,1.35,1.35,1.35,1.35,1.37,1.37,1.45,1.58,1.37,1.37,1.14,1.49,1.36,1.36,1.36,1.29,1.36,1.36,1.38,2.10,1.37,1.37,1.27,1.46	300	200	1
12	4	4.20	4.20	2.00	-	300	200	1
13	18	4.88	4.00	7.50	1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.19,1.26,1.44,1.19,1.19,1.35,1.32,1.18,1.18,1.19,1.14,1.19,1.19,1.21,1.92,1.19,1.19,1.10,1.27	300	200	1
14	18	4.88	4.00	7.50	1.17,1.17,1.17,1.17,1.17,1.17,1.16,1.16,1.42,1.27,1.16,1.16,1.24,1.38,1.17,1.17,1.16,1.20,1.16,1.16,1.10,1.24,1.16,1.16,1.22,1.52	300	200	1
15	18	4.20	4.20	2.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
16	18	4.20	4.20	2.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
101	7	13.25	13.25	6.31	-	300	200	1
102	4	1.30	1.30	2.00	-	300	200	1
103	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.20,1.17,1.18,1.18,1.10,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.13,1.18,1.18,1.17,1.17	300	200	1
104	15	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.62,1.67,1.67,1.67,1.65,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.73,1.68,1.67,1.67,1.66,1.68	300	200	1
105	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.69,1.66,1.67,1.67,1.58,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.68,1.62,1.67,1.67,1.65,1.66	300	200	1
106	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.20,1.17,1.18,1.18,1.07,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.15,1.18,1.18,1.16,1.18	300	200	1
107	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.69,1.66,1.67,1.67,1.57,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.68,1.63,1.67,1.67,1.65,1.66	300	200	1
108	18	1.33	1.33	2.05	2.19,2.20,2.19,2.20,2.19,2.19,2.32,2.32,2.09,2.08,2.34,2.34,2.11,2.07,2.26,2.26,2.25,2.11,2.29,2.29,2.34,2.09,2.35,2.35,2.12,2.05	300	200	1
109	1	2.60	2.60	4.00	-	300	200	1
110	15	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.62,1.67,1.67,1.67,1.65,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.74,1.68,1.67,1.67,1.66,1.68	300	200	1
111	18	1.33	1.33	2.05	2.16,2.16,2.16,2.17,2.16,2.16,2.12,2.12,2.08,2.06,2.11,2.11,2.04,2.07,2.12,2.12,2.12,2.35,2.12,2.12,2.11,1.58,2.11,2.11,2.33,2.08	300	200	1
112	4	1.30	1.30	2.00	-	300	200	1

113	18	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.05,1.10,1.24,1.05,1.05,1.04,1.14,1.04,1.04,1.04,1.03,1.04,1.04,1.05,2.71,1.05,1.05,1.03,1.11	300	200	1
114	18	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.19,1.11,1.04,1.04,1.05,1.20,1.04,1.04,1.04,1.05,1.04,1.04,1.03,1.06,1.04,1.04,1.05,1.33	300	200	1
115	18	10.20	10.20	10.20	1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.17,1.15,1.12,1.17,1.17,1.34,1.14,1.17,1.17,1.18,1.21,1.17,1.17,1.17,1.09,1.17,1.17,1.21,1.14	300	200	1
116	18	6.63	6.63	10.20	1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.19,1.15,1.14,1.19,1.19,1.17,1.13,1.18,1.18,1.18,1.17,1.19,1.19,1.21,1.15,1.19,1.19,1.17,1.11	300	200	1
201	7	13.25	13.25	6.31	-	300	200	1
202	4	1.30	1.30	2.00	-	300	200	1
203	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.20,1.17,1.18,1.18,1.05,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.15,1.18,1.18,1.16,1.17	300	200	1
204	15	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.62,1.67,1.67,1.67,1.65,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.74,1.68,1.67,1.67,1.65,1.68	300	200	1
205	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.68,1.66,1.67,1.67,1.55,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.68,1.63,1.66,1.66,1.64,1.66	300	200	1
206	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.20,1.17,1.18,1.18,1.05,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.15,1.18,1.18,1.16,1.17	300	200	1
207	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.69,1.66,1.67,1.67,1.55,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.68,1.63,1.67,1.67,1.65,1.66	300	200	1
208	18	1.33	1.33	2.05	2.07,2.07,2.07,2.07,2.07,2.07,2.07,2.07,2.12,2.10,2.07,2.07,2.09,2.11,2.07,2.07,2.07,2.08,2.07,2.07,1.93,2.09,2.07,2.07,2.08,2.12	300	200	1
209	1	2.60	2.60	4.00	-	300	200	1
210	15	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.62,1.67,1.67,1.67,1.65,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.74,1.68,1.67,1.67,1.66,1.68	300	200	1
211	18	1.33	1.33	2.05	2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.11,2.11,2.08,2.08,1.64,2.10,2.08,2.08,2.08,2.07,2.08,2.08,2.09,2.37,2.08,2.08,2.06,2.10	300	200	1
212	4	1.30	1.30	2.00	-	300	200	1
213	18	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.05,1.08,1.15,1.05,1.05,1.04,1.10,1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.40,1.05,1.05,1.04,1.08	300	200	1
214	18	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.16,1.08,1.04,1.04,1.05,1.13,1.04,1.04,1.04,1.05,1.04,1.04,1.04,1.05,1.04,1.04,1.05,1.19	300	200	1
215	18	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.17,1.16,1.16,1.15,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.20,1.16,1.16,1.16,1.16	300	200	1
216	18	10.20	10.20	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.17,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.15,1.16,1.16,1.16,1.16,1.17	300	200	1
301	7	13.25	13.25	6.31	-	300	200	1
302	4	1.30	1.30	2.00	-	300	200	1
303	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.20,1.17,1.18,1.18,1.07,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.15,1.18,1.18,1.16,1.18	300	200	1
304	15	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.62,1.67,1.67,1.67,1.65,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.74,1.68,1.67,1.67,1.66,1.68	300	200	1
305	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.69,1.66,1.67,1.67,1.57,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.68,1.63,1.67,1.67,1.65,1.66	300	200	1
306	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.20,1.17,1.18,1.18,1.10,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.13,1.18,1.18,1.17,1.17	300	200	1
307	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.69,1.66,1.67,1.67,1.58,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.68,1.62,1.67,1.67,1.65,1.66	300	200	1
308	18	1.33	1.33	2.05	2.09,2.09,2.09,2.09,2.09,2.09,2.11,2.11,1.89,1.84,2.11,2.11,2.07,1.69,2.10,2.10,2.10,2.08,2.10,2.10,2.28,1.96,2.11,2.11,2.08,1.57	300	200	1
309	1	2.60	2.60	4.00	-	300	200	1
310	15	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.62,1.67,1.67,1.67,1.65,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.73,1.68,1.67,1.67,1.66,1.68	300	200	1
311	18	1.33	1.33	2.05	2.09,2.09,2.09,2.09,2.09,2.09,2.08,2.08,1.90,1.61,2.08,2.08,1.98,1.76,2.08,2.08,2.09,2.20,2.08,2.08,2.07,1.30,2.08,2.08,2.27,1.82	300	200	1
312	4	1.30	1.30	2.00	-	300	200	1
313	18	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.10,1.24,1.05,1.05,1.04,1.14,1.04,1.04,1.04,1.03,1.04,1.04,1.05,2.70,1.05,1.05,1.03,1.11	300	200	1
314	18	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.19,1.11,1.04,1.04,1.05,1.20,1.04,1.04,1.04,1.05,1.04,1.04,1.03,1.06,1.04,1.04,1.05,1.33	300	200	1

315	18	10.20	10.20	10.20	1.21,1.21,1.21,1.21,1.21,1.21,1.21,1.21,1.19,1.18,1.21,1.21,1.30,1.19,1.21,1.21,1.21,1.23,1.21,1.21,1.21,1.14,1.21,1.21,1.23,1.19	300	200	1
316	18	6.63	6.63	10.20	1.21,1.21,1.21,1.21,1.21,1.21,1.22,1.22,1.20,1.19,1.22,1.22,1.21,1.18,1.22,1.22,1.22,1.21,1.22,1.22,1.23,1.20,1.22,1.22,1.21,1.17	300	200	1
401	7	13.25	13.25	6.31	-	300	200	1
402	4	4.20	4.20	2.00	-	300	200	1
403	15	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.20,1.18,1.19,1.19,1.07,1.18,1.18,1.18,1.19,1.19,1.19,1.19,1.20,1.15,1.18,1.18,1.17,1.18	300	200	1
404	15	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.61,1.68,1.67,1.67,1.64,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.75,1.68,1.67,1.67,1.65,1.68	300	200	1
405	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.69,1.66,1.67,1.67,1.55,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.68,1.62,1.67,1.67,1.64,1.66	300	200	1
406	15	0.92	0.92	1.42	1.18,1.18,1.18,1.17,1.18,1.18,1.17,1.17,1.20,1.16,1.17,1.17,1.41,1.16,1.17,1.17,1.18,1.18,1.17,1.17,1.19,1.12,1.17,1.17,1.14,1.16	300	200	1
407	15	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.70,1.65,1.67,1.67,1.40,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.69,1.61,1.67,1.67,1.64,1.66	300	200	1
408	18	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	1	2.60	2.60	4.00	-	300	200	1
410	15	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.59,1.68,1.67,1.67,1.64,1.68,1.67,1.67,1.68,1.67,1.68,1.68,1.79,1.68,1.67,1.67,1.65,1.68	300	200	1
411	18	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
412	4	1.30	1.30	2.00	-	300	200	1
413	18	4.88	4.00	7.50	1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.19,1.26,1.44,1.19,1.19,1.35,1.31,1.18,1.18,1.19,1.14,1.19,1.19,1.21,1.92,1.19,1.19,1.10,1.27	300	200	1
414	18	4.88	4.00	7.50	1.17,1.17,1.17,1.17,1.17,1.17,1.16,1.16,1.42,1.27,1.16,1.16,1.24,1.38,1.17,1.17,1.16,1.20,1.16,1.16,1.10,1.24,1.16,1.16,1.22,1.52	300	200	1
415	18	10.20	10.20	10.20	1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.11,1.12,1.10,1.10,1.11,1.11,1.10,1.10,1.10,1.10,1.10,1.10,1.11,1.18,1.10,1.10,1.09,1.11	300	200	1
416	18	6.63	6.63	10.20	1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.11,1.11,1.10,1.10,1.11,1.12,1.10,1.10,1.10,1.10,1.10,1.10,1.09,1.11,1.10,1.10,1.10,1.12	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	174.12	42.30	42.30	75.35	75.35
2	142.83	141.72	16.17	16.17	42.85	42.85
3	79.65	74.02	10.99	6.26	29.14	16.61
4	79.65	72.01	10.99	6.26	29.14	16.61
5	79.65	73.44	10.99	6.26	29.14	16.61
6	79.65	74.02	10.99	6.26	29.14	16.61
7	79.65	73.44	10.99	6.26	29.14	16.61
8	120.60	115.40	23.36	6.45	30.09	45.74
9	48.35	43.11	2.85	2.85	14.51	14.51
10	79.65	72.01	10.99	6.26	29.14	16.61
11	120.60	115.40	23.36	6.45	30.09	45.74
12	142.83	131.65	16.17	16.17	42.85	42.85
13	120.60	84.02	19.29	6.45	30.09	45.74
14	120.60	84.02	19.43	6.45	30.09	45.74
15	120.60	96.18	23.36	6.45	30.09	45.74
16	120.60	96.18	23.36	6.45	30.09	45.74
101	251.16	174.12	42.30	42.30	75.35	75.35
102	142.83	141.72	16.17	16.17	42.85	42.85
103	79.65	74.02	10.99	6.26	29.14	16.61

104	79.65	72.01	10.99	6.26	29.14	16.61
105	79.65	73.44	10.99	6.26	29.14	16.61
106	79.65	74.02	10.99	6.26	29.14	16.61
107	79.65	73.44	10.99	6.26	29.14	16.61
108	120.60	115.40	23.36	6.45	30.09	45.74
109	48.35	43.11	2.85	2.85	14.51	14.51
110	79.65	72.01	10.99	6.26	29.14	16.61
111	120.60	115.40	23.36	6.45	30.09	45.74
112	142.83	141.72	16.17	16.17	42.85	42.85
113	120.60	84.03	18.18	6.45	30.09	45.74
114	120.60	84.03	18.18	6.45	30.09	45.74
115	120.60	33.17	14.95	6.45	30.09	45.74
116	120.60	68.63	15.21	6.45	30.09	45.74
201	251.16	174.12	42.30	42.30	75.35	75.35
202	142.83	141.72	16.17	16.17	42.85	42.85
203	79.65	74.02	10.99	6.26	29.14	16.61
204	79.65	72.01	10.99	6.26	29.14	16.61
205	79.65	73.44	10.99	6.26	29.14	16.61
206	79.65	74.02	10.99	6.26	29.14	16.61
207	79.65	73.44	10.99	6.26	29.14	16.61
208	120.60	115.40	23.36	6.45	30.09	45.74
209	48.35	43.11	2.85	2.85	14.51	14.51
210	79.65	72.01	10.99	6.26	29.14	16.61
211	120.60	115.40	23.36	6.45	30.09	45.74
212	142.83	141.72	16.17	16.17	42.85	42.85
213	120.60	84.02	18.29	6.45	30.09	45.74
214	120.60	84.02	18.30	6.45	30.09	45.74
215	120.60	68.63	15.67	6.45	30.09	45.74
216	120.60	33.17	15.70	6.45	30.09	45.74
301	251.16	174.12	42.30	42.30	75.35	75.35
302	142.83	141.72	16.17	16.17	42.85	42.85
303	79.65	74.02	10.99	6.26	29.14	16.61
304	79.65	72.01	10.99	6.26	29.14	16.61
305	79.65	73.44	10.99	6.26	29.14	16.61
306	79.65	74.02	10.99	6.26	29.14	16.61
307	79.65	73.44	10.99	6.26	29.14	16.61
308	120.60	115.40	23.36	6.45	30.09	45.74
309	48.35	43.11	2.85	2.85	14.51	14.51
310	79.65	72.01	10.99	6.26	29.14	16.61
311	120.60	115.40	23.36	6.45	30.09	45.74
312	142.83	141.72	16.17	16.17	42.85	42.85
313	120.60	84.03	18.18	6.45	30.09	45.74
314	120.60	84.03	18.18	6.45	30.09	45.74
315	120.60	33.17	15.53	6.45	30.09	45.74
316	120.60	68.63	16.03	6.45	30.09	45.74
401	251.16	174.12	42.30	42.30	75.35	75.35
402	142.83	131.65	16.17	16.17	42.85	42.85
403	79.65	74.02	10.99	6.26	29.14	16.61
404	79.65	72.01	10.99	6.26	29.14	16.61
405	79.65	73.44	10.99	6.26	29.14	16.61
406	79.65	74.02	10.99	6.26	29.14	16.61
407	79.65	73.44	10.99	6.26	29.14	16.61

407	79.65	73.44	10.99	6.26	29.14	16.61
408	120.60	96.18	23.36	6.45	30.09	45.74
409	48.35	43.11	2.85	2.85	14.51	14.51
410	79.65	72.01	10.99	6.26	29.14	16.61
411	120.60	96.18	23.36	6.45	30.09	45.74
412	142.83	141.72	16.17	16.17	42.85	42.85
413	120.60	84.02	19.29	6.45	30.09	45.74
414	120.60	84.02	19.43	6.45	30.09	45.74
415	120.60	33.17	14.95	6.45	30.09	45.74
416	120.60	68.63	14.93	6.45	30.09	45.74

Design Ratio

Member ID	P	M_z	M_y	V_y	V_z	(P,M_z,M_y)	Worst LC	KL/r	δ	Status
1	0.032	0.224	0.060	0.007	0.007	0.227	#16	0.354	Not Required	Pass
2	0.002	0.217	0.029	0.051	0.005	0.247	#13	0.052	Not Required	Pass
3	0.003	0.422	0.028	0.041	0.006	0.451	#13	0.044	Not Required	Pass
4	0.001	0.347	0.057	0.035	0.010	0.403	#21	0.117	Not Required	Pass
5	0.002	0.262	0.016	0.042	0.005	0.279	#13	0.073	Not Required	Pass
6	0.002	0.592	0.064	0.062	0.013	0.645	#13	0.044	Not Required	Pass
7	0.003	0.367	0.072	0.059	0.016	0.390	#13	0.073	Not Required	Pass
8	0.002	0.091	0.027	0.029	0.003	0.106	#21	0.088	Not Required	Pass
9	0.001	0.074	0.044	0.003	0.003	0.116	#21	0.198	Not Required	Pass
10	0.004	0.492	0.036	0.050	0.006	0.505	#21	0.078	Not Required	Pass
11	0.003	0.104	0.030	0.036	0.003	0.112	#13	0.088	Not Required	Pass
12	0.002	0.375	0.042	0.075	0.007	0.418	#13	0.167	Not Required	Pass
13	0.004	0.089	0.072	0.047	0.004	0.135	#21	0.265	Not Required	Pass
14	0.003	0.074	0.069	0.039	0.004	0.115	#24	0.177	Not Required	Pass
15	0.000	0.017	0.007	0.013	0.001	0.022	#21	Not Required	Not Required	Pass
16	0.000	0.014	0.007	0.011	0.001	0.021	#21	Not Required	Not Required	Pass
101	0.043	0.280	0.009	0.010	0.001	0.283	#16	0.354	Not Required	Pass
102	0.000	0.422	0.052	0.088	0.009	0.474	#13	0.034	Not Required	Pass
103	0.003	0.699	0.027	0.071	0.004	0.719	#13	0.044	Not Required	Pass
104	0.003	0.591	0.045	0.060	0.008	0.620	#21	0.078	Not Required	Pass
105	0.003	0.433	0.055	0.070	0.011	0.445	#13	0.073	Not Required	Pass
106	0.003	0.677	0.019	0.068	0.003	0.684	#13	0.044	Not Required	Pass
107	0.003	0.420	0.047	0.068	0.009	0.425	#13	0.073	Not Required	Pass
108	0.002	0.039	0.025	0.034	0.003	0.065	#21	0.088	Not Required	Pass
109	0.003	0.073	0.019	0.001	0.000	0.093	#13	0.198	Not Required	Pass
110	0.003	0.566	0.054	0.057	0.010	0.608	#21	0.078	Not Required	Pass
111	0.002	0.046	0.025	0.040	0.003	0.067	#21	0.088	Not Required	Pass
112	0.001	0.398	0.050	0.084	0.009	0.449	#13	0.034	Not Required	Pass
113	0.004	0.198	0.068	0.055	0.004	0.246	#21	0.265	Not Required	Pass
114	0.004	0.179	0.070	0.047	0.004	0.235	#21	0.265	Not Required	Pass
115	0.010	0.225	0.036	0.044	0.003	0.252	#21	0.675	Not Required	Pass
116	0.003	0.189	0.039	0.037	0.003	0.229	#21	0.439	Not Required	Pass
201	0.041	0.284	0.000	0.009	0.000	0.287	#16	0.354	Not Required	Pass
202	0.001	0.389	0.048	0.082	0.008	0.437	#13	0.034	Not Required	Pass
203	0.003	0.659	0.021	0.067	0.003	0.673	#13	0.044	Not Required	Pass
204	0.003	0.546	0.047	0.055	0.008	0.580	#21	0.078	Not Required	Pass
205	0.003	0.409	0.049	0.066	0.010	0.417	#13	0.073	Not Required	Pass

206	0.003	0.660	0.021	0.067	0.003	0.674	#13	0.044	Not Required	Pass
207	0.003	0.409	0.049	0.066	0.010	0.417	#13	0.073	Not Required	Pass
208	0.002	0.044	0.024	0.032	0.003	0.056	#21	0.088	Not Required	Pass
209	0.003	0.067	0.014	0.001	0.000	0.081	#13	0.198	Not Required	Pass
210	0.003	0.546	0.047	0.055	0.008	0.580	#21	0.078	Not Required	Pass
211	0.002	0.052	0.024	0.039	0.003	0.060	#21	0.088	Not Required	Pass
212	0.001	0.389	0.048	0.082	0.008	0.437	#13	0.034	Not Required	Pass
213	0.003	0.181	0.065	0.051	0.004	0.227	#21	0.265	Not Required	Pass
214	0.003	0.155	0.065	0.042	0.004	0.205	#21	0.265	Not Required	Pass
215	0.004	0.172	0.037	0.039	0.003	0.200	#21	0.439	Not Required	Pass
216	0.006	0.143	0.038	0.032	0.003	0.183	#21	0.675	Not Required	Pass
301	0.043	0.280	0.009	0.010	0.001	0.283	#16	0.354	Not Required	Pass
302	0.001	0.398	0.050	0.084	0.009	0.449	#13	0.034	Not Required	Pass
303	0.003	0.677	0.019	0.068	0.003	0.684	#13	0.044	Not Required	Pass
304	0.003	0.566	0.054	0.057	0.010	0.608	#21	0.078	Not Required	Pass
305	0.003	0.420	0.047	0.068	0.009	0.425	#13	0.073	Not Required	Pass
306	0.003	0.698	0.027	0.071	0.004	0.719	#13	0.044	Not Required	Pass
307	0.003	0.433	0.055	0.070	0.011	0.444	#13	0.073	Not Required	Pass
308	0.002	0.050	0.028	0.037	0.003	0.063	#21	0.088	Not Required	Pass
309	0.003	0.073	0.019	0.001	0.000	0.092	#13	0.198	Not Required	Pass
310	0.003	0.591	0.045	0.060	0.008	0.620	#21	0.078	Not Required	Pass
311	0.003	0.064	0.027	0.044	0.003	0.068	#21	0.088	Not Required	Pass
312	0.000	0.422	0.052	0.088	0.009	0.474	#13	0.034	Not Required	Pass
313	0.004	0.199	0.069	0.055	0.004	0.246	#21	0.265	Not Required	Pass
314	0.004	0.179	0.070	0.047	0.004	0.235	#21	0.265	Not Required	Pass
315	0.009	0.166	0.038	0.040	0.003	0.198	#21	0.675	Not Required	Pass
316	0.003	0.138	0.038	0.034	0.003	0.177	#21	0.439	Not Required	Pass
401	0.032	0.224	0.060	0.007	0.007	0.227	#16	0.354	Not Required	Pass
402	0.002	0.374	0.042	0.075	0.007	0.418	#13	0.167	Not Required	Pass
403	0.002	0.592	0.064	0.062	0.013	0.645	#13	0.044	Not Required	Pass
404	0.004	0.492	0.036	0.050	0.006	0.505	#21	0.078	Not Required	Pass
405	0.003	0.367	0.072	0.059	0.016	0.391	#13	0.073	Not Required	Pass
406	0.003	0.422	0.028	0.041	0.006	0.452	#13	0.044	Not Required	Pass
407	0.002	0.262	0.016	0.042	0.005	0.279	#13	0.073	Not Required	Pass
408	0.000	0.014	0.007	0.011	0.001	0.021	#21	Not Required	Not Required	Pass
409	0.001	0.074	0.044	0.003	0.003	0.116	#21	0.198	Not Required	Pass
410	0.001	0.347	0.057	0.035	0.010	0.403	#21	0.117	Not Required	Pass
411	0.000	0.017	0.007	0.013	0.001	0.022	#21	Not Required	Not Required	Pass
412	0.002	0.217	0.029	0.051	0.005	0.247	#13	0.052	Not Required	Pass
413	0.004	0.089	0.072	0.047	0.004	0.135	#21	0.177	Not Required	Pass
414	0.003	0.074	0.069	0.039	0.004	0.115	#24	0.265	Not Required	Pass
415	0.010	0.240	0.037	0.036	0.003	0.265	#21	0.675	Not Required	Pass
416	0.003	0.202	0.039	0.029	0.003	0.243	#21	0.439	Not Required	Pass

Definitions

Φ_t	Safety factor for tensile
Φ_c	Safety factor for compression
Φ_b	Safety factor for flexure
Φ_v	Safety factor for shear
E	Modulus of elasticity
F_y	Specified minimum yield stress
F_u	Specified minimum tensile strength

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

REFERENCES	CALCULATIONS	RESULTS

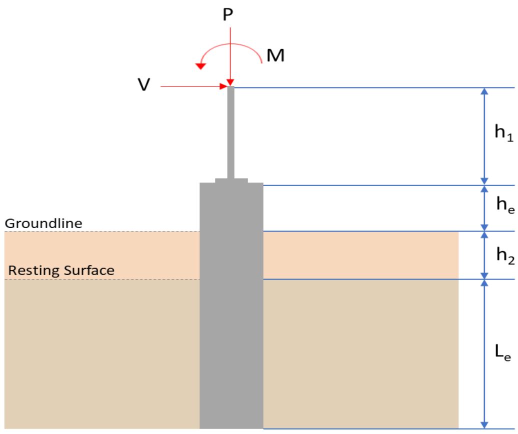
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular

$b = 48\ \text{in}$ - Pile width

$D = 48\ \text{in}$ - Pile depth

$L = 4\ \text{ft}$ - 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)	3.923	5.553
V_x (kip)	-0.318	-0.540
V_z (kip)	0.351	0.506
M_x (kipft)	0.442	0.632
M_z (kipft)	5.633	9.481

Material Properties

$f'_{ck} = 2.5\ \text{ksi}$ - 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,

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

$$H_o = \frac{(-0.318\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.050637\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(5.633\ \text{kipft}) + ((-0.318\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.89697\ \text{kipft/ft}$$

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:
$L_{e,x} = 3.9121\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.351\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.055892\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.442\ \text{kipft}) + ((0.351\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.070382\ \text{kipft/ft}$$

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:
$L_{e,z} = 2.3895\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(3.9121\ \text{ft}), (2.3895\ \text{ft})]$$

$$L_{e,req} = 3.912\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (4\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 4\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(3.912\ \text{ft})}{(4\ \text{ft})}$$

$$Ratio = 0.978$$

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

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

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

$$q = \frac{(3.923\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.24519\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.24519\ \text{kip/ft}^2)}{(2000\ \text{psf})}$$

$$Ratio = 0.12259$$

Status: **PASS**
Ratio: **0.120**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(4\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 1$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.050637\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.89697\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.89697\ \text{kipft/ft}) \times (4\ \text{ft})) + \left(3 \times (-0.050637\ \text{kip/ft}) \times (4\ \text{ft})^2\right)}{(6 \times (0.89697\ \text{kipft/ft})) + (4 \times (-0.050637\ \text{kip/ft}) \times (4\ \text{ft}))}$$

$$a = 2.7103\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.89697\ \text{kipft/ft})) + (3 \times (-0.050637\ \text{kip/ft}) \times (4\ \text{ft}))]^{\ 2}}{(4\ \text{ft})^2 \times [(3 \times (0.89697\ \text{kipft/ft})) + (2 \times (-0.050637\ \text{kip/ft}) \times (4\ \text{ft}))]}$$

$$p = 0.18214\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.89697\ \text{kipft/ft})) + ((-0.050637\ \text{kip/ft}) \times (4\ \text{ft}))]}{(4\ \text{ft})^2}$$

$$s = 0.59678\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(2.7103\ \text{ft})}{2}$$

$$p_a = 0.20327\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.18214 \text{ kip/ft}^2\right)}{\left(0.20327 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.89604$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150 \text{ psf/ft}) \times (4 \text{ ft})$$

$$p_s = 0.6 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.59678 \text{ kip/ft}^2\right)}{\left(0.6 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.99463$$

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

Considering z-direction:

$H_o = 0.055892 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 0.070382 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.070382 \text{ kipft/ft}) \times (4 \text{ ft})) + \left(3 \times (0.055892 \text{ kip/ft}) \times (4 \text{ ft})^2\right)}{(6 \times (0.070382 \text{ kipft/ft})) + (4 \times (0.055892 \text{ kip/ft}) \times (4 \text{ ft}))}$$

$$a = 2.8931 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.070382 \text{ kipft/ft})) + (3 \times (0.055892 \text{ kip/ft}) \times (4 \text{ ft}))]^{\;2}}{(4 \text{ ft})^2 \times [(3 \times (0.070382 \text{ kipft/ft})) + (2 \times (0.055892 \text{ kip/ft}) \times (4 \text{ ft}))]}$$

$$p = 0.064567 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.070382 \text{ kipft/ft})) + ((0.055892 \text{ kip/ft}) \times (4 \text{ ft}))]}{(4 \text{ ft})^2}$$

$$s = 0.13662 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(2.8931 \text{ ft})}{2}$$

$$p_a = 0.21698 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.064567 \text{ kip/ft}^2\right)}{\left(0.21698 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.29757$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\text{ psf/ft}) \times (4\text{ ft})$$

$$p_s = 0.6\text{ kip/ft}^2$$

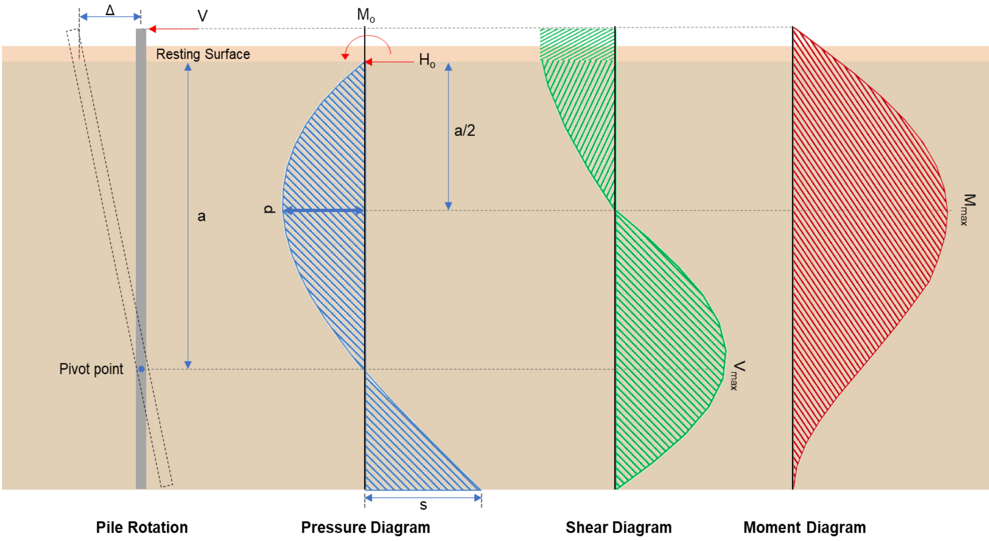
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.13662\text{ kip/ft}^2)}{(0.6\text{ kip/ft}^2)}$$

$$Ratio = 0.22771$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.54\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = -0.085987\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(9.481\text{ kipft}) + ((-0.54\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 1.5097\text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(1.5097\text{ kipft/ft})}{(-0.085987\text{ kip/ft})}$$

$$E = 17.557\text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.5097\text{ kipft/ft}) \times (4\text{ ft})) + \left(3 \times (-0.085987\text{ kip/ft}) \times (4\text{ ft})^2\right)}{}$$

$$a = \frac{\ldots}{(6 \times (1.5097\ \text{kipft/ft})) + (4 \times (-0.085987\ \text{kip/ft}) \times (4\ \text{ft}))}$$

$$a = 2.7106\ \text{ft}$$

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

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

$$V_{max} = ((-0.085987\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (17.557\ \text{ft})}{(4\ \text{ft})} + 3\right) \times \left(\frac{(2.7106\ \text{ft})}{(4\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (17.557\ \text{ft})}{(4\ \text{ft})} + 2\right) \times \left(\frac{(2.7106\ \text{ft})}{(4\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 2.903\ \text{kip}$$

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

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

$$M_{max} = ((-0.085987\ \text{kip/ft}) \times (48\ \text{in}) \times (4\ \text{ft})) \times \left[\left(\frac{(17.557\ \text{ft})}{(4\ \text{ft})} + \frac{(2.7106\ \text{ft})}{2 \times (4\ \text{ft})}\right) - \left[\left(\frac{4 \times (17.557\ \text{ft})}{(4\ \text{ft})} + 3\right) \times \left(\frac{(2.7106\ \text{ft})}{2 \times (4\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (17.557\ \text{ft})}{(4\ \text{ft})} + 2\right) \times \left(\frac{(2.7106\ \text{ft})}{2 \times (4\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 5.6799\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.506\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.080573\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.632\ \text{kipft}) + ((0.506\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.10064\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.10064\ \text{kipft/ft})}{(0.080573\ \text{kip/ft})}$$

$$E = 1.249\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.10064\ \text{kipft/ft}) \times (4\ \text{ft})) + \left(3 \times (0.080573\ \text{kip/ft}) \times (4\ \text{ft})^2\right)}{(6 \times (0.10064\ \text{kipft/ft})) + (4 \times (0.080573\ \text{kip/ft}) \times (4\ \text{ft}))}$$

$$a = 2.8937\ \text{ft}$$

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

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

$$V_{max} = ((0.080573\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (1.249\ \text{ft})}{(4\ \text{ft})} + 3\right) \times \left(\frac{(2.8937\ \text{ft})}{(4\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (1.249\ \text{ft})}{(4\ \text{ft})} + 2\right) \times \left(\frac{(2.8937\ \text{ft})}{(4\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.39438\ \text{kip}$$

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

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

$$M_{max} = ((0.080573\ \text{kip/ft}) \times (48\ \text{in}) \times (4\ \text{ft})) \times \left[\left(\frac{(1.249\ \text{ft})}{(4\ \text{ft})} + \frac{(2.8937\ \text{ft})}{2 \times (4\ \text{ft})}\right) - \left[\left(\frac{4 \times (1.249\ \text{ft})}{(4\ \text{ft})} + 3\right) \times \left(\frac{(2.8937\ \text{ft})}{2 \times (4\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (1.249\ \text{ft})}{(4\ \text{ft})} + 2\right) \times \left(\frac{(2.8937\ \text{ft})}{2 \times (4\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.67443\ \text{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(5.553\ \text{kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.412\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.412\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

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,

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

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

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

Ties:

25.7.2.2 Since longitudinal reinforcement is $\leq$ No. 10ø: Use #3(0.375 in)

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

Main reinforcement: **14 - #5 (0.625 in)**
Ties: **#3(0.375 in) - 10 in**

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

$$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(2304\ \text{in}^2\right) - \left(4.2951\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(4.2951\ \text{in}^2\right)\right)\right]$$

$$\phi P_N = 2675.2\ \text{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(5.553\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0020757$$

Status: PASS
Ratio: 0.000

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,max} = 296.21 \text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}, P = 5.553 \text{ kip} \rightarrow 5553 \text{ lbf},$

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(5553 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.23 \text{ kip}$$

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

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

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

$$V_{c,b} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + (0.05 \times (2500 \text{ psi}))\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,b} = 348.89 \text{ kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (119.23 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 119.23 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.23 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.58 \text{ kip}$$

Considering x-direction:

$V_{max} = 2.903 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(2.903 \text{ kip})}{(110.58 \text{ kip})}$$

$$Ratio = 0.026253$$

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

Considering z-direction:

$V_{max} = 0.39438 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.39438 \text{ kip})}{(110.58 \text{ kip})}$$

$$Ratio = 0.0035665$$

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:
$\phi M_{n,1}$

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

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

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

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

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

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

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

Therefore,
ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 5.6799 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(5.6799 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.022756$$

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

Considering z-direction:

$M_{max} = 0.67443 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(0.67443 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.0027021$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

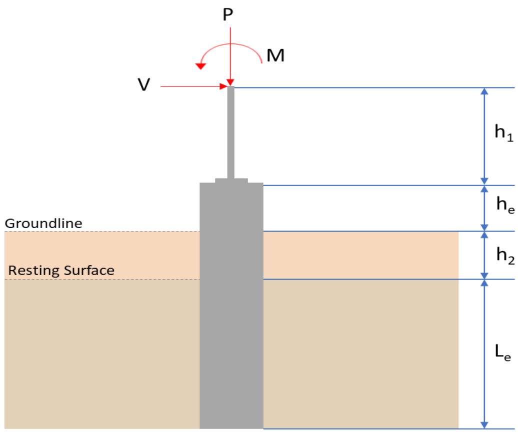
SkyCiv Foundation Design

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

$L = 4\ \text{ft}$ - 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)	3.923	5.553
V_x (kip)	-0.318	-0.540
V_z (kip)	-0.351	-0.506
M_x (kipft)	-0.444	-0.636
M_z (kipft)	5.634	9.483

Material Properties

$f'_{ck} = 2.5\ \text{ksi}$ - 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,

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

$$H_o = \frac{(-0.318\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.050637\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(5.634\text{ kipft}) + ((-0.318\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 0.89713\text{ kipft/ft}$$

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:
$L_{e,x} = 3.9123\text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.351\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = -0.055892\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.444\text{ kipft}) + ((-0.351\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 0.070701\text{ kipft/ft}$$

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:
$L_{e,z} = 1.1874\text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(3.9123\text{ ft}), (1.1874\text{ ft})]$$

$$L_{e,req} = 3.912\text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (4\text{ ft}) - (0\text{ ft}) - (0\text{ ft})$$

$$L_e = 4\text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(3.912\text{ ft})}{(4\text{ ft})}$$

$$Ratio = 0.978$$

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

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

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

$$q = \frac{(3.923\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.24519\ \mathrm{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.24519\ \mathrm{kip/ft}^2\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.12259$$

Status: **PASS**
Ratio: **0.120**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(4\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.050637\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.89713\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.89713\ \mathrm{kipft/ft}) \times (4\ \mathrm{ft})) + \left(3 \times (-0.050637\ \mathrm{kip/ft}) \times (4\ \mathrm{ft})^2\right)}{(6 \times (0.89713\ \mathrm{kipft/ft})) + (4 \times (-0.050637\ \mathrm{kip/ft}) \times (4\ \mathrm{ft}))}$$

$$a = 2.7103\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.89713\ \mathrm{kipft/ft})) + (3 \times (-0.050637\ \mathrm{kip/ft}) \times (4\ \mathrm{ft}))]^{\,2}}{(4\ \mathrm{ft})^2 \times [(3 \times (0.89713\ \mathrm{kipft/ft})) + (2 \times (-0.050637\ \mathrm{kip/ft}) \times (4\ \mathrm{ft}))]}$$

$$p = 0.18218\ \mathrm{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.89713\ \mathrm{kipft/ft})) + ((-0.050637\ \mathrm{kip/ft}) \times (4\ \mathrm{ft}))]}{(4\ \mathrm{ft})^2}$$

$$s = 0.59689\ \mathrm{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(2.7103\ \mathrm{ft})}{2}$$

$$p_a = 0.20327\ \mathrm{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.18218\ \mathrm{kip/ft^2}\right)}{\left(0.20327\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.89624$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (4\ \mathrm{ft})$$

$$p_s = 0.6\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.59689\ \mathrm{kip/ft^2}\right)}{\left(0.6\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.99482$$

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

Considering z-direction:

$H_o = -0.055892\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.070701\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.070701\ \mathrm{kipft/ft}) \times (4\ \mathrm{ft})) + \left(3 \times (-0.055892\ \mathrm{kip/ft}) \times (4\ \mathrm{ft})^2\right)}{(6 \times (0.070701\ \mathrm{kipft/ft})) + (4 \times (-0.055892\ \mathrm{kip/ft}) \times (4\ \mathrm{ft}))}$$

$$a = 2.8928\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.070701\ \mathrm{kipft/ft})) + (3 \times (-0.055892\ \mathrm{kip/ft}) \times (4\ \mathrm{ft}))]^{\,2}}{(4\ \mathrm{ft})^2 \times [(3 \times (0.070701\ \mathrm{kipft/ft})) + (2 \times (-0.055892\ \mathrm{kip/ft}) \times (4\ \mathrm{ft}))]}$$

$$p = -0.030009\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.070701\ \mathrm{kipft/ft})) + ((-0.055892\ \mathrm{kip/ft}) \times (4\ \mathrm{ft}))]}{(4\ \mathrm{ft})^2}$$

$$s = -0.030812\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(2.8928\ \mathrm{ft})}{2}$$

$$p_a = 0.21696\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.030009\ \mathrm{kip/ft^2}\right)}{\left(0.21696\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.13832$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\text{ psf/ft}) \times (4\text{ ft})$$

$$p_s = 0.6\text{ kip/ft}^2$$

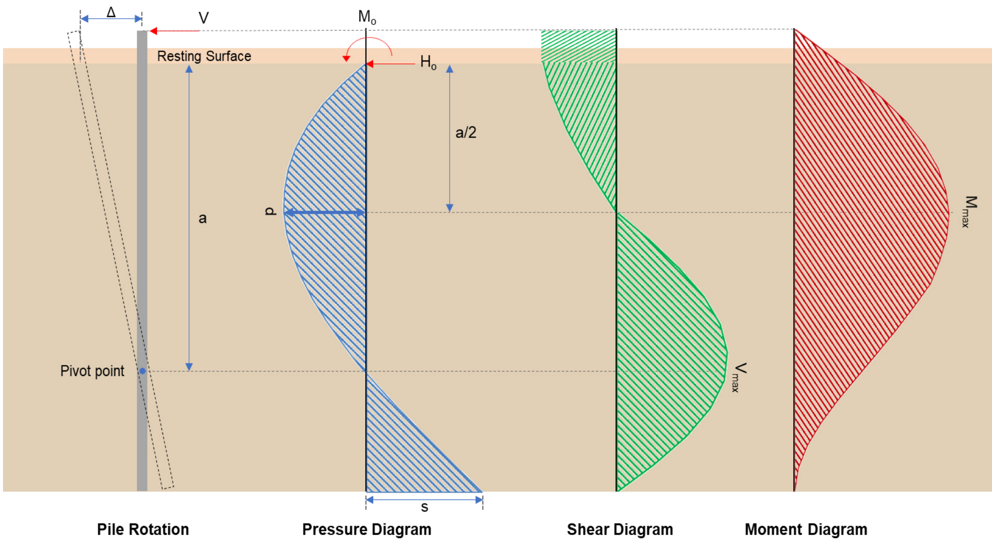
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.030812\text{ kip/ft}^2\right)}{\left(0.6\text{ kip/ft}^2\right)}$$

$$Ratio = -0.051354$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.54\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = -0.085987\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(9.483\text{ kipft}) + ((-0.54\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 1.51\text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(1.51\text{ kipft/ft})}{(-0.085987\text{ kip/ft})}$$

$$E = 17.561\text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.51\text{ kipft/ft}) \times (4\text{ ft})) + \left(3 \times (-0.085987\text{ kip/ft}) \times (4\text{ ft})^2\right)}{\ldots}$$

$$a = \frac{}{(6 \times (1.51\ \mathrm{kipft/ft})) + (4 \times (-0.085987\ \mathrm{kip/ft}) \times (4\ \mathrm{ft}))}$$

$$a = 2.7106\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.085987\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (17.561\ \mathrm{ft})}{(4\ \mathrm{ft})} + 3\right) \times \left(\frac{(2.7106\ \mathrm{ft})}{(4\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (17.561\ \mathrm{ft})}{(4\ \mathrm{ft})} + 2\right) \times \left(\frac{(2.7106\ \mathrm{ft})}{(4\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 2.9036\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.085987\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (4\ \mathrm{ft})) \times \left[\left(\frac{(17.561\ \mathrm{ft})}{(4\ \mathrm{ft})} + \frac{(2.7106\ \mathrm{ft})}{2 \times (4\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (17.561\ \mathrm{ft})}{(4\ \mathrm{ft})} + 3\right) \times \left(\frac{(2.7106\ \mathrm{ft})}{2 \times (4\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (17.561\ \mathrm{ft})}{(4\ \mathrm{ft})} + 2\right) \times \left(\frac{(2.7106\ \mathrm{ft})}{2 \times (4\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 5.681\ \mathrm{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.506\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.080573\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.636\ \mathrm{kipft}) + ((-0.506\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.10127\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.10127\ \mathrm{kipft/ft})}{(-0.080573\ \mathrm{kip/ft})}$$

$$E = 1.2569\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.10127\ \mathrm{kipft/ft}) \times (4\ \mathrm{ft})) + \left(3 \times (-0.080573\ \mathrm{kip/ft}) \times (4\ \mathrm{ft})^2\right)}{(6 \times (0.10127\ \mathrm{kipft/ft})) + (4 \times (-0.080573\ \mathrm{kip/ft}) \times (4\ \mathrm{ft}))}$$

$$a = 2.8932\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.080573\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (1.2569\ \mathrm{ft})}{(4\ \mathrm{ft})} + 3\right) \times \left(\frac{(2.8932\ \mathrm{ft})}{(4\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (1.2569\ \mathrm{ft})}{(4\ \mathrm{ft})} + 2\right) \times \left(\frac{(2.8932\ \mathrm{ft})}{(4\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.39548\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.080573\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (4\ \mathrm{ft})) \times \left[\left(\frac{(1.2569\ \mathrm{ft})}{(4\ \mathrm{ft})} + \frac{(2.8932\ \mathrm{ft})}{2 \times (4\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (1.2569\ \mathrm{ft})}{(4\ \mathrm{ft})} + 3\right) \times \left(\frac{(2.8932\ \mathrm{ft})}{2 \times (4\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (1.2569\ \mathrm{ft})}{(4\ \mathrm{ft})} + 2\right) \times \left(\frac{(2.8932\ \mathrm{ft})}{2 \times (4\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.67664\ \mathrm{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(5.553\ \mathrm{kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5\ \mathrm{ksi}) \times (2304\ \mathrm{in}^2))}{(60\ \mathrm{ksi}) - (0.85 \times (2.5\ \mathrm{ksi}))}, (0.08 \times (2304\ \mathrm{in}^2))\right]$$

$$A_{st,required} = -84.412\ \mathrm{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.412\ \mathrm{in}^2), (0.0018 \times (2304\ \mathrm{in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

Status: PASS
Ratio: 0.970

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

Main reinforcement: **14 - #5 (0.625 in)**
Ties: **#3(0.375 in) - 10 in**

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

$$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(2304\ \text{in}^2\right) - \left(4.2951\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(4.2951\ \text{in}^2\right)\right)\right]$$

$$\phi P_N = 2675.2\ \text{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(5.553\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0020757$$

Status: PASS
Ratio: 0.000

Shear Strength (ACI 318-19, LRFD)

Parameters:

$b_w = 48\ \text{in}$ - Effective width,
22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,
22.5.5.1.1 $V_{c,max}$ - Max shear strength of concrete

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

$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,max} = 296.21 \text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 5.553 \text{ kip} \rightarrow 5553 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(5553 \text{ lbf})}{6 \times (2304 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.23 \text{ kip}$$

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

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

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

$$V_{c,b} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + (0.05 \times (2500 \text{ psi})) \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,b} = 348.89 \text{ kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (119.23 \text{ kip}), (348.89 \text{ kip}) \right]$$

$$V_c = 119.23 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.23 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.58 \text{ kip}$$

Considering x-direction:

$V_{max} = 2.9036 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(2.9036 \text{ kip})}{(110.58 \text{ kip})}$$

$$Ratio = 0.026258$$

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

Considering z-direction:

$V_{max} = 0.39548 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.39548 \text{ kip})}{(110.58 \text{ kip})}$$

$$Ratio = 0.0035765$$

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:
$\phi M_{n,1}$

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

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

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

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

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

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

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

Therefore,
ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 5.681 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(5.681 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.02276$$

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

Considering z-direction:

$M_{max} = 0.67664 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(0.67664 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.0027109$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

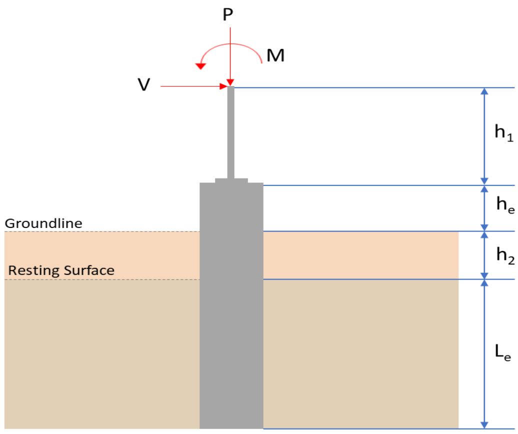
SkyCiv Foundation Design

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
$L = 4.5\ \text{ft}$ - 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)	5.285	7.506
V_x (kip)	-0.442	-0.737
V_z (kip)	-0.056	-0.081
M_x (kipft)	-0.084	-0.121
M_z (kipft)	7.065	11.859

Material Properties

$f'_{ck} = 2.5\ \text{ksi}$ - 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,

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

$$H_o = \frac{(-0.442\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.070382\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(7.065\ \mathrm{kipft}) + ((-0.442\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 1.125\ \mathrm{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 4.1679\ \mathrm{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.056\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.0089172\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.084\ \mathrm{kipft}) + ((-0.056\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.013376\ \mathrm{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 0.8505\ \mathrm{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(4.1679\ \mathrm{ft}), (0.8505\ \mathrm{ft})]$$

$$L_{e,req} = 4.168\ \mathrm{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (4.5\ \mathrm{ft}) - (0\ \mathrm{ft}) - (0\ \mathrm{ft})$$

$$L_e = 4.5\ \mathrm{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(4.168\ \mathrm{ft})}{(4.5\ \mathrm{ft})}$$

$$Ratio = 0.92622$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(5.285\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.33031\ \text{kip}/\text{ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.33031\ \text{kip}/\text{ft}^2\right)}{(2000\ \text{psf})}$$

$$Ratio = 0.16516$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(4.5\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 1.125$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.070382\ \text{kip}/\text{ft}$ - Lateral force per length of pile,
$M_o = 1.125\ \text{kipft}/\text{ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.125\ \text{kipft}/\text{ft}) \times (4.5\ \text{ft})) + \left(3 \times (-0.070382\ \text{kip}/\text{ft}) \times (4.5\ \text{ft})^2\right)}{(6 \times (1.125\ \text{kipft}/\text{ft})) + (4 \times (-0.070382\ \text{kip}/\text{ft}) \times (4.5\ \text{ft}))}$$

$$a = 3.0593\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (1.125\ \text{kipft}/\text{ft})) + (3 \times (-0.070382\ \text{kip}/\text{ft}) \times (4.5\ \text{ft}))]^2}{(4.5\ \text{ft})^2 \times [(3 \times (1.125\ \text{kipft}/\text{ft})) + (2 \times (-0.070382\ \text{kip}/\text{ft}) \times (4.5\ \text{ft}))]}$$

$$p = 0.17024\ \text{kip}/\text{ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (1.125\ \text{kipft}/\text{ft})) + ((-0.070382\ \text{kip}/\text{ft}) \times (4.5\ \text{ft}))]}{(4.5\ \text{ft})^2}$$

$$s = 0.57282\ \text{kip}/\text{ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf}/\text{ft}) \times \frac{(3.0593\ \text{ft})}{2}$$

$$p_a = 0.22944\ \text{kip}/\text{ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.17024 \text{ kip/ft}^2\right)}{\left(0.22944 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.74196$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150 \text{ psf/ft}) \times (4.5 \text{ ft})$$

$$p_s = 0.675 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.57282 \text{ kip/ft}^2\right)}{\left(0.675 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.84863$$

Status: **PASS**
Ratio: **0.850**

Considering z-direction:

$H_o = -0.0089172 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 0.013376 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.013376 \text{ kipft/ft}) \times (4.5 \text{ ft})) + \left(3 \times (-0.0089172 \text{ kip/ft}) \times (4.5 \text{ ft})^2\right)}{(6 \times (0.013376 \text{ kipft/ft})) + (4 \times (-0.0089172 \text{ kip/ft}) \times (4.5 \text{ ft}))}$$

$$a = 3.25 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.013376 \text{ kipft/ft})) + (3 \times (-0.0089172 \text{ kip/ft}) \times (4.5 \text{ ft}))]^{\,2}}{(4.5 \text{ ft})^2 \times [(3 \times (0.013376 \text{ kipft/ft})) + (2 \times (-0.0089172 \text{ kip/ft}) \times (4.5 \text{ ft}))]}$$

$$p = -0.0041283 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.013376 \text{ kipft/ft})) + ((-0.0089172 \text{ kip/ft}) \times (4.5 \text{ ft}))]}{(4.5 \text{ ft})^2}$$

$$s = -0.0039632 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(3.25 \text{ ft})}{2}$$

$$p_a = 0.24375 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.0041283 \text{ kip/ft}^2\right)}{\left(0.24375 \text{ kip/ft}^2\right)}$$

$$Ratio = -0.016937$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150 \text{ psf/ft}) \times (4.5 \text{ ft})$$

$$p_s = 0.675 \text{ kip/ft}^2$$

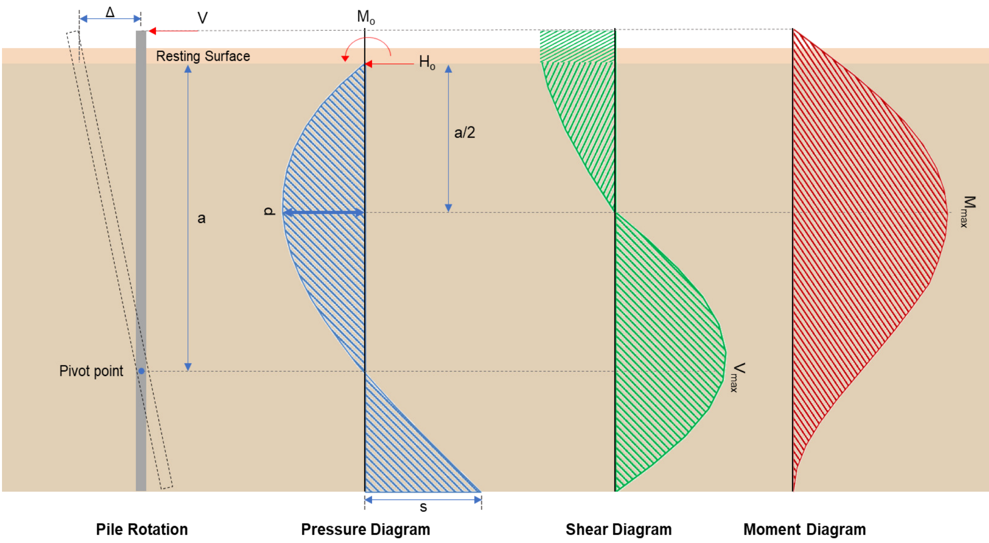
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.0039632 \text{ kip/ft}^2\right)}{\left(0.675 \text{ kip/ft}^2\right)}$$

$$Ratio = -0.0058714$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.737 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.11736 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(11.859 \text{ kipft}) + ((-0.737 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 1.8884 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(1.8884 \text{ kipft/ft})}{(-0.11736 \text{ kip/ft})}$$

$$E = 16.091 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.8884 \text{ kipft/ft}) \times (4.5 \text{ ft})) + \left(3 \times (-0.11736 \text{ kip/ft}) \times (4.5 \text{ ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (1.8884\ \mathrm{kipft/ft})) + (4 \times (-0.11736\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))}$$

$$a = 3.0589\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.11736\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (16.091\ \mathrm{ft})}{(4.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(3.0589\ \mathrm{ft})}{(4.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (16.091\ \mathrm{ft})}{(4.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(3.0589\ \mathrm{ft})}{(4.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 3.2838\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.11736\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (4.5\ \mathrm{ft})) \times \left[\left(\frac{(16.091\ \mathrm{ft})}{(4.5\ \mathrm{ft})} + \frac{(3.0589\ \mathrm{ft})}{2 \times (4.5\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (16.091\ \mathrm{ft})}{(4.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(3.0589\ \mathrm{ft})}{2 \times (4.5\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (16.091\ \mathrm{ft})}{(4.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(3.0589\ \mathrm{ft})}{2 \times (4.5\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 7.1951\ \mathrm{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.081\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.012898\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.121\ \mathrm{kipft}) + ((-0.081\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.019268\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.019268\ \mathrm{kipft/ft})}{(-0.012898\ \mathrm{kip/ft})}$$

$$E = 1.4938\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.019268\ \mathrm{kipft/ft}) \times (4.5\ \mathrm{ft})) + \left(3 \times (-0.012898\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft})^2\right)}{(6 \times (0.019268\ \mathrm{kipft/ft})) + (4 \times (-0.012898\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))}$$

$$a = 3.2503\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.012898\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (1.4938\ \text{ft})}{(4.5\ \text{ft})} + 3\right) \times \left(\frac{(3.2503\ \text{ft})}{(4.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (1.4938\ \text{ft})}{(4.5\ \text{ft})} + 2\right) \times \left(\frac{(3.2503\ \text{ft})}{(4.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.064898\ \text{kip}$$

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

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

$$M_{max} = ((-0.012898\ \text{kip/ft}) \times (48\ \text{in}) \times (4.5\ \text{ft})) \times \left[\left(\frac{(1.4938\ \text{ft})}{(4.5\ \text{ft})} + \frac{(3.2503\ \text{ft})}{2 \times (4.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (1.4938\ \text{ft})}{(4.5\ \text{ft})} + 3\right) \times \left(\frac{(3.2503\ \text{ft})}{2 \times (4.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (1.4938\ \text{ft})}{(4.5\ \text{ft})} + 2\right) \times \left(\frac{(3.2503\ \text{ft})}{2 \times (4.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.12542\ \text{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(7.506\ \text{kip})}{(0.65) \times (0.8)} - \left(0.85 \times (2.5\ \text{ksi}) \times \left(2304\ \text{in}^2\right)\right)}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, \left(0.08 \times \left(2304\ \text{in}^2\right)\right)\right]$$

$$A_{st,required} = -84.347\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.347\ \text{in}^2\right), \left(0.0018 \times \left(2304\ \text{in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

Status: PASS
Ratio: 0.970

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

25.7.2.2 Since longitudinal reinforcement is $\leq$ No. 10ø: Use #3(0.375 in)

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

Main reinforcement: **14 - #5 (0.625 in)**
Ties: **#3(0.375 in) - 10 in**

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

$$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(2304\ \text{in}^2\right) - \left(4.2951\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(4.2951\ \text{in}^2\right)\right)\right]$$

$$\phi P_N = 2675.2\ \text{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(7.506\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0028058$$

Status: PASS
Ratio: 0.000

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,max} = 296.21 \text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 7.506 \text{ kip} \rightarrow 7506 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(7506 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.49 \text{ kip}$$

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

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

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

$$V_{c,b} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + (0.05 \times (2500 \text{ psi}))\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,b} = 348.89 \text{ kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (119.49 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 119.49 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.49 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.75 \text{ kip}$$

Considering x-direction:

$V_{max} = 3.2838 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(3.2838\ \text{kip})}{(110.75\ \text{kip})}$$

$$Ratio = 0.029651$$

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

Considering z-direction:

$V_{max} = 0.064898\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.064898\ \text{kip})}{(110.75\ \text{kip})}$$

$$Ratio = 0.000586$$

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:
$\phi M_{n,1}$

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

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

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

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

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

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

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

Therefore,
ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 7.1951\ \text{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(7.1951\ \text{kipft})}{(249.6\ \text{kipft})}$$

$$Ratio = 0.028827$$

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

Considering z-direction:

$M_{max} = 0.12542\ \text{kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(0.12542\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$ $$Ratio = 0.00050248$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

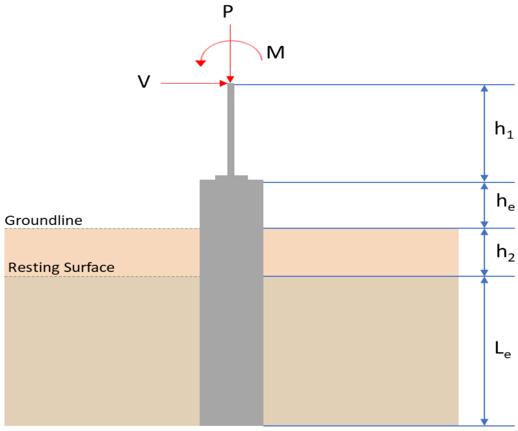
SkyCiv Foundation Design

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

$L = 4.5\ \text{ft}$ - 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)	5.032	7.143
V_x (kip)	-0.413	-0.692
V_z (kip)	0.001	0.001
M_x (kipft)	0.000	0.000
M_z (kipft)	7.137	12.027

Material Properties

$f'_{ck} = 2.5\ \text{ksi}$ - 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,

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

$$H_o = \frac{(-0.413\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.065764\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(7.137 \text{ kipft}) + ((-0.413 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 1.1365 \text{ kipft/ft}$$

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:
$L_{e,x} = 4.2045 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.001 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.00015924 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0 \text{ kipft}) + ((0.001 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0 \text{ kipft/ft}$$

L_e - Required depth of embedment in earth,

$$L_e = 3.0 \sqrt{\frac{H_o}{R}}$$

$$L_e = 3.0 \times \sqrt{\frac{(0.00015924 \text{ kip/ft})}{(150 \text{ psf/ft})}}$$

$$L_e = 0.097745 \text{ ft}$$

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(4.2045 \text{ ft}), (0.097745 \text{ ft})]$$

$$L_{e,req} = 4.205 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (4.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 4.5 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(4.205 \text{ ft})}{(4.5 \text{ ft})}$$

$$Ratio = 0.93444$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(5.032\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.3145\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.3145\ \text{kip/ft}^2\right)}{(2000\ \text{psf})}$$

$$Ratio = 0.15725$$

Status: **PASS**
Ratio: **0.160**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(4.5\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 1.125$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.065764\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 1.1365\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.1365\ \text{kipft/ft}) \times (4.5\ \text{ft})) + \left(3 \times (-0.065764\ \text{kip/ft}) \times (4.5\ \text{ft})^2\right)}{(6 \times (1.1365\ \text{kipft/ft})) + (4 \times (-0.065764\ \text{kip/ft}) \times (4.5\ \text{ft}))}$$

$$a = 3.0555\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (1.1365\ \text{kipft/ft})) + (3 \times (-0.065764\ \text{kip/ft}) \times (4.5\ \text{ft}))]^2}{(4.5\ \text{ft})^2 \times [(3 \times (1.1365\ \text{kipft/ft})) + (2 \times (-0.065764\ \text{kip/ft}) \times (4.5\ \text{ft}))]}$$

$$p = 0.1759\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (1.1365\ \text{kipft/ft})) + ((-0.065764\ \text{kip/ft}) \times (4.5\ \text{ft}))]}{(4.5\ \text{ft})^2}$$

$$s = 0.58577\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(3.0555\ \text{ft})}{2}$$

$$p_a = 0.22916 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.1759 \text{ kip/ft}^2)}{(0.22916 \text{ kip/ft}^2)}$$

$$Ratio = 0.76759$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150 \text{ psf/ft}) \times (4.5 \text{ ft})$$

$$p_s = 0.675 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.58577 \text{ kip/ft}^2)}{(0.675 \text{ kip/ft}^2)}$$

$$Ratio = 0.86781$$

Status: **PASS**
Ratio: **0.870**

Considering z-direction:

$H_o = 0.00015924 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 0 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0 \text{ kipft/ft}) \times (4.5 \text{ ft})) + \left(3 \times (0.00015924 \text{ kip/ft}) \times (4.5 \text{ ft})^2\right)}{(6 \times (0 \text{ kipft/ft})) + (4 \times (0.00015924 \text{ kip/ft}) \times (4.5 \text{ ft}))}$$

$$a = 3.375 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0 \text{ kipft/ft})) + (3 \times (0.00015924 \text{ kip/ft}) \times (4.5 \text{ ft})]^{\;2}}{(4.5 \text{ ft})^2 \times [(3 \times (0 \text{ kipft/ft})) + (2 \times (0.00015924 \text{ kip/ft}) \times (4.5 \text{ ft}))]}$$

$$p = 0.00011943 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0 \text{ kipft/ft})) + ((0.00015924 \text{ kip/ft}) \times (4.5 \text{ ft}))]}{(4.5 \text{ ft})^2}$$

$$s = 0.00021231 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(3.375 \text{ ft})}{2}$$

$$p_a = 0.25312 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.00011943 \text{ kip/ft}^2)}{(0.25312 \text{ kip/ft}^2)}$$

$$Ratio = 0.00047181$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150 \text{ psf/ft}) \times (4.5 \text{ ft})$$

$$p_s = 0.675 \text{ kip/ft}^2$$

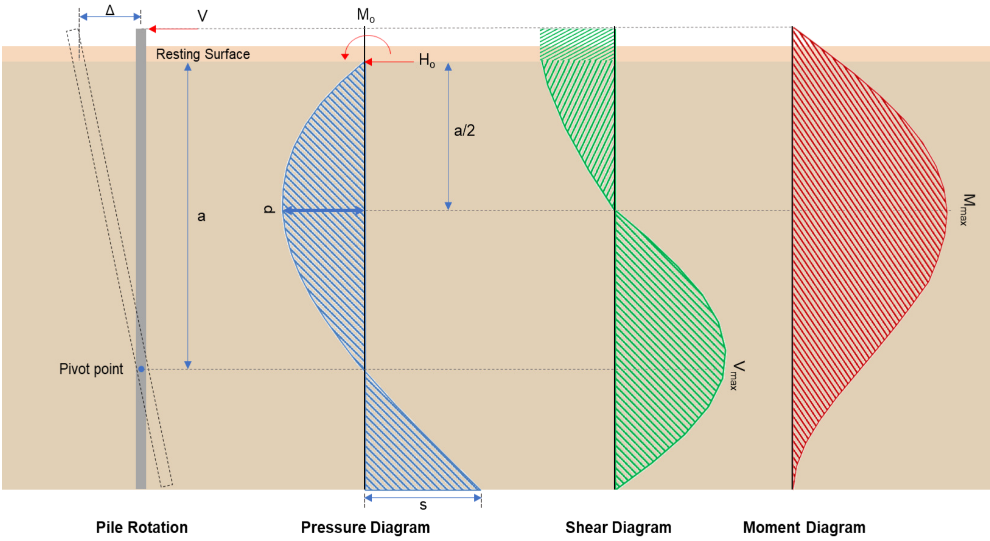
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.00021231 \text{ kip/ft}^2)}{(0.675 \text{ kip/ft}^2)}$$

$$Ratio = 0.00031454$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.692 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.11019 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(12.027 \text{ kipft}) + ((-0.692 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 1.9151 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(1.9151 \text{ kipft/ft})}{(-0.11019 \text{ kip/ft})}$$

$$E = 17.38 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$(6\,M_o) + (4\,H_o\,L_e)$$

$$a = \frac{(4 \times (1.9151\ \text{kipft/ft}) \times (4.5\ \text{ft})) + \left(3 \times (-0.11019\ \text{kip/ft}) \times (4.5\ \text{ft})^2\right)}{(6 \times (1.9151\ \text{kipft/ft})) + (4 \times (-0.11019\ \text{kip/ft}) \times (4.5\ \text{ft}))}$$

$$a = 3.0552\ \text{ft}$$

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

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

$$V_{max} = ((-0.11019\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (17.38\ \text{ft})}{(4.5\ \text{ft})} + 3\right) \times \left(\frac{(3.0552\ \text{ft})}{(4.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (17.38\ \text{ft})}{(4.5\ \text{ft})} + 2\right) \times \left(\frac{(3.0552\ \text{ft})}{(4.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 3.3075\ \text{kip}$$

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

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

$$M_{max} = ((-0.11019\ \text{kip/ft}) \times (48\ \text{in}) \times (4.5\ \text{ft})) \times \left[\left(\frac{(17.38\ \text{ft})}{(4.5\ \text{ft})} + \frac{(3.0552\ \text{ft})}{2 \times (4.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (17.38\ \text{ft})}{(4.5\ \text{ft})} + 3\right) \times \left(\frac{(3.0552\ \text{ft})}{2 \times (4.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (17.38\ \text{ft})}{(4.5\ \text{ft})} + 2\right) \times \left(\frac{(3.0552\ \text{ft})}{2 \times (4.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 7.2602\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.001\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.00015924\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0\ \text{kipft}) + ((0.001\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0\ \text{kipft/ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0\ \text{kipft/ft}) \times (4.5\ \text{ft})) + \left(3 \times (0.00015924\ \text{kip/ft}) \times (4.5\ \text{ft})^2\right)}{(6 \times (0\ \text{kipft/ft})) + (4 \times (0.00015924\ \text{kip/ft}) \times (4.5\ \text{ft}))}$$

$$a = 3.375\ \text{ft}$$

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

$$V_{max} = (H_o\,b)\left[1 - \left(9\,\frac{a}{L_e}^2\right)\left(8\,\frac{a}{L_e}^3\right)\right]$$

$$V_{max} = ((0.00015924\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left(9 \times \frac{(3.375\ \text{ft})}{(4.5\ \text{ft})}^2\right)\left(8 \times \frac{(3.375\ \text{ft})}{(4.5\ \text{ft})}^3\right)\right]$$

$$V_{max} = 0.0004379\ \text{kip}$$

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

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

$$M_{max} = ((0.00015924\ \text{kip/ft}) \times (48\ \text{in}) \times (4.5\ \text{ft})) \times \left[\frac{(3.375\ \text{ft})}{2 \times (4.5\ \text{ft})} - \left(3 \times \frac{(3.375\ \text{ft})}{2 \times (4.5\ \text{ft})}^{3}\right) + \left(2 \times \frac{(3.375\ \text{ft})}{2 \times (4.5\ \text{ft})}^{4}\right)\right]$$

$$M_{max} = 0.00073475\ \text{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(7.143\ \text{kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.359\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.359\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

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

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

$$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\text{ ksi}) \times \left[\left(2304\text{ in}^2\right) - \left(4.2951\text{ in}^2\right)\right]\right) + \left((60\text{ ksi}) \times \left(4.2951\text{ in}^2\right)\right)\right]$$

$$\phi P_N = 2675.2\text{ kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(7.143\text{ kip})}{(2675.2\text{ kip})}$$

$$Ratio = 0.0026701$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

$b_w = 48\text{ in}$ - Effective width,
22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\text{ ksi} \rightarrow 2500\text{ psi}$,
22.5.5.1.1 $V_{c,max}$ - Max shear strength of concrete

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

$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\text{ psi})} \times (48\text{ in}) \times (38.4\text{ in})$$

$$V_{c,max} = 296.21\text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\text{ ksi} \rightarrow 2500\text{ psi}, P = 7.143\text{ kip} \rightarrow 7143\text{ lbf}$,
22.5.5.1.1(a) $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\text{ psi})} + \frac{(7143\text{ lbf})}{6 \times (2304\text{ in}^2)}\right] \times (48\text{ in}) \times (38.4\text{ in})$$

$$V_{c,a} = 119.44\text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\text{ ksi} \rightarrow 2500\text{ psi}$,
22.5.5.1.2 $V_{c,b}$ - Shear strength of concrete (b)

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

$$V_{c,b} = \left[2 \times (0.64282) \times \sqrt{(2500\text{ psi})} + (0.05 \times (2500\text{ psi}))\right] \times (48\text{ in}) \times (38.4\text{ in})$$

$$V_{c,b} = 348.89\text{ kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\text{ kip}), (119.44\text{ kip}), (348.89\text{ kip})\right]$$

$$V_c = 119.44\text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.44\text{ kip}) + (50.894\text{ kip}))$$

$$\phi V_n = 110.72\text{ kip}$$

Considering x-direction:

$V_{max} = 3.3075\text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(3.3075\text{ kip})}{(110.72\text{ kip})}$$

$$Ratio = 0.029874$$

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

Considering z-direction:

$V_{max} = 0.0004379\text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.0004379\text{ kip})}{(110.72\text{ kip})}$$

$$Ratio = 3.9552{\times}10^{-6}$$

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:
$\phi M_{n,1}$

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

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

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

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

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

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

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

Therefore,
ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 7.2602\text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(7.2602\text{ kipft})}{(249.6\text{ kipft})}$$

$$Ratio = 0.029087$$

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

Considering z-direction:

$M_{max} = 0.00073475\text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.00073475\text{ kipft})}{(249.6\text{ kipft})}$$

$$Ratio = 2.9437{\times}10^{-6}$$

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

REFERENCES	CALCULATIONS	RESULTS

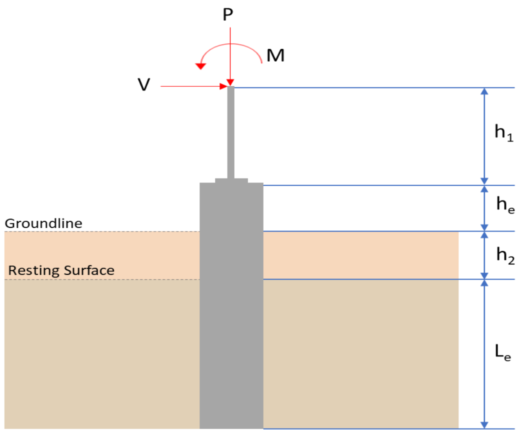
SkyCiv Foundation Design

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
$L = 4.5\ \text{ft}$ - 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)	5.286	7.506
V_x (kip)	-0.442	-0.737
V_z (kip)	0.055	0.079
M_x (kipft)	0.081	0.117
M_z (kipft)	7.065	11.860

Material Properties

$f'_{ck} = 2.5\ \text{ksi}$ - 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,

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

$$H_o = \frac{(-0.442\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.070382\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(7.065\ \text{kipft}) + ((-0.442\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 1.125\ \text{kipft/ft}$$

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:
$L_{e,x} = 4.1679\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.055\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.008758\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.081\ \text{kipft}) + ((0.055\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.012898\ \text{kipft/ft}$$

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:
$L_{e,z} = 1.1825\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(4.1679\ \text{ft}), (1.1825\ \text{ft})]$$

$$L_{e,req} = 4.168\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (4.5\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 4.5\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(4.168\ \text{ft})}{(4.5\ \text{ft})}$$

$$Ratio = 0.92622$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\,D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(5.286 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.33037 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.33037 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.16519$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(4.5 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.125$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.070382 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 1.125 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.125 \text{ kipft/ft}) \times (4.5 \text{ ft})) + \left(3 \times (-0.070382 \text{ kip/ft}) \times (4.5 \text{ ft})^2\right)}{(6 \times (1.125 \text{ kipft/ft})) + (4 \times (-0.070382 \text{ kip/ft}) \times (4.5 \text{ ft}))}$$

$$a = 3.0593 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (1.125 \text{ kipft/ft})) + (3 \times (-0.070382 \text{ kip/ft}) \times (4.5 \text{ ft}))]^2}{(4.5 \text{ ft})^2 \times [(3 \times (1.125 \text{ kipft/ft})) + (2 \times (-0.070382 \text{ kip/ft}) \times (4.5 \text{ ft}))]}$$

$$p = 0.17024 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (1.125 \text{ kipft/ft})) + ((-0.070382 \text{ kip/ft}) \times (4.5 \text{ ft}))]}{(4.5 \text{ ft})^2}$$

$$s = 0.57282 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(3.0593 \text{ ft})}{2}$$

$$p_a = 0.22944 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.17024\ \mathrm{kip/ft^2}\right)}{\left(0.22944\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.74196$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = \left(150\ \mathrm{psf/ft}\right) \times \left(4.5\ \mathrm{ft}\right)$$

$$p_s = 0.675\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.57282\ \mathrm{kip/ft^2}\right)}{\left(0.675\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.84863$$

Status: **PASS**
Ratio: **0.850**

Considering z-direction:

$H_o = 0.008758\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.012898\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{\left(4 \times \left(0.012898\ \mathrm{kipft/ft}\right) \times \left(4.5\ \mathrm{ft}\right)\right) + \left(3 \times \left(0.008758\ \mathrm{kip/ft}\right) \times \left(4.5\ \mathrm{ft}\right)^2\right)}{\left(6 \times \left(0.012898\ \mathrm{kipft/ft}\right)\right) + \left(4 \times \left(0.008758\ \mathrm{kip/ft}\right) \times \left(4.5\ \mathrm{ft}\right)\right)}$$

$$a = 3.2515\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times \left[\left(4 \times \left(0.012898\ \mathrm{kipft/ft}\right)\right) + \left(3 \times \left(0.008758\ \mathrm{kip/ft}\right) \times \left(4.5\ \mathrm{ft}\right)\right)\right]^2}{\left(4.5\ \mathrm{ft}\right)^2 \times \left[\left(3 \times \left(0.012898\ \mathrm{kipft/ft}\right)\right) + \left(2 \times \left(0.008758\ \mathrm{kip/ft}\right) \times \left(4.5\ \mathrm{ft}\right)\right)\right]}$$

$$p = 0.0090895\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times \left[\left(2 \times \left(0.012898\ \mathrm{kipft/ft}\right)\right) + \left(\left(0.008758\ \mathrm{kip/ft}\right) \times \left(4.5\ \mathrm{ft}\right)\right)\right]}{\left(4.5\ \mathrm{ft}\right)^2}$$

$$s = 0.019321\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = \left(150\ \mathrm{psf/ft}\right) \times \frac{\left(3.2515\ \mathrm{ft}\right)}{2}$$

$$p_a = 0.24386\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0090895\ \mathrm{kip/ft^2}\right)}{\left(0.24386\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.037273$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\text{ psf/ft}) \times (4.5\text{ ft})$$

$$p_s = 0.675\text{ kip/ft}^2$$

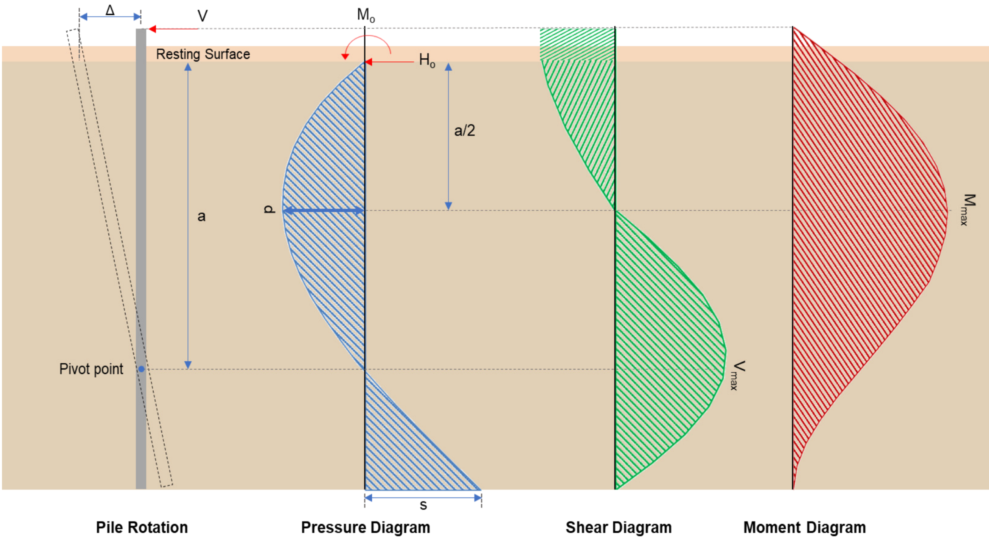
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.019321\text{ kip/ft}^2)}{(0.675\text{ kip/ft}^2)}$$

$$Ratio = 0.028623$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.737\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = -0.11736\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(11.86\text{ kipft}) + ((-0.737\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 1.8885\text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(1.8885\text{ kipft/ft})}{(-0.11736\text{ kip/ft})}$$

$$E = 16.092\text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.8885\text{ kipft/ft}) \times (4.5\text{ ft})) + \left(3 \times (-0.11736\text{ kip/ft}) \times (4.5\text{ ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (1.8885\ \mathrm{kipft/ft})) + (4 \times (-0.11736\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))}$$

$$a = 3.0589\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.11736\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (16.092\ \mathrm{ft})}{(4.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(3.0589\ \mathrm{ft})}{(4.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (16.092\ \mathrm{ft})}{(4.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(3.0589\ \mathrm{ft})}{(4.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 3.284\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.11736\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (4.5\ \mathrm{ft})) \times \left[\left(\frac{(16.092\ \mathrm{ft})}{(4.5\ \mathrm{ft})} + \frac{(3.0589\ \mathrm{ft})}{2 \times (4.5\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (16.092\ \mathrm{ft})}{(4.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(3.0589\ \mathrm{ft})}{2 \times (4.5\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (16.092\ \mathrm{ft})}{(4.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(3.0589\ \mathrm{ft})}{2 \times (4.5\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 7.1957\ \mathrm{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.079\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = 0.01258\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.117\ \mathrm{kipft}) + ((0.079\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.018631\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.018631\ \mathrm{kipft/ft})}{(0.01258\ \mathrm{kip/ft})}$$

$$E = 1.481\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.018631\ \mathrm{kipft/ft}) \times (4.5\ \mathrm{ft})) + \left(3 \times (0.01258\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft})^2\right)}{(6 \times (0.018631\ \mathrm{kipft/ft})) + (4 \times (0.01258\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))}$$

$$a = 3.2511\ \mathrm{ft}$$

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

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

$$V_{max} = ((0.01258\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (1.481\ \text{ft})}{(4.5\ \text{ft})} + 3\right) \times \left(\frac{(3.2511\ \text{ft})}{(4.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (1.481\ \text{ft})}{(4.5\ \text{ft})} + 2\right) \times \left(\frac{(3.2511\ \text{ft})}{(4.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.063047\ \text{kip}$$

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

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

$$M_{max} = ((0.01258\ \text{kip/ft}) \times (48\ \text{in}) \times (4.5\ \text{ft})) \times \left[\left(\frac{(1.481\ \text{ft})}{(4.5\ \text{ft})} + \frac{(3.2511\ \text{ft})}{2 \times (4.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (1.481\ \text{ft})}{(4.5\ \text{ft})} + 3\right) \times \left(\frac{(3.2511\ \text{ft})}{2 \times (4.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (1.481\ \text{ft})}{(4.5\ \text{ft})} + 2\right) \times \left(\frac{(3.2511\ \text{ft})}{2 \times (4.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.12176\ \text{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(7.506\ \text{kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.347\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.347\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

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

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

$$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(2304\ \text{in}^2\right) - \left(4.2951\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(4.2951\ \text{in}^2\right)\right)\right]$$

$$\phi P_N = 2675.2\ \text{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(7.506\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0028058$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,max} = 296.21 \text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 7.506 \text{ kip} \rightarrow 7506 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(7506 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.49 \text{ kip}$$

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

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

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

$$V_{c,b} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + (0.05 \times (2500 \text{ psi}))\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,b} = 348.89 \text{ kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (119.49 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 119.49 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.49 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.75 \text{ kip}$$

Considering x-direction:

$V_{max} = 3.284 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(3.284\ \mathrm{kip})}{(110.75\ \mathrm{kip})}$$

$$Ratio = 0.029654$$

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

Considering z-direction:

$V_{max} = 0.063047\ \mathrm{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.063047\ \mathrm{kip})}{(110.75\ \mathrm{kip})}$$

$$Ratio = 0.00056929$$

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:
$\phi M_{n,1}$

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

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

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

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

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

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

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

Therefore,
ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 7.1957\ \mathrm{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(7.1957\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$

$$Ratio = 0.028829$$

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

Considering z-direction:

$M_{max} = 0.12176\ \mathrm{kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(0.12176\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.00048784$$		Status: **PASS** Ratio: **0.000**