Project Details

Project Name: Sartori - V1Jb

Location: 12760 Gilbert Creek Rd, Willamina, OR 97396, USA

Unique ID: 4P-19.75-6TOP-XD-12-L-4Hx12W-F8B6

Dealer: ______________________________

Date: Tue Oct 22 2024

Number of Modules: 48

Number of Poles: 4

Date Sold:

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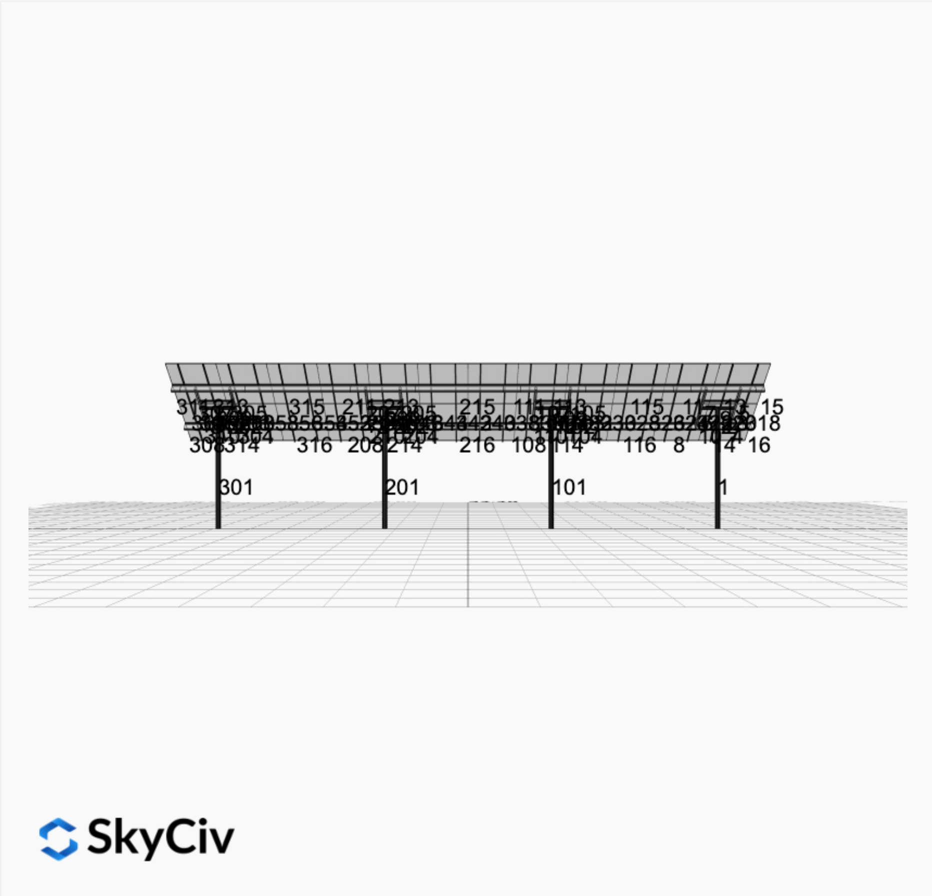

Array Dimensions N/S	15.05 ft
Array Dimensions E/W	68.80 ft
Winter Tilt Angle	35
Front Edge Clearance	10 ft

MT Solar Bill of Materials (4P-19.75-6TOP-XD-12-L-4Hx12W-F8B6)

Part	Short Description	BOM Qty
MTS-PC-6	6IN 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-HOOK-4PK	Hook Clamp	12

Rail Bill of Materials

Part	Qty
Rails (179in)	24
Rail Attachment	48

Part	Qty
Module Mid Clamp	72
Module End Clamp	48
Ground Lug	12

Site Details:

Site Address: 12760 Gilbert Creek Rd, Willamina, OR 97396, USA

Array Specification

Duty Classification:	XD
Module Width:	44.65 in
Module Length:	67.80in
Number of Rows:	4
Number of Columns:	12
Total Number of Modules:	48
Winter Tilt Angle:	35
Front Edge Clearance:	10
Total Array Height at Tilt:	18.63 ft
Total Frame Length:	68.75 ft
Frame Weight:	5394 lbs
Array Dimensions N/S:	15.05 ft
Array Dimensions E/W:	68.80 ft
Rail Length:	180.60 in
Rail Spacing:	2.87 ft

Support Specifications

Pole Size:	6in Pipe Sch 80
Pole Length above Grade:	14.32 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: 6.00 ft Pile 2: 6.50 ft Pile 3: 6.50 ft Pile 4: 6.00 ft
Foundation Volume:	14.815 y^3

Site Info

Risk Category:	I
Exposure:	B
Soil Classification:	sand
Site Location:	12760 Gilbert Creek Rd, Willamina, OR 97396, USA
Wind Speed:	90 mph

Snow Load:	72 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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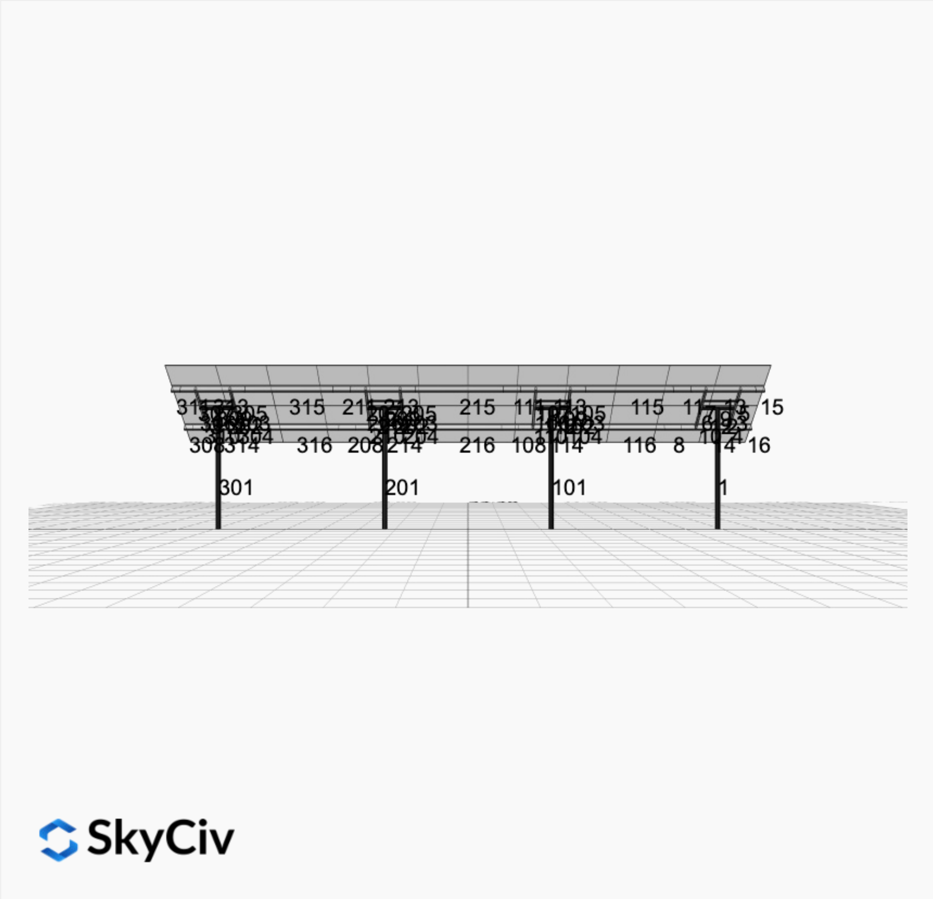
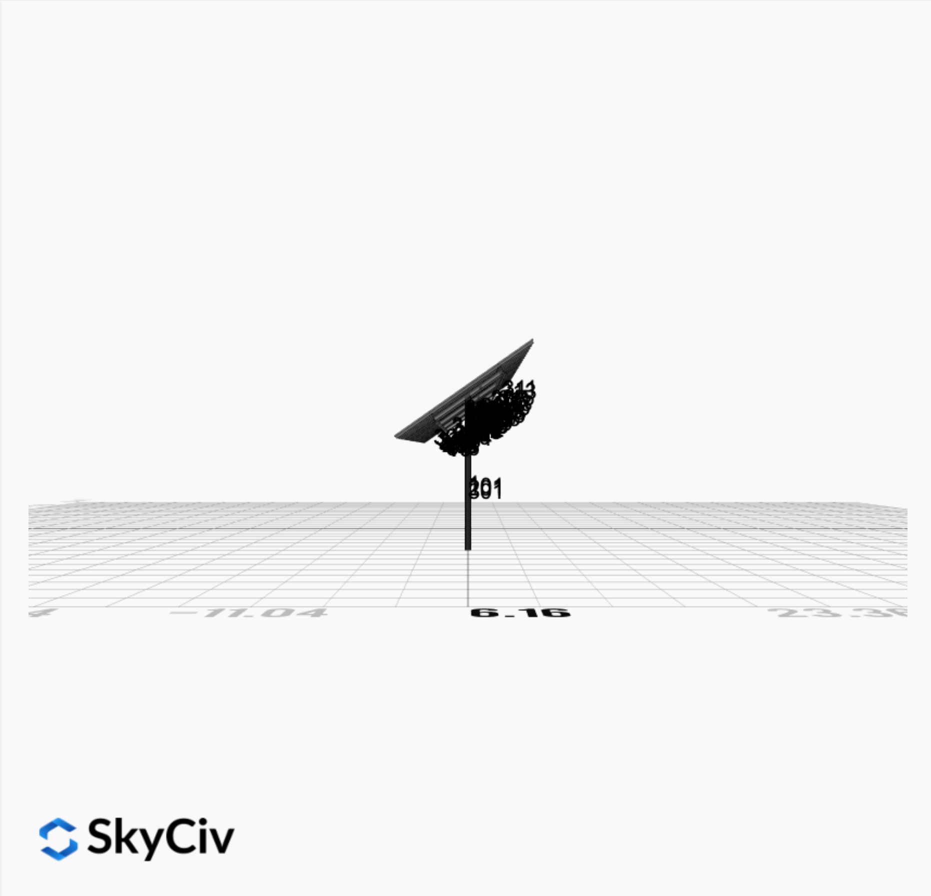
Design Notes:

- 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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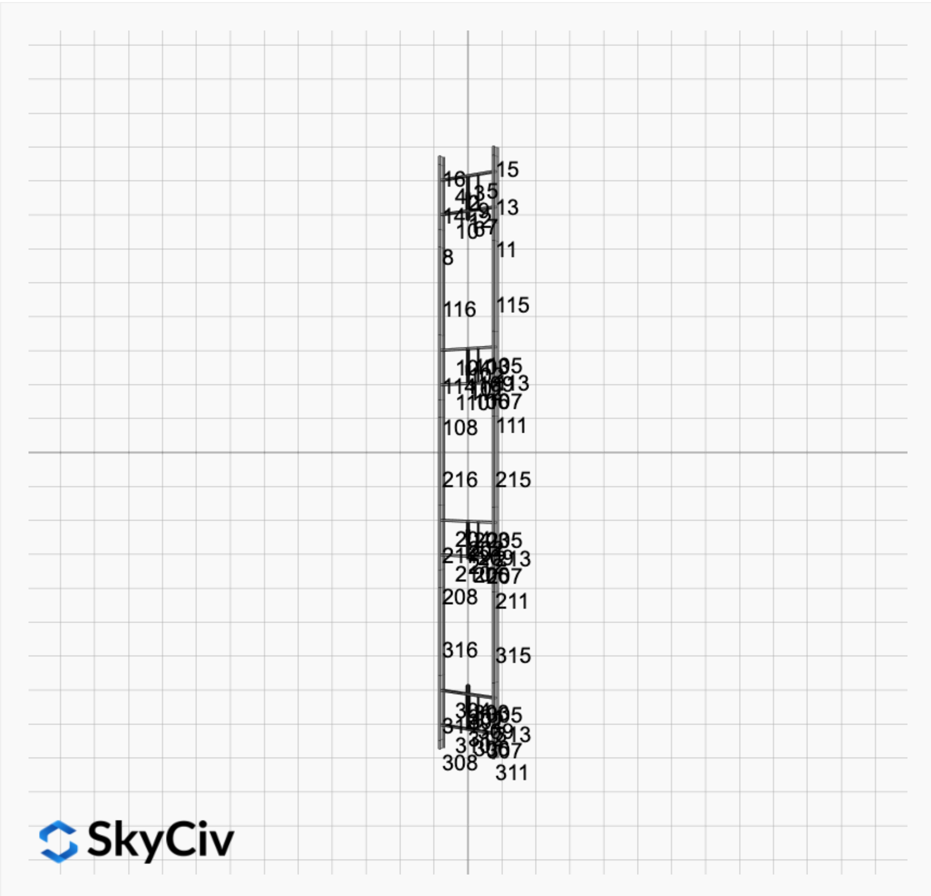
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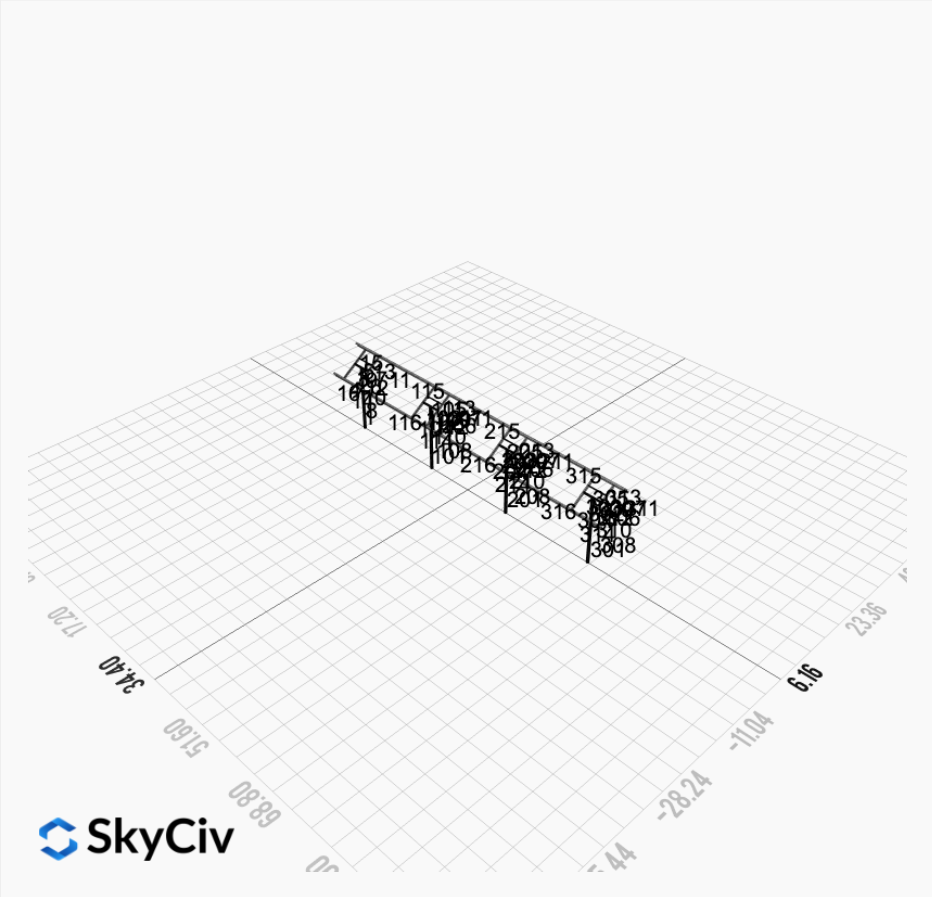
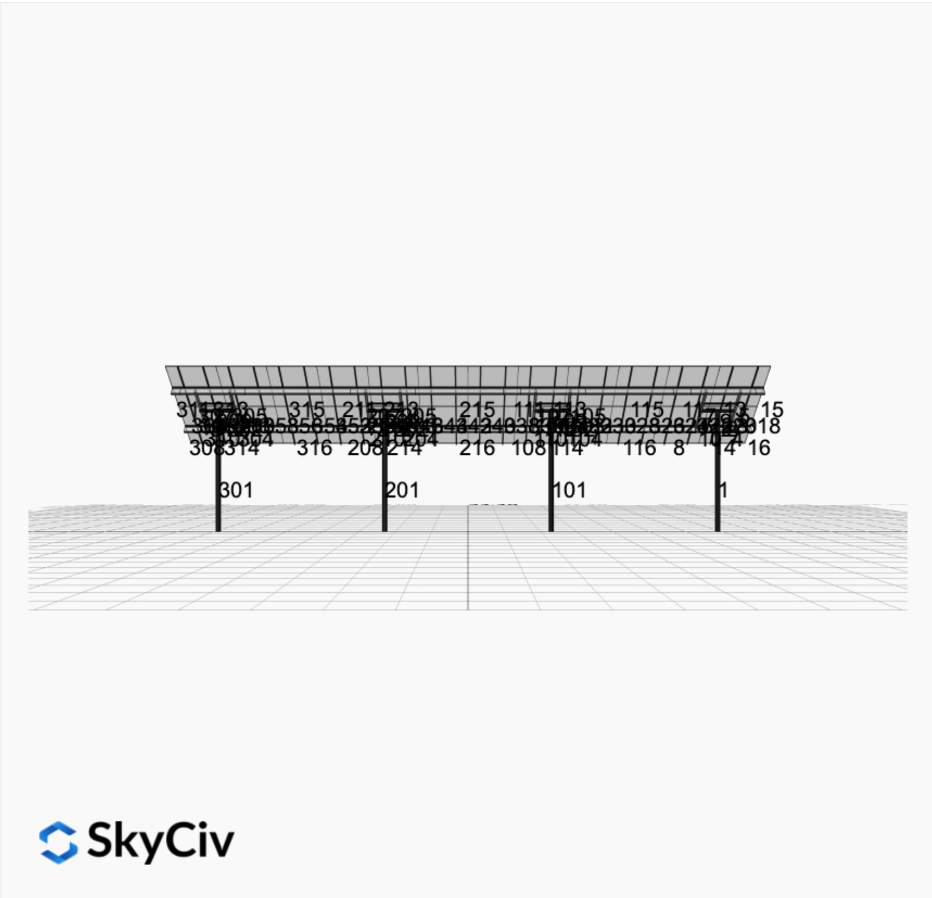
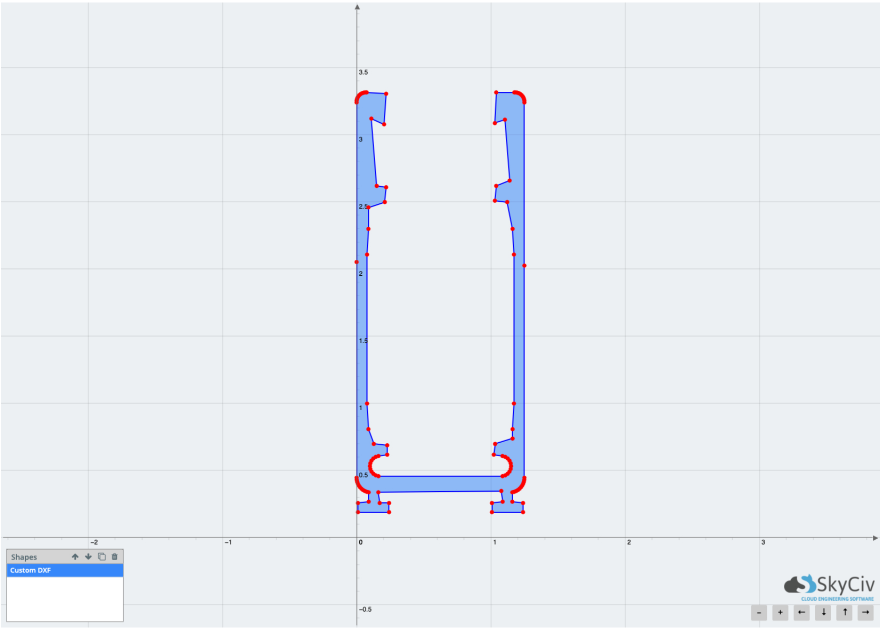


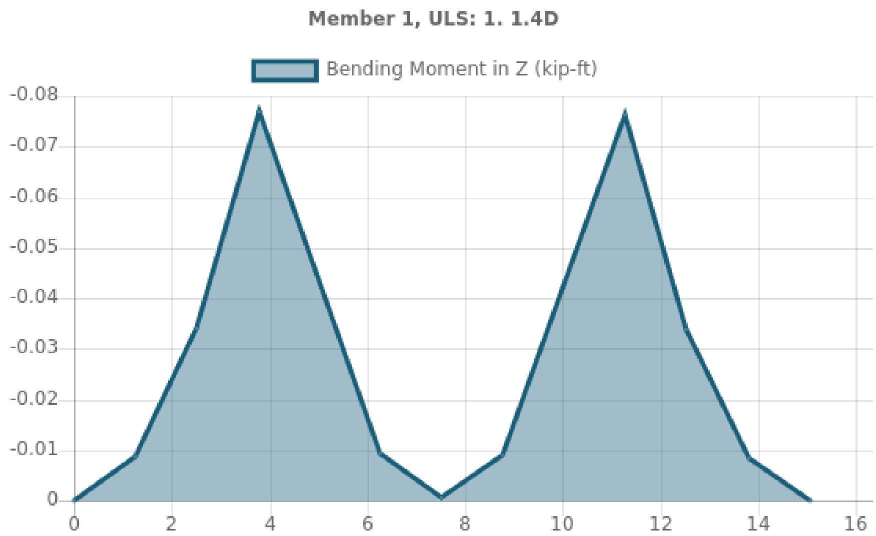


Rail Design Check

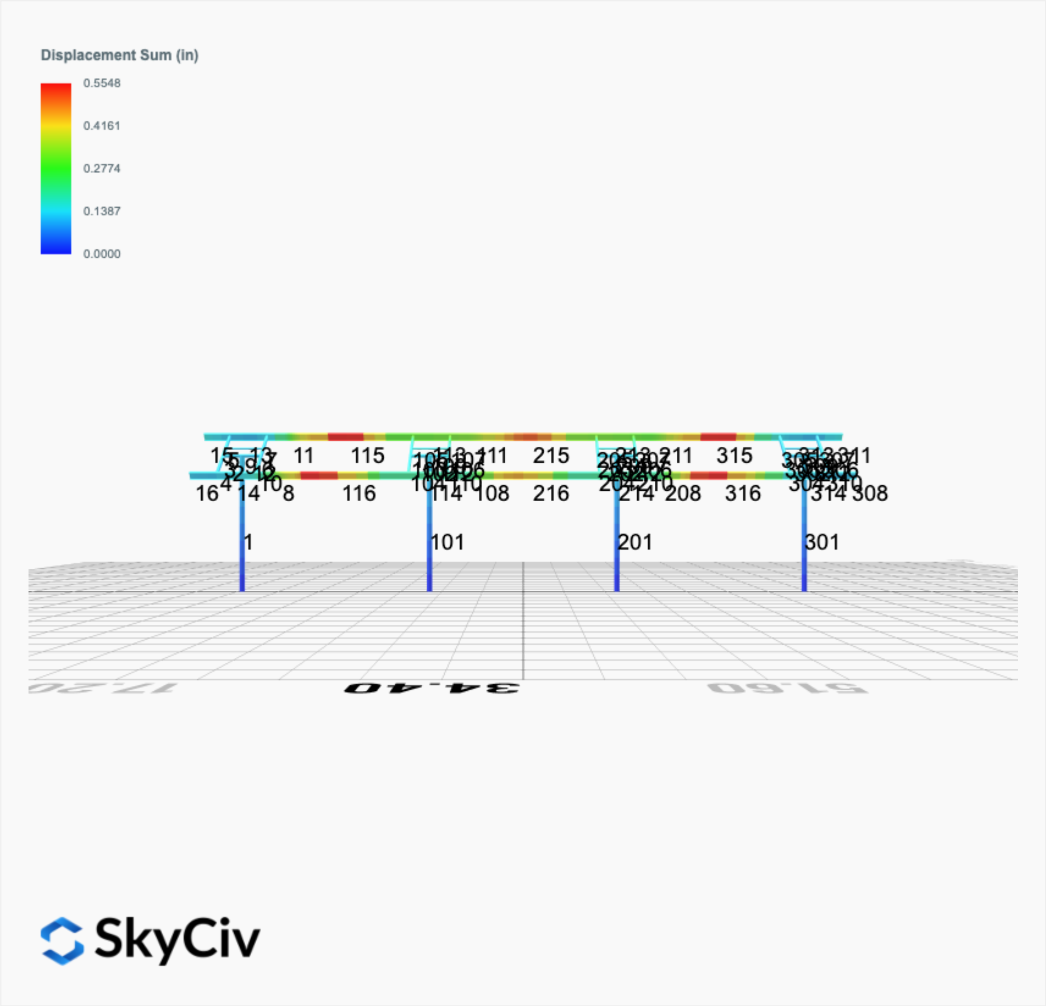
Rail Length: 15.049999999999999 ft
Additional Restraints Required: None
Tributary Width: 2.8666666666666667 ft
Material: Aluminium
Density: 169 lb/ft^3
Elasticity Modulus: 10000 ksi
Fy: 34.5 ksi
Fu: 37 ksi
Snow (X): 0.0651 kip/ft
Snow (Y): -0.0456 kip/ft
Wind uplift Case A: 0.0434 kip/ft
Wind uplift Case A: 0.0434 kip/ft
Wind uplift Case B (X): 0.0000 kip/ft
Wind uplift Case B (Y): 0.0587 kip/ft

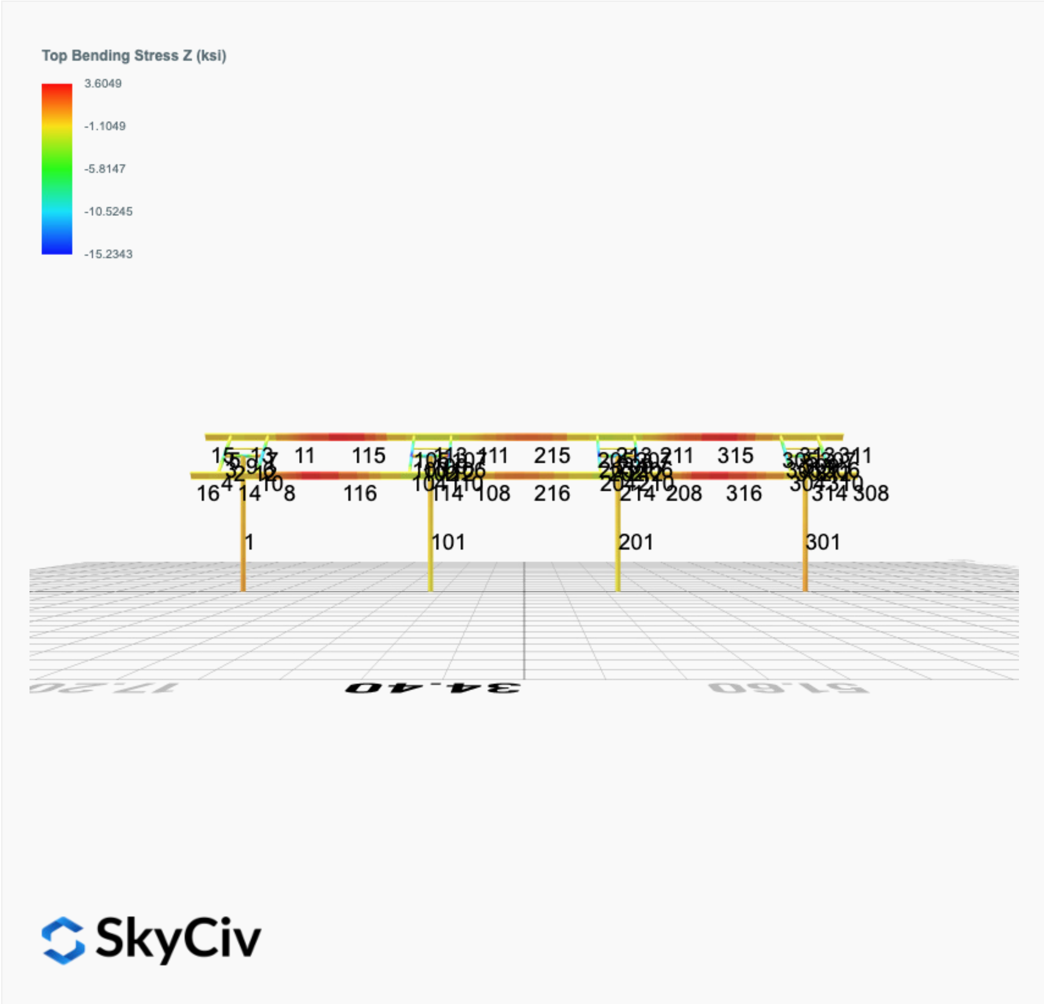


Result Check	Max Limit	Max Value	Utility	Status
Custom Stress Limit	34.5	17.19274332	0.498	PASS
Material Yield	34.5	17.19274332	0.498	PASS
Material Strength	37	17.19274332	0.465	PASS

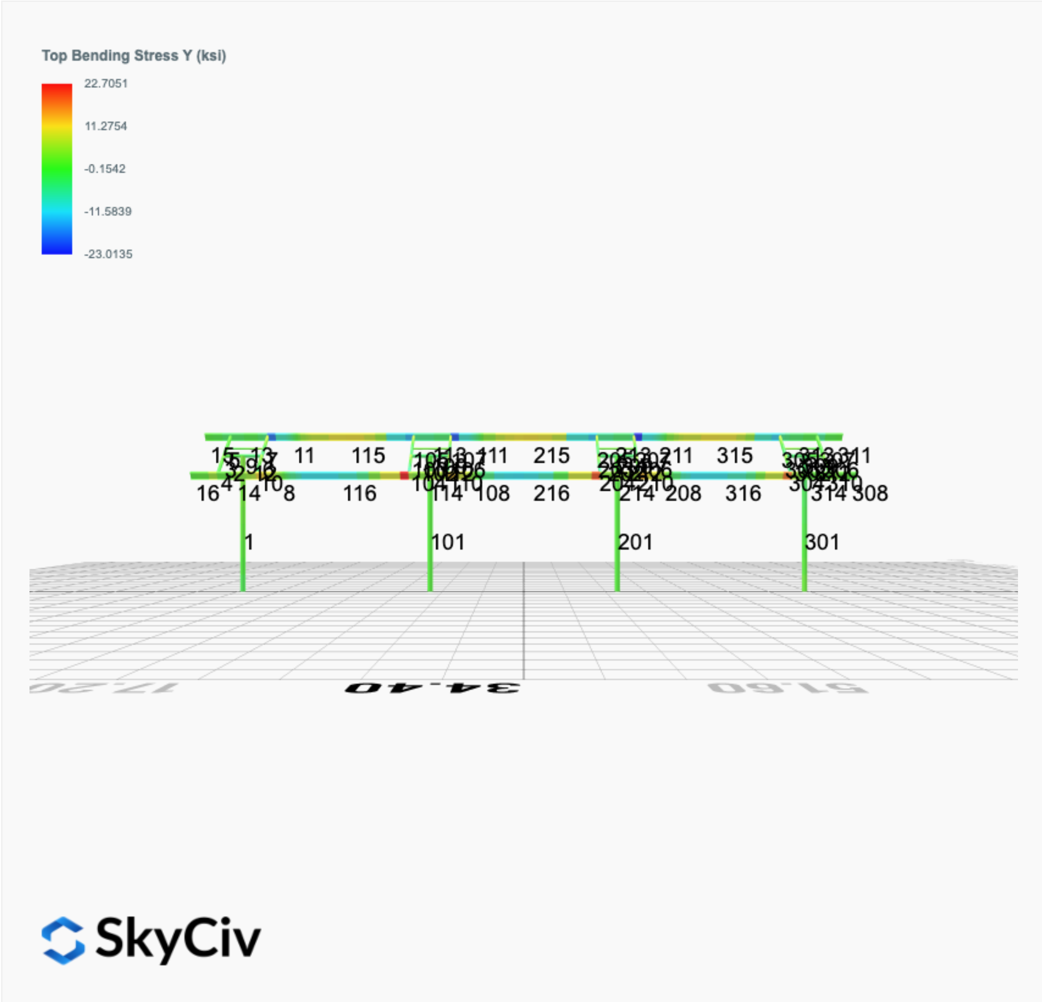


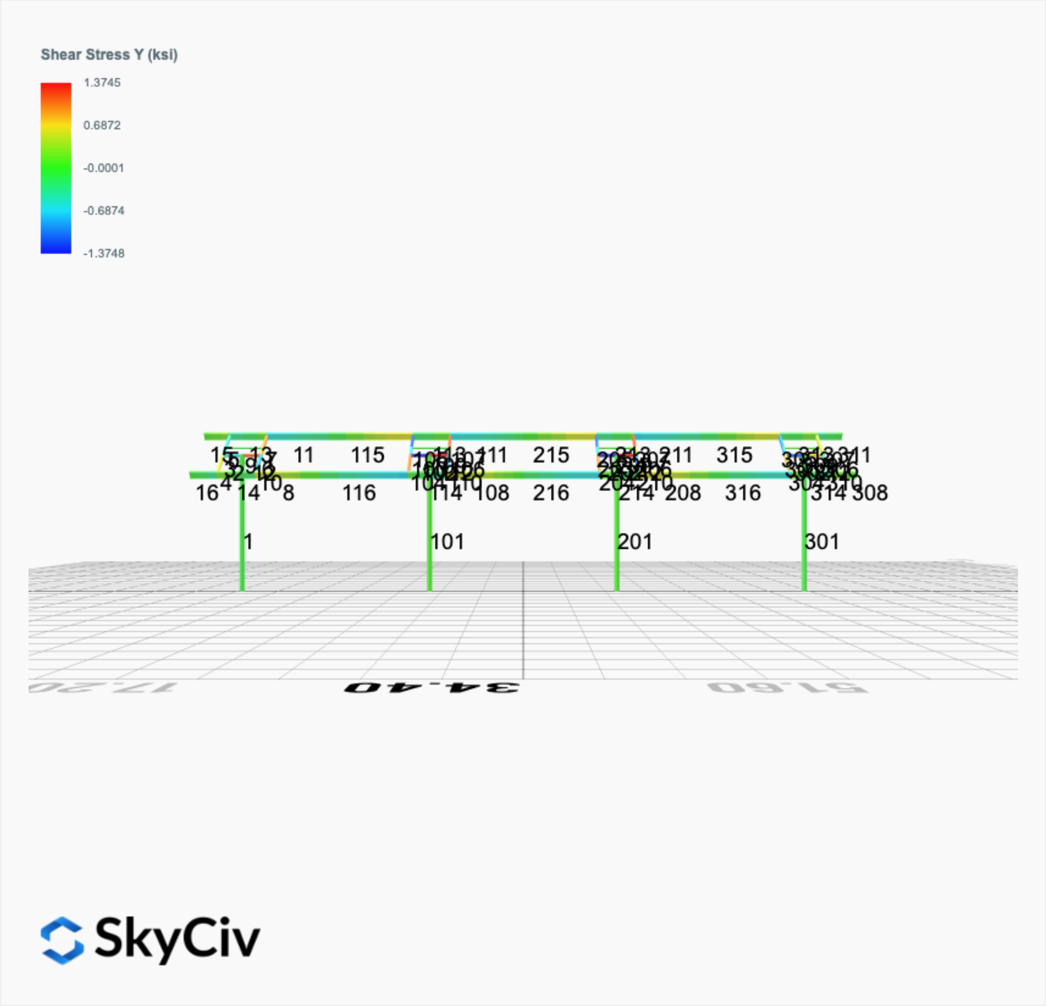
FEM Results (Envelope Worst Case for each member)





Top Bending Stress Z (ksi)
3.6049
-1.1049
-5.8147
-10.5245
-15.2343
11
115
215
315
16
14
8
116
108
216
208
316
308
1
101
201
301
17.20
34.40
51.60
SkyCiv


Top Bending Stress Y (ksi)
22.7051
11.2754
-0.1542
-11.5839
-23.0135
11
115
215
315
16
14
8
116
114
108
216
214
208
316
314
308
1
101
201
301
SkyCiv


Shear Stress Y (ksi)
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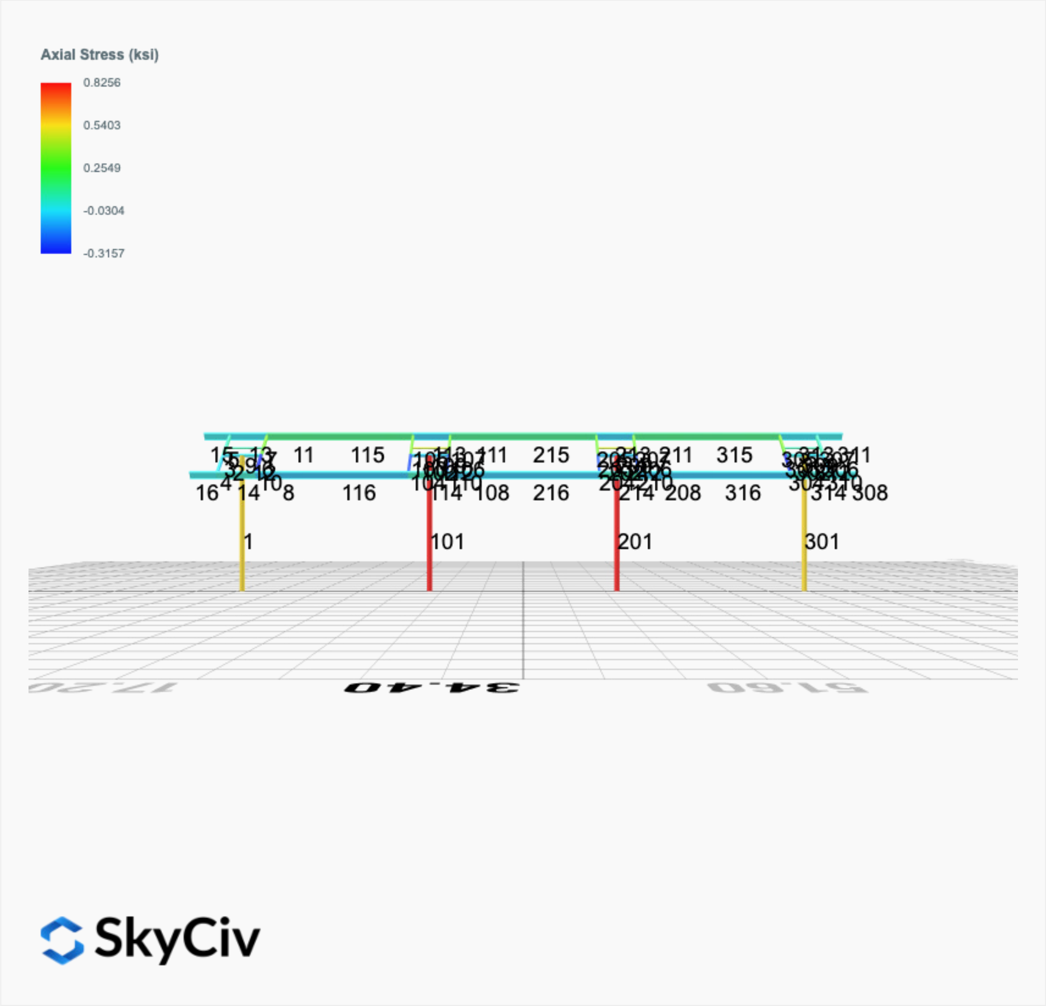
0.6872
-0.0001
-0.6874
-1.3748
SkyCiv


Axial Stress (ksi)
0.8256
0.5403
0.2549
-0.0304
-0.3157
15
13
11
115
111
215
211
315
16
14
8
116
114
108
216
214
208
316
314
308
1
101
201
301
17.20
34.40
51.60
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	0.0257	2.0135	0.0630	0.2921	-0.0700	-0.2918
ULS: 2. D + L	0.0257	2.0135	0.0630	0.2921	-0.0700	-0.2918
ULS: 3. D + (S or Lr or R)	0.1170	6.8183	0.2923	1.3597	-0.3271	-1.4266
ULS: 3. D + (S or Lr or R)	0.0257	2.0135	0.0630	0.2921	-0.0700	-0.2918
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0942	5.6171	0.2350	1.0928	-0.2628	-1.1429
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0257	2.0135	0.0630	0.2921	-0.0700	-0.2918
ULS: 5b. D + 0.7E	0.0257	2.0135	0.0630	0.2921	-0.0700	-0.2918
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0942	5.6171	0.2350	1.0928	-0.2628	-1.1429
ULS: 8. 0.6D + 0.7E	0.0154	1.2081	0.0378	0.1753	-0.0420	-0.1751
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.3834	3.8944	0.2457	1.1291	-0.5220	20.9991
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.3834	3.8944	0.2457	1.1291	-0.5220	20.9991
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.2036	0.4331	-0.0828	-0.3726	0.2898	-17.0900
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.0395	0.6802	-0.0807	-0.3634	0.2884	-18.5912
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.9627	7.0278	0.3720	1.7206	-0.6018	14.8253
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.9627	7.0278	0.3720	1.7206	-0.6018	14.8253
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.9776	4.4318	0.1256	0.5943	0.0070	-13.7415
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.8545	4.6172	0.1272	0.6012	0.0059	-14.8674
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.0312	3.4242	0.2000	0.9199	-0.4090	15.6764
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.0312	3.4242	0.2000	0.9199	-0.4090	15.6764
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.9091	0.8282	-0.0463	-0.2065	0.1998	-12.8904
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.7860	1.0136	-0.0448	-0.1995	0.1988	-14.0163
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.3937	3.0890	0.2205	1.0123	-0.4940	21.1159
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.3937	3.0890	0.2205	1.0123	-0.4940	21.1159
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.1933	-0.3723	-0.1080	-0.4895	0.3177	-16.9732
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.0292	-0.1251	-0.1059	-0.4802	0.3163	-18.4745

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	11.6832
Shear X	-2.3486
Shear Z	0.6134
Moment X	2.8595
Moment Y (Twist)	1.0012
Moment Z	36.5149

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	7.0278
Shear X	-1.3937
Shear Z	0.3720
Moment X	1.7206
Moment Y (Twist)	0.6018
Moment Z	21.1159

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	-0.0257	2.6058	0.0013	0.0046	-0.0082	0.3501
ULS: 2. D + L	-0.0257	2.6058	0.0013	0.0046	-0.0082	0.3501
ULS: 3. D + (S or Lr or R)	-0.1172	9.5448	0.0067	0.0243	-0.0397	1.5829
ULS: 3. D + (S or Lr or R)	-0.0257	2.6058	0.0013	0.0046	-0.0082	0.3501
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0943	7.8100	0.0053	0.0194	-0.0318	1.2747

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0257	2.6058	0.0013	0.0046	-0.0082	0.3501
ULS: 5b. D + 0.7E	-0.0257	2.6058	0.0013	0.0046	-0.0082	0.3501
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0943	7.8100	0.0053	0.0194	-0.0318	1.2747
ULS: 8. 0.6D + 0.7E	-0.0154	1.5635	0.0008	0.0027	-0.0049	0.2101
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.8133	5.2902	0.0430	0.1932	-0.1389	26.7116
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.8133	5.2902	0.0430	0.1932	-0.1389	26.7116
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.4936	0.3343	-0.0291	-0.1318	0.0886	-20.4428
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.2082	0.7291	-0.0357	-0.1624	0.1067	-21.6687
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.4350	9.8233	0.0366	0.1608	-0.1299	21.0459
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.4350	9.8233	0.0366	0.1608	-0.1299	21.0459
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.0452	6.1064	-0.0175	-0.0829	0.0408	-14.3200
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.8312	6.4025	-0.0224	-0.1059	0.0544	-15.2394
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.3664	4.6191	0.0326	0.1460	-0.1062	20.1212
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.3664	4.6191	0.0326	0.1460	-0.1062	20.1212
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.1138	0.9022	-0.0215	-0.0977	0.0644	-15.2446
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.8997	1.1983	-0.0265	-0.1206	0.0780	-16.1640
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.8030	4.2479	0.0425	0.1914	-0.1356	26.5716
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.8030	4.2479	0.0425	0.1914	-0.1356	26.5716
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.5039	-0.7081	-0.0296	-0.1336	0.0919	-20.5829
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.2185	-0.3132	-0.0362	-0.1642	0.1100	-21.8087

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	16.4544
Shear X	-3.0368
Shear Z	0.0820
Moment X	0.3687
Moment Y (Twist)	0.2668
Moment Z	47.4466

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	9.8233
Shear X	-1.8133
Shear Z	0.0430
Moment X	0.1932
Moment Y (Twist)	0.1389
Moment Z	26.7116

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	-0.0257	2.6059	-0.0017	-0.0083	0.0084	0.3498
ULS: 2. D + L	-0.0257	2.6059	-0.0017	-0.0083	0.0084	0.3498
ULS: 3. D + (S or Lr or R)	-0.1170	9.5448	-0.0084	-0.0416	0.0407	1.5817
ULS: 3. D + (S or Lr or R)	-0.0257	2.6059	-0.0017	-0.0083	0.0084	0.3498
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0942	7.8101	-0.0067	-0.0333	0.0326	1.2737
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0257	2.6059	-0.0017	-0.0083	0.0084	0.3498
ULS: 5b. D + 0.7E	-0.0257	2.6059	-0.0017	-0.0083	0.0084	0.3498
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0942	7.8101	-0.0067	-0.0333	0.0326	1.2737
ULS: 8. 0.6D + 0.7E	-0.0154	1.5635	-0.0010	-0.0050	0.0050	0.2099
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.8133	5.2904	-0.0442	-0.2037	0.1378	26.7122
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.8133	5.2904	-0.0442	-0.2037	0.1378	26.7122
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.4936	0.3342	0.0294	0.1337	-0.0874	-20.4437
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.2082	0.7290	0.0359	0.1632	-0.1055	-21.6699

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	-1.4349	9.8235	-0.0386	-0.1798	0.1297	21.0455
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.4349	9.8235	-0.0386	-0.1798	0.1297	21.0455
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.0453	6.1063	0.0165	0.0732	-0.0392	-14.3214
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.8313	6.4024	0.0214	0.0953	-0.0528	-15.2411
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.3664	4.6193	-0.0336	-0.1548	0.1055	20.1216
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.3664	4.6193	-0.0336	-0.1548	0.1055	20.1216
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.1138	0.9021	0.0216	0.0982	-0.0635	-15.2453
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.8997	1.1982	0.0265	0.1203	-0.0770	-16.1649
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.8030	4.2481	-0.0435	-0.2003	0.1345	26.5723
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.8030	4.2481	-0.0435	-0.2003	0.1345	26.5723
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.5039	-0.7082	0.0300	0.1370	-0.0908	-20.5836
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.2185	-0.3134	0.0366	0.1665	-0.1088	-21.8098

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	16.4546
Shear X	-3.0367
Shear Z	-0.0844
Moment X	-0.3918
Moment Y (Twist)	0.2652
Moment Z	47.4477

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	9.8235
Shear X	-1.8133
Shear Z	-0.0442
Moment X	-0.2037
Moment Y (Twist)	0.1378
Moment Z	26.7122

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	0.0257	2.0133	-0.0626	-0.2923	0.0685	-0.2923
ULS: 2. D + L	0.0257	2.0133	-0.0626	-0.2923	0.0685	-0.2923
ULS: 3. D + (S or Lr or R)	0.1172	6.8177	-0.2905	-1.3608	0.3204	-1.4290
ULS: 3. D + (S or Lr or R)	0.0257	2.0133	-0.0626	-0.2923	0.0685	-0.2923
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0943	5.6166	-0.2335	-1.0936	0.2574	-1.1448
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0257	2.0133	-0.0626	-0.2923	0.0685	-0.2923
ULS: 5b. D + 0.7E	0.0257	2.0133	-0.0626	-0.2923	0.0685	-0.2923
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0943	5.6166	-0.2335	-1.0936	0.2574	-1.1448
ULS: 8. 0.6D + 0.7E	0.0154	1.2080	-0.0376	-0.1754	0.0411	-0.1754
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.3832	3.8940	-0.2445	-1.1288	0.5169	20.9961
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.3832	3.8940	-0.2445	-1.1288	0.5169	20.9961
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.2035	0.4332	0.0825	0.3720	-0.2882	-17.0885
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.0394	0.6803	0.0805	0.3628	-0.2874	-18.5899
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.9624	7.0271	-0.3700	-1.7211	0.5937	14.8215
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.9624	7.0271	-0.3700	-1.7211	0.5937	14.8215
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.9776	4.4315	-0.1247	-0.5955	-0.0101	-13.7419
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.8545	4.6168	-0.1262	-0.6023	-0.0095	-14.8680
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.0310	3.4238	-0.1990	-0.9197	0.4048	15.6740
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.0310	3.4238	-0.1990	-0.9197	0.4048	15.6740
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.9091	0.8282	0.0462	0.2059	-0.1990	-12.8894
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.7860	1.0136	0.0448	0.1990	-0.1984	-14.0155

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.3935	3.0887	-0.2195	-1.0119	0.4895	21.1130
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.3935	3.0887	-0.2195	-1.0119	0.4895	21.1130
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.1932	-0.3722	0.1075	0.4889	-0.3156	-16.9716
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.0291	-0.1250	0.1056	0.4797	-0.3148	-18.4730

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	11.6821
Shear X	-2.3483
Shear Z	-0.6101
Moment X	-2.8617
Moment Y (Twist)	0.9908
Moment Z	36.5098

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	7.0271
Shear X	-1.3935
Shear Z	-0.3700
Moment X	-1.7211
Moment Y (Twist)	0.5937
Moment Z	21.1130

Project Details

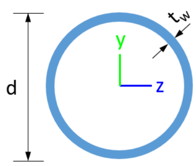
Design Code:	AISC 360-16 LRFD
Provision:	LRFD
Country:	United States
User Name:	sales@mtsolar.us
Project Name:	Sartori - V1Jb
Unit System:	imperial

Design Input Information

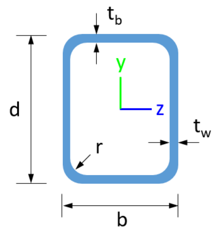
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

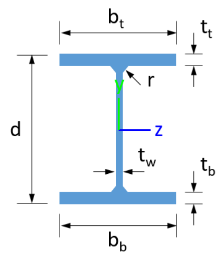
Section Dimensions



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					
8	6in Pipe Sch 80	6.63	0.43					



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
8	6in Pipe Sch 80	8.40	80.98	40.49	40.49	0.00	16.60	16.60
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	8	30.06	30.06	14.32	-	300	200	1
2	6	1.30	1.30	2.00	-	300	200	1
3	17	0.92	0.92	1.42	1.19,1.18,1.19,1.17,1.18,1.19,1.17,1.17,1.32,1.12,1.17,1.17,1.14,1.15,1.17,1.17,1.18,1.18,1.17,1.17,1.08,1.12,1.17,1.17,1.15,1.16	300	200	1
4	17	2.44	2.44	3.75	1.70,1.68,1.70,1.67,1.69,1.70,1.67,1.67,1.87,1.68,1.68,1.68,1.64,1.73,1.67,1.67,1.67,1.67,1.68,1.68,1.35,1.71,1.67,1.67,1.65,1.76	300	200	1
5	17	1.52	1.52	2.33	1.69,1.67,1.69,1.67,1.68,1.69,1.67,1.67,1.79,1.63,1.67,1.67,1.64,1.65,1.67,1.67,1.67,1.67,1.67,1.67,1.46,1.62,1.67,1.67,1.65,1.66	300	200	1
6	17	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.19,1.19,1.17,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.19,1.16,1.17,1.19,1.19,1.18,1.18	300	200	1
7	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.62,1.65,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.63,1.65,1.67,1.67,1.66,1.66	300	200	1
8	20	1.33	1.33	2.05	1.20,1.20,1.20,1.20,1.20,1.20,1.20,1.20,1.04,1.29,1.20,1.20,1.19,1.33,1.20,1.20,1.20,1.21,1.20,1.20,1.18,1.34,1.20,1.20,1.20,1.04	300	200	1
9	3	2.60	2.60	4.00	-	300	200	1
10	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.34,1.68,1.67,1.67,1.65,1.93,1.67,1.67,1.67,1.67,1.68,1.68,1.56,1.71,1.67,1.67,1.65,1.53	300	200	1
11	20	1.33	1.33	2.05	1.24,1.24,1.24,1.24,1.24,1.24,1.30,1.30,1.30,2.17,1.32,1.32,1.43,1.45,1.27,1.27,1.21,1.19,1.30,1.30,2.15,1.79,1.33,1.33,1.39,1.42	300	200	1
12	6	4.20	4.20	2.00	-	300	200	1
13	20	4.88	4.00	7.50	1.57,1.59,1.57,1.58,1.59,1.57,1.28,1.28,1.76,1.71,1.24,1.24,1.28,1.41,1.36,1.36,1.94,2.15,1.28,1.28,1.56,1.61,1.23,1.23,1.24,1.37	300	200	1
14	20	4.88	4.00	7.50	2.00,2.06,2.00,2.08,2.03,2.00,2.18,2.18,1.72,1.68,2.20,2.20,2.41,2.13,2.13,2.13,2.02,1.94,2.15,2.15,3.67,1.70,2.21,2.21,2.34,2.37	300	200	1
15	20	2.10	2.10	1.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33	300	200	1
16	20	2.10	2.10	1.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33	300	200	1
101	8	30.06	30.06	14.32	-	300	200	1
102	6	4.20	4.20	2.00	-	300	200	1
103	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.23,1.14,1.18,1.18,1.16,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.00,1.15,1.18,1.18,1.17,1.17	300	200	1
104	17	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.88,1.68,1.67,1.67,1.65,1.75,1.67,1.67,1.67,1.67,1.67,1.67,1.54,1.70,1.67,1.67,1.65,2.28	300	200	1
105	17	1.52	1.52	2.33	1.68,1.67,1.68,1.66,1.67,1.68,1.67,1.67,1.71,1.64,1.67,1.67,1.65,1.66,1.66,1.66,1.67,1.67,1.67,1.67,1.51,1.64,1.67,1.67,1.66,1.66	300	200	1
106	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.27,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.14,1.17,1.18,1.18,1.18,1.18	300	200	1
107	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,2.34,1.65,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.61,1.65,1.67,1.67,1.66,1.66	300	200	1
108	20	1.33	1.33	2.05	2.09,2.09,2.09,2.09,2.09,2.09,2.01,2.01,1.04,2.30,1.89,1.89,1.60,1.28,2.07,2.07,2.14,2.11,2.00,2.00,1.24,2.26,1.87,1.87,1.67,1.02	300	200	1
109	3	2.60	2.60	4.00	-	300	200	1
110	17	2.44	2.44	3.75	1.69,1.67,1.69,1.67,1.68,1.69,1.67,1.67,2.10,1.68,1.67,1.67,1.65,1.79,1.67,1.67,1.67,1.67,1.67,1.67,1.57,1.70,1.67,1.67,1.66,1.46	300	200	1
111	20	1.33	1.33	2.05	1.83,1.83,1.84,1.80,1.83,1.84,1.37,1.37,1.01,1.09,1.32,1.32,1.20,1.23,1.53,1.53,2.10,2.38,1.37,1.37,1.07,1.15,1.31,1.31,1.22,1.25	300	200	1
112	6	1.30	1.30	2.00	-	300	200	1

113	20	4.88	4.00	7.50	1.09,1.09,1.09,1.10,1.09,1.09,1.17,1.17,1.11,1.25,1.32,1.32,3.51,3.94,1.12,1.12,1.08,1.07,1.16,1.16,1.25,1.66,1.44,1.44,3.95,3.40	300	200	1
114	20	4.88	4.00	7.50	1.08,1.08,1.08,1.08,1.08,1.08,1.10,1.10,1.08,1.08,1.10,1.10,1.13,1.81,1.09,1.09,1.07,1.08,1.10,1.10,2.30,1.12,1.11,1.11,1.12,2.21	300	200	1
115	20	10.20	10.20	10.20	1.12,1.12,1.12,1.12,1.12,1.12,1.08,1.08,1.91,1.14,1.08,1.08,1.06,1.07,1.09,1.09,1.16,1.18,1.08,1.08,1.18,1.07,1.08,1.08,1.06,1.07	300	200	1
116	20	10.20	10.20	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.15,1.15,1.63,1.16,1.14,1.14,1.13,3.12,1.16,1.16,1.17,1.16,1.15,1.15,1.07,1.16,1.14,1.14,1.13,1.36	300	200	1
201	8	30.06	30.06	14.32	-	300	200	1
202	6	1.30	1.30	2.00	-	300	200	1
203	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.27,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.14,1.17,1.18,1.18,1.18,1.18	300	200	1
204	17	2.44	2.44	3.75	1.69,1.67,1.69,1.67,1.68,1.69,1.67,1.67,2.03,1.68,1.67,1.67,1.65,1.79,1.67,1.67,1.67,1.67,1.67,1.67,1.57,1.70,1.67,1.67,1.66,1.47	300	200	1
205	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,2.34,1.65,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.61,1.65,1.67,1.67,1.66,1.66	300	200	1
206	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.23,1.14,1.18,1.18,1.16,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.00,1.15,1.18,1.18,1.17,1.17	300	200	1
207	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.71,1.64,1.67,1.67,1.65,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.51,1.64,1.67,1.67,1.66,1.66	300	200	1
208	20	1.33	1.33	2.05	1.74,1.74,1.74,1.74,1.74,1.74,1.61,1.61,1.11,1.95,1.58,1.58,1.47,1.63,1.68,1.68,1.83,1.78,1.61,1.61,1.25,2.03,1.57,1.57,1.50,1.18	300	200	1
209	3	2.60	2.60	4.00	-	300	200	1
210	17	2.44	2.44	3.75	1.69,1.67,1.69,1.67,1.68,1.69,1.67,1.67,1.88,1.68,1.67,1.67,1.65,1.75,1.67,1.67,1.67,1.67,1.67,1.67,1.54,1.70,1.67,1.67,1.66,2.46	300	200	1
211	20	1.33	1.33	2.05	1.50,1.50,1.50,1.49,1.50,1.50,1.27,1.27,1.11,1.02,1.23,1.23,1.13,1.16,1.37,1.37,1.75,1.91,1.27,1.27,1.00,1.08,1.23,1.23,1.16,1.18	300	200	1
212	6	4.20	4.20	2.00	-	300	200	1
213	20	4.88	4.00	7.50	1.09,1.09,1.09,1.10,1.09,1.09,1.17,1.17,1.11,1.25,1.32,1.32,3.51,3.93,1.12,1.12,1.08,1.07,1.17,1.17,1.25,1.66,1.44,1.44,3.95,3.40	300	200	1
214	20	4.88	4.00	7.50	1.08,1.08,1.08,1.08,1.08,1.08,1.10,1.10,1.08,1.09,1.10,1.10,1.13,1.80,1.09,1.09,1.07,1.08,1.10,1.10,2.32,1.12,1.11,1.11,1.12,2.24	300	200	1
215	20	10.20	10.20	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.11,1.11,1.03,1.04,1.10,1.10,1.07,1.08,1.13,1.13,1.18,1.20,1.11,1.11,1.03,1.06,1.10,1.10,1.08,1.09	300	200	1
216	20	10.20	10.20	10.20	1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.16,1.12,1.22,1.15,1.15,1.13,2.60,1.17,1.17,1.19,1.18,1.16,1.16,1.08,1.24,1.15,1.15,1.14,1.01	300	200	1
301	8	30.06	30.06	14.32	-	300	200	1
302	6	4.20	4.20	2.00	-	300	200	1
303	17	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.19,1.19,1.17,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.19,1.16,1.17,1.19,1.19,1.18,1.18	300	200	1
304	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.34,1.68,1.67,1.67,1.65,1.93,1.67,1.67,1.67,1.67,1.68,1.68,1.56,1.71,1.67,1.67,1.65,1.53	300	200	1
305	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.62,1.65,1.67,1.67,1.65,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.62,1.65,1.67,1.67,1.66,1.66	300	200	1
306	17	0.92	0.92	1.42	1.19,1.18,1.19,1.17,1.18,1.19,1.17,1.17,1.32,1.12,1.17,1.17,1.14,1.15,1.17,1.17,1.18,1.18,1.17,1.17,1.08,1.12,1.17,1.17,1.15,1.16	300	200	1
307	17	1.52	1.52	2.33	1.69,1.67,1.69,1.67,1.68,1.69,1.67,1.67,1.78,1.63,1.67,1.67,1.64,1.65,1.67,1.67,1.67,1.67,1.67,1.67,1.46,1.62,1.67,1.67,1.65,1.66	300	200	1
308	20	2.10	2.10	1.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33	300	200	1
309	3	2.60	2.60	4.00	-	300	200	1
310	17	2.44	2.44	3.75	1.70,1.68,1.70,1.67,1.69,1.70,1.67,1.67,1.87,1.68,1.68,1.68,1.64,1.73,1.67,1.67,1.67,1.67,1.68,1.68,1.35,1.71,1.67,1.67,1.65,1.76	300	200	1
311	20	2.10	2.10	1.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33	300	200	1
312	6	1.30	1.30	2.00	-	300	200	1
313	20	4.88	4.00	7.50	1.59,1.61,1.59,1.60,1.60,1.59,1.28,1.28,1.76,1.71,1.24,1.24,1.28,1.41,1.36,1.36,1.96,2.17,1.28,1.28,1.56,1.60,1.24,1.24,1.24,1.37	300	200	1
314	20	4.88	4.00	7.5	2.02,2.08,2.02,2.10,2.05,2.02,2.21,2.21,1.72,1.69,2.22,2.22,2.44,2.14,2.15,2.15,2.04,1.96,2.18,2.18,3.7	30	20	1

314	20	4.88	4.00	0	5,1.71,2.24,2.24,2.37,2.38	0	0	1
315	20	10.20	10.20	10.20	1.08,1.08,1.08,1.08,1.08,1.08,1.09,1.09,2.22,1.38,1.10,1.10,1.14,1.13,1.07,1.07,1.08,1.08,1.09,1.09,1.44,1.22,1.10,1.10,1.13,1.13	300	200	1
316	20	10.20	10.20	10.20	1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.63,1.09,1.08,1.08,1.07,3.03,1.08,1.08,1.08,1.08,1.08,1.08,1.06,1.09,1.08,1.08,1.07,1.28	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	378.22	70.28	62.23	62.23	113.47	113.47
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	229.64	27.16	27.16	75.30	75.30
13	159.30	97.43	37.68	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	378.22	70.28	62.23	62.23	113.47	113.47
102	251.01	229.64	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	32.78	6.46	56.26	44.91
114	159.30	97.43	32.82	6.46	56.26	44.91
115	159.30	32.87	20.40	6.46	56.26	44.91
116	159.30	32.87	20.70	6.46	56.26	44.91
201	378.22	70.28	62.23	62.23	113.47	113.47
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	229.64	27.16	27.16	75.30	75.30
213	159.30	97.43	32.79	6.46	56.26	44.91
214	159.30	97.43	32.83	6.46	56.26	44.91
215	159.30	32.87	19.84	6.46	56.26	44.91
216	159.30	32.87	19.47	6.46	56.26	44.91
301	378.22	70.28	62.23	62.23	113.47	113.47
302	251.01	229.64	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	37.76	6.46	56.26	44.91
314	159.30	97.43	46.90	6.46	56.26	44.91
315	159.30	32.87	20.69	6.46	56.26	44.91
316	159.30	32.87	20.34	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	0.166	0.587	0.095	0.021	0.005	0.681	#13	0.822	Not Required	Pass
2	0.002	0.215	0.071	0.054	0.014	0.272	#21	0.036	Not Required	Pass
3	0.006	0.359	0.027	0.034	0.006	0.377	#21	0.046	Not Required	Pass
4	0.005	0.356	0.065	0.036	0.015	0.423	#21	0.082	Not Required	Pass
5	0.005	0.222	0.032	0.035	0.009	0.229	#21	0.076	Not Required	Pass
6	0.013	0.567	0.128	0.058	0.038	0.701	#21	0.046	Not Required	Pass
7	0.014	0.352	0.214	0.056	0.053	0.394	#21	0.076	Not Required	Pass
8	0.006	0.133	0.219	0.031	0.026	0.270	#24	0.102	Not Required	Pass
9	0.007	0.049	0.092	0.003	0.006	0.129	#21	0.206	Not Required	Pass
10	0.014	0.518	0.198	0.051	0.043	0.621	#21	0.082	Not Required	Pass
11	0.009	0.124	0.230	0.035	0.026	0.276	#24	0.102	Not Required	Pass
12	0.001	0.433	0.108	0.095	0.020	0.523	#21	0.174	Not Required	Pass
13	0.013	0.054	0.592	0.046	0.033	0.601	#23	0.306	Not Required	Pass
14	0.006	0.072	0.576	0.042	0.033	0.588	#24	0.204	Not Required	Pass
15	0.000	0.004	0.015	0.006	0.004	0.018	#21	Not Required	Not Required	Pass
16	0.000	0.004	0.015	0.006	0.004	0.018	#21	Not Required	Not Required	Pass
101	0.234	0.762	0.013	0.027	0.001	0.847	#13	0.822	Not Required	Pass
102	0.005	0.457	0.122	0.105	0.018	0.574	#21	0.174	Not Required	Pass
103	0.013	0.630	0.081	0.062	0.011	0.718	#21	0.046	Not Required	Pass
104	0.013	0.654	0.243	0.065	0.053	0.821	#21	0.082	Not Required	Pass
105	0.013	0.391	0.251	0.061	0.064	0.454	#21	0.076	Not Required	Pass
106	0.013	0.666	0.077	0.066	0.010	0.740	#21	0.046	Not Required	Pass
107	0.013	0.414	0.221	0.065	0.058	0.477	#21	0.076	Not Required	Pass
108	0.006	0.048	0.223	0.037	0.026	0.251	#21	0.102	Not Required	Pass
109	0.023	0.053	0.055	0.002	0.001	0.107	#21	0.206	Not Required	Pass
110	[illegible]	0.662	0.208	0.066	0.046	0.802	#21	0.082	Not Required	Pass

110	0.012	0.662	0.208	0.066	0.046	0.802	#21	0.082	Not Required	Pass
111	0.009	0.079	0.233	0.037	0.026	0.261	#24	0.102	Not Required	Pass
112	0.005	0.477	0.132	0.107	0.023	0.601	#21	0.036	Not Required	Pass
113	0.013	0.135	0.681	0.049	0.035	0.774	#21	0.306	Not Required	Pass
114	0.011	0.191	0.672	0.053	0.035	0.825	#21	0.306	Not Required	Pass
115	0.039	0.376	0.321	0.039	0.027	0.718	#21	0.780	Not Required	Pass
116	0.011	0.355	0.313	0.042	0.027	0.670	#21	0.780	Not Required	Pass
201	0.234	0.762	0.013	0.027	0.001	0.847	#13	0.822	Not Required	Pass
202	0.005	0.477	0.132	0.107	0.023	0.601	#21	0.036	Not Required	Pass
203	0.013	0.666	0.077	0.066	0.010	0.740	#21	0.046	Not Required	Pass
204	0.012	0.662	0.208	0.066	0.045	0.802	#21	0.082	Not Required	Pass
205	0.013	0.415	0.221	0.065	0.058	0.477	#21	0.076	Not Required	Pass
206	0.013	0.630	0.081	0.062	0.011	0.718	#21	0.046	Not Required	Pass
207	0.013	0.391	0.251	0.061	0.064	0.454	#21	0.076	Not Required	Pass
208	0.006	0.081	0.293	0.042	0.028	0.302	#21	0.102	Not Required	Pass
209	0.023	0.053	0.055	0.002	0.001	0.108	#21	0.206	Not Required	Pass
210	0.013	0.653	0.244	0.065	0.053	0.821	#21	0.082	Not Required	Pass
211	0.009	0.108	0.301	0.039	0.027	0.334	#21	0.102	Not Required	Pass
212	0.005	0.457	0.122	0.105	0.018	0.573	#21	0.174	Not Required	Pass
213	0.013	0.135	0.682	0.049	0.035	0.774	#21	0.306	Not Required	Pass
214	0.011	0.191	0.672	0.053	0.035	0.824	#21	0.306	Not Required	Pass
215	0.039	0.296	0.328	0.037	0.026	0.641	#21	0.780	Not Required	Pass
216	0.019	0.223	0.324	0.037	0.026	0.549	#21	0.780	Not Required	Pass
301	0.166	0.587	0.094	0.021	0.005	0.681	#13	0.822	Not Required	Pass
302	0.001	0.432	0.108	0.095	0.020	0.522	#21	0.174	Not Required	Pass
303	0.013	0.567	0.128	0.058	0.038	0.700	#21	0.046	Not Required	Pass
304	0.014	0.517	0.198	0.051	0.043	0.621	#21	0.082	Not Required	Pass
305	0.014	0.352	0.214	0.055	0.053	0.394	#21	0.076	Not Required	Pass
306	0.006	0.360	0.027	0.034	0.006	0.377	#21	0.046	Not Required	Pass
307	0.005	0.223	0.032	0.035	0.009	0.230	#21	0.076	Not Required	Pass
308	0.000	0.004	0.015	0.006	0.004	0.018	#21	Not Required	Not Required	Pass
309	0.007	0.049	0.092	0.003	0.006	0.129	#21	0.206	Not Required	Pass
310	0.005	0.357	0.065	0.036	0.015	0.424	#21	0.082	Not Required	Pass
311	0.000	0.004	0.015	0.006	0.004	0.018	#21	Not Required	Not Required	Pass
312	0.002	0.216	0.071	0.054	0.014	0.273	#21	0.036	Not Required	Pass
313	0.013	0.054	0.591	0.046	0.033	0.601	#23	0.204	Not Required	Pass
314	0.006	0.072	0.576	0.042	0.033	0.587	#24	0.306	Not Required	Pass
315	0.039	0.394	0.321	0.035	0.026	0.726	#21	0.780	Not Required	Pass
316	0.011	0.382	0.313	0.031	0.026	0.697	#21	0.780	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

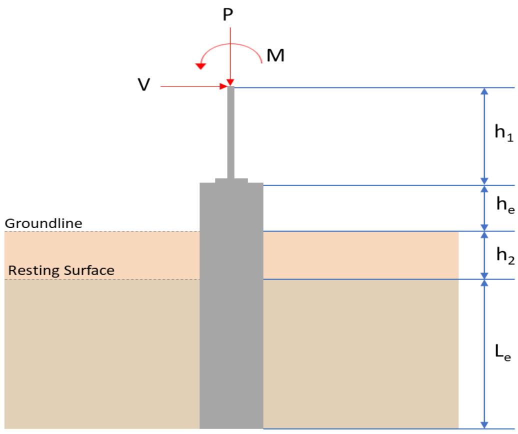
SkyCiv Foundation Design

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
$L = 6\ \mathrm{ft}$ - 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) $(\mathrm{psf/ft})$
1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	7.028	11.683
V_x (kip)	-1.394	-2.349
V_z (kip)	0.372	0.613
M_x (kipft)	1.721	2.859
M_z (kipft)	21.116	36.515

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,

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

$$H_o = \frac{(-1.394\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.22197\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(21.116\ \text{kipft}) + ((-1.394\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 3.3624\ \text{kipft/ft}$$

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:
$L_{e,x} = 5.7704\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.372\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.059236\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.721\ \text{kipft}) + ((0.372\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.27404\ \text{kipft/ft}$$

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:
$L_{e,z} = 3.2194\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(5.7704\ \text{ft}), (3.2194\ \text{ft})]$$

$$L_{e,req} = 5.77\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 6\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(5.77\ \text{ft})}{(6\ \text{ft})}$$

$$Ratio = 0.96167$$

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

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

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

$$q = \frac{(7.028\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.43925\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.43925\ \text{kip/ft}^2\right)}{(2000\ \text{psf})}$$

$$Ratio = 0.21962$$

Status: **PASS**
Ratio: **0.220**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(6\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 1.5$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.22197\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 3.3624\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (3.3624\ \text{kipft/ft}) \times (6\ \text{ft})) + \left(3 \times (-0.22197\ \text{kip/ft}) \times (6\ \text{ft})^2\right)}{(6 \times (3.3624\ \text{kipft/ft})) + (4 \times (-0.22197\ \text{kip/ft}) \times (6\ \text{ft}))}$$

$$a = 4.1045\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (3.3624\ \text{kipft/ft})) + (3 \times (-0.22197\ \text{kip/ft}) \times (6\ \text{ft}))]^2}{(6\ \text{ft})^2 \times [(3 \times (3.3624\ \text{kipft/ft})) + (2 \times (-0.22197\ \text{kip/ft}) \times (6\ \text{ft}))]}$$

$$p = 0.25084\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (3.3624\ \text{kipft/ft})) + ((-0.22197\ \text{kip/ft}) \times (6\ \text{ft}))]}{(6\ \text{ft})^2}$$

$$s = 0.89883\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(4.1045\ \text{ft})}{2}$$

$$p_a = 0.30783\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.25084\ \mathrm{kip/ft^2}\right)}{\left(0.30783\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.81484$$

Status: **PASS**
Ratio: **0.810**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6\ \mathrm{ft})$$

$$p_s = 0.9\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.89883\ \mathrm{kip/ft^2}\right)}{\left(0.9\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.9987$$

Status: **PASS**
Ratio: **1.000**

Considering z-direction:

$H_o = 0.059236\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.27404\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.27404\ \mathrm{kipft/ft}) \times (6\ \mathrm{ft})) + \left(3 \times (0.059236\ \mathrm{kip/ft}) \times (6\ \mathrm{ft})^2\right)}{(6 \times (0.27404\ \mathrm{kipft/ft})) + (4 \times (0.059236\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))}$$

$$a = 4.2318\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.27404\ \mathrm{kipft/ft})) + (3 \times (0.059236\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))]^{\ 2}}{(6\ \mathrm{ft})^2 \times [(3 \times (0.27404\ \mathrm{kipft/ft})) + (2 \times (0.059236\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))]}$$

$$p = 0.063549\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.27404\ \mathrm{kipft/ft})) + ((0.059236\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))]}{(6\ \mathrm{ft})^2}$$

$$s = 0.15058\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.2318\ \mathrm{ft})}{2}$$

$$p_a = 0.31739\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.063549\ \mathrm{kip/ft^2}\right)}{\left(0.31739\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.20022$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6\ \mathrm{ft})$$

$$p_s = 0.9\ \mathrm{kip/ft^2}$$

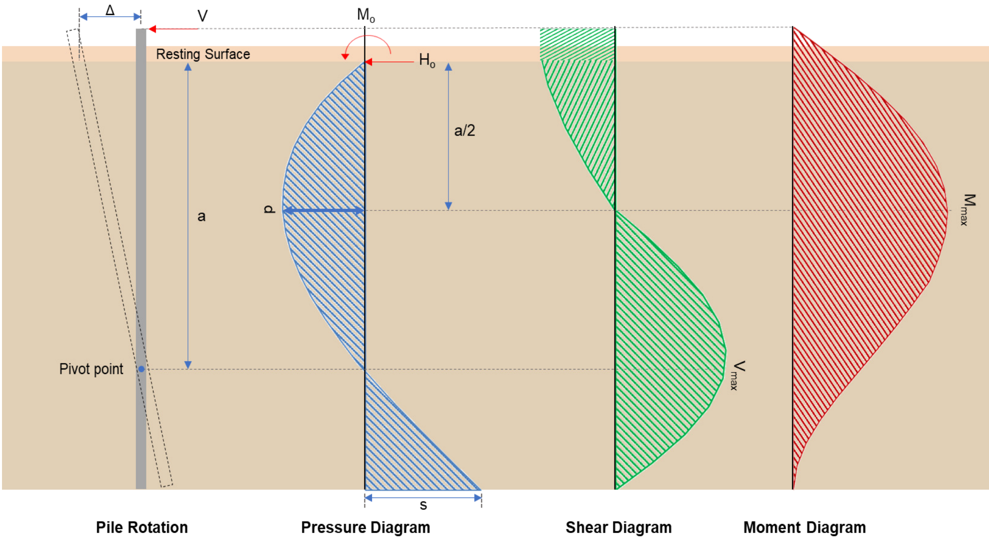
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.15058\ \mathrm{kip/ft^2})}{(0.9\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.16732$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.349\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.37404\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(36.515\ \mathrm{kipft}) + ((-2.349\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 5.8145\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(5.8145\ \mathrm{kipft/ft})}{(-0.37404\ \mathrm{kip/ft})}$$

$$E = 15.545\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.8145\ \mathrm{kipft/ft}) \times (6\ \mathrm{ft})) + \left(3 \times (-0.37404\ \mathrm{kip/ft}) \times (6\ \mathrm{ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (5.8145\ \mathrm{kipft/ft})) + (4 \times (-0.37404\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))}$$

$$a = 4.1023\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.37404\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (15.545\ \mathrm{ft})}{(6\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.1023\ \mathrm{ft})}{(6\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (15.545\ \mathrm{ft})}{(6\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.1023\ \mathrm{ft})}{(6\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 7.8504\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.37404\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (6\ \mathrm{ft})) \times \left[\left(\frac{(15.545\ \mathrm{ft})}{(6\ \mathrm{ft})} + \frac{(4.1023\ \mathrm{ft})}{2 \times (6\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (15.545\ \mathrm{ft})}{(6\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.1023\ \mathrm{ft})}{2 \times (6\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (15.545\ \mathrm{ft})}{(6\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.1023\ \mathrm{ft})}{2 \times (6\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 22.732\ \mathrm{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.613\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = 0.097611\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(2.859\ \mathrm{kipft}) + ((0.613\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.45525\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.45525\ \mathrm{kipft/ft})}{(0.097611\ \mathrm{kip/ft})}$$

$$E = 4.6639\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.45525\ \mathrm{kipft/ft}) \times (6\ \mathrm{ft})) + \left(3 \times (0.097611\ \mathrm{kip/ft}) \times (6\ \mathrm{ft})^2\right)}{(6 \times (0.45525\ \mathrm{kipft/ft})) + (4 \times (0.097611\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))}$$

$$a = 4.2308\ \mathrm{ft}$$

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

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

$$V_{max} = ((0.097611\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.6639\ \text{ft})}{(6\ \text{ft})} + 3\right) \times \left(\frac{(4.2308\ \text{ft})}{(6\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (4.6639\ \text{ft})}{(6\ \text{ft})} + 2\right) \times \left(\frac{(4.2308\ \text{ft})}{(6\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.7956\ \text{kip}$$

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

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

$$M_{max} = ((0.097611\ \text{kip/ft}) \times (48\ \text{in}) \times (6\ \text{ft})) \times \left[\left(\frac{(4.6639\ \text{ft})}{(6\ \text{ft})} + \frac{(4.2308\ \text{ft})}{2 \times (6\ \text{ft})}\right) - \left[\left(\frac{4 \times (4.6639\ \text{ft})}{(6\ \text{ft})} + 3\right) \times \left(\frac{(4.2308\ \text{ft})}{2 \times (6\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (4.6639\ \text{ft})}{(6\ \text{ft})} + 2\right) \times \left(\frac{(4.2308\ \text{ft})}{2 \times (6\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 2.1765\ \text{kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(11.683\ \text{kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.208\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.208\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

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 25.7.2.1	Since longitudinal reinforcement is $\leq$ No. 10ø: Use #3(0.375 in) 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**	
22.4.2.2	**Axial Compression Strength (ACI 318-19, LRFD)** 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 $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(11.683\ \text{kip})}{(2675.2\ \text{kip})}$$ $$Ratio = 0.0043672$$	Status: **PASS** Ratio: **0.000**
22.5.2.2 22.5.5.1.3 22.5.5.1.1	**Shear Strength (ACI 318-19, LRFD)** **Parameters:** $b_w = 48\ \text{in}$ - Effective width, d - Effective depth $$d = 0.80\ D$$ $$d = 0.80 \times (48\ \text{in})$$ $$d = 38.4\ \text{in}$$ 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 $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $V_{c,max}$ - 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 $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,$P = 11.683 \text{ kip} \rightarrow 11683 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(11683 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.04 \text{ kip}$$

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

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.04 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.04 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((120.04 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.11 \text{ kip}$$

Considering x-direction:

$V_{max} = 7.8504 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(7.8504 \text{ kip})}{(111.11 \text{ kip})}$$

$$Ratio = 0.070655$$

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

Considering z-direction:

$V_{max} = 0.7956 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.7956 \text{ kip})}{(111.11 \text{ kip})}$$

$$Ratio = 0.0071606$$

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:
$\phi M_{n,1}$

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

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

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

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

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

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

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

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:

$M_{max} = 22.732 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(22.732 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.091075$$

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

Considering z-direction:

$M_{max} = 2.1765 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(2.1765\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.0087201$$	Status: **PASS** Ratio: **0.010**

REFERENCES	CALCULATIONS	RESULTS

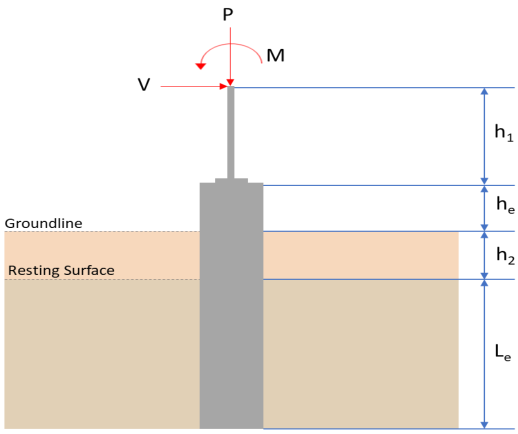
SkyCiv Foundation Design

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
$L = 6\ \mathrm{ft}$ - 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)	7.027	11.682
V_x (kip)	-1.394	-2.348
V_z (kip)	-0.370	-0.610
M_x (kipft)	-1.721	-2.862
M_z (kipft)	21.113	36.510

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,

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

$$H_o = \frac{(-1.394\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.22197\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(21.113\ \mathrm{kipft}) + ((-1.394\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 3.3619\ \mathrm{kipft/ft}$$

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:
$L_{e,x} = 5.7701\ \mathrm{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.37\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.058917\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.721\ \mathrm{kipft}) + ((-0.37\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.27404\ \mathrm{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 2.3814\ \mathrm{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(5.7701\ \mathrm{ft}), (2.3814\ \mathrm{ft})]$$

$$L_{e,req} = 5.77\ \mathrm{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6\ \mathrm{ft}) - (0\ \mathrm{ft}) - (0\ \mathrm{ft})$$

$$L_e = 6\ \mathrm{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(5.77\ \mathrm{ft})}{(6\ \mathrm{ft})}$$

$$Ratio = 0.96167$$

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

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

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

$$q = \frac{(7.027 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.43919 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.43919 \text{ kip/ft}^2\right)}{(2000 \text{ psf})}$$

$$Ratio = 0.21959$$

Status: **PASS**
Ratio: **0.220**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(6 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.5$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.22197 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 3.3619 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (3.3619 \text{ kipft/ft}) \times (6 \text{ ft})) + \left(3 \times (-0.22197 \text{ kip/ft}) \times (6 \text{ ft})^2\right)}{(6 \times (3.3619 \text{ kipft/ft})) + (4 \times (-0.22197 \text{ kip/ft}) \times (6 \text{ ft}))}$$

$$a = 4.1045 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (3.3619 \text{ kipft/ft})) + (3 \times (-0.22197 \text{ kip/ft}) \times (6 \text{ ft}))]^{\,2}}{(6 \text{ ft})^2 \times [(3 \times (3.3619 \text{ kipft/ft})) + (2 \times (-0.22197 \text{ kip/ft}) \times (6 \text{ ft}))]}$$

$$p = 0.25078 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (3.3619 \text{ kipft/ft})) + ((-0.22197 \text{ kip/ft}) \times (6 \text{ ft}))]}{(6 \text{ ft})^2}$$

$$s = 0.89867 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.1045 \text{ ft})}{2}$$

$$p_a = 0.30783 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.25078\ \mathrm{kip/ft^2}\right)}{\left(0.30783\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.81467$$

Status: **PASS**
Ratio: **0.810**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6\ \mathrm{ft})$$

$$p_s = 0.9\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.89867\ \mathrm{kip/ft^2}\right)}{\left(0.9\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.99853$$

Status: **PASS**
Ratio: **1.000**

Considering z-direction:

$H_o = -0.058917\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.27404\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.27404\ \mathrm{kipft/ft}) \times (6\ \mathrm{ft})) + \left(3 \times (-0.058917\ \mathrm{kip/ft}) \times (6\ \mathrm{ft})^2\right)}{(6 \times (0.27404\ \mathrm{kipft/ft})) + (4 \times (-0.058917\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))}$$

$$a = 4.2312\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.27404\ \mathrm{kipft/ft})) + (3 \times (-0.058917\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))]^{\ 2}}{(6\ \mathrm{ft})^2 \times [(3 \times (0.27404\ \mathrm{kipft/ft})) + (2 \times (-0.058917\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))]}$$

$$p = 0.00023023\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.27404\ \mathrm{kipft/ft})) + ((-0.058917\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))]}{(6\ \mathrm{ft})^2}$$

$$s = 0.032431\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.2312\ \mathrm{ft})}{2}$$

$$p_a = 0.31734\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.00023023\ \mathrm{kip/ft^2}\right)}{\left(0.31734\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.00072549$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6\ \mathrm{ft})$$

$$p_s = 0.9\ \mathrm{kip/ft^2}$$

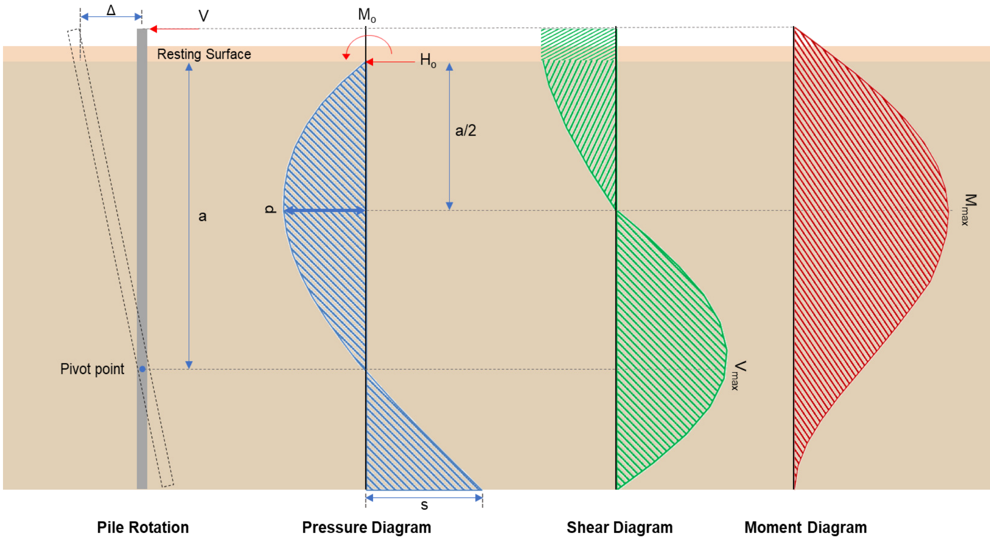
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.032431\ \mathrm{kip/ft^2})}{(0.9\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.036034$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.348\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.37389\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(36.51\ \mathrm{kipft}) + ((-2.348\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 5.8137\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(5.8137\ \mathrm{kipft/ft})}{(-0.37389\ \mathrm{kip/ft})}$$

$$E = 15.549\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.8137\ \mathrm{kipft/ft}) \times (6\ \mathrm{ft})) + \left(3 \times (-0.37389\ \mathrm{kip/ft}) \times (6\ \mathrm{ft})^2\right)}{\ldots}$$

$$a = \frac{}{(6 \times (5.8137\ \mathrm{kipft/ft})) + (4 \times (-0.37389\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))}$$

$$a = 4.1023\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.37389\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (15.549\ \mathrm{ft})}{(6\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.1023\ \mathrm{ft})}{(6\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (15.549\ \mathrm{ft})}{(6\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.1023\ \mathrm{ft})}{(6\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 7.8491\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.37389\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (6\ \mathrm{ft})) \times \left[\left(\frac{(15.549\ \mathrm{ft})}{(6\ \mathrm{ft})} + \frac{(4.1023\ \mathrm{ft})}{2 \times (6\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (15.549\ \mathrm{ft})}{(6\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.1023\ \mathrm{ft})}{2 \times (6\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (15.549\ \mathrm{ft})}{(6\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.1023\ \mathrm{ft})}{2 \times (6\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 22.728\ \mathrm{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.61\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.097134\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(2.862\ \mathrm{kipft}) + ((-0.61\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.45573\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.45573\ \mathrm{kipft/ft})}{(-0.097134\ \mathrm{kip/ft})}$$

$$E = 4.6918\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.45573\ \mathrm{kipft/ft}) \times (6\ \mathrm{ft})) + \left(3 \times (-0.097134\ \mathrm{kip/ft}) \times (6\ \mathrm{ft})^2\right)}{(6 \times (0.45573\ \mathrm{kipft/ft})) + (4 \times (-0.097134\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))}$$

$$a = 4.2301\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.097134\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.6918\ \text{ft})}{(6\ \text{ft})} + 3\right) \times \left(\frac{(4.2301\ \text{ft})}{(6\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (4.6918\ \text{ft})}{(6\ \text{ft})} + 2\right) \times \left(\frac{(4.2301\ \text{ft})}{(6\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.79488\ \text{kip}$$

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

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

$$M_{max} = ((-0.097134\ \text{kip/ft}) \times (48\ \text{in}) \times (6\ \text{ft})) \times \left[\left(\frac{(4.6918\ \text{ft})}{(6\ \text{ft})} + \frac{(4.2301\ \text{ft})}{2 \times (6\ \text{ft})}\right) - \left[\left(\frac{4 \times (4.6918\ \text{ft})}{(6\ \text{ft})} + 3\right) \times \left(\frac{(4.2301\ \text{ft})}{2 \times (6\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (4.6918\ \text{ft})}{(6\ \text{ft})} + 2\right) \times \left(\frac{(4.2301\ \text{ft})}{2 \times (6\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 2.1754\ \text{kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(11.682\ \text{kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.208\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.208\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

Status: PASS
Ratio: 0.970

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(11.682\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0043668$$

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 $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 11.682 \text{ kip} \rightarrow 11682 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(11682 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.04 \text{ kip}$$

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

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.04 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.04 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((120.04 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.11 \text{ kip}$$

Considering x-direction:

$V_{max} = 7.8491 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(7.8491 \text{ kip})}{(111.11 \text{ kip})}$$ $$Ratio = 0.070643$$	Status: **PASS** Ratio: **0.070**
	Considering z-direction: $V_{max} = 0.79488 \text{ kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.79488 \text{ kip})}{(111.11 \text{ kip})}$$ $$Ratio = 0.0071541$$	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: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 ksi)} \times 18432.001 in^3$$ $$\phi M_{n,1} = 249.600 kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6 \text{ kipft}$$ 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:** $M_{max} = 22.728 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(22.728 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.09106$$	Status: **PASS** Ratio: **0.090**
	Considering z-direction: $M_{max} = 2.1754 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(2.1754\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$ $$Ratio = 0.0087155$$	Status: **PASS** Ratio: **0.010**

REFERENCES	CALCULATIONS	RESULTS

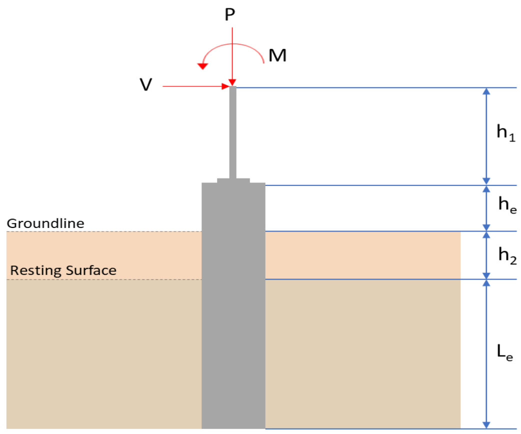
SkyCiv Foundation Design

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)	9.823	16.454
V_x (kip)	-1.813	-3.037
V_z (kip)	0.043	0.082
M_x (kipft)	0.193	0.369
M_z (kipft)	26.712	47.447

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,

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

$$H_o = \frac{(-1.813\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.28869\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(26.712\ \text{kipft}) + ((-1.813\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 4.2535\ \text{kipft/ft}$$

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:
$L_{e,x} = 6.1587\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.043\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.0068471\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.193\ \text{kipft}) + ((0.043\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.030732\ \text{kipft/ft}$$

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:
$L_{e,z} = 1.451\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.1587\ \text{ft}), (1.451\ \text{ft})]$$

$$L_{e,req} = 6.159\ \text{ft}$$

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

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

$$Ratio = \frac{(6.159\ \text{ft})}{(6.5\ \text{ft})}$$

$$Ratio = 0.94754$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\ D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(9.823\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.61394\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.61394\ \text{kip/ft}^2\right)}{(2000\ \text{psf})}$$

$$Ratio = 0.30697$$

Status: **PASS**
Ratio: **0.310**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

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

$$L/D = 1.625$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.28869\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 4.2535\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.2535\ \text{kipft/ft}) \times (6.5\ \text{ft})) + \left(3 \times (-0.28869\ \text{kip/ft}) \times (6.5\ \text{ft})^2\right)}{(6 \times (4.2535\ \text{kipft/ft})) + (4 \times (-0.28869\ \text{kip/ft}) \times (6.5\ \text{ft}))}$$

$$a = 4.4564\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (4.2535\ \text{kipft/ft})) + (3 \times (-0.28869\ \text{kip/ft}) \times (6.5\ \text{ft}))]^{\,2}}{(6.5\ \text{ft})^2 \times [(3 \times (4.2535\ \text{kipft/ft})) + (2 \times (-0.28869\ \text{kip/ft}) \times (6.5\ \text{ft}))]}$$

$$p = 0.25542\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (4.2535\ \text{kipft/ft})) + ((-0.28869\ \text{kip/ft}) \times (6.5\ \text{ft}))]}{(6.5\ \text{ft})^2}$$

$$s = 0.94161\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(4.4564\ \text{ft})}{2}$$

$$p_a = 0.33423\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

	$$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.25542 \text{ kip/ft}^2\right)}{\left(0.33423 \text{ kip/ft}^2\right)}$$ $$Ratio = 0.7642$$	Status: **PASS** Ratio: **0.760**
	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 $$Ratio = \frac{s}{p_s}$$ $$Ratio = \frac{\left(0.94161 \text{ kip/ft}^2\right)}{\left(0.975 \text{ kip/ft}^2\right)}$$ $$Ratio = 0.96575$$	Status: **PASS** Ratio: **0.970**
	Considering z-direction: $H_o = 0.0068471 \text{ kip/ft}$ - Lateral force per length of pile, $M_o = 0.030732 \text{ kipft/ft}$ - Overturning moment per length of pile, a - Distance from resting surface to pivot point, $$a = \frac{(4\, M_o\, L_e) + \left(3\, H_o\, L_e^2\right)}{(6\, M_o) + (4\, H_o\, L_e)}$$ $$a = \frac{(4 \times (0.030732 \text{ kipft/ft}) \times (6.5 \text{ ft})) + \left(3 \times (0.0068471 \text{ kip/ft}) \times (6.5 \text{ ft})^2\right)}{(6 \times (0.030732 \text{ kipft/ft})) + (4 \times (0.0068471 \text{ kip/ft}) \times (6.5 \text{ ft}))}$$ $$a = 4.5994 \text{ ft}$$ p - Earth pressure against the pile at distance a/2 from resting surface, $$p = \frac{0.75\, [(4\, M_o) + (3\, H_o\, L_e)]^2}{L_e^2\, [(3\, M_o) + (2\, H_o\, L_e)]}$$ $$p = \frac{0.75 \times [(4 \times (0.030732 \text{ kipft/ft})) + (3 \times (0.0068471 \text{ kip/ft}) \times (6.5 \text{ ft}))]^{\ 2}}{(6.5 \text{ ft})^2 \times [(3 \times (0.030732 \text{ kipft/ft})) + (2 \times (0.0068471 \text{ kip/ft}) \times (6.5 \text{ ft}))]}$$ $$p = 0.0064425 \text{ kip/ft}^2$$ s - Earth pressure against the pile at distance L_e, $$s = \frac{6\, [(2\, M_o) + (H_o\, L_e)]}{L_e^2}$$ $$s = \frac{6 \times [(2 \times (0.030732 \text{ kipft/ft})) + ((0.0068471 \text{ kip/ft}) \times (6.5 \text{ ft}))]}{(6.5 \text{ ft})^2}$$ $$s = 0.015049 \text{ kip/ft}^2$$ **Check lateral soil pressure capacity:** p_a - Allowable lateral soil pressure at depth a/2, $$p_a = R\, \frac{a}{2}$$ $$p_a = (150 \text{ psf/ft}) \times \frac{(4.5994 \text{ ft})}{2}$$ $$p_a = 0.34496 \text{ kip/ft}^2$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.0064425 \text{ kip/ft}^2\right)}{\left(0.34496 \text{ kip/ft}^2\right)}$$	

$$Ratio = 0.018676$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

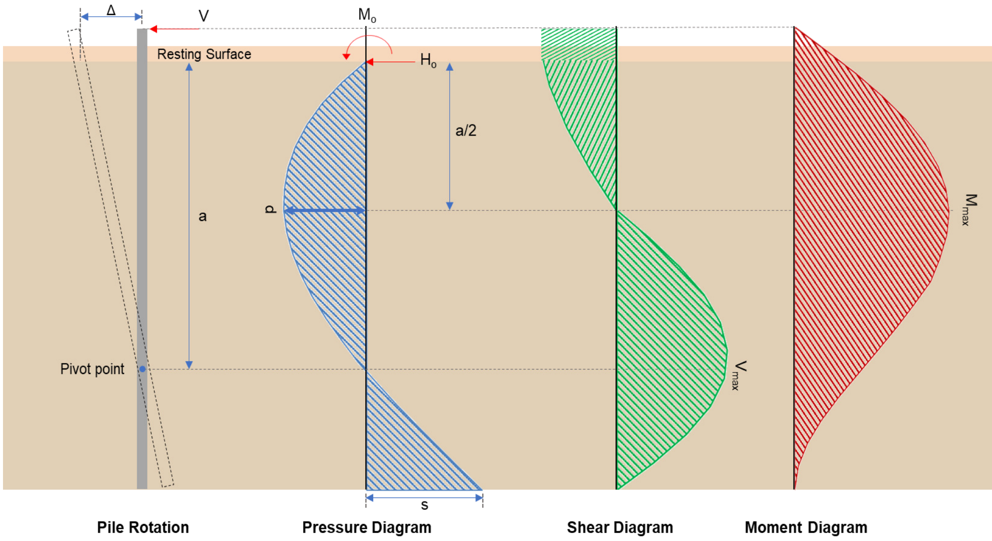
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.015049\ \mathrm{kip/ft^2})}{(0.975\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.015435$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.037\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.4836\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(47.447\ \mathrm{kipft}) + ((-3.037\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 7.5553\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(7.5553\ \mathrm{kipft/ft})}{(-0.4836\ \mathrm{kip/ft})}$$

$$E = 15.623\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.5553\ \mathrm{kipft/ft}) \times (6.5\ \mathrm{ft})) + \left(3 \times (-0.4836\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (7.5553\ \mathrm{kipft/ft})) + (4 \times (-0.4836\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))}$$

$$a = 4.451\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.4836\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (15.623\ \mathrm{ft})}{(6.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.451\ \mathrm{ft})}{(6.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (15.623\ \mathrm{ft})}{(6.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.451\ \mathrm{ft})}{(6.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 9.5071\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.4836\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (6.5\ \mathrm{ft})) \times \left[\left(\frac{(15.623\ \mathrm{ft})}{(6.5\ \mathrm{ft})} + \frac{(4.451\ \mathrm{ft})}{2 \times (6.5\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (15.623\ \mathrm{ft})}{(6.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.451\ \mathrm{ft})}{2 \times (6.5\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (15.623\ \mathrm{ft})}{(6.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.451\ \mathrm{ft})}{2 \times (6.5\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 29.752\ \mathrm{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.082\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = 0.013057\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.369\ \mathrm{kipft}) + ((0.082\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.058758\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.058758\ \mathrm{kipft/ft})}{(0.013057\ \mathrm{kip/ft})}$$

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

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.058758\ \mathrm{kipft/ft}) \times (6.5\ \mathrm{ft})) + \left(3 \times (0.013057\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft})^2\right)}{(6 \times (0.058758\ \mathrm{kipft/ft})) + (4 \times (0.013057\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))}$$

$$a = 4.5991\ \mathrm{ft}$$

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

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

$$V_{max} = ((0.013057\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.5\ \text{ft})}{(6.5\ \text{ft})} + 3\right) \times \left(\frac{(4.5991\ \text{ft})}{(6.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (4.5\ \text{ft})}{(6.5\ \text{ft})} + 2\right) \times \left(\frac{(4.5991\ \text{ft})}{(6.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.09862\ \text{kip}$$

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

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

$$M_{max} = ((0.013057\ \text{kip/ft}) \times (48\ \text{in}) \times (6.5\ \text{ft})) \times \left[\left(\frac{(4.5\ \text{ft})}{(6.5\ \text{ft})} + \frac{(4.5991\ \text{ft})}{2 \times (6.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (4.5\ \text{ft})}{(6.5\ \text{ft})} + 3\right) \times \left(\frac{(4.5991\ \text{ft})}{2 \times (6.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (4.5\ \text{ft})}{(6.5\ \text{ft})} + 2\right) \times \left(\frac{(4.5991\ \text{ft})}{2 \times (6.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.29009\ \text{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(16.454\ \text{kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5\ \text{ksi}) \times \left(2304\ \text{in}^2\right)\right)}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, \left(0.08 \times \left(2304\ \text{in}^2\right)\right)\right]$$

$$A_{st,required} = -84.049\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.049\ \text{in}^2\right), \left(0.0018 \times \left(2304\ \text{in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

Status: PASS
Ratio: 0.970

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(16.454 \text{ kip})}{(2675.2 \text{ kip})}$$

$$Ratio = 0.0061506$$

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 $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 16.454 \text{ kip} \rightarrow 16454 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(16454 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.68 \text{ kip}$$

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

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.68 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.68 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((120.68 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.52 \text{ kip}$$

Considering x-direction:

$V_{max} = 9.5071 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(9.5071 \text{ kip})}{(111.52 \text{ kip})}$$ $$Ratio = 0.085248$$	Status: **PASS** Ratio: **0.090**
	Considering z-direction: $V_{max} = 0.09862 \text{ kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.09862 \text{ kip})}{(111.52 \text{ kip})}$$ $$Ratio = 0.0008843$$	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: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 ksi)} \times 18432.001 in^3$$ $$\phi M_{n,1} = 249.600 kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6 \text{ kipft}$$ 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:** $M_{max} = 29.752 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(29.752 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.1192$$	Status: **PASS** Ratio: **0.120**
	Considering z-direction: $M_{max} = 0.29009 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(0.29009 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.0011622$$		Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

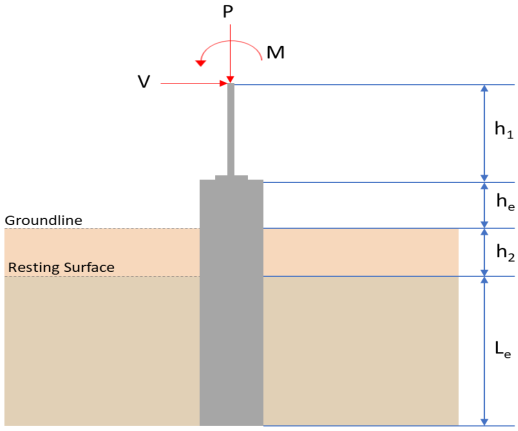
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \text{in}$ - Pile width
$D = 48\ \text{in}$ - Pile depth
$L = 6.5\ \text{ft}$ - 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)	9.823	16.455
V_x (kip)	-1.813	-3.037
V_z (kip)	-0.044	-0.084
M_x (kipft)	-0.204	-0.392
M_z (kipft)	26.712	47.448

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,

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

$$H_o = \frac{(-1.813\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.28869\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(26.712\ \mathrm{kipft}) + ((-1.813\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 4.2535\ \mathrm{kipft/ft}$$

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:
$L_{e,x} = 6.1587\ \mathrm{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.044\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.0070064\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.204\ \mathrm{kipft}) + ((-0.044\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.032484\ \mathrm{kipft/ft}$$

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:
$L_{e,z} = 1.273\ \mathrm{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.1587\ \mathrm{ft}), (1.273\ \mathrm{ft})]$$

$$L_{e,req} = 6.159\ \mathrm{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.159\ \mathrm{ft})}{(6.5\ \mathrm{ft})}$$

$$Ratio = 0.94754$$

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

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

	$$q = \frac{P_v}{A}$$ $$q = \frac{(9.823\ \text{kip})}{(16\ \text{ft}^2)}$$ $$q = 0.61394\ \text{kip/ft}^2$$ **Check bearing capacity ratio:** $Ratio$ - Capacity $$Ratio = \frac{q}{q_a}$$ $$Ratio = \frac{\left(0.61394\ \text{kip/ft}^2\right)}{(2000\ \text{psf})}$$ $$Ratio = 0.30697$$		Status: **PASS** Ratio: **0.310**
Czerniak	**Lateral Soil Pressure (ASD):** L/D - Length to least lateral dimension ratio, $$L/D = \frac{L}{D}$$ $$L/D = \frac{(6.5\ \text{ft})}{(48\ \text{in})}$$ $$L/D = 1.625$$ Since L/D $\leq$ 10, Pile is short. **Considering x-direction:** $H_o = -0.28869\ \text{kip/ft}$ - Lateral force per length of pile, $M_o = 4.2535\ \text{kipft/ft}$ - Overturning moment per length of pile, a - Distance from resting surface to pivot point, $$a = \frac{(4\,M_o\,L_e) + \left(3\,H_o\,L_e^2\right)}{(6\,M_o) + (4\,H_o\,L_e)}$$ $$a = \frac{(4 \times (4.2535\ \text{kipft/ft}) \times (6.5\ \text{ft})) + \left(3 \times (-0.28869\ \text{kip/ft}) \times (6.5\ \text{ft})^2\right)}{(6 \times (4.2535\ \text{kipft/ft})) + (4 \times (-0.28869\ \text{kip/ft}) \times (6.5\ \text{ft}))}$$ $$a = 4.4564\ \text{ft}$$ p - Earth pressure against the pile at distance a/2 from resting surface, $$p = \frac{0.75\,[(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\,[(3\,M_o) + (2\,H_o\,L_e)]}$$ $$p = \frac{0.75 \times [(4 \times (4.2535\ \text{kipft/ft})) + (3 \times (-0.28869\ \text{kip/ft}) \times (6.5\ \text{ft}))]^2}{(6.5\ \text{ft})^2 \times [(3 \times (4.2535\ \text{kipft/ft})) + (2 \times (-0.28869\ \text{kip/ft}) \times (6.5\ \text{ft}))]}$$ $$p = 0.25542\ \text{kip/ft}^2$$ s - Earth pressure against the pile at distance L_e, $$s = \frac{6\,[(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$ $$s = \frac{6 \times [(2 \times (4.2535\ \text{kipft/ft})) + ((-0.28869\ \text{kip/ft}) \times (6.5\ \text{ft}))]}{(6.5\ \text{ft})^2}$$ $$s = 0.94161\ \text{kip/ft}^2$$ **Check lateral soil pressure capacity:** p_a - Allowable lateral soil pressure at depth a/2, $$p_a = R\,\frac{a}{2}$$ $$p_a = (150\ \text{psf/ft}) \times \frac{(4.4564\ \text{ft})}{2}$$ $$p_a = 0.33423\ \text{kip/ft}^2$$ $Ratio$ - Lateral soil capacity		

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

$$Ratio = \frac{\left(0.25542\ \mathrm{kip/ft^2}\right)}{\left(0.33423\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.7642$$

Status: **PASS**
Ratio: **0.760**

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

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

$$Ratio = \frac{\left(0.94161\ \mathrm{kip/ft^2}\right)}{\left(0.975\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.96575$$

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

Considering z-direction:

$H_o = -0.0070064\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.032484\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.032484\ \mathrm{kipft/ft}) \times (6.5\ \mathrm{ft})) + \left(3 \times (-0.0070064\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft})^2\right)}{(6 \times (0.032484\ \mathrm{kipft/ft})) + (4 \times (-0.0070064\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))}$$

$$a = 4.595\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.032484\ \mathrm{kipft/ft})) + (3 \times (-0.0070064\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]^{\,2}}{(6.5\ \mathrm{ft})^2 \times [(3 \times (0.032484\ \mathrm{kipft/ft})) + (2 \times (-0.0070064\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}$$

$$p = 0.00012466\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.032484\ \mathrm{kipft/ft})) + ((-0.0070064\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}{(6.5\ \mathrm{ft})^2}$$

$$s = 0.0027588\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.595\ \mathrm{ft})}{2}$$

$$p_a = 0.34463\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.00012466\ \mathrm{kip/ft^2}\right)}{\left(0.34463\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.00036171$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

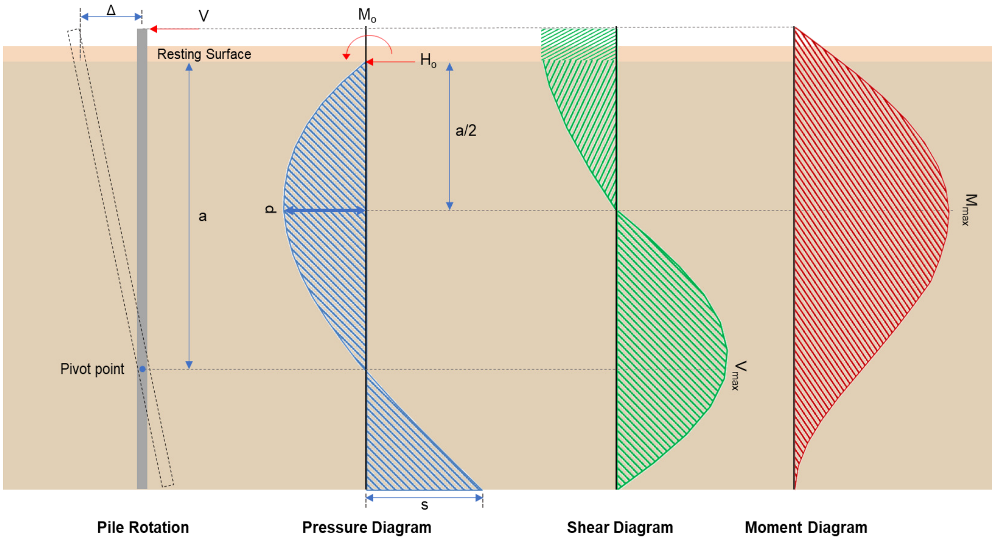
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0027588\ \mathrm{kip/ft^2}\right)}{\left(0.975\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0028296$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.037\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.4836\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(47.448\ \mathrm{kipft}) + ((-3.037\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 7.5554\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(7.5554\ \mathrm{kipft/ft})}{(-0.4836\ \mathrm{kip/ft})}$$

$$E = 15.623\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.5554\ \mathrm{kipft/ft}) \times (6.5\ \mathrm{ft})) + \left(3 \times (-0.4836\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (7.5554 \text{ kipft/ft})) + (4 \times (-0.4836 \text{ kip/ft}) \times (6.5 \text{ ft}))}$$

$$a = 4.4509 \text{ ft}$$

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

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

$$V_{max} = ((-0.4836 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (15.623 \text{ ft})}{(6.5 \text{ ft})} + 3\right) \times \left(\frac{(4.4509 \text{ ft})}{(6.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (15.623 \text{ ft})}{(6.5 \text{ ft})} + 2\right) \times \left(\frac{(4.4509 \text{ ft})}{(6.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 9.5073 \text{ kip}$$

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

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

$$M_{max} = ((-0.4836 \text{ kip/ft}) \times (48 \text{ in}) \times (6.5 \text{ ft})) \times \left[\left(\frac{(15.623 \text{ ft})}{(6.5 \text{ ft})} + \frac{(4.4509 \text{ ft})}{2 \times (6.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (15.623 \text{ ft})}{(6.5 \text{ ft})} + 3\right) \times \left(\frac{(4.4509 \text{ ft})}{2 \times (6.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (15.623 \text{ ft})}{(6.5 \text{ ft})} + 2\right) \times \left(\frac{(4.4509 \text{ ft})}{2 \times (6.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 29.752 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.084 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.013376 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.392 \text{ kipft}) + ((-0.084 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.06242 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.06242 \text{ kipft/ft})}{(-0.013376 \text{ kip/ft})}$$

$$E = 4.6667 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.06242 \text{ kipft/ft}) \times (6.5 \text{ ft})) + \left(3 \times (-0.013376 \text{ kip/ft}) \times (6.5 \text{ ft})^2\right)}{(6 \times (0.06242 \text{ kipft/ft})) + (4 \times (-0.013376 \text{ kip/ft}) \times (6.5 \text{ ft}))}$$

$$a = 4.5941 \text{ ft}$$

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

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

$$V_{max} = ((-0.013376\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.6667\ \text{ft})}{(6.5\ \text{ft})} + 3\right) \times \left(\frac{(4.5941\ \text{ft})}{(6.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (4.6667\ \text{ft})}{(6.5\ \text{ft})} + 2\right) \times \left(\frac{(4.5941\ \text{ft})}{(6.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.10344\ \text{kip}$$

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

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

$$M_{max} = ((-0.013376\ \text{kip/ft}) \times (48\ \text{in}) \times (6.5\ \text{ft})) \times \left[\left(\frac{(4.6667\ \text{ft})}{(6.5\ \text{ft})} + \frac{(4.5941\ \text{ft})}{2 \times (6.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (4.6667\ \text{ft})}{(6.5\ \text{ft})} + 3\right) \times \left(\frac{(4.5941\ \text{ft})}{2 \times (6.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (4.6667\ \text{ft})}{(6.5\ \text{ft})} + 2\right) \times \left(\frac{(4.5941\ \text{ft})}{2 \times (6.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.30499\ \text{kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(16.455\ \text{kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.049\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.049\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

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

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

$$Ratio = \frac{(16.455\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.006151$$

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 $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 16.455 \text{ kip} \rightarrow 16455 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(16455 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.68 \text{ kip}$$

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

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.68 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.68 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((120.68 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.52 \text{ kip}$$

Considering x-direction:

$V_{max} = 9.5073 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(9.5073\ \mathrm{kip})}{(111.52\ \mathrm{kip})}$$ $$Ratio = 0.08525$$	Status: **PASS** Ratio: **0.090**
	Considering z-direction: $V_{max} = 0.10344\ \mathrm{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.10344\ \mathrm{kip})}{(111.52\ \mathrm{kip})}$$ $$Ratio = 0.00092749$$	Status: **PASS** Ratio: **0.000**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{b\,D^2}{6}$$ $$S_m = \frac{(48\ \mathrm{in}) \times (48\ \mathrm{in})^2}{6}$$ $$S_m = 18432\ \mathrm{in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 ksi)} \times 18432.001 in^3$$ $$\phi M_{n,1} = 249.600 kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \mathrm{ksi}) \times \left(18432\ \mathrm{in}^3\right)$$ $$\phi M_{n,2} = 2121.6\ \mathrm{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\ \mathrm{kipft}), (2121.6\ \mathrm{kipft})]$$ $$\phi M_n = 249.6\ \mathrm{kipft}$$ **Considering x-direction:** $M_{max} = 29.752\ \mathrm{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(29.752\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$ $$Ratio = 0.1192$$	Status: **PASS** Ratio: **0.120**
	Considering z-direction: $M_{max} = 0.30499\ \mathrm{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(0.30499\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.0012219$$		Status: **PASS** Ratio: **0.000**