Project Details

Project Name: City of South Bend|Central Fire Station 5x10 - V1Jb

Location: 1222 S Michigan St, South Bend, IN 46601, USA

Unique ID: 4P-19.75-8TOP-XD-12-L-5Hx10W-3G4B

Dealer: ______________________________

Date: Fri Jun 13 2025

Number of Modules: 50

Number of Poles: 4

Date Sold:

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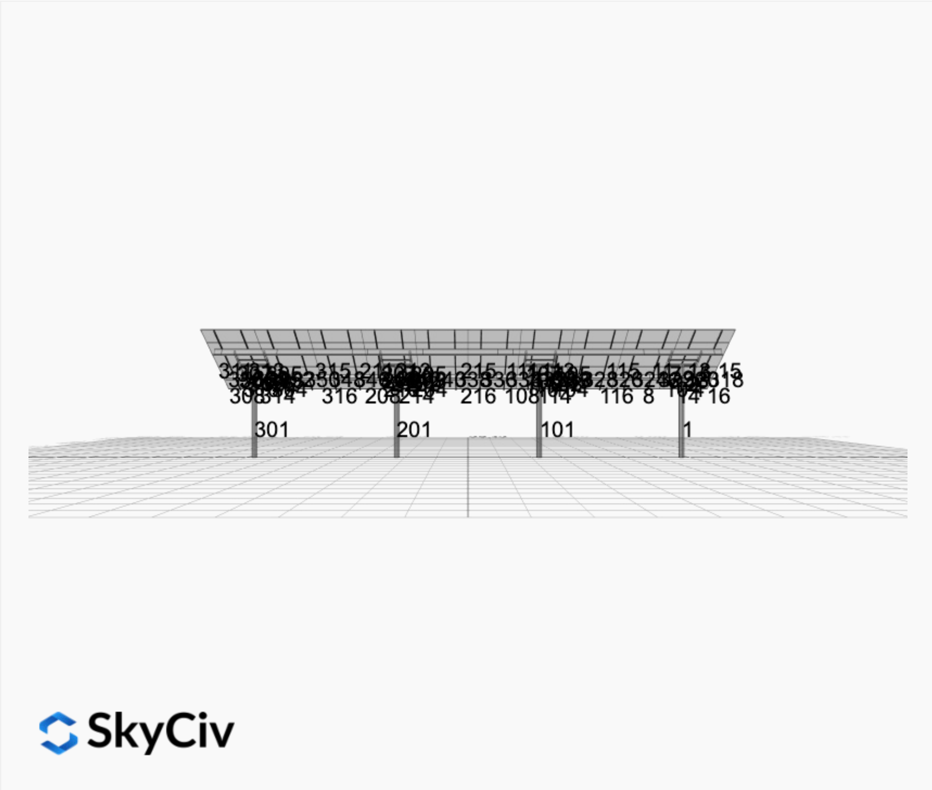


Array Dimensions N/S	17.42 ft
Array Dimensions E/W	70.25 ft
Winter Tilt Angle	26
Front Edge Clearance	9 ft

MT Solar Bill of Materials (4P-19.75-8TOP-XD-12-L-5Hx10W-3G4B)

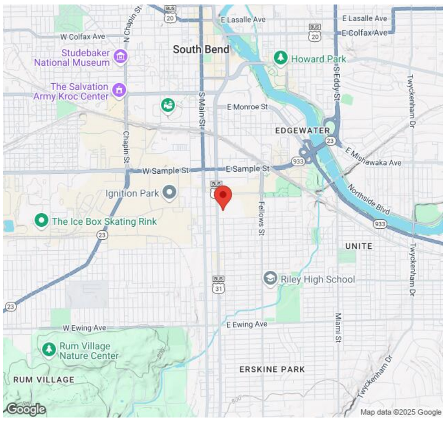
Part	Short Description	BOM Qty
MTS-PC-8	8IN Pole Cap Assembly	4
MTS-HF-XD	H-Frame Assembly-XD	4
MTS-XD-Wing-12	12IN XD Wing	4
MTS-XD-Splice-90	90IN XD Splice	6
MTS-XD-Splice-57	57IN XD Splice	6
MTS-CLAMP-ANGLE-4PK	Angle Clamp	10

Rail Bill of Materials

Part	Qty
Rails (209in)	20
Rail Attachment	80
Module Mid Clamp	80
Module End Clamp	40

Part	Qty
Ground Lug	10

Site Details:



Site Address: 1222 S Michigan St, South Bend, IN 46601, USA

Array Specification

Duty Classification:	XD
Module Width:	41.30 in
Module Length:	83.30in
Number of Rows:	5
Number of Columns:	10
Total Number of Modules:	50
Winter Tilt Angle:	26
Front Edge Clearance:	9
Total Array Height at Tilt:	16.63 ft
Total Frame Length:	68.75 ft
Module Info/Notes:	Crossroads 450w
Array Dimensions N/S:	17.42 ft
Array Dimensions E/W:	70.25 ft
Rail Length:	209.00 in
Rail Spacing:	3.51 ft

Support Specifications

Pole Size:	8in Pipe Sch 40
Pole Length above Grade:	12.82 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: 6.50 ft Pile 2: 7.00 ft Pile 3: 7.00 ft Pile 4: 6.50 ft
Foundation Volume:	16.000 y^3

Site Info

Risk Category:	I
Exposure:	B
Soil Classification:	sand
Site Location:	1222 S Michigan St, South Bend, IN 46601, USA
Wind Speed:	115 mph

Snow Load:	45 psf

Design Disclaimer

This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

AutoDesigner Input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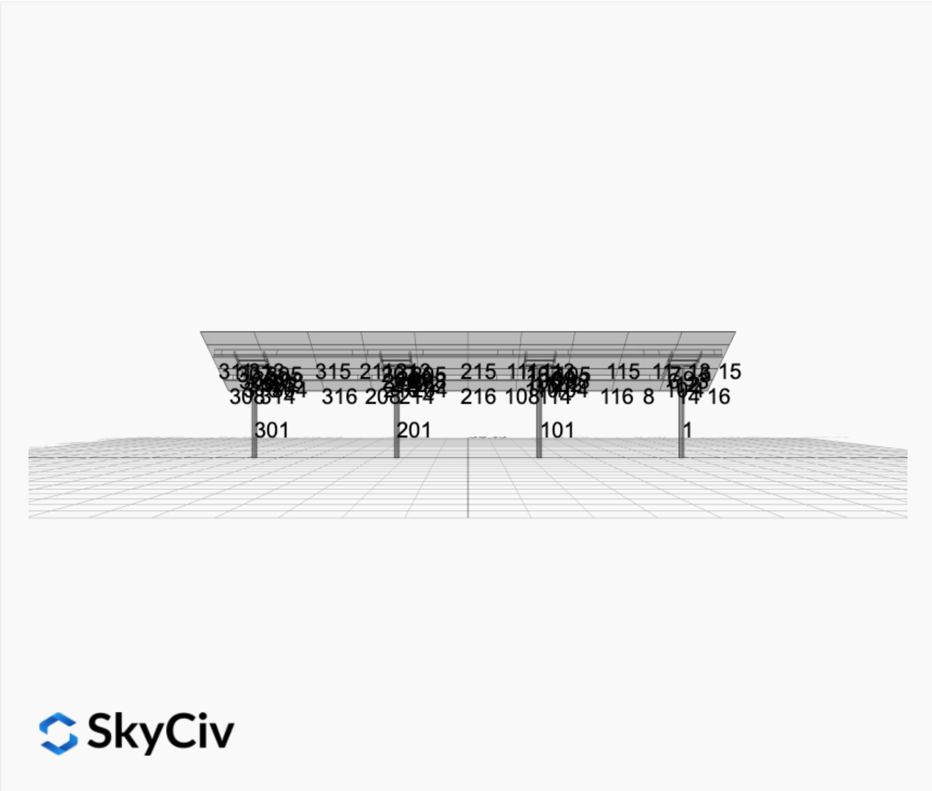
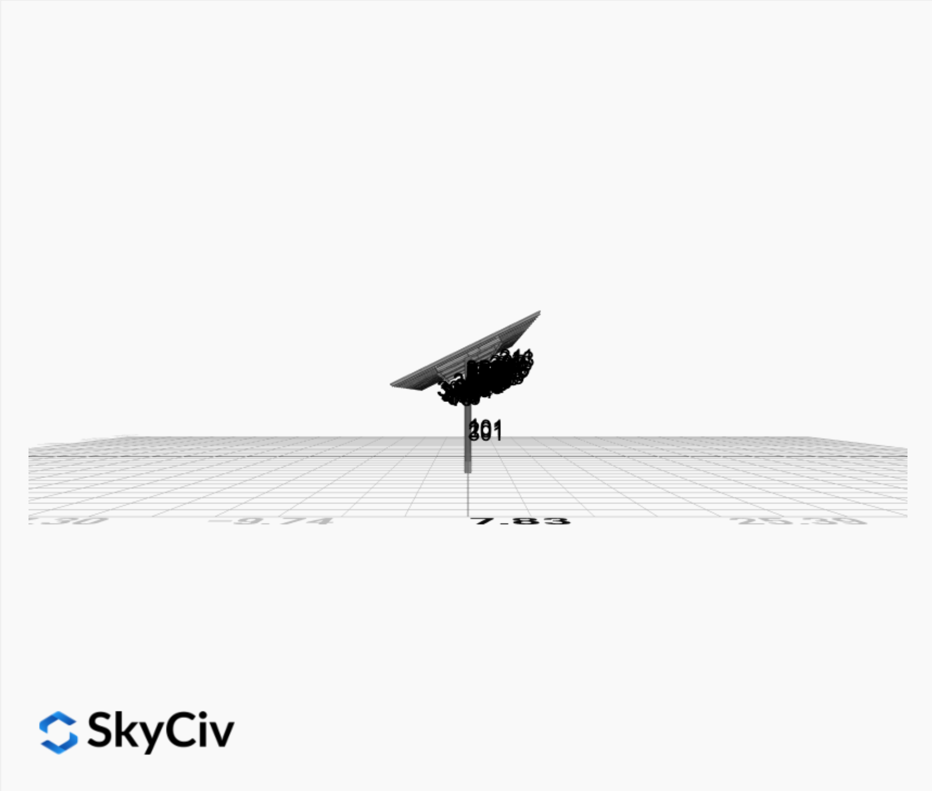
Design Notes:

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

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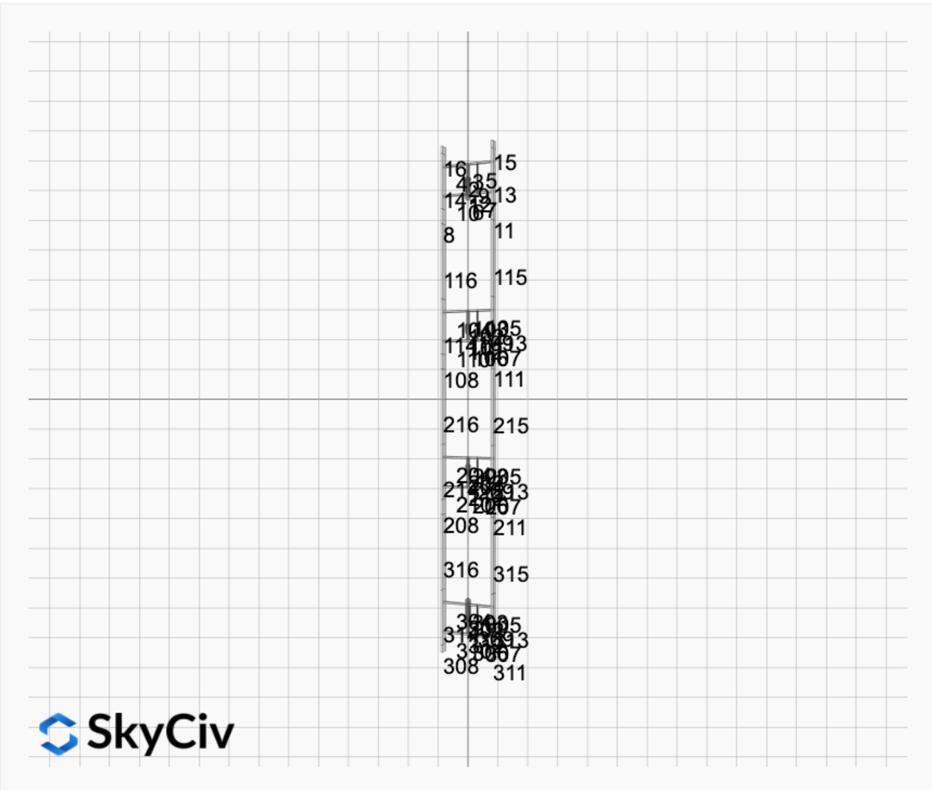
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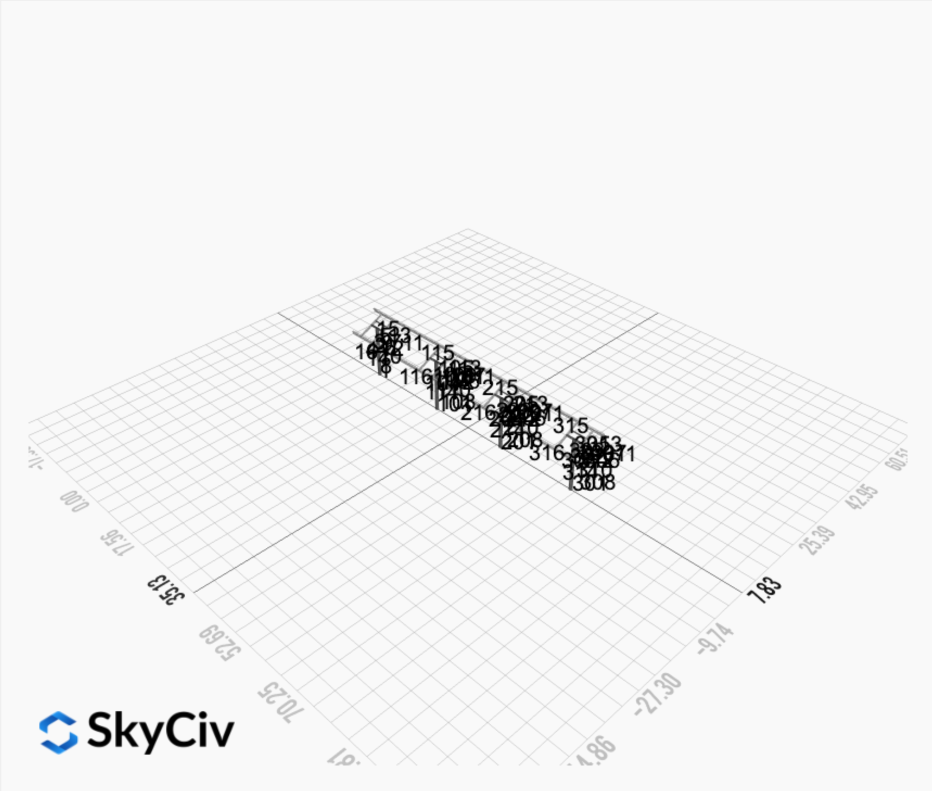
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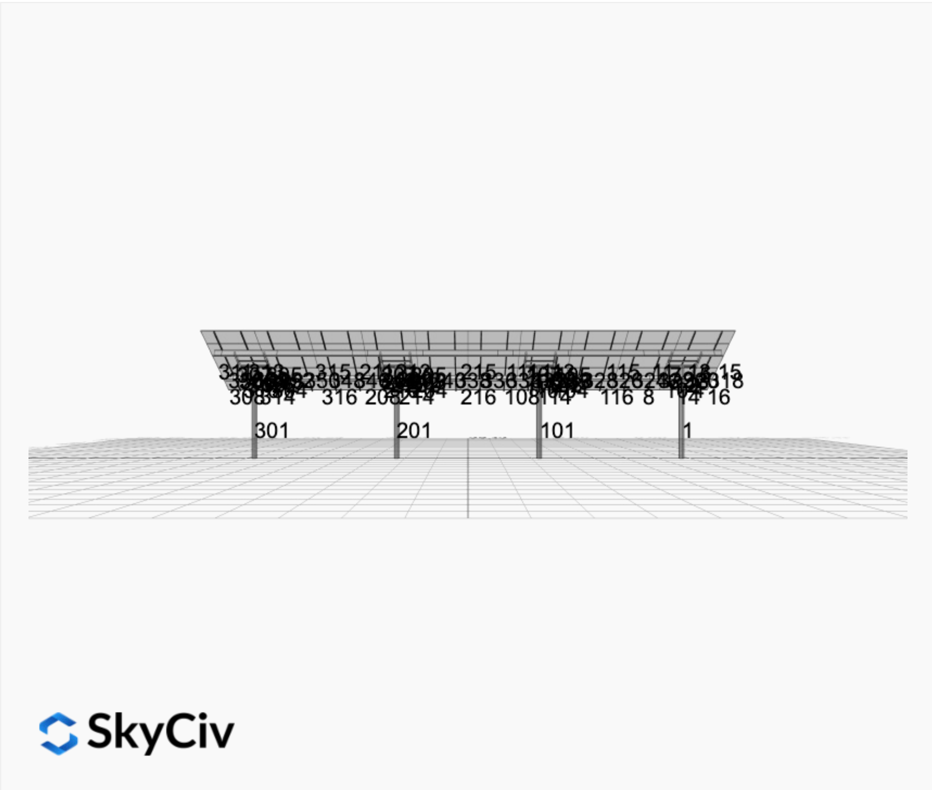
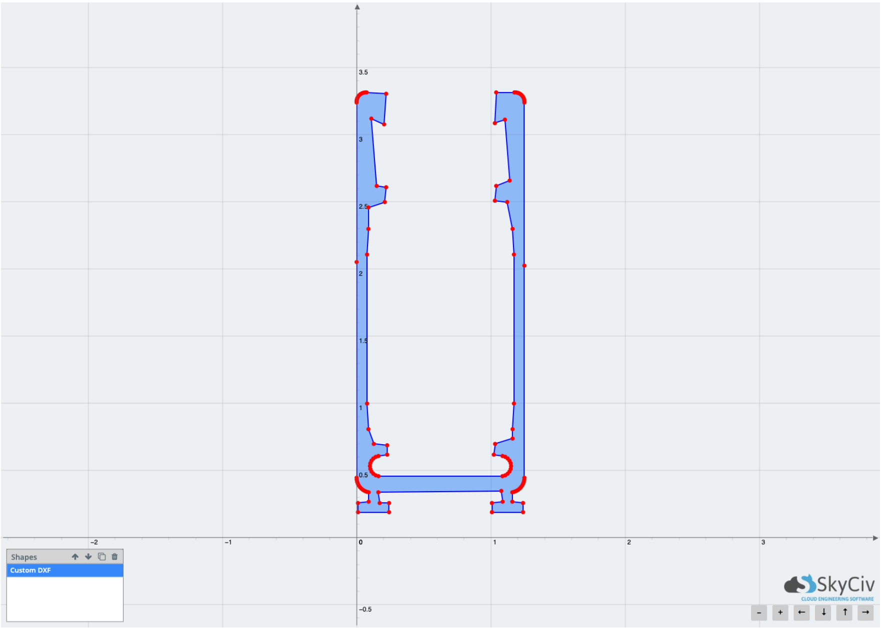
35.13
52.69
70.25
7.83
-9.74
-27.30
25.39
42.95

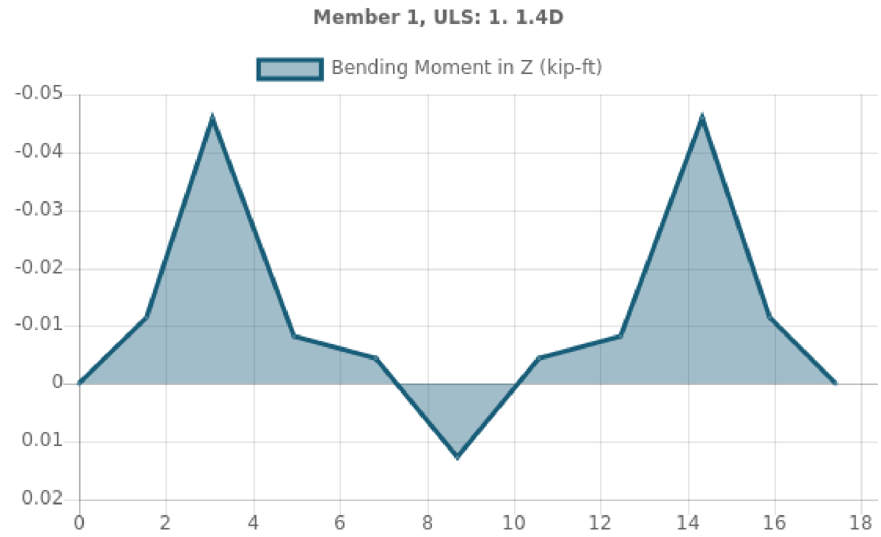

301
201
101
1

Rail Design Check

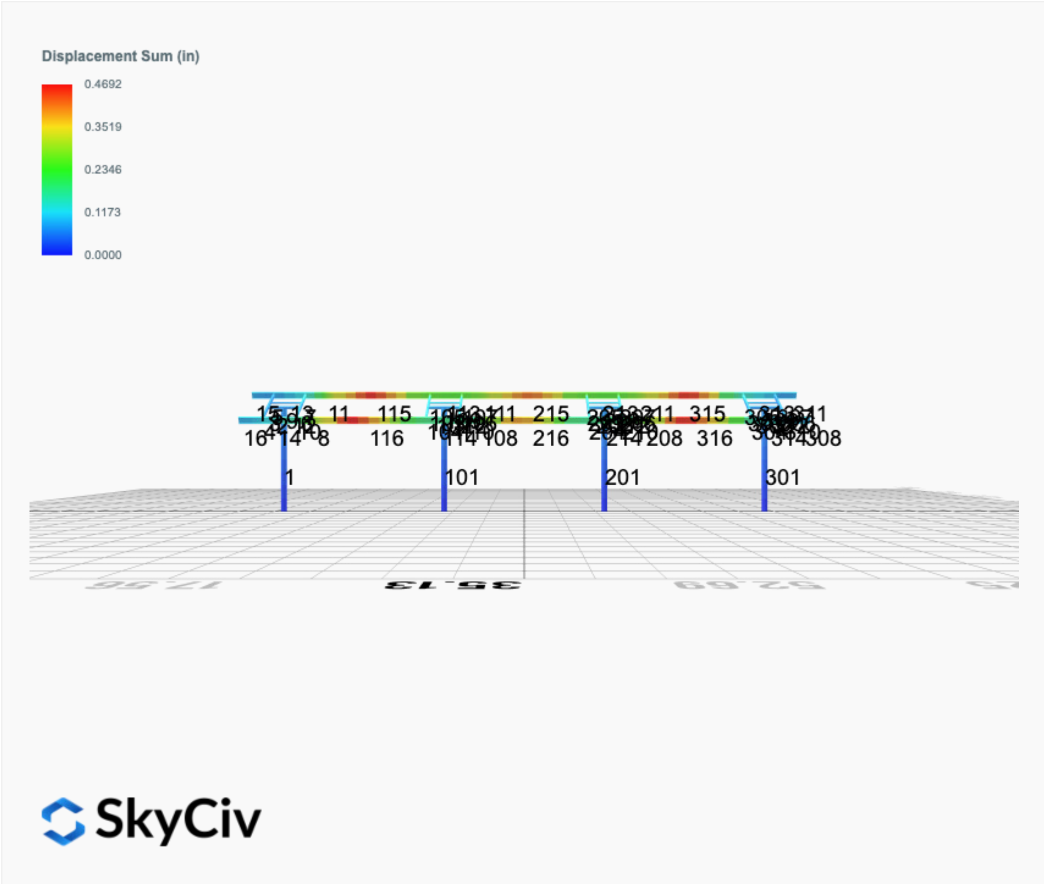
Rail Length: 17.416666666666668 ft
Additional Restraints Required: 4ft Spread Clamps
Tributary Width: 3.5124999999999997 ft
Material: Aluminium
Density: 169 lb/ft^3
Elasticity Modulus: 10000 ksi
Fy: 34.5 ksi
Fu: 37 ksi
Snow (X): 0.0687 kip/ft
Snow (Y): -0.0335 kip/ft
Wind uplift Case A: 0.0814 kip/ft
Wind uplift Case A: 0.0814 kip/ft
Wind uplift Case B (X): 0.0000 kip/ft
Wind uplift Case B (Y): 0.1176 kip/ft

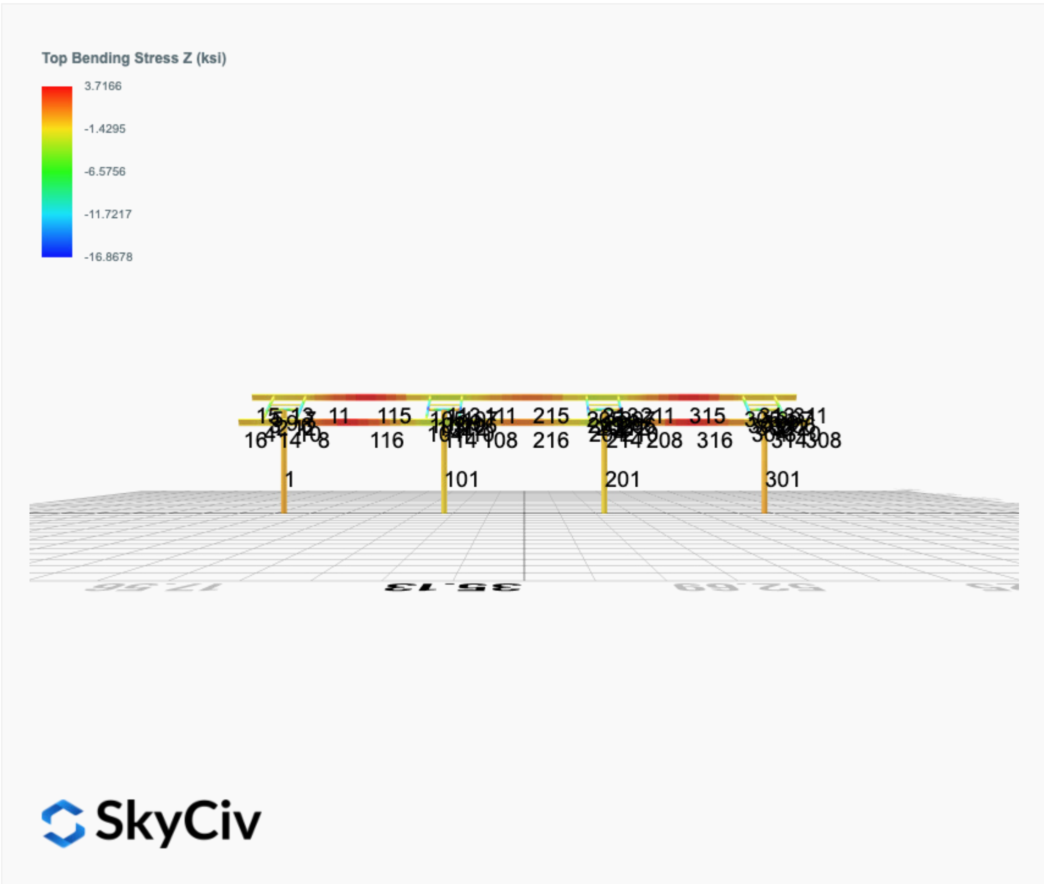


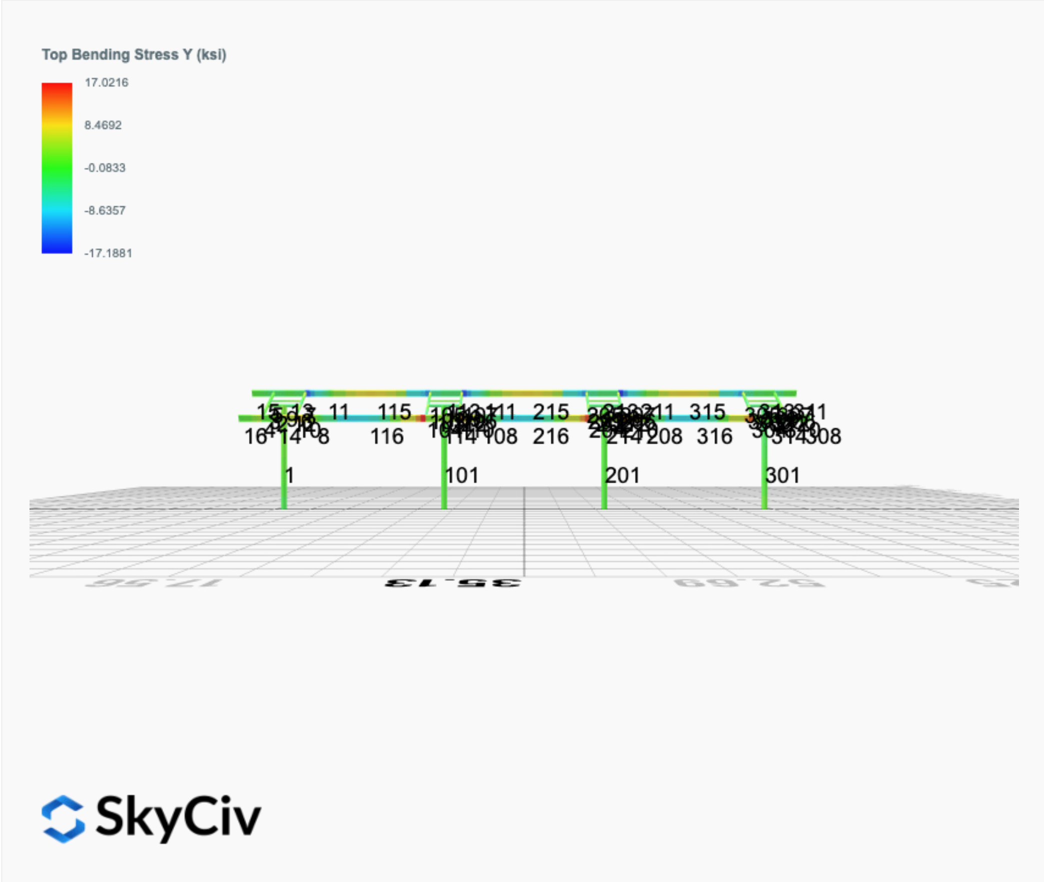
Result Check	Max Limit	Max Value	Utility	Status
Custom Stress Limit	34.5	12.24634932	0.355	PASS
Material Yield	34.5	12.24634932	0.355	PASS
Material Strength	37	12.24634932	0.331	PASS



FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
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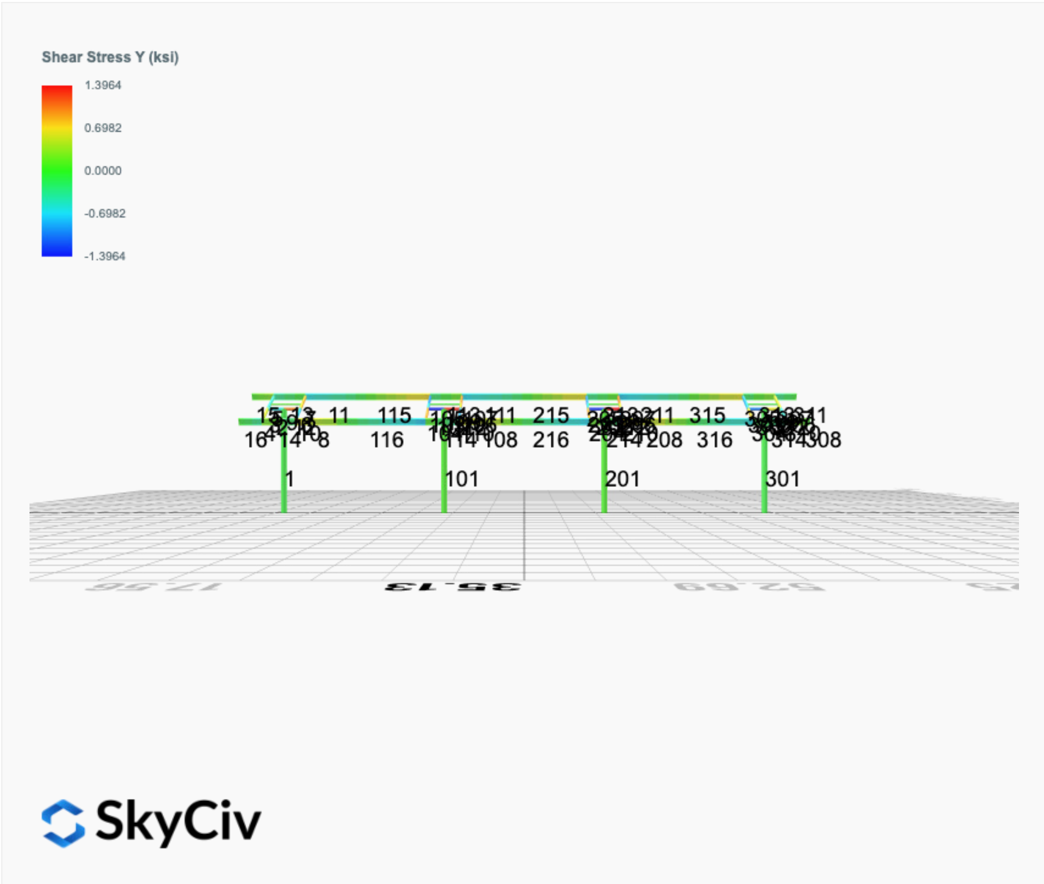
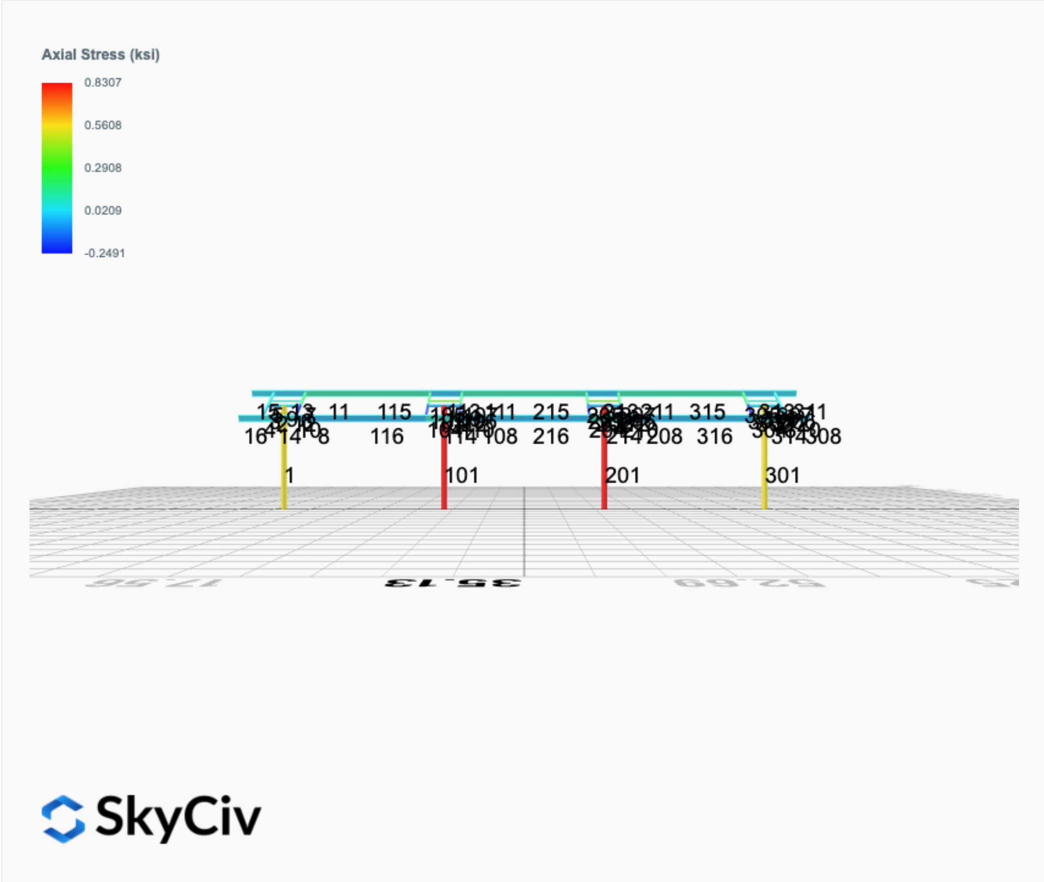
-0.0833
-8.6357
-17.1881
1
101
201
301
35.13
SkyCiv


Shear Stress Y (ksi)
1.3964
0.6982
0.0000
-0.6982
-1.3964
1
101
201
301
35.13
SkyCiv


Axial Stress (ksi)
0.8307
0.5608
0.2908
0.0209
-0.2491
SkyCiv

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

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	0.0303	2.0831	0.0832	0.3299	-0.0507	-0.3272
ULS: 2. D + L	0.0303	2.0831	0.0832	0.3299	-0.0507	-0.3272
ULS: 3. D + (S or Lr or R)	0.1293	6.8218	0.3573	1.4194	-0.2190	-1.4883
ULS: 3. D + (S or Lr or R)	0.0303	2.0831	0.0832	0.3299	-0.0507	-0.3272
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.1046	5.6371	0.2888	1.1470	-0.1769	-1.1980
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0303	2.0831	0.0832	0.3299	-0.0507	-0.3272
ULS: 5b. D + 0.7E	0.0303	2.0831	0.0832	0.3299	-0.0507	-0.3272
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.1046	5.6371	0.2888	1.1470	-0.1769	-1.1980
ULS: 8. 0.6D + 0.7E	0.0182	1.2499	0.0499	0.1979	-0.0304	-0.1963
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.7442	5.5775	0.3626	1.4138	-0.6336	23.5298
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.7442	5.5775	0.3626	1.4138	-0.6336	23.5298
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.5666	-0.9537	-0.1506	-0.5741	0.4351	-19.7299
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.3835	-0.5319	-0.1524	-0.5803	0.4538	-25.5737
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.2263	8.2579	0.4984	1.9600	-0.6141	16.6948
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.2263	8.2579	0.4984	1.9600	-0.6141	16.6948
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.2568	3.3595	0.1134	0.4690	0.1875	-15.7501
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.1195	3.6758	0.1121	0.4644	0.2014	-20.1329
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.3006	4.7039	0.2928	1.1428	-0.4879	17.5656
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.3006	4.7039	0.2928	1.1428	-0.4879	17.5656
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.1826	-0.1945	-0.0922	-0.3481	0.3137	-14.8793
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.0452	0.1218	-0.0935	-0.3527	0.3276	-19.2621
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.7563	4.7443	0.3294	1.2819	-0.6133	23.6607
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.7563	4.7443	0.3294	1.2819	-0.6133	23.6607
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.5545	-1.7870	-0.1839	-0.7060	0.4554	-19.5991
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.3714	-1.3652	-0.1857	-0.7122	0.4740	-25.4428

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	12.9978
Shear X	-2.9575
Shear Z	0.7800
Moment X	3.0858
Moment Y (Twist)	1.1322
Moment Z	44.0704

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	8.2579
Shear X	-1.7563
Shear Z	0.4984
Moment X	1.9600
Moment Y (Twist)	0.6336
Moment Z	25.5737

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	-0.0303	2.7661	-0.0059	-0.0238	0.0087	0.3896
ULS: 2. D + L	-0.0303	2.7661	-0.0059	-0.0238	0.0087	0.3896
ULS: 3. D + (S or Lr or R)	-0.1293	9.7435	-0.0250	-0.1014	0.0366	1.6210
ULS: 3. D + (S or Lr or R)	-0.0303	2.7661	-0.0059	-0.0238	0.0087	0.3896
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.1046	7.9991	-0.0202	-0.0820	0.0296	1.3132

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0303	2.7661	-0.0059	-0.0238	0.0087	0.3896
ULS: 5b. D + 0.7E	-0.0303	2.7661	-0.0059	-0.0238	0.0087	0.3896
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.1046	7.9991	-0.0202	-0.0820	0.0296	1.3132
ULS: 8. 0.6D + 0.7E	-0.0182	1.6596	-0.0035	-0.0143	0.0052	0.2338
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.4703	7.9126	0.0112	0.0386	-0.0701	32.6269
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.4703	7.9126	0.0112	0.0386	-0.0701	32.6269
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.1045	-1.7241	-0.0154	-0.0576	0.0630	-25.6729
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.7443	-1.0319	-0.0342	-0.1299	0.1128	-32.4169
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.9346	11.8590	-0.0074	-0.0352	-0.0295	25.4911
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.9346	11.8590	-0.0074	-0.0352	-0.0295	25.4911
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.4965	4.6315	-0.0274	-0.1073	0.0704	-18.2337
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.2264	5.1506	-0.0415	-0.1615	0.1077	-23.2917
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.8603	6.6260	0.0069	0.0230	-0.0504	24.5676
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.8603	6.6260	0.0069	0.0230	-0.0504	24.5676
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.5708	-0.6016	-0.0131	-0.0491	0.0494	-19.1573
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.3007	-0.0824	-0.0272	-0.1034	0.0868	-24.2152
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.4582	6.8062	0.0136	0.0481	-0.0736	32.4710
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.4582	6.8062	0.0136	0.0481	-0.0736	32.4710
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.1166	-2.8305	-0.0131	-0.0481	0.0595	-25.8288
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.7564	-2.1383	-0.0319	-0.1204	0.1094	-32.5727

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	18.7677
Shear X	-4.1456
Shear Z	-0.0681
Moment X	-0.2623
Moment Y (Twist)	0.2094
Moment Z	56.2748

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	11.8590
Shear X	-2.4703
Shear Z	-0.0415
Moment X	-0.1615
Moment Y (Twist)	0.1128
Moment Z	32.6269

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	-0.0303	2.7661	0.0059	0.0238	-0.0087	0.3896
ULS: 2. D + L	-0.0303	2.7661	0.0059	0.0238	-0.0087	0.3896
ULS: 3. D + (S or Lr or R)	-0.1293	9.7435	0.0250	0.1013	-0.0363	1.6210
ULS: 3. D + (S or Lr or R)	-0.0303	2.7661	0.0059	0.0238	-0.0087	0.3896
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.1046	7.9991	0.0202	0.0819	-0.0294	1.3132
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0303	2.7661	0.0059	0.0238	-0.0087	0.3896
ULS: 5b. D + 0.7E	-0.0303	2.7661	0.0059	0.0238	-0.0087	0.3896
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.1046	7.9991	0.0202	0.0819	-0.0294	1.3132
ULS: 8. 0.6D + 0.7E	-0.0182	1.6596	0.0035	0.0143	-0.0052	0.2338
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.4703	7.9126	-0.0112	-0.0386	0.0702	32.6269
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.4703	7.9126	-0.0112	-0.0386	0.0702	32.6269
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.1045	-1.7241	0.0154	0.0576	-0.0630	-25.6729
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.7443	-1.0319	0.0342	0.1299	-0.1128	-32.4169

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	-1.9346	11.8590	0.0074	0.0351	0.0297	25.4911
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.9346	11.8590	0.0074	0.0351	0.0297	25.4911
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.4965	4.6315	0.0274	0.1072	-0.0701	-18.2337
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.2264	5.1506	0.0415	0.1615	-0.1075	-23.2917
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.8603	6.6260	-0.0069	-0.0230	0.0504	24.5676
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.8603	6.6260	-0.0069	-0.0230	0.0504	24.5676
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.5708	-0.6016	0.0131	0.0491	-0.0494	-19.1573
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.3007	-0.0824	0.0272	0.1034	-0.0868	-24.2152
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.4582	6.8062	-0.0136	-0.0481	0.0736	32.4710
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.4582	6.8062	-0.0136	-0.0481	0.0736	32.4710
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.1166	-2.8305	0.0131	0.0480	-0.0595	-25.8288
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.7564	-2.1383	0.0319	0.1204	-0.1094	-32.5727

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	18.7677
Shear X	-4.1456
Shear Z	0.0681
Moment X	0.2625
Moment Y (Twist)	0.2093
Moment Z	56.2750

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	11.8590
Shear X	-2.4703
Shear Z	0.0415
Moment X	0.1615
Moment Y (Twist)	0.1128
Moment Z	32.6269

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	0.0303	2.0831	-0.0832	-0.3299	0.0507	-0.3272
ULS: 2. D + L	0.0303	2.0831	-0.0832	-0.3299	0.0507	-0.3272
ULS: 3. D + (S or Lr or R)	0.1293	6.8218	-0.3573	-1.4196	0.2193	-1.4880
ULS: 3. D + (S or Lr or R)	0.0303	2.0831	-0.0832	-0.3299	0.0507	-0.3272
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.1046	5.6371	-0.2888	-1.1472	0.1771	-1.1978
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0303	2.0831	-0.0832	-0.3299	0.0507	-0.3272
ULS: 5b. D + 0.7E	0.0303	2.0831	-0.0832	-0.3299	0.0507	-0.3272
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.1046	5.6371	-0.2888	-1.1472	0.1771	-1.1978
ULS: 8. 0.6D + 0.7E	0.0182	1.2499	-0.0499	-0.1979	0.0304	-0.1963
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.7442	5.5775	-0.3626	-1.4138	0.6336	23.5299
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.7442	5.5775	-0.3626	-1.4138	0.6336	23.5299
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.5666	-0.9537	0.1506	0.5741	-0.4351	-19.7299
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.3835	-0.5319	0.1524	0.5803	-0.4537	-25.5737
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.2263	8.2579	-0.4984	-1.9601	0.6143	16.6950
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.2263	8.2579	-0.4984	-1.9601	0.6143	16.6950
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.2568	3.3595	-0.1134	-0.4692	-0.1872	-15.7499
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.1195	3.6758	-0.1121	-0.4646	-0.2012	-20.1327
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.3006	4.7039	-0.2928	-1.1429	0.4879	17.5656
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.3006	4.7039	-0.2928	-1.1429	0.4879	17.5656
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.1826	-0.1945	0.0922	0.3481	-0.3137	-14.8792
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.0452	0.1218	0.0935	0.3527	-0.3276	-19.2621

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.7563	4.7443	-0.3294	-1.2819	0.6133	23.6607
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.7563	4.7443	-0.3294	-1.2819	0.6133	23.6607
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.5545	-1.7870	0.1839	0.7060	-0.4554	-19.5990
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.3714	-1.3652	0.1857	0.7122	-0.4740	-25.4428

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	12.9978
Shear X	-2.9575
Shear Z	-0.7801
Moment X	-3.0867
Moment Y (Twist)	1.1328
Moment Z	44.0711

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	8.2579
Shear X	-1.7563
Shear Z	-0.4984
Moment X	-1.9601
Moment Y (Twist)	0.6336
Moment Z	25.5737

Project Details

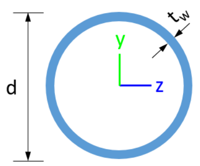
Design Code:	AISC 360-16 LRFD
Provision:	LRFD
Country:	United States
User Name:	sales@mtsolar.us
Unit System:	imperial

Design Input Information

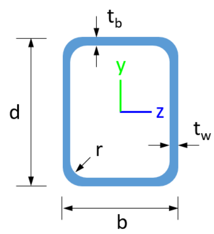
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

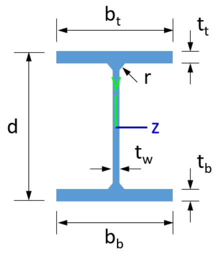
Section Dimensions



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					
9	8in Pipe Sch 40	8.63	0.32					



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
9	8in Pipe Sch 40	8.40	144.98	72.49	72.49	0.00	22.21	22.21
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	9	26.92	26.92	12.82	-	300	200	1
2	6	1.30	1.30	2.00	-	300	200	1
3	17	0.92	0.92	1.42	1.19,1.18,1.19,1.17,1.18,1.19,1.17,1.17,1.14,1.16,1.17,1.17,1.16,1.16,1.17,1.17,1.18,1.18,1.17,1.17,1.14,1.15,1.17,1.17,1.16,1.16	300	200	1
4	17	2.44	2.44	3.75	1.70,1.68,1.70,1.67,1.69,1.70,1.67,1.67,1.64,1.68,1.67,1.67,1.65,1.72,1.67,1.67,1.68,1.67,1.68,1.68,1.62,1.71,1.67,1.67,1.66,1.74	300	200	1
5	17	1.52	1.52	2.33	1.69,1.67,1.69,1.67,1.68,1.69,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.63,1.65,1.67,1.67,1.66,1.66	300	200	1
6	17	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.19,1.19,1.18,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.19,1.19,1.19,1.19,1.17,1.18,1.19,1.19,1.18,1.18	300	200	1
7	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.67	300	200	1
8	20	1.33	1.33	2.05	1.22,1.22,1.22,1.22,1.22,1.22,1.21,1.21,1.20,1.36,1.21,1.21,1.21,1.34,1.21,1.21,1.22,1.23,1.21,1.21,1.21,1.43,1.21,1.21,1.21,1.07	300	200	1
9	3	2.60	2.60	4.00	-	300	200	1
10	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.65,1.69,1.67,1.67,1.66,2.84,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.71,1.67,1.67,1.66,1.59	300	200	1
11	20	1.33	1.33	2.05	1.24,1.24,1.24,1.24,1.24,1.24,1.28,1.28,1.40,1.41,1.28,1.28,1.30,1.34,1.26,1.26,1.22,1.17,1.27,1.27,1.36,1.38,1.29,1.29,1.30,1.33	300	200	1
12	6	1.30	1.30	2.00	-	300	200	1
13	20	4.88	4.00	7.50	1.51,1.53,1.51,1.53,1.52,1.51,1.31,1.31,1.24,1.43,1.29,1.29,1.25,1.33,1.38,1.38,1.82,2.25,1.31,1.31,1.20,1.39,1.28,1.28,1.26,1.34	300	200	1
14	20	4.88	4.00	7.50	1.70,1.75,1.70,1.76,1.73,1.70,1.84,1.84,2.12,1.83,1.85,1.85,1.93,2.20,1.80,1.80,1.70,1.65,1.83,1.83,2.09,1.87,1.86,1.86,1.91,2.32	300	200	1
15	20	2.10	2.10	1.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
16	20	2.10	2.10	1.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
101	9	26.92	26.92	12.82	-	300	200	1
102	6	1.30	1.30	2.00	-	300	200	1
103	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.17	300	200	1
104	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.85,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.70,1.67,1.67,1.66,1.57	300	200	1
105	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
106	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
107	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
108	20	1.33	1.33	2.05	2.37,2.39,2.37,2.39,2.38,2.37,2.31,2.31,2.11,1.86,2.29,2.29,2.20,1.10,2.37,2.37,2.37,2.12,2.31,2.31,2.12,1.68,2.29,2.29,2.21,1.09	300	200	1
109	3	2.60	2.60	4.00	-	300	200	1
110	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.87,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.70,1.67,1.67,1.66,1.57	300	200	1
111	20	1.33	1.33	2.05	2.09,2.09,2.09,2.09,2.09,2.09,1.78,1.78,1.29,1.35,1.69,1.69,1.54,1.48,2.06,2.06,2.33,1.91,1.78,1.78,1.36,1.39,1.67,1.67,1.58,1.50	300	200	1
112	6	1.30	1.30	2.00	-	300	200	1

113	20	4.88	4.00	7.50	1.07,1.07,1.07,1.07,1.07,1.07,1.09,1.09,1.77,1.38,1.09,1.09,1.11,1.14,1.07,1.07,1.06,1.04,1.08,1.08,1.17,1.28,1.09,1.09,1.10,1.13	300	200	1
114	20	4.88	4.00	7.50	1.06,1.06,1.06,1.06,1.06,1.07,1.07,1.09,1.27,1.07,1.07,1.08,1.08,1.07,1.07,1.06,1.06,1.07,1.07,1.09,1.45,1.07,1.07,1.07,1.07	300	200	1
115	20	6.63	6.63	10.20	1.14,1.14,1.14,1.14,1.14,1.14,1.12,1.12,1.06,1.07,1.11,1.11,1.10,1.09,1.13,1.13,1.17,1.23,1.12,1.12,1.07,1.08,1.11,1.11,1.10,1.09	300	200	1
116	20	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.11,1.16,1.16,1.16,1.52,1.16,1.16,1.16,1.15,1.16,1.16,1.16,1.10,1.16,1.16,1.16,2.09	300	200	1
201	9	26.92	26.92	12.82	-	300	200	1
202	6	1.30	1.30	2.00	-	300	200	1
203	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
204	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.88,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.70,1.67,1.67,1.66,1.57	300	200	1
205	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
206	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.17	300	200	1
207	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
208	20	1.33	1.33	2.05	1.98,1.99,1.98,1.99,1.98,1.98,1.96,1.96,1.86,1.49,1.95,1.95,1.92,1.03,1.98,1.98,2.02,1.87,1.96,1.96,1.89,1.40,1.95,1.95,1.93,1.26	300	200	1
209	3	2.60	2.60	4.00	-	300	200	1
210	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.85,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.70,1.67,1.67,1.66,1.57	300	200	1
211	20	1.33	1.33	2.05	1.76,1.76,1.76,1.75,1.76,1.76,1.49,1.49,1.20,1.25,1.45,1.45,1.37,1.34,1.60,1.60,2.08,2.36,1.49,1.49,1.26,1.27,1.44,1.44,1.39,1.35	300	200	1
212	6	1.30	1.30	2.00	-	300	200	1
213	20	4.88	4.00	7.50	1.07,1.07,1.07,1.07,1.07,1.07,1.09,1.09,1.77,1.38,1.09,1.09,1.11,1.14,1.07,1.07,1.06,1.04,1.08,1.08,1.17,1.28,1.09,1.09,1.10,1.13	300	200	1
214	20	4.88	4.00	7.50	1.06,1.06,1.06,1.06,1.06,1.06,1.07,1.07,1.09,1.27,1.07,1.07,1.08,1.08,1.07,1.07,1.06,1.06,1.07,1.07,1.09,1.46,1.07,1.07,1.07,1.07	300	200	1
215	20	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.13,1.13,1.08,1.09,1.12,1.12,1.11,1.11,1.14,1.14,1.19,1.30,1.13,1.13,1.09,1.10,1.12,1.12,1.12,1.11	300	200	1
216	20	6.63	6.63	10.20	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.13,1.17,1.17,1.17,1.04,1.18,1.18,1.18,1.17,1.17,1.17,1.17,1.12,1.17,1.17,1.17,1.29	300	200	1
301	9	26.92	26.92	12.82	-	300	200	1
302	6	1.30	1.30	2.00	-	300	200	1
303	17	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.19,1.19,1.18,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.19,1.19,1.19,1.19,1.17,1.18,1.19,1.19,1.18,1.18	300	200	1
304	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.65,1.69,1.67,1.67,1.66,2.84,1.67,1.67,1.68,1.67,1.67,1.67,1.64,1.71,1.67,1.67,1.66,1.59	300	200	1
305	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.67	300	200	1
306	17	0.92	0.92	1.42	1.19,1.18,1.19,1.17,1.18,1.19,1.17,1.17,1.14,1.16,1.17,1.17,1.16,1.16,1.17,1.17,1.18,1.18,1.17,1.17,1.14,1.15,1.17,1.17,1.16,1.16	300	200	1
307	17	1.52	1.52	2.33	1.69,1.67,1.69,1.67,1.68,1.69,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.63,1.65,1.67,1.67,1.66,1.66	300	200	1
308	20	2.10	2.10	1.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
309	3	2.60	2.60	4.00	-	300	200	1
310	17	2.44	2.44	3.75	1.70,1.68,1.70,1.67,1.69,1.70,1.67,1.67,1.64,1.68,1.67,1.67,1.65,1.72,1.67,1.67,1.68,1.67,1.68,1.68,1.62,1.71,1.67,1.67,1.66,1.74	300	200	1
311	20	2.10	2.10	1.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
312	6	1.30	1.30	2.00	-	300	200	1
313	20	4.88	4.00	7.50	1.51,1.53,1.51,1.53,1.52,1.51,1.31,1.31,1.24,1.43,1.29,1.29,1.25,1.33,1.38,1.38,1.82,2.25,1.31,1.31,1.20,1.39,1.28,1.28,1.26,1.34	300	200	1
314	20	4.88	4.00	7.50	1.70,1.74,1.70,1.76,1.73,1.70,1.84,1.84,2.12,1.83,1.85,1.85,1.93,2.20,1.80,1.80,1.70,1.65,1.83,1.83,2.09,1.87,1.86,1.86,1.91,2.33	300	200	1

315	20	6.63	6.63	10.20	1.08,1.08,1.08,1.08,1.08,1.08,1.07,1.07,1.11,1.11,1.08,1.08,1.08,1.09,1.08,1.08,1.08,1.08,1.07,1.07,1.10,1.10,1.08,1.08,1.08,1.09	300	200	1
316	20	6.63	6.63	10.20	1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.07,1.09,1.08,1.08,1.08,1.85,1.08,1.08,1.08,1.08,1.08,1.07,1.10,1.08,1.08,1.08,1.85	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	377.97	156.17	83.29	83.29	113.39	113.39
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	36.61	6.46	56.26	44.91
14	159.30	97.43	46.90	6.46	56.26	44.91
15	159.30	137.23	46.90	6.46	56.26	44.91
16	159.30	137.23	46.90	6.46	56.26	44.91
101	377.97	156.17	83.29	83.29	113.39	113.39
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	31.90	6.46	56.26	44.91
114	159.30	97.43	32.28	6.46	56.26	44.91
115	159.30	75.13	20.50	6.46	56.26	44.91
116	159.30	75.13	21.17	6.46	56.26	44.91
201	377.97	156.17	83.29	83.29	113.39	113.39
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	31.90	6.46	56.26	44.91
214	159.30	97.43	32.28	6.46	56.26	44.91
215	159.30	75.13	20.88	6.46	56.26	44.91
216	159.30	75.13	20.04	6.46	56.26	44.91
301	377.97	156.17	83.29	83.29	113.39	113.39
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	137.23	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	137.23	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	36.61	6.46	56.26	44.91
314	159.30	97.43	46.90	6.46	56.26	44.91
315	159.30	75.13	20.68	6.46	56.26	44.91
316	159.30	75.13	20.68	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	0.083	0.529	0.083	0.026	0.007	0.544	#13	0.550	Not Required	Pass
2	0.002	0.252	0.085	0.062	0.017	0.313	#21	0.054	Not Required	Pass
3	0.005	0.434	0.021	0.042	0.006	0.437	#21	0.046	Not Required	Pass
4	0.004	0.429	0.065	0.043	0.015	0.495	#21	0.122	Not Required	Pass
5	0.004	0.269	0.024	0.043	0.007	0.273	#21	0.076	Not Required	Pass
6	0.010	0.675	0.109	0.069	0.031	0.789	#21	0.046	Not Required	Pass
7	0.011	0.419	0.174	0.067	0.043	0.457	#21	0.076	Not Required	Pass
8	0.005	0.153	0.185	0.038	0.020	0.249	#21	0.102	Not Required	Pass
9	0.006	0.073	0.087	0.004	0.006	0.154	#21	0.206	Not Required	Pass
10	0.011	0.637	0.157	0.064	0.034	0.704	#21	0.082	Not Required	Pass
11	0.008	0.147	0.193	0.041	0.020	0.240	#21	0.102	Not Required	Pass
12	0.002	0.505	0.127	0.104	0.024	0.597	#21	0.054	Not Required	Pass
13	0.011	0.072	0.477	0.054	0.026	0.485	#24	0.306	Not Required	Pass
14	0.005	0.077	0.466	0.051	0.026	0.486	#24	0.204	Not Required	Pass
15	0.000	0.004	0.011	0.007	0.003	0.016	#21	Not Required	Not Required	Pass
16	0.000	0.004	0.011	0.007	0.003	0.016	#21	Not Required	Not Required	Pass
101	0.120	0.676	0.007	0.037	0.001	0.726	#13	0.550	Not Required	Pass
102	0.004	0.564	0.157	0.123	0.026	0.692	#21	0.054	Not Required	Pass
103	0.010	0.803	0.063	0.080	0.009	0.871	#21	0.046	Not Required	Pass
104	0.010	0.814	0.183	0.081	0.039	0.937	#21	0.082	Not Required	Pass
105	0.010	0.498	0.190	0.079	0.049	0.547	#21	0.076	Not Required	Pass
106	0.010	0.807	0.060	0.080	0.009	0.865	#21	0.046	Not Required	Pass
107	0.010	0.501	0.171	0.080	0.045	0.548	#21	0.076	Not Required	Pass
108	0.005	0.051	0.174	0.045	0.020	0.225	#21	0.102	Not Required	Pass
109	0.018	0.071	0.050	0.001	0.000	0.125	#21	0.206	Not Required	Pass
110	0.010	0.799	0.164	0.080	0.036	0.912	#21	0.082	Not Required	Pass

111	0.008	0.069	0.179	0.046	0.020	0.214	#24	0.102	Not Required	Pass
112	0.004	0.558	0.161	0.121	0.029	0.687	#21	0.054	Not Required	Pass
113	0.011	0.221	0.517	0.063	0.027	0.695	#21	0.306	Not Required	Pass
114	0.009	0.263	0.513	0.065	0.027	0.731	#21	0.306	Not Required	Pass
115	0.014	0.432	0.254	0.050	0.021	0.693	#21	0.507	Not Required	Pass
116	0.006	0.407	0.253	0.052	0.021	0.659	#21	0.507	Not Required	Pass
201	0.120	0.676	0.007	0.037	0.001	0.726	#13	0.550	Not Required	Pass
202	0.004	0.558	0.161	0.121	0.029	0.687	#21	0.054	Not Required	Pass
203	0.010	0.807	0.060	0.080	0.009	0.865	#21	0.046	Not Required	Pass
204	0.010	0.799	0.164	0.080	0.036	0.912	#21	0.082	Not Required	Pass
205	0.010	0.501	0.171	0.080	0.045	0.548	#21	0.076	Not Required	Pass
206	0.010	0.803	0.063	0.080	0.009	0.871	#21	0.046	Not Required	Pass
207	0.010	0.498	0.190	0.079	0.049	0.547	#21	0.076	Not Required	Pass
208	0.005	0.083	0.221	0.052	0.021	0.249	#21	0.102	Not Required	Pass
209	0.018	0.071	0.050	0.001	0.000	0.125	#21	0.206	Not Required	Pass
210	0.010	0.814	0.183	0.081	0.039	0.937	#21	0.082	Not Required	Pass
211	0.008	0.103	0.225	0.050	0.021	0.230	#21	0.102	Not Required	Pass
212	0.004	0.564	0.157	0.123	0.026	0.692	#21	0.054	Not Required	Pass
213	0.011	0.221	0.517	0.063	0.027	0.695	#21	0.306	Not Required	Pass
214	0.009	0.263	0.512	0.065	0.027	0.731	#21	0.306	Not Required	Pass
215	0.014	0.297	0.255	0.046	0.020	0.556	#21	0.507	Not Required	Pass
216	0.008	0.239	0.251	0.045	0.020	0.491	#21	0.507	Not Required	Pass
301	0.083	0.529	0.083	0.026	0.007	0.544	#13	0.550	Not Required	Pass
302	0.002	0.505	0.127	0.104	0.024	0.597	#21	0.054	Not Required	Pass
303	0.010	0.675	0.109	0.069	0.031	0.789	#21	0.046	Not Required	Pass
304	0.011	0.637	0.157	0.064	0.034	0.704	#21	0.082	Not Required	Pass
305	0.011	0.418	0.173	0.067	0.043	0.457	#21	0.076	Not Required	Pass
306	0.005	0.434	0.021	0.042	0.006	0.437	#21	0.046	Not Required	Pass
307	0.004	0.269	0.024	0.043	0.007	0.273	#21	0.076	Not Required	Pass
308	0.000	0.004	0.011	0.007	0.003	0.016	#21	Not Required	Not Required	Pass
309	0.006	0.073	0.087	0.004	0.006	0.154	#21	0.206	Not Required	Pass
310	0.004	0.429	0.065	0.043	0.015	0.495	#21	0.122	Not Required	Pass
311	0.000	0.004	0.011	0.007	0.003	0.016	#21	Not Required	Not Required	Pass
312	0.002	0.252	0.085	0.062	0.017	0.313	#21	0.054	Not Required	Pass
313	0.011	0.072	0.477	0.054	0.026	0.484	#24	0.204	Not Required	Pass
314	0.005	0.077	0.466	0.051	0.026	0.486	#24	0.306	Not Required	Pass
315	0.014	0.453	0.254	0.041	0.020	0.708	#21	0.507	Not Required	Pass
316	0.006	0.442	0.249	0.038	0.020	0.691	#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

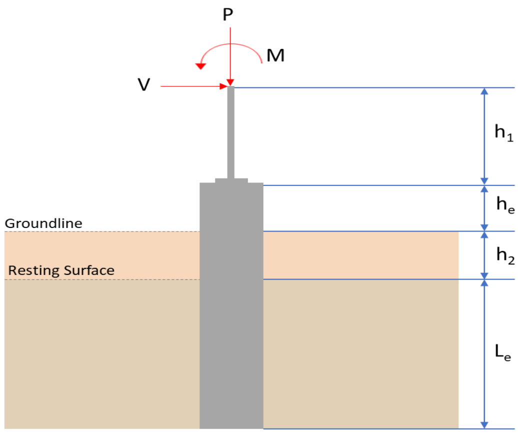
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 6.5\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	8.258	12.998
V_x (kip)	-1.756	-2.957
V_z (kip)	0.498	0.780
M_x (kipft)	1.960	3.086
M_z (kipft)	25.574	44.070

Material Properties

$f'_{ck} = 2.5\ \mathrm{ksi}$ - Concrete strength,

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.756\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.27962\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(25.574 \text{ kipft}) + ((-1.756 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 4.0723 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 6.0723 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.498 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0793 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.96 \text{ kipft}) + ((0.498 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.3121 \text{ kipft/ft}$$

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:
$L_{e,z} = 3.4603 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.0723 \text{ ft}), (3.4603 \text{ ft})]$$

$$L_{e,req} = 6.072 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 6.5 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.072 \text{ ft})}{(6.5 \text{ ft})}$$

$$Ratio = 0.93415$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(8.258\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.51612\ \mathrm{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.51612\ \mathrm{kip/ft}^2\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.25806$$

Status: **PASS**
Ratio: **0.260**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(6.5\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1.625$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.27962\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 4.0723\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.0723\ \mathrm{kipft/ft}) \times (6.5\ \mathrm{ft})) + \left(3 \times (-0.27962\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft})^2\right)}{(6 \times (4.0723\ \mathrm{kipft/ft})) + (4 \times (-0.27962\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))}$$

$$a = 4.4575\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (4.0723\ \mathrm{kipft/ft})) + (3 \times (-0.27962\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]^{\ 2}}{(6.5\ \mathrm{ft})^2 \times [(3 \times (4.0723\ \mathrm{kipft/ft})) + (2 \times (-0.27962\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}$$

$$p = 0.24291\ \mathrm{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (4.0723\ \mathrm{kipft/ft})) + ((-0.27962\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}{(6.5\ \mathrm{ft})^2}$$

$$s = 0.89852\ \mathrm{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.4575\ \mathrm{ft})}{2}$$

$$p_a = 0.33432\ \mathrm{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.24291 \text{ kip/ft}^2\right)}{\left(0.33432 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.72658$$

Status: **PASS**
Ratio: **0.730**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150 \text{ psf/ft}) \times (6.5 \text{ ft})$$

$$p_s = 0.975 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.89852 \text{ kip/ft}^2\right)}{\left(0.975 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.92156$$

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

Considering z-direction:

$H_o = 0.0793 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 0.3121 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.3121 \text{ kipft/ft}) \times (6.5 \text{ ft})) + \left(3 \times (0.0793 \text{ kip/ft}) \times (6.5 \text{ ft})^2\right)}{(6 \times (0.3121 \text{ kipft/ft})) + (4 \times (0.0793 \text{ kip/ft}) \times (6.5 \text{ ft}))}$$

$$a = 4.6172 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.3121 \text{ kipft/ft})) + (3 \times (0.0793 \text{ kip/ft}) \times (6.5 \text{ ft}))]^2}{(6.5 \text{ ft})^2 \times [(3 \times (0.3121 \text{ kipft/ft})) + (2 \times (0.0793 \text{ kip/ft}) \times (6.5 \text{ ft}))]}$$

$$p = 0.070481 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.3121 \text{ kipft/ft})) + ((0.0793 \text{ kip/ft}) \times (6.5 \text{ ft}))]}{(6.5 \text{ ft})^2}$$

$$s = 0.16184 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.6172 \text{ ft})}{2}$$

$$p_a = 0.34629 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.070481 \text{ kip/ft}^2\right)}{\left(0.34629 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.20353$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6.5\ \mathrm{ft})$$

$$p_s = 0.975\ \mathrm{kip/ft^2}$$

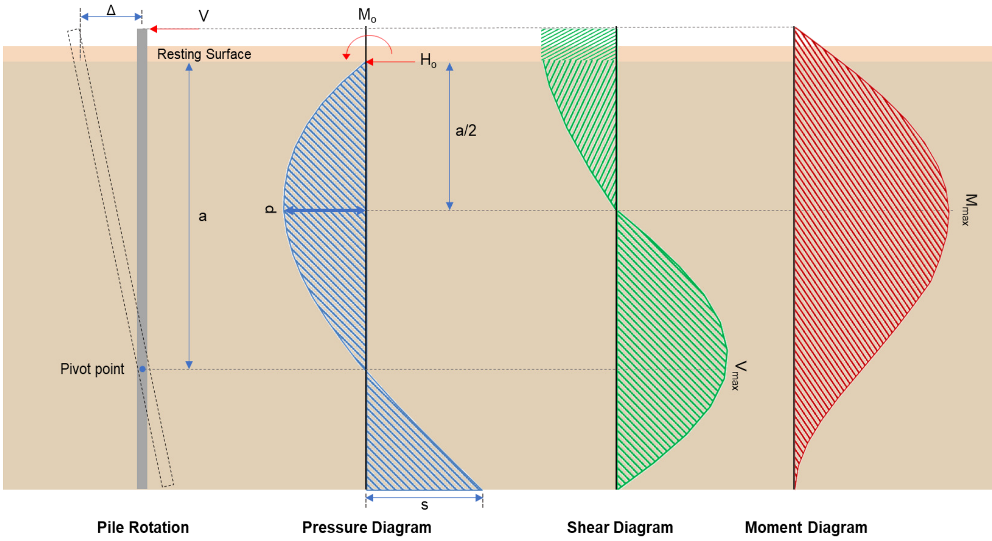
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.16184\ \mathrm{kip/ft^2}\right)}{\left(0.975\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.16599$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.957\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.47086\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(44.07\ \mathrm{kipft}) + ((-2.957\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 7.0175\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(7.0175\ \mathrm{kipft/ft})}{(-0.47086\ \mathrm{kip/ft})}$$

$$E = 14.904\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \left(4 \times (7.0175\ \mathrm{kipft/ft}) \times (6.5\ \mathrm{ft})\right) + \left(3 \times (-0.47086\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft})^2\right)$$

$$a = \frac{}{(6 \times (7.0175 \text{ kipft/ft})) + (4 \times (-0.47086 \text{ kip/ft}) \times (6.5 \text{ ft}))}$$

$$a = 4.4553 \text{ ft}$$

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

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

$$V_{max} = ((-0.47086 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.904 \text{ ft})}{(6.5 \text{ ft})} + 3\right) \times \left(\frac{(4.4553 \text{ ft})}{(6.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.904 \text{ ft})}{(6.5 \text{ ft})} + 2\right) \times \left(\frac{(4.4553 \text{ ft})}{(6.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 8.8869 \text{ kip}$$

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

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

$$M_{max} = ((-0.47086 \text{ kip/ft}) \times (48 \text{ in}) \times (6.5 \text{ ft})) \times \left[\left(\frac{(14.904 \text{ ft})}{(6.5 \text{ ft})} + \frac{(4.4553 \text{ ft})}{2 \times (6.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (14.904 \text{ ft})}{(6.5 \text{ ft})} + 3\right) \times \left(\frac{(4.4553 \text{ ft})}{2 \times (6.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (14.904 \text{ ft})}{(6.5 \text{ ft})} + 2\right) \times \left(\frac{(4.4553 \text{ ft})}{2 \times (6.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 27.767 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.78 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.1242 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(3.086 \text{ kipft}) + ((0.78 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.4914 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.4914 \text{ kipft/ft})}{(0.1242 \text{ kip/ft})}$$

$$E = 3.9564 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.4914 \text{ kipft/ft}) \times (6.5 \text{ ft})) + \left(3 \times (0.1242 \text{ kip/ft}) \times (6.5 \text{ ft})^2\right)}{(6 \times (0.4914 \text{ kipft/ft})) + (4 \times (0.1242 \text{ kip/ft}) \times (6.5 \text{ ft}))}$$

$$a = 4.6165 \text{ ft}$$

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

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

$$V_{max} = ((0.1242\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.9564\ \text{ft})}{(6.5\ \text{ft})} + 3\right) \times \left(\frac{(4.6165\ \text{ft})}{(6.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.9564\ \text{ft})}{(6.5\ \text{ft})} + 2\right) \times \left(\frac{(4.6165\ \text{ft})}{(6.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.86515\ \text{kip}$$

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

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

$$M_{max} = ((0.1242\ \text{kip/ft}) \times (48\ \text{in}) \times (6.5\ \text{ft})) \times \left[\left(\frac{(3.9564\ \text{ft})}{(6.5\ \text{ft})} + \frac{(4.6165\ \text{ft})}{2 \times (6.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (3.9564\ \text{ft})}{(6.5\ \text{ft})} + 3\right) \times \left(\frac{(4.6165\ \text{ft})}{2 \times (6.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.9564\ \text{ft})}{(6.5\ \text{ft})} + 2\right) \times \left(\frac{(4.6165\ \text{ft})}{2 \times (6.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 2.5229\ \text{kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(12.998\ \text{kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5\ \text{ksi}) \times \left(2304\ \text{in}^2\right)\right)}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, \left(0.08 \times \left(2304\ \text{in}^2\right)\right)\right]$$

$$A_{st,required} = -84.164\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.164\ \text{in}^2\right), \left(0.0018 \times \left(2304\ \text{in}^2\right)\right)\right]$$

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

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. 10⌀: Use #3(0.375 in)

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(12.998\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0048587$$

Status: PASS
Ratio: 0.000

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 12.998 \text{ kip} \rightarrow 12998 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(12998 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.22 \text{ kip}$$

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

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.22 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.22 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((120.22 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.22 \text{ kip}$$

Considering x-direction:

$V_{max} = 8.8869 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(8.8869 \text{ kip})}{(111.22 \text{ kip})}$$ $$Ratio = 0.079902$$	Status: **PASS** Ratio: **0.080**
	Considering z-direction: $V_{max} = 0.86515$ kip - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.86515 \text{ kip})}{(111.22 \text{ kip})}$$ $$Ratio = 0.0077785$$	Status: **PASS** Ratio: **0.010**
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:** $M_{max} = 27.767$ kipft - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(27.767 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.11125$$	Status: **PASS** Ratio: **0.110**
	Considering z-direction: $M_{max} = 2.5229$ kipft - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(2.5229 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.010108$$	Status: **PASS** Ratio: **0.010**

REFERENCES	CALCULATIONS	RESULTS

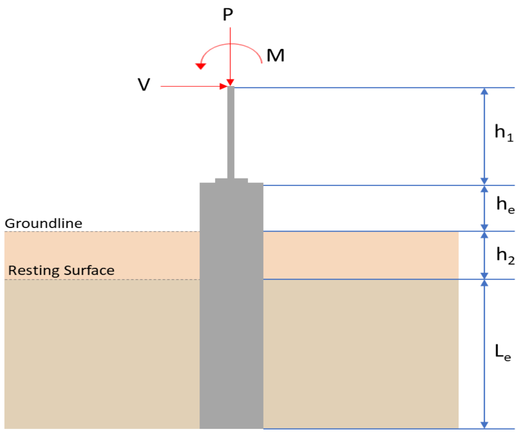
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48 \text{ in}$ - Pile width
$D = 48 \text{ in}$ - Pile depth
$L = 6.5 \text{ ft}$ - Total pile length
$h_1 = 0 \text{ ft}$ - Lateral load height from the top of the pile,
$h_2 = 0 \text{ ft}$ - Depth to resisting surface
$h_e = 0 \text{ ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	8.258	12.998
V_x (kip)	-1.756	-2.957
V_z (kip)	-0.498	-0.780
M_x (kipft)	-1.960	-3.087
M_z (kipft)	25.574	44.071

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,

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

$$H_o = \frac{(-1.756 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.27962 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(25.574\ \text{kipft}) + ((-1.756\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 4.0723\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 6.0723\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.498\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.0793\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.96\ \text{kipft}) + ((-0.498\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.3121\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 2.3875\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.0723\ \text{ft}), (2.3875\ \text{ft})]$$

$$L_{e,req} = 6.072\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6.5\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 6.5\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.072\ \text{ft})}{(6.5\ \text{ft})}$$

$$Ratio = 0.93415$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\,D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(8.258\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.51612\ \mathrm{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.51612\ \mathrm{kip/ft}^2\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.25806$$

Status: **PASS**
Ratio: **0.260**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(6.5\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1.625$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.27962\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 4.0723\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.0723\ \mathrm{kipft/ft}) \times (6.5\ \mathrm{ft})) + \left(3 \times (-0.27962\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft})^2\right)}{(6 \times (4.0723\ \mathrm{kipft/ft})) + (4 \times (-0.27962\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))}$$

$$a = 4.4575\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (4.0723\ \mathrm{kipft/ft})) + (3 \times (-0.27962\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]^2}{(6.5\ \mathrm{ft})^2 \times [(3 \times (4.0723\ \mathrm{kipft/ft})) + (2 \times (-0.27962\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}$$

$$p = 0.24291\ \mathrm{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (4.0723\ \mathrm{kipft/ft})) + ((-0.27962\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}{(6.5\ \mathrm{ft})^2}$$

$$s = 0.89852\ \mathrm{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.4575\ \mathrm{ft})}{2}$$

$$p_a = 0.33432\ \mathrm{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.24291\ \mathrm{kip/ft^2}\right)}{\left(0.33432\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.72658$$

Status: **PASS**
Ratio: **0.730**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6.5\ \mathrm{ft})$$

$$p_s = 0.975\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.89852\ \mathrm{kip/ft^2}\right)}{\left(0.975\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.92156$$

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

Considering z-direction:

$H_o = -0.0793\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.3121\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.3121\ \mathrm{kipft/ft}) \times (6.5\ \mathrm{ft})) + \left(3 \times (-0.0793\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft})^2\right)}{(6 \times (0.3121\ \mathrm{kipft/ft})) + (4 \times (-0.0793\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))}$$

$$a = 4.6172\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.3121\ \mathrm{kipft/ft})) + (3 \times (-0.0793\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]^{\ 2}}{(6.5\ \mathrm{ft})^2 \times [(3 \times (0.3121\ \mathrm{kipft/ft})) + (2 \times (-0.0793\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}$$

$$p = -0.016659\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.3121\ \mathrm{kipft/ft})) + ((-0.0793\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}{(6.5\ \mathrm{ft})^2}$$

$$s = 0.015445\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.6172\ \mathrm{ft})}{2}$$

$$p_a = 0.34629\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.016659\ \mathrm{kip/ft^2}\right)}{\left(0.34629\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.048106$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6.5\ \mathrm{ft})$$

$$p_s = 0.975\ \mathrm{kip/ft^2}$$

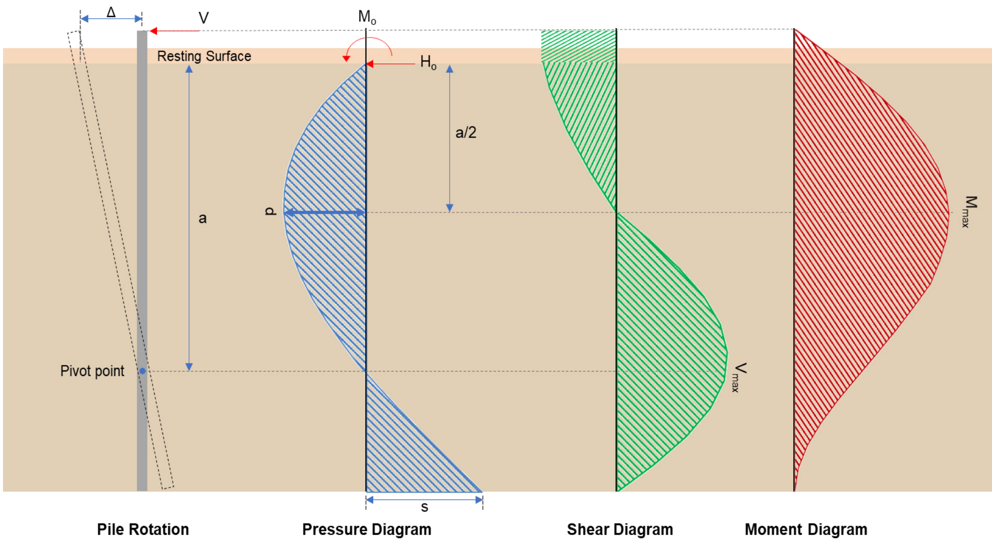
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.015445\ \mathrm{kip/ft^2}\right)}{\left(0.975\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.015841$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.957\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.47086\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(44.071\ \mathrm{kipft}) + ((-2.957\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 7.0177\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(7.0177\ \mathrm{kipft/ft})}{(-0.47086\ \mathrm{kip/ft})}$$

$$E = 14.904\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.0177\ \mathrm{kipft/ft}) \times (6.5\ \mathrm{ft})) + \left(3 \times (-0.47086\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (7.0177\ \text{kipft/ft})) + (4 \times (-0.47086\ \text{kip/ft}) \times (6.5\ \text{ft}))}$$

$$a = 4.4553\ \text{ft}$$

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

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

$$V_{max} = ((-0.47086\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.904\ \text{ft})}{(6.5\ \text{ft})} + 3\right) \times \left(\frac{(4.4553\ \text{ft})}{(6.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.904\ \text{ft})}{(6.5\ \text{ft})} + 2\right) \times \left(\frac{(4.4553\ \text{ft})}{(6.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 8.8871\ \text{kip}$$

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

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

$$M_{max} = ((-0.47086\ \text{kip/ft}) \times (48\ \text{in}) \times (6.5\ \text{ft})) \times \left[\left(\frac{(14.904\ \text{ft})}{(6.5\ \text{ft})} + \frac{(4.4553\ \text{ft})}{2 \times (6.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (14.904\ \text{ft})}{(6.5\ \text{ft})} + 3\right) \times \left(\frac{(4.4553\ \text{ft})}{2 \times (6.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (14.904\ \text{ft})}{(6.5\ \text{ft})} + 2\right) \times \left(\frac{(4.4553\ \text{ft})}{2 \times (6.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 27.768\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.78\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.1242\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(3.087\ \text{kipft}) + ((-0.78\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.49156\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.49156\ \text{kipft/ft})}{(-0.1242\ \text{kip/ft})}$$

$$E = 3.9577\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.49156\ \text{kipft/ft}) \times (6.5\ \text{ft})) + \left(3 \times (-0.1242\ \text{kip/ft}) \times (6.5\ \text{ft})^2\right)}{(6 \times (0.49156\ \text{kipft/ft})) + (4 \times (-0.1242\ \text{kip/ft}) \times (6.5\ \text{ft}))}$$

$$a = 4.6164\ \text{ft}$$

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

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

$$V_{max} = ((-0.1242\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.9577\ \text{ft})}{(6.5\ \text{ft})} + 3\right) \times \left(\frac{(4.6164\ \text{ft})}{(6.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.9577\ \text{ft})}{(6.5\ \text{ft})} + 2\right) \times \left(\frac{(4.6164\ \text{ft})}{(6.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.86533\ \text{kip}$$

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

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

$$M_{max} = ((-0.1242\ \text{kip/ft}) \times (48\ \text{in}) \times (6.5\ \text{ft})) \times \left[\left(\frac{(3.9577\ \text{ft})}{(6.5\ \text{ft})} + \frac{(4.6164\ \text{ft})}{2 \times (6.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (3.9577\ \text{ft})}{(6.5\ \text{ft})} + 3\right) \times \left(\frac{(4.6164\ \text{ft})}{2 \times (6.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.9577\ \text{ft})}{(6.5\ \text{ft})} + 2\right) \times \left(\frac{(4.6164\ \text{ft})}{2 \times (6.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 2.5235\ \text{kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(12.998\ \text{kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.164\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.164\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(12.998\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0048587$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,$P = 12.998 \text{ kip} \rightarrow 12998 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(12998 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.22 \text{ kip}$$

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

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

$$V_c = Min\,[(296.21 \text{ kip}), (120.22 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 120.22 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((120.22 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.22 \text{ kip}$$

Considering x-direction:

$V_{max} = 8.8871 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(8.8871\text{ kip})}{(111.22\text{ kip})}$$

$$Ratio = 0.079904$$

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

Considering z-direction:

$V_{max} = 0.86533\text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.86533\text{ kip})}{(111.22\text{ kip})}$$

$$Ratio = 0.0077801$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

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

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

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

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

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

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

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

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

Therefore,
ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 27.768\text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(27.768\text{ kipft})}{(249.6\text{ kipft})}$$

$$Ratio = 0.11125$$

Status: **PASS**
Ratio: **0.110**

Considering z-direction:

$M_{max} = 2.5235\text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

		$$Ratio = \frac{(2.5235 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.01011$$	Status: **PASS** Ratio: **0.010**

REFERENCES	CALCULATIONS	RESULTS

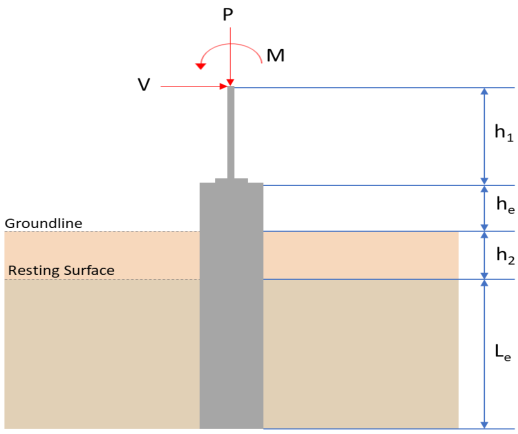
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 7\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	11.859	18.768
V_x (kip)	-2.470	-4.146
V_z (kip)	-0.042	-0.068
M_x (kipft)	-0.162	-0.262
M_z (kipft)	32.627	56.275

Material Properties

$f'_{ck} = 2.5\ \mathrm{ksi}$ - Concrete strength,

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.47\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.39331\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(32.627\ \mathrm{kipft}) + ((-2.47\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 5.1954\ \mathrm{kipft/ft}$$

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:
$L_{e,x} = 6.4167\ \mathrm{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.042\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.0066879\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.162\ \mathrm{kipft}) + ((-0.042\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.025796\ \mathrm{kipft/ft}$$

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:
$L_{e,z} = 1.1684\ \mathrm{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.4167\ \mathrm{ft}), (1.1684\ \mathrm{ft})]$$

$$L_{e,req} = 6.417\ \mathrm{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.417\ \mathrm{ft})}{(7\ \mathrm{ft})}$$

$$Ratio = 0.91671$$

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

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

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

$$q = \frac{(11.859 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.74119 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.74119 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.37059$$

Status: **PASS**
Ratio: **0.370**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.75$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.39331 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 5.1954 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.1954 \text{ kipft/ft}) \times (7 \text{ ft})) + \left(3 \times (-0.39331 \text{ kip/ft}) \times (7 \text{ ft})^2\right)}{(6 \times (5.1954 \text{ kipft/ft})) + (4 \times (-0.39331 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.819 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (5.1954 \text{ kipft/ft})) + (3 \times (-0.39331 \text{ kip/ft}) \times (7 \text{ ft}))]^2}{(7 \text{ ft})^2 \times [(3 \times (5.1954 \text{ kipft/ft})) + (2 \times (-0.39331 \text{ kip/ft}) \times (7 \text{ ft}))]}$$

$$p = 0.2381 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (5.1954 \text{ kipft/ft})) + ((-0.39331 \text{ kip/ft}) \times (7 \text{ ft}))]}{(7 \text{ ft})^2}$$

$$s = 0.93521 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.819 \text{ ft})}{2}$$

$$p_a = 0.36142 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.2381\ \mathrm{kip/ft^2}\right)}{\left(0.36142\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.65879$$

Status: **PASS**
Ratio: **0.660**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.93521\ \mathrm{kip/ft^2}\right)}{\left(1.05\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.89068$$

Status: **PASS**
Ratio: **0.890**

Considering z-direction:

$H_o = -0.0066879\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.025796\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.025796\ \mathrm{kipft/ft}) \times (7\ \mathrm{ft})) + \left(3 \times (-0.0066879\ \mathrm{kip/ft}) \times (7\ \mathrm{ft})^2\right)}{(6 \times (0.025796\ \mathrm{kipft/ft})) + (4 \times (-0.0066879\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))}$$

$$a = 4.986\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.025796\ \mathrm{kipft/ft})) + (3 \times (-0.0066879\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))]^{\ 2}}{(7\ \mathrm{ft})^2 \times [(3 \times (0.025796\ \mathrm{kipft/ft})) + (2 \times (-0.0066879\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))]}$$

$$p = -0.0013084\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.025796\ \mathrm{kipft/ft})) + ((-0.0066879\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))]}{(7\ \mathrm{ft})^2}$$

$$s = 0.00058495\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.986\ \mathrm{ft})}{2}$$

$$p_a = 0.37395\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.0013084\ \mathrm{kip/ft^2}\right)}{\left(0.37395\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.0034988$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

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

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

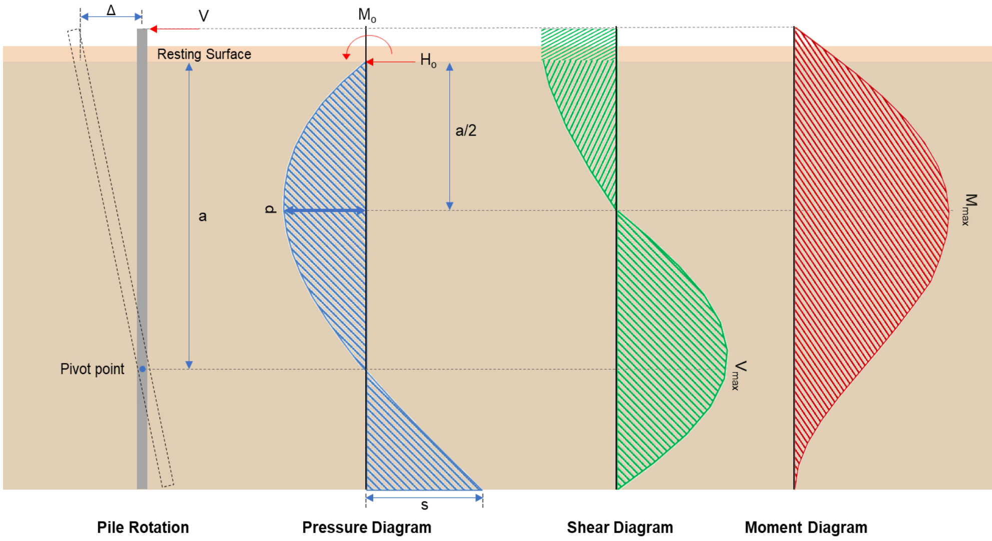
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.00058495 \text{ kip/ft}^2)}{(1.05 \text{ kip/ft}^2)}$$

$$Ratio = 0.00055709$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.146 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.66019 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(56.275 \text{ kipft}) + ((-4.146 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 8.961 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(8.961 \text{ kipft/ft})}{(-0.66019 \text{ kip/ft})}$$

$$E = 13.573 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.961 \text{ kipft/ft}) \times (7 \text{ ft})) + \left(3 \times (-0.66019 \text{ kip/ft}) \times (7 \text{ ft})^2\right)}{\ldots}$$

$$a = \frac{}{(6 \times (8.961\ \text{kipft/ft})) + (4 \times (-0.66019\ \text{kip/ft}) \times (7\ \text{ft}))}$$

$$a = 4.8159\ \text{ft}$$

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

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

$$V_{max} = ((-0.66019\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (13.573\ \text{ft})}{(7\ \text{ft})} + 3\right) \times \left(\frac{(4.8159\ \text{ft})}{(7\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (13.573\ \text{ft})}{(7\ \text{ft})} + 2\right) \times \left(\frac{(4.8159\ \text{ft})}{(7\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 10.804\ \text{kip}$$

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

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

$$M_{max} = ((-0.66019\ \text{kip/ft}) \times (48\ \text{in}) \times (7\ \text{ft})) \times \left[\left(\frac{(13.573\ \text{ft})}{(7\ \text{ft})} + \frac{(4.8159\ \text{ft})}{2 \times (7\ \text{ft})}\right) - \left[\left(\frac{4 \times (13.573\ \text{ft})}{(7\ \text{ft})} + 3\right) \times \left(\frac{(4.8159\ \text{ft})}{2 \times (7\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (13.573\ \text{ft})}{(7\ \text{ft})} + 2\right) \times \left(\frac{(4.8159\ \text{ft})}{2 \times (7\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 36.133\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.068\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.010828\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.262\ \text{kipft}) + ((-0.068\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.04172\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.04172\ \text{kipft/ft})}{(-0.010828\ \text{kip/ft})}$$

$$E = 3.8529\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.04172\ \text{kipft/ft}) \times (7\ \text{ft})) + \left(3 \times (-0.010828\ \text{kip/ft}) \times (7\ \text{ft})^2\right)}{(6 \times (0.04172\ \text{kipft/ft})) + (4 \times (-0.010828\ \text{kip/ft}) \times (7\ \text{ft}))}$$

$$a = 4.9862\ \text{ft}$$

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

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

$$V_{max} = ((-0.010828 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.8529 \text{ ft})}{(7 \text{ ft})} + 3\right) \times \left(\frac{(4.9862 \text{ ft})}{(7 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.8529 \text{ ft})}{(7 \text{ ft})} + 2\right) \times \left(\frac{(4.9862 \text{ ft})}{(7 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.071001 \text{ kip}$$

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

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

$$M_{max} = ((-0.010828 \text{ kip/ft}) \times (48 \text{ in}) \times (7 \text{ ft})) \times \left[\left(\frac{(3.8529 \text{ ft})}{(7 \text{ ft})} + \frac{(4.9862 \text{ ft})}{2 \times (7 \text{ ft})}\right) - \left[\left(\frac{4 \times (3.8529 \text{ ft})}{(7 \text{ ft})} + 3\right) \times \left(\frac{(4.9862 \text{ ft})}{2 \times (7 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.8529 \text{ ft})}{(7 \text{ ft})} + 2\right) \times \left(\frac{(4.9862 \text{ ft})}{2 \times (7 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.22142 \text{ kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(18.768 \text{ kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2))\right]$$

$$A_{st,required} = -83.972 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-83.972 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(18.768\text{ kip})}{(2675.2\text{ kip})}$$

$$Ratio = 0.0070156$$

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 $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 18.768 \text{ kip} \rightarrow 18768 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(18768 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.99 \text{ kip}$$

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

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.99 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.99 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((120.99 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.72 \text{ kip}$$

Considering x-direction:

$V_{max} = 10.804 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(10.804 \text{ kip})}{(111.72 \text{ kip})}$$ $$Ratio = 0.096702$$	Status: **PASS** Ratio: **0.100**
	Considering z-direction: $V_{max} = 0.071001 \text{ kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.071001 \text{ kip})}{(111.72 \text{ kip})}$$ $$Ratio = 0.00063551$$	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:** $M_{max} = 36.133 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(36.133 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.14476$$	Status: **PASS** Ratio: **0.140**
	Considering z-direction: $M_{max} = 0.22142 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(0.22142\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$ $$Ratio = 0.00088712$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

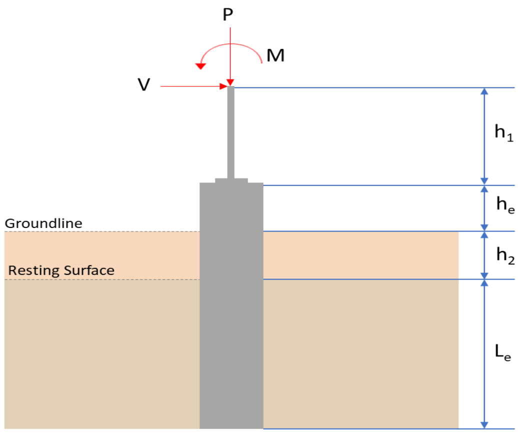
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 7\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	11.859	18.768
V_x (kip)	-2.470	-4.146
V_z (kip)	0.042	0.068
M_x (kipft)	0.161	0.263
M_z (kipft)	32.627	56.275

Material Properties

$f'_{ck} = 2.5\ \mathrm{ksi}$ - Concrete strength,

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.47\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.39331\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(32.627\ \text{kipft}) + ((-2.47\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 5.1954\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 6.4167\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.042\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.0066879\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.161\ \text{kipft}) + ((0.042\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.025637\ \text{kipft/ft}$$

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:
$L_{e,z} = 1.3757\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.4167\ \text{ft}), (1.3757\ \text{ft})]$$

$$L_{e,req} = 6.417\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.417\ \text{ft})}{(7\ \text{ft})}$$

$$Ratio = 0.91671$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\ D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(11.859 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.74119 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.74119 \text{ kip/ft}^2\right)}{(2000 \text{ psf})}$$

$$Ratio = 0.37059$$

Status: **PASS**
Ratio: **0.370**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.75$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.39331 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 5.1954 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.1954 \text{ kipft/ft}) \times (7 \text{ ft})) + \left(3 \times (-0.39331 \text{ kip/ft}) \times (7 \text{ ft})^2\right)}{(6 \times (5.1954 \text{ kipft/ft})) + (4 \times (-0.39331 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.819 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (5.1954 \text{ kipft/ft})) + (3 \times (-0.39331 \text{ kip/ft}) \times (7 \text{ ft}))]^{\ 2}}{(7 \text{ ft})^2 \times [(3 \times (5.1954 \text{ kipft/ft})) + (2 \times (-0.39331 \text{ kip/ft}) \times (7 \text{ ft}))]}$$

$$p = 0.2381 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (5.1954 \text{ kipft/ft})) + ((-0.39331 \text{ kip/ft}) \times (7 \text{ ft}))]}{(7 \text{ ft})^2}$$

$$s = 0.93521 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.819 \text{ ft})}{2}$$

$$p_a = 0.36142 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

	$$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.2381\ \mathrm{kip/ft^2}\right)}{\left(0.36142\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.65879$$ p_s - Allowable lateral soil pressure at depth L_e, $$p_s = R\, L_e$$ $$p_s = (150\ \mathrm{psf/ft}) \times (7\ \mathrm{ft})$$ $$p_s = 1.05\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{s}{p_s}$$ $$Ratio = \frac{\left(0.93521\ \mathrm{kip/ft^2}\right)}{\left(1.05\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.89068$$	Status: **PASS** Ratio: **0.660** Status: **PASS** Ratio: **0.890**	
	Considering z-direction: $H_o = 0.0066879\ \mathrm{kip/ft}$ - Lateral force per length of pile, $M_o = 0.025637\ \mathrm{kipft/ft}$ - Overturning moment per length of pile, a - Distance from resting surface to pivot point, $$a = \frac{(4\, M_o\, L_e) + \left(3\, H_o\, L_e^2\right)}{(6\, M_o) + (4\, H_o\, L_e)}$$ $$a = \frac{(4 \times (0.025637\ \mathrm{kipft/ft}) \times (7\ \mathrm{ft})) + \left(3 \times (0.0066879\ \mathrm{kip/ft}) \times (7\ \mathrm{ft})^2\right)}{(6 \times (0.025637\ \mathrm{kipft/ft})) + (4 \times (0.0066879\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))}$$ $$a = 4.9869\ \mathrm{ft}$$ p - Earth pressure against the pile at distance a/2 from resting surface, $$p = \frac{0.75\,[(4\, M_o) + (3\, H_o\, L_e)]^2}{L_e^2\,[(3\, M_o) + (2\, H_o\, L_e)]}$$ $$p = \frac{0.75 \times [(4 \times (0.025637\ \mathrm{kipft/ft})) + (3 \times (0.0066879\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))]^{\ 2}}{(7\ \mathrm{ft})^2 \times [(3 \times (0.025637\ \mathrm{kipft/ft})) + (2 \times (0.0066879\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))]}$$ $$p = 0.0052994\ \mathrm{kip/ft^2}$$ s - Earth pressure against the pile at distance L_e, $$s = \frac{6\,[(2\, M_o) + (H_o\, L_e)]}{L_e^2}$$ $$s = \frac{6 \times [(2 \times (0.025637\ \mathrm{kipft/ft})) + ((0.0066879\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))]}{(7\ \mathrm{ft})^2}$$ $$s = 0.012011\ \mathrm{kip/ft^2}$$ **Check lateral soil pressure capacity:** p_a - Allowable lateral soil pressure at depth a/2, $$p_a = R\,\frac{a}{2}$$ $$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.9869\ \mathrm{ft})}{2}$$ $$p_a = 0.37402\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.0052994\ \mathrm{kip/ft^2}\right)}{\left(0.37402\ \mathrm{kip/ft^2}\right)}$$		

$$Ratio = 0.014169$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

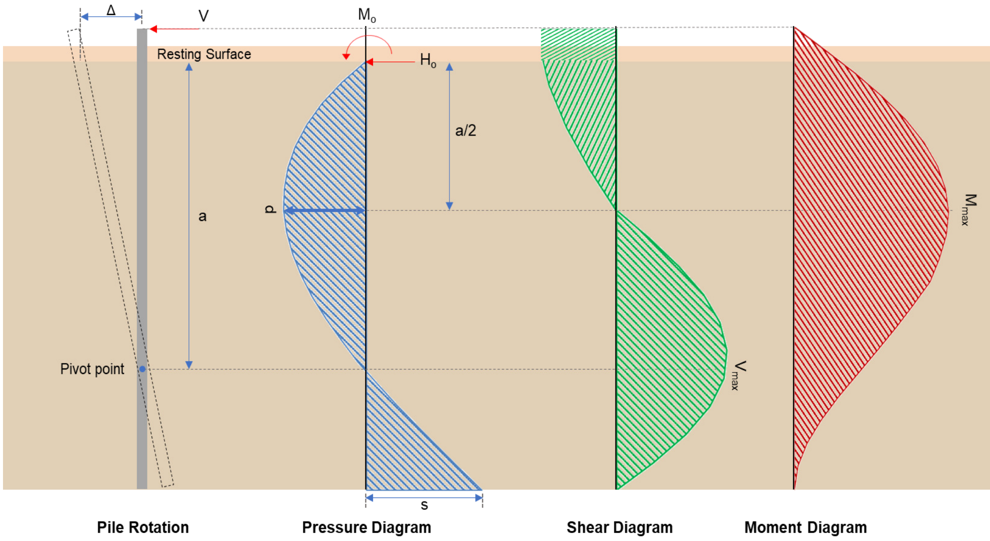
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.012011\ \mathrm{kip/ft^2})}{(1.05\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.011439$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.146\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.66019\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(56.275\ \mathrm{kipft}) + ((-4.146\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 8.961\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(8.961\ \mathrm{kipft/ft})}{(-0.66019\ \mathrm{kip/ft})}$$

$$E = 13.573\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.961\ \mathrm{kipft/ft}) \times (7\ \mathrm{ft})) + \left(3 \times (-0.66019\ \mathrm{kip/ft}) \times (7\ \mathrm{ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (8.961\ \mathrm{kipft/ft})) + (4 \times (-0.66019\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))}$$

$$a = 4.8159\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.66019\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (13.573\ \mathrm{ft})}{(7\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.8159\ \mathrm{ft})}{(7\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (13.573\ \mathrm{ft})}{(7\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.8159\ \mathrm{ft})}{(7\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 10.804\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.66019\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (7\ \mathrm{ft})) \times \left[\left(\frac{(13.573\ \mathrm{ft})}{(7\ \mathrm{ft})} + \frac{(4.8159\ \mathrm{ft})}{2 \times (7\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (13.573\ \mathrm{ft})}{(7\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.8159\ \mathrm{ft})}{2 \times (7\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (13.573\ \mathrm{ft})}{(7\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.8159\ \mathrm{ft})}{2 \times (7\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 36.133\ \mathrm{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.068\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = 0.010828\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.263\ \mathrm{kipft}) + ((0.068\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.041879\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.041879\ \mathrm{kipft/ft})}{(0.010828\ \mathrm{kip/ft})}$$

$$E = 3.8676\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.041879\ \mathrm{kipft/ft}) \times (7\ \mathrm{ft})) + \left(3 \times (0.010828\ \mathrm{kip/ft}) \times (7\ \mathrm{ft})^2\right)}{(6 \times (0.041879\ \mathrm{kipft/ft})) + (4 \times (0.010828\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))}$$

$$a = 4.9856\ \mathrm{ft}$$

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

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

$$V_{max} = ((0.010828 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.8676 \text{ ft})}{(7 \text{ ft})} + 3\right) \times \left(\frac{(4.9856 \text{ ft})}{(7 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.8676 \text{ ft})}{(7 \text{ ft})} + 2\right) \times \left(\frac{(4.9856 \text{ ft})}{(7 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.07116 \text{ kip}$$

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

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

$$M_{max} = ((0.010828 \text{ kip/ft}) \times (48 \text{ in}) \times (7 \text{ ft})) \times \left[\left(\frac{(3.8676 \text{ ft})}{(7 \text{ ft})} + \frac{(4.9856 \text{ ft})}{2 \times (7 \text{ ft})}\right) - \left[\left(\frac{4 \times (3.8676 \text{ ft})}{(7 \text{ ft})} + 3\right) \times \left(\frac{(4.9856 \text{ ft})}{2 \times (7 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.8676 \text{ ft})}{(7 \text{ ft})} + 2\right) \times \left(\frac{(4.9856 \text{ ft})}{2 \times (7 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.22198 \text{ kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(18.768 \text{ kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2))\right]$$

$$A_{st,required} = -83.972 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max[(-83.972 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

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,

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

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

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

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

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

$$Ratio = \frac{(18.768\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0070156$$

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 $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 18.768 \text{ kip} \rightarrow 18768 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(18768 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.99 \text{ kip}$$

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

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.99 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.99 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((120.99 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.72 \text{ kip}$$

Considering x-direction:

$V_{max} = 10.804 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(10.804 \text{ kip})}{(111.72 \text{ kip})}$$

$$Ratio = 0.096702$$

Status: **PASS**
Ratio: **0.100**

Considering z-direction:

$V_{max} = 0.07116 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.07116 \text{ kip})}{(111.72 \text{ kip})}$$

$$Ratio = 0.00063693$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

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

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

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

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

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

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

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

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

Therefore,
ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 36.133 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(36.133 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.14476$$

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

Considering z-direction:

$M_{max} = 0.22198 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(0.22198 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.00088934$$		Status: **PASS** Ratio: **0.000**