Your Project Calculations

Project Name: D50Schools-JB-Area1

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=D50Schools-JB-Area1&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/9_2023

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=aIX3gh7TgxMOmpzOvr2bhDNisawKGGcwGZyEzRxxcBwvWesZ5qIHJZdmai1MPRss

Array Specification

Product:	Beam
Unique ID:	4P-22.5-6TOP-XD-45-L-5Hx11W-57IG
Duty Classification:	XD
Module Width:	44.65 in
Module Length:	89.69in
Number of Rows:	5
Number of Columns:	11
Total Number of Modules:	55
Desired Tilt Angle:	10
Front Edge Clearance:	14
Total Array Height at Tilt:	17.25 ft
Total Frame Length:	82.50 ft
Frame Weight:	4859 lbs
Array Dimensions N/S:	18.81 ft
Array Dimensions E/W:	83.13 ft
Rail Length:	225.75 in
Rail Spacing:	3.78 ft
Rail Check:	PASS (97% utilized)

Support Specifications

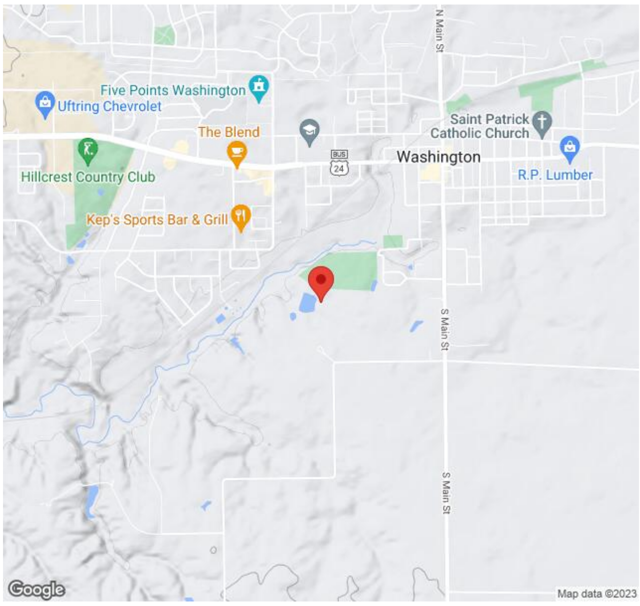
Pole Size:	6in Pipe Sch 80
Pole Length above Grade:	15.63 ft
Number of Poles:	4
Pole Spacing:	22.5 ft

Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 5.75 ft Pile 2: 6.00 ft Pile 3: 6.00 ft Pile 4: 5.75 ft
Foundation Volume:	13.926 y^3
Foundation Result:	PASSED
Mount Twist:	0.163458 kip

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	Washington, IL 61571, USA
Wind Speed:	100 mph
Snow Load:	20 psf
Design Uplift Pressure:	Multiple pressures
Design Downforce Pressure:	Multiple pressures
Design Snow Pressure:	0.012096 ksf



Design Disclaimer

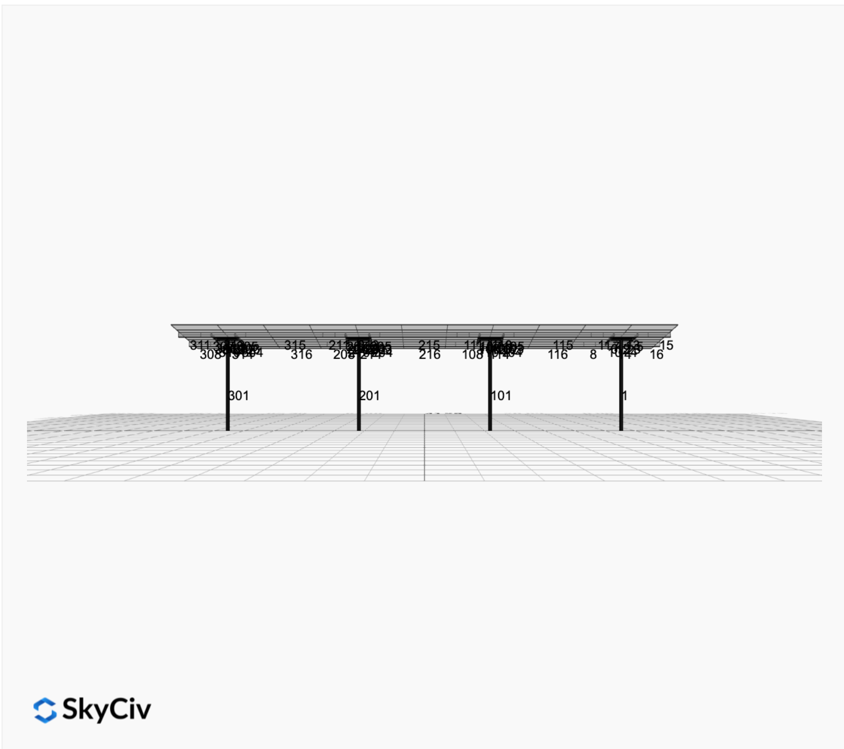
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

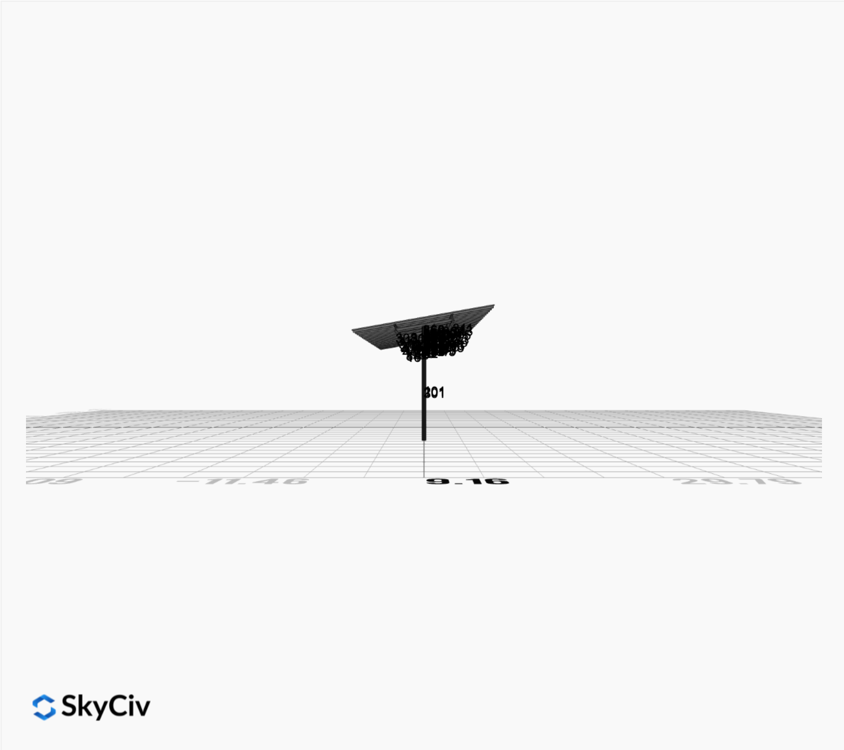
AutoDesigner Input

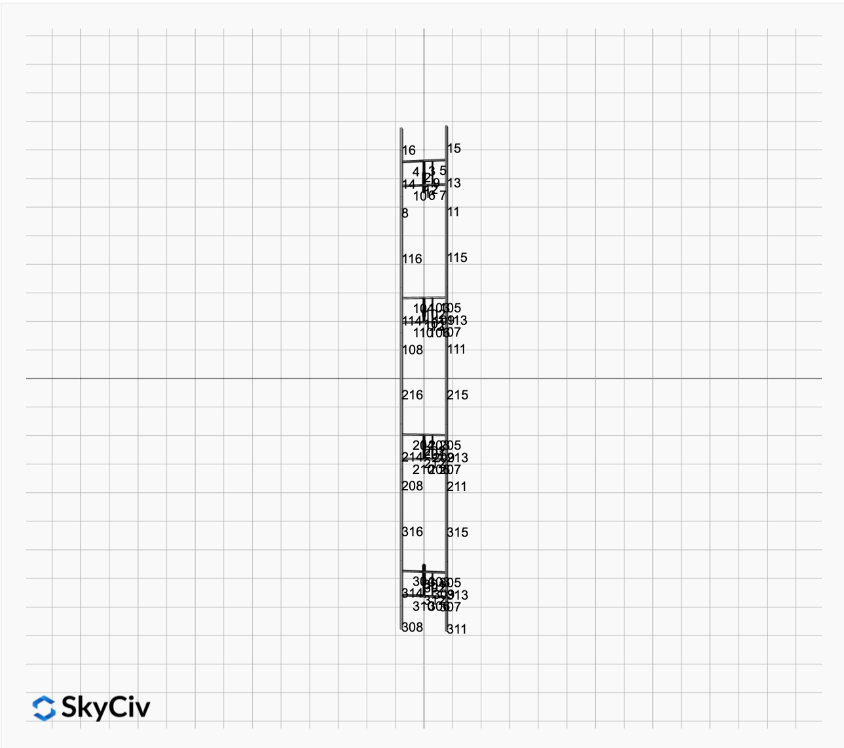

```
{"wind_speed_override":null,"snow_load_override":null,"direct_snow_load":false,"add_angle_brace":false,"product_type":"Beam","project_id":"D50Schools-JB-Area1","site_address":"Washington, IL 61571, USA","module_width":44.65,"module_length":89.69,"number_rows":"5","number_columns":11,"pole_mount_section":"4_40","core_pipe_width":65,"core_pipe_section":"2_40","adjuster_section":"2_40","core_beam_height":65,"core_beam_section":"HSS3x2x1/8","main_pipe_section":"2_12GA","pole_spacing":"15","tilt_angle":10,"ground_clearance":14,"risk_category":"I","exposure_category":"C","frame_duty_override":"auto","pole_override":"auto","soil_type":"sand","customer_foundation_override":"48_Square","foundation_type":"Square","foundation_size":48,"check_rails":true}
```

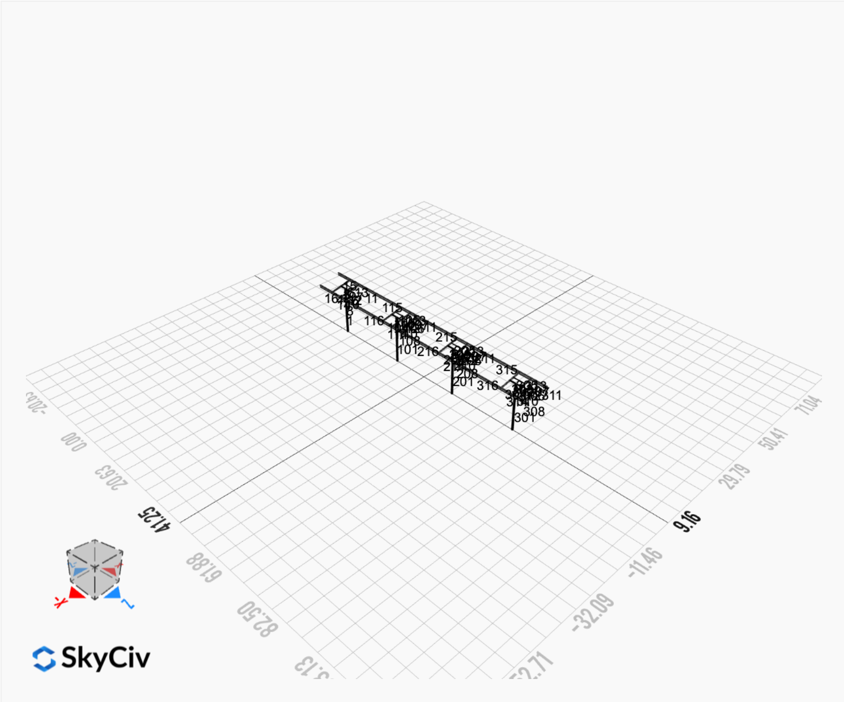

Design Notes:

- 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




301
9.16
-11.46

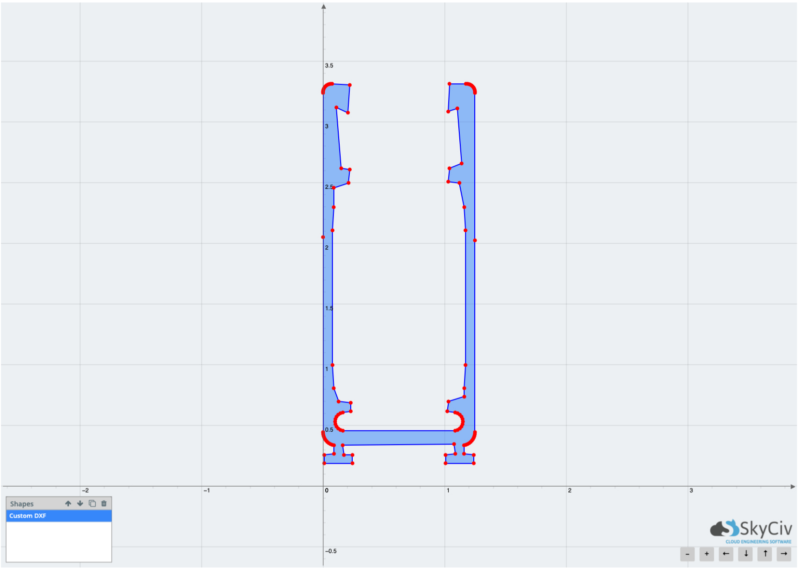

16
15
13
11
8
116
115
108
111
216
215
208
211
316
315
308
311


9.16
-11.46
-32.09
29.79
50.41
71.04
41.25
20.63
0.00
61.88
82.50
301
308
201
101
SkyCiv

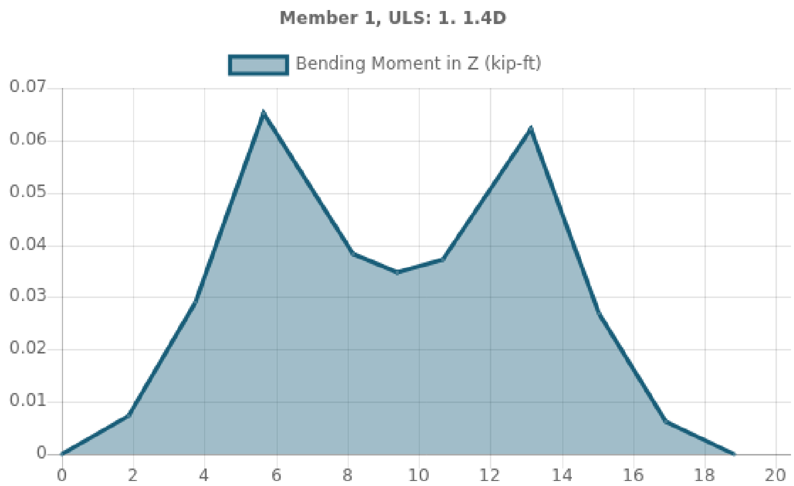

301
201
101
1
SkyCiv

Rail Design Check

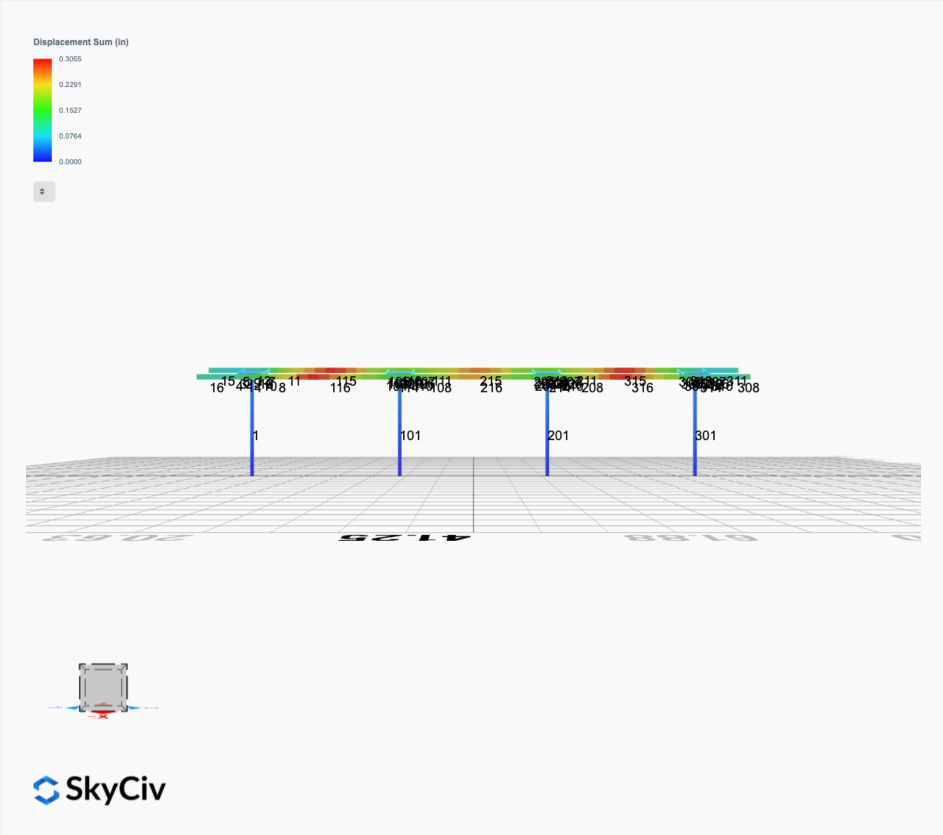
Rail Length: 18.8125 ft
Additional Restraints Required: None
Tributary Width: 3.77875 ft
Material: Aluminium
Density: 169 lb/ft^3
Elasticity Modulus: 10000 ksi
Fy: 34.5 ksi
Fu: 37 ksi
Snow (X): 0.0450 kip/ft
Snow (Y): -0.0079 kip/ft
Wind uplift Case A: 0.0641 kip/ft
Wind uplift Case A: 0.0641 kip/ft
Wind uplift Case B (X): 0.0000 kip/ft
Wind uplift Case B (Y): 0.0913 kip/ft

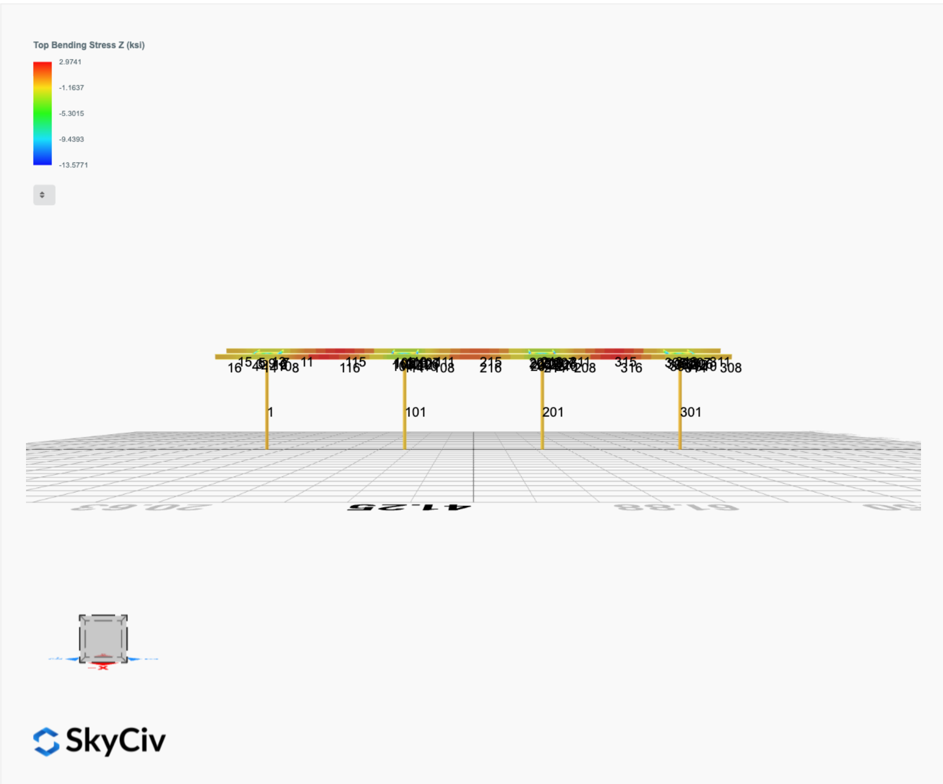


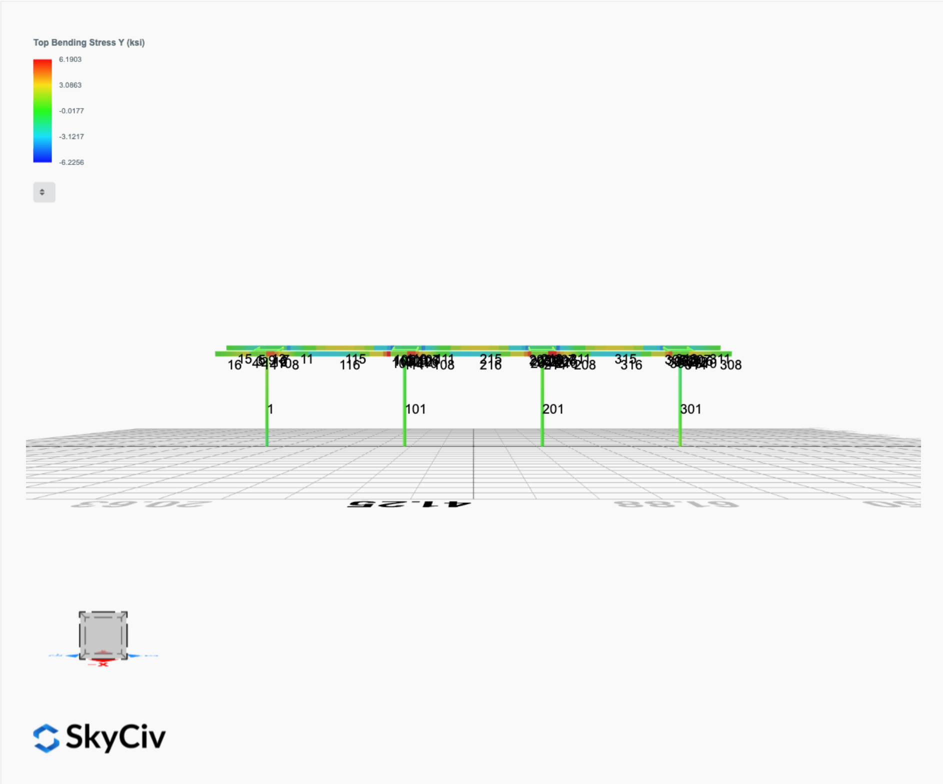
Result Check	Max Limit	Max Value	Utility	Status
Custom Stress Limit	34.5	33.63074903	0.975	PASS
Material Yield	34.5	33.63074903	0.975	PASS
Material Strength	37	33.63074903	0.909	PASS



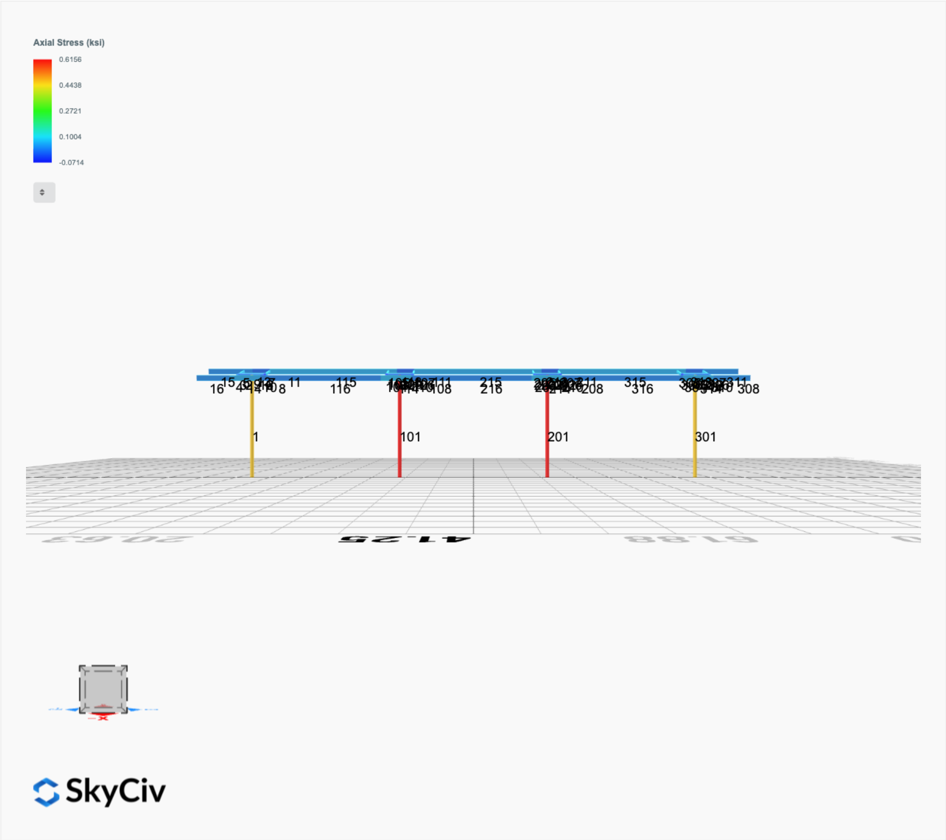
FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
6.1903
3.0863
-0.0177
-3.1217
-6.2256
1
101
201
301
41.25
SkyCiv


Shear Stress Y (ksi)
1.0357
0.5178
0.0000
-0.5178
-1.0357
1
101
201
301
41.25
SkyCiv


Axial Stress (ksi)
0.6156
0.4438
0.2721
0.1004
-0.0714
1
101
201
301
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	0.0080	2.6780	0.0419	0.2136	-0.0106	-0.0778
ULS: 2. D + L	0.0080	2.6780	0.0419	0.2136	-0.0106	-0.0778
ULS: 3. D + (S or Lr or R)	0.0245	6.7481	0.1294	0.6603	-0.0329	-0.3048
ULS: 3. D + (S or Lr or R)	0.0080	2.6780	0.0419	0.2136	-0.0106	-0.0778
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0203	5.7306	0.1075	0.5487	-0.0273	-0.2480
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0080	2.6780	0.0419	0.2136	-0.0106	-0.0778
ULS: 5b. D + 0.7E	0.0080	2.6780	0.0419	0.2136	-0.0106	-0.0778
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0203	5.7306	0.1075	0.5487	-0.0273	-0.2480
ULS: 8. 0.6D + 0.7E	0.0048	1.6068	0.0252	0.1282	-0.0064	-0.0467
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.7445	6.7128	0.1454	0.7406	-0.0906	16.1519
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.7445	6.7128	0.1454	0.7406	-0.0906	16.1519
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.5159	-0.1436	-0.0214	-0.1058	0.0326	-5.4385
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.4840	0.2089	-0.0283	-0.1400	0.0486	-16.3932
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.5440	8.7567	0.1851	0.9439	-0.0873	11.9242
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.5440	8.7567	0.1851	0.9439	-0.0873	11.9242
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.4013	3.6144	0.0600	0.3091	0.0051	-4.2686
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.3773	3.8788	0.0548	0.2835	0.0171	-12.4846
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.5564	5.7041	0.1196	0.6089	-0.0706	12.0945
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.5564	5.7041	0.1196	0.6089	-0.0706	12.0945
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.3889	0.5618	-0.0056	-0.0260	0.0218	-4.0983
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.3650	0.8262	-0.0107	-0.0516	0.0338	-12.3143
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.7477	5.6416	0.1287	0.6552	-0.0863	16.1830
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.7477	5.6416	0.1287	0.6552	-0.0863	16.1830
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.5127	-1.2148	-0.0382	-0.1913	0.0368	-5.4074
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.4808	-0.8623	-0.0451	-0.2254	0.0529	-16.3621

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	13.0903
Shear X	-1.2541
Shear Z	0.2800
Moment X	1.4396
Moment Y (Twist)	0.1634
Moment Z	29.4284

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	8.7567
Shear X	-0.7477
Shear Z	0.1851
Moment X	0.9439
Moment Y (Twist)	0.0906
Moment Z	16.3932

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	-0.0080	3.2092	-0.0066	-0.0335	0.0031	0.1451
ULS: 2. D + L	-0.0080	3.2092	-0.0066	-0.0335	0.0031	0.1451
ULS: 3. D + (S or Lr or R)	-0.0245	8.3831	-0.0202	-0.1034	0.0095	0.3910
ULS: 3. D + (S or Lr or R)	-0.0080	3.2092	-0.0066	-0.0335	0.0031	0.1451
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0203	7.0896	-0.0168	-0.0859	0.0079	0.3295
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0080	3.2092	-0.0066	-0.0335	0.0031	0.1451
ULS: 5b. D + 0.7E	-0.0080	3.2092	-0.0066	-0.0335	0.0031	0.1451

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0203	7.0896	-0.0168	-0.0859	0.0079	0.3295
ULS: 8. 0.6D + 0.7E	-0.0048	1.9255	-0.0039	-0.0201	0.0019	0.0871
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.8673	8.3151	-0.0111	-0.0582	-0.0092	18.8856
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.8673	8.3151	-0.0111	-0.0582	-0.0092	18.8856
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.6144	-0.3796	0.0018	0.0089	0.0019	-6.2569
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.4998	0.0989	-0.0075	-0.0370	0.0184	-18.0758
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.6648	10.9190	-0.0202	-0.1044	-0.0013	14.3849
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.6648	10.9190	-0.0202	-0.1044	-0.0013	14.3849
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.4464	4.3981	-0.0105	-0.0541	0.0070	-4.4720
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.3605	4.7569	-0.0174	-0.0886	0.0194	-13.3362
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.6524	7.0386	-0.0100	-0.0520	-0.0061	14.2005
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.6524	7.0386	-0.0100	-0.0520	-0.0061	14.2005
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.4588	0.5176	-0.0003	-0.0017	0.0022	-4.6564
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.3729	0.8765	-0.0072	-0.0361	0.0146	-13.5206
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.8641	7.0314	-0.0085	-0.0448	-0.0104	18.8276
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.8641	7.0314	-0.0085	-0.0448	-0.0104	18.8276
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.6176	-1.6632	0.0044	0.0223	0.0006	-6.3149
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.5030	-1.1848	-0.0048	-0.0236	0.0172	-18.1339

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	16.3821
Shear X	-1.4405
Shear Z	-0.0332
Moment X	-0.1698
Moment Y (Twist)	0.0366
Moment Z	34.0984

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	10.9190
Shear X	-0.8673
Shear Z	-0.0202
Moment X	-0.1044
Moment Y (Twist)	0.0194
Moment Z	18.8856

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	-0.0080	3.2092	0.0066	0.0335	-0.0031	0.1451
ULS: 2. D + L	-0.0080	3.2092	0.0066	0.0335	-0.0031	0.1451
ULS: 3. D + (S or Lr or R)	-0.0245	8.3831	0.0202	0.1034	-0.0094	0.3910
ULS: 3. D + (S or Lr or R)	-0.0080	3.2092	0.0066	0.0335	-0.0031	0.1451
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0203	7.0896	0.0168	0.0859	-0.0078	0.3295
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0080	3.2092	0.0066	0.0335	-0.0031	0.1451
ULS: 5b. D + 0.7E	-0.0080	3.2092	0.0066	0.0335	-0.0031	0.1451
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0203	7.0896	0.0168	0.0859	-0.0078	0.3295
ULS: 8. 0.6D + 0.7E	-0.0048	1.9255	0.0039	0.0201	-0.0019	0.0871
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.8673	8.3151	0.0111	0.0582	0.0092	18.8856
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.8673	8.3151	0.0111	0.0582	0.0092	18.8856
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.6144	-0.3796	-0.0018	-0.0089	-0.0019	-6.2569
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.4998	0.0989	0.0075	0.0370	-0.0184	-18.0758
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.6648	10.9190	0.0202	0.1044	0.0014	14.3849
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.6648	10.9190	0.0202	0.1044	0.0014	14.3849
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.4464	4.3981	0.0105	0.0541	-0.0069	-4.4720
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.3605	4.7569	0.0175	0.0886	-0.0194	-13.3362

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.6524	7.0386	0.0100	0.0520	0.0061	14.2005
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.6524	7.0386	0.0100	0.0520	0.0061	14.2005
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.4588	0.5176	0.0003	0.0017	-0.0022	-4.6564
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.3729	0.8765	0.0072	0.0361	-0.0146	-13.5206
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.8641	7.0314	0.0085	0.0448	0.0104	18.8276
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.8641	7.0314	0.0085	0.0448	0.0104	18.8276
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.6176	-1.6632	-0.0044	-0.0223	-0.0006	-6.3149
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.5030	-1.1848	0.0048	0.0236	-0.0172	-18.1339

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	16.3821
Shear X	-1.4405
Shear Z	0.0332
Moment X	0.1699
Moment Y (Twist)	0.0365
Moment Z	34.0985

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	10.9190
Shear X	-0.8673
Shear Z	0.0202
Moment X	0.1044
Moment Y (Twist)	0.0194
Moment Z	18.8856

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	0.0080	2.6780	-0.0419	-0.2136	0.0106	-0.0778
ULS: 2. D + L	0.0080	2.6780	-0.0419	-0.2136	0.0106	-0.0778
ULS: 3. D + (S or Lr or R)	0.0245	6.7481	-0.1294	-0.6604	0.0329	-0.3047
ULS: 3. D + (S or Lr or R)	0.0080	2.6780	-0.0419	-0.2136	0.0106	-0.0778
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0203	5.7306	-0.1075	-0.5487	0.0273	-0.2480
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0080	2.6780	-0.0419	-0.2136	0.0106	-0.0778
ULS: 5b. D + 0.7E	0.0080	2.6780	-0.0419	-0.2136	0.0106	-0.0778
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0203	5.7306	-0.1075	-0.5487	0.0273	-0.2480
ULS: 8. 0.6D + 0.7E	0.0048	1.6068	-0.0252	-0.1282	0.0064	-0.0467
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.7445	6.7128	-0.1454	-0.7406	0.0906	16.1519
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.7445	6.7128	-0.1454	-0.7406	0.0906	16.1519
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.5159	-0.1436	0.0214	0.1058	-0.0326	-5.4385
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.4840	0.2089	0.0283	0.1400	-0.0486	-16.3932
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.5440	8.7567	-0.1851	-0.9439	0.0873	11.9243
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.5440	8.7567	-0.1851	-0.9439	0.0873	11.9243
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.4013	3.6144	-0.0600	-0.3091	-0.0051	-4.2685
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.3773	3.8788	-0.0548	-0.2835	-0.0171	-12.4845
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.5564	5.7041	-0.1196	-0.6089	0.0706	12.0945
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.5564	5.7041	-0.1196	-0.6089	0.0706	12.0945
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.3889	0.5618	0.0056	0.0260	-0.0218	-4.0983
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.3650	0.8262	0.0107	0.0516	-0.0338	-12.3143
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.7477	5.6416	-0.1287	-0.6552	0.0864	16.1830
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.7477	5.6416	-0.1287	-0.6552	0.0864	16.1830
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.5127	-1.2148	0.0382	0.1913	-0.0368	-5.4074
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.4808	-0.8623	0.0451	0.2254	-0.0529	-16.3621

Worst Case Reactions LRFD

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	13.0903
Shear X	-1.2541
Shear Z	-0.2800
Moment X	-1.4396
Moment Y (Twist)	0.1635
Moment Z	29.4288

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

Result	Value (kip, kip-ft)
Axial	8.7567
Shear X	-0.7477
Shear Z	-0.1851
Moment X	-0.9439
Moment Y (Twist)	0.0906
Moment Z	16.3932

Project Details

Design Code:	AISC 360-16 LRFD
Provision:	LRFD
Country:	United States
User Name:	sales@mtsolar.us
Project Name:	D50Schools-JB-Area1
Unit System:	imperial

Design Input Information

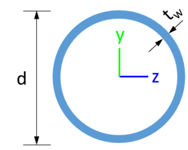
Design Factors

Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

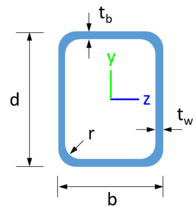
Design Materials

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

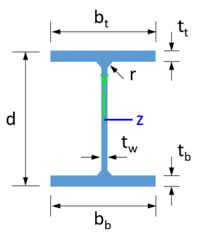
Section Dimensions



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	32.83	32.83	15.63	-	300	200	1
2	6	1.30	1.30	2.00	-	300	200	1
3	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.21,1.16,1.18,1.18,1.15,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.22,1.16,1.18,1.18,1.16,1.17	300	200	1
4	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.63,1.68,1.67,1.67,1.65,1.69,1.67,1.67,1.68,1.67,1.68,1.68,1.57,1.69,1.67,1.67,1.66,1.69	300	200	1
5	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.71,1.66,1.67,1.67,1.64,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.73,1.65,1.67,1.67,1.65,1.66	300	200	1
6	17	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.21,1.18,1.18,1.18,1.16,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.22,1.17,1.18,1.18,1.17,1.18	300	200	1
7	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.71,1.66,1.67,1.67,1.65,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.72,1.65,1.67,1.67,1.66,1.66	300	200	1
8	20	1.33	1.33	2.05	1.52,1.52,1.52,1.52,1.52,1.52,1.46,1.46,1.65,2.02,1.45,1.45,1.57,2.16,1.49,1.49,1.51,1.61,1.47,1.47,1.69,1.96,1.45,1.45,1.57,2.27	300	200	1
9	3	2.60	2.60	4.00	-	300	200	1
10	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.64,1.68,1.67,1.67,1.65,1.69,1.67,1.67,1.67,1.67,1.68,1.68,1.58,1.69,1.67,1.67,1.66,1.68	300	200	1
11	20	1.33	1.33	2.05	1.56,1.56,1.56,1.56,1.56,1.56,1.66,1.66,1.75,2.11,1.67,1.67,1.50,2.00,1.61,1.61,1.56,1.40,1.64,1.64,1.66,2.12,1.68,1.68,1.51,1.93	300	200	1
12	6	1.30	1.30	2.00	-	300	200	1
13	20	4.88	4.00	7.50	1.12,1.12,1.12,1.12,1.12,1.12,1.11,1.11,1.22,1.21,1.11,1.11,1.09,1.12,1.12,1.12,1.13,1.13,1.12,1.12,1.18,1.24,1.11,1.11,1.10,1.12	300	200	1
14	20	4.88	4.00	7.50	1.12,1.12,1.12,1.13,1.12,1.12,1.12,1.12,1.15,1.15,1.12,1.12,1.14,1.33,1.12,1.12,1.12,1.13,1.12,1.12,1.17,1.15,1.12,1.12,1.14,1.47	300	200	1
15	20	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
16	20	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
101	8	32.83	32.83	15.63	-	300	200	1
102	6	1.30	1.30	2.00	-	300	200	1
103	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.21,1.17,1.18,1.18,1.16,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.21,1.16,1.18,1.18,1.17,1.17	300	200	1
104	17	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.64,1.68,1.67,1.67,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.60,1.68,1.67,1.67,1.66,1.68	300	200	1
105	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.70,1.66,1.67,1.67,1.65,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.71,1.65,1.67,1.67,1.66,1.66	300	200	1
106	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.21,1.17,1.18,1.18,1.16,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.21,1.17,1.18,1.18,1.17,1.18	300	200	1
107	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.70,1.66,1.67,1.67,1.65,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.71,1.65,1.67,1.67,1.66,1.66	30	20	1

				[illegible]	[illegible]	0	0	
108	20	1.33	1.33	2.05	2.22,2.21,2.22,2.21,2.22,2.22,2.04,2.04,2.26,2.15,2.01,2.01,2.23,2.04,2.14,2.14,2.21,2.25,2.07,2.07,2.26,2.22,2.00,2.00,2.23,1.72	300	200	1
109	3	2.60	2.60	4.00	-	300	200	1
110	17	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.64,1.68,1.67,1.67,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.60,1.68,1.67,1.67,1.66,1.68	300	200	1
111	20	1.33	1.33	2.05	2.23,2.23,2.23,2.23,2.23,2.23,2.32,2.32,2.00,1.90,2.33,2.33,2.26,2.11,2.27,2.27,2.23,1.76,2.30,2.30,2.12,1.81,2.33,2.33,2.25,2.12	300	200	1
112	6	1.30	1.30	2.00	-	300	200	1
113	20	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.12,1.19,1.04,1.04,1.04,1.09,1.04,1.04,1.04,1.03,1.04,1.04,1.05,1.24,1.04,1.04,1.04,1.07	300	200	1
114	20	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.10,1.04,1.04,1.04,1.34,1.04,1.04,1.03,1.04,1.04,1.04,1.10,1.08,1.04,1.04,1.04,1.70	300	200	1
115	20	8.42	8.42	12.95	1.17,1.17,1.17,1.17,1.17,1.17,1.15,1.15,1.19,1.11,1.15,1.15,1.16,1.12,1.16,1.16,1.17,1.21,1.15,1.15,1.18,1.11,1.15,1.15,1.16,1.13	300	200	1
116	20	8.42	8.42	12.95	1.17,1.17,1.17,1.17,1.17,1.17,1.18,1.18,1.16,1.13,1.19,1.19,1.17,1.11,1.18,1.18,1.18,1.16,1.18,1.18,1.16,1.14,1.19,1.19,1.17,1.11	300	200	1
201	8	32.83	32.83	15.63	-	300	200	1
202	6	1.30	1.30	2.00	-	300	200	1
203	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.21,1.17,1.18,1.18,1.16,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.21,1.17,1.18,1.18,1.17,1.18	300	200	1
204	17	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.64,1.68,1.67,1.67,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.60,1.68,1.67,1.67,1.66,1.68	300	200	1
205	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.70,1.66,1.67,1.67,1.65,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.71,1.65,1.67,1.67,1.66,1.66	300	200	1
206	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.21,1.17,1.18,1.18,1.16,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.21,1.16,1.18,1.18,1.17,1.17	300	200	1
207	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.70,1.66,1.67,1.67,1.65,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.71,1.65,1.67,1.67,1.66,1.66	300	200	1
208	20	1.33	1.33	2.05	2.31,2.31,2.31,2.31,2.31,2.31,2.26,2.26,2.32,2.08,2.25,2.25,2.33,1.61,2.28,2.28,2.30,2.28,2.27,2.27,2.25,2.09,2.25,2.25,2.33,1.44	300	200	1
209	3	2.60	2.60	4.00	-	300	200	1
210	17	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.64,1.68,1.67,1.67,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.60,1.68,1.67,1.67,1.66,1.68	300	200	1
211	20	1.33	1.33	2.05	2.34,2.34,2.34,2.35,2.34,2.34,2.12,2.12,2.24,1.58,2.11,2.11,2.16,1.89,2.15,2.15,2.33,2.17,2.13,2.13,2.27,1.53,2.11,2.11,2.26,1.98	300	200	1
212	6	1.30	1.30	2.00	-	300	200	1
213	20	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.12,1.19,1.04,1.04,1.04,1.09,1.04,1.04,1.04,1.03,1.04,1.04,1.05,1.24,1.04,1.04,1.04,1.07	300	200	1
214	20	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.10,1.04,1.04,1.04,1.34,1.04,1.04,1.03,1.04,1.04,1.04,1.10,1.09,1.04,1.04,1.04,1.70	300	200	1
215	20	8.42	8.42	12.95	1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.16,1.20,1.13,1.16,1.16,1.17,1.14,1.17,1.17,1.18,1.23,1.16,1.16,1.19,1.12,1.16,1.16,1.18,1.14	300	200	1
216	20	8.42	8.42	12.95	1.19,1.19,1.19,1.19,1.19,1.19,1.20,1.20,1.17,1.15,1.20,1.20,1.18,1.13,1.19,1.19,1.19,1.18,1.20,1.20,1.17,1.15,1.20,1.20,1.18,1.12	300	200	1
301	8	32.83	32.83	15.63	-	300	200	1

302	6	1.30	1.30	2.00	-	300	200	1
303	17	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.21,1.18,1.18,1.18,1.16,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.22,1.17,1.18,1.18,1.17,1.18	300	200	1
304	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.64,1.68,1.67,1.67,1.65,1.69,1.67,1.67,1.67,1.67,1.68,1.68,1.58,1.69,1.67,1.67,1.66,1.68	300	200	1
305	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.71,1.66,1.67,1.67,1.65,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.72,1.65,1.67,1.67,1.66,1.66	300	200	1
306	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.21,1.16,1.18,1.18,1.15,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.22,1.16,1.18,1.18,1.16,1.17	300	200	1
307	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.71,1.66,1.67,1.67,1.64,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.73,1.65,1.67,1.67,1.65,1.66	300	200	1
308	20	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
309	3	2.60	2.60	4.00	-	300	200	1
310	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.63,1.68,1.67,1.67,1.65,1.69,1.67,1.67,1.68,1.67,1.68,1.68,1.57,1.69,1.67,1.67,1.66,1.69	300	200	1
311	20	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
312	6	1.30	1.30	2.00	-	300	200	1
313	20	4.88	4.00	7.50	1.12,1.12,1.12,1.12,1.12,1.12,1.11,1.11,1.22,1.21,1.11,1.11,1.09,1.12,1.12,1.12,1.13,1.13,1.12,1.12,1.18,1.24,1.11,1.11,1.10,1.12	300	200	1
314	20	4.88	4.00	7.50	1.12,1.12,1.12,1.13,1.12,1.12,1.12,1.12,1.15,1.15,1.12,1.12,1.14,1.33,1.12,1.12,1.12,1.13,1.12,1.12,1.17,1.15,1.12,1.12,1.14,1.47	300	200	1
315	20	8.42	8.42	12.95	1.11,1.12,1.11,1.12,1.12,1.11,1.11,1.11,1.13,1.15,1.11,1.11,1.11,1.13,1.11,1.11,1.12,1.12,1.11,1.11,1.12,1.15,1.11,1.11,1.11,1.13	300	200	1
316	20	8.42	8.42	12.95	1.11,1.12,1.11,1.12,1.11,1.11,1.11,1.11,1.12,1.13,1.11,1.11,1.12,1.16,1.11,1.11,1.11,1.12,1.11,1.11,1.12,1.13,1.11,1.11,1.12,1.18	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	58.94	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	142.47	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	142.47	46.90	6.46	56.26	44.91
12	251.01	248.88	27.16	27.16	75.30	75.30
13	159.30	116.35	33.31	6.46	56.26	44.91
14	159.30	116.35	34.23	6.46	56.26	44.91
15	159.30	55.15	46.90	6.46	56.26	44.91
16	159.30	55.15	46.90	6.46	56.26	44.91
101	378.22	58.94	62.23	62.23	113.47	113.47
102	251.01	248.88	27.16	27.16	75.30	75.30

103	151.65	150.70	20.17	14.14	54.12	28.95
104	151.65	145.15	20.17	14.14	54.12	28.95
105	151.65	149.10	20.17	14.14	54.12	28.95
106	151.65	150.70	20.17	14.14	54.12	28.95
107	151.65	149.10	20.17	14.14	54.12	28.95
108	159.30	142.47	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	142.47	46.90	6.46	56.26	44.91
112	251.01	248.88	27.16	27.16	75.30	75.30
113	159.30	116.35	31.48	6.46	56.26	44.91
114	159.30	116.35	31.48	6.46	56.26	44.91
115	159.30	48.27	14.74	6.46	56.26	44.91
116	159.30	48.27	14.74	6.46	56.26	44.91
201	378.22	58.94	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	142.47	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	142.47	46.90	6.46	56.26	44.91
212	251.01	248.88	27.16	27.16	75.30	75.30
213	159.30	116.35	31.48	6.46	56.26	44.91
214	159.30	116.35	31.48	6.46	56.26	44.91
215	159.30	48.27	14.88	6.46	56.26	44.91
216	159.30	48.27	14.88	6.46	56.26	44.91
301	378.22	58.94	62.23	62.23	113.47	113.47
302	251.01	248.88	27.16	27.16	75.30	75.30
303	151.65	150.70	20.17	14.14	54.12	28.95
304	151.65	145.15	20.17	14.14	54.12	28.95
305	151.65	149.10	20.17	14.14	54.12	28.95
306	151.65	150.70	20.17	14.14	54.12	28.95
307	151.65	149.10	20.17	14.14	54.12	28.95
308	159.30	55.15	46.90	6.46	56.26	44.91
309	75.10	66.32	4.25	4.25	22.53	22.53
310	151.65	145.15	20.17	14.14	54.12	28.95
311	159.30	55.15	46.90	6.46	56.26	44.91
312	251.01	248.88	27.16	27.16	75.30	75.30
313	159.30	116.35	33.31	6.46	56.26	44.91
314	159.30	116.35	34.23	6.46	56.26	44.91
315	159.30	48.27	14.74	6.46	56.26	44.91
316	159.30	48.27	14.74	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	0.222	0.473	0.047	0.011	0.002	0.636	#13	0.897	Not Required	Pass
2	0.002	0.346	0.044	0.075	0.007	0.379	#21	0.036	Not Required	Pass
3	0.002	0.550	0.013	0.054	0.005	0.553	#21	0.046	Not Required	Pass

4	0.002	0.492	0.042	0.049	0.010	0.528	#21	0.082	Not Required	Pass
5	0.002	0.341	0.035	0.055	0.009	0.346	#21	0.076	Not Required	Pass
6	0.003	0.664	0.030	0.067	0.006	0.695	#21	0.046	Not Required	Pass
7	0.003	0.411	0.077	0.066	0.020	0.429	#21	0.076	Not Required	Pass
8	0.001	0.089	0.101	0.038	0.007	0.117	#13	0.102	Not Required	Pass
9	0.006	0.077	0.028	0.003	0.001	0.108	#21	0.206	Not Required	Pass
10	0.004	0.578	0.070	0.058	0.014	0.602	#21	0.082	Not Required	Pass
11	0.002	0.091	0.103	0.044	0.007	0.121	#13	0.102	Not Required	Pass
12	0.001	0.453	0.050	0.091	0.010	0.491	#21	0.054	Not Required	Pass
13	0.003	0.184	0.203	0.055	0.009	0.290	#21	0.306	Not Required	Pass
14	0.003	0.161	0.201	0.048	0.009	0.299	#24	0.204	Not Required	Pass
15	0.000	0.053	0.046	0.023	0.004	0.099	#21	Not Required	Not Required	Pass
16	0.000	0.047	0.046	0.021	0.004	0.093	#21	Not Required	Not Required	Pass
101	0.278	0.548	0.006	0.013	0.000	0.742	#13	0.897	Not Required	Pass
102	0.002	0.515	0.058	0.106	0.009	0.562	#21	0.054	Not Required	Pass
103	0.003	0.763	0.019	0.076	0.001	0.783	#21	0.046	Not Required	Pass
104	0.004	0.696	0.079	0.070	0.016	0.745	#21	0.082	Not Required	Pass
105	0.004	0.473	0.083	0.075	0.022	0.494	#21	0.076	Not Required	Pass
106	0.003	0.757	0.019	0.076	0.004	0.770	#21	0.046	Not Required	Pass
107	0.003	0.470	0.069	0.075	0.018	0.490	#21	0.076	Not Required	Pass
108	0.002	0.072	0.085	0.042	0.007	0.157	#21	0.102	Not Required	Pass
109	0.009	0.078	0.022	0.001	0.001	0.104	#21	0.206	Not Required	Pass
110	0.003	0.678	0.068	0.068	0.014	0.722	#21	0.082	Not Required	Pass
111	0.002	0.066	0.086	0.047	0.007	0.152	#21	0.102	Not Required	Pass
112	0.002	0.503	0.059	0.104	0.011	0.549	#21	0.054	Not Required	Pass
113	0.003	0.280	0.222	0.061	0.009	0.471	#21	0.306	Not Required	Pass
114	0.004	0.280	0.221	0.056	0.009	0.471	#21	0.306	Not Required	Pass
115	0.006	0.559	0.118	0.050	0.008	0.667	#21	0.644	Not Required	Pass
116	0.004	0.497	0.117	0.046	0.008	0.595	#21	0.644	Not Required	Pass
201	0.278	0.548	0.006	0.013	0.000	0.742	#13	0.897	Not Required	Pass
202	0.002	0.503	0.059	0.104	0.011	0.549	#21	0.054	Not Required	Pass
203	0.003	0.757	0.019	0.076	0.004	0.770	#21	0.046	Not Required	Pass
204	0.003	0.678	0.068	0.068	0.014	0.722	#21	0.082	Not Required	Pass
205	0.003	0.470	0.069	0.075	0.018	0.490	#21	0.076	Not Required	Pass
206	0.003	0.763	0.019	0.076	0.001	0.783	#21	0.046	Not Required	Pass
207	0.004	0.473	0.083	0.075	0.022	0.494	#21	0.076	Not Required	Pass
208	0.001	0.062	0.117	0.046	0.008	0.179	#21	0.102	Not Required	Pass
209	0.009	0.078	0.022	0.001	0.001	0.104	#21	0.206	Not Required	Pass
210	0.004	0.696	0.079	0.070	0.016	0.745	#21	0.082	Not Required	Pass
211	0.002	0.059	0.118	0.050	0.008	0.171	#21	0.102	Not Required	Pass
212	0.002	0.515	0.058	0.106	0.009	0.562	#21	0.054	Not Required	Pass
213	0.003	0.280	0.222	0.061	0.009	0.471	#21	0.306	Not Required	Pass
214	0.004	0.280	0.221	0.056	0.009	0.471	#21	0.306	Not Required	Pass
215	0.007	0.438	0.099	0.047	0.007	0.534	#21	0.644	Not Required	Pass
216	0.006	0.346	0.099	0.042	0.007	0.446	#21	0.644	Not Required	Pass
301	0.222	0.473	0.047	0.011	0.002	0.636	#13	0.897	Not Required	Pass
302	0.001	0.453	0.050	0.091	0.010	0.491	#21	0.054	Not Required	Pass
303	0.003	0.664	0.030	0.067	0.006	0.695	#21	0.046	Not Required	Pass
304	0.004	0.578	0.070	0.058	0.014	0.602	#21	0.082	Not Required	Pass
305	0.003	0.411	0.077	0.066	0.020	0.429	#21	0.076	Not Required	Pass
306	0.002	0.550	0.013	0.054	0.005	0.553	#21	0.046	Not Required	Pass
307	0.002	0.341	0.035	0.055	0.009	0.346	#21	0.076	Not Required	Pass
308	0.000	0.047	0.046	0.021	0.004	0.093	#21	Not Required	Not Required	Pass
309	0.006	0.077	0.028	0.003	0.001	0.108	#21	0.206	Not Required	Pass

309	0.000	0.077	0.028	0.003	0.001	0.108	#21	0.206	Not Required	Pass
310	0.002	0.492	0.042	0.049	0.010	0.528	#21	0.082	Not Required	Pass
311	0.000	0.053	0.046	0.023	0.004	0.099	#21	Not Required	Not Required	Pass
312	0.002	0.346	0.044	0.075	0.007	0.379	#21	0.036	Not Required	Pass
313	0.003	0.184	0.203	0.055	0.009	0.290	#21	0.204	Not Required	Pass
314	0.003	0.161	0.201	0.048	0.009	0.299	#24	0.306	Not Required	Pass
315	0.006	0.586	0.103	0.044	0.007	0.688	#21	0.644	Not Required	Pass
316	0.004	0.523	0.101	0.038	0.007	0.625	#21	0.644	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

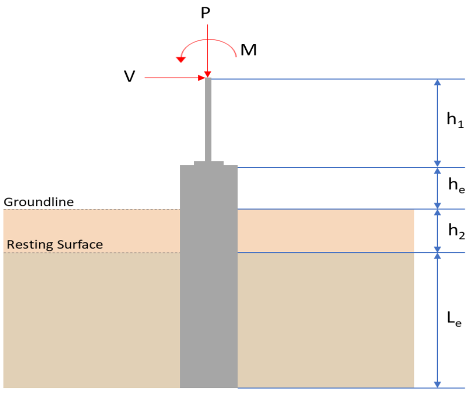
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48$ in - Pile width
$D = 48$ in - Pile depth
$L = 5.75$ ft - Total pile length
$h_1 = 0$ ft - Lateral load height from the top of the pile,
$h_2 = 0$ ft - Depth to resisting surface
$h_e = 0$ ft - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	8.757	13.090
V_x (kip)	-0.748	-1.254
V_z (kip)	0.185	0.280
M_x (kipft)	0.944	1.440
M_z (kipft)	16.393	29.428

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.748 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.11911 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(16.393\ \text{kipft}) + ((-0.748\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 2.6104\ \text{kipft/ft}$$

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:
$L_{e,x} = 5.532\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.185\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.029459\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.944\ \text{kipft}) + ((0.185\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.15032\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 2.5473\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(5.532\ \text{ft}), (2.5473\ \text{ft})]$$

$$L_{e,req} = 5.532\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (5.75\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 5.75\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(5.532\ \text{ft})}{(5.75\ \text{ft})}$$

$$Ratio = 0.96209$$

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

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

$$q = \frac{(8.757\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.54731\ \text{kip/ft}^2$$

$q = 0.54731\ \text{kip/ft}^2$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.54731\ \text{kip/ft}^2\right)}{(2000\ \text{psf})}$$

$$Ratio = 0.27366$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(5.75\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 1.4375$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.11911\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 2.6104\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.6104\ \text{kipft/ft}) \times (5.75\ \text{ft})) + \left(3 \times (-0.11911\ \text{kip/ft}) \times (5.75\ \text{ft})^2\right)}{(6 \times (2.6104\ \text{kipft/ft})) + (4 \times (-0.11911\ \text{kip/ft}) \times (5.75\ \text{ft}))}$$

$$a = 3.9047\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (2.6104\ \text{kipft/ft})) + (3 \times (-0.11911\ \text{kip/ft}) \times (5.75\ \text{ft}))]^{\ 2}}{(5.75\ \text{ft})^2 \times [(3 \times (2.6104\ \text{kipft/ft})) + (2 \times (-0.11911\ \text{kip/ft}) \times (5.75\ \text{ft}))]}$$

$$p = 0.24694\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (2.6104\ \text{kipft/ft})) + ((-0.11911\ \text{kip/ft}) \times (5.75\ \text{ft}))]}{(5.75\ \text{ft})^2}$$

$$s = 0.82314\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(3.9047\ \text{ft})}{2}$$

$$p_a = 0.29285\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.24694\ \text{kip/ft}^2\right)}{\left(0.29285\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.84324$$

Status: **PASS**
Ratio: **0.840**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (5.75\ \mathrm{ft})$$

$$p_s = 0.8625\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.82314\ \mathrm{kip/ft^2}\right)}{\left(0.8625\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.95436$$

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

Considering z-direction:

$H_o = 0.029459\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.15032\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.15032\ \mathrm{kipft/ft}) \times (5.75\ \mathrm{ft})) + \left(3 \times (0.029459\ \mathrm{kip/ft}) \times (5.75\ \mathrm{ft})^2\right)}{(6 \times (0.15032\ \mathrm{kipft/ft})) + (4 \times (0.029459\ \mathrm{kip/ft}) \times (5.75\ \mathrm{ft}))}$$

$$a = 4.0389\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.15032\ \mathrm{kipft/ft})) + (3 \times (0.029459\ \mathrm{kip/ft}) \times (5.75\ \mathrm{ft}))]^{\,2}}{(5.75\ \mathrm{ft})^2 \times [(3 \times (0.15032\ \mathrm{kipft/ft})) + (2 \times (0.029459\ \mathrm{kip/ft}) \times (5.75\ \mathrm{ft}))]}$$

$$p = 0.035355\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.15032\ \mathrm{kipft/ft})) + ((0.029459\ \mathrm{kip/ft}) \times (5.75\ \mathrm{ft}))]}{(5.75\ \mathrm{ft})^2}$$

$$s = 0.085297\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.0389\ \mathrm{ft})}{2}$$

$$p_a = 0.30292\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.035355\ \mathrm{kip/ft^2}\right)}{\left(0.30292\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.11672$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (5.75\ \mathrm{ft})$$

$$p_s = 0.8625\ \mathrm{kip/ft^2}$$

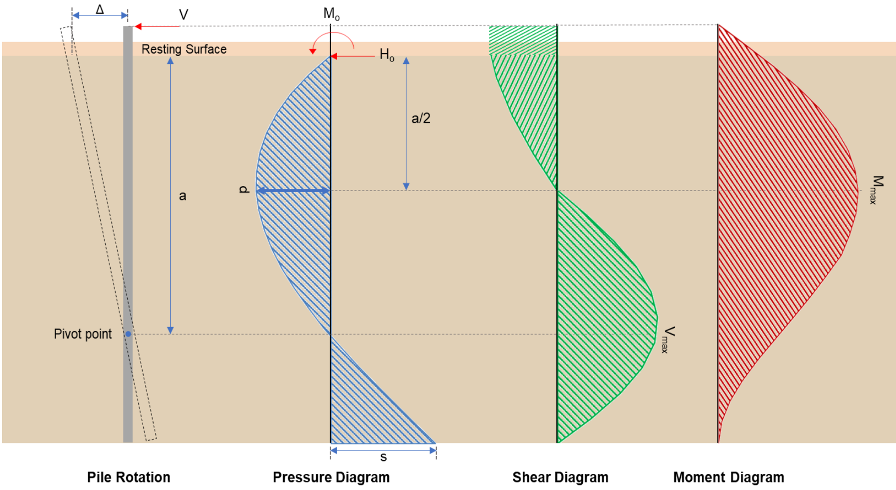
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.085297\ \text{kip/ft}^2)}{(0.8625\ \text{kip/ft}^2)}$$

$$Ratio = 0.098895$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.254\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.19968\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(29.428\ \text{kipft}) + ((-1.254\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 4.686\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(4.686\ \text{kipft/ft})}{(-0.19968\ \text{kip/ft})}$$

$$E = 23.467\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.686\ \text{kipft/ft}) \times (5.75\ \text{ft})) + \left(3 \times (-0.19968\ \text{kip/ft}) \times (5.75\ \text{ft})^2\right)}{(6 \times (4.686\ \text{kipft/ft})) + (4 \times (-0.19968\ \text{kip/ft}) \times (5.75\ \text{ft}))}$$

$$a = 3.9006\ \text{ft}$$

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

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

$$V_{max} = ((-0.19968\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (23.467\ \text{ft})}{(5.75\ \text{ft})} + 3\right) \times \left(\frac{(3.9006\ \text{ft})}{(5.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (23.467\ \text{ft})}{(5.75\ \text{ft})} + 2\right) \times \left(\frac{(3.9006\ \text{ft})}{(5.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 6.3044\ \text{kip}$$

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

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

$$M_{max} = ((-0.19968\text{ kip/ft}) \times (48\text{ in}) \times (5.75\text{ ft})) \times \left[\left(\frac{(23.467\text{ ft})}{(5.75\text{ ft})} + \frac{(3.9006\text{ ft})}{2 \times (5.75\text{ ft})}\right) - \left[\left(\frac{4 \times (23.467\text{ ft})}{(5.75\text{ ft})} + 3\right) \times \left(\frac{(3.9006\text{ ft})}{2 \times (5.75\text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (23.467\text{ ft})}{(5.75\text{ ft})} + 2\right) \times \left(\frac{(3.9006\text{ ft})}{2 \times (5.75\text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 17.704\text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.28\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = 0.044586\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.44\text{ kipft}) + ((0.28\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 0.2293\text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.2293\text{ kipft/ft})}{(0.044586\text{ kip/ft})}$$

$$E = 5.1429\text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.2293\text{ kipft/ft}) \times (5.75\text{ ft})) + \left(3 \times (0.044586\text{ kip/ft}) \times (5.75\text{ ft})^2\right)}{(6 \times (0.2293\text{ kipft/ft})) + (4 \times (0.044586\text{ kip/ft}) \times (5.75\text{ ft}))}$$

$$a = 4.038\text{ ft}$$

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

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

$$V_{max} = ((0.044586\text{ kip/ft}) \times (48\text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (5.1429\text{ ft})}{(5.75\text{ ft})} + 3\right) \times \left(\frac{(4.038\text{ ft})}{(5.75\text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (5.1429\text{ ft})}{(5.75\text{ ft})} + 2\right) \times \left(\frac{(4.038\text{ ft})}{(5.75\text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.40018\text{ kip}$$

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

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

$$M_{max} = ((0.044586\text{ kip/ft}) \times (48\text{ in}) \times (5.75\text{ ft})) \times \left[\left(\frac{(5.1429\text{ ft})}{(5.75\text{ ft})} + \frac{(4.038\text{ ft})}{2 \times (5.75\text{ ft})}\right) - \left[\left(\frac{4 \times (5.1429\text{ ft})}{(5.75\text{ ft})} + 3\right) \times \left(\frac{(4.038\text{ ft})}{2 \times (5.75\text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (5.1429\text{ ft})}{(5.75\text{ ft})} + 2\right) \times \left(\frac{(4.038\text{ ft})}{2 \times (5.75\text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 1.0583 \text{ kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(13.09 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.161 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.161 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

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

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(13.09\text{ kip})}{(2675.2\text{ kip})}$$

$$Ratio = 0.0048931$$

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 $f'_{ck} = 2.5\text{ ksi} \rightarrow 2500\text{ psi}$, $P = 13.09\text{ kip} \rightarrow 13090\text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\text{ psi})} + \frac{(13090\text{ lbf})}{6 \times (2304\text{ in}^2)}\right] \times (48\text{ in}) \times (38.4\text{ in})$$

$$V_{c,a} = 120.23\text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\text{ kip}), (120.23\text{ kip}), (348.89\text{ kip})\right]$$

$$V_c = 120.23\text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((120.23\ \mathrm{kip}) + (50.894\ \mathrm{kip}))$$

$$\phi V_n = 111.23\ \mathrm{kip}$$

Considering x-direction:

$V_{max} = 6.3044\ \mathrm{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(6.3044\ \mathrm{kip})}{(111.23\ \mathrm{kip})}$$

$$Ratio = 0.056678$$

Status: **PASS**
Ratio: **0.060**

Considering z-direction:

$V_{max} = 0.40018\ \mathrm{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.40018\ \mathrm{kip})}{(111.23\ \mathrm{kip})}$$

$$Ratio = 0.0035977$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

	$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f'_c)} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f'_{ck}\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \mathrm{ksi}) \times \left(18432\ \mathrm{in}^3\right)$$ $$\phi M_{n,2} = 2121.6\ \mathrm{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\ \mathrm{kipft}), (2121.6\ \mathrm{kipft})]$$ $$\phi M_n = 249.6\ \mathrm{kipft}$$ **Considering x-direction:** $M_{max} = 17.704\ \mathrm{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(17.704\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$ $$Ratio = 0.07093$$	Status: **PASS** Ratio: **0.070**
	Considering z-direction: $M_{max} = 1.0583\ \mathrm{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(1.0583\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$ $$Ratio = 0.0042399$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

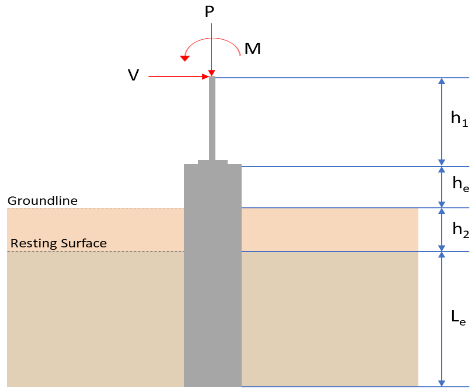
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 5.75\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	8.757	13.090
V_x (kip)	-0.748	-1.254
V_z (kip)	-0.185	-0.280
M_x (kipft)	-0.944	-1.440
M_z (kipft)	16.393	29.429

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,

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

$$H_o = \frac{(-0.748\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.11911\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(16.393\ \text{kipft}) + ((-0.748\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 2.6104\ \text{kipft/ft}$$

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:
$L_{e,x} = 5.532\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.185\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.029459\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.944\ \text{kipft}) + ((-0.185\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.15032\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 2.0351\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(5.532\ \text{ft}), (2.0351\ \text{ft})]$$

$$L_{e,req} = 5.532\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (5.75\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 5.75\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(5.532\ \text{ft})}{(5.75\ \text{ft})}$$

$$Ratio = 0.96209$$

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

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

$$q = \frac{(8.757\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.54731\ \text{kip/ft}^2$$

$q = 0.54731\ \mathrm{kip/ft}^2$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.54731\ \mathrm{kip/ft^2})}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.27366$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(5.75\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1.4375$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.11911\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 2.6104\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.6104\ \mathrm{kipft/ft}) \times (5.75\ \mathrm{ft})) + \left(3 \times (-0.11911\ \mathrm{kip/ft}) \times (5.75\ \mathrm{ft})^2\right)}{(6 \times (2.6104\ \mathrm{kipft/ft})) + (4 \times (-0.11911\ \mathrm{kip/ft}) \times (5.75\ \mathrm{ft}))}$$

$$a = 3.9047\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (2.6104\ \mathrm{kipft/ft})) + (3 \times (-0.11911\ \mathrm{kip/ft}) \times (5.75\ \mathrm{ft}))]^2}{(5.75\ \mathrm{ft})^2 \times [(3 \times (2.6104\ \mathrm{kipft/ft})) + (2 \times (-0.11911\ \mathrm{kip/ft}) \times (5.75\ \mathrm{ft}))]}$$

$$p = 0.24694\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (2.6104\ \mathrm{kipft/ft})) + ((-0.11911\ \mathrm{kip/ft}) \times (5.75\ \mathrm{ft}))]}{(5.75\ \mathrm{ft})^2}$$

$$s = 0.82314\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(3.9047\ \mathrm{ft})}{2}$$

$$p_a = 0.29285\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.24694\ \mathrm{kip/ft^2})}{(0.29285\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.84324$$

Status: **PASS**
Ratio: **0.840**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (5.75\ \mathrm{ft})$$

$$p_s = 0.8625\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.82314\ \mathrm{kip/ft^2})}{(0.8625\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.95436$$

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

Considering z-direction:

$H_o = -0.029459\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.15032\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.15032\ \mathrm{kipft/ft}) \times (5.75\ \mathrm{ft})) + \left(3 \times (-0.029459\ \mathrm{kip/ft}) \times (5.75\ \mathrm{ft})^2\right)}{(6 \times (0.15032\ \mathrm{kipft/ft})) + (4 \times (-0.029459\ \mathrm{kip/ft}) \times (5.75\ \mathrm{ft}))}$$

$$a = 4.0389\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.15032\ \mathrm{kipft/ft})) + (3 \times (-0.029459\ \mathrm{kip/ft}) \times (5.75\ \mathrm{ft}))]^{\,2}}{(5.75\ \mathrm{ft})^2 \times [(3 \times (0.15032\ \mathrm{kipft/ft})) + (2 \times (-0.029459\ \mathrm{kip/ft}) \times (5.75\ \mathrm{ft}))]}$$

$$p = 0.0017532\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.15032\ \mathrm{kipft/ft})) + ((-0.029459\ \mathrm{kip/ft}) \times (5.75\ \mathrm{ft}))]}{(5.75\ \mathrm{ft})^2}$$

$$s = 0.023819\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.0389\ \mathrm{ft})}{2}$$

$$p_a = 0.30292\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0017532\ \mathrm{kip/ft^2})}{(0.30292\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.0057877$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (5.75\ \mathrm{ft})$$

$$p_s = 0.8625\ \mathrm{kip/ft^2}$$

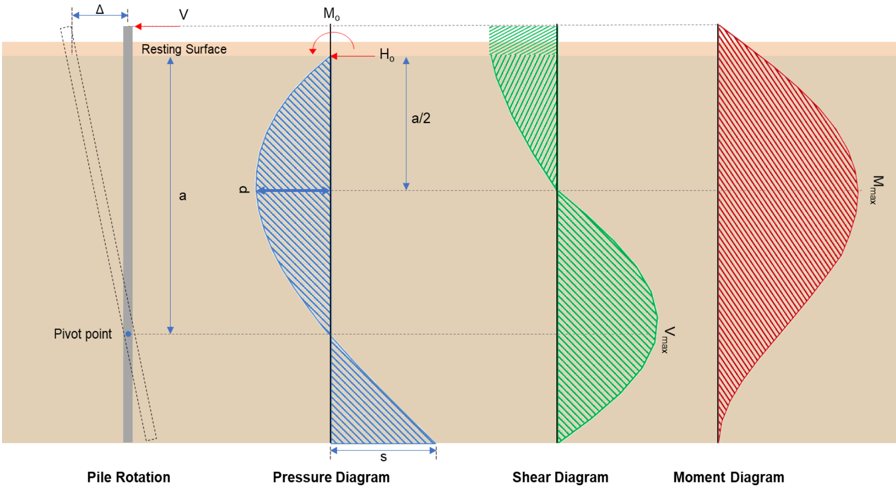
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.023819\ \mathrm{kip/ft^2})}{(0.8625\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.027616$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.254\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.19968\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(29.429\ \mathrm{kipft}) + ((-1.254\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 4.6861\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(4.6861\ \mathrm{kipft/ft})}{(-0.19968\ \mathrm{kip/ft})}$$

$$E = 23.468\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.6861\ \mathrm{kipft/ft}) \times (5.75\ \mathrm{ft})) + \left(3 \times (-0.19968\ \mathrm{kip/ft}) \times (5.75\ \mathrm{ft})^2\right)}{(6 \times (4.6861\ \mathrm{kipft/ft})) + (4 \times (-0.19968\ \mathrm{kip/ft}) \times (5.75\ \mathrm{ft}))}$$

$$a = 3.9006\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.19968\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (23.468\ \mathrm{ft})}{(5.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(3.9006\ \mathrm{ft})}{(5.75\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (23.468\ \mathrm{ft})}{(5.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(3.9006\ \mathrm{ft})}{(5.75\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 6.3046\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.19968\ \text{kip/ft}) \times (48\ \text{in}) \times (5.75\ \text{ft})) \times \left[\left(\frac{(23.468\ \text{ft})}{(5.75\ \text{ft})} + \frac{(3.9006\ \text{ft})}{2 \times (5.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (23.468\ \text{ft})}{(5.75\ \text{ft})} + 3\right) \times \left(\frac{(3.9006\ \text{ft})}{2 \times (5.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (23.468\ \text{ft})}{(5.75\ \text{ft})} + 2\right) \times \left(\frac{(3.9006\ \text{ft})}{2 \times (5.75\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 17.705\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.28\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.044586\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.44\ \text{kipft}) + ((-0.28\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.2293\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.2293\ \text{kipft/ft})}{(-0.044586\ \text{kip/ft})}$$

$$E = 5.1429\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.2293\ \text{kipft/ft}) \times (5.75\ \text{ft})) + \left(3 \times (-0.044586\ \text{kip/ft}) \times (5.75\ \text{ft})^2\right)}{(6 \times (0.2293\ \text{kipft/ft})) + (4 \times (-0.044586\ \text{kip/ft}) \times (5.75\ \text{ft}))}$$

$$a = 4.038\ \text{ft}$$

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

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

$$V_{max} = ((-0.044586\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (5.1429\ \text{ft})}{(5.75\ \text{ft})} + 3\right) \times \left(\frac{(4.038\ \text{ft})}{(5.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (5.1429\ \text{ft})}{(5.75\ \text{ft})} + 2\right) \times \left(\frac{(4.038\ \text{ft})}{(5.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.40018\ \text{kip}$$

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

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

$$M_{max} = ((-0.044586\ \text{kip/ft}) \times (48\ \text{in}) \times (5.75\ \text{ft})) \times \left[\left(\frac{(5.1429\ \text{ft})}{(5.75\ \text{ft})} + \frac{(4.038\ \text{ft})}{2 \times (5.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (5.1429\ \text{ft})}{(5.75\ \text{ft})} + 3\right) \times \left(\frac{(4.038\ \text{ft})}{2 \times (5.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (5.1429\ \text{ft})}{(5.75\ \text{ft})} + 2\right) \times \left(\frac{(4.038\ \text{ft})}{2 \times (5.75\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 1.0583 \text{ kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(13.09\text{ kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5\text{ ksi}) \times (2304\text{ in}^2))}{(60\text{ ksi}) - (0.85 \times (2.5\text{ ksi}))}, (0.08 \times (2304\text{ in}^2))\right]$$

$$A_{st,required} = -84.161 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.161\text{ in}^2), (0.0018 \times (2304\text{ in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

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

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

	Axial Compression Strength (ACI 318-19, LRFD)	
22.4.2.2	ϕP_N - Allowable axial compressive strength $$\phi P_N = \phi\, 0.80\, \left[\left(0.85\, f'_{ck}\, \left[A_g - A_{st}\right]\right) + \left(f_{yk}\, A_{st}\right)\right]$$ $$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(2304\ \text{in}^2\right) - \left(4.2951\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(4.2951\ \text{in}^2\right)\right)\right]$$ $$\phi P_N = 2675.2\ \text{kip}$$ $Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(13.09\ \text{kip})}{(2675.2\ \text{kip})}$$ $$Ratio = 0.0048931$$	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 $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 13.09\ \text{kip} \rightarrow 13090\ \text{lbf}$,	
22.5.5.1.1(a)	$V_{c,a}$ - Shear strength of concrete (a) $$V_{c,a} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \frac{P}{6\, A_g}\right]\, b_w\, d$$ $$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(13090\ \text{lbf})}{6 \times (2304\ \text{in}^2)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$ $$V_{c,a} = 120.23\ \text{kip}$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,	
22.5.5.1.2	$V_{c,b}$ - Shear strength of concrete (b) $$V_{c,b} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \left(0.05\, f'_{ck}\right)\right]\, b_w\, d$$ $$V_{c,b} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + (0.05 \times (2500\ \text{psi}))\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$ $$V_{c,b} = 348.89\ \text{kip}$$ V_c - Governing shear strength of concrete $$V_c = Min\left[V_{c,max}, V_{c,a}, V_{c,b}\right]$$ $$V_c = Min\left[(296.21\ \text{kip}), (120.23\ \text{kip}), (348.89\ \text{kip})\right]$$ $$V_c = 120.23\ \text{kip}$$	

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((120.23\ \mathrm{kip}) + (50.894\ \mathrm{kip}))$$

$$\phi V_n = 111.23\ \mathrm{kip}$$

Considering x-direction:

$V_{max} = 6.3046\ \mathrm{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(6.3046\ \mathrm{kip})}{(111.23\ \mathrm{kip})}$$

$$Ratio = 0.05668$$

Status: **PASS**
Ratio: **0.060**

Considering z-direction:

$V_{max} = 0.40018\ \mathrm{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.40018\ \mathrm{kip})}{(111.23\ \mathrm{kip})}$$

$$Ratio = 0.0035977$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

<table>
<tr><td></td><td>

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

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

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

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

</td><td></td></tr>
<tr><td>*14.5.2.1b*</td><td>

$\phi M_{n,2}$

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

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

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

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:

$M_{max} = 17.705 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(17.705 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.070933$$

</td><td>Status: **PASS**
Ratio: **0.070**</td></tr>
<tr><td></td><td>

Considering z-direction:

$M_{max} = 1.0583 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(1.0583 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.0042399$$

</td><td>Status: **PASS**
Ratio: **0.000**</td></tr>
</table>

REFERENCES	CALCULATIONS	RESULTS

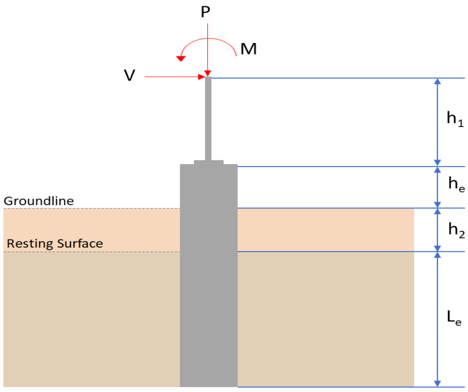
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48$ in - Pile width
$D = 48$ in - Pile depth
$L = 6$ ft - Total pile length
$h_1 = 0$ ft - Lateral load height from the top of the pile,
$h_2 = 0$ ft - Depth to resisting surface
$h_e = 0$ ft - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	10.919	16.382
V_x (kip)	-0.867	-1.440
V_z (kip)	-0.020	-0.033
M_x (kipft)	-0.104	-0.170
M_z (kipft)	18.886	34.098

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.867 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.13806 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(18.886 \text{ kipft}) + ((-0.867 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 3.0073 \text{ kipft/ft}$$

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:
$L_{e,x} = 5.7764 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.02 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0031847 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.104 \text{ kipft}) + ((-0.02 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.016561 \text{ kipft/ft}$$

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:
$L_{e,z} = 1.0404 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(5.7764 \text{ ft}), (1.0404 \text{ ft})]$$

$$L_{e,req} = 5.776 \text{ ft}$$

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

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

$$Ratio = \frac{(5.776 \text{ ft})}{(6 \text{ ft})}$$

$$Ratio = 0.96267$$

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

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

$$q = \frac{(10.919 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.68244 \text{ kip/ft}^2$$

$q = 0.68244\ \text{kip/ft}$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.68244\ \text{kip/ft}^2\right)}{(2000\ \text{psf})}$$

$$Ratio = 0.34122$$

Status: **PASS**
Ratio: **0.340**

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:

$H_o = -0.13806\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 3.0073\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (3.0073\ \text{kipft/ft}) \times (6\ \text{ft})) + \left(3 \times (-0.13806\ \text{kip/ft}) \times (6\ \text{ft})^2\right)}{(6 \times (3.0073\ \text{kipft/ft})) + (4 \times (-0.13806\ \text{kip/ft}) \times (6\ \text{ft}))}$$

$$a = 4.0776\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (3.0073\ \text{kipft/ft})) + (3 \times (-0.13806\ \text{kip/ft}) \times (6\ \text{ft}))]^{\ 2}}{(6\ \text{ft})^2 \times [(3 \times (3.0073\ \text{kipft/ft})) + (2 \times (-0.13806\ \text{kip/ft}) \times (6\ \text{ft}))]}$$

$$p = 0.25766\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (3.0073\ \text{kipft/ft})) + ((-0.13806\ \text{kip/ft}) \times (6\ \text{ft}))]}{(6\ \text{ft})^2}$$

$$s = 0.86438\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(4.0776\ \text{ft})}{2}$$

$$p_a = 0.30582\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.25766\ \text{kip/ft}^2\right)}{\left(0.30582\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.84254$$

Status: **PASS**
Ratio: **0.840**

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

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

$$Ratio = \frac{(0.86438\ \mathrm{kip/ft^2})}{(0.9\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.96043$$

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

Considering z-direction:

$H_o = -0.0031847\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.016561\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.016561\ \mathrm{kipft/ft}) \times (6\ \mathrm{ft})) + \left(3 \times (-0.0031847\ \mathrm{kip/ft}) \times (6\ \mathrm{ft})^2\right)}{(6 \times (0.016561\ \mathrm{kipft/ft})) + (4 \times (-0.0031847\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))}$$

$$a = 4.2174\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.016561\ \mathrm{kipft/ft})) + (3 \times (-0.0031847\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))]^2}{(6\ \mathrm{ft})^2 \times [(3 \times (0.016561\ \mathrm{kipft/ft})) + (2 \times (-0.0031847\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))]}$$

$$p = 0.00014449\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.016561\ \mathrm{kipft/ft})) + ((-0.0031847\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))]}{(6\ \mathrm{ft})^2}$$

$$s = 0.0023355\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.2174\ \mathrm{ft})}{2}$$

$$p_a = 0.3163\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.00014449\ \mathrm{kip/ft^2})}{(0.3163\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.00045681$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

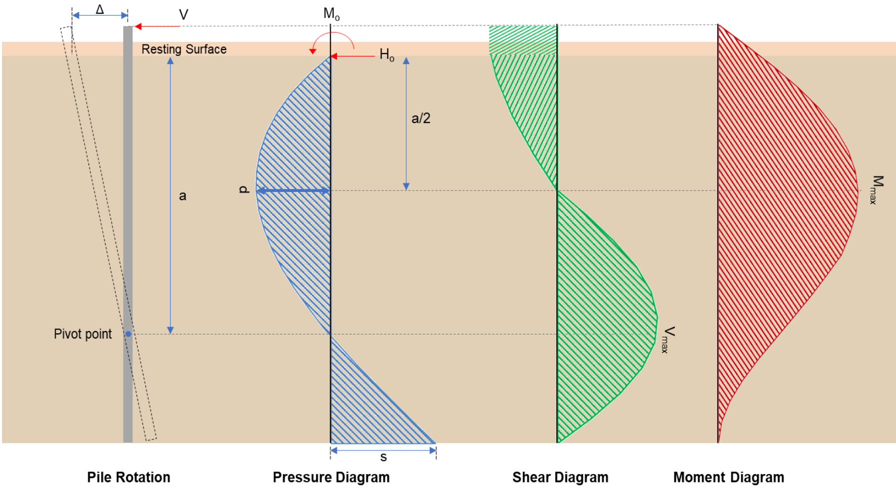
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0023355 \text{ kip/ft}^2)}{(0.9 \text{ kip/ft}^2)}$$

$$Ratio = 0.002595$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.44 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.2293 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(34.098 \text{ kipft}) + ((-1.44 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 5.4296 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(5.4296 \text{ kipft/ft})}{(-0.2293 \text{ kip/ft})}$$

$$E = 23.679 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.4296 \text{ kipft/ft}) \times (6 \text{ ft})) + \left(3 \times (-0.2293 \text{ kip/ft}) \times (6 \text{ ft})^2\right)}{(6 \times (5.4296 \text{ kipft/ft})) + (4 \times (-0.2293 \text{ kip/ft}) \times (6 \text{ ft}))}$$

$$a = 4.0723 \text{ ft}$$

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

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

$$V_{max} = ((-0.2293 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (23.679 \text{ ft})}{(6 \text{ ft})} + 3\right) \times \left(\frac{(4.0723 \text{ ft})}{(6 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (23.679 \text{ ft})}{(6 \text{ ft})} + 2\right) \times \left(\frac{(4.0723 \text{ ft})}{(6 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 7.02 \text{ kip}$$

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

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

$$M_{max} = ((-0.2293 \text{ kip/ft}) \times (48 \text{ in}) \times (6 \text{ ft})) \times \left[\left(\frac{(23.679 \text{ ft})}{(6 \text{ ft})} + \frac{(4.0723 \text{ ft})}{2 \times (6 \text{ ft})} \right) - \left[\left(\frac{4 \times (23.679 \text{ ft})}{(6 \text{ ft})} + 3 \right) \times \left(\frac{(4.0723 \text{ ft})}{2 \times (6 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (23.679 \text{ ft})}{(6 \text{ ft})} + 2 \right) \times \left(\frac{(4.0723 \text{ ft})}{2 \times (6 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 20.556 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.033 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0052548 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.17 \text{ kipft}) + ((-0.033 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.02707 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.02707 \text{ kipft/ft})}{(-0.0052548 \text{ kip/ft})}$$

$$E = 5.1515 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.02707 \text{ kipft/ft}) \times (6 \text{ ft})) + \left(3 \times (-0.0052548 \text{ kip/ft}) \times (6 \text{ ft})^2\right)}{(6 \times (0.02707 \text{ kipft/ft})) + (4 \times (-0.0052548 \text{ kip/ft}) \times (6 \text{ ft}))}$$

$$a = 4.2185 \text{ ft}$$

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

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

$$V_{max} = ((-0.0052548 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (5.1515 \text{ ft})}{(6 \text{ ft})} + 3 \right) \times \left(\frac{(4.2185 \text{ ft})}{(6 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (5.1515 \text{ ft})}{(6 \text{ ft})} + 2 \right) \times \left(\frac{(4.2185 \text{ ft})}{(6 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.045837 \text{ kip}$$

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

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

$$M_{max} = ((-0.0052548 \text{ kip/ft}) \times (48 \text{ in}) \times (6 \text{ ft})) \times \left[\left(\frac{(5.1515 \text{ ft})}{(6 \text{ ft})} + \frac{(4.2185 \text{ ft})}{2 \times (6 \text{ ft})} \right) - \left[\left(\frac{4 \times (5.1515 \text{ ft})}{(6 \text{ ft})} + 3 \right) \times \left(\frac{(4.2185 \text{ ft})}{2 \times (6 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (5.1515 \text{ ft})}{(6 \text{ ft})} + 2 \right) \times \left(\frac{(4.2185 \text{ ft})}{2 \times (6 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.12617 \text{ kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(16.382 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.052 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.052 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

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

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(16.382\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0061237$$

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 $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 16.382\ \text{kip} \rightarrow 16382\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(16382\ \text{lbf})}{6 \times \left(2304\ \text{in}^2\right)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 120.67\ \text{kip}$$

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

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

$$V_c = Min\left[(296.21\ \text{kip}), (120.67\ \text{kip}), (348.89\ \text{kip})\right]$$

$$V_c = 120.67\ \text{kip}$$

	The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$,	
22.5.1.2	$V_{s,a}$ - Shear strength of steel (a) $$V_{s,a} = 8\sqrt{f'_{ck}}\, b_w\, d$$ $$V_{s,a} = 8 \times \sqrt{(2500\ \mathrm{psi})} \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$ $$V_{s,a} = 737.28\ \mathrm{kip}$$ A_v - Ties rebar area, $$A_v = \frac{\pi\, d_{ties}^2}{4}$$ $$A_v = \frac{\pi \times (0.375\ \mathrm{in})^2}{4}$$ $$A_v = 0.11045\ \mathrm{in}^2$$	
22.5.8.5.3	$V_{s,b}$ - Shear strength of steel (b) $$V_{s,b} = \frac{2\, A_v\, f_{ywk}\, d}{s_{ties}}$$ $$V_{s,b} = \frac{2 \times \left(0.11045\ \mathrm{in}^2\right) \times (60\ \mathrm{ksi}) \times (38.4\ \mathrm{in})}{(10\ \mathrm{in})}$$ $$V_{s,b} = 50.894\ \mathrm{kip}$$ V_s - Governing shear strength of steel $$V_s = MIN\left[V_{s,a}, V_{s,b}\right]$$ $$V_s = MIN\left[(737.28\ \mathrm{kip}), (50.894\ \mathrm{kip})\right]$$ $$V_s = 50.894\ \mathrm{kip}$$	
22.5.1.1	ϕV_n - Allowable shear strength $$\phi V_n = \phi\ (V_c + V_s)$$ $$\phi V_n = (0.65) \times ((120.67\ \mathrm{kip}) + (50.894\ \mathrm{kip}))$$ $$\phi V_n = 111.52\ \mathrm{kip}$$ **Considering x-direction:** $V_{max} = 7.02\ \mathrm{kip}$ - Maximum shear force in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(7.02\ \mathrm{kip})}{(111.52\ \mathrm{kip})}$$ $$Ratio = 0.062951$$	Status: **PASS** Ratio: **0.060**
	Considering z-direction: $V_{max} = 0.045837\ \mathrm{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.045837\ \mathrm{kip})}{(111.52\ \mathrm{kip})}$$ $$Ratio = 0.00041103$$	Status: **PASS** Ratio: **0.000**
	Flexural Strength (ACI 318-19, LRFD) S_m - Section modulus $$S_m = \frac{b\, D^2}{6}$$ $$S_m = \frac{(48\ \mathrm{in}) \times (48\ \mathrm{in})^2}{6}$$ $$S_m = 18432\ \mathrm{in}^3$$	

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

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

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

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

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

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

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

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

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:

$M_{max} = 20.556 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(20.556 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.082355$$

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

Considering z-direction:

$M_{max} = 0.12617 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.12617 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.00050551$$

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

REFERENCES	CALCULATIONS	RESULTS

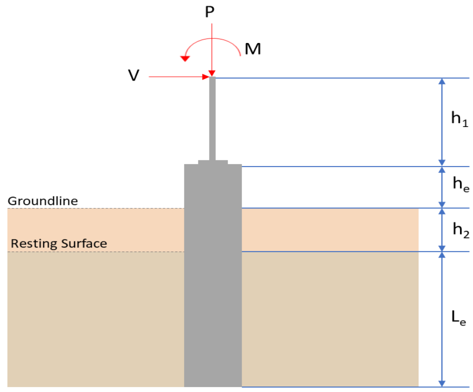
SkyCiv Foundation Design

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
$L = 6\ \text{ft}$ - Total pile length
$h_1 = 0\ \text{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \text{ft}$ - Depth to resisting surface
$h_e = 0\ \text{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	10.919	16.382
V_x (kip)	-0.867	-1.440
V_z (kip)	0.020	0.033
M_x (kipft)	0.104	0.170
M_z (kipft)	18.886	34.099

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.867\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.13806\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(18.886 \text{ kipft}) + ((-0.867 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 3.0073 \text{ kipft/ft}$$

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:
$L_{e,x} = 5.7764 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.02 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0031847 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.104 \text{ kipft}) + ((0.02 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.016561 \text{ kipft/ft}$$

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:
$L_{e,z} = 1.1561 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(5.7764 \text{ ft}), (1.1561 \text{ ft})]$$

$$L_{e,req} = 5.776 \text{ ft}$$

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

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

$$Ratio = \frac{(5.776 \text{ ft})}{(6 \text{ ft})}$$

$$Ratio = 0.96267$$

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

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

$$q = \frac{(10.919 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.68244 \text{ kip/ft}^2$$

$q = 0.68244\ \mathrm{kip/ft^2}$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.68244\ \mathrm{kip/ft^2})}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.34122$$

Status: **PASS**
Ratio: **0.340**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

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

$$L/D = 1.5$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.13806\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 3.0073\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (3.0073\ \mathrm{kipft/ft}) \times (6\ \mathrm{ft})) + \left(3 \times (-0.13806\ \mathrm{kip/ft}) \times (6\ \mathrm{ft})^2\right)}{(6 \times (3.0073\ \mathrm{kipft/ft})) + (4 \times (-0.13806\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))}$$

$$a = 4.0776\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (3.0073\ \mathrm{kipft/ft})) + (3 \times (-0.13806\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))]^{\ 2}}{(6\ \mathrm{ft})^2 \times [(3 \times (3.0073\ \mathrm{kipft/ft})) + (2 \times (-0.13806\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))]}$$

$$p = 0.25766\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (3.0073\ \mathrm{kipft/ft})) + ((-0.13806\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))]}{(6\ \mathrm{ft})^2}$$

$$s = 0.86438\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.0776\ \mathrm{ft})}{2}$$

$$p_a = 0.30582\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.25766\ \mathrm{kip/ft^2})}{(0.30582\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.84254$$

Status: **PASS**
Ratio: **0.840**

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

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

$$Ratio = \frac{\left(0.86438\ \mathrm{kip/ft^2}\right)}{\left(0.9\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.96043$$

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

Considering z-direction:

$H_o = 0.0031847\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.016561\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.016561\ \mathrm{kipft/ft}) \times (6\ \mathrm{ft})) + \left(3 \times (0.0031847\ \mathrm{kip/ft}) \times (6\ \mathrm{ft})^2\right)}{(6 \times (0.016561\ \mathrm{kipft/ft})) + (4 \times (0.0031847\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))}$$

$$a = 4.2174\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.016561\ \mathrm{kipft/ft})) + (3 \times (0.0031847\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))]^{\ 2}}{(6\ \mathrm{ft})^2 \times [(3 \times (0.016561\ \mathrm{kipft/ft})) + (2 \times (0.0031847\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))]}$$

$$p = 0.003619\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.016561\ \mathrm{kipft/ft})) + ((0.0031847\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))]}{(6\ \mathrm{ft})^2}$$

$$s = 0.0087049\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.2174\ \mathrm{ft})}{2}$$

$$p_a = 0.3163\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.003619\ \mathrm{kip/ft^2}\right)}{\left(0.3163\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.011441$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

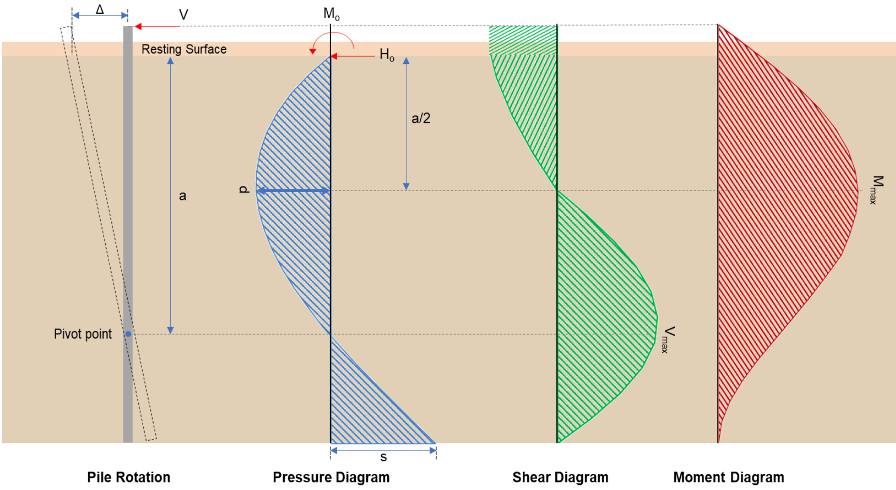
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0087049 \text{ kip/ft}^2)}{(0.9 \text{ kip/ft}^2)}$$

$$Ratio = 0.0096721$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.44 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.2293 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(34.099 \text{ kipft}) + ((-1.44 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 5.4298 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(5.4298 \text{ kipft/ft})}{(-0.2293 \text{ kip/ft})}$$

$$E = 23.68 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.4298 \text{ kipft/ft}) \times (6 \text{ ft})) + \left(3 \times (-0.2293 \text{ kip/ft}) \times (6 \text{ ft})^2\right)}{(6 \times (5.4298 \text{ kipft/ft})) + (4 \times (-0.2293 \text{ kip/ft}) \times (6 \text{ ft}))}$$

$$a = 4.0723 \text{ ft}$$

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

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

$$V_{max} = ((-0.2293 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (23.68 \text{ ft})}{(6 \text{ ft})} + 3\right) \times \left(\frac{(4.0723 \text{ ft})}{(6 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (23.68 \text{ ft})}{(6 \text{ ft})} + 2\right) \times \left(\frac{(4.0723 \text{ ft})}{(6 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 7.0202 \text{ kip}$$

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

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

$$M_{max} = ((-0.2293\text{ kip/ft})\times(48\text{ in})\times(6\text{ ft}))\times\left[\left(\frac{(23.68\text{ ft})}{(6\text{ ft})}+\frac{(4.0723\text{ ft})}{2\times(6\text{ ft})}\right) - \left[\left(\frac{4\times(23.68\text{ ft})}{(6\text{ ft})}+3\right)\times\left(\frac{(4.0723\text{ ft})}{2\times(6\text{ ft})}\right)^3\right]+\left[\left(\frac{3\times(23.68\text{ ft})}{(6\text{ ft})}+2\right)\times\left(\frac{(4.0723\text{ ft})}{2\times(6\text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 20.556\text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.033\text{ kip})}{1.57\times(48\text{ in})}$$

$$H_o = 0.0052548\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.17\text{ kipft})+((0.033\text{ kip})\times(0\text{ ft}))}{1.57\times(48\text{ in})}$$

$$M_o = 0.02707\text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.02707\text{ kipft/ft})}{(0.0052548\text{ kip/ft})}$$

$$E = 5.1515\text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4\times(0.02707\text{ kipft/ft})\times(6\text{ ft}))+\left(3\times(0.0052548\text{ kip/ft})\times(6\text{ ft})^2\right)}{(6\times(0.02707\text{ kipft/ft}))+(4\times(0.0052548\text{ kip/ft})\times(6\text{ ft}))}$$

$$a = 4.2185\text{ ft}$$

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

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

$$V_{max} = ((0.0052548\text{ kip/ft})\times(48\text{ in}))\times\left[1-\left[3\times\left(\frac{4\times(5.1515\text{ ft})}{(6\text{ ft})}+3\right)\times\left(\frac{(4.2185\text{ ft})}{(6\text{ ft})}\right)^2\right]+\left[4\times\left(\frac{3\times(5.1515\text{ ft})}{(6\text{ ft})}+2\right)\times\left(\frac{(4.2185\text{ ft})}{(6\text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.045837\text{ kip}$$

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

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

$$M_{max} = ((0.0052548\text{ kip/ft})\times(48\text{ in})\times(6\text{ ft}))\times\left[\left(\frac{(5.1515\text{ ft})}{(6\text{ ft})}+\frac{(4.2185\text{ ft})}{2\times(6\text{ ft})}\right) - \left[\left(\frac{4\times(5.1515\text{ ft})}{(6\text{ ft})}+3\right)\times\left(\frac{(4.2185\text{ ft})}{2\times(6\text{ ft})}\right)^3\right]+\left[\left(\frac{3\times(5.1515\text{ ft})}{(6\text{ ft})}+2\right)\times\left(\frac{(4.2185\text{ ft})}{2\times(6\text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.12617 \text{ kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(16.382 \text{ kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2))\right]$$

$$A_{st,required} = -84.052 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.052 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

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

	Ties: **#3(0.375 in) - 10 in**	
	Axial Compression Strength (ACI 318-19, LRFD)	
22.4.2.2	ϕP_N - Allowable axial compressive strength $$\phi P_N = \phi\, 0.80\, \left[\left(0.85\, f'_{ck}\, \left[A_g - A_{st}\right]\right) + \left(f_{yk}\, A_{st}\right)\right]$$ $$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(2304\ \text{in}^2\right) - \left(4.2951\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(4.2951\ \text{in}^2\right)\right)\right]$$ $$\phi P_N = 2675.2\ \text{kip}$$	
	$Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(16.382\ \text{kip})}{(2675.2\ \text{kip})}$$ $$Ratio = 0.0061237$$	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 $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 16.382\ \text{kip} \rightarrow 16382\ \text{lbf}$,	
22.5.5.1.1(a)	$V_{c,a}$ - Shear strength of concrete (a) $$V_{c,a} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \frac{P}{6\, A_g}\right]\, b_w\, d$$ $$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(16382\ \text{lbf})}{6 \times \left(2304\ \text{in}^2\right)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$ $$V_{c,a} = 120.67\ \text{kip}$$ 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 $$V_c = Min\left[V_{c,max}, V_{c,a}, V_{c,b}\right]$$ $$V_c = Min\left[(296.21\ \text{kip}), (120.67\ \text{kip}), (348.89\ \text{kip})\right]$$ $$V_c = 120.67\ \text{kip}$$	

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((120.67\ \text{kip}) + (50.894\ \text{kip}))$$

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

Considering x-direction:

$V_{max} = 7.0202\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(7.0202\ \text{kip})}{(111.52\ \text{kip})}$$

$$Ratio = 0.062952$$

Status: **PASS**
Ratio: **0.060**

Considering z-direction:

$V_{max} = 0.045837\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.045837\ \text{kip})}{(111.52\ \text{kip})}$$

$$Ratio = 0.00041103$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

	$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f'_{ck}\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6 \text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$ $$\phi M_n = 249.6 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 20.556 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(20.556 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.082357$$	Status: **PASS** Ratio: **0.080**
	Considering z-direction: $M_{max} = 0.12617 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.12617 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.00050551$$	Status: **PASS** Ratio: **0.000**