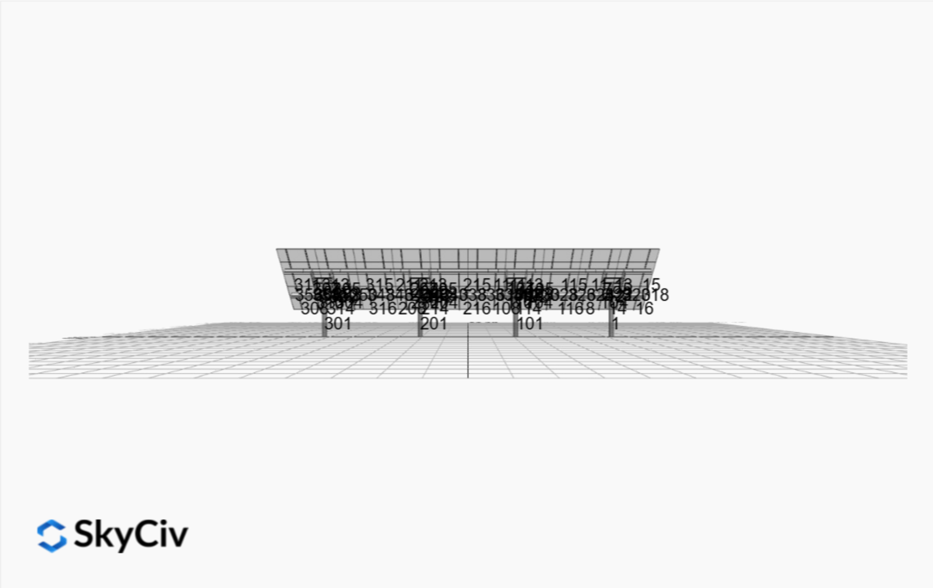
Project Details

Project Name: MTSOLAR_B8B88854D6E4
Location: 3 Whatley Farm Rd, Topsham, ME 04086, USA
Unique ID: 4P-19.75-10TOP-XD-45-L-5Hx10W-93EJ
Dealer: ______________________________

Date: Sat May 24 2025
Number of Modules: 50
Number of Poles: 4
Date Sold:
____



Array Dimensions N/S	18.96 ft
Array Dimensions E/W	75.58 ft
Winter Tilt Angle	40
Front Edge Clearance	5 ft

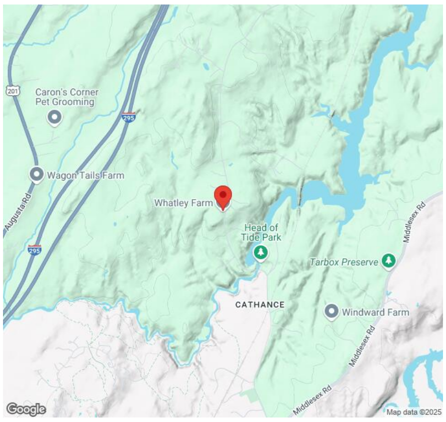
MT Solar Bill of Materials (4P-19.75-10TOP-XD-45-L-5Hx10W-93EJ)

Part	Short Description	BOM Qty
MTS-PC-10	10IN Pole Cap Assembly	4
MTS-HF-XD	H-Frame Assembly-XD	4
MTS-XD-Wing-45	45IN XD Wing	4
MTS-XD-Splice-90	90IN XD Splice	6
MTS-XD-Splice-57	57IN XD Splice	6
MTS-CLAMP-ANGLE-4PK	Angle Clamp	10

Rail Bill of Materials

Part	Qty
Rails (228in)	20
Rail Attachment	80
Module Mid Clamp	80
Module End Clamp	40
Ground Lug	10

Site Details:



Site Address: 3 Whatley Farm Rd, Topsham, ME 04086, USA

Array Specification

Duty Classification:	XD
Module Width:	45.00 in
Module Length:	89.70in
Number of Rows:	5
Number of Columns:	10
Total Number of Modules:	50
Winter Tilt Angle:	40
Front Edge Clearance:	5
Total Array Height at Tilt:	17.19 ft
Total Frame Length:	74.25 ft
Module Info/Notes:	
Array Dimensions N/S:	18.96 ft
Array Dimensions E/W:	75.58 ft
Rail Length:	227.50 in
Rail Spacing:	3.78 ft

Support Specifications

Pole Size:	10in Pipe Sch 40
Pole Length above Grade:	11.09 ft
Number of Poles:	4
Pole Spacing:	19.75 ft

Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 8.00 ft Pile 2: 8.25 ft Pile 3: 8.25 ft Pile 4: 8.00 ft
Foundation Volume:	19.259 y^3

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	3 Whatley Farm Rd, Topsham, ME 04086, USA
Wind Speed:	104 mph

Snow Load:	60 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


```
{"wind_speed_override":null,"snow_load_override":null,"direct_snow_load":false,"add_angle_brace":false,"product_type":"Beam","designer_name":"","designer_email":"jnickwh@gmail.com","designer_phone":"2077510706","project_id":"MTSOLAR_B8B88854D6E4","site_address":"3 Whatley Farm Rd, Topsham, ME 04086, USA","module_info":"","module_width":45,"module_length":89.7,"number_rows":"5","number_columns":10,"pole_mount_section":"4_40","core_pipe_width":65,"core_pipe_section":"2_40","adjuster_section":"2_40","core_beam_height":65,"core_beam_section":"HSS3x2x1/8","main_pipe_section":"2_12GA","pole_spacing":"15","tilt_angle":40,"ground_clearance":5,"risk_category":"I","exposure_category":"C","frame_duty_override":"auto","pole_override":"auto","soil_type":"sand","customer_foundation_override":"48_Square","foundation_type":"Square","foundation_size":48,"check_rails":false}
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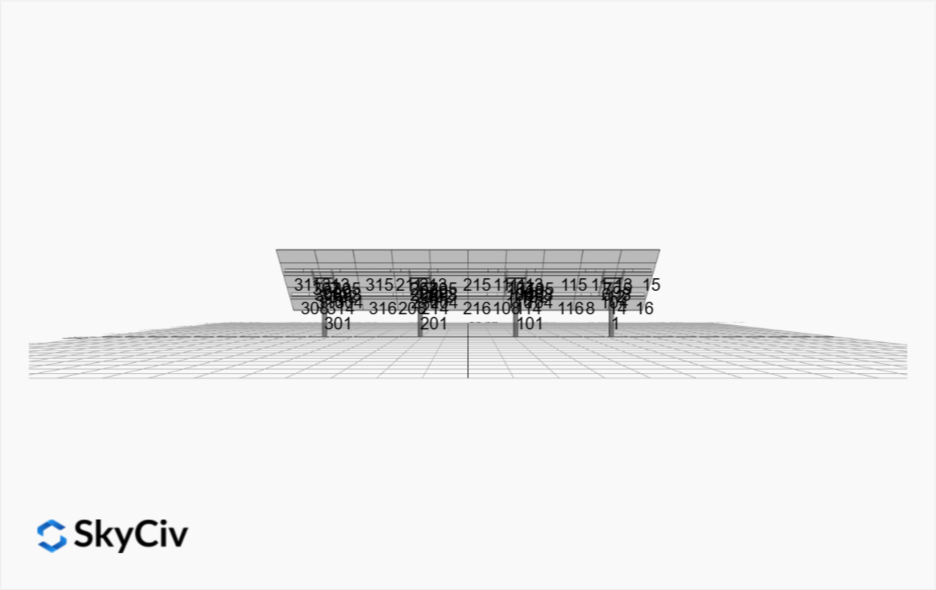
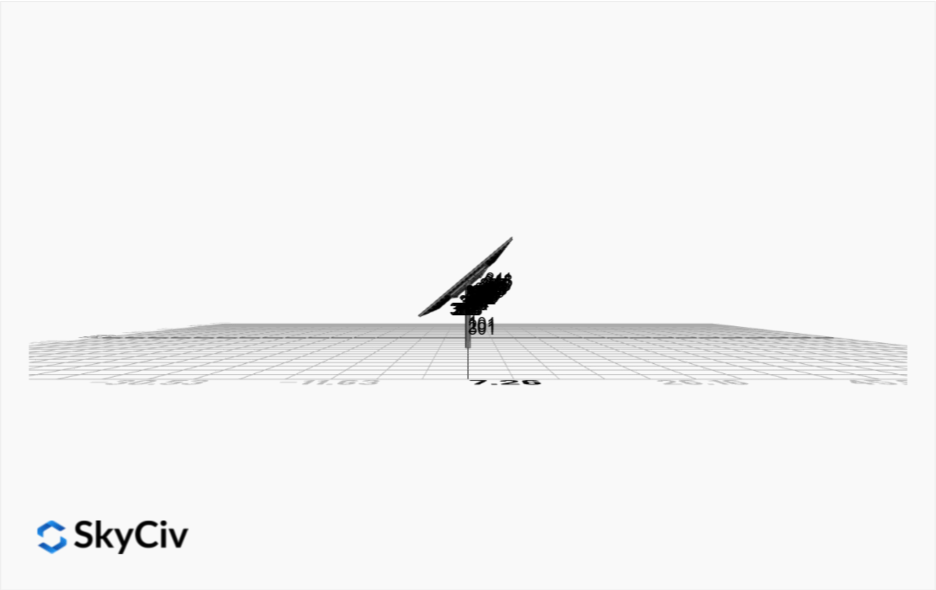
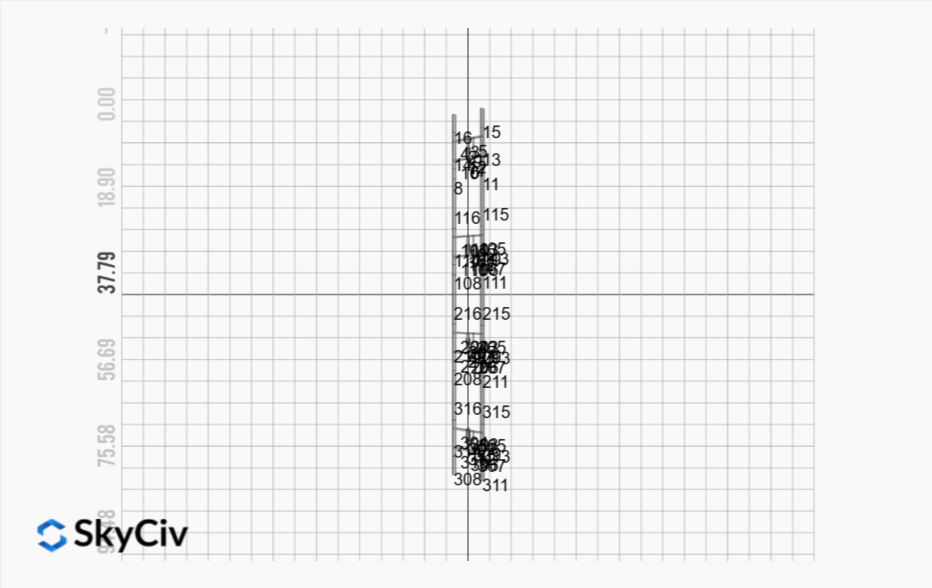
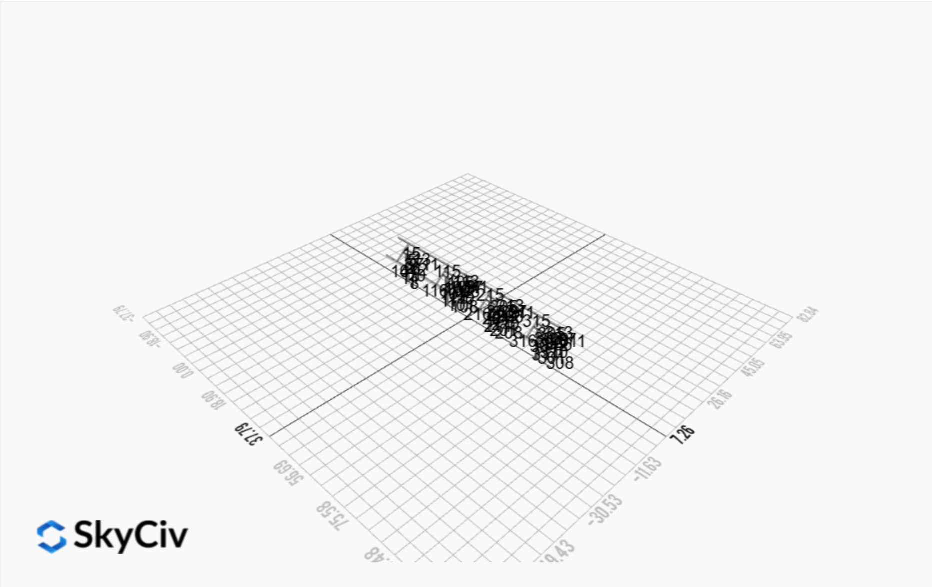
Design Notes:

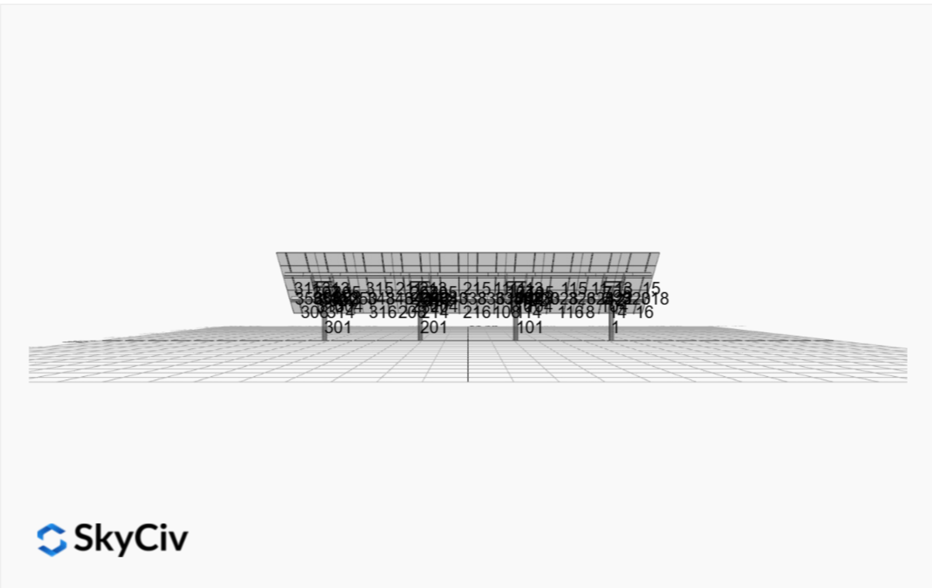
- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Soil Parameters used in this Autodesign are all estimates, proper geotechnical reports are required to confirm soil profiles
- Wind speeds, snow loads and other site specific results are based on ASCE 7 2016
- Steel frame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



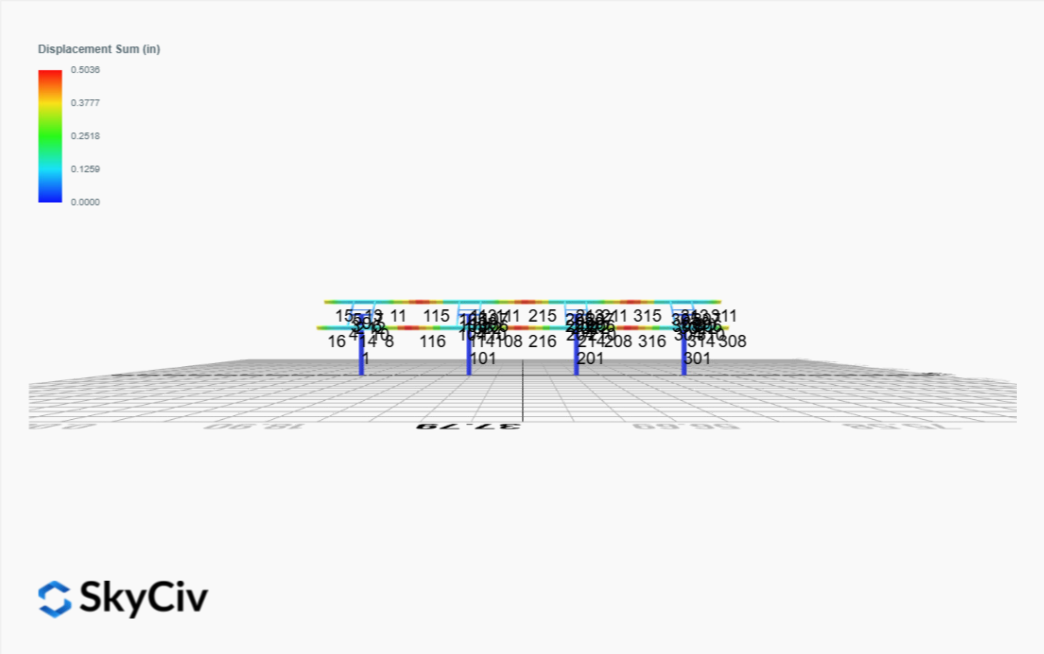


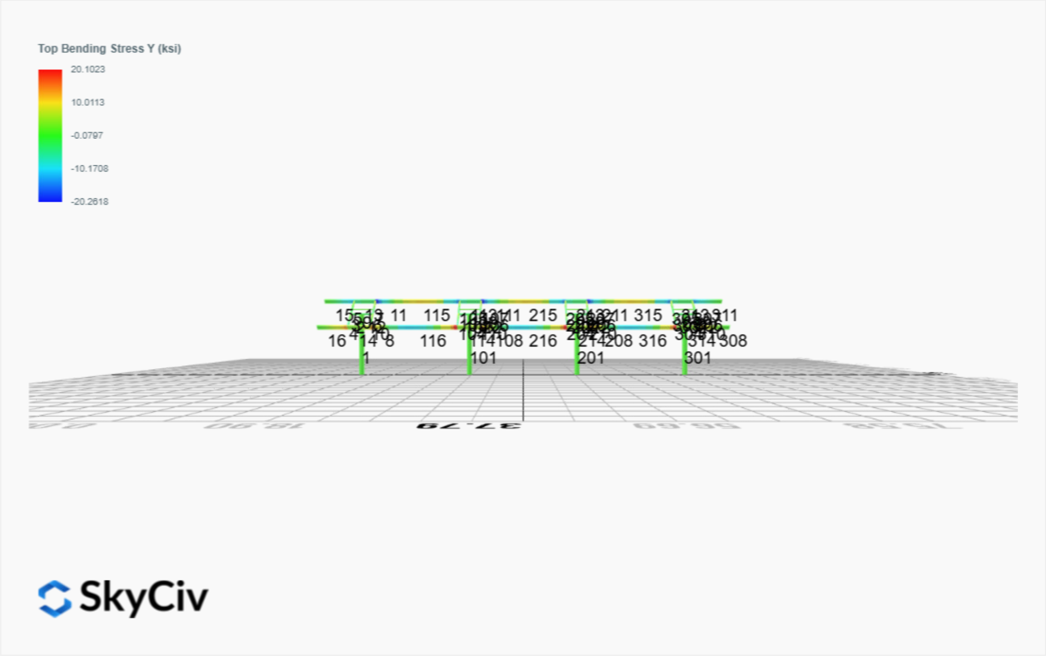






FEM Results (Envelope Worst Case for each member)




Top Bending Stress Y (ksi)
20.1023
10.0113
-0.0797
-10.1708
-20.2618
SkyCiv


Shear Stress Y (ksi)
1.1318
0.5659
0.0000
-0.5659
-1.1318
SkyCiv


Axial Stress (ksi)
0.4796
0.2899
0.1002
-0.0895
-0.2793

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	0.0099	2.6077	0.0318	0.0934	0.0077	-0.0793
ULS: 2. D + L	0.0099	2.6077	0.0318	0.0934	0.0077	-0.0793
ULS: 3. D + (S or Lr or R)	0.0362	7.5688	0.1162	0.3426	0.0263	-0.3366
ULS: 3. D + (S or Lr or R)	0.0099	2.6077	0.0318	0.0934	0.0077	-0.0793
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0296	6.3285	0.0951	0.2803	0.0216	-0.2722
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0099	2.6077	0.0318	0.0934	0.0077	-0.0793
ULS: 5b. D + 0.7E	0.0099	2.6077	0.0318	0.0934	0.0077	-0.0793
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0296	6.3285	0.0951	0.2803	0.0216	-0.2722
ULS: 8. 0.6D + 0.7E	0.0060	1.5646	0.0191	0.0560	0.0046	-0.0476
ULS: 5a. D + 0.6W_Wind downforce Case A only	-4.8143	8.3303	0.1604	0.4195	-0.6079	55.3147
ULS: 5a. D + 0.6W_Wind downforce Case B only	-4.8143	8.3303	0.1604	0.4195	-0.6079	55.3147
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.8517	-1.9511	-0.0672	-0.1578	0.4826	-41.9759
ULS: 5a. D + 0.6W_Wind uplift Case B only	3.2847	-1.2709	-0.0637	-0.1484	0.4710	-47.0970
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.5885	10.6205	0.1916	0.5249	-0.4401	41.2732
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.5885	10.6205	0.1916	0.5249	-0.4401	41.2732
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.9110	2.9094	0.0208	0.0919	0.3778	-31.6947
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.4857	3.4195	0.0235	0.0990	0.3691	-35.5355
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.6082	6.8997	0.1283	0.3380	-0.4540	41.4662
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.6082	6.8997	0.1283	0.3380	-0.4540	41.4662
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.8913	-0.8114	-0.0425	-0.0950	0.3639	-31.5017
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.4660	-0.3013	-0.0398	-0.0879	0.3552	-35.3426
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-4.8183	7.2872	0.1477	0.3821	-0.6110	55.3464
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-4.8183	7.2872	0.1477	0.3821	-0.6110	55.3464
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.8477	-2.9942	-0.0800	-0.1952	0.4795	-41.9442
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	3.2807	-2.3140	-0.0764	-0.1857	0.4680	-47.0653

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	15.8363
Shear X	-8.0404
Shear Z	0.2960
Moment X	0.7904
Moment Y (Twist)	1.0260
Moment Z	92.8882

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	10.6205
Shear X	-4.8183
Shear Z	0.1916
Moment X	0.5249
Moment Y (Twist)	0.6110
Moment Z	55.3464

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	-0.0099	2.8928	-0.0007	-0.0022	0.0024	0.1343
ULS: 2. D + L	-0.0099	2.8928	-0.0007	-0.0022	0.0024	0.1343
ULS: 3. D + (S or Lr or R)	-0.0362	8.6037	-0.0024	-0.0080	0.0088	0.4501
ULS: 3. D + (S or Lr or R)	-0.0099	2.8928	-0.0007	-0.0022	0.0024	0.1343
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0296	7.1760	-0.0020	-0.0066	0.0072	0.3712

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0099	2.8928	-0.0007	-0.0022	0.0024	0.1343
ULS: 5b. D + 0.7E	-0.0099	2.8928	-0.0007	-0.0022	0.0024	0.1343
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0296	7.1760	-0.0020	-0.0066	0.0072	0.3712
ULS: 8. 0.6D + 0.7E	-0.0060	1.7357	-0.0004	-0.0013	0.0014	0.0806
ULS: 5a. D + 0.6W_Wind downforce Case A only	-5.5290	9.4969	0.0153	0.0357	-0.0986	63.3179
ULS: 5a. D + 0.6W_Wind downforce Case B only	-5.5290	9.4969	0.0153	0.0357	-0.0986	63.3179
ULS: 5a. D + 0.6W_Wind uplift Case A only	4.3918	-2.3726	-0.0116	-0.0279	0.0731	-47.5808
ULS: 5a. D + 0.6W_Wind uplift Case B only	3.7146	-1.5698	-0.0165	-0.0404	0.0994	-53.0945
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-4.1690	12.1291	0.0100	0.0218	-0.0686	47.7589
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-4.1690	12.1291	0.0100	0.0218	-0.0686	47.7589
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.2717	3.2269	-0.0102	-0.0258	0.0602	-35.4152
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.7637	3.8290	-0.0139	-0.0352	0.0799	-39.5505
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-4.1493	7.8459	0.0113	0.0262	-0.0734	47.5220
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-4.1493	7.8459	0.0113	0.0262	-0.0734	47.5220
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.2914	-1.0563	-0.0089	-0.0215	0.0555	-35.6520
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.7834	-0.4542	-0.0125	-0.0308	0.0752	-39.7873
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-5.5251	8.3398	0.0156	0.0366	-0.0996	63.2642
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-5.5251	8.3398	0.0156	0.0366	-0.0996	63.2642
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	4.3958	-3.5298	-0.0113	-0.0270	0.0722	-47.6345
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	3.7185	-2.7270	-0.0162	-0.0395	0.0985	-53.1483

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	18.1117
Shear X	-9.2223
Shear Z	-0.0287
Moment X	-0.0704
Moment Y (Twist)	0.1716
Moment Z	106.6084

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	12.1291
Shear X	-5.5290
Shear Z	-0.0165
Moment X	-0.0404
Moment Y (Twist)	0.0996
Moment Z	63.3179

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	-0.0099	2.8928	0.0007	0.0022	-0.0024	0.1343
ULS: 2. D + L	-0.0099	2.8928	0.0007	0.0022	-0.0024	0.1343
ULS: 3. D + (S or Lr or R)	-0.0362	8.6037	0.0025	0.0080	-0.0086	0.4501
ULS: 3. D + (S or Lr or R)	-0.0099	2.8928	0.0007	0.0022	-0.0024	0.1343
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0296	7.1760	0.0020	0.0066	-0.0070	0.3712
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0099	2.8928	0.0007	0.0022	-0.0024	0.1343
ULS: 5b. D + 0.7E	-0.0099	2.8928	0.0007	0.0022	-0.0024	0.1343
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0296	7.1760	0.0020	0.0066	-0.0070	0.3712
ULS: 8. 0.6D + 0.7E	-0.0060	1.7357	0.0004	0.0013	-0.0014	0.0806
ULS: 5a. D + 0.6W_Wind downforce Case A only	-5.5290	9.4969	-0.0153	-0.0357	0.0986	63.3179
ULS: 5a. D + 0.6W_Wind downforce Case B only	-5.5290	9.4969	-0.0153	-0.0357	0.0986	63.3179
ULS: 5a. D + 0.6W_Wind uplift Case A only	4.3918	-2.3726	0.0116	0.0279	-0.0731	-47.5808
ULS: 5a. D + 0.6W_Wind uplift Case B only	3.7146	-1.5698	0.0165	0.0404	-0.0994	-53.0945

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	-4.1690	12.1291	-0.0100	-0.0219	0.0687	47.7589
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-4.1690	12.1291	-0.0100	-0.0219	0.0687	47.7589
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.2717	3.2269	0.0102	0.0258	-0.0601	-35.4152
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.7637	3.8290	0.0139	0.0352	-0.0798	-39.5505
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-4.1492	7.8459	-0.0113	-0.0262	0.0734	47.5220
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-4.1492	7.8459	-0.0113	-0.0262	0.0734	47.5220
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.2914	-1.0563	0.0089	0.0215	-0.0554	-35.6520
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.7834	-0.4542	0.0125	0.0308	-0.0751	-39.7873
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-5.5251	8.3398	-0.0156	-0.0366	0.0996	63.2642
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-5.5251	8.3398	-0.0156	-0.0366	0.0996	63.2642
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	4.3958	-3.5298	0.0113	0.0270	-0.0722	-47.6345
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	3.7185	-2.7270	0.0162	0.0395	-0.0984	-53.1483

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	18.1117
Shear X	-9.2223
Shear Z	0.0287
Moment X	0.0709
Moment Y (Twist)	0.1714
Moment Z	106.6085

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	12.1291
Shear X	-5.5290
Shear Z	0.0165
Moment X	0.0404
Moment Y (Twist)	0.0996
Moment Z	63.3179

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	0.0099	2.6077	-0.0318	-0.0934	-0.0077	-0.0792
ULS: 2. D + L	0.0099	2.6077	-0.0318	-0.0934	-0.0077	-0.0792
ULS: 3. D + (S or Lr or R)	0.0362	7.5688	-0.1163	-0.3428	-0.0261	-0.3365
ULS: 3. D + (S or Lr or R)	0.0099	2.6077	-0.0318	-0.0934	-0.0077	-0.0792
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0296	6.3285	-0.0952	-0.2805	-0.0215	-0.2722
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0099	2.6077	-0.0318	-0.0934	-0.0077	-0.0792
ULS: 5b. D + 0.7E	0.0099	2.6077	-0.0318	-0.0934	-0.0077	-0.0792
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0296	6.3285	-0.0952	-0.2805	-0.0215	-0.2722
ULS: 8. 0.6D + 0.7E	0.0060	1.5646	-0.0191	-0.0560	-0.0046	-0.0475
ULS: 5a. D + 0.6W_Wind downforce Case A only	-4.8143	8.3303	-0.1604	-0.4195	0.6080	55.3147
ULS: 5a. D + 0.6W_Wind downforce Case B only	-4.8143	8.3303	-0.1604	-0.4195	0.6080	55.3147
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.8517	-1.9511	0.0672	0.1578	-0.4826	-41.9759
ULS: 5a. D + 0.6W_Wind uplift Case B only	3.2847	-1.2709	0.0637	0.1484	-0.4710	-47.0970
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.5885	10.6205	-0.1916	-0.5250	0.4402	41.2733
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.5885	10.6205	-0.1916	-0.5250	0.4402	41.2733
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.9110	2.9094	-0.0209	-0.0920	-0.3777	-31.6946
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.4857	3.4195	-0.0235	-0.0991	-0.3690	-35.5355
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.6082	6.8997	-0.1283	-0.3380	0.4541	41.4662
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.6082	6.8997	-0.1283	-0.3380	0.4541	41.4662
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.8913	-0.8114	0.0425	0.0950	-0.3639	-31.5017
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.4660	-0.3013	0.0398	0.0879	-0.3552	-35.3425

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-4.8183	7.2872	-0.1477	-0.3821	0.6110	55.3464
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-4.8183	7.2872	-0.1477	-0.3821	0.6110	55.3464
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.8477	-2.9942	0.0800	0.1952	-0.4795	-41.9442
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	3.2807	-2.3140	0.0764	0.1857	-0.4679	-47.0653

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	15.8362
Shear X	-8.0404
Shear Z	-0.2960
Moment X	-0.7910
Moment Y (Twist)	1.0260
Moment Z	92.8893

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	10.6205
Shear X	-4.8183
Shear Z	-0.1916
Moment X	-0.5250
Moment Y (Twist)	0.6110
Moment Z	55.3464

Project Details

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

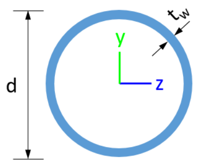
User Name: sales@mtsolar.us
Unit System: imperial

Design Input Information

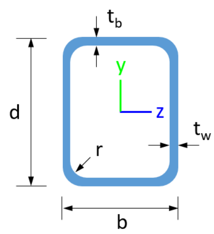
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

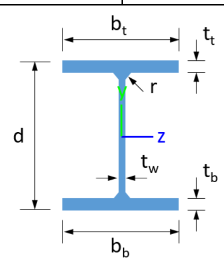
Section Dimensions



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



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



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

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

3	2in Pipe Sch 120	1.67	1.91	0.96	0.96	0.00	1.13	1.13
6	4in Pipe Sch 120	5.58	23.29	11.64	11.64	0.00	7.24	7.24
11	10in Pipe Sch 40	11.91	321.47	160.73	160.73	0.00	39.38	39.38
17	HSS5x3x1/4	3.37	11.00	4.81	10.70	0.93	3.77	5.38
20	W10x12	3.54	0.05	2.18	53.80	50.90	1.74	12.60

Member Properties

Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	11	23.30	23.30	11.09	-	300	200	1
2	6	1.30	1.30	2.00	-	300	200	1
3	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.20,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17	300	200	1
4	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.82,1.67,1.67,1.66,1.64,1.67,1.67,1.68,1.67,1.67,1.67,1.65,2.06,1.67,1.67,1.66,1.65	300	200	1
5	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.69,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66	300	200	1
6	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
7	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.69,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
8	20	1.33	1.33	2.05	1.69,1.69,1.69,1.69,1.69,1.69,1.68,1.68,1.67,1.19,1.68,1.68,1.68,1.48,1.68,1.68,1.72,1.74,1.68,1.68,1.68,1.00,1.68,1.68,1.68,1.51	300	200	1
9	3	2.60	2.60	4.00	-	300	200	1
10	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.31,1.67,1.67,1.66,1.65,1.67,1.67,1.68,1.67,1.67,1.67,1.66,1.25,1.67,1.67,1.66,1.66	300	200	1
11	20	1.33	1.33	2.05	1.71,1.71,1.71,1.71,1.71,1.71,1.77,1.77,1.81,1.87,1.78,1.78,1.79,1.84,1.75,1.75,1.62,1.35,1.77,1.77,1.81,1.86,1.78,1.78,1.78,1.83	300	200	1
12	6	1.30	1.30	2.00	-	300	200	1
13	20	4.88	4.00	7.50	1.11,1.11,1.11,1.11,1.11,1.11,1.10,1.10,1.10,1.12,1.10,1.10,1.10,1.11,1.11,1.11,1.12,1.09,1.10,1.10,1.10,1.12,1.10,1.10,1.10,1.11	300	200	1
14	20	4.88	4.00	7.50	1.11,1.11,1.11,1.11,1.11,1.11,1.10,1.10,1.11,1.30,1.10,1.10,1.11,1.05,1.11,1.11,1.11,1.13,1.10,1.10,1.11,1.24,1.10,1.10,1.11,1.04	300	200	1
15	20	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
16	20	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33	300	200	1
101	11	23.30	23.30	11.09	-	300	200	1
102	6	1.30	1.30	2.00	-	300	200	1
103	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
104	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,2.44,1.67,1.67,1.66,1.65,1.67,1.67,1.68,1.67,1.67,1.67,1.66,1.17,1.67,1.67,1.66,1.66	300	200	1
105	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
106	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
107	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
108	20	1.33	1.33	2.05	2.08,2.08,2.08,2.09,2.08,2.08,2.08,2.08,2.08,1.40,2.08,2.08,2.08,2.09,2.08,2.08,2.10,2.08,2.08,2.08,2.08,1.70,2.08,2.08,2.08,2.09	300	200	1
109	3	2.60	2.60	4.00	-	300	200	1
110	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.11,1.67,1.67,1.66,1.65,1.67,1.67,1.68,1.67,1.67,1.67,1.66,1.14,1.67,1.67,1.66,1.66	300	200	1
111	20	1.33	1.33	2.05	2.08,2.08,2.08,2.08,2.08,2.08,2.06,2.06,1.88,1.90,2.06,2.06,1.98,1.97,2.07,2.07,2.36,1.63,2.06,2.06,1.89,1.90,2.05,2.05,2.00,1.98	300	200	1
112	6	1.30	1.30	2.00	-	300	200	1

113	20	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.05,1.06,1.06,1.05,1.05,1.05,1.06,1.05,1.05,1.04,1.02,1.05,1.05,1.06,1.06,1.05,1.05,1.05,1.06	300	200	1
114	20	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.05,1.05,1.07,1.05,1.05,1.05,1.05,1.05,1.05,1.03,1.04,1.05,1.05,1.05,1.06,1.05,1.05,1.05,1.05	300	200	1
115	20	6.63	6.63	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.14,1.14,1.13,1.12,1.13,1.13,1.13,1.13,1.14,1.14,1.18,1.33,1.14,1.14,1.13,1.13,1.13,1.13,1.13,1.13	300	200	1
116	20	6.63	6.63	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,2.60,1.15,1.15,1.15,1.16,1.15,1.15,1.16,1.15,1.15,1.15,1.15,1.57,1.15,1.15,1.15,1.16	300	200	1
201	11	23.30	23.30	11.09	-	300	200	1
202	6	1.30	1.30	2.00	-	300	200	1
203	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
204	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.11,1.67,1.67,1.66,1.65,1.67,1.67,1.68,1.67,1.67,1.67,1.66,1.14,1.67,1.67,1.66,1.66	300	200	1
205	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
206	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
207	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
208	20	1.33	1.33	2.05	2.07,2.07,2.07,2.07,2.07,2.07,2.07,2.07,2.06,1.02,2.07,2.07,2.06,2.09,2.07,2.07,2.08,2.07,2.07,2.07,2.06,1.88,2.07,2.07,2.06,2.08	300	200	1
209	3	2.60	2.60	4.00	-	300	200	1
210	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,2.44,1.67,1.67,1.66,1.65,1.67,1.67,1.68,1.67,1.67,1.67,1.66,1.17,1.67,1.67,1.66,1.66	300	200	1
211	20	1.33	1.33	2.05	2.07,2.07,2.07,2.07,2.07,2.07,1.88,1.88,1.71,1.72,1.85,1.85,1.80,1.78,1.98,1.98,2.20,1.79,1.88,1.88,1.72,1.73,1.85,1.85,1.81,1.79	300	200	1
212	6	1.30	1.30	2.00	-	300	200	1
213	20	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.05,1.06,1.06,1.05,1.05,1.05,1.06,1.05,1.05,1.04,1.02,1.05,1.05,1.06,1.06,1.05,1.05,1.05,1.06	300	200	1
214	20	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.05,1.05,1.06,1.05,1.05,1.05,1.05,1.05,1.05,1.03,1.04,1.05,1.05,1.05,1.06,1.05,1.05,1.05,1.05	300	200	1
215	20	6.63	6.63	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.14,1.14,1.13,1.14,1.14,1.14,1.14,1.14,1.15,1.15,1.18,1.96,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14	300	200	1
216	20	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.15,1.15,1.15,1.10,1.15,1.15,1.15,1.16,1.16,1.16,1.16,1.16,1.15,1.15,1.15,1.65,1.15,1.15,1.15,1.16	300	200	1
301	11	23.30	23.30	11.09	-	300	200	1
302	6	1.30	1.30	2.00	-	300	200	1
303	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
304	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.31,1.67,1.67,1.66,1.65,1.67,1.67,1.68,1.67,1.67,1.67,1.66,1.25,1.67,1.67,1.66,1.66	300	200	1
305	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.69,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
306	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.20,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17	300	200	1
307	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.69,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66	300	200	1
308	20	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33	300	200	1
309	3	2.60	2.60	4.00	-	300	200	1
310	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.82,1.67,1.67,1.66,1.64,1.67,1.67,1.68,1.67,1.67,1.67,1.65,2.06,1.67,1.67,1.66,1.65	300	200	1
311	20	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
312	6	1.30	1.30	2.00	-	300	200	1
313	20	4.88	4.00	7.50	1.11,1.11,1.11,1.11,1.11,1.11,1.10,1.10,1.10,1.12,1.10,1.10,1.10,1.11,1.11,1.11,1.12,1.09,1.10,1.10,1.10,1.12,1.10,1.10,1.10,1.11	300	200	1
314	20	4.88	4.00	7.50	1.11,1.11,1.11,1.11,1.11,1.11,1.10,1.10,1.11,1.30,1.10,1.10,1.11,1.05,1.11,1.11,1.11,1.13,1.10,1.10,1.11,1.24,1.10,1.10,1.11,1.04	300	200	1

315	20	6.63	6.63	10.20	1.12,1.12,1.12,1.12,1.12,1.12,1.13,1.13,1.13,1.14,1.13,1.13,1.13,1.13,1.13,1.13,1.11,1.12,1.13,1.13,1.13,1.14,1.13,1.13,1.13,1.13	300	200	1
316	20	6.63	6.63	10.20	1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,2.50,1.12,1.12,1.12,1.10,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.22,1.12,1.12,1.12,1.10	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	535.87	350.93	147.68	147.68	160.76	160.76
2	251.01	248.88	27.16	27.16	75.30	75.30
3	151.65	150.70	20.17	14.14	54.12	28.95
4	151.65	145.15	20.17	14.14	54.12	28.95
5	151.65	149.10	20.17	14.14	54.12	28.95
6	151.65	150.70	20.17	14.14	54.12	28.95
7	151.65	149.10	20.17	14.14	54.12	28.95
8	159.30	140.46	46.90	6.46	56.26	44.91
9	75.10	66.32	4.25	4.25	22.53	22.53
10	151.65	145.15	20.17	14.14	54.12	28.95
11	159.30	140.46	46.90	6.46	56.26	44.91
12	251.01	248.88	27.16	27.16	75.30	75.30
13	159.30	97.43	33.34	6.46	56.26	44.91
14	159.30	97.43	31.80	6.46	56.26	44.91
15	159.30	55.15	46.90	6.46	56.26	44.91
16	159.30	55.15	46.90	6.46	56.26	44.91
101	535.87	350.93	147.68	147.68	160.76	160.76
102	251.01	248.88	27.16	27.16	75.30	75.30
103	151.65	150.70	20.17	14.14	54.12	28.95
104	151.65	145.15	20.17	14.14	54.12	28.95
105	151.65	149.10	20.17	14.14	54.12	28.95
106	151.65	150.70	20.17	14.14	54.12	28.95
107	151.65	149.10	20.17	14.14	54.12	28.95
108	159.30	140.46	46.90	6.46	56.26	44.91
109	75.10	66.32	4.25	4.25	22.53	22.53
110	151.65	145.15	20.17	14.14	54.12	28.95
111	159.30	140.46	46.90	6.46	56.26	44.91
112	251.01	248.88	27.16	27.16	75.30	75.30
113	159.30	97.43	31.31	6.46	56.26	44.91
114	159.30	97.43	31.63	6.46	56.26	44.91
115	159.30	75.13	21.66	6.46	56.26	44.91
116	159.30	75.13	22.11	6.46	56.26	44.91
201	535.87	350.93	147.68	147.68	160.76	160.76
202	251.01	248.88	27.16	27.16	75.30	75.30
203	151.65	150.70	20.17	14.14	54.12	28.95
204	151.65	145.15	20.17	14.14	54.12	28.95
205	151.65	149.10	20.17	14.14	54.12	28.95
206	151.65	150.70	20.17	14.14	54.12	28.95
207	151.65	149.10	20.17	14.14	54.12	28.95
208	159.30	140.46	46.90	6.46	56.26	44.91
209	75.10	66.32	4.25	4.25	22.53	22.53
210	151.65	145.15	20.17	14.14	54.12	28.95
211	159.30	140.46	46.90	6.46	56.26	44.91
212	251.01	248.88	27.16	27.16	75.30	75.30

212	251.01	248.88	27.16	27.16	75.30	75.30
213	159.30	97.43	31.32	6.46	56.26	44.91
214	159.30	97.43	31.62	6.46	56.26	44.91
215	159.30	75.13	21.86	6.46	56.26	44.91
216	159.30	75.13	21.25	6.46	56.26	44.91
301	535.87	350.93	147.68	147.68	160.76	160.76
302	251.01	248.88	27.16	27.16	75.30	75.30
303	151.65	150.70	20.17	14.14	54.12	28.95
304	151.65	145.15	20.17	14.14	54.12	28.95
305	151.65	149.10	20.17	14.14	54.12	28.95
306	151.65	150.70	20.17	14.14	54.12	28.95
307	151.65	149.10	20.17	14.14	54.12	28.95
308	159.30	55.15	46.90	6.46	56.26	44.91
309	75.10	66.32	4.25	4.25	22.53	22.53
310	151.65	145.15	20.17	14.14	54.12	28.95
311	159.30	55.15	46.90	6.46	56.26	44.91
312	251.01	248.88	27.16	27.16	75.30	75.30
313	159.30	97.43	33.36	6.46	56.26	44.91
314	159.30	97.43	31.79	6.46	56.26	44.91
315	159.30	75.13	21.41	6.46	56.26	44.91
316	159.30	75.13	21.19	6.46	56.26	44.91

Design Ratio

Member ID	P	M_z	M_y	V_y	V_z	(P,M_z,M_y)	Worst LC	KL/r	δ	Status
1	0.045	0.629	0.017	0.050	0.002	0.656	#13	0.380	Not Required	Pass
2	0.004	0.404	0.264	0.093	0.051	0.668	#13	0.036	Not Required	Pass
3	0.010	0.733	0.048	0.072	0.003	0.755	#13	0.046	Not Required	Pass
4	0.009	0.688	0.164	0.069	0.036	0.755	#13	0.082	Not Required	Pass
5	0.010	0.455	0.160	0.073	0.041	0.470	#13	0.076	Not Required	Pass
6	0.013	0.830	0.094	0.083	0.018	0.881	#13	0.046	Not Required	Pass
7	0.013	0.515	0.221	0.082	0.056	0.542	#13	0.076	Not Required	Pass
8	0.002	0.087	0.229	0.048	0.026	0.236	#24	0.102	Not Required	Pass
9	0.017	0.065	0.078	0.002	0.002	0.141	#13	0.206	Not Required	Pass
10	0.013	0.768	0.211	0.077	0.046	0.818	#13	0.082	Not Required	Pass
11	0.003	0.089	0.235	0.052	0.026	0.239	#24	0.102	Not Required	Pass
12	0.003	0.494	0.301	0.110	0.056	0.796	#13	0.054	Not Required	Pass
13	0.007	0.247	0.598	0.067	0.033	0.751	#21	0.306	Not Required	Pass
14	0.011	0.232	0.590	0.062	0.033	0.726	#21	0.204	Not Required	Pass
15	0.000	0.072	0.207	0.032	0.016	0.269	#21	Not Required	Not Required	Pass
16	0.000	0.068	0.207	0.030	0.016	0.267	#21	Not Required	Not Required	Pass
101	0.052	0.722	0.002	0.057	0.000	0.747	#13	0.380	Not Required	Pass
102	0.004	0.512	0.322	0.117	0.061	0.834	#13	0.036	Not Required	Pass
103	0.013	0.886	0.078	0.088	0.011	0.927	#13	0.046	Not Required	Pass
104	0.013	0.843	0.214	0.084	0.046	0.917	#13	0.082	Not Required	Pass
105	0.013	0.550	0.221	0.088	0.057	0.577	#13	0.076	Not Required	Pass
106	0.013	0.900	0.078	0.090	0.011	0.939	#13	0.046	Not Required	Pass
107	0.013	0.559	0.218	0.089	0.056	0.586	#13	0.076	Not Required	Pass
108	0.002	0.061	0.225	0.049	0.026	0.261	#21	0.102	Not Required	Pass
109	0.020	0.067	0.062	0.001	0.000	0.134	#13	0.206	Not Required	Pass
110	0.013	0.847	0.210	0.084	0.046	0.915	#13	0.082	Not Required	Pass

111	0.003	0.075	0.230	0.052	0.026	0.263	#21	0.102	Not Required	Pass
112	0.004	0.519	0.328	0.117	0.062	0.849	#13	0.036	Not Required	Pass
113	0.008	0.257	0.602	0.068	0.033	0.801	#21	0.306	Not Required	Pass
114	0.012	0.266	0.597	0.065	0.034	0.799	#21	0.306	Not Required	Pass
115	0.006	0.368	0.325	0.053	0.026	0.641	#21	0.507	Not Required	Pass
116	0.002	0.339	0.325	0.051	0.026	0.623	#21	0.507	Not Required	Pass
201	0.052	0.722	0.002	0.057	0.000	0.747	#13	0.380	Not Required	Pass
202	0.004	0.519	0.329	0.117	0.062	0.849	#13	0.036	Not Required	Pass
203	0.013	0.900	0.078	0.090	0.011	0.939	#13	0.046	Not Required	Pass
204	0.013	0.847	0.210	0.084	0.046	0.915	#13	0.082	Not Required	Pass
205	0.013	0.559	0.218	0.089	0.056	0.586	#13	0.076	Not Required	Pass
206	0.013	0.886	0.078	0.088	0.011	0.927	#13	0.046	Not Required	Pass
207	0.013	0.550	0.221	0.088	0.057	0.577	#13	0.076	Not Required	Pass
208	0.002	0.072	0.234	0.051	0.026	0.265	#21	0.102	Not Required	Pass
209	0.020	0.067	0.062	0.001	0.000	0.134	#13	0.206	Not Required	Pass
210	0.013	0.843	0.214	0.084	0.046	0.917	#13	0.082	Not Required	Pass
211	0.003	0.085	0.238	0.053	0.026	0.265	#21	0.102	Not Required	Pass
212	0.004	0.512	0.322	0.117	0.061	0.834	#13	0.036	Not Required	Pass
213	0.008	0.257	0.602	0.068	0.033	0.801	#21	0.306	Not Required	Pass
214	0.012	0.266	0.597	0.065	0.034	0.799	#21	0.306	Not Required	Pass
215	0.006	0.340	0.325	0.052	0.026	0.612	#21	0.507	Not Required	Pass
216	0.003	0.297	0.324	0.049	0.026	0.586	#21	0.507	Not Required	Pass
301	0.045	0.629	0.017	0.050	0.002	0.656	#13	0.380	Not Required	Pass
302	0.003	0.494	0.302	0.110	0.056	0.796	#13	0.054	Not Required	Pass
303	0.013	0.830	0.094	0.083	0.018	0.881	#13	0.046	Not Required	Pass
304	0.013	0.768	0.211	0.077	0.046	0.818	#13	0.082	Not Required	Pass
305	0.013	0.515	0.220	0.082	0.056	0.542	#13	0.076	Not Required	Pass
306	0.010	0.733	0.048	0.072	0.003	0.755	#13	0.046	Not Required	Pass
307	0.010	0.455	0.160	0.073	0.041	0.470	#13	0.076	Not Required	Pass
308	0.000	0.068	0.207	0.030	0.016	0.267	#21	Not Required	Not Required	Pass
309	0.017	0.065	0.078	0.002	0.002	0.141	#13	0.206	Not Required	Pass
310	0.009	0.688	0.164	0.069	0.036	0.755	#13	0.082	Not Required	Pass
311	0.000	0.072	0.207	0.032	0.016	0.269	#21	Not Required	Not Required	Pass
312	0.004	0.404	0.264	0.093	0.051	0.668	#13	0.036	Not Required	Pass
313	0.007	0.247	0.598	0.067	0.033	0.751	#21	0.204	Not Required	Pass
314	0.011	0.232	0.591	0.062	0.033	0.726	#21	0.306	Not Required	Pass
315	0.006	0.370	0.325	0.052	0.026	0.644	#21	0.507	Not Required	Pass
316	0.002	0.346	0.324	0.048	0.026	0.629	#21	0.507	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

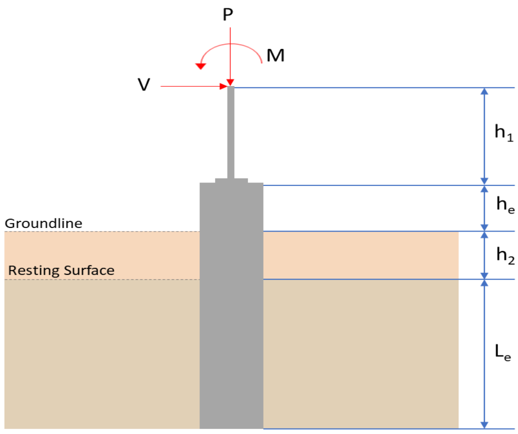
SkyCiv Foundation Design

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
$L = 8\ \text{ft}$ - Total pile length
$h_1 = 0\ \text{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \text{ft}$ - Depth to resisting surface
$h_e = 0\ \text{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	10.620	15.836
V_x (kip)	-4.818	-8.040
V_z (kip)	0.192	0.296
M_x (kipft)	0.525	0.790
M_z (kipft)	55.346	92.888

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,

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

$$H_o = \frac{(-4.818\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.7672\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(55.346\ \mathrm{kipft}) + ((-4.818\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 8.8131\ \mathrm{kipft/ft}$$

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:
$L_{e,x} = 7.2018\ \mathrm{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.192\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = 0.030573\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.525\ \mathrm{kipft}) + ((0.192\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.083599\ \mathrm{kipft/ft}$$

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:
$L_{e,z} = 2.2059\ \mathrm{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.2018\ \mathrm{ft}), (2.2059\ \mathrm{ft})]$$

$$L_{e,req} = 7.202\ \mathrm{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8\ \mathrm{ft}) - (0\ \mathrm{ft}) - (0\ \mathrm{ft})$$

$$L_e = 8\ \mathrm{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.202\ \mathrm{ft})}{(8\ \mathrm{ft})}$$

$$Ratio = 0.90025$$

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

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

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

$$q = \frac{(10.62\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.66375\ \mathrm{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.66375\ \mathrm{kip/ft}^2\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.33187$$

Status: **PASS**
Ratio: **0.330**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 2$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.7672\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 8.8131\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.8131\ \mathrm{kipft/ft}) \times (8\ \mathrm{ft})) + \left(3 \times (-0.7672\ \mathrm{kip/ft}) \times (8\ \mathrm{ft})^2\right)}{(6 \times (8.8131\ \mathrm{kipft/ft})) + (4 \times (-0.7672\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))}$$

$$a = 5.5447\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (8.8131\ \mathrm{kipft/ft})) + (3 \times (-0.7672\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]^2}{(8\ \mathrm{ft})^2 \times [(3 \times (8.8131\ \mathrm{kipft/ft})) + (2 \times (-0.7672\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]}$$

$$p = 0.23461\ \mathrm{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (8.8131\ \mathrm{kipft/ft})) + ((-0.7672\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]}{(8\ \mathrm{ft})^2}$$

$$s = 1.0771\ \mathrm{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.5447\ \mathrm{ft})}{2}$$

$$p_a = 0.41585\ \mathrm{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.23461 \text{ kip/ft}^2\right)}{\left(0.41585 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.56417$$

Status: **PASS**
Ratio: **0.560**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150 \text{ psf/ft}) \times (8 \text{ ft})$$

$$p_s = 1.2 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.0771 \text{ kip/ft}^2\right)}{\left(1.2 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.89754$$

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

Considering z-direction:

$H_o = 0.030573 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 0.083599 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.083599 \text{ kipft/ft}) \times (8 \text{ ft})) + \left(3 \times (0.030573 \text{ kip/ft}) \times (8 \text{ ft})^2\right)}{(6 \times (0.083599 \text{ kipft/ft})) + (4 \times (0.030573 \text{ kip/ft}) \times (8 \text{ ft}))}$$

$$a = 5.774 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.083599 \text{ kipft/ft})) + (3 \times (0.030573 \text{ kip/ft}) \times (8 \text{ ft}))]^2}{(8 \text{ ft})^2 \times [(3 \times (0.083599 \text{ kipft/ft})) + (2 \times (0.030573 \text{ kip/ft}) \times (8 \text{ ft}))]}$$

$$p = 0.018069 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.083599 \text{ kipft/ft})) + ((0.030573 \text{ kip/ft}) \times (8 \text{ ft}))]}{(8 \text{ ft})^2}$$

$$s = 0.038605 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.774 \text{ ft})}{2}$$

$$p_a = 0.43305 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.018069 \text{ kip/ft}^2\right)}{\left(0.43305 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.041725$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8\ \mathrm{ft})$$

$$p_s = 1.2\ \mathrm{kip/ft^2}$$

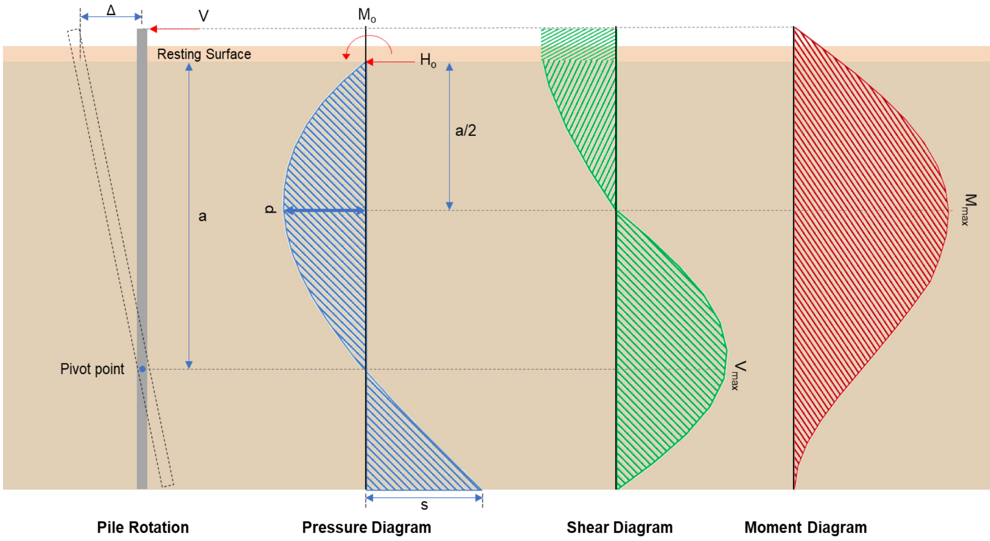
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.038605\ \mathrm{kip/ft^2})}{(1.2\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.032171$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-8.04\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -1.2803\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(92.888\ \mathrm{kipft}) + ((-8.04\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 14.791\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(14.791\ \mathrm{kipft/ft})}{(-1.2803\ \mathrm{kip/ft})}$$

$$E = 11.553\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (14.791\ \mathrm{kipft/ft}) \times (8\ \mathrm{ft})) + \left(3 \times (-1.2803\ \mathrm{kip/ft}) \times (8\ \mathrm{ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (14.791\ \mathrm{kipft/ft})) + (4 \times (-1.2803\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))}$$

$$a = 5.5439\ \mathrm{ft}$$

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

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

$$V_{max} = ((-1.2803\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (11.553\ \mathrm{ft})}{(8\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.5439\ \mathrm{ft})}{(8\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (11.553\ \mathrm{ft})}{(8\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.5439\ \mathrm{ft})}{(8\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 16.463\ \mathrm{kip}$$

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

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

$$M_{max} = ((-1.2803\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (8\ \mathrm{ft})) \times \left[\left(\frac{(11.553\ \mathrm{ft})}{(8\ \mathrm{ft})} + \frac{(5.5439\ \mathrm{ft})}{2 \times (8\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (11.553\ \mathrm{ft})}{(8\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.5439\ \mathrm{ft})}{2 \times (8\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (11.553\ \mathrm{ft})}{(8\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.5439\ \mathrm{ft})}{2 \times (8\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 62.141\ \mathrm{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.296\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = 0.047134\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.79\ \mathrm{kipft}) + ((0.296\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.1258\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.1258\ \mathrm{kipft/ft})}{(0.047134\ \mathrm{kip/ft})}$$

$$E = 2.6689\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.1258\ \mathrm{kipft/ft}) \times (8\ \mathrm{ft})) + \left(3 \times (0.047134\ \mathrm{kip/ft}) \times (8\ \mathrm{ft})^2\right)}{(6 \times (0.1258\ \mathrm{kipft/ft})) + (4 \times (0.047134\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))}$$

$$a = 5.7777\ \mathrm{ft}$$

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

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

$$V_{max} = ((0.047134\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.6689\ \text{ft})}{(8\ \text{ft})} + 3\right) \times \left(\frac{(5.7777\ \text{ft})}{(8\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (2.6689\ \text{ft})}{(8\ \text{ft})} + 2\right) \times \left(\frac{(5.7777\ \text{ft})}{(8\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.2377\ \text{kip}$$

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

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

$$M_{max} = ((0.047134\ \text{kip/ft}) \times (48\ \text{in}) \times (8\ \text{ft})) \times \left[\left(\frac{(2.6689\ \text{ft})}{(8\ \text{ft})} + \frac{(5.7777\ \text{ft})}{2 \times (8\ \text{ft})}\right) - \left[\left(\frac{4 \times (2.6689\ \text{ft})}{(8\ \text{ft})} + 3\right) \times \left(\frac{(5.7777\ \text{ft})}{2 \times (8\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (2.6689\ \text{ft})}{(8\ \text{ft})} + 2\right) \times \left(\frac{(5.7777\ \text{ft})}{2 \times (8\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.81696\ \text{kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(15.836\ \text{kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.07\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max[(-84.07\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))]$$

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

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

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

$$Ratio = \frac{(15.836\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0059196$$

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

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 $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 15.836 \text{ kip} \rightarrow 15836 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(15836 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.6 \text{ kip}$$

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

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.6 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.6 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((120.6 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.47 \text{ kip}$$

Considering x-direction:

$V_{max} = 16.463 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(16.463\ \mathrm{kip})}{(111.47\ \mathrm{kip})}$$

$$Ratio = 0.14769$$

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

Considering z-direction:

$V_{max} = 0.2377\ \mathrm{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.2377\ \mathrm{kip})}{(111.47\ \mathrm{kip})}$$

$$Ratio = 0.0021324$$

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:

$M_{max} = 62.141\ \mathrm{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(62.141\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$

$$Ratio = 0.24896$$

Status: **PASS**
Ratio: **0.250**

Considering z-direction:

$M_{max} = 0.81696\ \mathrm{kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(0.81696 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.0032731$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

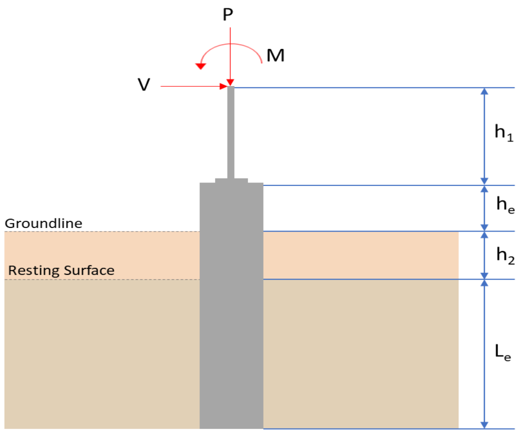
SkyCiv Foundation Design

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

$L = 8\ \text{ft}$ - Total pile length

$h_1 = 0\ \text{ft}$ - Lateral load height from the top of the pile,

$h_2 = 0\ \text{ft}$ - Depth to resisting surface

$h_e = 0\ \text{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	10.620	15.836
V_x (kip)	-4.818	-8.040
V_z (kip)	-0.192	-0.296
M_x (kipft)	-0.525	-0.791
M_z (kipft)	55.346	92.889

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,

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

$$H_o = \frac{(-4.818\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.7672\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(55.346\ \text{kipft}) + ((-4.818\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 8.8131\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 7.2018\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.192\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.030573\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.525\ \text{kipft}) + ((-0.192\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.083599\ \text{kipft/ft}$$

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:
$L_{e,z} = 1.5633\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.2018\ \text{ft}), (1.5633\ \text{ft})]$$

$$L_{e,req} = 7.202\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 8\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.202\ \text{ft})}{(8\ \text{ft})}$$

$$Ratio = 0.90025$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\,D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(10.62 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.66375 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.66375 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.33187$$

Status: **PASS**
Ratio: **0.330**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 2$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.7672 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 8.8131 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.8131 \text{ kipft/ft}) \times (8 \text{ ft})) + \left(3 \times (-0.7672 \text{ kip/ft}) \times (8 \text{ ft})^2\right)}{(6 \times (8.8131 \text{ kipft/ft})) + (4 \times (-0.7672 \text{ kip/ft}) \times (8 \text{ ft}))}$$

$$a = 5.5447 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (8.8131 \text{ kipft/ft})) + (3 \times (-0.7672 \text{ kip/ft}) \times (8 \text{ ft}))]^2}{(8 \text{ ft})^2 \times [(3 \times (8.8131 \text{ kipft/ft})) + (2 \times (-0.7672 \text{ kip/ft}) \times (8 \text{ ft}))]}$$

$$p = 0.23461 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (8.8131 \text{ kipft/ft})) + ((-0.7672 \text{ kip/ft}) \times (8 \text{ ft}))]}{(8 \text{ ft})^2}$$

$$s = 1.0771 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.5447 \text{ ft})}{2}$$

$$p_a = 0.41585 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.23461\ \mathrm{kip/ft^2}\right)}{\left(0.41585\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.56417$$

Status: **PASS**
Ratio: **0.560**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8\ \mathrm{ft})$$

$$p_s = 1.2\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.0771\ \mathrm{kip/ft^2}\right)}{\left(1.2\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.89754$$

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

Considering z-direction:

$H_o = -0.030573\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.083599\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.083599\ \mathrm{kipft/ft}) \times (8\ \mathrm{ft})) + \left(3 \times (-0.030573\ \mathrm{kip/ft}) \times (8\ \mathrm{ft})^2\right)}{(6 \times (0.083599\ \mathrm{kipft/ft})) + (4 \times (-0.030573\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))}$$

$$a = 5.774\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.083599\ \mathrm{kipft/ft})) + (3 \times (-0.030573\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]^{\ 2}}{(8\ \mathrm{ft})^2 \times [(3 \times (0.083599\ \mathrm{kipft/ft})) + (2 \times (-0.030573\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]}$$

$$p = -0.0078407\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.083599\ \mathrm{kipft/ft})) + ((-0.030573\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]}{(8\ \mathrm{ft})^2}$$

$$s = -0.0072552\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.774\ \mathrm{ft})}{2}$$

$$p_a = 0.43305\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.0078407\ \mathrm{kip/ft^2}\right)}{\left(0.43305\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.018106$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8\ \mathrm{ft})$$

$$p_s = 1.2\ \mathrm{kip/ft^2}$$

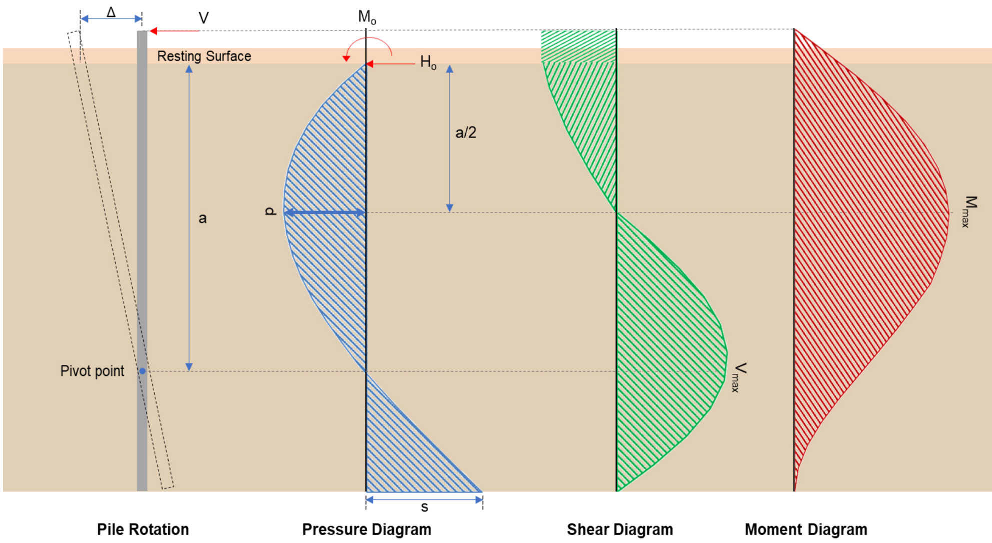
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.0072552\ \mathrm{kip/ft^2}\right)}{\left(1.2\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.006046$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-8.04\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -1.2803\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(92.889\ \mathrm{kipft}) + ((-8.04\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 14.791\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(14.791\ \mathrm{kipft/ft})}{(-1.2803\ \mathrm{kip/ft})}$$

$$E = 11.553\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (14.791\ \mathrm{kipft/ft}) \times (8\ \mathrm{ft})) + \left(3 \times (-1.2803\ \mathrm{kip/ft}) \times (8\ \mathrm{ft})^2\right)}{}$$

$$a = \frac{\quad}{(6 \times (14.791\ \mathrm{kipft/ft})) + (4 \times (-1.2803\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))}$$

$$a = 5.5439\ \mathrm{ft}$$

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

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

$$V_{max} = ((-1.2803\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (11.553\ \mathrm{ft})}{(8\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.5439\ \mathrm{ft})}{(8\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (11.553\ \mathrm{ft})}{(8\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.5439\ \mathrm{ft})}{(8\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 16.463\ \mathrm{kip}$$

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

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

$$M_{max} = ((-1.2803\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (8\ \mathrm{ft})) \times \left[\left(\frac{(11.553\ \mathrm{ft})}{(8\ \mathrm{ft})} + \frac{(5.5439\ \mathrm{ft})}{2 \times (8\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (11.553\ \mathrm{ft})}{(8\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.5439\ \mathrm{ft})}{2 \times (8\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (11.553\ \mathrm{ft})}{(8\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.5439\ \mathrm{ft})}{2 \times (8\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 62.142\ \mathrm{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.296\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.047134\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.791\ \mathrm{kipft}) + ((-0.296\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.12596\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.12596\ \mathrm{kipft/ft})}{(-0.047134\ \mathrm{kip/ft})}$$

$$E = 2.6723\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.12596\ \mathrm{kipft/ft}) \times (8\ \mathrm{ft})) + \left(3 \times (-0.047134\ \mathrm{kip/ft}) \times (8\ \mathrm{ft})^2\right)}{(6 \times (0.12596\ \mathrm{kipft/ft})) + (4 \times (-0.047134\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))}$$

$$a = 5.7775\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.047134\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.6723\ \mathrm{ft})}{(8\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.7775\ \mathrm{ft})}{(8\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (2.6723\ \mathrm{ft})}{(8\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.7775\ \mathrm{ft})}{(8\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.23784\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.047134\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (8\ \mathrm{ft})) \times \left[\left(\frac{(2.6723\ \mathrm{ft})}{(8\ \mathrm{ft})} + \frac{(5.7775\ \mathrm{ft})}{2 \times (8\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (2.6723\ \mathrm{ft})}{(8\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.7775\ \mathrm{ft})}{2 \times (8\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (2.6723\ \mathrm{ft})}{(8\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.7775\ \mathrm{ft})}{2 \times (8\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.81751\ \mathrm{kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(15.836\ \mathrm{kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5\ \mathrm{ksi}) \times (2304\ \mathrm{in}^2))}{(60\ \mathrm{ksi}) - (0.85 \times (2.5\ \mathrm{ksi}))}, (0.08 \times (2304\ \mathrm{in}^2))\right]$$

$$A_{st,required} = -84.07\ \mathrm{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.07\ \mathrm{in}^2), (0.0018 \times (2304\ \mathrm{in}^2))\right]$$

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

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,

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

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

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

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,

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

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

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

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

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(15.836\ \text{kip}\right)}{\left(2675.2\ \text{kip}\right)}$$

$$Ratio = 0.0059196$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 15.836 \text{ kip} \rightarrow 15836 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(15836 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.6 \text{ kip}$$

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

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.6 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.6 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((120.6 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.47 \text{ kip}$$

Considering x-direction:

$V_{max} = 16.463 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(16.463 \text{ kip})}{(111.47 \text{ kip})}$$ $$Ratio = 0.14769$$	Status: **PASS** Ratio: **0.150**
	Considering z-direction: $V_{max} = 0.23784 \text{ kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.23784 \text{ kip})}{(111.47 \text{ kip})}$$ $$Ratio = 0.0021337$$	Status: **PASS** Ratio: **0.000**
14.5.2.1b	**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: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6 \text{ kipft}$$ 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:** $M_{max} = 62.142 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(62.142 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.24897$$	Status: **PASS** Ratio: **0.250**
	Considering z-direction: $M_{max} = 0.81751 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(0.81751 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.0032753$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

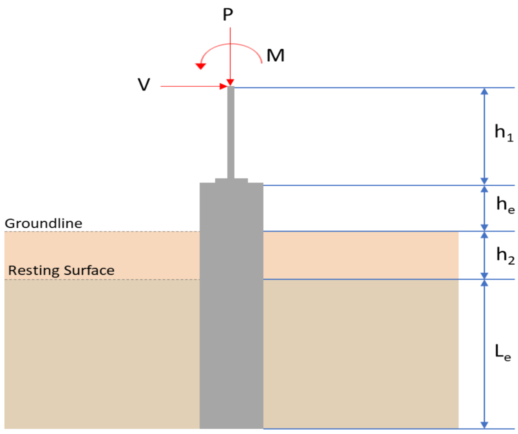
SkyCiv Foundation Design

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
$L = 8.25\text{ ft}$ - Total pile length
$h_1 = 0\text{ ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\text{ ft}$ - Depth to resisting surface
$h_e = 0\text{ ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	12.129	18.112
V_x (kip)	-5.529	-9.222
V_z (kip)	-0.016	-0.029
M_x (kipft)	-0.040	-0.070
M_z (kipft)	63.318	106.608

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,

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

$$H_o = \frac{(-5.529\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = -0.88041\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(63.318\ \mathrm{kipft}) + ((-5.529\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 10.082\ \mathrm{kipft/ft}$$

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:
$L_{e,x} = 7.448\ \mathrm{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.016\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.0025478\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.04\ \mathrm{kipft}) + ((-0.016\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.0063694\ \mathrm{kipft/ft}$$

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:
$L_{e,z} = 0.73504\ \mathrm{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.448\ \mathrm{ft}), (0.73504\ \mathrm{ft})]$$

$$L_{e,req} = 7.448\ \mathrm{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8.25\ \mathrm{ft}) - (0\ \mathrm{ft}) - (0\ \mathrm{ft})$$

$$L_e = 8.25\ \mathrm{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.448\ \mathrm{ft})}{(8.25\ \mathrm{ft})}$$

$$Ratio = 0.90279$$

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

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

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

$$q = \frac{(12.129\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.75806\ \mathrm{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.75806\ \mathrm{kip/ft}^2\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.37903$$

Status: **PASS**
Ratio: **0.380**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8.25\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 2.0625$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.88041\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 10.082\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (10.082\ \mathrm{kipft/ft}) \times (8.25\ \mathrm{ft})) + \left(3 \times (-0.88041\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft})^2\right)}{(6 \times (10.082\ \mathrm{kipft/ft})) + (4 \times (-0.88041\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))}$$

$$a = 5.7231\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (10.082\ \mathrm{kipft/ft})) + (3 \times (-0.88041\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]^2}{(8.25\ \mathrm{ft})^2 \times [(3 \times (10.082\ \mathrm{kipft/ft})) + (2 \times (-0.88041\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]}$$

$$p = 0.24093\ \mathrm{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (10.082\ \mathrm{kipft/ft})) + ((-0.88041\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]}{(8.25\ \mathrm{ft})^2}$$

$$s = 1.1373\ \mathrm{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.7231\ \mathrm{ft})}{2}$$

$$p_a = 0.42923\ \mathrm{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

	$$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.24093 \text{ kip/ft}^2\right)}{\left(0.42923 \text{ kip/ft}^2\right)}$$ $$Ratio = 0.56131$$ p_s - Allowable lateral soil pressure at depth L_e, $$p_s = R\, L_e$$ $$p_s = (150 \text{ psf/ft}) \times (8.25 \text{ ft})$$ $$p_s = 1.2375 \text{ kip/ft}^2$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{s}{p_s}$$ $$Ratio = \frac{\left(1.1373 \text{ kip/ft}^2\right)}{\left(1.2375 \text{ kip/ft}^2\right)}$$ $$Ratio = 0.91905$$	Status: **PASS** Ratio: **0.560** Status: **PASS** Ratio: **0.920**
	Considering z-direction: $H_o = -0.0025478 \text{ kip/ft}$ - Lateral force per length of pile, $M_o = 0.0063694 \text{ kipft/ft}$ - Overturning moment per length of pile, a - Distance from resting surface to pivot point, $$a = \frac{(4\, M_o\, L_e) + \left(3\, H_o\, L_e^2\right)}{(6\, M_o) + (4\, H_o\, L_e)}$$ $$a = \frac{(4 \times (0.0063694 \text{ kipft/ft}) \times (8.25 \text{ ft})) + \left(3 \times (-0.0025478 \text{ kip/ft}) \times (8.25 \text{ ft})^2\right)}{(6 \times (0.0063694 \text{ kipft/ft})) + (4 \times (-0.0025478 \text{ kip/ft}) \times (8.25 \text{ ft}))}$$ $$a = 5.9727 \text{ ft}$$ p - Earth pressure against the pile at distance a/2 from resting surface, $$p = \frac{0.75\, [(4\, M_o) + (3\, H_o\, L_e)]^2}{L_e^2\, [(3\, M_o) + (2\, H_o\, L_e)]}$$ $$p = \frac{0.75 \times [(4 \times (0.0063694 \text{ kipft/ft})) + (3 \times (-0.0025478 \text{ kip/ft}) \times (8.25 \text{ ft}))]^{\,2}}{(8.25 \text{ ft})^2 \times [(3 \times (0.0063694 \text{ kipft/ft})) + (2 \times (-0.0025478 \text{ kip/ft}) \times (8.25 \text{ ft}))]}$$ $$p = -0.00067866 \text{ kip/ft}^2$$ s - Earth pressure against the pile at distance L_e, $$s = \frac{6\, [(2\, M_o) + (H_o\, L_e)]}{L_e^2}$$ $$s = \frac{6 \times [(2 \times (0.0063694 \text{ kipft/ft})) + ((-0.0025478 \text{ kip/ft}) \times (8.25 \text{ ft}))]}{(8.25 \text{ ft})^2}$$ $$s = -0.00072994 \text{ kip/ft}^2$$ **Check lateral soil pressure capacity:** p_a - Allowable lateral soil pressure at depth a/2, $$p_a = R\, \frac{a}{2}$$ $$p_a = (150 \text{ psf/ft}) \times \frac{(5.9727 \text{ ft})}{2}$$ $$p_a = 0.44795 \text{ kip/ft}^2$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(-0.00067866 \text{ kip/ft}^2\right)}{\left(0.44795 \text{ kip/ft}^2\right)}$$		

$$Ratio = -0.001515$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8.25\ \mathrm{ft})$$

$$p_s = 1.2375\ \mathrm{kip/ft^2}$$

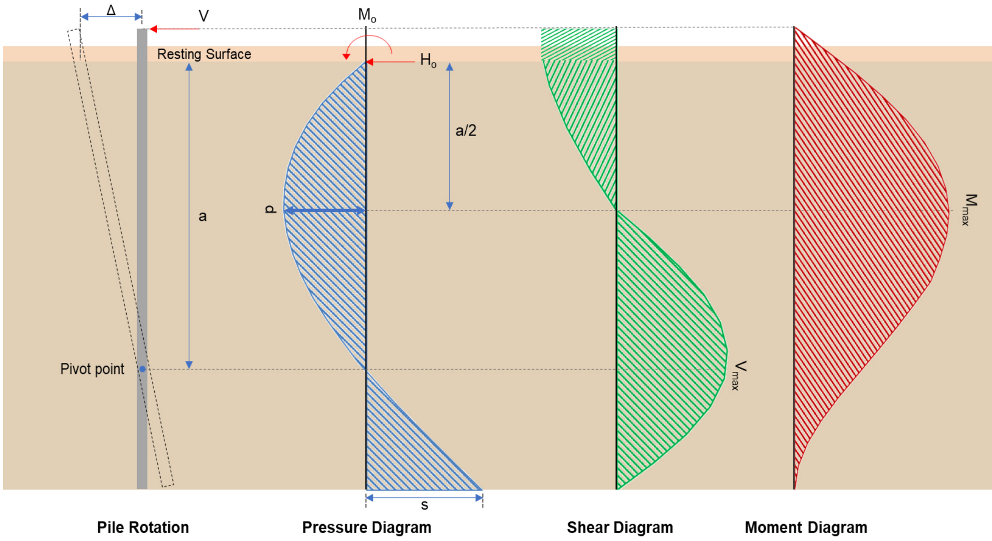
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.00072994\ \mathrm{kip/ft^2}\right)}{\left(1.2375\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.00058985$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-9.222\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -1.4685\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(106.61\ \mathrm{kipft}) + ((-9.222\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 16.976\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(16.976\ \mathrm{kipft/ft})}{(-1.4685\ \mathrm{kip/ft})}$$

$$E = 11.56\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (16.976\ \mathrm{kipft/ft}) \times (8.25\ \mathrm{ft})) + \left(3 \times (-1.4685\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (16.976\ \text{kipft/ft})) + (4 \times (-1.4685\ \text{kip/ft}) \times (8.25\ \text{ft}))}$$

$$a = 5.7216\ \text{ft}$$

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

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

$$V_{max} = ((-1.4685\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (11.56\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.7216\ \text{ft})}{(8.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (11.56\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.7216\ \text{ft})}{(8.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 18.437\ \text{kip}$$

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

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

$$M_{max} = ((-1.4685\ \text{kip/ft}) \times (48\ \text{in}) \times (8.25\ \text{ft})) \times \left[\left(\frac{(11.56\ \text{ft})}{(8.25\ \text{ft})} + \frac{(5.7216\ \text{ft})}{2 \times (8.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (11.56\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.7216\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (11.56\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.7216\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 71.667\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.029\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.0046178\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.07\ \text{kipft}) + ((-0.029\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.011146\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.011146\ \text{kipft/ft})}{(-0.0046178\ \text{kip/ft})}$$

$$E = 2.4138\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.011146\ \text{kipft/ft}) \times (8.25\ \text{ft})) + \left(3 \times (-0.0046178\ \text{kip/ft}) \times (8.25\ \text{ft})^2\right)}{(6 \times (0.011146\ \text{kipft/ft})) + (4 \times (-0.0046178\ \text{kip/ft}) \times (8.25\ \text{ft}))}$$

$$a = 5.9778\ \text{ft}$$

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

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

$$V_{max} = ((-0.0046178\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.4138\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.9778\ \text{ft})}{(8.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (2.4138\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.9778\ \text{ft})}{(8.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.021972\ \text{kip}$$

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

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

$$M_{max} = ((-0.0046178\ \text{kip/ft}) \times (48\ \text{in}) \times (8.25\ \text{ft})) \times \left[\left(\frac{(2.4138\ \text{ft})}{(8.25\ \text{ft})} + \frac{(5.9778\ \text{ft})}{2 \times (8.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (2.4138\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.9778\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (2.4138\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.9778\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.07713\ \text{kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(18.112\ \text{kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5\ \text{ksi}) \times \left(2304\ \text{in}^2\right)\right)}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, \left(0.08 \times \left(2304\ \text{in}^2\right)\right)\right]$$

$$A_{st,required} = -83.994\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-83.994\ \text{in}^2\right), \left(0.0018 \times \left(2304\ \text{in}^2\right)\right)\right]$$

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

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

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

$$Ratio = \frac{(18.112\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0067704$$

Status: PASS
Ratio: 0.010

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 $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 18.112 \text{ kip} \rightarrow 18112 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(18112 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.9 \text{ kip}$$

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

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

$$V_c = Min\,[(296.21 \text{ kip}), (120.9 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 120.9 \text{ kip}$$

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

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((120.9 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.67 \text{ kip}$$

Considering x-direction:

$V_{max} = 18.437 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(18.437 \text{ kip})}{(111.67 \text{ kip})}$$ $$Ratio = 0.16511$$	Status: **PASS** Ratio: **0.170**
	Considering z-direction: $V_{max} = 0.021972 \text{ kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.021972 \text{ kip})}{(111.67 \text{ kip})}$$ $$Ratio = 0.00019676$$	Status: **PASS** Ratio: **0.000**
14.5.2.1b	**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: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\; 0.85\; f_{ck}'\; S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6 \text{ kipft}$$ 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:** $M_{max} = 71.667 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(71.667 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.28713$$	Status: **PASS** Ratio: **0.290**
	Considering z-direction: $M_{max} = 0.07713 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

		$$Ratio = \frac{(0.07713\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.00030901$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

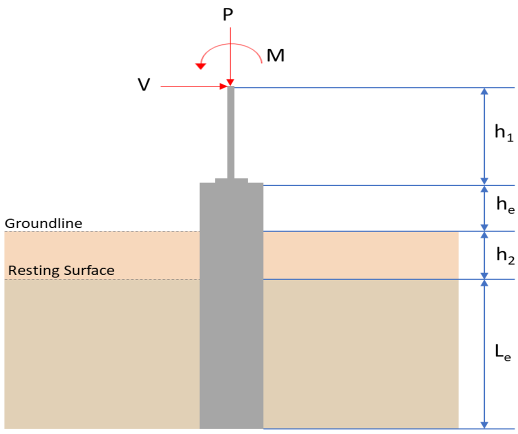
SkyCiv Foundation Design

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
$L = 8.25 \text{ ft}$ - Total pile length
$h_1 = 0 \text{ ft}$ - Lateral load height from the top of the pile,
$h_2 = 0 \text{ ft}$ - Depth to resisting surface
$h_e = 0 \text{ ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	12.129	18.112
V_x (kip)	-5.529	-9.222
V_z (kip)	0.016	0.029
M_x (kipft)	0.040	0.071
M_z (kipft)	63.318	106.608

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,

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

$$H_o = \frac{(-5.529 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.88041 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(63.318\text{ kipft}) + ((-5.529\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 10.082\text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 7.448\text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.016\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = 0.0025478\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.04\text{ kipft}) + ((0.016\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 0.0063694\text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 0.86247\text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.448\text{ ft}), (0.86247\text{ ft})]$$

$$L_{e,req} = 7.448\text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8.25\text{ ft}) - (0\text{ ft}) - (0\text{ ft})$$

$$L_e = 8.25\text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.448\text{ ft})}{(8.25\text{ ft})}$$

$$Ratio = 0.90279$$

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

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

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

$$q = \frac{(12.129 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.75806 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.75806 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.37903$$

Status: **PASS**
Ratio: **0.380**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8.25 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 2.0625$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.88041 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 10.082 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (10.082 \text{ kipft/ft}) \times (8.25 \text{ ft})) + \left(3 \times (-0.88041 \text{ kip/ft}) \times (8.25 \text{ ft})^2\right)}{(6 \times (10.082 \text{ kipft/ft})) + (4 \times (-0.88041 \text{ kip/ft}) \times (8.25 \text{ ft}))}$$

$$a = 5.7231 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (10.082 \text{ kipft/ft})) + (3 \times (-0.88041 \text{ kip/ft}) \times (8.25 \text{ ft}))]^{\,2}}{(8.25 \text{ ft})^2 \times [(3 \times (10.082 \text{ kipft/ft})) + (2 \times (-0.88041 \text{ kip/ft}) \times (8.25 \text{ ft}))]}$$

$$p = 0.24093 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (10.082 \text{ kipft/ft})) + ((-0.88041 \text{ kip/ft}) \times (8.25 \text{ ft}))]}{(8.25 \text{ ft})^2}$$

$$s = 1.1373 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.7231 \text{ ft})}{2}$$

$$p_a = 0.42923 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

	$$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.24093\ \mathrm{kip/ft^2}\right)}{\left(0.42923\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.56131$$ p_s - Allowable lateral soil pressure at depth L_e, $$p_s = R\,L_e$$ $$p_s = (150\ \mathrm{psf/ft}) \times (8.25\ \mathrm{ft})$$ $$p_s = 1.2375\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{s}{p_s}$$ $$Ratio = \frac{\left(1.1373\ \mathrm{kip/ft^2}\right)}{\left(1.2375\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.91905$$	Status: **PASS** Ratio: **0.560** Status: **PASS** Ratio: **0.920**	

Considering z-direction:

$H_o = 0.0025478\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.0063694\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0063694\ \mathrm{kipft/ft}) \times (8.25\ \mathrm{ft})) + \left(3 \times (0.0025478\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft})^2\right)}{(6 \times (0.0063694\ \mathrm{kipft/ft})) + (4 \times (0.0025478\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))}$$

$$a = 5.9727\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.0063694\ \mathrm{kipft/ft})) + (3 \times (0.0025478\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]^2}{(8.25\ \mathrm{ft})^2 \times [(3 \times (0.0063694\ \mathrm{kipft/ft})) + (2 \times (0.0025478\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]}$$

$$p = 0.0014126\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.0063694\ \mathrm{kipft/ft})) + ((0.0025478\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]}{(8.25\ \mathrm{ft})^2}$$

$$s = 0.0029759\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.9727\ \mathrm{ft})}{2}$$

$$p_a = 0.44795\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0014126\ \mathrm{kip/ft^2}\right)}{\left(0.44795\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0031534$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8.25\ \mathrm{ft})$$

$$p_s = 1.2375\ \mathrm{kip/ft^2}$$

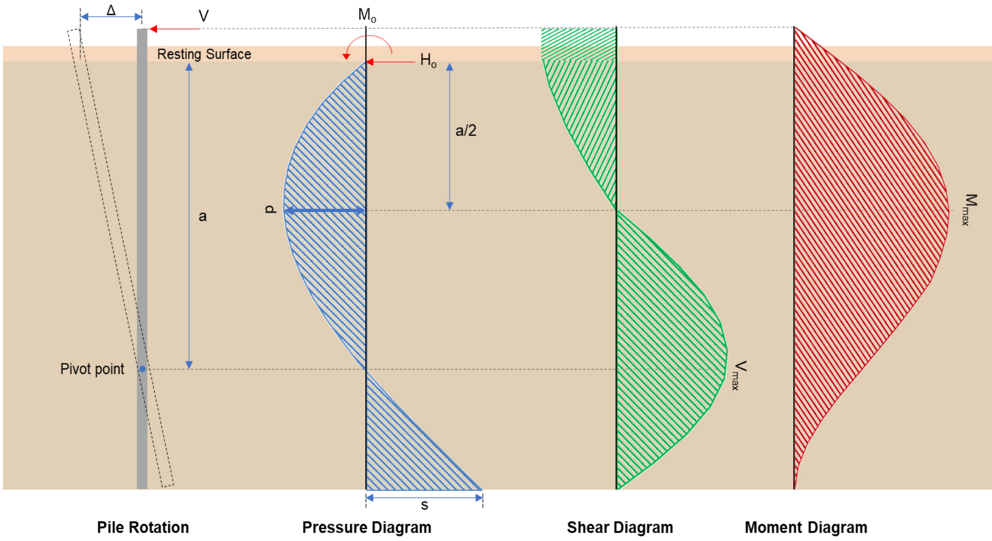
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0029759\ \mathrm{kip/ft^2}\right)}{\left(1.2375\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0024048$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-9.222\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -1.4685\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(106.61\ \mathrm{kipft}) + ((-9.222\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 16.976\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(16.976\ \mathrm{kipft/ft})}{(-1.4685\ \mathrm{kip/ft})}$$

$$E = 11.56\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (16.976\ \mathrm{kipft/ft}) \times (8.25\ \mathrm{ft})) + \left(3 \times (-1.4685\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (16.976\ \mathrm{kipft/ft})) + (4 \times (-1.4685\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))}$$

$$a = 5.7216\ \mathrm{ft}$$

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

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

$$V_{max} = ((-1.4685\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (11.56\ \mathrm{ft})}{(8.25\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.7216\ \mathrm{ft})}{(8.25\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (11.56\ \mathrm{ft})}{(8.25\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.7216\ \mathrm{ft})}{(8.25\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 18.437\ \mathrm{kip}$$

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

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

$$M_{max} = ((-1.4685\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (8.25\ \mathrm{ft})) \times \left[\left(\frac{(11.56\ \mathrm{ft})}{(8.25\ \mathrm{ft})} + \frac{(5.7216\ \mathrm{ft})}{2 \times (8.25\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (11.56\ \mathrm{ft})}{(8.25\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.7216\ \mathrm{ft})}{2 \times (8.25\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (11.56\ \mathrm{ft})}{(8.25\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.7216\ \mathrm{ft})}{2 \times (8.25\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 71.667\ \mathrm{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.029\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = 0.0046178\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.071\ \mathrm{kipft}) + ((0.029\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.011306\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.011306\ \mathrm{kipft/ft})}{(0.0046178\ \mathrm{kip/ft})}$$

$$E = 2.4483\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.011306\ \mathrm{kipft/ft}) \times (8.25\ \mathrm{ft})) + \left(3 \times (0.0046178\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft})^2\right)}{(6 \times (0.011306\ \mathrm{kipft/ft})) + (4 \times (0.0046178\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))}$$

$$a = 5.9757\ \mathrm{ft}$$

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

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

$$V_{max} = ((0.0046178\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.4483\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.9757\ \text{ft})}{(8.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (2.4483\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.9757\ \text{ft})}{(8.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.022106\ \text{kip}$$

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

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

$$M_{max} = ((0.0046178\ \text{kip/ft}) \times (48\ \text{in}) \times (8.25\ \text{ft})) \times \left[\left(\frac{(2.4483\ \text{ft})}{(8.25\ \text{ft})} + \frac{(5.9757\ \text{ft})}{2 \times (8.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (2.4483\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.9757\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (2.4483\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.9757\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.077681\ \text{kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(18.112\ \text{kip})}{(0.65) \times (0.8)} - \left(0.85 \times (2.5\ \text{ksi}) \times \left(2304\ \text{in}^2\right)\right)}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, \left(0.08 \times \left(2304\ \text{in}^2\right)\right)\right]$$

$$A_{st,required} = -83.994\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-83.994\ \text{in}^2\right), \left(0.0018 \times \left(2304\ \text{in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(18.112\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0067704$$

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

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 $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 18.112 \text{ kip} \rightarrow 18112 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(18112 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.9 \text{ kip}$$

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

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.9 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.9 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((120.9 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.67 \text{ kip}$$

Considering x-direction:

$V_{max} = 18.437 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(18.437\text{ kip})}{(111.67\text{ kip})}$$ $$Ratio = 0.16511$$	Status: **PASS** Ratio: **0.170**
	Considering z-direction: $V_{max} = 0.022106\text{ kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.022106\text{ kip})}{(111.67\text{ kip})}$$ $$Ratio = 0.00019796$$	Status: **PASS** Ratio: **0.000**
14.5.2.1b	**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: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f'_c)} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\,0.85\,f'_{ck}\,S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\text{ ksi}) \times \left(18432\text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6\text{ kipft}$$ 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:** $M_{max} = 71.667\text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(71.667\text{ kipft})}{(249.6\text{ kipft})}$$ $$Ratio = 0.28713$$	Status: **PASS** Ratio: **0.290**
	Considering z-direction: $M_{max} = 0.077681\text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(0.077681 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.00031122$$	Status: **PASS** Ratio: **0.000**